TEHRAN METRO LINE#6

Improvement of Production and Quality Through Lean Methods and Cooperation With The Public Client

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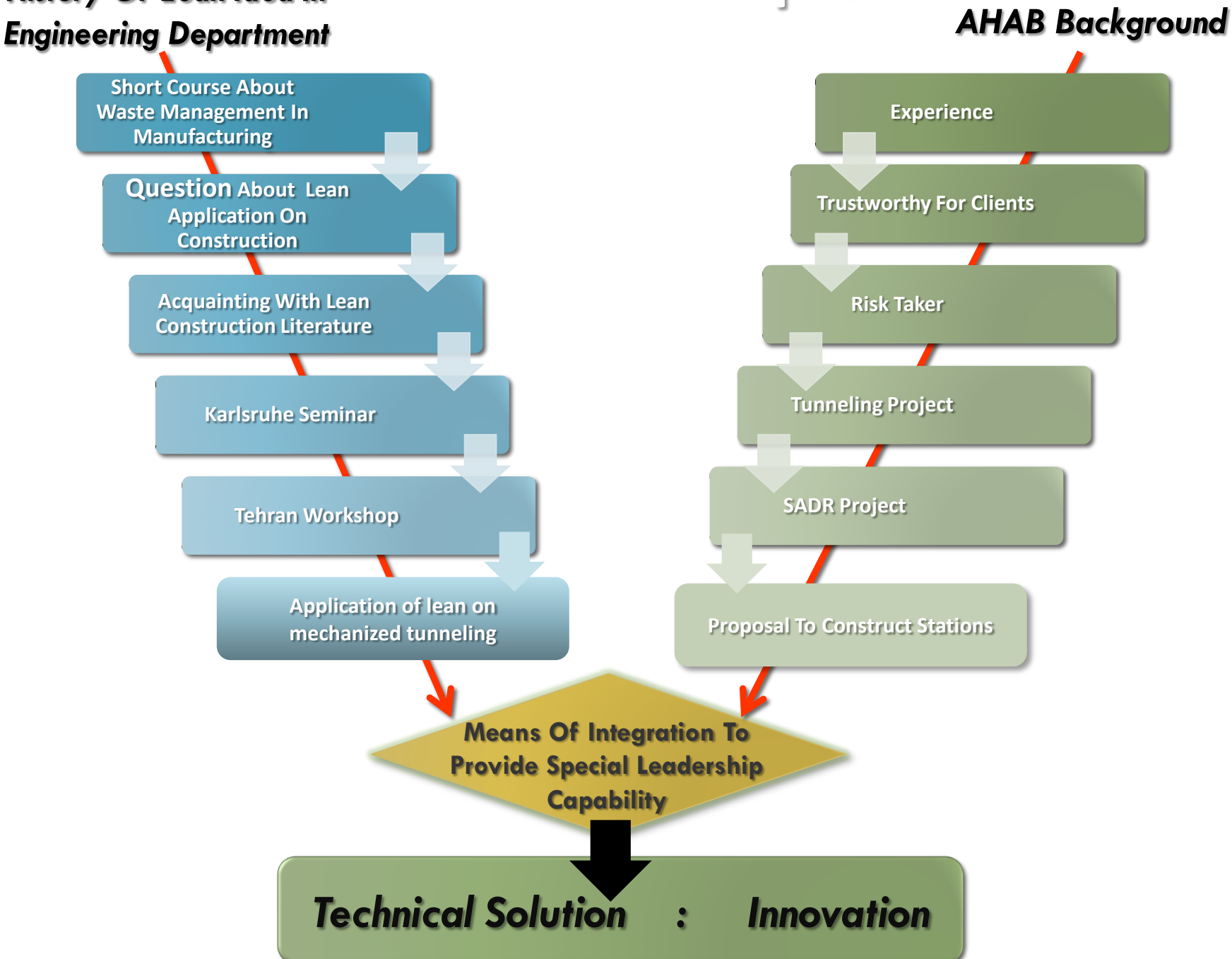
AHAB Company Profile

Engineering and Construction of Infrastructures:

Dams, Tunnels, Pipe Lines, Irrigation Plants,…

Main Concepts



2005

- Course About Waste Management In Manufacturing Including:

2006

- Search To Check Lean Application
- Acquainted With Lean Construction Institute Web Site

2009

- Karlsruhe - LIPS conference

2010

- Tehran workshop

2011

- Application of lean on mechanized tunneling

General terms learned:

- ✓ *Poka yoke*
- ✓ *Mistake proof*
- ✓ *6 sigma*
- ✓ *5 S*
- ✓ *Design for production*
- ✓ *Lean production*

Master minds:

- Glenn Ballard, PhD
- Gregory Howell, P.E.
- …

participants of the tunneling project who attended in workshop:
Client: Tehran metro
EPC Contractor: AHAB Co.
MC: Behro

Tehran workshop

Teheran Sept. 27 - 29, 2010

By Prof. Dr. – Ing. Fritz Gehbauer. M.S

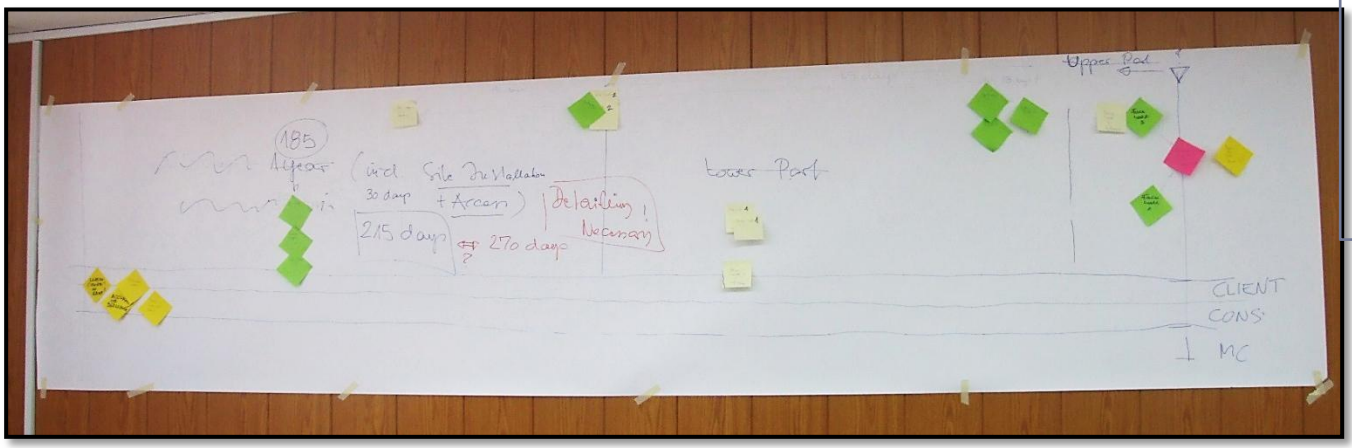
participants of the workshop:

- **Client:** *TEHRAN URBAN AND SUBURBAN RAILWAY COMPANY (METRO)*
- **MC:** *TEHRAN BEHRO CONSULTING ENGINEERS*
- **EPC CONTRACTOR OF TUNNELING OF PHASE ONE:** ***AHAB CO.***

Main concepts of seminar:

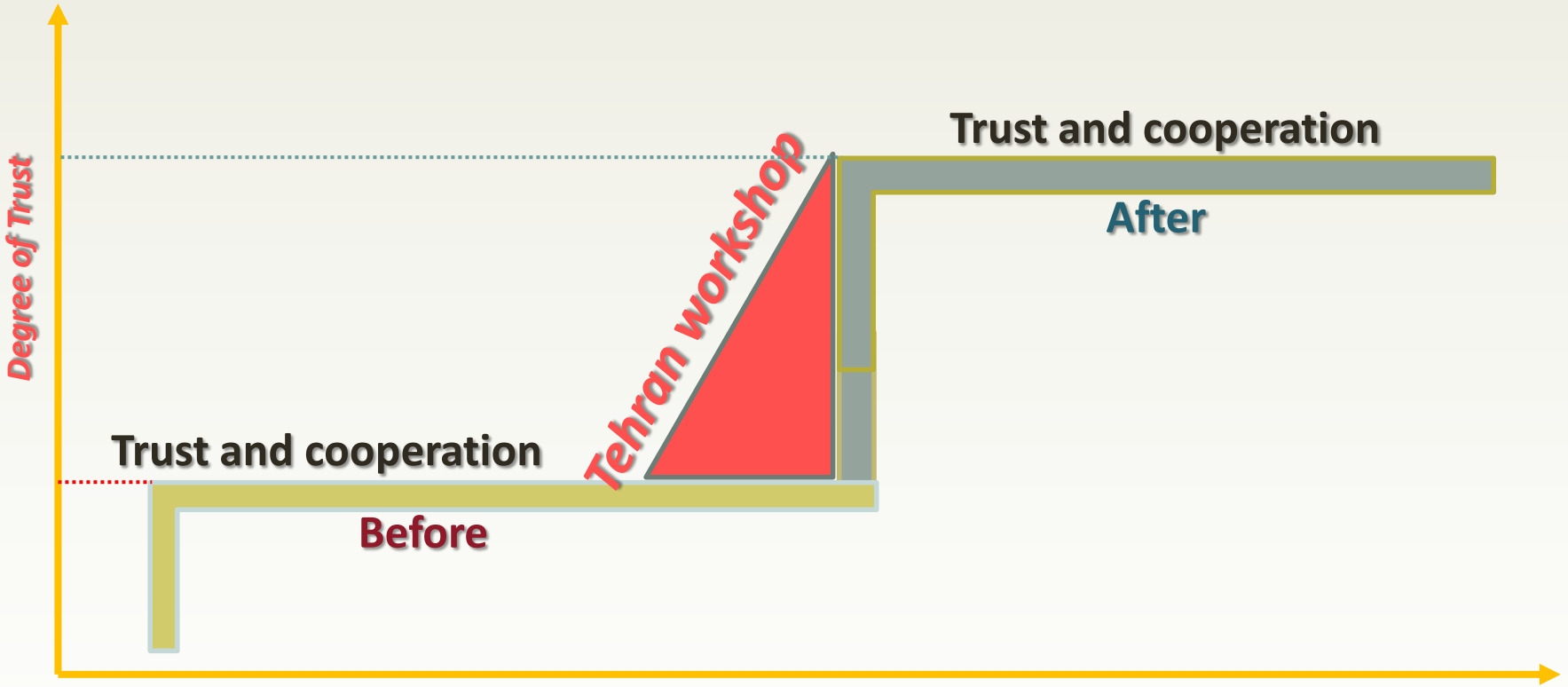
- ***What is Lean?***
- ***factors which are hindering project work***
- ***The Last Planner System (LPS) of Project Planning and Control***
- ***New forms of cooperation***
- ***Alliancing, Team building***
- ***The Big Room***

Tehran workshop



Group work on the planning of tunneling project phases

What Were Tehran Workshop's Effect...?



