Focus on Lean Construction at Umm Lekhba (Landmark) Interchange

Nader Halimeh
Parsons International Limited, Doha, Qatar
naderhalimeh@gmail.com

Abstract

Umm Lekhba (Landmark) Interchange is the largest four level Interchange built in Doha-Qatar, which has 9 flyover bridges with 11 km in total length, constructed partly using 735 heavy precast concrete segments fabricated off-site, transported, and installed using heavy cranes and launching trusses with a minimum impact on the public traffic flow and on the shopping activities at the busiest interchange in Doha. The Lean Construction Institution–Qatar (LCI-Q) was established in October 2019, and the Lean Construction implementation became mandatory for all new projects of Ashghal in Qatar as of 2022, however the construction of Landmark Interchange was started in May 2017, and two of its flyover bridges were opened to traffic at the end of 2019. The contract of the Landmark project did not mandate implementation of Lean Construction but the contractor had implemented part of Lean Construction and BIM techniques at his own cost to overcome the challenges faced in the design and construction of the project, including consideration of using the Last Planner System, Organization/Standardization of the workplace, implementation of Just in Time concept, using a systematic procurement approach, utilization of Multi-layer subcontractors and consultants, etc. This paper will present briefly the construction of Landmark Bridges and discuss Lean implementation during the construction.

Keywords: Lean construction; Precast segments; Landmark

1 Introduction

Lean Construction is a project delivery process that uses lean methods for maximizing stake holder value while reducing waste by emphasizing collaboration between teams on the project, the goal of Lean Construction is to increase Productivity, Profits, and Innovation in the Industry, based on Lean Construction Institution (LCI-US), which funded the research sources, showing that the projects which implemented lean building tools and techniques give much better outcomes across variety of benchmarks. (LCI, 2022). The Lean Construction methods include the Last Planner System, Choosing by Advantages, Target Value Delivery, Integrated Project Delivery, etc. The Lean Principles are the concepts that help us to achieve the Lean Philosophy and can include: Continuous Flow, Single Piece Flow, Pull, Small Batch Size, Fast Switch Over, Visual Management, etc. The Lean Construction tools that allow using the Lean methods within the projects including Software, Analog (aka stickies), Hybrid implementation. (Do, 2022).

The term Lean Construction was born and used for the first time in the year 1993 on the first endeavour of the International Group for Lean Construction, organized by: Glenn Ballard and Lauri Koskela, both worked together with Greg Howell in the late 1980s and early 1990s to improve construction through planning production, and they have developed the Last Planner System and the Target Value Delivery methods for Lean Construction. (Do, 2022).

In addition to the above mentioned Lean Construction methods, there are several methods imported from Toyota Production System (TPS) that have been translated well into the Design and Construction including: 5whys, 5s, A3 Problem Solving, PDCA (Plan, Do, Check, Act), Poka-Yoke (Error Proofing), Single Minute Exchange of Die (SMED), Standardized Work, Value Stream Mapping and Visual Management, however the first book which was published on Lean Construction in 1993 titled **"**The Machine that Changed the World" showed many similarities with Toyota Production System. (Do, 2022).

The Public Works Authority Infrastructure Affairs had engaged the Consolidated Contractor Group and Tayseer (CCC/TCC) to design and build Al-Bustan Street North Project, including the Landmark interchange (Junction B6), which is the last main Junction on the new Sabah Al Ahmad Corridor. The construction of Landmark flyover bridges will be briefly presented and the Lean implementation will be discussed in this paper.

2 Al Bustan Street North Project

Al-Bustan Street North Project is a re-development of the existing Al-Bustan Street North into a length of expressway approximately 3.6 kms., in addition to re-construction of Al-Bustan Street North/Al-Markhiya Street, Al-Ittihad Street, upgrading of approximately 1.7 kms. section from Al-Shamal road and the construction of Al-Ittihad Bridge, Duhail TTM and Duhail Green Belt.

