

PARC: A CASE STUDY

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1.0 Introduction

Working under the company name Construction Concepts, Mike Casten, Greg Howell and Glenn Ballard initiated a productivity improvement program on PARC, following an initial site visit and diagnosis in September, 1994. The program extended from November 1994 until August 1995.

PARC was a 2.1 billion dollar refinery expansion for Maraven, one of the operating divisions of Petroleos de Venezuela (PDVSA), the national oil company. The project consisted of three engineer-procure-construction management (EPC) packages, which were done by Foster Wheeler (Package A), Bechtel (Package B), and Kellogg (Package D). Kellogg also had program management (MPMT), carried out with a composite team drawn from Maraven, British Petroleum, and Kellogg, along with a number of Venezuelan contract employees.

All of the direct work at the site was subcontracted to Venezuelan construction contractors. When Mike Casten first visited the project, there were 10,000 direct workers and plans to increase the workforce to 18,000 in order to offset poor productivity. Although construction was then approximately 40% complete, engineering was still issuing new drawings and changing old ones.

Increasing the workforce to 18,000 was not a viable solution for two reasons: 1) lack of skilled workers, and 2) inability of the project to accelerate the supply of work. After implementation of the productivity improvement program, productivity improved substantially and the project was completed with a maximum direct workforce of 10,900. All critical units were completed on schedule by the end of 1995, although some less critical units slipped into 1996.

2.0 The Approach

In the initial report of October 25, 1994, Construction Concepts recommended a program of productivity improvement with the objective to improve three key factors that determine productivity:

- 1) How well the project is supplying the basic elements of work to the crews. The elements of work are information, materials, tools, equipment, etc.
- 2) The method used by the crew to perform the work.
- 3) How well the accomplishment of the work itself fills the needs of the workers.

This approach is based on a production management model oriented to the way work gets done, and is very different from a contract management model, with its single-minded orientation to enforcing commitments. The consultants realized that prevailing construction project management theory and practice are based on the contract management model, and recognized that changes would have to be made in management practices.

In situ management was doing a first rate job of applying current management practices. The project did not "go wrong" because of some error in applying accepted techniques. Those techniques were not sufficient for the task.

The improvement strategy, illustrated in Figure 1, was based on the idea that planning reliability is the key to improved performance. The goal was to give only workable assignments to direct workers, and to increase the predictability of work flow to every organization. So doing would allow a better match of labor to work, and release energy and time for improving work methods.

