Thought-provoking

Who had built it? What from? How? Why?

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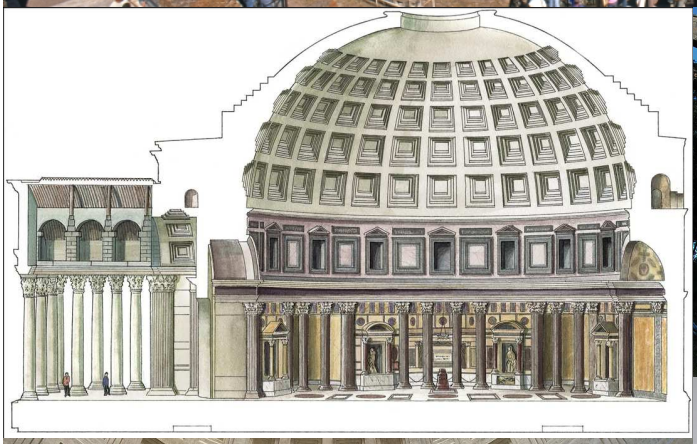
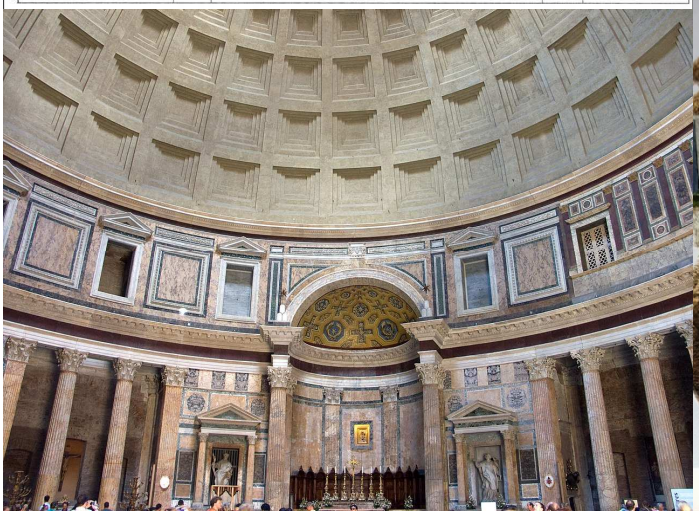
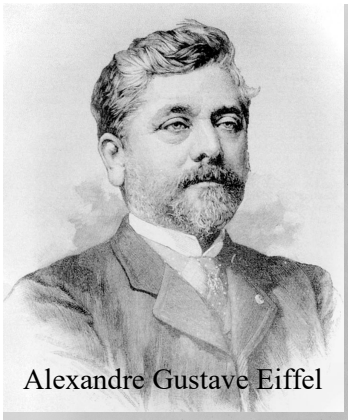
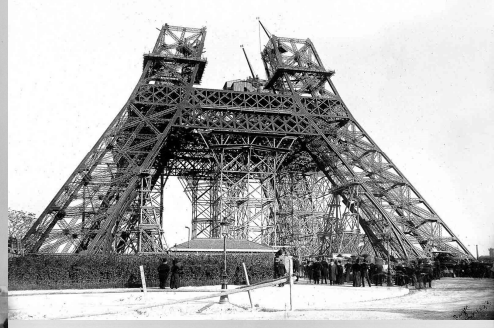
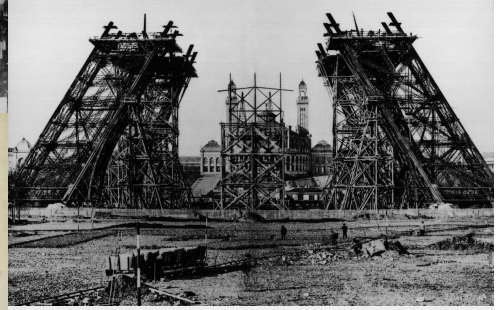




Thought-provoking
Who had built it? What from? How? Why?

