IMPLEMENTATION OF LEAN CONCEPTS FOR PUBLIC SECTOR ENGINEERING DESIGN AND CONSTRUCTION: A CASE STUDY

John A. Kuprenas[1]

ABSTRACT

This work details the implementation of lean thinking concepts, tools, and processes in the City of Los Angeles, Bureau of Engineering—one of the largest public engineering organizations on the world. Poor past project delivery performance has lead to a radical change in the Bureau's organizational structure and project delivery processes. Central to the entire change is a shift toward a lean production model, centered on systems optimization. This work describes the reasons for the shift to lean thinking that began in the Bureau in the spring of 1997. The Bureau re-organization and the systems optimization background training are detailed. The ongoing training that is used to further foster lean thinking concepts is next reviewed. The majority of the paper is devoted to explaining specific lean thinking processes that were used as part of the transformation of the Bureau. Implementation of lean thinking is illustrated through detailed descriptions and examples the use of specific tools. Executive management and strategic planning efforts necessary to implement the lean thinking methods are explained and illustrated. Methods of reporting the transformation throughout the Bureau's workforce and to the Bureau's partners are also detailed and sample reporting and communication products are provided. Conclusions describe the performance improvements achieved to date through lean thinking, the obstacles the effort has yet to overcome, and mistakes made along the path so far. Future research needs identified through this effort are also included and discussed.

KEY WORDS

Engineering, design, construction, public sector, training, project controls, training, lean processes.

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INTRODUCTION

This work details the implementation of lean thinking concepts, tools, and processes in the City of Los Angeles, Bureau of Engineering—one of the largest public engineering organizations on the world. The Bureau of Engineering is a 1000+ employee public engineering, design, and construction organization that annually, completes over 300 capital improvement projects with a value of over $300 million dollars and issues over 33,000 permits. Poor past project delivery performance has lead to a radical change in the Bureau's organizational structure and project delivery processes. Central to the entire change is a shift toward a lean production model, centered on systems optimization.

Lean thinking embraces attaining value efficiently through new methods of thinking in order to re-form processes and organizations (Horman et al. 1997 and Seymour et al. 1997). Fundamental to lean thinking is the conversion of waste into customer defined value. In design and construction, value can be defined as a quality product completed within agreed upon schedule and budget while fulfilling pre-defined scope and program requirements. Schedule and budget can often be lowered in an effort to improve value, but often at the expense of quality. Hence, overall value is not improved. In addition, baseline values for schedule and budget from which to attempt improvements are often difficult to determine because much design and construction is unique. This work describes the efforts to implement a shift toward a lean project delivery process where value is improved cost and schedule performance while pre-established scope and program requirements are still met.

BACKGROUND FOR CHANGE

Over the past three years, several groups have analyzed the Bureau of Engineering. These groups found that projects would often become lost in the cracks in the project delivery system. The reports asserted that within the system, little or no ownership of projects existed and no performance measures were in place to measure project status. The negative impression created from these reports led to an ultimatum from the Mayor of the City of Los Angeles. If the project delivery process was not radically changed within one year of September 1996, the Bureau would be subjected to substantial cuts in budget and staff. These negative reports and subsequent ultimatum served as "the crisis" needed to facilitate a major change. The radical change undertaken was a shift toward a lean approach to project delivery with a move toward a strong project management style of project delivery and organization.

ORGANIZATIONAL CHANGES

The first step in the transformation was a fundamental change in the organizational structure of the Bureau. In the past the Bureau organization was a functional/geographic blend structure. The Bureau's new structure is a program-based matrix where each program contains a matrix of project managers and direct technical staff with additional support from shared technical resources. This program based matrix organizational form is an attempt to combine the advantages of the pure functional structure (technical expertise, uniformity of process, and fewer staff requirements) and the project organizational structure (simplified coordination and commitment to end product). The current Bureau organization consists of six major programs. Figure 1 shows a comparison between the original functional organization and the new program based organization.