New and Successful Approach to

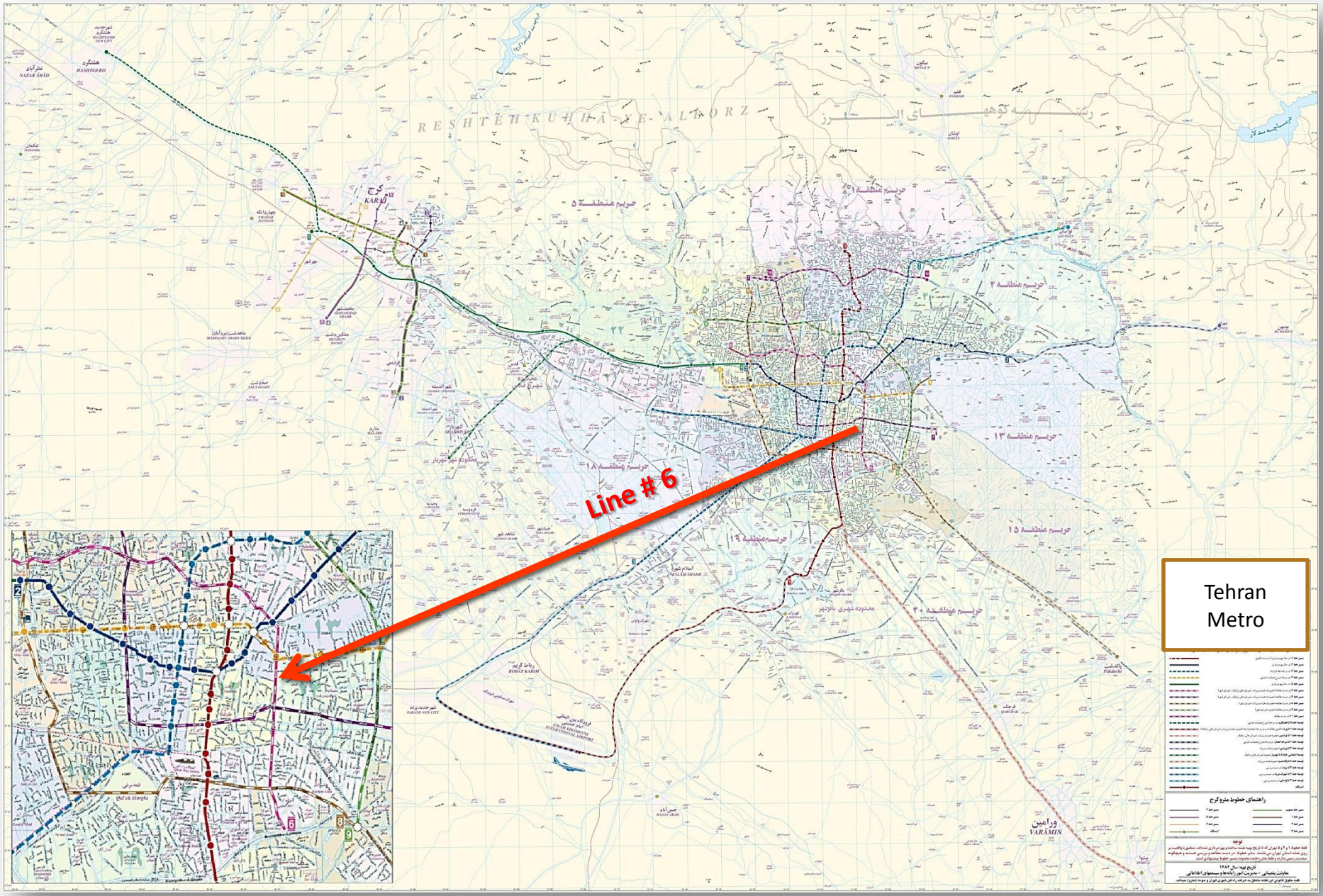
Collaborative Planning

With The

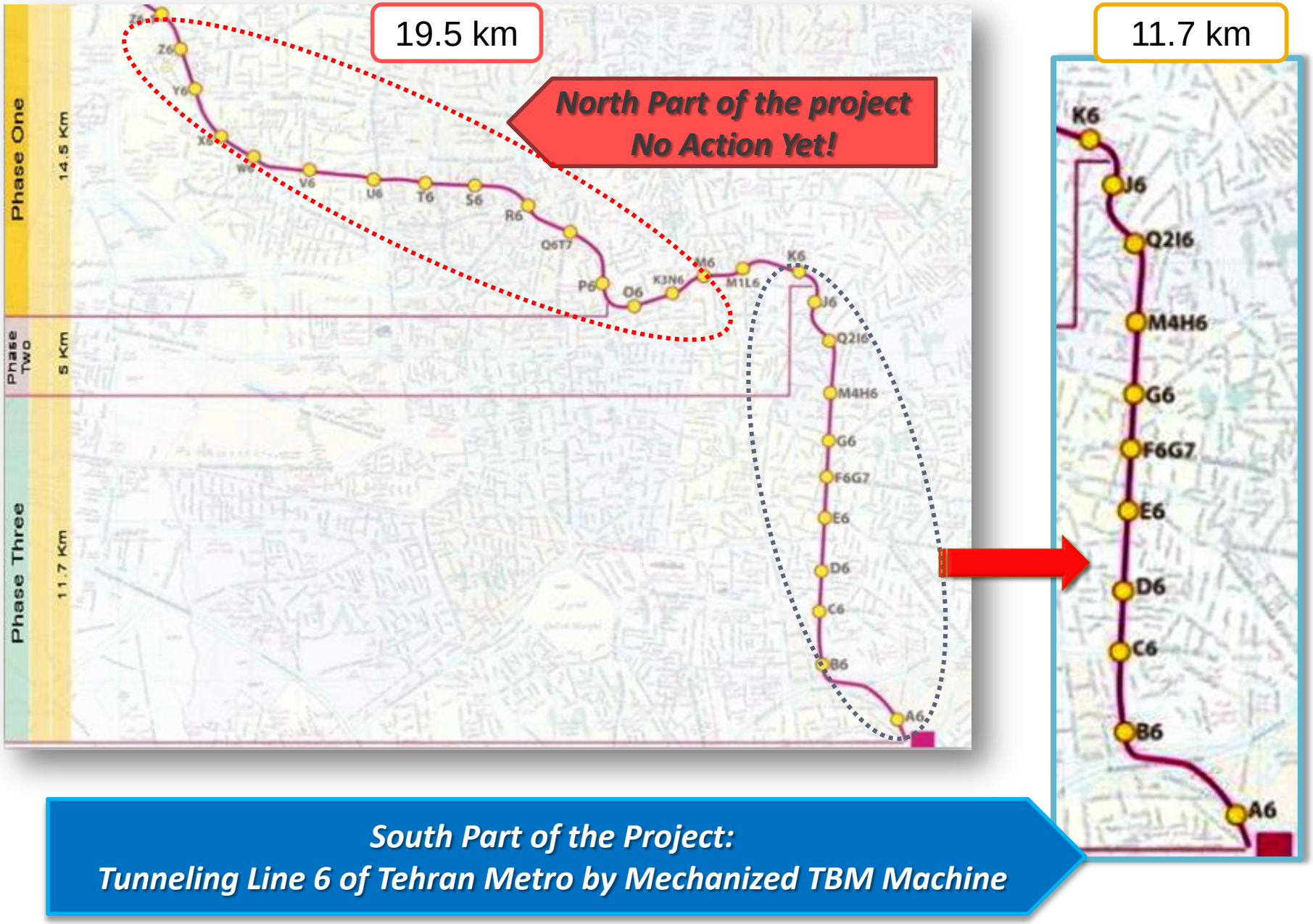
Public Client, Consultants and the Contractor

MECHANIZED TUNNELING TBM PROJECT

Tehran Metro Map

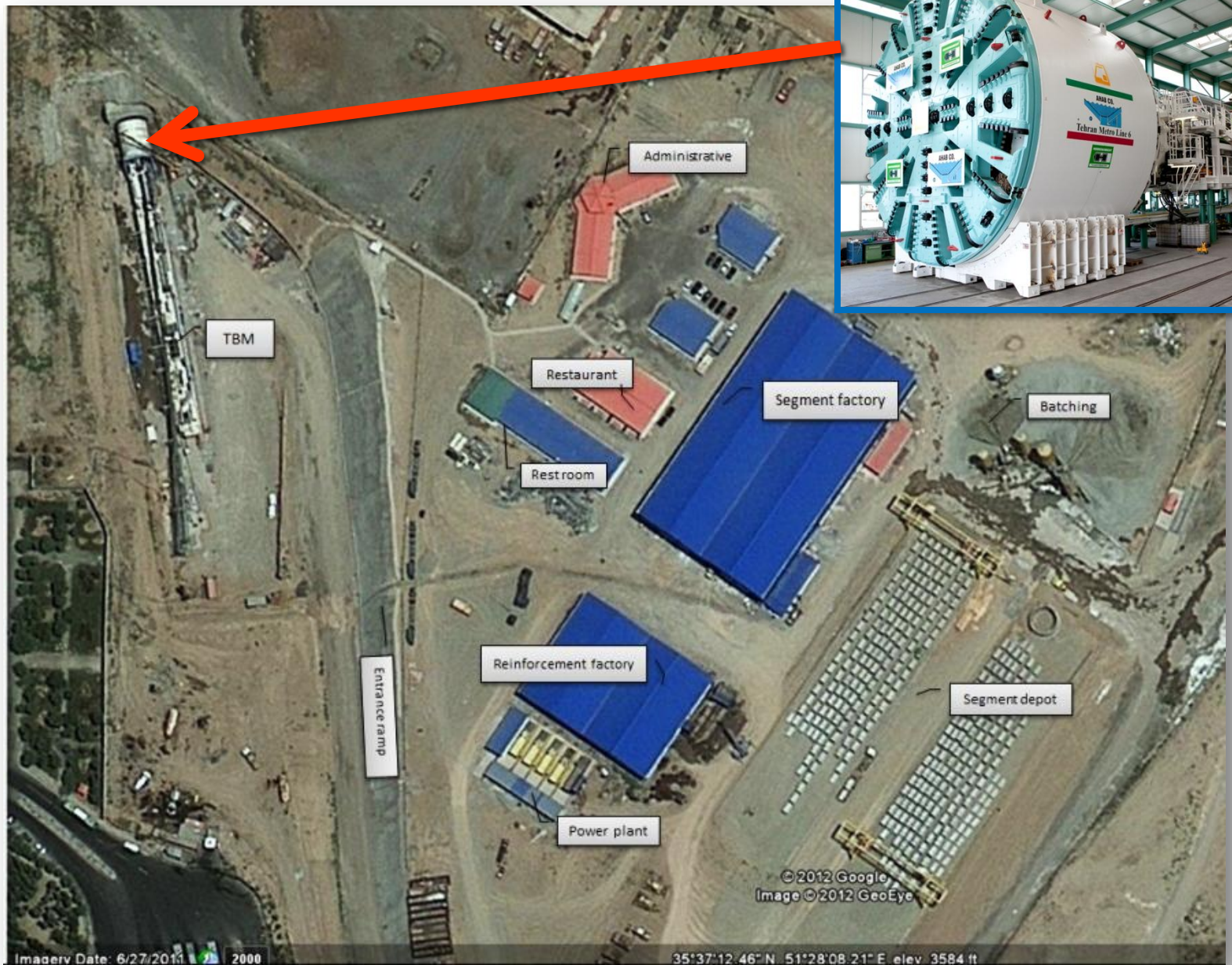


Introduction



South Part of the Project:
Tunneling Line 6 of Tehran Metro by Mechanized TBM Machine