Al-Bustan Street North starts from Al-Luqta roundabout and ends at the Landmark Mall, it includes a section of Al-Ittihad Street and Al-Ittihad bridge connecting Al-Gharafa with Khalifa City North, the scope of works of the project comprises the design and construction of 4 main Junctions with 4 lanes in each direction, including the largest 4 levels interchange in Doha, which have 9 flyover bridges with 11 km in total length (Junction B6), one left turn bridge connecting the project with Al-Ittihad Street (Junction B5), one Cut and Cover Tunnel (Junction K1), and one Viaduct of two twin Bridges (Junction B4), in addition to the micro tunnelling, signs, utilities, retaining walls, pedestrian bridges, pedestrian/cycle paths, traffic signals, gantry signs, landscaping works and street lighting. The location map of Al-Bustan Street North Project is shown in Figure 1 below.

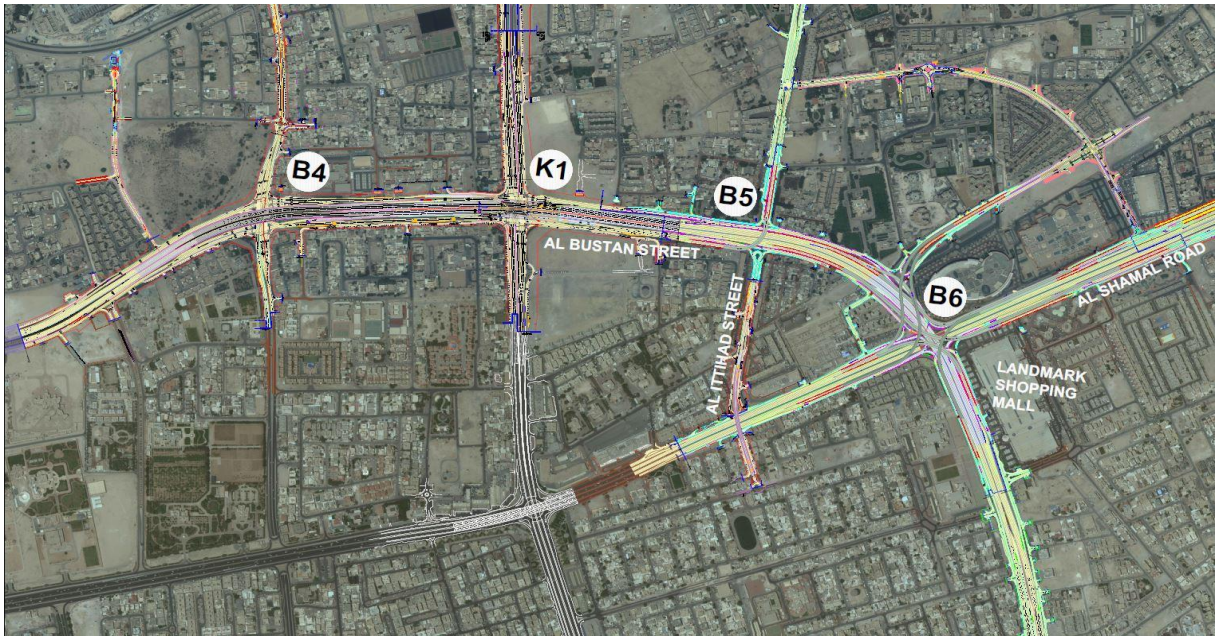

Fig. 1: Location map for Al-Bustan Street North Project

3 Construction of Junction B6 (Landmark) Interchange

Junction B6 Interchange consists of nine flyover bridges, B6-B1 and B6-B2 bridges at grade level, B6-B3, B6-B4, B6-B5 and B6-B9 bridges at level +1, B6-B6, B6-B7 and B6-B8 bridges at level +2. The span arrangements for bridges varies from 36.0m to 90.0m, consisting of simple and continuous superstructure of precast segmental and cast in-situ box girder. The bridge section depths are varying from 2.0 m to 4.5 m. There are in principle two bridge deck widths, wide deck for level +1 and narrow deck for level +2. Figure 2 below shows all flyover bridges of Junction B6.