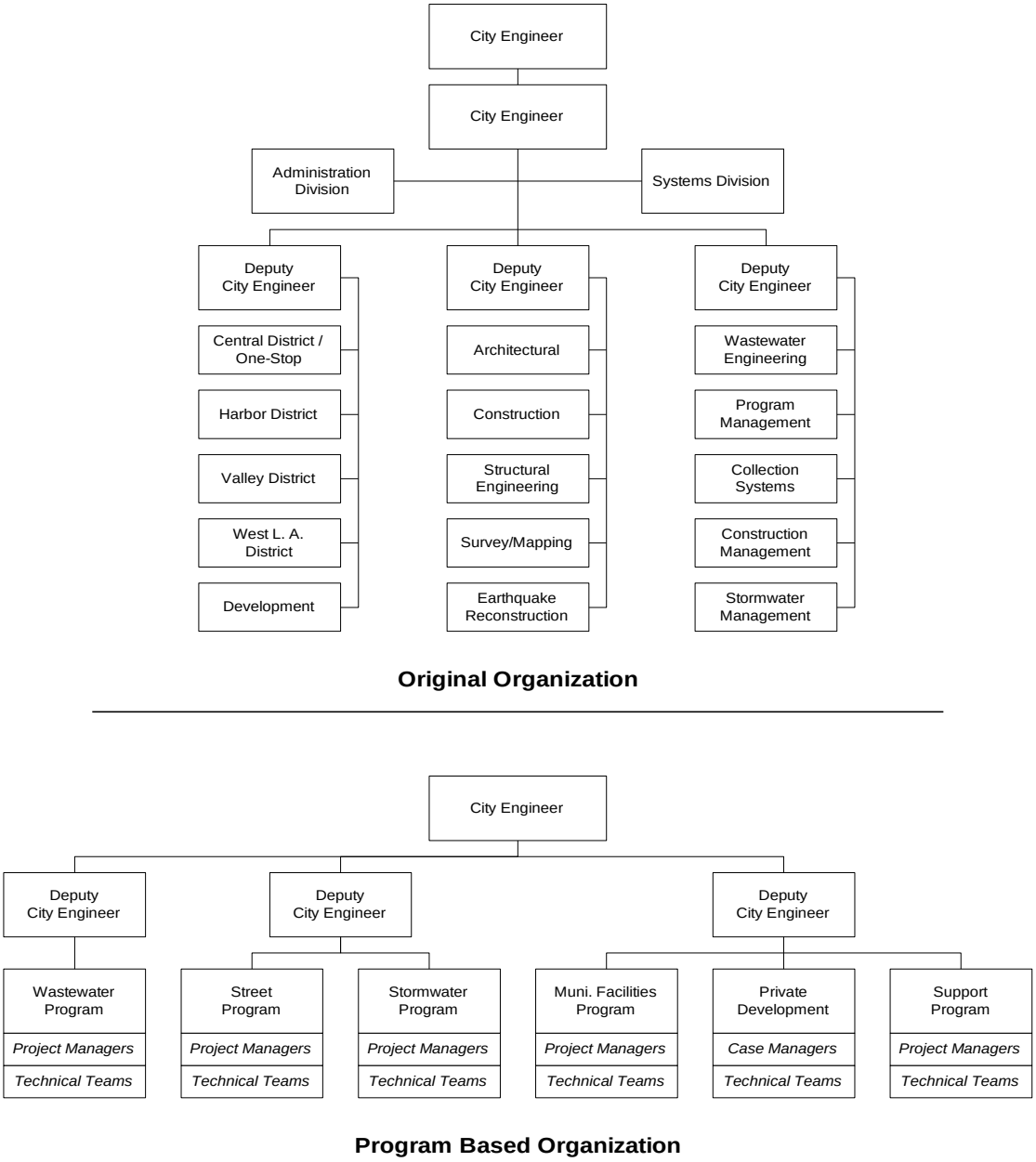

Figure 1: Organizational Structure Changes

The shift to a lean approach also required rethinking the roles of many of the Bureau staff. In the old functional organization, section heads would work on many projects without any overall guidance with respect to budget and schedule. Often projects would be reworked and redesigned many times over just to keep the team busy or because of arbitrary changes imposed by the division head who did not have a complete understanding of project scope and program. In other cases, time constraints led to designers passing work along when the design work had errors or was not complete. The thinking of the designers was that because of the multiple layers within the organization, any corrections would be made at the next level up. The new organizational structure has fewer layers and is centered on just three positions—Program Managers, Project Managers, and Service Provider/Technical Team Leaders. The reorganization is based on

increased value (in terms of producing a design within a timeframe and a budget) being supplied by each position.

The Project Manager is the focus for project delivery. The Project Manager has responsibility to see that a project gets completed at the specified scope, quality, budget, and schedule but is not responsible for specific (design) activities that are necessary to produce a finished project. The Bureau calls this a "single-hat" Project Manager. The Project Manager ensures from the outset that expectations, roles and responsibilities are established through formalized specific project agreements (called Handshake Agreements) in which all stakeholders and service providers will commit to project scope, budgets, and schedules for their various components of project delivery. These formalized agreements become the commitments of the functional staff. The Project Manager's responsibility as the project team leader is to insure that the project stays on track with respect to the agreements and that any problems that arise are resolved immediately. The Project Manager does not supervise any of the design team staff. Supervision is conducted through the existing Division organizational lines. True authority and success for a Project Manager will not come from civil service rank, but rather a blend of experience, rank, and the ability to lead a team.

The primary functions of the Service Provider/Technical Team Leader are to perform the technical task (i.e., civil design) within the approved Handshake Agreement values, to be aware of the Master Project Schedule, and to advise the Project Manager on all technical team interfaces and potential problems. The Leaders have responded well to their "new" responsibilities. They appreciate the fact that their expectations are established through formalized specific project agreements of project delivery. There is now more time available to do what they do best—designing a project.

Program Managers function as the leaders for each of the Bureau's seven programs. This program management group is responsible annual program delivery (50 to 100 completed projects) and responsible for problems that may be technical or specific to an individual project but only because of program level consequences. If the Project Managers and Service Provider/Technical Team Leaders are performing their jobs, little value will be added to the project design production process by the Program Manager position. Unfortunately, the Bureau still functions within the City bureaucracy, and the Program Manager's function has become cutting political red tape in order to keep the program and projects moving.