Tunneling Contract

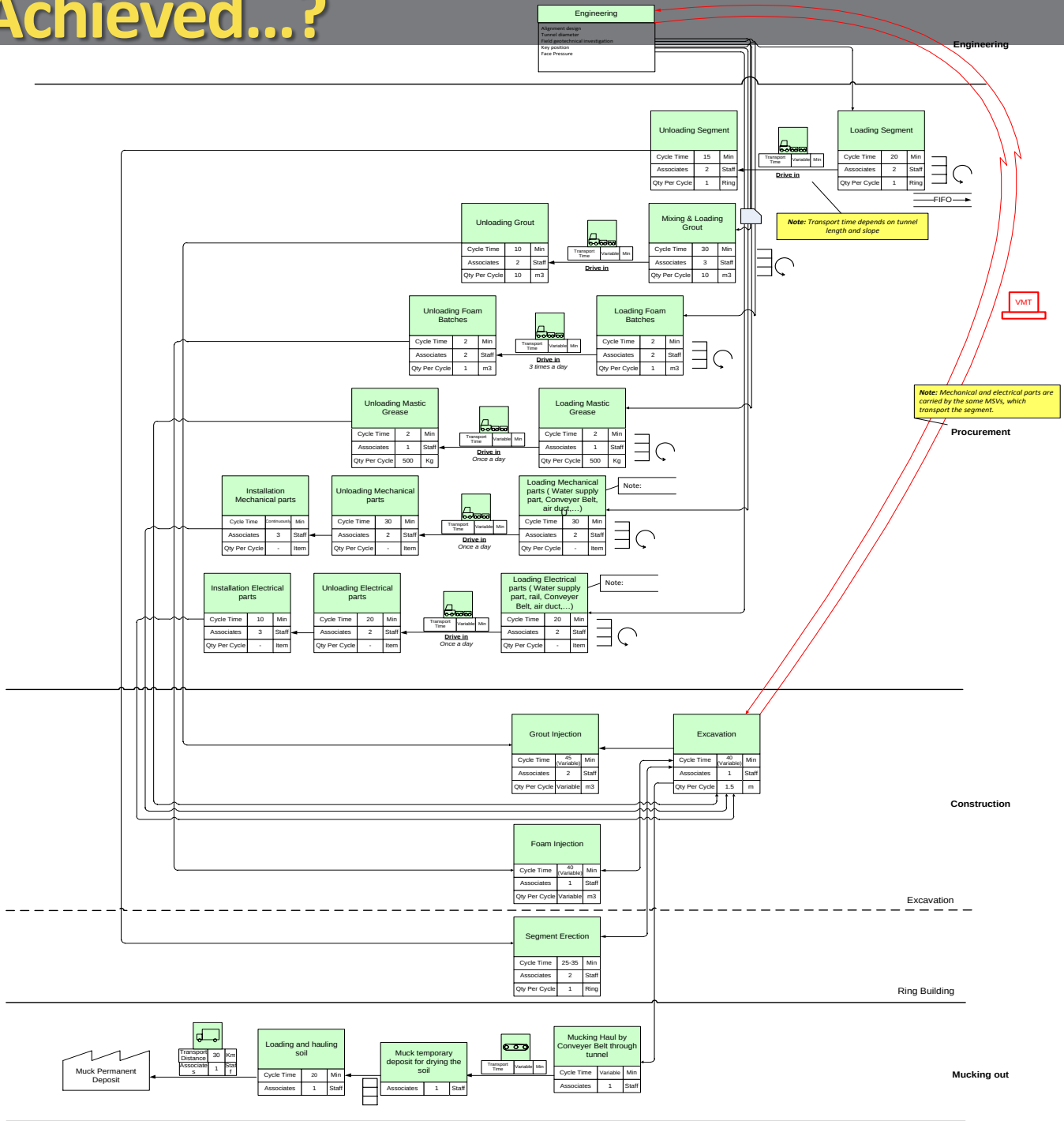


With a TBM and very Limited Space at the Tunnel Face Just In Time Is a Must...!

How Was This Achieved...?

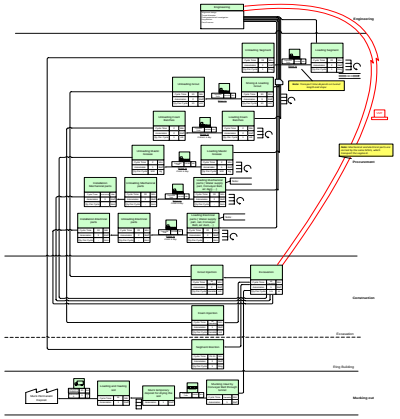
VSM

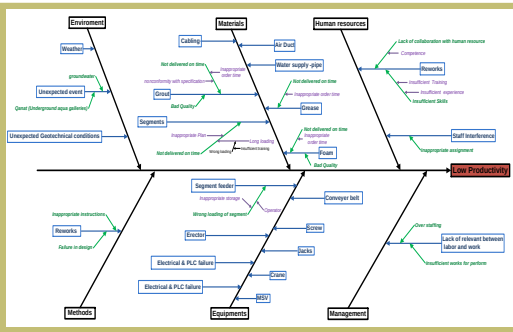
Value Stream Mapping of Mechanized Tunneling In Tehran Metro Line # 6



HOW WAS THIS ACHIEVED…?

Lean construction concepts and means were applied for control of the TBM operation to identify the amount and the extent of the effective uncertainties. It was enhanced by using turtle diagrams & cause and effect diagram





How Was This Achieved…?

By:

3- With what ? (Equipment/Facility)	Comments
TBM	Diameter of cutter head 9.15 m
Conveyor	To transporting soil out of the tunnel
Power plant	5 MW power plant for TBM
Water	
Rail	Due to moving TBM
Vacuum lifting device	lifting segments from MSV and put them on feeder
segment feeder	Transporting segments to erector
Erector	Installing Segments on the tunnel wall

5- With who ? (From training records)	Requirement	Number(s) (2 shifts)
TBM Supervisor	mechanic engineer	1
TBM operator	Trained operator	1
Electrical supervisor	Electronic engineer	1
Power plant controler	Electronic engineer	4
TBM serviceman	Skilled Labour	2
H&E (conveyor belt)	Skilled Labour	2
Welder	Labour	2
Erector operator	Mechanic technician	2
Segment feeder operator	Mechanic technician	2
Grout responsible	Skilled Labour	2
Mechanical part responsible	Mechanic engineer	2
PLC man	Electronic engineer	1
VMT responsible	surveyor	1
Installing air duct responsible	Skilled Labour	1
Cleaner	Labour	3
	Sum	27

2- Inputs (Information/process)	Comments
Alignment design	AHAB
Tunnel diameter	9.15 m
Average of advancing	15 m/day (10 rings/day)
excavation capacity	24 m/day (16 rings/day)
Length of the tunnel	11700 m
Field geotechnical investigation	AHAB
Face pressure	Gueno consulting engineers
key position	in accordance with path direction
VMT	
Required grout rate in a ring	8 m3 / ring

1- Process name: Tunnel Mining	
Advance rate	1.5 m (1 ring)
Excavating duration	35-45 min
Ring Installing Duration	25-35 min
Process before	*Process after*
Segment production	*Ring Installation*
Steel Cage Production	*Muck out*
Transporting Grout, Foam, Grease,…	*Waste Water*

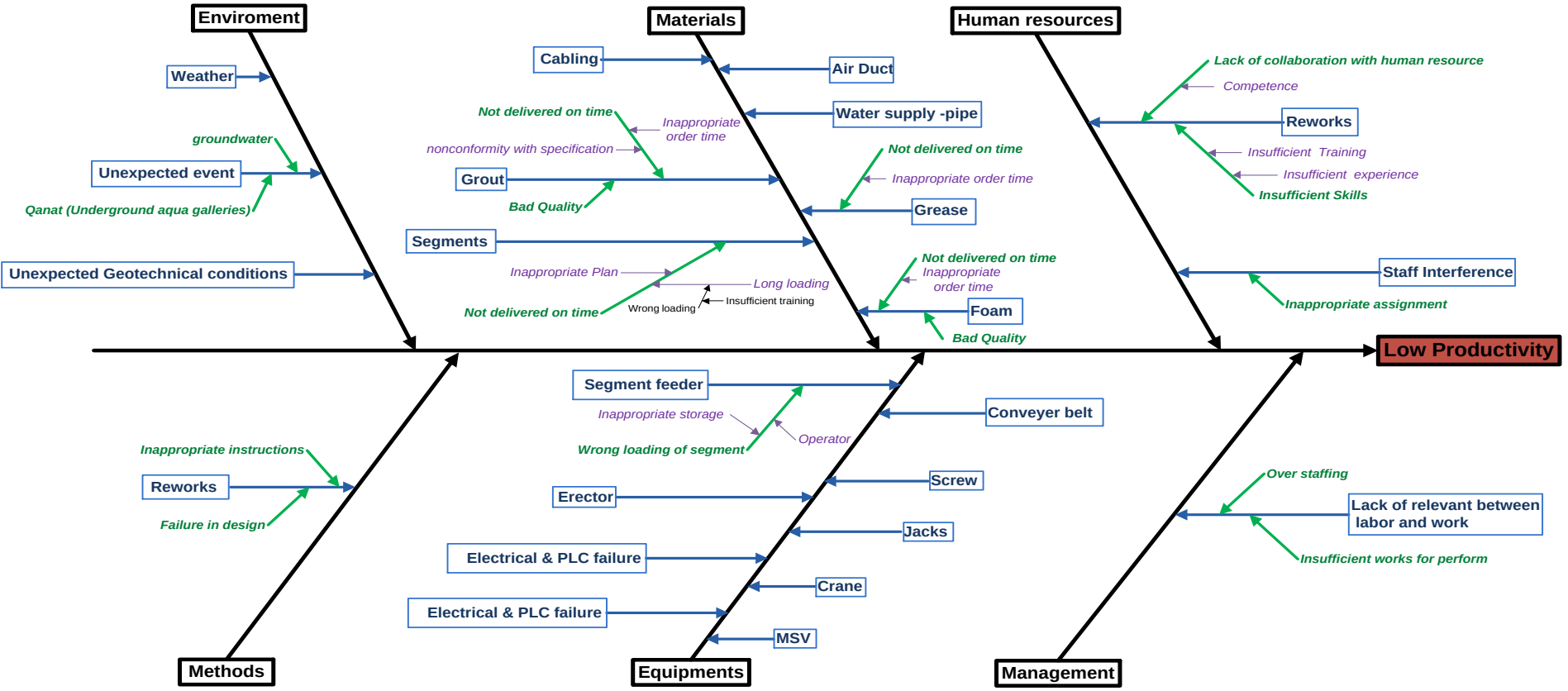
7- Outputs (Product/Process)	omments
Advanced (m/day)	Prepared for ring installation
Number of built rings per day	2 shifts

4- How ? (From flow chart)	Requirement/ who provides?
TBM Excavating instruction	Herrenknecht Co.
Rail installation	Rail
Adding conveyor belt (each 250 m)	Conveyor belt
Water Supply instraction	
electrification instruction	cable,hook bolt
feeder charging instruction	Herrenknecht Co.
Grout injection instruction	
installing & adding air duct	

6- Performance (Process standard & measurement)	mments
Efficiency	Advance rate (meter/month)
Daily Excavation	Meter
Deviation rate	Conflict with designed direction
VMT Reporst	
Excavation standard	OSHA

How Was This Achieved…?

