Training and Technical Oversight for the Road to Mandalay Project

Final/End of Project Report

November 2015

This document was produced for review by the United States Agency for International Development. It was prepared by CDM International Inc. (CDM Smith) for the Training and Technical Oversight for the Road to Mandalay, USAID/Burma *under Contract No: EDH-1-00-08-00023-00; Order No: AID-482-TO-14-00001.*

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Title: Final/End of Project Report

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ACRONYMS

AASHTO	American Association of State Highways and Transportation Officials
ASEAN	Association of Southeast Asian Nations
ADB	Asia Development Bank
ASTM	American Society for Testing and Materials
BOQ	Bills of Quantities
GOB	Government of Burma
IGS	International Geomatic Services
MOC	Burma Ministry of Construction
MOU	Memorandum of Understanding
M&E	Monitoring and Evaluation
MP	Mile Post
MUTCD	Manual on Uniform Traffic Control Devices
OFAC	Office of Foreign Assets Control
OJT	On-the-Job Training
PMEP	Performance Monitoring and Evaluation Plan
PO	Purchase Order
PoP	Period of Performance
RFP	Request for Proposal
RFQ	Request for Quotation
RRPM	Raised Reflective Pavement Markers
SDN	Specially Designated Nationals
TOCOR	Task Order Contracting Officer Representative
UN	United Nations
US	United States
USAID	United States Agency for International Development
USDOT	United States Department of Transportation
USG	United States Government
WHO	World Health Organization

EXECUTIVE SUMMARY

Project Overview

The Rangoon to Mandalay Expressway in Burma is a 386 mile-long four-lane divided highway with provisions for an eight-lane divided highway. Completed in 2011, this "Road to Mandalay" was planned, designed and built by the Burma Ministry of Construction (MOC) in order to connect the highly-populated city of Rangoon with the new capital in Naypyidaw, the former royal capital of Mandalay, and other parts of northern Burma. However, the highway has serious design and safety flaws. When these defects are combined with poor driving habits and high traffic volumes, frequent accidents result (see **Table 1**) – so many accidents that the road has been nicknamed the "Death Highway." Design and construction deficiencies include improper horizontal and vertical alignments, poor placement of Jersey barriers and guardrails, uneven pavement surfaces, and overly narrow, poorly aligned bridges.

Table 1. Accidents on the Road to Mandalay

Year	Crashes	Injuries	Deaths
2013	259	622	113
2014*	375	704	136

**Note: 2014 values are for 11 months.*
Source: Burma Traffic Police

Improving Road Safety and MOC Capacity through USAID's "Training and Technical Oversight for the Road to Mandalay Project." After assessing road and bridge safety issues in Burma through site visits and discussions with Burmese public works and transport officials, USAID cooperated with the MOC to design a project for improving the technical capacity of MOC engineers and technicians. In September 2014, USAID awarded CDM International, Inc. (CDM Smith) a contract to implement the "Training and Technical Oversight for the Road to Mandalay Project." CDM Smith teamed with International Geomatic Services (IGS), a Burmese consulting firm, to build the expertise and capacity of MOC engineering staff in various aspects of road and bridge design; to identify and procure equipment and materials for road safety improvements; and to support and oversee the installation of roads safety equipment and materials along a 10 km pilot section of the highway. Training and installation were conducted in accordance with the standards of the American Association of State Highways and Transportation Officials (AASHTO) and the American Society for Testing and Materials (ASTM). The project comprised three components:

- ***Component 1: Training***. Prepared and delivered AASHTO-standardized training to government staff in highway and pavement design and bridge design.
- ***Component 2: Procurement***. Procured materials, including reference and training documentation, for safety upgrades of the 10 km pilot section.
- ***Component 3: Construction Oversight of the 10 km Pilot Section***. Supervised the implementation of design for safety upgrades on the aforementioned 10 km pilot section of the Road to Mandalay.

Project Implementation & Results

Component 1: Training. CDM Smith's Project Team developed the training program and course curriculum in consultation with MOC staff and USAID, working with the MOC to identify and vet the 40 proposed training participants. Over the course of three weeks, two of CDM Smith's engineers each taught 13-14 training modules, usually during the morning hours from 9 a.m. to midday so that trainees could carry out professional duties in the afternoons. Each course included field trips and design software demonstrations. Upon completion,

trainees received certificates and AASHTO reference materials were provided. Student evaluations and MOC feedback indicated that the design trainings were a success.

Component 2: Procurement. To complement training and to show tangible, physical results, the project team procured highway safety equipment and materials to install on a selected 10km pilot section. All procurement activities were completed in close coordination with the MOC and in accordance with USAID procurement regulations. To obtain the necessary materials for the road safety improvements, the team assessed available vendors and developed three procurement packages. The first package included *pavement marking materials and equipment* to delineate the edge of pavement and the centerline using retroreflectivity technology, particularly important for night traffic. The second package comprised *work-zone safety equipment* for road maintenance and construction activities. The final package consisted of *traffic signage* to alert motorists of poor horizontal and vertical alignments. New technology was introduced to reduce damage and injuries from vehicular crashes into traffic posts. For each package, the project team developed a Bill of Quantities (BOQ); obtained quotations; and selected suppliers. All procurement items cleared customs efficiently and were delivered to the MOC to be prepared for installation under Component 3.

Component 3: Construction Oversight of the 10km Pilot Section. The MOC decided to complete the works using its own maintenance crews and equipment, with significant support from CDM Smith in purchasing incidental materials, tools and equipment for its work crews. The MOC counterparts were frequently briefed to develop a complete understanding of the construction activities (crew size, traffic control measures, equipment and materials) required to complete the work expeditiously. In early August 2015, two MOC work crews began five days of on-the-job materials and equipment training from the pavement marking supplier.

Work zone safety was major focus of the training. The pavement marking crews, working along the pilot section in opposite directions, quickly completed the line marking; the signage work crews soon followed, completing installation in late September 2014. The works were then inspected and approved by the MOC, CDM Smith, and USAID. All of the construction works were completed successfully and without worker injury or incident.

Some surplus line-marking materials remained from the installation efforts at the 10km pilot section. The MOC agreed to use these extra materials along sections of the expressway that posed high risks for traffic crashes. To date, five priority sections have been identified by MOC. CDM Smith recommends that the MOC also keep a quantity of these materials in reserve for repair purposes; rumble strips, in particular, tend to require continual maintenance.

Impacts, Impediments & Lessons Learned, and Recommendations

Ever since the Road to Mandalay's completion in 2011, accidents, injuries, and deaths along the expressway have been increasing. In addition to providing immediate tangible benefits along the pilot section, the project includes recommendations to help improve long-term safety. If the safety measures and lessons learned from this project are applied to the entire expressway, one can expect the number of accidents to decrease, particularly night time accidents. Impacts, lessons learned, and recommendations that have arisen from the Project are as follows:

Project Impacts

Improved awareness of innovative technology and low-cost solutions. The Project successfully introduced U.S. design technology and road safety measures to the MOC design staff. In the case of the use of breakaway coupling signage, for instance, the MOC was

introduced to technologies that have yet to be adopted by many countries in the Association of Southeast Asian Nations (ASEAN). The highway and bridge design trainees now have the basic design tools and knowledge to prepare long term improvements to the pilot section and other locations along the expressway and other roads in Burma.

Practical knowledge gained from on-the-job training and demonstrations to augment classroom work. The on-the-job training (OJT) and pilot section demonstrations achieved two objectives: to familiarize MOC designers, management and maintenance crews with thermoplastic line marking and signage using retroreflective technology, and to improve work zone safety. The MOC crews are now able to continue both activities without further guidance.

Demonstrated commitment and buy-in from the Burmese MOC. For implementation success and sustained impact of the Project, the strong commitment and engagement of the MOC was critical. At Project start-up, CDM Smith entered into a Memorandum of Understanding (MOU) with the MOC, which engaged the MOC in active project participation. The MOC "bought-in" to the objectives and approach of the project, demonstrating support throughout all three components and helping to address key challenges that might have otherwise resulted in significant delays.

Increased knowledge of work zone safety practices by the MOC. Standardized work zone safety measures are not yet regularly practiced in Burma. To demonstrate the benefits of worker safety procedures, CDM Smith used individual safety equipment and traffic control equipment throughout the work zone. All of the works along the pilot section were completed without injury or accident, and the demonstration proved a beneficial learning experience for MOC management and work crews.

Improved road safety along the 10km pilot section of the Road to Mandalay. As a result of the completion of the pilot section roads improvement installations, the safety of that portion of the highway was visibly improved for both daytime and night-time driving. In particular, the advantages of the retro-reflective line marking and signage are significant, allowing drivers more visibility for nighttime driving. A project video of the completed section has been developed by the US Embassy in Rangoon to show the marked improvement in the pilot section of the highway.[1]

Impediments and Lessons Learned

Ensure flexibility and adaptability in project approach and implementation. Working in Burma currently requires a flexible and adaptable approach to account for potential unexpected delays and bureaucratic procedures and requirements of the Government of Burma (GOB), in addition to constraints related to the U.S. Office of Foreign Assets Control's (OFAC) sanction programs in the country. Meeting venues might change; training participants might not meet the vetting requirements under OFAC if they are on the Specially Designated Nationals (SDN) List; and customs processes might delay shipments and derail planned installation schedules. Weather, too, was a major potential obstacle; monsoon season and its accompanying flooding episodes were approaching, which could have affected the roads installations.

In working with USAID/Burma and local partner International Geomatic Services (IGS), the CDM Smith Team sought to anticipate potential obstacles and accommodate necessary changes in the program implementation when possible. Through its monitoring and evaluation (M&E) process, the team was able to address them. For example, a late change in the training venue

[1] (https://www.facebook.com/usembassy rangoon/videos/vb.122393807842447/912529468828873/?type=2&theater).

posed some logistical challenges, but was ultimately accommodated. Similarly, the procurement process – planning, identifying equipment and materials, soliciting proposals, selecting compliant vendors, and clearing customs – required an extension of the project period of performance (PoP), but was ultimately a great success. Future project work plans in Burma should build this flexibility into their schedules.

Coordinate closely with Burmese partners. With the many governmental requirements, processes, and other nuances of working in Burma, an in-depth understanding of local procedures and processes is critical. In accordance with the terms of the MOU, the MOC's support was key to ensuring committed participation from the MOC trainees and construction staff. In addition, the MOC helped the CDM Smith team ensure that all shipping requirements and documentation were compliant with Burmese regulations; and as a result, shipments cleared customs with minimal delay and procurement was completed in record time compared to other projects in the country. Close and continuous coordination with the MOC, and local partner IGS, was key to the project's success.

Recommendations: Building on Project Results

Sustain and build upon project results. Much more remains to be done in Burma in terms of road safety. Scaling up the impacts of this Project is important because roads safety in Burma is a national crisis. Improvements should cover the entire network of national primary and secondary road, and the Project training and the installation activities can serve as a model for interventions on the remainder of the Road to Mandalay and other road networks in the country.

Continue to build technical capacity of MOC staff. USAID, the MOC, and other potential donors such as the ADB should seek to continue to build on the successful results of this initial road safety infrastructure project, developing a cadre of skilled Burmese technicians, engineers and managers. Using the training platform developed under this Project, expansion of the training will help to sustain – and augment – the results and impacts of this project.

Build technical expertise in work zone safety and traffic engineering. All road projects should have a safety plan and the MOC should adopt work zone safety procedures, both for its own works as well as those completed by contactors. Additionally, the MOC should build capacity so that its traffic safety programs are managed by qualified engineers.