SYSTEMS OPTIMIZATION TRAINING

After the organizational modifications were completed, training in lean processes was begun. The training consisted of two parts as shown in Figure 2. All Bureau employees were trained in sixteen (16) hours of the principals of System Optimization. This training offered a new fundamental approach to managing and problem solving. Bureau staff were taught that the Bureau of Engineering is a network of interdependent processes that must work together to allow the Bureau to achieve its vision. Systems Optimization training began in August 1997. The first phase of the training was completed in February 1998.

The second portion of the System Optimization training was given to 200 employees of the Bureau. This two day training program began in December 1997 and was completed in March 1998. The focus of this segment of the training was to provide Bureau staff with selected technical tools that assist with data collection, analysis, problem identification, devising and implementing solutions, and monitoring results. The

topics included in this second segment of systems optimization training are also shown in Figure 2.

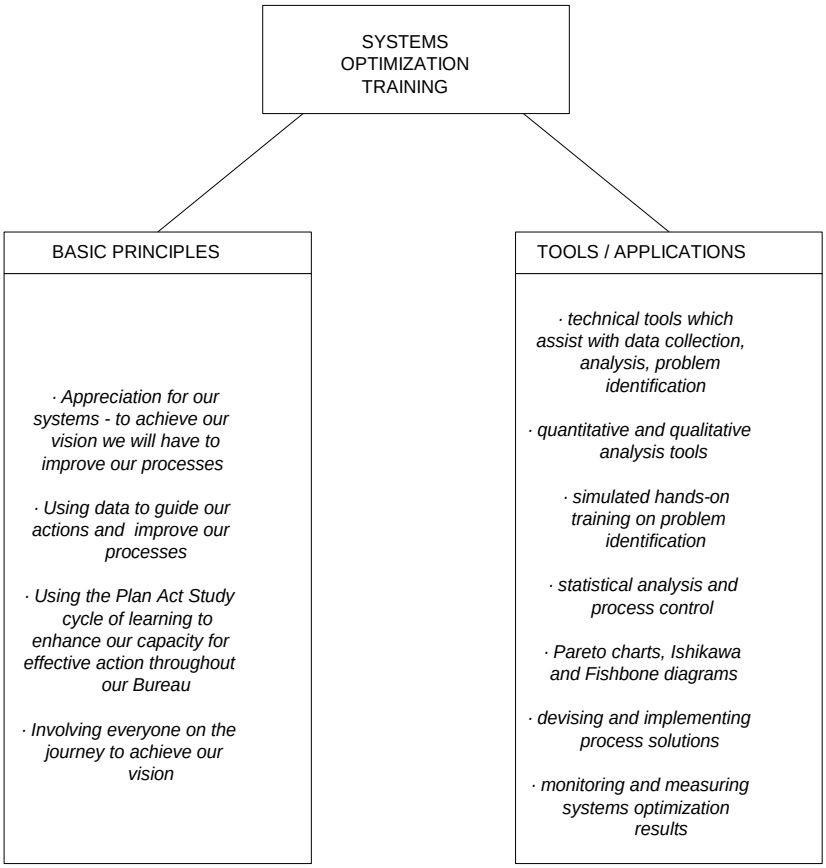

Figure 2: Systems Optimization Training—Course Breakdown

Ongoing, weekly training is now being held for the new project managers and technical team leaders. The focus of this training is on Department and City processes. Topics included in these training sessions have included:

- Federal funding of projects
- Environmental documents and requirements
- The bid process—City requirements
- The award process—City requirements
- Supplier/Designer Handshake Agreements
- Funding of projects through the City Administrative Officer (CAO)
- Control Charts
- Resolution Authority process (funding of staff positions)
- Role of the City's Contract administration inspector

This roundtable training is typically done by Bureau staff, for Bureau staff, and is centered on problems identified in performing the work and how best to solve these problems. The training has been well received and is planned to permanently continue.

LEAN PROCESSES

The new lean thinking and processes implemented within the Bureau are manifested through developing new techniques to document processes, establishing formal agreements with service providers and customers/clients, defining performance measures, and improving reporting and progress measurement techniques. The following sections detail each of these implementations.

DOCUMENTATION

Processes make up the system that delivers projects in the Bureau of Engineering. Lean thinking requires an examination of the steps of each process and the removal of waste. In an attempt to improve process performance the Bureau has identified "red beads"—wasted steps or procedures that do not enhance the process performance. Fishbone diagrams and flowcharts were created for the significant red beads. A fishbone chart for the process problem of a lack of electrical engineers available to the design division in municipal facilities program is shown in Figure 3. Based on the study of the electrical engineering problem, two solutions were implemented within the last six months. A technical services group of electrical and mechanical engineers was created in May of 1998 for the all programs to use in order to help smooth the workload fluctuations within the programs. In addition, electrical engineer vacancies are eligible to be filled starting July 1, 1998.