By:



COMPARISON OF TUNNELING CONSTRUCTION PROJECTS IN TEHRAN

AHAB Has Had More Progress In Tunneling Construction

* Same Project
* Same Ground Condition
* Same Equipment
* Same Environment
* Same City
* Same…

More Collaboration

Less Reworking

More Quality

More Quantity

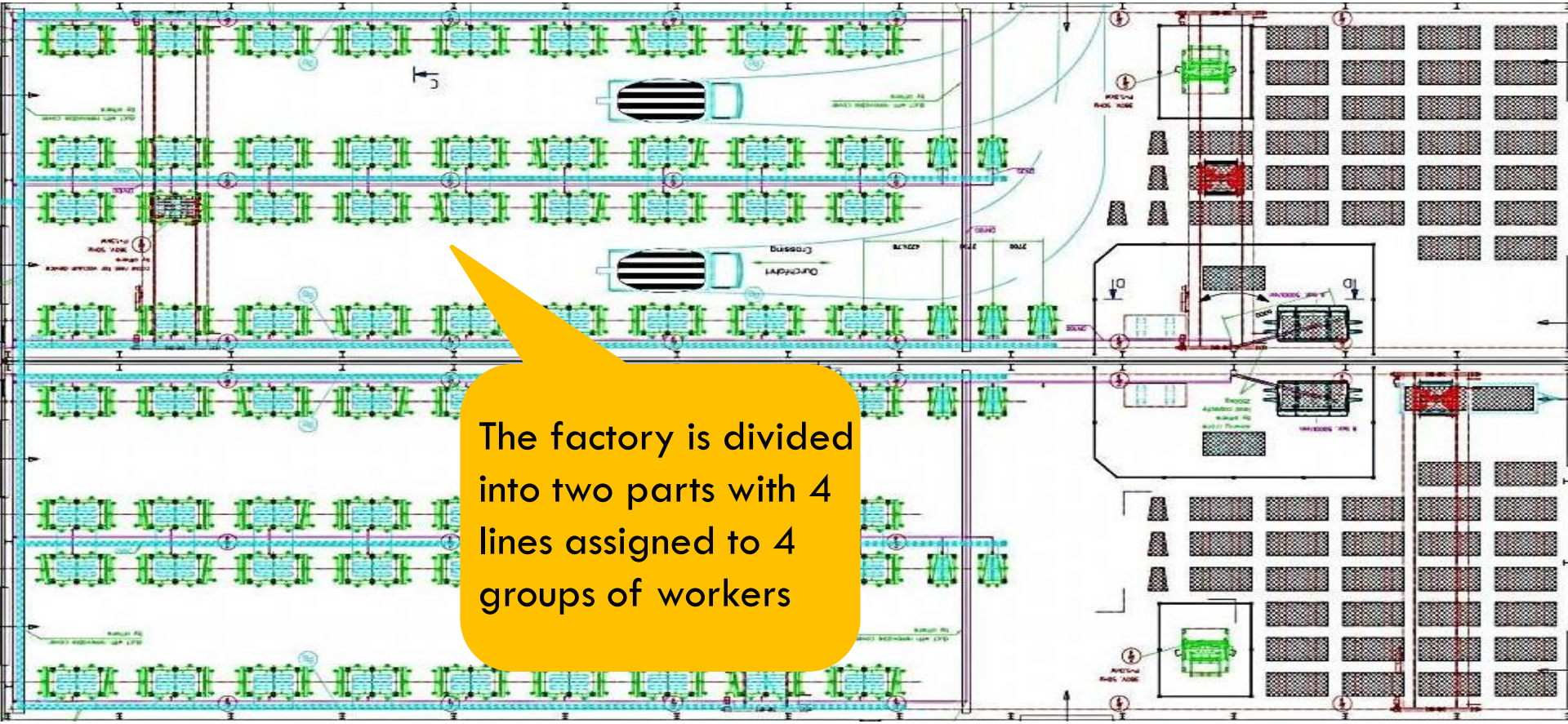
Less Cost

SEGMENT


South Part Tunnel of Tehran Metro Line 6
PILAN
AHAB Co
A1-5
89/12/20
A1-1
89/12/08
A1-3
90/2/6
A1-1
90/2/5


HYUNDAI
K7 90/3/9

Segment Plant and innovation



The segment factory is designed for 9 sets which form 9 complete rings…

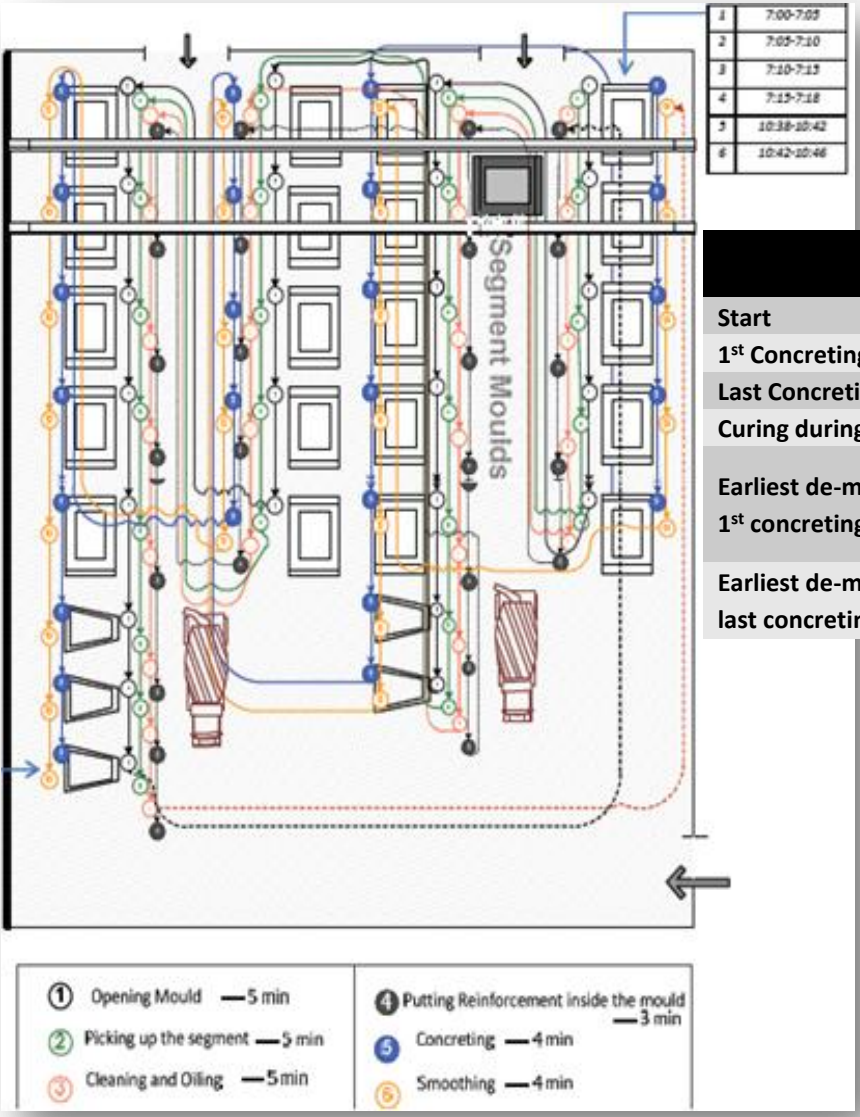
Through VSM and Lean Manufacturing Methods:

- ENERGY SAVING
- REDUCED INVENTORY
- INCREASE QUALITY
- …

Production of The work begins by de-molding the previous day or shift production, all segments one by one

Other activities are added to complete the process

Work Flow 1



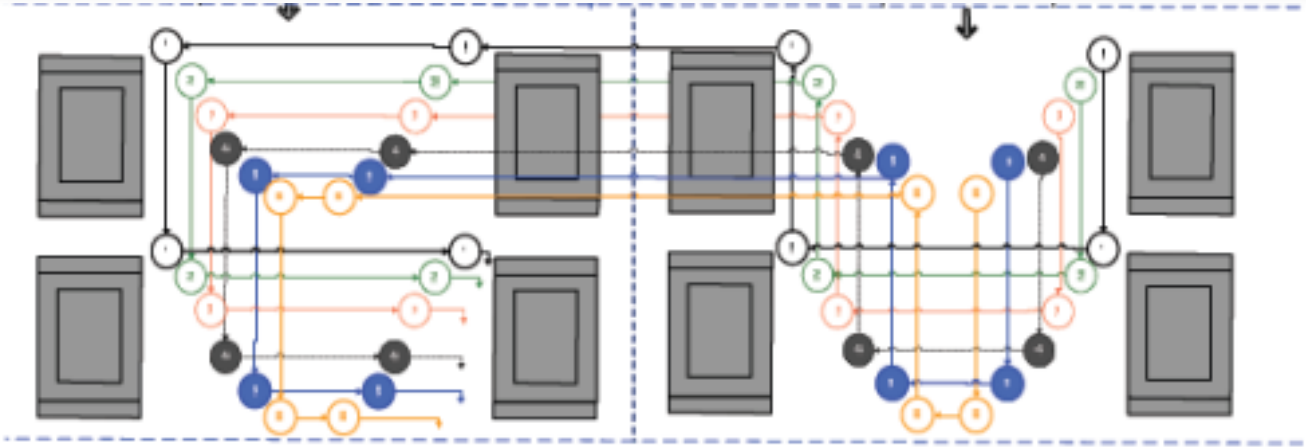
Dayshift	
Start	7:00
1st Concreting	10:38
Last Concreting	14:30
Curing during	10 hrs.
Earliest de-molding time for 1st concreting	20:38
Earliest de-molding time for last concreting	00:38