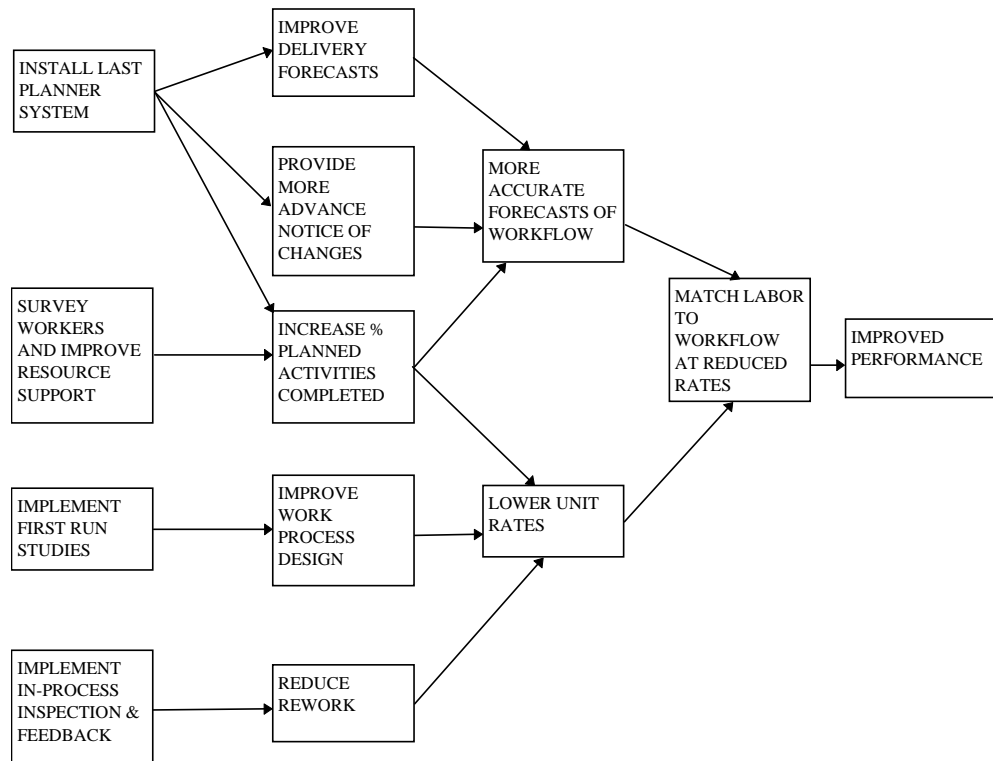


Figure 1: Improvement Strategy

3.0 The Committee

A Productivity Improvement Committee was formed under the sponsorship of the MPMT and EPC senior managers. Its members were:

- MPMT coordinator: Ernie Richards
 - MPMT controls: Steve McDermott and Steve Parnham
 - Package A coordinator: Jack Rothert
 - Package B coordinator: Eric Tandy
 - Package D coordinator: Jacques DeRidder
 - MPMT productivity analysts: José Díaz and Isabelino Marcano
 - Package A productivity analysts: Jairo Tremus and Cristóbal Sanchez
 - Package B productivity analysts: José de la Cruz and Rita Dominguez
 - Package D productivity analysts: Antonio Chirinos and Lesli Colina
 - Consultants: Mike Casten, Greg Howell and Glenn Ballard
- (Package A superintendents rotated through one month assignments to the Committee. Eventually, a number of subcontractors designated their own productivity analysts, who also became members of the Committee.)

This Committee set direction and supported efforts to improve the flow of information and materials to the craft workers. It also helped selected subcontractors:

- 1) Implement detailed production planning.
- 2) Improve the quality of Weekly Work Plans and thus increase the percentage of planned activities completed.
- 3) Institutionalise the practice of work methods improvement.

An additional objective was to help subcontractors match labor to the flow of work into backlog. Unpredictable timing and amount of work, together with the pressure for production, prevented significant achievement of this objective, and negatively impacted productivity.

4.0 Actions Taken

Beginning in November, 1994, key subcontractors were introduced to the Last Planner System, which includes various elements of detailed production planning: 6 week lookahead schedules, screening processes for creating workable assignments, sizing assignments to crew capacity, and charting and acting on reasons for not doing planned work. The key measurements in the Last Planner System are PPC charts, which measure the percentage of weekly planned activities that are completed, and Reasons charts, which measure the distribution of causes for failing to complete planned work. These provide the subcontractor and the EPC contractor means of controlling and improving plan quality and productivity.

Rasacaven did electrical power distribution in Package D. Figure 1 shows the results of charting their PPC from the week ending 12 March, 1995 through the week ending 21 July, 1995. During that period, PPC ranged from 45% to 100% of planned work completed. The trend was upward, achieving a level of approximately 90%, double the initial measurement.