Fig. 2: Junction B6 (Landmark) with all Flyover Bridges

Fig. 3: Landmark Interchange during the Substructure Construction

3.1 Substructure Construction

Consolidated Contractor Group and Tayseer (CCC/TCC) had divided Junction B6 site into five working zones. Temporary Traffic Management (TTM), Relocation of Existing Utilities and Removal of all Constraints were given top priority to enable the construction of 101 foundation and pier columns required for the flyover bridges, in addition to the retaining wall foundations. Fabrication of 735 heavy precast segments was carried off-site at VSL yard which is located 50kms. south of Doha. The development of the design to satisfy the client and stake holders' requirements was continued during all phases of construction, including new design for Junction B6-B9 and Junction B6-B4 bridges, and design improvement for other bridges. MSE earth wall system was adopted for all bridges of the project. Substructure during construction is shown on Figure 3 above.

3.2 Precast Concrete Segment Construction

The balanced cantilever construction technique was adopted for all bridges which have precast concrete segment as their superstructure. The balanced cantilever construction is an effective method when the access from below is restricted or impossible, the superstructure made of box section–precast segments. The segments were casted, cured, and stored off-site in a controlled manner in a tailored made casting yard. The pier and first pier segments were casted using bulkhead on both faces, next segments were matching cast on one side using the previously completed segment and bulkhead on the other. The segments had shear keys to enhance precision when re-assembled on site as shown in Figure 4 below. The segments were transported to the site for installation using trailers, nominal segment lengths were limited to a maximum of 3.4 meters to fit within one traffic lane width. The largest segment height was limited to 4.5 m to ensure that the trailer plus segment height is clear under the existing bridges on the route from the casting yard to the site. The largest segment weight taken was ninety metric tons. The superstructure installation used was started from the top of the pier, with the pier segment fixed to the top of the column either permanently for monolithic piers or temporarily using U-Ties during the construction as shown in Figure 5. Additional temporary supports at piers, (on one side of the pier used where necessary), stitches between pier segment and the first pair of segments were deployed for alignment adjustment. Next, segments were hoisted by the crane, either directly to the desired position for post-tensioning, or onto the transporter waiting on the top of the pier segment before transported to the cantilever tips and dropped into place by the Lifting Frames (Figure 6). Once the segments are in place, a temporary post-tensioning with the use of Prestressed bars were applied to secure the segment temporarily to the earlier completed section. The segments were equipped with temporary concrete bottom blister with cone opening provisions in the top slab or the temporary steel upper blister, which were designed for the weight of the segment and the temporarily post-tensioning works. Epoxy resin was used to be applied between segments; the segments were installed on alternate sides of the pier columns so that the out-of-balance moment was kept to a minimum. The segment installation sequence was repeated till the completion of the last pair of segments. Closure stitching was applied between the two cantilever tips coming out from consecutive piers. While for the end span segments, and at the expansion pier columns, the segments were installed on traditional falsework and stitched to the cantilever tip. Continuous post-tensioning was subsequently applied to complete the installation works for the superstructure. Street furniture and road surfacing were applied to complete the bridge work.