Expand road safety programs to more roads in Burma. Drawing upon lessons learned from this Project, a road safety improvement program to improve three or four high accident primary and secondary roads should be considered, with capacity building through training and technical assistance as a major feature. Long-term improvements, such /as major realignments, should also be considered.

Promote an integrated approach to road safety. Road safety should be tackled holistically, with cohesive policies focusing on institutional strategies, technical assistance, and public awareness conducted on national and local levels. It is recommended that short and long term road safety programs support the efforts of the GOB, with technical assistance offered to national and local institutions, as well as the private sector.

Evaluate and effectively use traffic accident data. Locally collected data must be consistent with national standards and international norms. Training in accident reporting and investigation is necessary to ensure consistency and accuracy, and to identify high priority road improvements. The CDM Smith Team recommends the development of a program to assist traffic police in the collection, analysis, storage, retrieval and distribution of traffic accident data. This process should include a review of the existing accident databases, analysis of these statistics, and an evaluation of current reporting and investigation methodologies.

I. INTRODUCTION

In September 2014, USAID awarded CDM International, Inc. (CDM Smith) a contract to implement the **"Training and Technical Oversight for the Road to Mandalay Project."** The initial period of performance was for 7 months, which was later extended to December 18, 2015. CDM Smith's team of international experts was supported by International Geomatic Services (IGS), a locally registered Burmese consulting firm based in Rangoon. IGS supported the project's procurement and construction activities, and worked closely with MOC counterpart staff to develop tailored capacity building training.

This Final/End of Project Report provides a summary of CDM Smith's implementation of USAID's "Training and Technical Oversight for the Road to Mandalay Project" during the period of September 2014-December 2015. The following sections describe the Project context; Project implementation and achievements; and conclusions and recommendations. Within these sections are discussions on challenges faced; assessments of the current status of each project component area; a summary of financial expenditures; and measurement of project performance relative to the Performance Monitoring and Evaluation Plan (PMEP).

1.1 Project Context: The Road to Mandalay

Mass motorization in Burma is relatively new and growing at a rapid pace. This, and other factors, have contributed to high accident rates in the country. One of Burma's most important roads is the 386-mile Rangoon to Mandalay Highway. Completed in 2011, the expressway connects the country's main metropolitan area in Rangoon with the capital in Naypyidaw, the former royal capital of Mandalay, and other major cities such as Bago (Pegu), Taungoo, Pyinmana, and Meikhtila. The four-lane divided highway (with provisions for an eventual expansion to an eight-lane divided highway) was funded, planned, designed and built by the Government of Burma (GOB) through the Ministry of Construction (MOC).

Road to Mandalay - Technical Information

Length: The road is 386 miles long and is divided into two main sections: (1) Rangoon to Naypyidaw – 201 miles; (2) Naypyidaw to Mandalay – 165 miles

Implementation: Design began in 2002; construction commenced in 2005; and the road was completed in 2011.

Current cross section: Two lanes (with a roadway width of 25ft) in each direction with a 4 foot shoulder and a median 30 feet wide.

Ultimate development: Four lanes in each direction.

Speed limit: 100 km/h or 60 mph.

Pavement: Cement concrete of 18 inches on subgrade in two lifts.

Traffic: Generally limited to passenger vehicles.

Figure 1. *Characteristics of the Road to Mandalay*

Figure 1 provides key characteristics of the highway. Designed and constructed without international technical or financial assistance – save for several USAID-funded preliminary design studies from the 1950s and 1960s that were referenced in setting the alignment (particularly near Mandalay) – the expressway is marked by outdated, hazardous features. The MOC plans to rectify some of these safety gaps.

Year	Crashes	Deaths	Injuries
2013	259	113	622
2014*	375	136	704

***Note:** The 2014 values are for 11 months.
Source: Burma Traffic Police

Table 2. Traffic Data for Road to Mandalay

The following ***driver and vehicle factors*** contribute to the accident problems in Burma:

- *Driver Skills*. Drivers often lack sufficient highway experience, education, and discipline. For most roads in Burma, speeds range from 60-80 km/hr. On this highway, vehicles commonly sustain speeds of 100 km/hr.

- *Vehicle Conditions***.** Most vehicles in Burma are imported second-hand, often in poor or technically deficient conditions and lacking suitable tires. Most cars have right-side steering wheels, but the roads and traffic flows in Burma are designed for left-side steering.

There are also notable ***technical shortcomings in the design and construction*** of the expressway itself that contribute to the high accident rates, including:

- *Design Features*. Poor horizontal and vertical alignments and inadequate super-elevation contribute to risks, as well as:
    - Narrow bridges.
    - Uneven pavement due to localized settlement and poor construction.
    - Unsafe U-turn designs.
    - Several poorly located and aligned bridges (on horizontal and vertical curves).
    - Unconventional placement of various traffic barriers.
- *Design Coordination*. There is poor coordination between bridge and roadway designs.
- *Signage and Pavement Markings*. Travel at night is particularly risky because the roadway lacks retroreflective line markings. Traffic signs and construction work areas are not properly marked and illuminated. Parapet concrete barriers, poor pavement markings, and uneven pavement structure also contribute to problematic driving conditions.
- *Road Maintenance*. Poor maintenance of the shoulder and clear zones is prevalent.

The following ***operational characteristics*** also contribute to unsafe high speed travel:

- Poor control of the right of way, including pedestrian and animal traffic; numerous at grade intersections with tertiary (unpaved) roads causing cross traffic; and *ad hoc* rest areas within right of way.
- Slow moving local traffic (pickup trucks, bicycles and motorcycles).
- Poor maintenance of the shoulder and run off area.
- Poor work zone safety practices for maintenance crews.
- Road maintenance equipment left on the roadway, without proper warnings.

Although the MOC is aware of these deficiencies and is taking steps to mitigate them, resolving the issues will take a long-term commitment and years to complete. The MOC plans to:

- Widen select bridges to four lanes over the course of several years;
- Install steel guard rails;
- Even pavement with asphalt concrete overlays;
- Regain control of the right of way by constructing short sections of parallel service roads outside of expressway limits for local, slow-moving traffic; and
- Close a portion of the *ad hoc* rest areas.

Figures 2 through 9 illustrate examples of public risks due to poor design, lack of safety measures, and improper usage by travelers.

Improper use of roadway and poor driving practices

Figure 2. *An ad hoc rest area, with a parked bus partially blocking one lane.*

Figure 3. *Drivers commonly disregard proper use of lanes.*

Faulty designs

Figure 4. *Super-elevation is in wrong direction; it should be rising.*

Figure 5. *Unique barrier configuration with super-elevation in the wrong direction.*

Insufficient signage and safety precautions

Figure 6. *Lack of warning signs; the maintenance truck is dangerously parked; and the work crew is without personal safety gear.*

Figure 7. *Warning signs are not adequately distanced to allow vehicles time to slow down, and signs are often unlit at night.*

Roadway and bridges not designed for pedestrian and bicycle use

Figure 8. *Narrow bridges are without provision for pedestrian usage such as sidewalk.*

Figure 9. *A pedestrians walking alongside the expressway is difficult to see at twilight.*

1.2 Project Objectives and Components

Recognizing the challenges and urgency of improving the so-called "Death Highway" and the general lack of MOC technical capacity to address them, USAID consulted with the GOB's public works and highway officials to design a project to improve the technical capacity of MOC engineers and technicians. USAID's key objective for the **"Training and Technical Oversight for the Road to Mandalay Project"** was to build the MOC's capacity in road and bridge design and construction. Sharing standards and best practices from the U.S. through CDM Smith's highway and bridge design engineers and road safety experts was a key part of this approach. Training on U.S. design methods and standards was conducted in a classroom setting, complemented by technical demonstrations and site visits along the 10 km pilot section of the Road to Mandalay.

The project consisted of three complementary components:

- ***Component 1: Training***. CDM Smith prepared and delivered training to MOC staff in highway and pavement design and bridge design in accordance with the standards of the AASHTO and ASTM. The highway design course included recommending safety upgrades to a 10 km pilot section of the Rangoon to Mandalay Expressway.
- ***Component 2: Procurement***. Using the BOQs for safety upgrades to the pilot section developed during the first component, CDM Smith worked with the MOC to procure the necessary materials and equipment in accordance with USAID procurement regulations, with support from the GOB.
- ***Component 3: Construction Oversight of Pilot Section***. CDM Smith provided a qualified construction superintendent to oversee the MOC's implementation of the safety upgrade designs on the pilot section.

Figure 13 illustrates the Road to Mandalay between Rangoon and Naypyidaw, including the location of the 10 km pilot section between Mile Post (MP) 165 and MP 171/2.

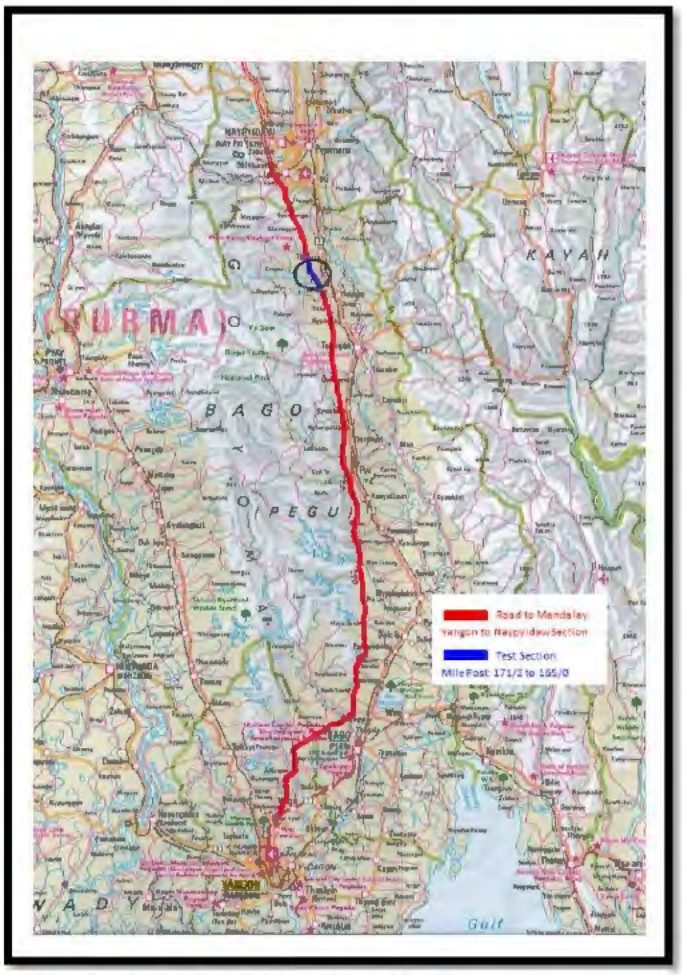

Figure 10. Map with 10 km Pilot Section.

1.3 Project Implementation Schedule

This project occurred over a 15 month period, between September 2014 and December 2015, including an 8-month, no-cost extension. Component 1 – Training was completed in slightly more than three and a half months; Component 2 – Procurement required nearly seven and a half months; and Component 3 – Construction Oversight took approximately two months.

Closeout activities (including final procurement transfers, site inspections, and contractual compliance activities) occurred over the final two months of the project.

The primary challenge in upholding the original schedule was due to underestimating the time needed to work with vendors and Burmese officials on procurement activities, including a lengthy GOB customs clearance processes. **Table 3** provides a summary of the project implementation schedule.