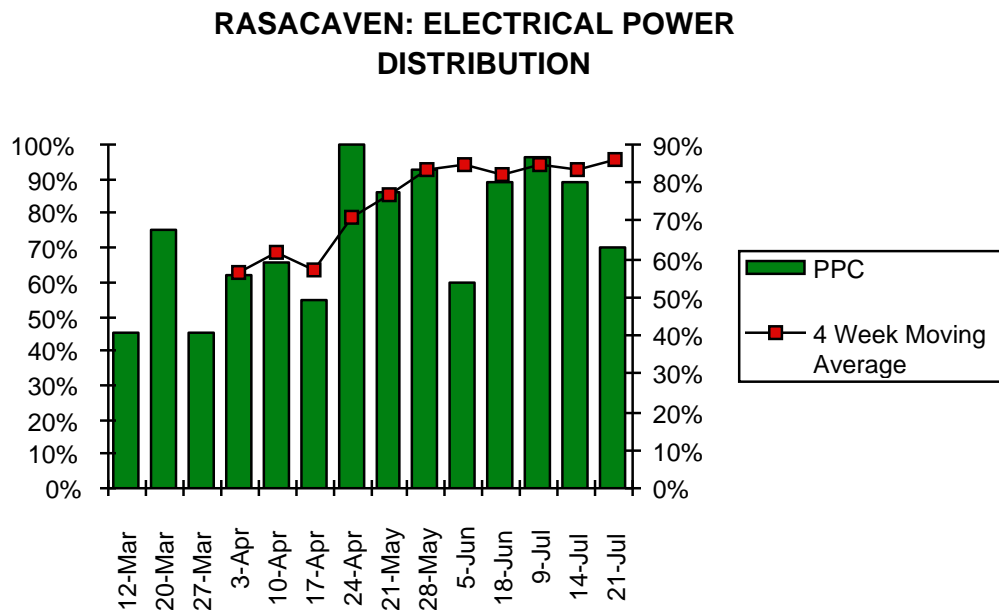


Figure 2: PPC

As illustrated in Figure 2, subcontractors tracked the reasons why planned work was not completed, in order to identify actionable causes, and improve the quality of planning. As "reasons" were removed, PPC increased.

The EPC contractor may have been unable to provide engineering information or materials to the subcontractor when the work was originally scheduled to be performed. However, the subcontractor should not have planned on doing work next week for which all resources were not on hand. "Reasons" included engineering, materials, access, scaffolding, changes in priority, etc. Tracking the reasons helped subcontractors learn how to do a better job of short-term planning, and also provided feedback to EPC contractors regarding the flow of engineering and materials.

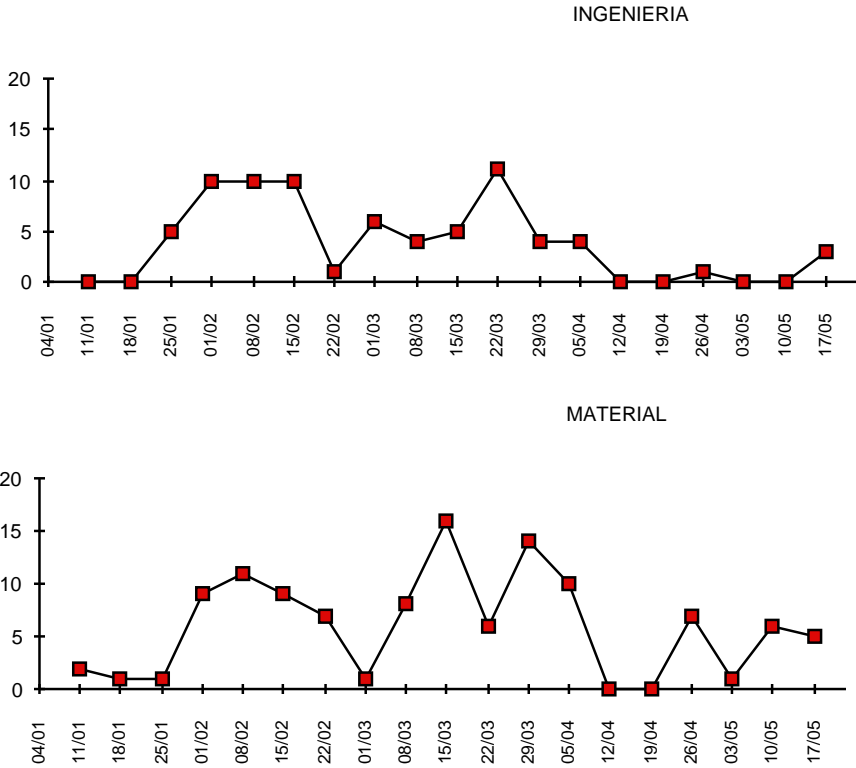


Figure 3: Reasons Why Assignments Were Not Completed

Starting in January, 1995, the subcontractors were introduced to First Run Studies (FRS), i.e. detailed planning, study and improvement of field operations. FRS are highly participative, and provide those doing the work an opportunity to improve work methods. After initial planning sessions, analysts use video to record how work was actually done, then review the video with those involved to find improvements.