Fig. 4: Precast Concrete Segment Fabrication in VSL Yard 50 kms. south of Doha

Fig. 5: Precast Concrete Segment Installation for Junction B6 bridge

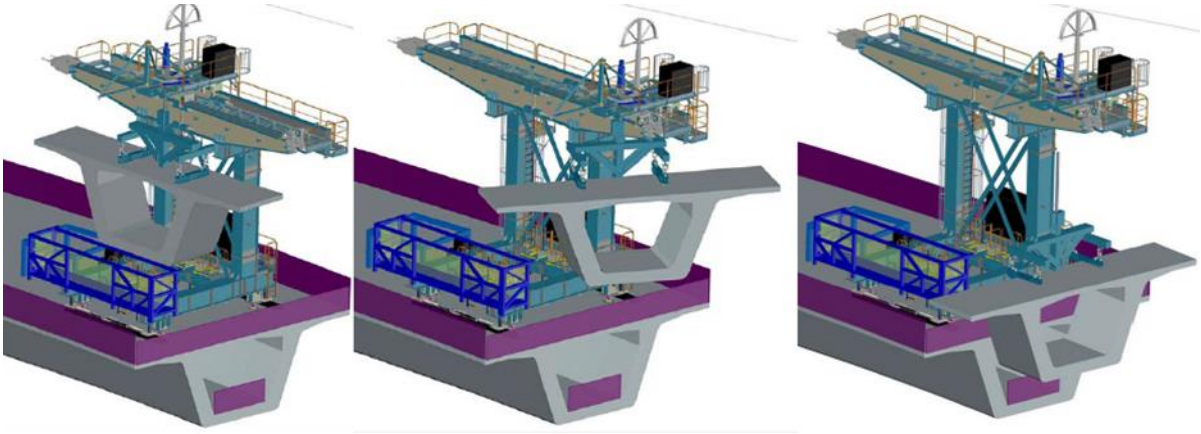

Fig. 6: Installation of Precast concrete Segments using Lifting Frame

Fig. 7: Photo for Shamal Road during Landmark Construction

3.3 Cast in-situ post-tensioning Superstructure Construction

Junction B6-B1, B6-B2 bridges were designed to be cast in-situ concrete post-tensioned voided slabs, the deck superstructure was supported on mechanical bearings over the abutment and the two pier columns, while a traditional formwork support was deployed and considered in the design.

4 Lean Implemantation during Construction

The contract of Landmark project does not mandate the implementation of Lean Construction; however, the Contractor had implemented part of Lean Construction and BIM techniques of the Landmark flyover bridges at his own cost, moreover and during the construction in August 2019, the senior management of the contractor had engaged the Global Management Consulting Firm "McKinsey" to study and provide their feedback about the project management and Lean Construction implementation. Part of the contractor key staff had been previously trained on the Lean Construction implementation under Boston Consulting Group 'BCG" in August 2015.

Based on the contractor planning team, the Lean principles and techniques were implemented to overcome the following changes:1) Design and Build Project, 2) Change in Design Strategy during Construction, 3)Value Engineering Proposals by the Contractor, by Change in the Design (example from underpass to overpass bridge) and Savings to the Client, which resulted in a tight working schedule due to design approval process requirement by the stakeholders, 4) Variation to the Contract, additional scope (from a concept design to detail design), which resulted in changes to the original scope of the work, 5) Procurement of Long Lead Items, 6) Managing Multiple sub-contractors and Suppliers, 7) Complexity in Construction, while maintaining free flow of traffic in the busiest interchange in Qatar.

The Lean Principles and techniques were implemented on Landmark Project as follows; 1) The baseline schedule was established in the beginning of the project, but due to the complexity of the project with unforeseen circumstances on site like existing utilities and design delays, the project started loosing track of meeting intermittent site established deadlines. 2) Pull Planning was established on how to achieve the completion date of each bridge as set in the baseline, the recovery baseline was set by involving all construction teams, the durations of each activity and the sequence was agreed with the construction team, the delivery of the design drawings, and the delivery of every material used to be discussed and considered in the developing of the schedule. 3)Three months look ahead schedules were issued to the construction team for close following-up, the schedules were part of the weekly progress meetings. The planning team compiled the progress of the week, and highlighted the slippage activities and discussed the ways of mitigation, maintaining the same target date. 4) The productivity of the crews was monitored on weekly basis, the reasons for shortage of the productivity were discussed and analysed in the weekly meetings. 5) The procurement of Long Lead Items was a big challenge, mainly due to the huge quantity of bridge bearings, identifying the required date for each bridge bearing on site and accordingly the schedule was provided to the supplier, some were procured by air fright to mitigate the delays. 6) All main sub-contractors of the project were engaged to be in integration with the contractor's main project program on a daily communication and during the weekly progress meetings.

Intermittent milestones of the program, for example, the nine bridges in the Landmark interchange, the target date to complete each bridge and open to traffic was a Milestone, which was strictly implemented in the project to respect the intermittent milestones. Weekly planning meetings with the construction team played a vital role in mitigating the delays by pull planning concepts as shown in

Figures 8, 9, 10 and 11 below.