Table 3. Project Implementation Schedule Summary

Date	Summary Activities
Component 1: Training	
September 2014	Signing of contract between USAID and CDM Smith and start of project
	First trip to Burma by Project Manager
October 2014	Submittal of training materials draft for USAID review
	Approval of change in training venue to Naypyidaw and of pilot section to MP 165 to MP 171/2 by MOC
	Review comments on training materials by USAID
November 2014	Signing of Memorandum of Understanding (MOU) between MOC and CDM Smith
	Final submittal of training materials
	Opening session of 3 week training program in highway and bridge design
December 2014	First highway design field trip and site visit
	Second highway design field trip and site visit
	Award of Certificates of Completion
	Bridge design field trip and final day of training
	Training team demobilizes from Burma
Component 2: Procurement	
December 2014	Identification of potential vendors and preparation of Bill of Quantities
January 2015	Continue contacting potential vendors and refining Bill of Quantities
February 2015	Request for waver of Geographic Code 937 sent to USAID
	Issue RFQs for Packages 1, 2 and 3
March 2015	Approval of Waver of Geographic Code 937 by USAID
	Receipt of Quotations (RFQ) for Packages 1, 2 and 3
April-May 2015	Finalized payment terms with Packages 1 and 2 vendor
	Issue Purchase Order (PO) for Package 3
	Request for consent to issue PO to PPI for Package 1 to USAID
	Consent received from USAID to issue PO to PPI for Package 1 and finalization of payment terms with Packages 1 and 2 vendor
	Issue PO for Packages 1 and 2
June 2015	Shipment of Package 3 goods from Jacksonville Florida USA
	Shipment of Packages 1 and 2 goods from Bangkok Thailand
July 2015	Arrival of Package 1 and 2 at Rangoon, Burma Port
	Release of Package 1 and 2 from Rangoon Port
	Arrival of Package 3 goods at Rangoon, Burma Port
	Release of Package 3 goods from Rangoon, Burma Port
Component 3: Construction Oversight of the Pilot Section	
August 2015	CDM Smith trainers in Naypyidaw and assemble equipment in Packages 1 and 2
	Start of formal On-the-Job Training (OJT) of MOC staff with the start of pavement marking in southerly direction.
	Pavement edge striping on the north bound lanes and on the south bound lanes
	Completion of OJT by Packages 1 and 2 Trainers

	Beginning of raised reflective pavement marker installation
	Beginning of pavement centerline marking in both directions
	Pavement centerline striping completed on both the north and south bound lanes; start of MOC sign installation work and rumble strip placement
	Completion of rumble strips
September 2015	Joint (USAID, MOC and CDM Smith) inspection of works and identification of repairs
	Completion of all of MOC signage works
	MOC and CDM Smith daylight and night inspection with identification of minor repairs.
	Joint (USAID, MOC and CDM Smith) final daylight and night inspection of works minor repairs; On-going repairs to rumble strip
	Completion of repairs
Project Closeout Activities	
October 2015	Presentations to USAID; Site visits
November 2015	Site visits, completion of contract

II. PROJECT IMPLEMENTATION & RESULTS

The following sections summarize activities, results, and current status and conditions under each of the three project components. As of the writing of this report, all three project components have been successfully completed.

2.1 Component 1: Training

The first project component focused on building MOC capacity through classroom training and site visits. Working with MOC partners, the CDM Smith Team prepared a training curriculum comprising a total of 27 short training modules, covering a spectrum of design subjects, to help MOC engineering design staff improve their understandings of modern, AASHTO-standardized highway and bridge design concepts.

2.1.1 Development of Training Programs

The training program needed to accommodate varied levels of expertise within the MOC. A brief assessment of the trainee's education and experience indicated that the skill sets of both the highway and bridge training groups varied widely, from those possessing doctorate and masters level degrees (sometimes from international institutions) to those having much less robust technical experience and educational backgrounds. As part of the Team's flexible and adaptable approach, the CDM Smith trainers recalibrated the courses to accommodate the varied levels of skills, focusing on basic understandings of AASHTO designs and tailoring the agenda to student interests and job responsibilities. Textbooks published by AASHTO and other training materials were provided to the students for reference and further advanced study.

Because MOC attendees had minimal experience designing pre-stressed and steel bridges, the bridge design training was modified to focus on reinforced concrete. Classroom instruction was supplemented with field trips to several bridges in need of upgrades. The highway design trainees also made several field trips to observe actual site conditions on the pilot section and discuss road safety improvements; this selected portion of the Road to Mandalay offered practical examples of the various design shortcomings found on the expressway.

The Team began preparing materials for the highway and bridge design training courses in September 2014, and the curriculum received USAID's approval in late October. Each course (highway and bridge design) was developed separately by the respective CDM Smith engineer

who would ultimately train the MOC staff. In November 2014, the three-week capacity-building training began.

2.1.2 Highway Design Training

Classroom. The Highway Design syllabus comprised 13 training modules and covered the subjects shown in **Table 4.**

Table 4. Highway Design Modules

Module 1	Overview of the course
Module 2	Functional Classification System (Chapter 1)
Module 3	Road Safety
Module 4	Design Control and Highway Capacity (Chapter 2)
Module 5	Elements of Design – Sight Distance (Chapter 3.2)
Module 6	Elements of Design – Horizontal Alignment (Chap 3.3)
Module 7	Elements of Design – Vertical Alignment (Chap 3.4)
Module 8	Elements of Design – Combining Horizontal and Vertical Alignment
Module 9	Overview of Road Maintenance, and Pavement Management and Design
Module 10	Overview of Road Drainage, Erosion and Sedimentation
Module 11	Roadside Design Elements – Barriers, Guardrails and Signs
Modules 12 & 13	Project Design - Application to pilot section and software demonstration

Note: Chapter numbers refer to AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2011, 6th Edition.

Each module was typically completed in one day; however, four days were ultimately spent on Modules 6, 7 and 8, which encompassed vertical and horizontal design. Modules 3, 9 and 10 covered very broad topics, so the training focused on providing an overview of those topics.

Highway Design Field Trips. Two highway design field trips were organized for the highway designers. On December 3, 2014, the trainees participated in the first field trip, accompanied by the USAID Task Order Contracting Officer Representative (TOCOR). This excursion involved the students' initial reconnaissance of the 10 km pilot section (MP 165 to 171/2). The second field trip took place during the training period and allowed small teams of trainees to independently identify road design flaws.

Figure 11. *Highway Design Training Participants on Field Trip Inspecting the Pilot Section*

2.1.3 Bridge Design Training

Classroom. The original bridge design syllabus comprised 14 training modules that covered the subjects shown in **Table 5.**

Table 5. Bridge Design Modules

Module 1	Overview of the course
Module 2	Design Superstructure
Module 3	Design Superstructure, Bearings
Module 4	Design Substructure, Abutments
Module 5	Design Substructure: Piers
Module 6	Composite Steel I-Girder Deck Bridge: General
Module 7	Composite Steel I-Girder Deck Bridge: Design of Steel Girders
Module 8	Composite Steel I-Girder Deck Bridge: Design of Bolted Splices
Module 9	Composite Steel I-Girder Deck Bridge: Miscellaneous Steel Design, Bearings
Module 10	Composite Steel I-Girder Deck Bridge: Design of Substructure
Module 11	Example Bridge Calculations, Drawings and Detailing: 20m spans – Part I
Module 12	Example Bridge Calculations, Drawings and Detailing: 20m spans - Part II
Module 13	Bridge Maintenance Manual
Module 14	Bridge Design Software

At the start-up of the training, the CDM Smith bridge design trainer encountered an unexpected constraint - the original high-level, technical nature of the concepts intended for this bridge design training program (as specified in the Scope of Work under the contract) was beyond the level of understanding of the MOC participants[2]. Prior planning with the MOC had indicated that the selected trainees had different levels of expertise, and an early assessment upon start-up revealed that many were junior level engineers with minimal or no experience in bridge design. Those who did have practical bridge design experience were only familiar at the elementary levels (e.g., single span reinforced concrete). None indicated any prior experience with pre-stressed concrete bridge structures, a very common form of construction for medium length spans in most Southeast Asian countries and in the U.S. **Table 6** summarizes the results of the trainee questionnaire.

Table 6. Summary of Questionnaire on Bridge Design Experience

	Does the Trainee have a Civil Engineering Degree (including bridges or structural engineering)?	Has the Trainee designed a bridge before?	Has the Trainee used AASHTO standards before?	Has the Trainee used computer software in design?
No	8 Trainees had no structural or bridge engineering taught at University	4 Trainees have not designed a bridge before	3 Trainees never used AASHTO codes before	3 Trainees never used bridge design software

[2] The original project's scope proposed the development of a training program that covered multi-span **concrete pre-stressed I beams** and **steel composite continuous bridge decks.** But this level of training did not match the proficiency and knowledge level of the participants. The CDM Smith adjusted the approach and tailored the training to suit the competency and qualifications of the participants. Introductory and general fundamentals were provided for many of these topics, particularly given the time available. Deeper training would be required and would typically require at least one semester of college study for completion.

Yes	12 Trainees had structural engineering courses, but none had bridge engineering courses at University	15 Trainees have designed a single span bridge before (up to 60' span reinforced concrete); nine Trainees have designed multiple bridge spans	Others had some experience with AASHTO standards.	Others had some experience.

Upon collecting and analyzing the questionnaires and discussing the results with the MOC, CDM Smith's bridge design trainer adjusted the level of technicality accordingly.

A revised training schedule, which drew upon the U.S. Federal Highway Administration's (FHWA) basic bridge engineering materials, was developed to provide trainees with a foundational level of understanding:

- Basic bridge engineering training in week one.
- Pre-stressed concrete design in week two and steel composite design in week two.
- Substructure, maintenance and discussion of bridge design software in week three.

Bridge Design Field Trip. The bridge design group took a day-long field trip to observe several flawed bridges along the Road to Mandalay. Among the bridges inspected was the Yadanabon Bridge, which spans the Irrawaddy River (Ayeyarwady River) in a suburb in Mandalay; it was designed and constructed by a Chinese contractor and completed in 2008. The trainees observed fatigue cracks in the webs of the bridge, which are caused by the movements (sway) that result from even low velocity winds, and thought critically about corrective mitigation measures to prevent the fatigue cracks from worsening.

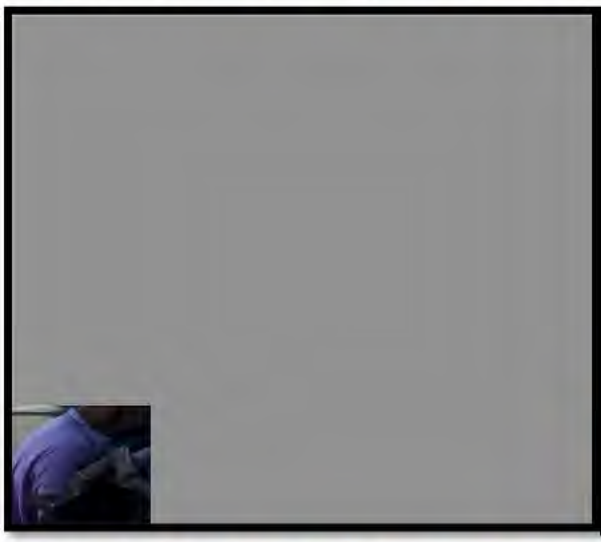

Figure 12. Field Trip to the Yadanabon Bridge in Mandalay on 10 Dec. 2014.

Figure 13. Field Trip to the Yadanabon Bridge in Mandalay on 10 Dec. 2014.

2.1.4 Completion of Training and Awarding of Certificates

Following the training, the team organized a "closing ceremony" on December 11, 2014, that was attended by senior managers of the MOC, the CDM Smith trainers, the USAID TOCOR, and the 40 trainees. Certificates of Completion, signed by the USAID Mission Director, were presented to the trainees.