In March, 1995, the consultants developed a model systems planning process, and began forming EPC/subcontractor teams to manage and execute production as work on the project transitioned to a systems mode.

Throughout the program, the consultants trained MPMT, EPC and subcontractor productivity analysts in the theory and techniques of productivity improvement.

5.0 Successes

Many subcontractors improved the quality of their production planning. Some showed improvements in performance factors. First Run Studies revealed the potential for improvement in field operations. Performance against estimate improved substantially in

1995 against prior years, despite large increases in quantities and movement into the systems completion phase of the project.

5.1 Improvements in the percentage of planned weekly assignments completed (PPC)

PPC is the immediate measure of the Last Planner System, indicating the quality of weekly production planning. It is largely in the control of the subcontractor because he can control what assignments are made. Although dependent on the EPC contractor for coordination with others, the subcontractor can avoid making assignments for which materials are missing or equipment is not available. Improving the quality of assignments reduces delays and releases time and energy for streamlining work processes. Following are some successes:

<u>Subcontractor</u>	<u>Improvement in PPC</u>
Ata	90%
Costa Norte	33%
Den Spie	64%
Distral Termica	50%
DSD	33%
Formiconi	50%
Piaca	30%
Rasacaven	45%
Sadeven (electrical)	70%
Segema (Pkg A)	50%

Figure 4: Improvement in PPC

5.2 Improvements in Productivity Factor (PF)

Productivity Factor (PF), sometimes called Performance Factor, measures productivity as a ratio of actual to earned labor hours. Each work activity has a budgeted labor rate, and each unit of that activity earns labor hours at the budgeted rate. If actual labor hours expended per unit exceed the budgeted rate, PF is worse than budget. If actual labor hours expended per unit are less than the budgeted rate, PF and productivity is better than budget. PF is an adequate measure of labor productivity, but for a number of reasons, its interpretation is not simple and direct. For example:

- 1) PF measures productivity against a budget or estimate, and consequently may improve and still remain worse than budget.
- 2) When there is greater labor capacity than available work, PF will show poor productivity, regardless how efficiently available work is executed.
- 3) With the transition from a bulk installation to a systems phase, especially when incomplete work has been counted as complete, it becomes more difficult to earn labor hours. Consequently, improvements may not be visible in PF measurements.

Nonetheless, there were measurable improvements in PF across the board, specifically in the reduced variance from estimate in 1995 as compared to prior years. Figure 4 shows the Class III estimate of project labor hours for 1993 to have been 21.8 million, and an actual expenditure of labor hours 28% above that estimate (PF=1.28). For 1994, the Class II estimate

had grown 33% to 28.9 million labor hours, and they again expended 28% more labor hours than estimated. The 1995 budget ballooned another 39% to 40.1 million labor hours, with only a 1% overrun in actual expenditures. The forecast made in September of 1995 increased the labor hours yet another 7%.

	Craft Workhours (x 1 million)			
	Class III (3/93)	Class II (3/94)	J95 Budget (2/95)	Sep Fcst (9/95)
EPC A	8	11.7	15.7	16.6
EPC B (site)	1.8	2.2	4.1	4.5
EPC B (mod yard)	1	1.1	1.5	1.8
EPC D	11	13.9	18.8	20
PARC	21.8	28.9	40.1	42.9
% Increase		1.33	1.39	1.07
Yearly PF vs Est.	1.28	1.28	1.01	

Figure 5: Annual PF vs Estimate

In addition, subcontractors showed improvement in PF in selected cases . A good example is provided by Formiconi in Package A, Unit B3. The impact of the implementation of detailed production planning is evident in both the reduced range of weekly measurements and the change in trend from negative to positive.