Nightshift	
Start	20:38
1st Concreting	00:38
Last Concreting	4:38
Curing during	10 hrs.
Earliest de-molding time for 1st concreting	10:38 (Next day)*
Earliest de-molding time for last concreting	14:38

This means: ***that day shift can't start working at 7:00 am on next day!***

designed to consider the importance of curing duration required and also in order to place plant facilities

Work Flow 2



Dayshift		Nightshift	
Start	7:00	Start	19:00
1st Concreting	7:33	1st Concreting	19:33
Last Concreting	17:00	Last Concreting	5:06
Curing during	10 hrs.	Curing during	10 hrs.
Earliest de-molding time for 1st concreting	17:33	Earliest de-molding time for 1st concreting	5:33 (Next day)
Earliest de-molding time for last concreting	3:00	Earliest de-molding time for last concreting	15:06

For creating the possibility of a two full cycle production with the cheapest curing system, the work flow 2 is the only chance

Segment Damages During Construction

Damaged category	Crack in axial	Crack in circumferential direction	Chipping at segment corner	Stripping around segment	Stripping around ring joint	Hair crack at inner surface	Stripping around erector guide	Others
Segment damaged	13	11	78	54	68	0	140	14
Total number of segment checked	9000	9000	9000	9000	9000	9000	9000	9000

Comparing These Results With *Sugimoto, 2006*, Shows The High Quality Of Segments During The Construction Tunnel In Tehran Metro Line#6

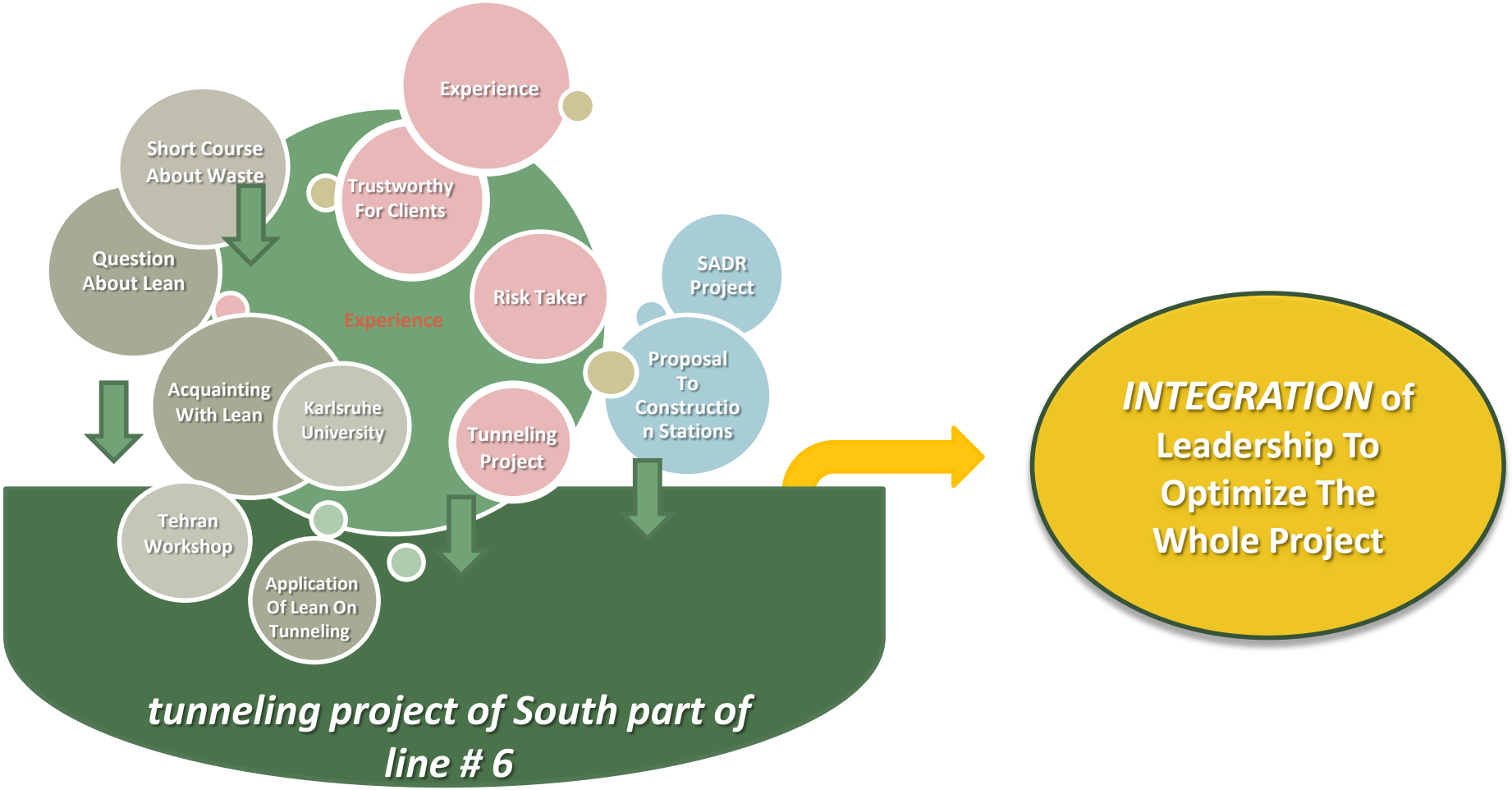
A Special Form of Cooperation With The Public Client

Second Part Of The Contract With The Price Of 100 Million Dollars Which Consist Of Building 13 Stations .

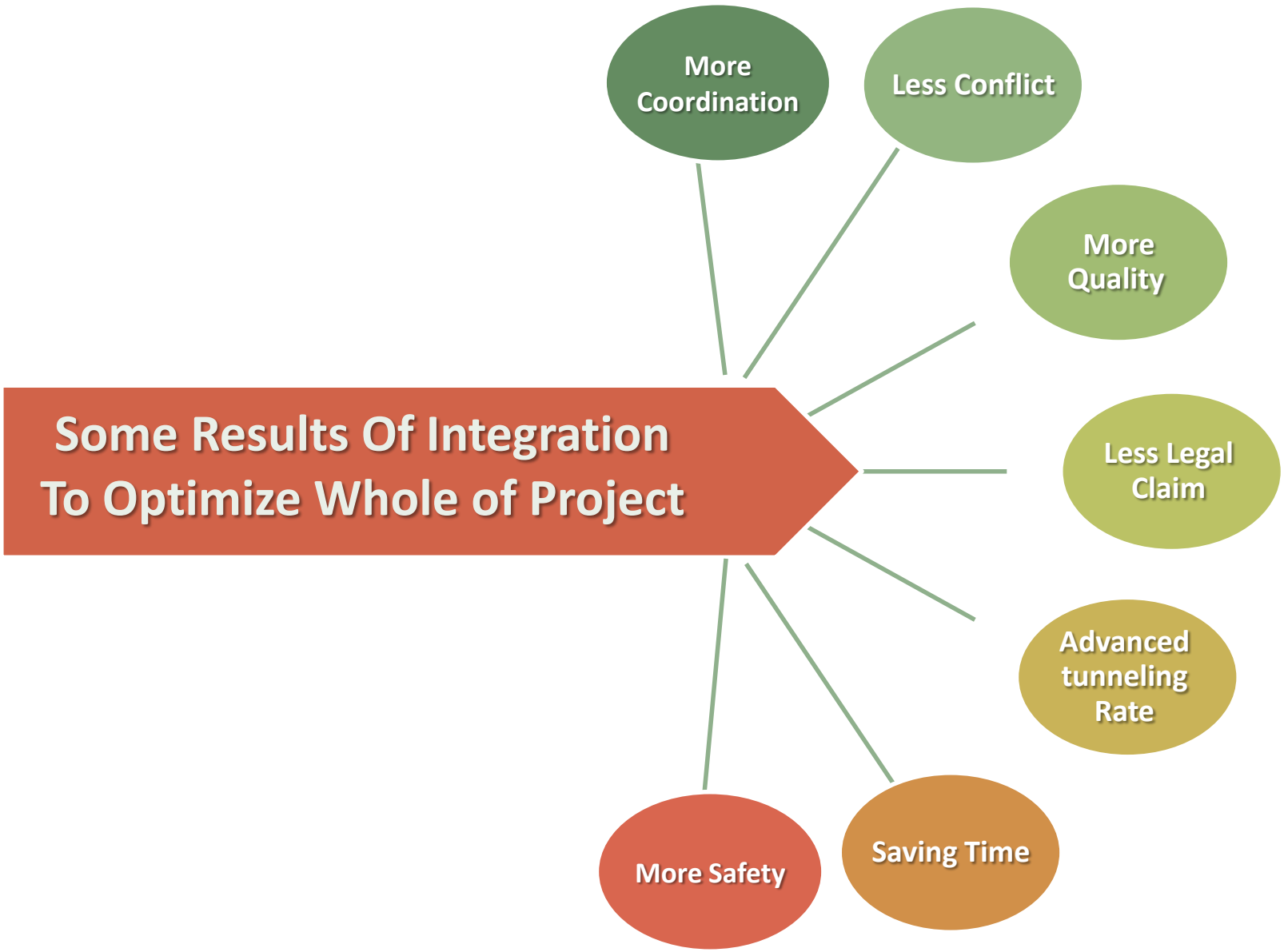
Financial resources of project is supported by a barter treaty which entitled “Sadr Complex”. It defines AHAB company as a investor on Engineering, Procurement and Construction of 9 stations in line # 6 and 4 stations in other lines.(1,2 &3)