Closing Ceremony Activities

Figure 14. Sample Certificate of Completion.

Figure 15. Turnover of AASHTO Reference Materials to MOC.

Figure 16. Bridge Design Trainees with Certificates of Completion.

Figure 17. Highway Design Trainees with Certificates of Completion.

2.1.5 Assessment of Current Conditions under Component 1- Training

As of the Final Report writing, all of the training activities under the project have been completed. MOC design engineers who participated in the training have received Certificates of Completion, in addition to textbooks ordered from AASHTO. The CDM Smith Team recognized that the project training provided a primer of key design topics and best practices, augmented by site visits and practical demonstrations during installation at the pilot section. Additional monitoring of trainees to track their understanding and application of skills enhanced during the project would be helpful in documenting impacts of the training program.

Follow up with the training participants might also help to identify potential future training sessions to build on the Project training courses.

2.2 Component 2: Procurement

To complement training and yield tangible, physical results, the project sought to demonstrate safety measures by identifying, procuring, and installing highway safety equipment and materials on a 10km pilot section. Component 2 focused on identifying and procuring the necessary safety equipment and materials. All procurement activities were developed in close coordination with the MOC and in accordance with USAID procurement regulations.

2.2.1 Development of the Procurement Packages

Based on an assessment of the available vendors and the required materials and equipment, three procurement packages were developed for the project:

- ***Package 1: Pavement marking materials and equipment.*** These items would be used for the clear, retro-reflectivity delineation of the pavement and the centerline; a technology that is particularly advantageous for night time driving when poor visibility creates hazardous conditions. Because the MOC lacked experience with thermoplastic line marking, this package included line marking equipment and five days of OJT by the vendor for MOC technicians and supervisors.

- ***Package 2: Work zone safety equipment.*** Because the MOC's work zone management efforts needed enhancement, CDM Smith introduced U.S. work zone safety practices and equipment to Burma in order to improve road safety during maintenance and construction activities. These practices and accompanying equipment can be applied during future work along the expressway and, eventually, to the rest of Burma's road networks.

- ***Package 3: Traffic signage***. It is important to warn motorists of poor horizontal and vertical alignments in advance of approaching them, day or night. With retro-reflective technology, signage can be seen clearly in dark conditions. Also included in this package were breakaway couplings, a new technology that reduces damage and injuries caused when a vehicle collides with a traffic sign post[3].

2.2.2 Development of the Bills of Quantities

Three procurement packages each incorporated a BOQ, as follows:

- ***Package 1*** - items for pavement marking materials, equipment and equipment training;
- ***Package 2*** - items for general road construction safety equipment; and,
- ***Package 3*** - items for roadway signage, reflective markers and associated materials.

The final configurations of the three packages were the result of an interactive process that included inputs from the MOC and potential vendors. **Attachment B** contains the Bill of Quantities for the three packages, and **Attachment C** contains the Bill of Quantities of small tools, materials, equipment and signs primarily purchased in Burma.

[3] A demonstration of the effectiveness of the breakaway couplings occurred on September 20, 2015 when a car crashed into two posts and sustained minor damage, with no injuries to its occupants.

2.2.3 Request for Quotations and Identifying Potential Suppliers

The Team's research revealed that vendors in the U.S., Burma, Thailand and Malaysia could supply all of the equipment and materials required for Package 1, the largest and most complex Package. While U.S. vendors expressed concerns about the Burmese sanctions regime, the Southeast Asian vendors showed an interest in providing the best combination of cost and delivery times. CDM Smith visited three vendors' offices to ascertain their interest and ability to deliver the requested materials, and then prepared cost estimates for each package based on the inquiries and vendor price lists. These inquiries and price lists ultimately informed the development of the Request for Quotation (RFQ).

CDM Smith requested and received a waiver from USAID of Geographic Code 937 (manufacture and source requirements), which limited the sourcing of vendors to only the recipient country (Burma), the U.S., and developing countries that were not on the Advanced Developing Countries list. The waiver enabled the Team to source potential vendors from Thailand and Malaysia, for example. The CDM Smith Team conducted internet research, telephone interviews, and in-person site visits to identify relevant vendors and document their potential interest in the equipment and supplies procurement.

2.2.4 Issuance, Receipt and Evaluation of RFQs and Issuing the Purchase Orders

Issuance of the RFQ. All interested, qualified companies were first sent a preliminary BOQ for Packages 1, 2 and or 3; from which they could decide to receive official RFQs for one, two or all three of the Packages. For Package 1, nine firms received the RFQ; five from the USA, two from Thailand, one from Malaysia and one from Burma. Nine firms were issued the RFQ for Package 2; seven from the USA and two from Thailand. Ten firms received copies of the RFQ for Package 3; seven from the USA, two from Thailand and one from Burma. All RFQs were all issued to the firms in February 2015.

Receipt of the Quotations. According to the original RFQ for Packages 1, 2 and 3, all Quotations were to be submitted by 25 February 2015. However, because very few Quotations were received by this time and three firms had requested an extension, an RFQ addendum was issued to extend the deadline to 7 March 2015. Three quotations were received Package 1; two for Package 2; and three for Package 3.

Evaluation of the RFQs and Selection of Vendors. Quotations for each package were evaluated in terms of completeness (i.e., ability to supply all items in the package), cost, and delivery time. Additional clarifications were requested from the vendors during evaluation.

- For Package 1, two Quotations were evaluated, one from the US and the other from Thailand. The third firm withdrew its quotation. The US vendor's quoted price was considerably higher than the Thai one and required a very long delivery time – 160 days from the Purchase Order issuance to the Burma arrival date. In contrast, the Thai vendor required only 45 days. For this reason, the Thai vendor was chosen.

- For Package 2, the least expensive of the three packages, two quotations were evaluated. Again, a very long delivery time was requested by the U.S. vendor. The Thai vendor was unable to provide two requested items, but they could provide alternative safety items of equal quality while offering a shorter delivery time and a slightly lower cost. Furthermore, because it was the same vendor chosen for Package 1, time spent clearing customs would be reduced if both Packages were consolidated in one shipment. The Team selected the Thai vendor for all of these reasons. With Packages 1 and 2 combined, work on the thermoplastic marking could begin independently of the arrival of the Package 3, which contained all the signage materials.

- For Package 3, quotes were received from a Thai vendor, one from a Burmese vendor and one from a U.S. vendor. The key challenge of this Package was scheduling the procurement of the specified breakaway couplings, which could only be bought from U.S. suppliers and could take several weeks. The US vendor – quoting the lowest price of the three firms – was ultimately chosen after it worked with a breakaway coupler manufacturer to guarantee a reasonable delivery time (Purchase Order issuance to arrival date) of 70-80 days.

Issuing the Purchase Orders. The Purchase Order for Package 3 goods was issued on 15 April 2015. Purchase Orders for goods from Packages 1 and 2 were issued on 28 April 2015.

2.2.5 Shipment and Receipt of Goods

CDM Smith's success in clearing the goods through customs was partially due to the Team's attention to detail and close coordination with the MOC shipping department. Several meetings were held with the MOC to ensure that national shipping requirements and customs tips – such as including the statement "Donated by the People of America" on the preliminary document (along with the Commercial Invoice, Bill of Lading and Packing List) – were understood, and a clearance agent was contacted to verify our compliance with the procedures. CDM Smith also worked with USAID to benefit from previous lessons learned, as well as another implementing partner importing a large amount of commodities on behalf of a Burmese ministry. All shipping documentation was delivered to the MOC expeditiously. Once the Packages arrived in Burma, cleared customs, and were delivered to the temporary MOC warehouse located at MP 175/5, all goods were immediately unpacked, inventoried and carefully stored.

2.2.6 Assessment of Current Conditions under Component 2 - Procurement

As of November 2015, all procurement activities under Component 2 have been completed and transferred to the MOC for installation on the pilot section. The CDM Smith team has inventoried the excess materials and equipment that remained from the pilot section and consulted with the MOC regarding plans to use the excess materials on other road segments. A final visit to the MOC in late November 2015 will be used to further discuss plans for use of excess materials.

Lessons learned from the procurement process are being documented and may be useful for future implementers.

2.3 Component 3: Construction Oversight of Pilot Section

During Component 3, highway safety design upgrades were applied to the 10 km pilot section identified during Component 2.

2.3.1 Pre- Construction Planning

The construction work required for the safety upgrades to the Road to Mandalay pilot section was defined during November and December 2014 and included:

- Reflective thermoplastic edge striping along both sides of the north and south bound lanes of the highway.
- Reflective thermoplastic centerline down the center of the north and south bound lanes.
- Reflective thermoplastic warning rumble strips in front of road curves.
- Reflective thermoplastic rumble strips at the approach to two U-turns.
- Erection of warning and regulatory signs.

- Installation of reflective warning devices (raised reflective pavement markers and barrier reflectors).

To facilitate this work, CDM Smith's highway designer used a Google Earth image to develop pilot section drawings that identified the locations of the rumble strips, raised reflective pavement markers, and the types and locations of warning and regulator signs. These were later simplified into single line drawing (developed in an Excel spreadsheet, shown in **Attachment A**) to coordinate the works for the section of road between MP 169.1 and MP 169.5 The drawings were also used to develop **Attachment D,** which uses MUTCD signs as symbols.

Reflective Thermoplastic Striping and Rumble Strips. A four-phase plan for the application of the reflective thermoplastic line striping was developed, with one crew working on the south bound traffic lanes and another on the north bound lanes.

- The first phase included (a) the placement of edge striping on the south bound lanes, starting with the shoulder edge striping along MP 171/2 to 164/7 MP; (b) the placement of edge striping on the north bound lanes, beginning with the shoulder edge striping along MP 164/7 to MP171/2; (c) the removal of the pre-existing non-reflective centerline striping on the south bound lane from MP 164/7 to MP171/2; and (d) the removal of the pre-existing non-reflective centerline striping on the south bound lane from MP171/2 to MP 164/7.
- The second phase included (a) the placement of edge striping on the south bound lanes, starting with the curb edge, from MP 164/7 to MP 171/2; and (b) and the placement of edge striping on the north bound lanes, starting with the curb edge, from MP 171/2to MP164/7.
- The third phase included (a) the placement of centerline striping on the south bound lane from MP 171/2 to 164/7; and (b) the placement of centerline striping on the north bound lane from MP 164/7 to MP 171/2.
- The fourth phase included (a) the placement of rumble strips on the south bound lanes, with the first rumble strip starting after MP 164/7 and the last before MP 171/2; and (b) placement on the north bound lanes after MP 171/2 to the last rumble strip before MP 164/7.

Drawings illustrating the four phases of the retro-reflective thermoplastic pavement striping work were created for review with the MOC and the striping crews before commencing work.

Traffic Warning Signs, Regulatory Signs and Object Markers. The signal line drawings showed the locations, dimensions and placement of rumble strips; as well as the types, locations, and horizontal and vertical distances for the installation of various signs. The MOC reviewed the drawings and later used them to plan and execute the work. Generally, rumble strips were located ahead of curves and U-turns. The sign location drawings included a (a) "not to scale" illustrative drawing of the types of signs over the length of the roadway, and (b) a single line diagram of the MP locations of existing signs to be removed and new signs (with MUTCD designations) to be installed.

Raised Reflective Warning Devices. Raised Reflective Pavement Markers (RRPMs) were placed at 35 foot intervals along the curves. One additional marker at each end extending 35 feet past the curve was established.