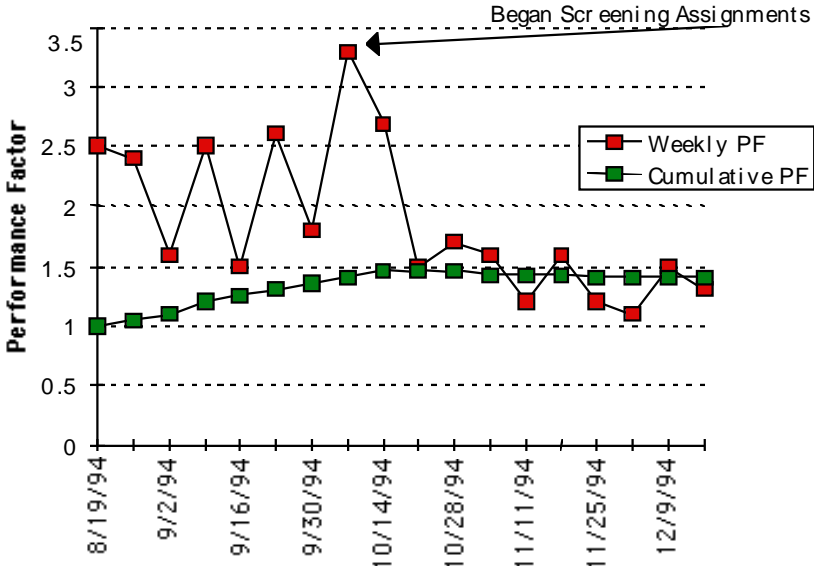


Figure 6: Impact of Screening Assignments

5.3 Improvements in First Run Studies

The most direct and accurate measure of improvement is provided by First Run Studies. In this, productivity analysts under the direction of the consultants: 1) measured performance in doing a specific type of work, 2) facilitated improvements, then 3) measured the improvement on a subsequent operation on the same type of work.

Following are examples of successes:

<u>Sub</u>	<u>Before</u>	<u>After</u>	<u>% Improvement</u>
Ata	3 supports/day	22 supports/day	600%
Costa Norte	1 54" dia. pipe in 4 hr-19 min	...in 32 min	700%
Den Spie	1 wire/5 min.	1 wire/3 min.	70%
Distral	10 isos/week	15 isos/week	50%
DSD	0.087m/min.	0.9 m/min.	800%
Formiconi	2.75 mh/LM	1.72 mh/LM	50%
Piaca	1 column/hr	3 columns/hr	200%
Rivaco FM	1 siding/13 min.	1 siding/8 min.	60%

Figure 7: First Run Study Successes

5.4 Transfer of Management Technology

The development of Venezuelan contractor capability will have benefits on future projects well beyond PARC. Transfer of management technology is one of the areas in which the productivity improvement program was most successful.

Several subcontractors have adopted productivity improvement as a corporate initiative, intending to establish the Last Planner system and First Run Studies as standard operating procedure: Den Spie, Costa Norte, Conteca, Rasacaven, Ata and GBC. Others are reported to be using elements of the improvement program on non-PARC projects.

Many subcontractors have applauded the use of detailed weekly work plans as a means of evaluating performance at the capataz and supervisor level. Several subcontractors have revised their craft compensation programs to structure incentives toward quality and productivity rather than to production.

Subcontractors also benefited from learning how to transition from bulk installation to a systems mode of planning and control. In general, many subcontractors are now significantly more sophisticated and capable in the type of project management that will make them better suppliers of construction services to Maraven and PDVSA in the future.

6.0 Experiments

A number of hypotheses were experimentally tested and confirmed during the course of productivity improvement efforts:

- PPC is an effective means of measuring plan reliability.
- The reliability of weekly work plans needs to be improved.
- Plan reliability can be improved by make ready and selection processes.

- Reasons charts are effective means of identifying the actions needed to improve plan reliability.
- Detailed production planning is difficult, and often undersupported.
- Group productivity increases with improvements in the plan reliability of that group.
- First Run Studies are effective means for improving the design of work methods.
- Craftspersons and front line supervisors can and will contribute to the improvement of work methods.
- Unions do not oppose First Run Studies or the changes resulting in improved methods.

These suggest other hypotheses to be experimentally tested in the future:

- Buffer sizes can be matched to project toughness.
- The quality of delivery (both materials and prerequisite work) forecasts can be improved.
- Flow variation can be reduced by improving the PPC of each member of supplier-customer chains.
- Once flow variation is reduced, project durations can be shortened by reducing buffers between members.
- Customer productivity rises with higher PPC of suppliers.
- Total group productivity rises with reduced flow variation.