Through Visions and Dreams to Reality of Leadership and Lean on

Tehran Metro Line #6



Tunneling and Stations an Integrated Project



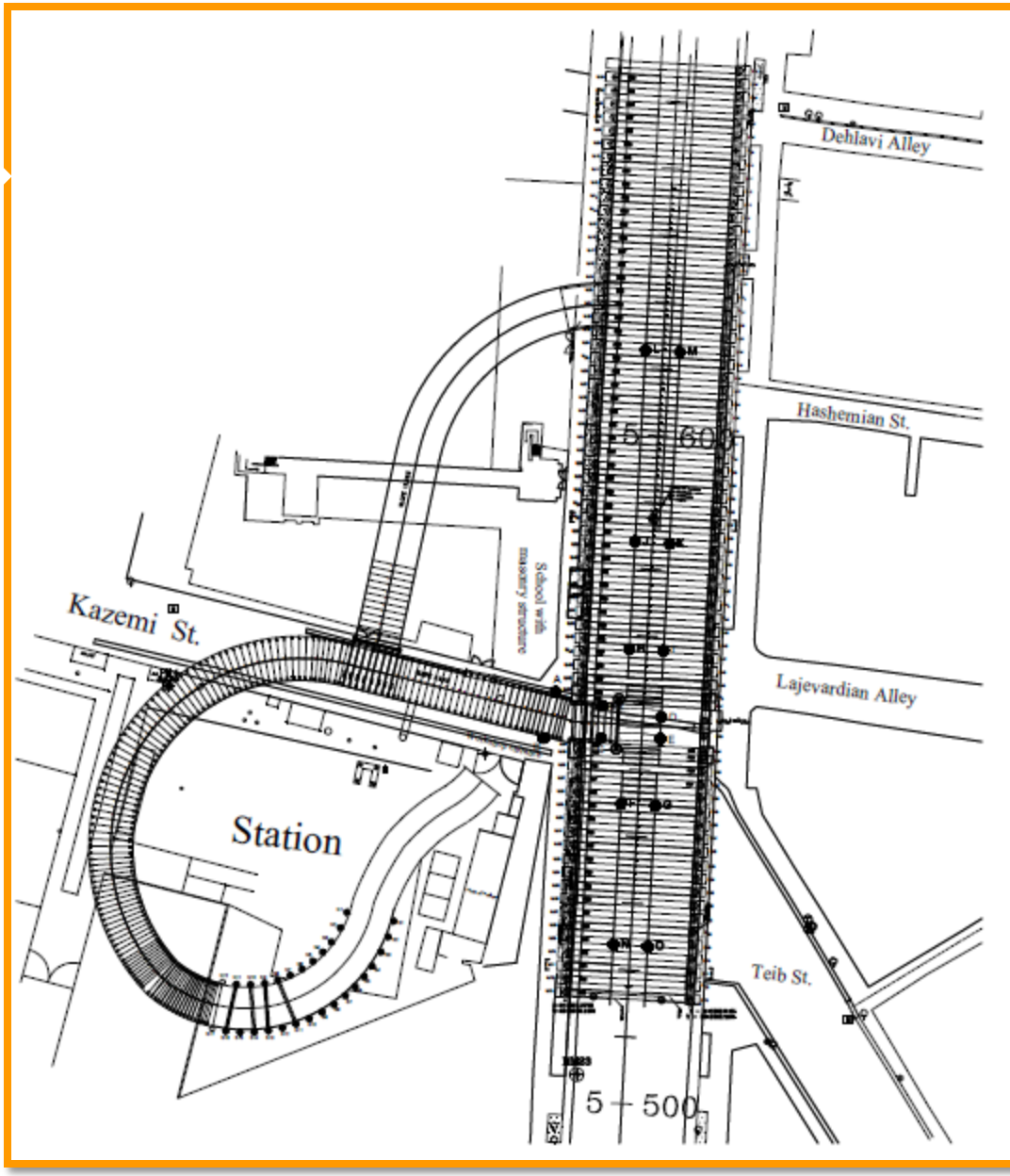
PROBLEMS DURING CONSTRUCTION

Plan of Station

Hard to access

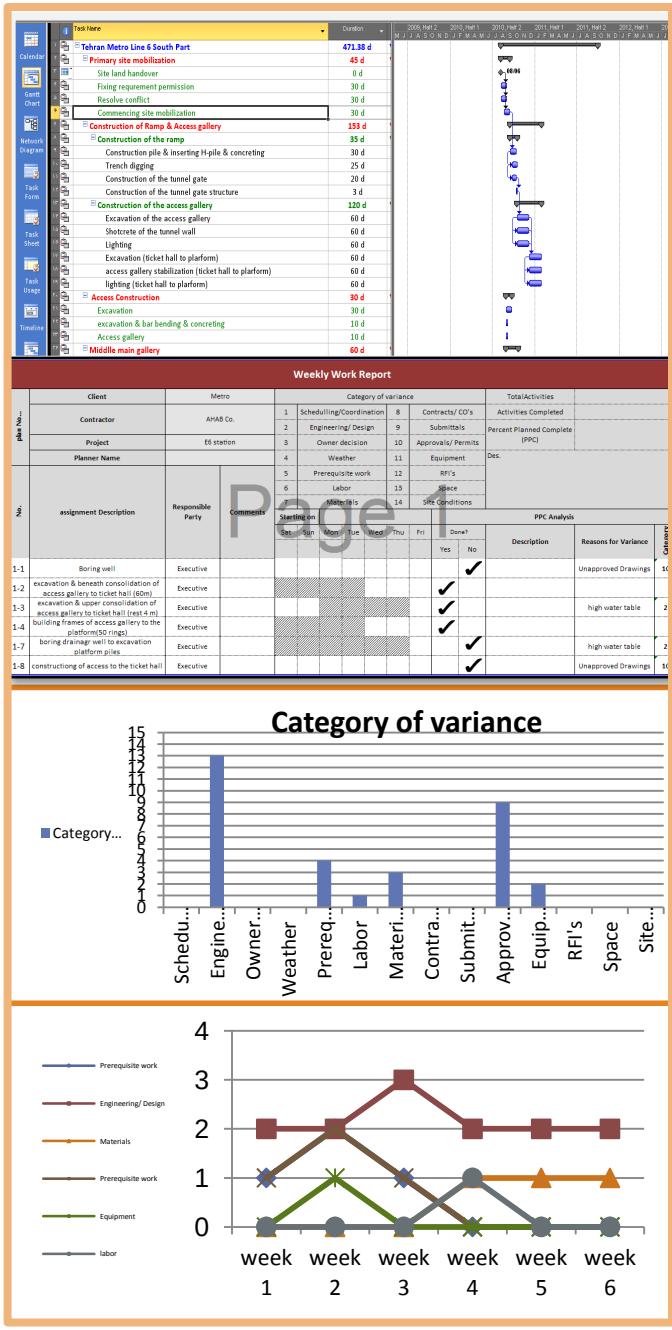
Water table

City mechanical, electrical and other facilities

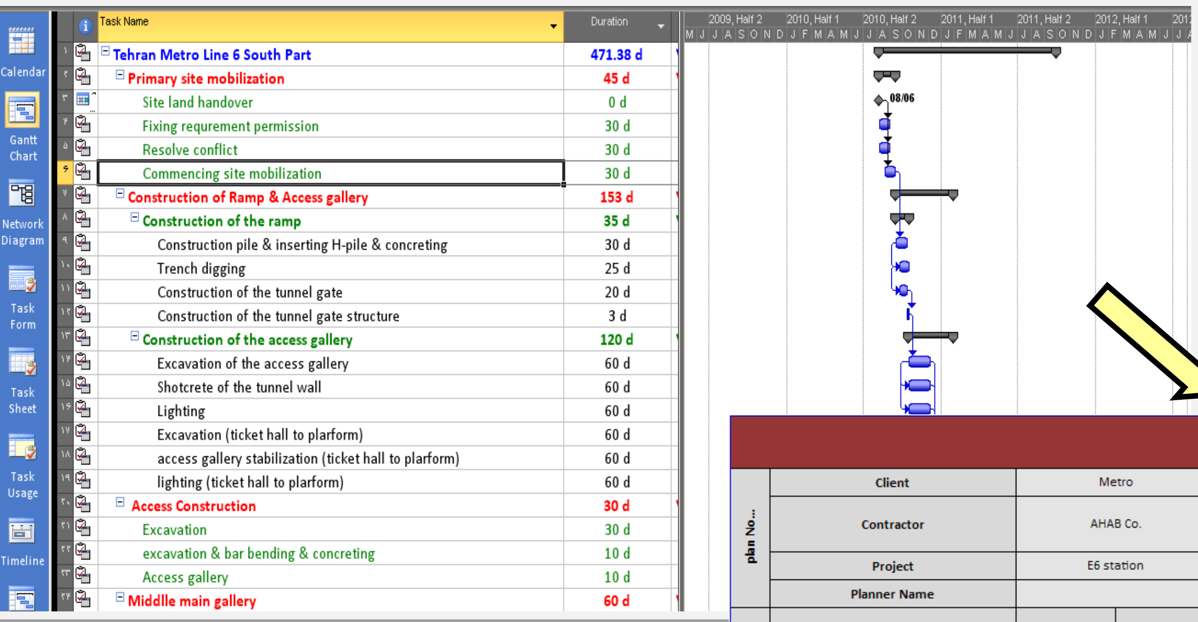


How Was This Achieved…?

LAST PLANNER



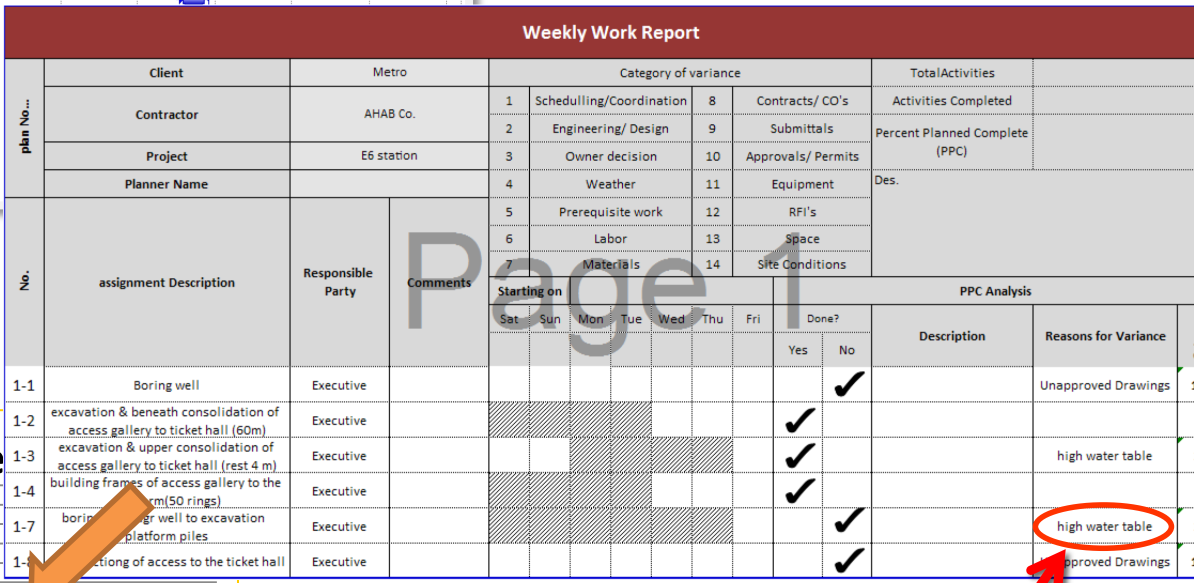
How Was This Achieved...?