Last Planner System (LPS) definition is a collaborative, commitment-based planning system that integrates the concept of the 'should-can-will-did' planning. It includes master scheduling and phase planning to define what should be done. Look ahead planning is based on constraints identification and removal (the make-ready process) to establish what can be done, weekly work planning based on reliable promises reflecting what will be done, and learning based upon analysis of the PPC (comparing 'did' against 'will') and the reason for variance. The goal of the Last Planner System is to improve the PPC since the PPC is the measure of the reliability of the work completed versus the work planned, the increase of the PPC will provide better productivity and safety for the construction. (Do, 2022).

Target Value Delivery (TVD) is a management practice that drives the design and construction to deliver customer values within project constraints (Bollard, 2009 and Do, 2022). The goal of TVD is to address Cost Reliability Value Delivery and Continuous Improvement of the projects (Do, 2022).

Fig. 8: Commitment meeting of Section, Construction and Project Managers

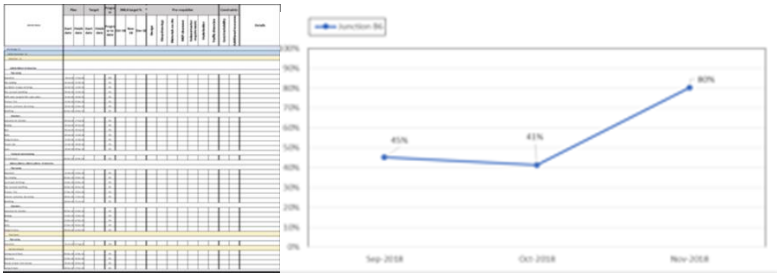

Fig. 9: Commitment to plan Work Sheet & KPI reliability CR%

Fig. 10: Crew Leaders Meeting and Updating the Progress on Daily Basis

Fig. 11: Lean Production Worksheet & KPI Target Percentage completed by Crew

5 Conclusion

Part of Lean principles and techniques were implemented by the contractor during construction of the Landmark bridges, including consideration of Waste Elimination, Organization/Standardization of the Workplace, Implementation of Just-in-Time Concept, implementation of Safety at Work Place, using 5whys for root cause analysis, consideration of total quantity management in the project, considering the use of the Last Planner System, using systematic procurement approach, utilization of multi-layer subcontracting and consultants for the project. It involved off-site construction technique, using digital and fast approval procedure for the critical project decisions. Supply chain management for the project, cost optimization, productivity measurement using Percent of Plan completed PPC, reduced consumption of resources, etc., which contributed to the successful, early and safe completion of the Landmark bridges, based on full collaboration between all parties involved in the construction including the client and the related stakeholders.

Lean Construction methods were not known during construction of Kizlac Motorway Viaduct in Turkey in late 1990s, however, a methodology similar to the "Target Value delivery" TVD of Lean Construction was adopted by the contractor for the design and construction at that time and led to the successful completion of the Viaduct (Halimeh,2000). It is recommended to mandate the use of the Last Planner System and Target Value Delivery methods for all new projects, because the two methodologies which were developed by "Glenn Ballard" and "Greg Howell" are unique and required for the Construction Industry (Do, 2022).

References

Do, Donah (2022). *The Art and Philosophy of Lean Construction*. Lean Construction Blog (Online Book). https://leanconstructionblog.com. San Francisco. California.

Lean Construction Institution, LCI (2022), (learning -search). www.leanconstruction.org

Halimeh, Nader (2000). *Construction of Kizlac Motorway Viaduct*. Bridge Engineering Conference 2000. (Fib Symposium). Egyptian Society of Engineers and Egyptian National Group of IABSE. Sharm Elsheikh- Egypt.

Cite as: Halimeh N., "Focus on Lean Construction at Umm Lekhba (Land Mark) Interchange", *The 2nd International Conference on Civil Infrastructure and Construction (CIC 2023)*, Doha, Qatar, 5-8 February 2023, DOI: https://doi.org/10.29117/cic.2023.0012