7.0 Formula for Greater Success

There would have been even greater improvements in productivity if the project had recognized subcontractor conditions earlier and had been more successful in changing management practices at every level. It would have been more successful if...

.....more EPC supervisors/controls personnel had required workable backlogs and helped subcontractors create these backlogs of workable assignments. Also, if they had used PPC and Reasons charts to improve subcontractor planning and to remove the constraints in EPC control. (Where this was done, subcontractor performance was consistently high.)

...EPC materials had been integrated with subcontractor planning and structured to support it. Field procurement generally did a good job in tough circumstances of acquiring materials, but they were not equipped as well to provide information for planning. Too often, subcontractors had to use an EPC requisitioning system to find out what materials they had to work with.

....more EPC/subcontractor teams had been successfully formed and had implemented the systems planning process, with its focus on managing the flow of work from system definition to backlogs of work lists, workable assignments, and systems ready for test.

....MPMT and EPC superintendents and managers had more fully adopted a "production management" as opposed to a "contracts management" model for control. There would have been less pressure put on subcontractors to meet target dates, and more attention placed on the subcontractors' abilities to plan and manage, so they could meet target dates.

While these measures would have increased the level of 'ex-pat' supervision and associated cost, this could have been recovered in improved productivity, schedule reduction, and lower subcontractor claims.

An additional major constraint was the late initiation of improvement efforts, its restriction to the job site; as opposed to also including engineering, procurement and fabrication. Further, the structure and timing of some incentives led project players to throw the lever in the wrong direction.

7.1 The Structure of Craft Incentives

Many craftspersons were paid production bonuses that caused them to select work to maximize bonuses, not to comply with sequencing requirements or to meet specific area or system targets. This also encouraged craftspersons to neglect work quality in favor of work quantity, contrary to their natural inclination. It took nearly 5 months to get only a handful of subcontractors to modify their compensation plans.

7.2 Subcontracting Strategy

Subcontractors were generally on fixed price or unit rate contracts. Fixed price contracts are appropriate when scope and quantities can be predetermined, and materials availability can be assured. Unit rate contracts are appropriate when quantities can be determined within a range not requiring additional subcontractor overhead. Materials are assumed to be available or shortages easily filled.

On certain subcontracts, actual conditions were quite different. Although varying by package, there were significant changes in design, wide swings in quantities of work, and material availability problems. In addition, subcontractors appear to be relying on Maraven to make them whole through claim settlements. In these cases, the cost discipline sought with fixed price and unit rate contracts was essentially lost.

The subcontracting strategy, and the thinking shaped by it, appear to have assumed a predictable, stable world in which production commitments could be made and kept. In retrospect, certain subcontracts should have been structured not only for production but for flexibility and responsiveness.

On balance, EPC contractors appeared to manage the subcontractors as if only the latter bore cost risk and the EPCs were to be judged solely on schedule performance. In some cases, the attitude seemed to be "It's all up to the subcontractors." While the EPC contractors vigorously pushed subcontractors to keep their contractual commitments, the EPCs were not always so consistent in delivering on their own commitments.

In addition, EPC contractors appear to have not fully recognized the interdependence of productivity and schedule. One example: under pressure for production, subcontractors did work out of sequence, thus increasing the labor requirement in future work, and devaluing the

percent complete in work already accomplished. EPC contractors' key measurement was physical progress and the primary weapon was push for production (for the most part, this can also be said for MPMT management as well). Push for production further deteriorated productivity, making it ever more difficult for subcontractors to make schedules. This led to greater push for production and demand for additional manpower in order to maintain earnings at lower production rates, thus making things progressively worse.

In turn, subcontractors, although pressured by the EPCs to eliminate non-productive workers, appeared in some cases to be comfortable and/or unwilling to incur union reaction, and resisted such initiatives.

7.3 The Distribution of Responsibilities and Capabilities

Subcontractors were expected to be responsible for quality control, production planning, material control, systems completion and documentation. In general, they had neither the experience, management processes, nor personnel needed to carry out these responsibilities. Although there were efforts made to help them develop such capabilities (training, productivity improvement program, etc), these efforts could have been more extensive and better structured. The contractual structure and the lack of resources budgeted for the task impeded technology transfer from EPC to subcontractor.