Task Name	Duration
Tehran Metro Line 6 South Part	471.38 d
Primary site mobilization	45 d
Site land handover	0 d
Fixing requrement permission	30 d
Resolve conflict	30 d
Commencing site mobilization	30 d
Construction of Ramp & Access gallery	153 d
Construction of the ramp	35 d
Construction pile & inserting H-pile & concreting	30 d
Trench digging	25 d
Construction of the tunnel gate	20 d
Construction of the tunnel gate structure	3 d
Construction of the access gallery	120 d
Excavation of the access gallery	60 d
Shotcrete of the tunnel wall	60 d
Lighting	60 d
Excavation (ticket hall to plarform)	60 d
access gallery stabilization (ticket hall to plarform)	60 d
lighting (ticket hall to plarform)	60 d
Access Construction	30 d
Excavation	30 d
excavation & bar bending & concreting	10 d
Access gallery	10 d
Middle main gallery	60 d

Time Schedule

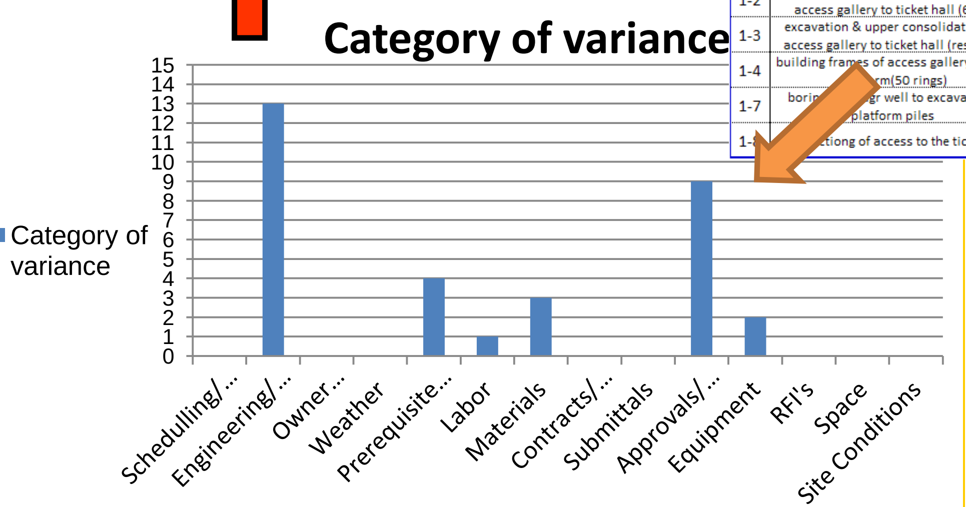
Weekly Report



Weekly Work Report

Client	Metro	Category of variance	TotalActivities
Contractor	AHAB Co.	1 Schedulling/Coordination; 8 Contracts/ CO's	Activities Completed
		2 Engineering/ Design; 9 Submittals	Percent Planned Complete (PPC)
Project	E6 station	3 Owner decision; 10 Approvals/ Permits	
Planner Name		4 Weather; 11 Equipment	Des.
		5 Prerequisite work; 12 RFI's	
		6 Labor; 13 Space	
		7 Materials; 14 Site Conditions	

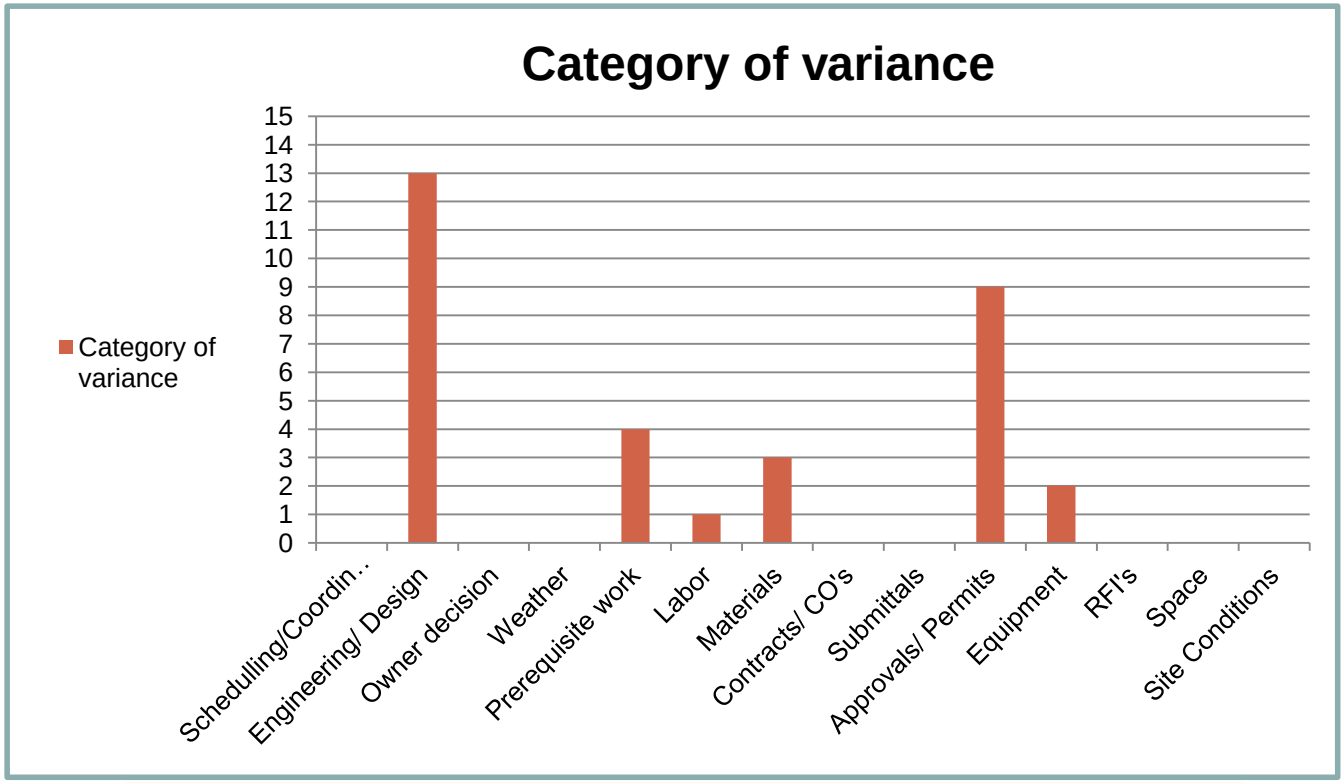
No.	assignment Description	Responsible Party	Comments	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Done? Yes	Done? No	Description	Reasons for Variance
1-1	Boring well	Executive										✓		Unapproved Drawings
1-2	excavation & beneath consolidation of access gallery to ticket hall (60m)	Executive									✓			
1-3	excavation & upper consolidation of access gallery to ticket hall (rest 4 m)	Executive									✓			high water table
1-4	building frames of access gallery to the ...rm(50 rings)	Executive									✓			
1-7	borin... gr well to excavation platform piles	Executive										✓		high water table
1-...	...tiong of access to the ticket hall	Executive										✓		...pproved Drawings

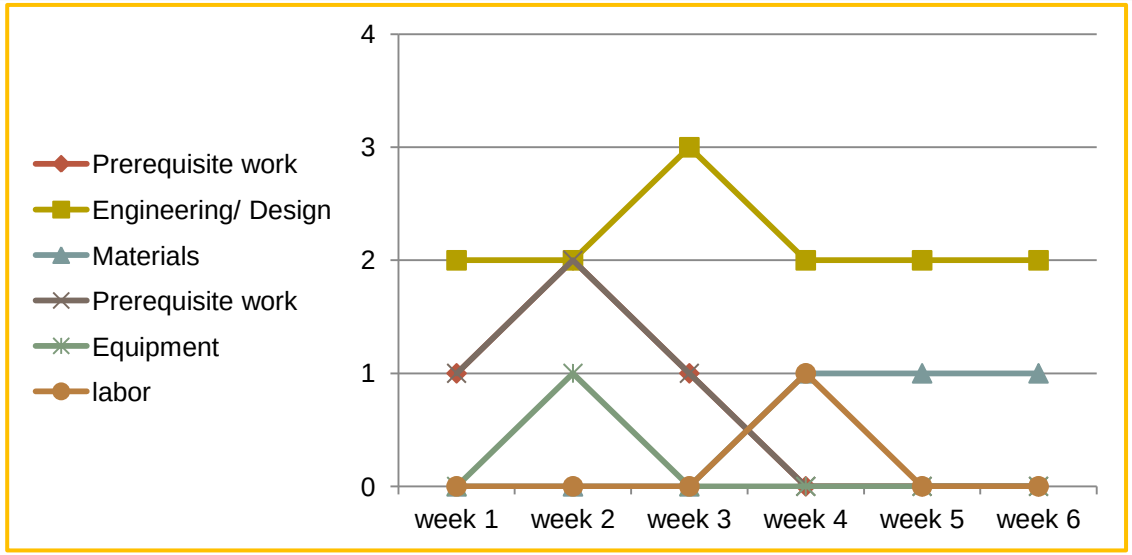


High Water table

How Was This Achieved…?

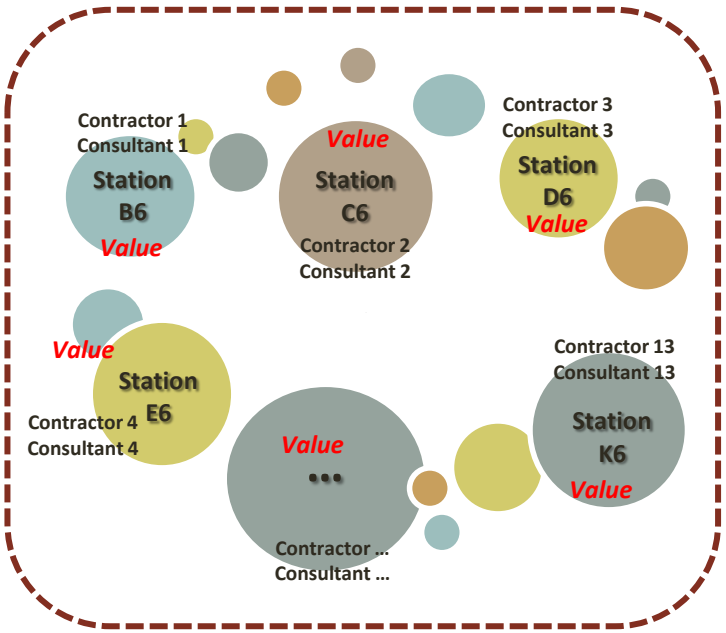
High underground water level caused serious problems in construction of station.
And, one of the most important causes of variances is inapplicable design.