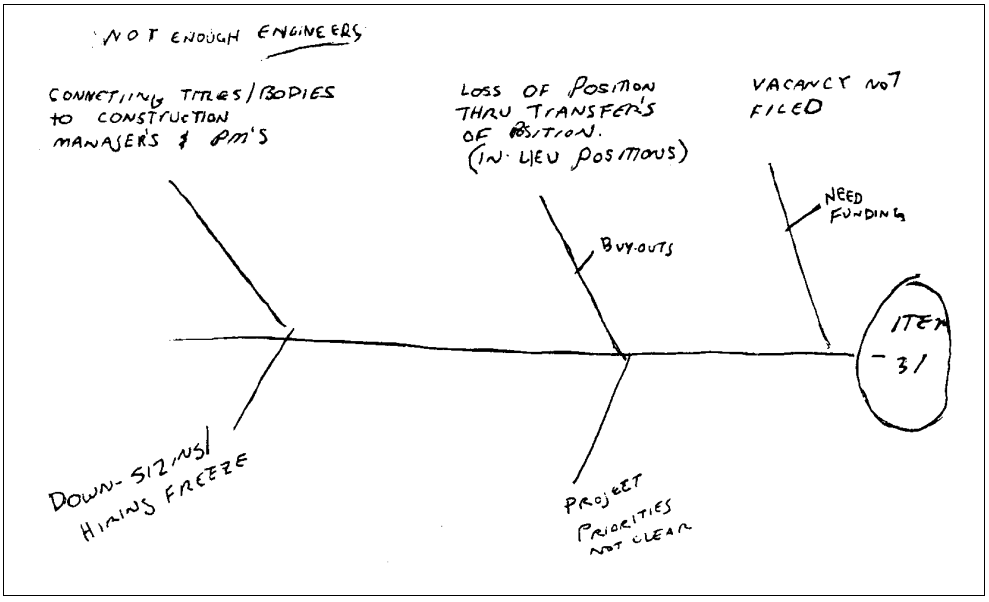

Figure 3: Fishbone Diagram for Electrical Engineer Problem

Another "red bead" was related to project priorities. Often times in the past, a "rush" project would be assigned to the Bureau. The project would be assigned to a program, and

much ongoing work within the program was dropped while designers completed the "rush" project. The projects that the design teams were working on were simply delayed. Months or years later, client agencies and public officials would hold the Bureau responsible for the delayed projects when completion milestones were not met. The "rush" projects were not a valid excuse for non-performance because after the fact, the "rush" projects would often be recognized as perhaps not as important as originally thought, or the "rush" projects were forgotten. To eliminate this problem, the Bureau developed a prioritization flowchart. The prioritization flowchart is shown in Figure 4. When a "rush" project now enters a Bureau program, the importance of the "rush" project is assessed using the flowchart to determine whether any ongoing design work should be stopped. If the ongoing work is stopped then clear documentation exists for the switch in the Service Provider/Technical Team effort. In the past, this changing of work sequences served as a classic example of how in the absence of lean thinking, internal and external uncertainties tend to push the design process away from the optimal sequence (Koskela et al. 1997).