Due to budget limitations, the EPCs were not allowed to increase their site supervision. In fact, in early 1995, EPCs were instructed to reduce field supervision by 10%.

7.4 Mental Models

As stated earlier, the improvement strategy was based on a production management model. However, the prevailing construction industry management thinking and practice was based on a contracts management model. That difference was never entirely overcome.

Its impact was evident in the continued push for production at all levels, consistent with the contract management perspective of specifying and enforcing obligations. In a stable, predictable world, contracts can be structured and executed independently from those of other players, but this was not that kind of world.

The interplay between incentives and mental models lent an additional negative spin. Subcontractors consistently complained about missing materials. EPC contractors consistently complained about unexploited work fronts. Both were actually planning system problems, but neither could be solved unilaterally. Neither party felt responsible for the performance of the larger planning system which contained both these problems. The productivity improvement initiative attempted to tackle the overall planning system, but was limited in effectiveness by starting late.

7.5 Starting Late

Subcontractors were already into the systems phase of their contracts before their planning systems were restructured and improved. Consequently, the opportunity to reap extensive gains in performance improvements was already past. While there were benefits from productivity improvement efforts in the systems phase, there would have been much greater benefits in time and cost if subcontractor limitations had been realized, and if productivity improvement efforts had been undertaken earlier in the project.

Starting earlier would have made it possible to shape relationships and work processes for maximum performance. It is very difficult to change in midstream, and impossible to achieve maximum results.

7.6 What Could Have Been Done Differently

Too often the old saying "Hindsight is 20/20" is used as an excuse for failing to learn from experience. If hindsight is so good, why should we face the same problems twice? The team learned a lot on this project. Learnings include:

- 1) More time could have been spent upfront, getting understanding and alignment from top management: including MPMT construction managers and project controls, which sends messages and directives contradictory to the improvement strategy. The consultants confused permission to launch a program with commitment to change management practices. MPMT naturally assumed that the problem was that the EPC contractors didn't know how to manage. The EPCs naturally assumed that the problem was that subcontractors didn't know how to manage. Subcontractor management naturally assumed that the problem was either the work force or the way in which others were managing. Few understood how everything fitted together. No one fully understood the need, and many were not prepared, to change their own management practices.

Although the above is generally true, there were individual managers ready and willing to learn. There were also differences between organizations, at every level, in their receptivity to different ways of thinking and managing. Over time, more individuals and key managers were persuaded, but far short of 100%, and very late in the game.

- 2) In March, the team began training subcontractor/EPC teams for each subcontract, and used productivity analysts assigned by MPMT, EPCs and subcontractors to support implementation. However, this could have been done a few months earlier, and training could have been more fully developed and rigorous. Also, initial efforts in this direction assumed that everyone would react properly to low PPC, and begin screening, installing buffers, etc. Too little regard was paid to the lack of knowhow, the unfamiliarity of the concepts, and the contrary pressure for production that became more intense as time went on.
- 3) The team often observed lack of clarity regarding who was making what planning decisions. Too little early emphasis was placed on the direction the EPCs were providing the subcontractors on planning. It is necessary to explicitly map out how EPC and subcontractor planning systems are structured to work together. It would also help to prepare earlier for the transition to systems planning processes.
- 4) As long as the task of controls is to signal when someone needs to be pressured, scolded or killed, there will inevitably be lots of bodies lying around regardless of the content of the controls data. If the task of controls is, in part, to monitor and diagnose the performance of management systems, systems improvement may result rather than bodies.

The problem was not that people were doing their jobs wrong. They were doing the wrong jobs. What was needed were changes in contractual structures and management processes. Providing information for decision making without changing the mental models with which that information is interpreted is not effective. The team should have made management controls an explicit component of the improvement program, proposing to improve

monitoring of performance against objectives and also extending control to the management processes that determine performance.

8.0 Recommendations

These are recommendations proposed by the consultants for others. Others undoubtedly also have recommendations for the consultants.

8.1 For the Owner

Recommendations for Maraven can be divided between those appropriate to the management of future individual projects and those directed at development of the entire infrastructure of developing, acquiring, and managing construction services.