Safety and Traffic Control Materials and Personal Protective Gear. The BOQ items developed for Package 2 included attire and equipment for personal safety and traffic control. Twenty traffic warning flags, four solar powered vehicle mounted solar arrow boards with two revolving lights, and an additional 20 traffic warning flags were later added to the PO for Package 3. Additional safety attire and equipment (as well as the traffic warning signs) were purchased in Thailand and

Burma. Upon receiving and reviewing manufacturer recommendations for the materials supplied under Packages 1 and 3; face masks and additional goggles, working gloves and overalls were purchased in Thailand and hand carried to the construction site to ensure that sufficient safety attire would be available in time for construction activities. Additionally, a personal safety attire policy was developed after reviewing the thermoplastic vendor's publications with the MOC and its work crews prior to the start of construction. Because temperatures of the pre-heaters acquired under Package 1 reach over 180 degrees centigrade, fire extinguishers were purchased in-country to accompany the equipment at all times.

Traffic warning signs based on MUTCD for use in construction areas were fabricated in Rangoon and assembled at the MOC temporary warehouse at MP 175/5, and six sets of traffic signs (five written in Burmese and one in English) were locally purchased. Prior to the start of construction, plans for each phase of the retroreflective thermoplastic striping construction were developed to coordinate necessary personnel, equipment, and traffic warning devices and signs. These plans were shared with the MOC and their crews before work began.

2.3.2 On-the-Job Training (OJT)

The Thai supplier of the pavement marking materials and equipment, PPI Company Limited (PPI), conducted five days of thermoplastic pavement marking training for the MOC operators and managers. Formal training of the line marking crews began at the MOC maintenance depot at MP 174/5, with a short opening ceremony for approximately 60 people, including MOC marking crews, engineers and supervisors. This was followed by a brief presentation by the Managing Director of PPI, who provided an overview of different pavement markings technologies with an emphasis on thermoplastic materials and equipment. The CDM Smith team described the line marking program agenda and operating procedures, stressing the need to observe construction safety practices (e.g., personal protective gear, traffic control, etc.) at all times.

As part of the OJT training, the MOC crews were later shown how to prepare the pavement for the application of the thermoplastic marking material. This involved two operations: the removal of the pre-existing, faded oil-based paint marking and an application of the primer for the thermoplastic. Thermoplastic training began at the northern end of the pilot section MP 171/2. Large pre-heaters were used to heat the thermoplastic material. A few minor glitches occurred during the initial equipment practice sessions, such as the high temperature causing the thermoplastic material to bubble; minor spills; crooked applications of primer; and the placement of just 200 meters of slightly misaligned thermoplastic line edge striping.

The observant trainers were quick to make corrections, and by the end of the second day, most of the initial problems had been resolved, substantially increasing the crew's productivity levels. Trainees and trainers were divided into two groups: one continued striping southward, the other began placing edge line striping at the southern end of the pilot section at MP 164/7. The two line striping crews progressed with minimal assistance from the trainers, and on the last day of OTJ they had finished the thermoplastic marking, independently, under the supervision of the trainers.

Figures 18 through **24** present some of the hands-on training demonstrations and practices during Component 3.

On-the-Job Training Activities

Figure 18. *OJT for the removal of old painted line markings.*

Figure 19. *OJT on the use of line-marking equipment.*

Figure 20. *OJT for applying primer to concrete roadways.*

Figure 21. *OJT on placement of retroreflective thermoplastic materials to the roadways.*

Figure 22. *OJT on the set up of pre-heaters for the first usage of thermo-plastic material.*

Figure 23. *OJT on worksite traffic control and safety measures for day light and night usage (no night time usage of equipment was required). Work zone traffic control equipment and signage was set up at beginning of work and dismantled at the end of work.*

Figure 24. *Police assisted with traffic control during construction.*

2.3.3 Installation and Construction

The safety upgrades along the 10 km pilot section included (a) the placement of reflective thermoplastic marking and rumble strips; (b) the installation of traffic warning signs, regulatory signs and object markers; and (c) the placement of reflective warning devices (RRPMs and concrete barrier reflectors).

Reflective Thermoplastic Marking and Rumble Strips. The reflective thermoplastic striping entailed (a) the placement of a yellow 15 cm wide continuous edge striping along the entire length of the roadway on both sides of the two lane divided roadway[4]; (b) the placement of a white 10 cm wide dashed centerline along the entire length of the roadway on both side of the two lane divided roadway; and (c) the placement of yellow reflective thermoplastic rumble strips with 10 cm wide lines on both sides of the two lane divided roadway at the approaches to eight curves and two U-turns. Placement of the reflective thermoplastic edge striping was completed on 21 August 2015; the centerline striping was finished by 25 August 2015.

The reflective thermoplastic rumble strips included ten raised yellow thermoplastic lines 10 cm wide and 7-8 cm high, spaced 40 cm apart. An arrangement of rumble strips was placed across the roadway before horizontal curves, and along the roadway on the approach before a U-turn. The rumble strip arrangement before the curves consisted of two sets of rumble strips, with the first starting at or just before the start of the road curve and extending across the road with a second strip placed approximately 27 meters behind. Arrangements for the two U-turns comprised three rumble strips placed approximately 27 meters apart, with the first starting around 152 meters before the U-turn and another rumble strip starting approximately 61 meters before the U-turn.

Rumble strip placement required that the crews to stop traffic. For worker and public safety, work traffic control procedures and placement of traffic warning signs were installed (e.g., "Be Prepared to Stop"); a flagman helped control traffic; and an arrow board was positioned approximately 200 meters ahead of the work. Other safety measures included placement of battery powered barricade lights, reflective traffic cones, and waffle boards to block one traffic lane. Traffic stopped about 200 meters in front of the work, allowing four to six strips/lines to be placed and harden before traffic was allowed to continue. The work had a minimal effect on the traffic flow.

The MOC crews placed a total of 58 rumble strips (16 at U-turn locations and 32 at curves) over the course of four days, from 25 August 2015 to 28 August 2015. Accomplishing all of the thermoplastic pavement striping along the pilot section – including rumble strip placement and repairs and extensions to the thermoplastic lines — required 56.4 tons of the following materials:

Table 7. Use of the Line Marking Materials on the Pilot Section

Materials	Number of Bags	Metric Tons
Yellow Thermoplastic (in 20 kg bags)	2,047	41.48
White Thermoplastic (in 20 kg bags)	514	10.29
Glass Beads (in 25 kg bags)	185	4.62

[4] US standard practice is the following: 1) the inner edge is yellow strip, 2) the center line is white, and 3) the outer edge is white. However, in Burma the standard is yellow lines on the inner and outer edge of the pavement and white for the center line.

Traffic Warning Signs, Regulatory Signs and Object Markers. The MOC crew installed 184 traffic warning signs, four traffic regularity signs, and 40 object marker signs; using 204 sign posts with closure caps and 132 breakaway couplings for all signs not protected by concrete barriers or guard rails. This new technology allows the post to "break away" from its foundation in the event of a collision, preventing injury to the driver and/or a front seat passenger and mitigating vehicle damages.

Figure 25. Installation of Breakaway Coupling

The couplings used for this project are compliant with US Federal Highway NCHRP 350[5]. They have a 360 degree shear point and can withstand winds loads of up to 120 mph. The coupling is simply installed by inserting the coupler into the top of a ground mounted anchor post, the bottom into sign post and tightening a set screw. The more difficult part of its installation is assuring that the total pole length, including the ground anchor and the sign post together, are plumb.

Sign installation was completed by 19 September 2015, and 36 pre-existing signs were removed in the following two days.

Figures 26 through **28** present the results of the installation activities.

Figure 26. *Curve at MP 166/2 with rumble strips, object markers, chevrons, raised reflective pavement markers and concrete barrier, reflectors.*

Figure 27. *Signs at U-turn intersecting road area MP 169/5.*

Figure 28. *Close-up of object marker, raised reflective pavement markers and concrete barrier reflectors.*

Reflective Warning Devices. The MOC installed a total of 340 RRPMs along the inside of all horizontal curves along the pilot section. The markers were placed at 35 foot intervals, with one additional marker extending 35 feet past the curve. Installation occurred at 16 locations and was completed on 20 August 2015. Additionally, 160 concrete barrier reflectors were placed along the pilot section at various locations and intervals (depending on the location of the barrier). Reflective marker placements were completed on 22 September 2015.

[5] Other coupling designs based on this publication are also acceptable.

Figures 29 through **32** present some of the additional work of crew members during signage installation.

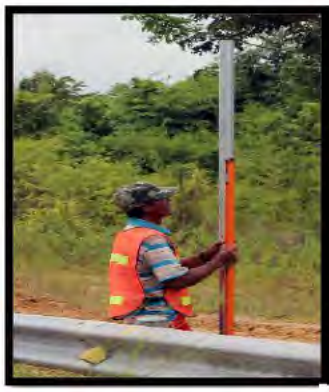

Figure 29. *A MOC crew member leveling and lining up a sign post.*

Figure 30. *The MOC crew installing chevrons behind an existing guard rail.*

Figure 31. *During day light, the chevrons help to identify the location of the curve. A useful pre-existing sign remains in place.*

Figure 32. *Traffic signage at MP 171 right hand curve in southerly direction (speed limit 80 km/hr)*

2.3.4 Pilot Section Inspections

Pavement striping was continuously monitored for temperature and alignment as the activity advanced. Aside from a section of edge striping placed on the first day of OJT, alignment discrepancies were usually immediately removed and replaced. Several other minor issues were identified and remedied, including a rumble strip near MP 169.5 that had not adhered to the road properly, perhaps due to a chilling of the thermoplastic during application; and early problems with the installation and placement of the signs. Corrective measures, which required the purchase of some additional small tools, were recommended by the team and implemented by the MOC. Finally, following the completion of pavement centerline striping, several nocturnal inspections were conducted to check for non-reflective "dead-spots," or sections lacking retro-reflectivity due to insufficient quantity of glass beads, along the roadway striping. Night inspections conducted by the MOC revealed several "dead spots," which were quickly corrected.

A day- and night-time inspection conducted by USAID TOCOR, CDM Smith, and the MOC on September 24, 2015 determined that all safety upgrades had been successfully completed.

Figure 33. *Chevrons, reflective markers and line marking showing the way forwards at night.*

2.3.5 Assessment of Current Conditions under Component 3 - Construction Oversight

All of the pilot section installation activities have been completed as of November 2015, as shown in the previous section. Daytime and nighttime inspections of the road have been conducted and have indicated a successful effort to improve safety on the pilot section of the Road to Mandalay. Plans are being developed to apply the excess project materials on other roads or segments of the Road to Mandalay. With a considerable amount of line marking material remaining, the MOC has decided to apply the surplus to the southerly extension of the pilot section line marking, as well as other high-risk sections of the expressway. Five priority sections have been identified by the MOC to date. CDM Smith also recommends that the MOC also reserve a quantity of these materials for repairs; rumble strips, for example, are especially likely to require continued maintenance.