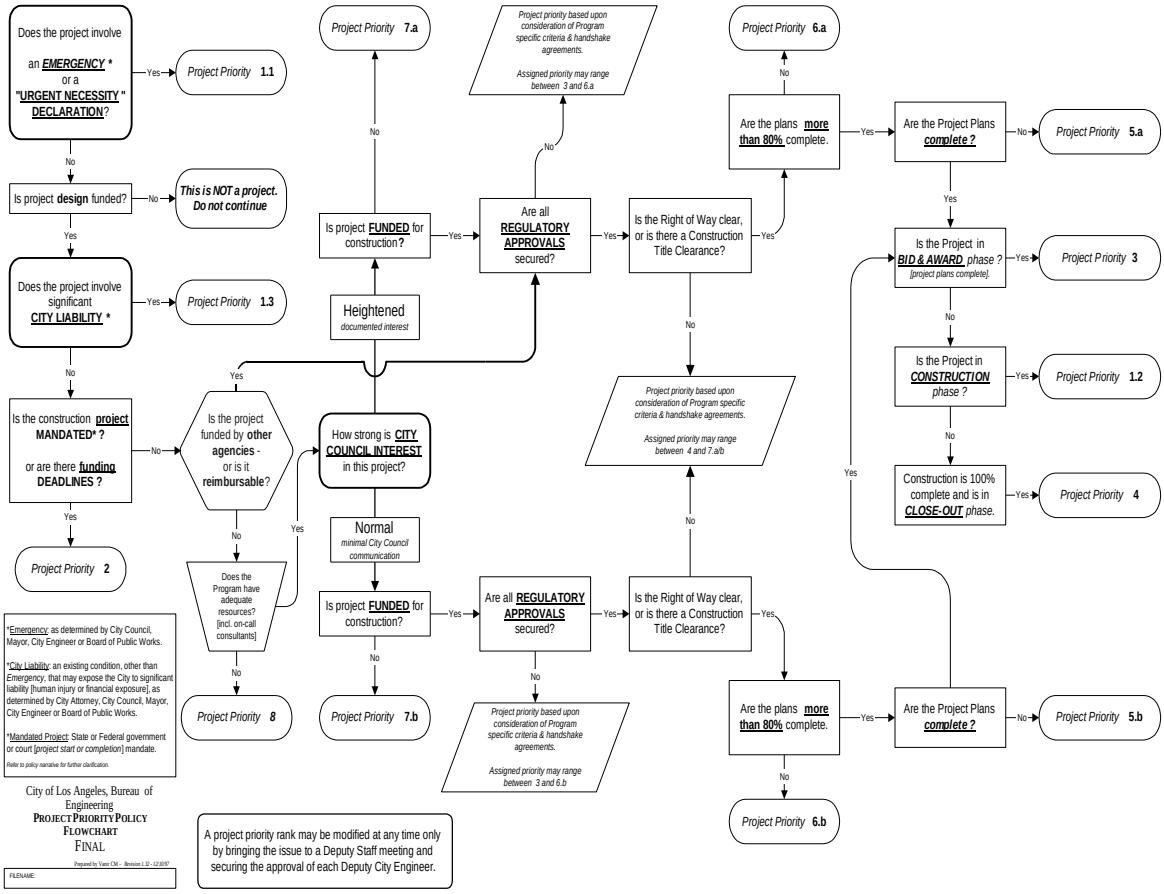

Figure 4: Flowchart of the Bid and Award Process

FORMAL AGREEMENTS

One critical element of the lean thinking is establishing criteria for process performance. The Project Manager ensures from the outset that expectations, roles and responsibilities are established through formalized specific project agreements (called Handshake Agreements) in which all service providers will commit to project scope, budgets, and schedules for the various components of project delivery. Service Provider/Technical Teams duties vary based on the team and range from detailed civil engineering design to compiling environmental impact documentation to review of bidder MBE/WBE compliance. The Handshake Agreements become the commitments of the functional staff. Handshake Agreements for all Bureau project design processes on all projects were finalized by June 1, 1998. Figure 5 shows a Handshake Agreement from the street program.

The Handshake Agreements are based upon templates of historical process performance. Templates set the time and budget for specific design sub-processes. These templates eliminate the temptation for project managers to “low ball” the design team to agree to an unrealistic performance standard, and prevent the temptation of the design teams to over-inflate their estimates in order to appear productive. The Handshake Agreements can also be used to help eliminate bottlenecks created by poor resource leveling. Future agreements will include a master project schedule so that the functional staff know when to expect a certain project to be delivered to be work on. Over time, the Bureau expects the Service Provider Teams to improve performance with respect to the template values as lean process improvements are implemented. These templates can be used to Benchmark internally (to compare within the organization, i.e., program to program) and competitively (with similar enterprises, i.e., another city’s engineering group). Both these measures are of value in a lean thinking process (Marosszeky and Karim 1997)

The second element needed to establish criteria for performance is documentation between the Bureau and client/customer agencies. In lean thinking, value can only be defined by the ultimate customer (Womack and Jones 1996). The Memorandum of Understanding (MOU) fills this value definition. An MOU is a formal, signed document between the design program and the Bureau's customer that clearly identify project scopes, responsibilities, and performance measures. An actual MOU table of contents is included in Figure 6. Notice the heavy emphasis on establishing customer requirements and scope, since scope creep has been a source of much wasted design effort within the Bureau.

Executive management and strategic planning efforts necessary to implement the lean thinking methods have been a struggle. Because of retirements at the executive level no strong champion exists for the process. At times this has delayed the effort. When a quick decision is needed, no one is available. A long consensus building, group decision is instead made. The champion is, in fact, a committee called the Managing Our Strategic Transformation (MOST) committee. MOST meets every other week and consists of the Bureau Deputy City Engineers, Program Managers, and key staff from the project management/systems optimization team. The “Champion by Committee” process is frustrating at times, but given the fact that the Bureau of Engineering is a municipal group and the nature of civil service, expecting a Champion to step forward is not realistic.

The MOST team does work effectively with the Bureau’s strategic planning group, a primary source for lean production suggestions. MOST tracks the development and

FORM GEN. 160 Rev. 6-80)

CITY OF LOS ANGELES

INTER-DEPARTMENTAL CORRESPONDENCE

Date: February 27, 1998

To: Technical Team Leaders
Tom Donahey, Survey & Mapping Division
Robert Paul, Construction Division
Vahik Vartanians, Street Improvement Division
Alex Vidaurrazaga, Structural & Geotechnical Engineering Division

From: Chris Salvaggio, Project Manager

Subject: **SCHEDULE FOR BERENICE AVENUE AT MONTECITO (W.O. E6000553)**

Congratulations, we have completed our first "handshake agreement" regarding the baseline budget and schedule for the Berenice Ave project. The Project Management and Control System (PMCS) report is attached. I will be contacting you for monthly updates to the report. In addition, please let me know as soon as possible if something happens that will affect our agreed upon budget and schedule. I would like to thank all of you again for your cooperation. If you have any questions or comments, please call me at 847-9670.