Project-oriented recommendations:

- 2) Match contracting strategy to project levels of difficulty and uncertainty, and structure to align incentives of the participants. Learn when and how to contract for efficiency of production and when to contract for responsiveness.
- 3) Require contractors to incorporate the improvement strategy into their management processes. The current model for project management is essentially dedicated to control of outcomes; i.e. to identifying and solving problems that would prevent meeting schedules and budgets. That model must be modified to focus control on management processes and to include breakthrough to new standards of performance.
- 4) Assure that resources are adequate to achieve project objectives such as technology transfer.
- 5) Align requirements and procedures to construction project needs, to minimize material and service acquisition lag times.
- 6) Improve ability to resist major scope changes throughout the project life cycle. (Accelerating change toward the front end of projects appears to be the solution, implemented by means of concurrent engineering.)
- 7) Find means for reducing union/labor constraints on performance, especially labor supply flexibility. There appeared to be a strange reluctance to confront labor issues; i.e. reluctance to demand compliance with prevailing rules, to contest damaging rules, or to invite labor representatives to help improve performance and thereby enable the workers to work at their crafts.

Infrastructure development:

Install a production management philosophy and attendant process changes throughout the industry. This would involve everyone from suppliers and fabricators to licensing and standards-setting entities, universities, training centers, contractors, and Maraven's own contracting and contracts management procedures.

8.2 For EPC Contractors

- 1) Integrate contract management and the management of work. While monitoring and enforcing compliance with contractual commitments is one of the responsibilities of managing a contractor, the parties inevitably occupy a nest of interdependencies, so that the manager can help the managed perform better. The managing contractor often provides directives, coordination with others, engineering information, materials, and sometimes management expertise. Focus on compliance must be supplemented by a perspective on the larger systems in which both parties are members, and an intent to improve the design and performance of those systems, thus enabling superior performance by the subcontractor.
- 2) Supplement control with breakthrough; conceive and structure the controls function to both solve problems that return the "system" to normal (budget, schedule, etc), but also to breakthrough to new standards of performance. In other words, integrate performance improvement into project management practices rather than leaving improvement efforts as a program carried out alongside project management.
- 3) Design processes that tie different functions and organizations together with the involvement of those players, and make the design explicit in the form of flow charts and instructions. Train as needed to insure capability and conformance to process design. Control process and system performance and not only outputs.
- 4) Provide complete materials management; i.e. manage the flow both of materials and information, integrate acquisition and delivery schedules with the production schedules of engineering and construction, and provide continuous information for production planning to all functions.
- 5) Use the system planning process to structure and manage work during the systems phase of future projects.

8.3 For Subcontractors

- 1) Standardise the Last Planner system and First Run Studies throughout your companies. Improve PPC by improving the quality of weekly work plans. Provide feedback to general contractors on assignments that cannot pass screens. Establish standard methods for key operations and use for planning and training.
- 2) Eliminate bonus plans, or switch from paying for production to paying for plan compliance (PPC).
- 3) Organise work forces to minimize nonproductive labor time; e.g. assign speciality workers to crews to perform specific tasks, not as a standby resource.
- 4) Develop capabilities in areas such as quality control, materials management, and planning and scheduling.

9.0 Conclusion

The key to improved performance is increased reliability of planning. There is plenty of evidence for the truth of that claim. Experience on this project demonstrates that plan reliability and performance can be achieved in the face of significant uncertainty. Nonetheless, it was extremely difficult to build backlogs of workable assignments. EPC and

subcontractor personnel were often unfamiliar with the concepts, and when they did understand them, were not always willing to make commitments in an environment of pressure and blame. The field's hunger for workable assignments was evident in the rate of backlog consumption. As soon as a little bit of work was prepared, it was eaten up by production. Just think what could have been achieved if the project had been more successful at creating backlogs, especially in the systems phase. But that's for future projects. The accomplishments on PARC should not be disregarded.

PARC is a massive undertaking that has involved approximately 300 national subcontractors, three major EPC contractors, and consumed 50 million field hours. Obviously, improvement is possible, and everyone must work to that goal. However, nothing should be taken from the fact that PARC was completed with 92% national services/labor participation, and was completed on schedule and within its approved budget.