Field inspection from November 24-25, 2015. As part of the final project inspection of the pilot section, the project team, comprising CDM Smith, IGS, and USAID representatives, conducted inspections of the road safety works done by MOC at five selected locations along the Road to Mandalay. The MOC had selected each of the locations where there had been major incidents (accidents) involving loss of life, injury and property damage. The inspection methodology used entailed a wind shield inspection of each location and ocular examination by foot at certain locations, particularly where the quality of the workmanship appeared not to have held up. The five sites were located at:

- MP 104/7 to MP 105/1
- MP 113/3 to MP 113/5
- MP 128/2 to MP 128/4
- MP 149/5 to MP 149/6
- MP 153/7 to MP 154/3

The works consist of line marking [yellow solid 15cm (6 inches) wide and both outer and inner edges of the roadway and a 10 cm (4 inches) white broke center line] and rumble strips (two sets of 10 yellow stripes perpendicular to the direction of traffic). The pavement marking enables drivers to see the location of the outer edges of the pavement, while the white center line defines the widths of the lanes. Together, they assist drivers to more accurately steer their vehicles, especially where the alignment changes. The rumble strips warn drivers through noise and vibrations to expect a curve or other changes in the alignment or road conditions. Generally, the works are well done and remain in good condition. There are several short

sections (less than 2 meters long) where the thermoplastic appears to be breaking up and/or deteriorating. The main causes of these failure may be due to insufficient quality control during construction (too low of temperature of the thermoplastic material and its application may be too thick). MOC indicated that possibly as an act of vandalism some persons may have broken short sections of the right pavement strip, which also contributed to some of the breakup of the yellow striping. It is recommended that MOC repair these sections prior to the rainy season.

Some of the rumble strips show deterioration of the thermoplastic material in the direction of the traffic. The exact cause is not known but this should be monitored by MOC. It is recommended that MOC repair the strips which show marked deteriorations due to traffic.

Figure 34: Current conditions of the five sections

MP 105 Showing chevrons, guardrail within median, line marking and rumble strips before curve.

MP 105 Rumble strip showing no signs of deterioration

MP 113 Failure of thermoplastic line marking right edge roughly 1.5 meter long.

MP 128 Failure of a small section thermoplastic striping

MP 128 Rumble strip showing deterioration along the edge of strips in the direction of traffic

MP 153/7 Start of section – Interchange includes ramps and shows alignment challenges. More signage is highly desirable along this section.

At MP 165 to 172/2, examination of the thermoplastic pavement marking indicated excellent condition, where no break up or damage sections were observed. The signage remained in

Table 8: *Observations along the Five Sections Using Thermoplastic Materials*

Travel in North Direction: Rangoon to Naypyidaw		South Direction: Naypyidaw to Rangoon	
Mile Post	**Comments**	**Comments**	**Mile Post**
From 104/7 To 105/1	Safety improvements are located on sharp right hand curve.		**From 105/1 To 104/7**
	Seven (7) project chevrons are utilized but only in the north direction. They clearly make the curve standout along with correctly placed guardrails inside of the median. Guardrails on right side are not necessary. The chevron are installed correctly. Rumble strips are within curve rather than placed before it. Line marking is in good condition and well placed. Raised pavement markers were observed.	Chevrons are not located in this direction. Line marking is in good condition with some very minor deterioration.	
From 113/3 to 113/5	Safety improvements are located on curve.		**From 113/5 to 113/3**
	Rumble strips are located before the curve. Some minor failure of the thermoplastic striping on right side was observed. It might have been placed at a too low of temperature.	The line marking is in good condition. No deterioration of the rumble strip due to traffic was observed. See comments below.	
From 128/2 to 128/4	Safety improvements are located on curve.		**From 128/4 to 128/2**
	Some minor deterioration of the thermoplastic line marking. It may be due to lack of proper removal of the old line marking or applying the thermoplastic at a too low temperature.	Condition on this side is better. Rumble strips show some deterioration due to traffic. This might be due to either poor placement of the material either due to too low of temperature or the thermoplastic material is too thick.	
From 149/5 To 149/6	Safety improvements located on tangent section.		**From 149/6 To 149/5**
	Improvements are limited to two rumble strips. Both are in good condition	The two rumble strips are in good condition.	
From 153/7 to 154/3	The safety improvements are located on overpass located on a curve. The vertical sight distances and length of the curve are not ideal for high speed travel. Since this section is also part of a small interchange, it should be redesigned to conform to AASHTO standards.		**From 154/3 to 153/7**
	The applications of the thermoplastic material is only applied to the high speed travel lanes. Its condition is general good. However some deterioration was notice toward the MP 154/3 where there were some gaps on the right side and some deterioration of the thermoplastic material.	The workmanship in this direction is good with discernable deterioration.	

excellent condition and no deterioration of the rumble strips was observed. **Table 8** describes the respective observations along the northern and southern directions of the road.

2.4 Participation in UN Road Safety Week

CDM Smith's Project Manager, Derek Sherman, was invited to participate and provide a presentation on road safety in Myanmar during the **UN Global Road Safety Week**. Week-long events were held in the People's Park in Rangoon and in other venues across the city. A World Health Organization (WHO) expert was quoted as having predicted that "Myanmar could have the world's third worst traffic accident death rate by 2020." With the accidents rates in the country a major concern and awareness raising of road safety issues important to decrease the fatalities, Mr. Sherman discussed some of the safety observations from the ongoing USAID project, including pedestrian and driver contributions to hazard risks as well as road design issues. He also discussed some of the elements of the WHO's "Ten Strategies for Keeping Children Safe on the Roads." Attendees at the workshop included the Mayor of Rangoon, the Chairman of Yangon Regional Government senior transportation officials, numerous traffic police officers, USAID, private sector representatives, and community-based organizations.

Figure 35. *Attendees at UN Global Road Safety Week*

2.5 Project Performance Monitoring and Evaluation

The CDM Smith team continually sought to measure Project progress, relative to the PMEP submitted during the Project start-up phase, throughout implementation to help the Team plan, manage, and achieve results. This section provides a summary of the performance status relative to the parameters established within the PMEP.

Table 9. Summary of Project Level Outcomes, Indicators and Milestones, Targets

Project level outcomes, indicators and milestone, performance targets and outcomes. *Strengthen capacity of Ministry of Construction (MOC) engineers and technicians to design technically sound and safer roads and bridges and in accordance with US standards. Implement a 10 km Pilot Section of Road Safety Improvement (Upgrades) in accordance to US standards including procurement of materials and equipment to support the project.*		
Indicator	**Target**	**Performance Outcomes**
Component 1: **Training**. Prepare and deliver training to government staff in highway and pavement design and bridge design, using AASHTO standards. The highway design training shall include an update of the design (excluding bridges) of a selected 10km section of the existing Rangoon to Mandalay road.		
Indicator: Provide capacity building in highway and bridge design through training for MOC engineers due to United States Government (USG) assistance.	40 trainees with three weeks training.	Performance outcomes successful.
Milestone 1: Trainees receiving improve highway and bridge design capacity due to USG assistance.	20 trainees in bridge design and 20 trainees in highway design plus on the on (OTJ) training for	Total of 20 each (forty total) trainees in road and bridge design participated in the training events. 36 trainees received Certificates of Completion on 11 Dec. 2014.

	20 highway engineers during construction.	MOC was unable to bring back highway design engineers for further OJT during construction due their diversion to other activities following record-setting floods in Burma.
Milestone 2: Training events completed due to USG assistance.	25 training events, including site visits.	Total of 30 days of training events (15 days each for highway and bridge design) including three site visits.
Milestone 3: Time to complete.	3 months.	Actual time was closer to 3.5 months. This included initial visit to Burma, preparation of training material and its review and approval and the training itself with some time for designing traffic safety upgrades.
Component 2: Procurement. Based on the BOQ for the safety upgrades developed during the training for the 10 km pilot section, undertake the procurement of materials and equipment, including reference and training documentation in accordance with USAID procurement regulations and with support from the GOB.		
Indicator: Procurement of materials and equipment in support of the program.	$500,000 for materials and equipment originally budgeted.	The actual values were less than foreseen, as shown below.
Milestone 1: Procurement.	$500,000 of materials and equipment procurement originally budgeted.	Less funds were expended on procurement than foreseen. Estimate was in the order of $300,000 in support of Components 1 and 3.
Milestone 2: Procurement of training materials including AASHTO reference material.	Not foreseen.	Estimated costs of roughly $50,000.
Milestone 3: Procurement of materials and equipment for the pilot section.	No budget initially foreseen but assumed to be total of $500,000.	Estimated costs of $250,000 in three international procurement packages and purchase of tools, equipment and materials in support of the work activities during construction. In additional, locally procured signs in Burmese were purchased.
Milestone 4: Time to complete.	Time allocated for this activity was unclear.	Actual time needed was from January through 3 weeks in July 2015, or over 7.5 months. Local procurement activities occurred during the construction activities.
Component 3: Construction Oversight of the 10km Pilot Section. The provision of a qualified construction superintendent to oversee the implementation of the safety upgrades on 10km pilot section.		
Indicator: Kilometers of road safety upgrades with USG assistance.	10 KM (no bridges).	Pilot section of 10 km with safety upgrades of road marking (pavement edge marking and center line) for total of over 60 km. Road signage for 10 km based on US Department of Transportation (USDOT) MUTCD standards (roughly 270 signs).
Milestone 1: Completion of road construction.	1 road segment.	Pilot section of over 10 km. At least 5 additional high traffic incident locations have been provided with road striping.

Milestone 2: Number of days of OJT of MOC road maintenance personnel of USG funded assistance.	5 days of OJT for MOC road maintenance technicians, supervisors and managers.	Material and equipment vendor provided five days of OJT for 40+ technicians and managers in retro-reflective thermoplastic line marking or at least 200 person days of training.
Milestone 3: Number of days of training and construction oversight with USG assistance.	86 days of training + 4 months installation (OJT).	Construction activities including OJT started on 4 August and was completed by the 24 September in roughly 6 weeks.
Milestone 4: Construction oversight.	Construction oversight during 4 months installation.	Construction oversight took approximately 6 weeks. Time saved in this activity was utilized for procurement activities.
Milestone 5: Work zone safety OJT.	No accidents or injuries through OJT.	The procurement included a number of work zone safety features, including workers' helmets and vests, signage in Burmese, and equipment to demarcate the work zone for daylight and night usage. There were no accidents or injuries that occurred during the construction of the safety upgrades.
General		
Milestone 1: Number of non-governmental beneficiaries.	Number of road and bridge users –TBD.	Road safety improvements completed for this Project benefit all road users driving through the Pilot section. There is no accurate traffic count data for the Road to Mandalay; however, estimates of the traffic volume range from 3,000 to 4,000 vehicles per day in both direction. If the average number of passengers per vehicle is assumed to be 4, including bus passengers, the upper limit this would be an estimated 16,000 beneficiaries per day, or 5.8 million per year.

2.6 Financial Summary

This section summarizes the Project finances (**Table 9**) by providing overviews of original and final budgets. The CDM Smith Pipeline Analysis indicates that through the end of the project performance period, the project will have reached its ceiling of $1,000,000. A budget realignment was approved and necessary due to:

- ***Schedule extension from 13 April 2015 to 18 December 2015.*** The key challenge of the original schedule was an inadequate allotment of time for Component 2 – Procurement, which entailed unexpected vendor delays and GOB customs clearance processes. Furthermore, the specific pilot section – which required specifications and standards for materials and equipment that could not be sourced within Burma – was not identified until mid-December 2014. Assembly (i.e., manufacture and fabrication of the materials and equipment) and delivery from outside countries required more time than allocated. In November 2015, delays for customs clearance of a final set of AASHTO textbooks resulted in an approved extension of the POP from November 30, 2015 until December 18, 2015.
- ***Additional labor costs.*** Additional labor costs arose for administrative and project management activities, as well as oversight and training activities during Component 3 – Implementation.

- ***Additional travel costs.*** Additional trips to Burma were necessary to oversee the materials and equipment installation; to ensure that materials and equipment were received and handled properly; and to train the MOC engineers.
- ***Purchase of books.*** The MOC requested additional training materials and books that exceeded the allotted book budget.