Attachment

Divisions	Design Schedule *C/P = Current / Planned				Design Budget			Performance		
	Start Date *C/P	Duration (WD) *C/P	Percent Work Complete	Completion Date *C/P	Budgeted Cost	Actual Cost to Date	Actual Cost This Period	Budget (Dollars)	Schedule (W/D)	Perf Ind
41 CONSTRUCTION DIVISION	7/1/98 7/1/98	108 108		11/30/98 11/30/98	$4,000			No PCT	On	
46 GEOTECHNICAL SERVICES	3/4/98 3/4/98	52 52		5/15/98 5/15/98	combine w/ structures			No PCT	On	
51-CENTRAL DISTRICT	11/24/97 A 11/24/97	265 265		11/30/98 11/30/98	$13,000			No PCT	On	
54 STRUCTURAL ENGINEERING	3/4/98 3/4/98	52 52		5/15/98 5/15/98	$11,000			No PCT	On	
63-SURVEY & MAPPING DIVISION	2/23/98 A 2/23/98	6 6		3/3/98 3/3/98	$6,000			No PCT	On	
E6000553 - PROJECT SUMMARY	11/24/97 A 11/24/97	265 265	11	11/30/98 11/30/98	$34,000			On	0 On	

BERENICE AVENUE AT MONTECITO E6000553 Printed: 2/26/98

Figure 5: Handshake Agreement

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Figure 6: Memorandum of Understanding (MOU) Table of Contents (1 of 2)

TABLE OF CONTENTS (Cont'd)

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Figure 6: Memorandum of Understanding (MOU) Table of Contents (2 of 2)

implementation of lean production/system optimization ideas through a matrix with over 200 ideas for lean process improvements.

PERFORMANCE MEASURES

Development of project delivery performance measures beyond traditional cost and schedule measures is done through control charts and letter grades for the Service Providers/Technical Teams. Control charts are a traditional statistical process control tool and are used in the Bureau to measure project performance. Project performance for design is measured as the effort required to produce to a set of plans. Effort is measured as labor hours. Plan complexity and size is measured by the dollars of construction cost. Figure 7 shows a control chart for this measure. The X-axis shows individual, numbered completed projects. The Y-axis is the ratio of hours to $100,000 construction cost. The chart shows one point outside the control limits, a special cause variation, for Project #19. This project was redesigned three times at the request of the client. As a result, design scopes are now firmly defined through MOU's with Bureau clients—waste has been eliminated. Other control charts done in the Bureau are more traditional measures of project delivery performance and value described by Alarcón and Serpell such of project cost verses budget, and change order costs verses construction award, and actual duration divided by planned duration (Alarcón and Serpell 1996). Special charts are applied to specific processes when further study is needed.

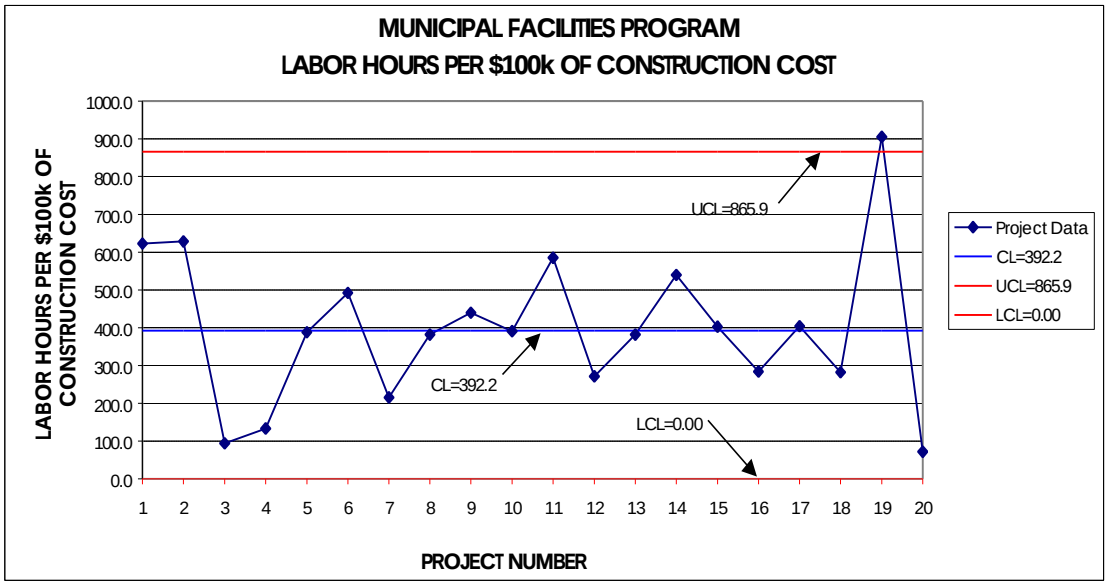


Figure 7: Control Chart

A letter grading system is used to judge performance of the Service Provider/Technical Teams in producing specific technical elements of a project. The Handshake Agreements establish the technical elements to be accomplished, as well as, the dollar and time budgets for the tasks. Performance of the team with respect to the Handshake Agreement gives a grade that can also be translated into an asterisk to indicate that the project needs attention. Letter grades are used in some cases, but the negative stigma of receiving an "F" grade was too great, so the asterisk system was adapted for use instead. The grading criterion used in the Bureau is shown in Figure 8.