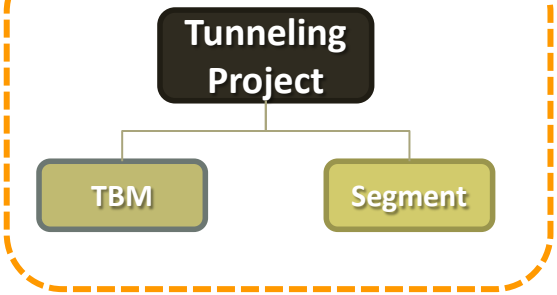


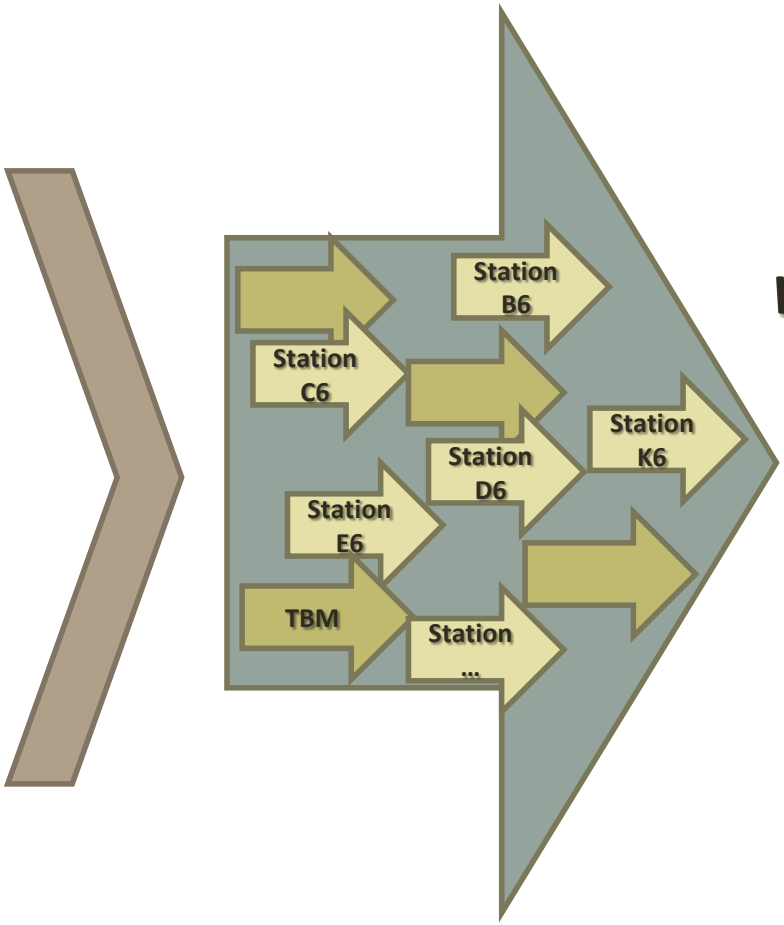


Tunnel and Station Construction

What Has Been Achieved...?







Whole Project

VALUE

Optimization

Contradiction of the values in project pieces

Resolved by INTEGRATION

NOW, WE HAVE

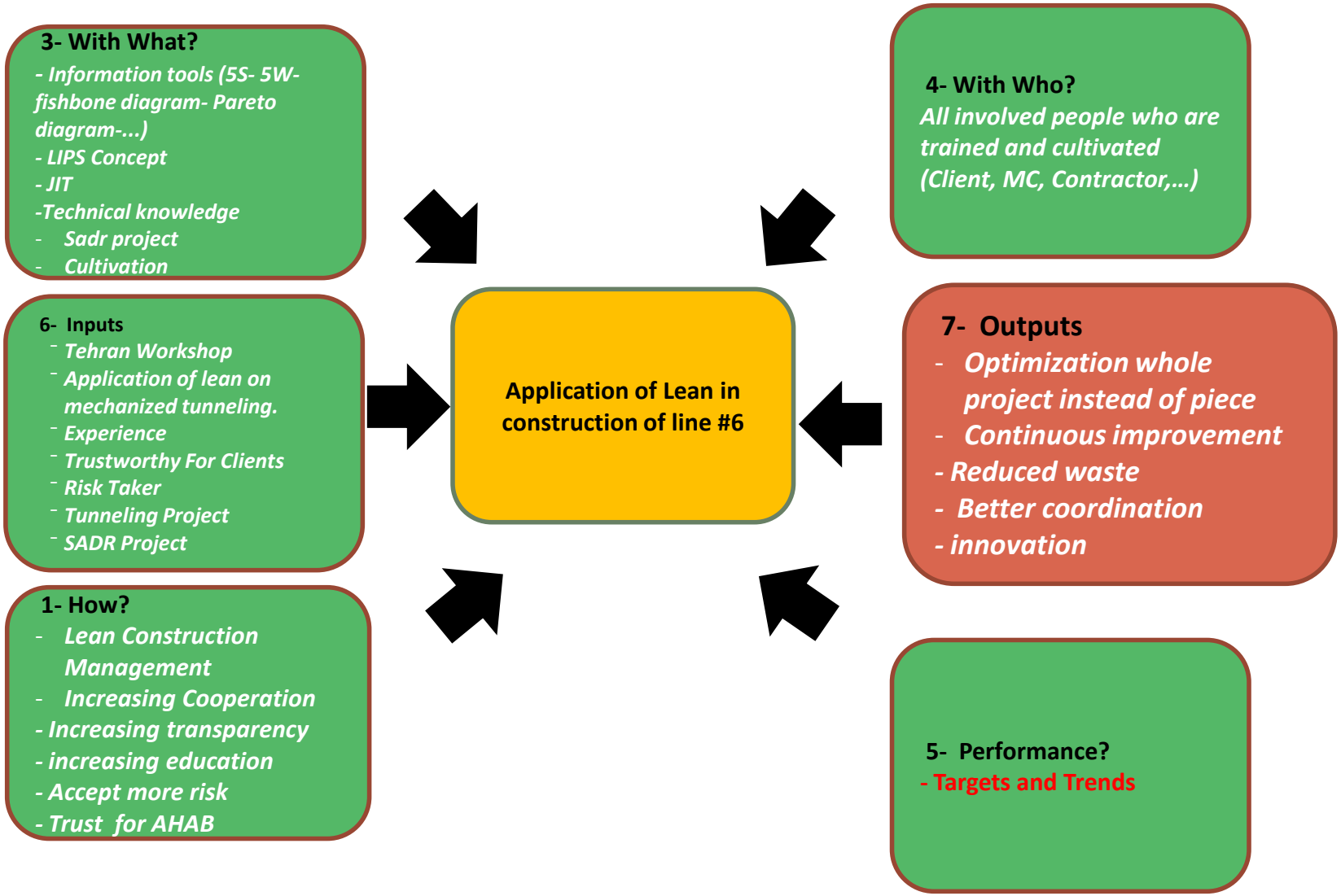
TRANSPARENCY

MUCH MORE THAN

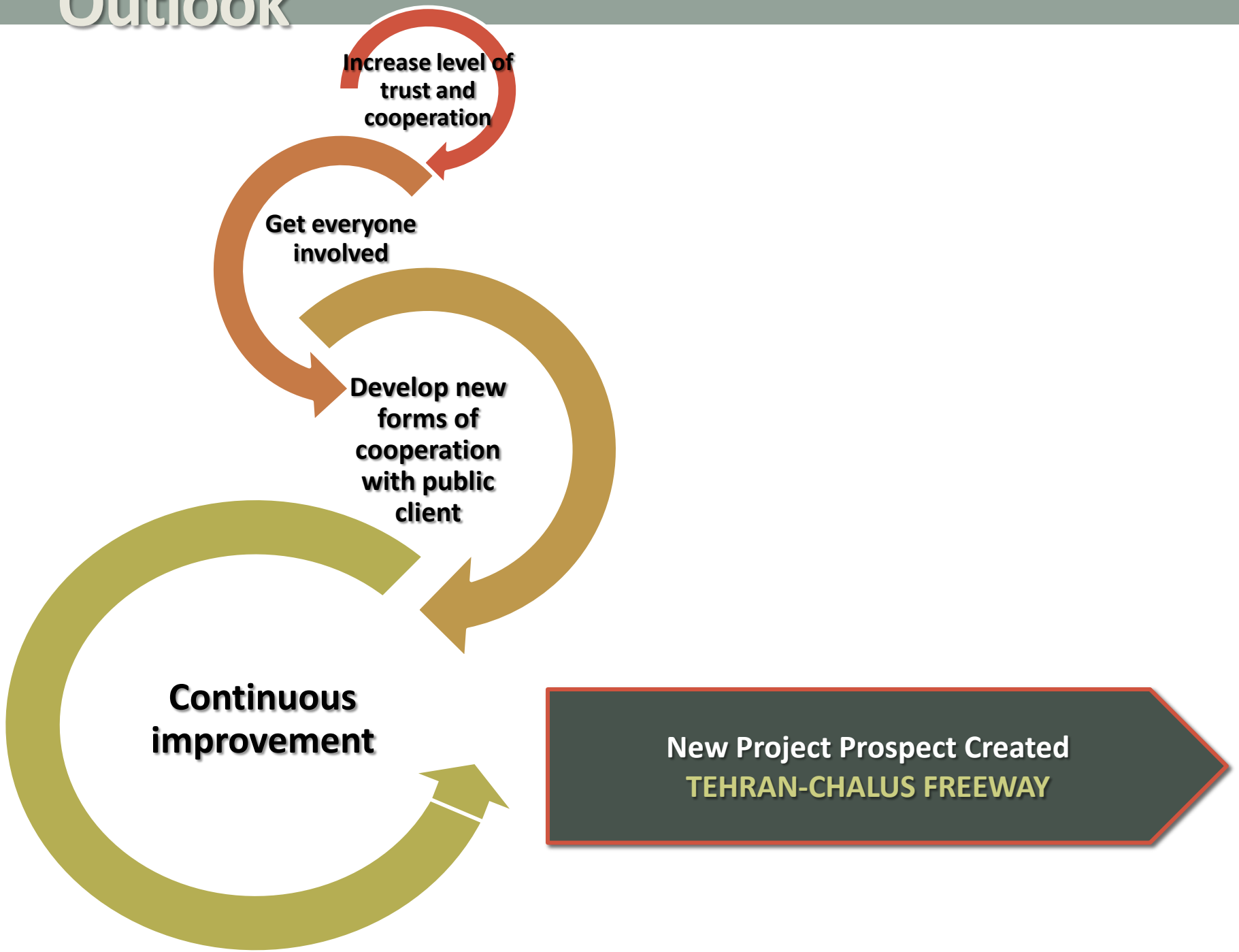
BEFORE

(We Had It But Not This Much)

SUMMARY


3- With What?
- Information tools (5S- 5W- fishbone diagram- Pareto diagram-...)
- LIPS Concept
- JIT
-Technical knowledge
- Sadr project
- Cultivation
4- With Who?
All involved people who are trained and cultivated (Client, MC, Contractor,...)
6- Inputs
- Tehran Workshop
- Application of lean on mechanized tunneling.
- Experience
- Trustworthy For Clients
- Risk Taker
- Tunneling Project
- SADR Project
Application of Lean in construction of line #6
7- Outputs
- Optimization whole project instead of piece
- Continuous improvement
- Reduced waste
- Better coordination
- innovation
1- How?
- Lean Construction Management
- Increasing Cooperation
- Increasing transparency
- increasing education
- Accept more risk
- Trust for AHAB
5- Performance?
- Targets and Trends

Outlook


Increase level of trust and cooperation
Get everyone involved
Develop new forms of cooperation with public client
Continuous improvement
New Project Prospect Created
TEHRAN-CHALUS FREEWAY