Table 10. Project Budget

Cost Element	Original budget (USD)	Final Budget (USD)
Direct Costs, including Fringe & Procurement	$807,270.93	$709,716.37
Indirect Costs	$122,958.24	$220,516.63
Total Estimated Cost	$930,229.17	$930,233.00
Fixed Fee	$69,767.19	$69,767.00
Total CPFF	$1,000,000.00	$1,000,000.00

III. IMPACTS, IMPEDIMENTS & LESSONS LEARNED, AND RECOMMENDATIONS

The Road to Mandalay Project created tangible safety benefits and a foundation for future improvements. In this section, lasting impacts are discussed; impediments and lessons learned are analyzed; and recommendations for continued improvements are made.

3.1 Project Impacts

Improved awareness of innovative technology and low-cost solutions. The project successfully introduced US design technologies and road safety measures to the MOC design staff. In the case of the breakaway coupling signage, for instance, the MOC learned a technology that has yet to be adopted by many advanced countries in the ASEAN.

While the road will ultimately require substantial, capital-intensive re-design and construction, the solutions presented in this Project offer immediate, low-cost measures to protect travelers. The highway and bridge design trainees now have the basic design tools, equipment, and knowledge necessary to improve the safety of the pilot section and other locations along the expressway and other rural roads in Burma.

The recommendations for the pilot section show how relatively low-cost solutions can be beneficial in the short term, while a more permanent solution will require redesign of sections of road and sizable capital investment. The highway designers have the basic design tools to prepare the long term improvements to the pilot section and other locations along the expressway and other rural roads in Burma.

Practical knowledge gained from on-the-job training and demonstrations to augment classroom work. The OJT and pilot section demonstrations had two objectives: (1) to familiarize MOC designers, management and maintenance crews with thermoplastic line marking and signage using retro-reflective technology; and (2) to improve work zone safety, which is not widely practiced in Burma, with the use of personal protective gear and traffic control equipment. Both were achieved. Quality work was completed and the MOC crews are now capable of continuing the activities without further guidance – as they plan to with the

applications of surplus thermoplastic at five other high-priority sites on the Road to Mandalay. Whether MOC adopts these technologies and applies them to other locations along the national road network with their own resources is yet to be seen. A small amount of surplus thermoplastic material remains and MOC will be applying to areas of the expressway which are prone to frequent crashes.

Demonstrated commitment and buy-in from the Burmese MOC. At project start-up, CDM Smith entered into a Memorandum of Understanding (MOU) with the MOC, which engaged the MOC in active project participation. The MOC "bought-in" to the objectives and approach of the project, demonstrating support throughout all three components. Together, both parties learned about implementing upgrades and completing procurement processes in Burma.

Increased knowledge of work zone safety practices by MOC. Standardized work zone safety measures are not yet regularly practiced in Burma. To demonstrate the benefits of worker safety procedures, CDM Smith used individual safety equipment and traffic control equipment throughout the work zone. All the works along the pilot section were completed without injury or accident, and the demonstration proved a beneficial learning experience for MOC management and work crews.

Improved road safety along the 10km Pilot Section of the Road to Mandalay. While nighttime travel along the Road to Mandalay poses a general risk, the safety advantages of the retro-reflective line marking and signage are significant. Collisions will occur less frequently, lives will be saved, and injuries and property damage will be reduced. Evidence of the value of the pilot section upgrades have already occurred: at 4 AM on 21 September 2015, a driver crashed through post with a breakaway coupling, turned sharply to the left, and then drove over a second breakaway coupling. Both breakaway posts gave way to the vehicle, so there was minimal damage to the car and no injuries among the driver or passengers. **Figure 34** presents photos after the accident and the benefit of the breakaway post. The series of photos from left to right is a reconstruction of the route traveled by the vehicle as it impacted two breakaway sign posts. The red arrows show the direction of travel. The right photo shows the result of the impact one post and the arrow shows direction in which direction the vehicle was traveling.

Figure 36. *Example of the benefits of breakaway coupling technology.*

With such evident benefits, there is expected to be a high demand for the installation of this technology along the expressway and other Burmese roads. Major improvements to road safety require more than technical upgrades to the roads themselves; it requires a complete change of driver attitudes and approach to driver education, stronger enforcement and policies that support road safety.

3.2 Impediments and Lessons Learned

Ensure flexibility and adaptability in project approach and implementation. Working in Burma currently requires a flexible and adaptable approach to account for potential unexpected delays and bureaucratic procedures and requirements of the GOB, in addition to constraints

related to the U.S. Office of Foreign Assets Control's ("OFAC") sanction programs in the country. Meeting venues might change (i.e., trainings were relocated to a MOC training facility in Naypyidaw); training participants might not meet the vetting requirements under OFAC if they are on the Specially Designated Nationals (SDN) List; and customs procedures and processes might delay shipments and derail planned installation schedules. Weather too was a major potential obstacle, particularly as monsoon season and corresponding flooding episodes was approaching, which could affect the roads installations.

Under Component 1, the training and experience of the participants in two courses varied considerably, requiring an adjustment of the training curriculum development. Whereas the highway design trainer was able to accommodate all trainees within the established syllabus, the bridge design trainer needed to significantly restructure his course in order for it to be a valuable learning experience for the MOC staff. The modifications gave the trainees a solid foundation for continued learning in the field of bridge design, and his degree of flexibility allowed for a successful completion of the course and high performance ratings for his efforts.

Under Component 2, the time schedule for procurement activities needed continual adjustments too to account for a number of variables that impact the schedule. This included time needed to identify vendors under the existing USAID project geographic code 937, the shipment timeframe, and the time needed to clear customs. Working with the MOC to prepare RFQs, select a preferred vendor, and award the purchase orders demanded a significant amount of coaching and capacity-building; and some vendors were reluctant to ship materials to Burma because the time and attention required and perceived risks of working there. The project schedule was expanded by five months for the customs process to be completed, which was still short relative to other implementers undergoing similar processes. Despite the challenge, and as a result of the time devoted to careful procurement preparation, the shipments arrived in good condition.

Coordinate closely with your local counterparts. When a project team closely coordinates activities with local counterparts, successful outcomes are likely to happen. The MOC helped ensure that all shipping requirements and documentation prepared by the project team were in accordance with Burmese requirements. Close coordination with the MOC ensured that the materials were able to clear customs and be delivered to the construction warehouse.

3.3 Recommendations: Building on Project Results

The pilot section upgrades will help reduce the high fatality and injury rates associated with the "death highway," and the MOC is encouraged to implement these technologies throughout the length of the Expressway. However, more comprehensive measures should be taken to ensure long-term national road safety.

Sustain and build upon project results. Much more remains to be done in Burma in terms of road safety; scaling up the impacts of this Project is important because roads safety in Burma is a national crisis. Improvements should cover the entire network of national primary and secondary road, and the Project training and the installation activities can serve as a model for interventions on the remainder of the Road to Mandalay and other road networks in the country.

Build technical expertise in work zone safety and traffic engineering. The MOC should adopt work zone safety procedures for its works, and all road projects within Burma should follow a safety plan. All road designs and implementations of safety features should be reviewed by a

qualified traffic engineer; therefore, the MOC should build a cadre of skilled engineers – including traffic engineers – to better manage these traffic safety programs.

Continue to build technical capacity of MOC staff. Various opportunities for building the technical expertise of MOC staff exist. For example, funding for a two-year graduate level training in traffic engineering at an American university might be made available to MOC staff; and various lengths of international internships at state highway/transportation departments might be awarded to qualified engineers.

Expand road safety programs to other road networks in Burma. The skills shared through this project should be applied to roads throughout Burma. While the expressway accident rate is high, primary and secondary roads have more frequent incidents of accidents involving pedestrians and non-motorized traffic. Replicating this project for other high-priority roads would improve local staff capacity. Training and technical assistance for short-term improvements (e.g., line marking and signage), as well as long-term improvements such as a major realignment, might be provided. This program should be coordinated with other similar ones by MOC and other funding agencies.

Promote an integrated approach to road safety. Road safety should be addressed holistically; implemented locally and coordinated at the national level to provide consistent policies and procedures. The approach should integrate policy, technical assistance, public awareness, and financing to provide a range of long-term solutions. Short and long term technical assistance should be provided in engineering, enforcement, and education fields; public involvement programs; and emergency services to build capacity for road safety management. These efforts would require coordination with national and local institutions to maximize program efficiency and fund the necessary resources. Specific recommendations include:

- Road safety programs and strategies should focus on both short and long-term objectives, recognizing that many results will take years to achieve.
- Provide *ad hoc* support to the national steering committee in regards to defining strategic goals; developing coherent national policies; and building more inclusive processes in order to allow greater participation of stakeholders from the private sector and civil society.
- Support the development of a national traffic incident database through coordinated data collection and management, report preparation, and distribution and evaluation.
- Assist the MOC and other agencies in utilizing the traffic incident database to identify short and long term engineering solutions.
- Assist in developing national traffic safety campaigns with the media, private sector and civil society.
- Assist in strengthening emergency services through improved communications, equipment, and paramedic technicians (first responders) training.
- Assist in identifying potential sources of funding for road safety.

Evaluate and effectively use traffic accident data. Training in accident reporting and investigation is necessary to ensure consistency and accuracy – and to identify future high priority road improvements. For this reason, the Team recommends the implementation of a program to build the capacity of the MOC and traffic police with:

- The collection, analysis, storage, retrieval and distribution of traffic crash data, including recommended changes to the existing database. A new database should be robust and allow for the geocoding of all data entries and GIS based outputs.
- An analysis and evaluation of traffic incident statistics, assisting governmental departments and others in interpreting and using the results.
- A review of incident reporting and investigation methodologies, with recommended changes, and capacity building in incident management and investigation.
- Establishment of national data collection standards in accordance with international norms. Locally collected data must be consistent with national standards.
- Training aimed at capacity building in accident reporting and investigation is a necessary requirement to ensure consistency and accuracy. The evaluation of traffic statistics is important in identifying road sections that are prone to accidents; this will require coordination between MOC and the Traffic Police to obtain the best results.

Attachment A

Straight line drawing showing location of signage using MUTCD Designation. MP 169.1 TO MP 169.5

MP POST	Left Side of Road – North Direction	Medium	Right Side of Road – South Direction	MP POST
169.1				169.1
169.11				169.11
169.12				169.12
169.13				169.13
169.14	W1-2R (80)			169.14
169.15				169.15
169.16	**Start Curve**		**End Curve**	169.16
169.17	W1-8R		W1-8L	169.17
169.2	OM3 R (in front of Post) W1-8R		W1-8L	169.2
169.21	W1-8R		W1-8L	169.21
169.22	W1-8R		W1-8L	169.22
169.23	8 Chevrons W1-8R		8 Chevrons W1-8L	169.23
169.24	(with Bk Coupling) W1-8R		(No BK Couplings) W1-8L	169.24
169.25	W1-8R		W1-8L	169.25
169.26	W1-8R		W1-8L	169.26
169.27	W1-8R		W1-8L	169.27
169.3	**End Curve**		**Start Curve**	169.3
169.31	*Remove existing U Turn Sign*		W1-2aL(80)	169.31
169.32	Caution U Turn Ahead (in Burmese)			169.32
169.33				169.33
169.34	W2-R2			169.34
169.35			(at end of guardrail) OM3 R	169.35
169.36		W1-11 & 100 M	*Remove existing Left Arrow Sign*	169.36
169.37				169.37
169.4			W1-2L & W13-1(80)	169.4
169.41	R1-1 (at intersecting Road)	W1-11 R1-2	R1-1 (at intersecting Road)	169.41
169.42		U Turn		169.42
169.43		R1-2 W1-11		169.43
169.44				169.44
169.45				169.45
169.46		W1-11 &100 M		169.46
169.47				169.47
169.5			W2-2R	169.5
169.51				169.51

Attachment B

Bills of Quantities

Package 1: Bill of Quantities

1	Thermoplastic pavement marking material – yellow color	66	Metric Tons
2	Thermoplastic pavement marking material – white color	22	Metric Tons
3	Glass beads	11	Metric Tons
4	Primer/sealer material	1,514	Liters
5	Primer application equipment	2	Each
6	Primer application equipment - spare parts	2	Lot
7	Self-Propelled Extrusion, Thermoplastic Applicator	3	Each
8	Thermoplastic Applicator - spare parts	3	Lots
9	Thermoplastic Pavement Marking Material Pre-Heater	2	Each
10	Thermoplastic Pavement Marking Material Pre-Heater-spare parts	2	Lots
11	Traffic Line Remover	2	Each
12	Traffic Line Remover - Spare and Replacement parts	4	Lots
13	Horizontal Retroreflectometer	1	Each
14	Vertical Retroreflectometer	1	Each

In addition to the items listed above, under the terms of the Purchase Order, the supplier was also required to provide On the Job Training (OJT) for all the equipment supplied.