REPORTING PERFORMANCE

Methods of reporting the lean project delivery system performance center on a new Project Management Control System (PMCS). The PMCS tracks Handshake Agreement progress of all Service Providers/Technical Teams. This tracking uses traditional measures of earned value and is reported at the Service Provider/Technical Team, Project Manager, and Program Manager levels. A sample Project Manager PMCS report is shown in Figure 9. Note that the grading system described in Figure 8 is used in this report. The handshake agreements coupled with the immediate ability of the Project Manager to recognize problems through PMCS constitute a lean thinking responsiveness planning model (Faniran et al. 1997).

PERFORMANCE INDEX

A letter grade calculation of an activity using Earned Value, Actual Costs, Baseline Schedule Duration, and Current Schedule Duration in accordance with the following criteria:

$$\text{Performance Index Schedule Variance (SV)} = \frac{\text{Current Duration}}{\text{Earned Baseline Duration}}$$

$$\text{Performance Index Budget Variance (BV)} = \frac{\text{Actual Cost To Date}}{^{*}\text{Earned Balue}}$$

*Earned Value is calculated as the percent complete times the budgeted cost (or PCT x BC) of an activity.

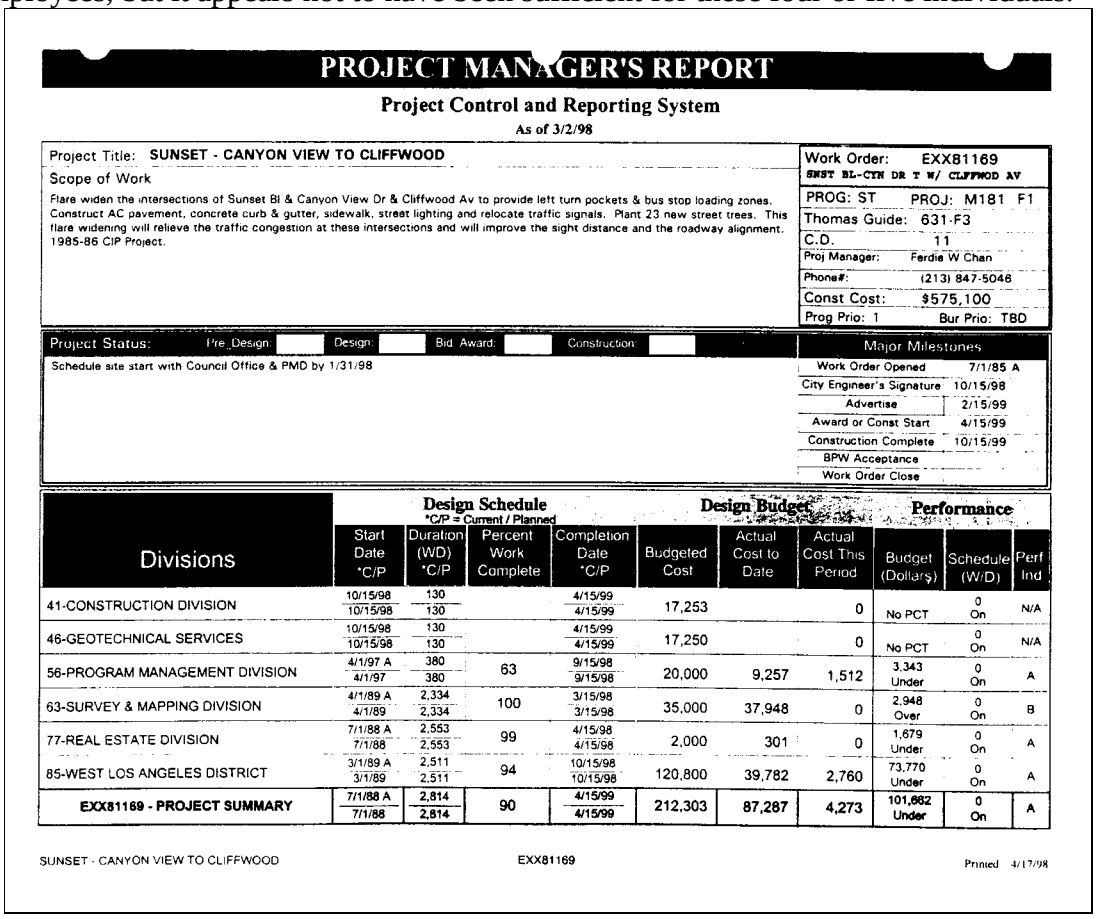
If:	Then grade is:
If SV and BV < 1.05 then	A
If SV or BV > 1.05 then	B
If SV or BV >1.20 or If SV and BV > 1.10 then	C or *
If SV or BV > 1.30 or If SV and BV > 1.20 then	D or *
If SV or BV > 1.50 or If SV and BV > 1.30	F or *

Figure 8: Performance Measurement/Grading Criteria

FUTURE STEPS AND CONCLUSIONS

To date the effort “feels” successful, yet project delivery performance enhancements and elimination of waste have been difficult to judge. Future research must focus on how to measure improvements. Within the Bureau, all 1,000 staff is aware that systems optimization is taking place. Perception among the Bureau’s Managers is that processes have been improved, and project delivery has been enhanced. One obstacle encountered has been a vocal few critics who oppose any change to their work place. The

implementation team has provided coping with change training for all 1,000 Bureau employees, but it appears not to have been sufficient for these four or five individuals.



PROJECT MANAGER'S REPORT

Project Control and Reporting System

As of 3/2/98

Project Title: **SUNSET - CANYON VIEW TO CLIFFWOOD**

Work Order: EXX81169
SNST BL-CYN DR T W/ CLFFWOD AV

Scope of Work

Flare widen the intersections of Sunset Bl & Canyon View Dr & Cliffwood Av to provide left turn pockets & bus stop loading zones. Construct AC pavement, concrete curb & gutter, sidewalk, street lighting and relocate traffic signals. Plant 23 new street trees. This flare widening will relieve the traffic congestion at these intersections and will improve the sight distance and the roadway alignment. 1985-86 CIP Project.

PROG: ST PROJ: M181 F1
Thomas Guide: 631-F3
C.D. 11
Proj Manager: Ferdie W Chan
Phone#: (213) 847-5048
Const Cost: $575,100
Prog Prio: 1 Bur Prio: TBD

Project Status: Pre_Design: Design: Bid Award: Construction:

Schedule site start with Council Office & PMD by 1/31/98

Major Milestones

Work Order Opened	7/1/85 A
City Engineer's Signature	10/15/98
Advertise	2/15/99
Award or Const Start	4/15/99
Construction Complete	10/15/99
BPW Acceptance	
Work Order Close	

Divisions	Design Schedule *C/P = Current / Planned				Design Budget			Performance		
	Start Date *C/P	Duration (WD) *C/P	Percent Work Complete	Completion Date *C/P	Budgeted Cost	Actual Cost to Date	Actual Cost This Period	Budget (Dollars)	Schedule (W/D)	Perf Ind
41-CONSTRUCTION DIVISION	10/15/98 10/15/98	130 130		4/15/99 4/15/99	17,253		0	No PCT	0 On	N/A
46-GEOTECHNICAL SERVICES	10/15/98 10/15/98	130 130		4/15/99 4/15/99	17,250		0	No PCT	0 On	N/A
56-PROGRAM MANAGEMENT DIVISION	4/1/97 A 4/1/97	380 380	63	9/15/98 9/15/98	20,000	9,257	1,512	3,343 Under	0 On	A
63-SURVEY & MAPPING DIVISION	4/1/89 A 4/1/89	2,334 2,334	100	3/15/98 3/15/98	35,000	37,948	0	2,948 Over	0 On	B
77-REAL ESTATE DIVISION	7/1/88 A 7/1/88	2,553 2,553	99	4/15/98 4/15/98	2,000	301	0	1,679 Under	0 On	A
85-WEST LOS ANGELES DISTRICT	3/1/89 A 3/1/89	2,511 2,511	94	10/15/98 10/15/98	120,800	39,782	2,760	73,770 Under	0 On	A
EXX81169 - PROJECT SUMMARY	7/1/88 A 7/1/88	2,814 2,814	90	4/15/99 4/15/99	212,303	87,287	4,273	101,662 Under	0 On	A

SUNSET - CANYON VIEW TO CLIFFWOOD EXX81169 Printed 4/17/98

Figure 9: PMCS Project Manager Report

In order to truly gauge success beyond just perception, hard data is required. Benchmark data for project delivery performance will become available as the control charts and the new PMCS continue to be used. Improvements in control chart centerlines and tightening of control limits would provide proof of improved performance. Improved composite program grade point averages on the PMCS would also show improved performance.

Much potential success lies in the over 200 systems optimization ideas still left to be studied and implemented. This task, however, requires time. One mistake often made in the Bureau was to assume that the lean thinking process changes would be immediate or that process changes had not happened. It is difficult to in see change when one works closely on the process, because the change occurs over months rather than days. In addition, the long time span from pre-design to design to construction makes an immediate assessment of the benefits of lean thinking quite difficult. Although the Bureau's work is complete when construction is complete and the contract is closed out, the life of a project does not end. Future research must also correlate lean process improvements in the design and construction phases to ongoing operational and maintenance costs of a completed project.

The lean thinking effort within the Bureau will continue for years to come, and more process will certainly become leaner. Changing one procedure may only save a few days or a week in the total project delivery time. Any one change is not substantial in itself, but

making five or ten processes leaner will create a significant change. This is the path the Bureau has chosen to follow.

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