Package 2: Bill of Quantities

1	Safety Vests -Class III - small	20	each
2	Safety Vests -Class III - medium	30	each
3	Safety Vests -Class III - Large	30	each
4	Safety Vests -Class III - Extra Large	2	each
5	Reflective Traffic Cones	50	each
6	Hard Hats	80	each
7	Safety Goggles	10	each
8	Heat Resistant Working Gloves	15	each
9	Battery Powered Barricade Lights with wheeled cart	20	each
10	Plastic Type II Waffle Board Barricade	20	each
11	Orange warning flag 30x30cm,60cm PVC handle 1" dia.	20	each
12	Vehicle Mounted Solar Arrow Board w/2 Revolving Lights	4	each

Package 3: Bill of Quantities

1	W13-1 (metric) 80 Km/h - 24"x24" Traffic signs	16	each
2	W13-1 (metric) 60 Km/h - 24"x24" Traffic signs	2	each
3	W1-2L - 36"x36" Traffic signs	8	each

4	W1-2R - 36"x36" Traffic signs	8	each
5	W1-2aR (metric) with designated speed 60 circled - 48"x48" Traffic signs	1	each
6	W1-2aL (metric) with designated speed 60 circled - 48"x48" Traffic signs	1	each
7	W1-2aR (metric) with designated speed 80 circled - 48"x48" Traffic signs	7	each
8	W1-2aL (metric) with designated speed 80 circled - 48"x48" Traffic signs	7	each
9	W1-8R - 30"x36" Traffic signs	64	each
10	W1-8L - 30"x36" Traffic signs	63	each
11	W5-2a - 48"x48" Traffic signs	10	each
12	OM3 L - 12"x36" Traffic signs	28	each
13	OM3 R - 12"x36" Traffic signs	29	each
14	W1-11 - 36"x36" Traffic signs	8	each
15	W3-2 - 48"x48" Traffic signs	4	each
16	R1-2 Without the word "YIELD" - 48"x48" Traffic signs	4	each
17	W3-5 w/o words "SPEED LIMIT" speed of 60 - 48"x48" Traffic signs	4	each
18	W2-2R - 36"x36" Traffic signs	5	each
19	W2-2L - 36"x36" Traffic signs	2	each
20	R1-1 - 36"x36" Traffic signs	4	each
21	Traffic Sign Mounting clamps for 2 3/8" Round Posts	646	each
22	Raised Reflective Pavement markers, 2 way, yellow, Stimsonite C80	500	each
23	Epoxy Adhesive for Pavement markers and reflectors - 2 gallon (A&B)	33	each
24	Red Warning Flags 24" with 36" wooden dowels	20	each
25	Guardrail Reflectors, yellow 1-way	500	each
26	Concrete Barrier Reflectors, Delineator, yellow 1-way	300	each
27	Sign Posts, Round, Galvanized 16 Gauge - 12 ft. long	391	each
28	Sign Posts Closure Caps 2 3/8" Round	340	each
29	Breakaway Round Sign Post Coupler, Designovations Snap & Safe S238R	273	each

Attachment C

Bill of Quantities for Small Purchases

Items purchased in Thailand: The flame torches were purchased to supplement and help expedite the thermoplastic striping work, giving the striping crews the ability to dry-out the road surface ahead of the work after intermittent showers. The face masks, goggles, work gloves and overalls were purchased after reviewing manufactures' reconditions for the materials to be supplied under Packages 1 and 3, to assure sufficient safety equipment as listed under Package 2 would be available and in two cases (face masks and overalls) to add needed safety equipment.

1	Flame torches for drying road surface	8	each
2	Disposable Ear Loop Face Masks	2	Boxes of 50
3	Safety Goggles	10	each
4	Heat Resistant Working Gloves	10	each
5	Safety overalls – yellow medium	5	each
6	Safety overalls – yellow medium	5	each

Traffic Signs (Diamond Grade) purchased in Burma: The 100 M signs and the Burmese Language U turn signs were added to increase the warning capacity at the two U turn intersections. The 60 KPH signs were added to enhance the warning capacity at the 60 mph curve along the roadway. The 2 Traffic chevron signs were purchased to replace sings that were damaged on the early morning of 22 September 2015 when they were struck by a car.

1	100 M – 30"x18"	4	each
2	Caution U Turn Ahead (in Burmese) – 18"x24"	4	each
3	60 KPH – 24"x24"	2	each
4	W1-8R - 30"x36" Traffic signs (right arrow chevron)	2	each

Traffic Safety/Warning Signs (High Reflective Grade) purchased in Burma: The pavement striping work was carried out with traffic traveling in both directions on the road. To safely execute the work, traffic working safe zones and stop areas were planned and later executed using the traffic cones, waffle boards and flashing lights provided under Package 2. To supplement these arrangements the above signs in Burmese, corresponding to recommendations in the Federal Highway Administration's *Manual of Uniform Traffic Control Devices* for use in construction areas, were fabricated, incorporated in the planned working safe zones and stop areas and used to provide forewarning as vehicles entered into or through work areas and to demonstrate to MOC the use and application of this type of sign.

1	Left Lane Closed to Traffic (in Burmese)- 36"x36"	6	each
2	Right Lane Closed to Traffic (in Burmese)- 36"x36"	6	each
3	Road Work Ahead Next 5 KM (in Burmese) – 36"x18"	4	each
4	Road Work Ahead (in Burmese) – 36"x36"	4	each
5	Be Prepared to Stop (in English) – 36"x36"	2	each
6	Be Prepared to Stop (in Burmese) – 36"x36	2	each
7	Construction Warning Stop Signs 30"x30"	4	each
8	Right Direction Arrow – 24"x12"	4	each
9	Construction Warning Stop Signs 30"x30"	4	each

After the safety/warning signs were fabricated in Rangoon they were transported to a fabrication yard in Rangoon where mounting holes were drilled and 24 sign posts using old wheel rims (which allowed them to be comparatively mobile) as a base were fabricated. The fabricator transported the signs to the MOC's maintenance camp at MP 174/5 near Naypyidaw where they assembled the signs and posts, before they were turned over to the MOC.

Information Signs purchased in Burma: Two USAID Branding Signs at the start and end of the 10 km pilot section. They are only temporary.

1	USAID Branding Sign in English and Burmese 96'x48" Vinyl (Temporary)	2	each

Materials, tools, and equipment purchased in Burma: Expect for the 12 V batteries (need for the blinking barricade lights purchased under the Package 2 purchase order), the fire extinguishers (need for safety reasons when operating the two thermoplastic pre-heaters purchased under Package 1) and the Acrylic Concrete Sealer, the above force account purchased items are tools, equipment and materials that were necessary to procure for MOC to expedite and complete the work.

1	N 50 ZL, 12 Volt batteries	20	each
2	4 Kg Dry Chemical Fire Extinguishers	2	each
3	Package of 10 cutting wheels for Sumo 4" Grinder	1	each
4	Vice grip plyers – 10 inch PRO10RQ	1	each
5	48 inch I Beam levels	2	each
6	AEG 13mm drill DB-63ORE	1	each
7	13 T bolt tightening tools – 4 each	4	each
8	Sumo 4" Grinder S70W	1	each
9	9.5 mm drill bits, package of 5	1	lot
10	Sencon 1mm electric Drill 521309	1	each
11	Hexagonal/L Key Tools	6	each
12	Box cutter/Knife	1	each
13	5 meter measuring tapes	5	each
14	13 mm wrench	5	each
15	Stanly Level Set (Caulk string Line)	2	each
16	1 Kw Yamabist portable generator	1	each
17	Surveyor String – 1 Package	1	each
18	3036 Copper wire – 1 meter length	1	each
19	7029 Copper wire – 1 meter length	1	each
20	3 way Electrical Plug	1	each
21	1 electrical connector	1	each
22	Electrical tape (bundle of 3)	1	each
23	Pliers	3	each
24	Screw driver	3	each
25	Extension Cord	1	each
26	Metal tool boxes	2	each
27	12 piece wrench set	2	each
28	Tube of clear silicone	2	each
29	Silicone extraction tool	1	each

30	Adjustable wrenches	2	each
31	Wrench clippers	2	each
32	Electric/battery operated igniter	4	each
33	Lubricating 15w-40 and 10-w4 and grease	1	lot
34	Plastic siphon	1	each
35	Backpack style water sprayers	2	each
36	2" carpenter nails	20	each
37	3/8 inch nuts and bolts	12	each
38	Ax heads	2	each
39	Hammers	2	each
40	Smart AR-320 interface Thermometers with batteries	2	each
41	Iron brushes	4	each
42	Spatulas	4	each
43	Steel mixing tools	2	each
44	Earth Drill Auger with 2 stroke engine	4	each
45	Earth Drill Auger Extension Connectors	4	each
46	WS.11 Acrylic Concrete Sealer – 18 Liter containers	21	each
47	4" Brush	1	each
48	4 " Roller	1	each
49	BODA Electric Grinding wheel	1	each
50	4" cutting wheels	10	each
51	13 mm T socket wrench	4	each
52	6 foot step ladder	2	each
53	Electric hammer drill – for drilling holes in concrete	1	each
54	Drill bit for hammer/drill – for drilling holes in concrete	1	each

Attachment D

Location of the Signs between MP 169.1 and MP 169.5

MI Post	LEFT SIDE ROAD	MEDIAN	RIGHT SIDE ROAD	MI Post
169.10				169.10
169.11				169.11
169.12				169.12
169.13				169.13
169.14				169.14
169.15				169.15
169.16	8 Chevrons Spaced evenly starting before the curve and ending before the end of the curve		8 Chevrons Spaced evenly starting before the curve and ending before the end of the curve	169.16
169.17				169.17
169.20				169.20
169.21				169.21
169.22				169.22
169.23				169.23
169.24				169.24
169.25				169.25
169.26				169.26
169.27				169.27
169.30				169.30
169.31				169.31
169.32				169.32
169.33				169.33
169.34				169.34
169.35				169.35
169.36				169.36
169.37				169.37
169.40				169.40
169.41				169.41
169.42				169.42
169.43				169.43
169.44				169.44
169.45				169.45
169.46				169.46
169.47				169.47
169.50				169.50
169.51				169.51
169.52				169.52
169.53				169.53
169.54				169.54