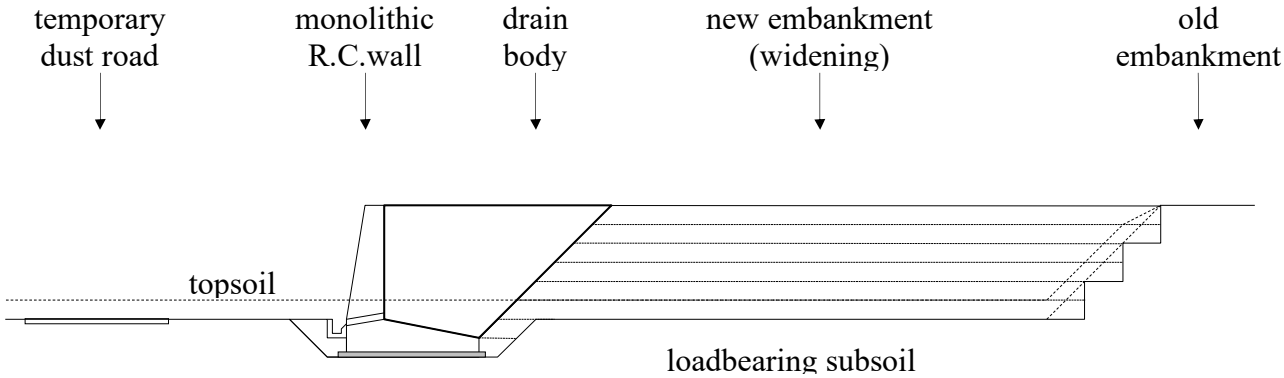

Alexandre Gustave Eiffel





BASICS OF SCHEDULING

(planning – contracting – executing)



ID	Activity Name	Time	Resource	Work day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Topsoil removal	2 d	1 bulldr																						
2	Step embankment	4 d	10 labr																						
3	Levelling	1 d	1 grader																						
4	Ditch excavation	2 d	1 excr																						
5	Blinding	3 d	5 labr																						
6	Formwork	3 d	2 carpr																						
7	Reinforcement	5 d	4 rodm																						

$$T = f(\S,\ \$,\ \lambda,\ \mu,\ \pi,\ \ldots)$$

$\S$: law & regulation
$\$$: financing
λ : location
μ : technology
π : time period

PRE-TENDER REPORT

(Site Survey)

Systematic audit of all facts and factors at the site that may have great influence on accomplishment

Nature: Geology and Topography
Flora and Fauna (Environm.Prot.)
Watershed (Permanent, Seasonal)
Weather Conditions (Extremities)
:

Human: Nearby Municipalities, Agriculture
Local Laws and Regulations
Local Authorities (Permits, …)
Local Customs (Holidays, …)
Education (Communication, …)
Location, Accessing the Site
:

Resource: Local Manufacturers and Suppliers
Local Labour Capacities
Local Mines, Pits, Deposits
Concurrents Local Projects
Transport Capacities
Accomodation Capacities
:

Time-estimates - Scheduling

problem solving by means of all technical sciences

ANALYSING
(breaking down the works, analysing components, …)

SYNTHETIZING
(composing processes, assigning resources, …)

MODELLING
(estimating, planning, proposing, programming, …)

APPLYING
(contracting, introducing, executing, …)

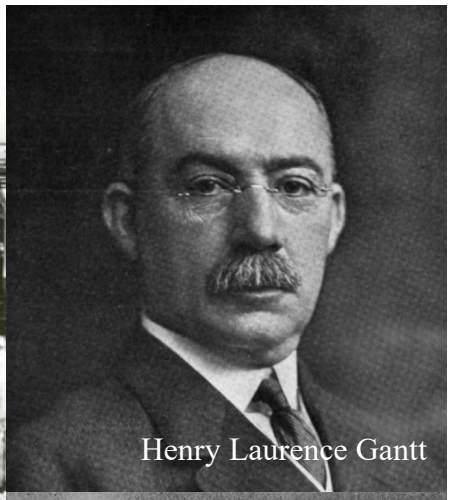
FEEDBACK
(measuring, monitoring, qualifying, …)

CONTROLLING
(regulating, directing, adjusting, …)

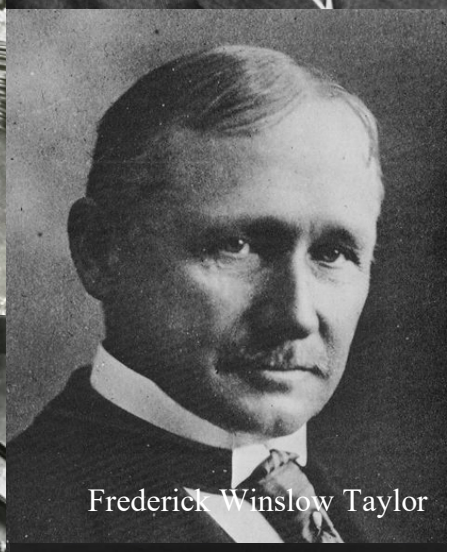
RECORDING (PUBLISHING)
(as-built drawings, building records, archives, …)

EVALUATING
(reviewing, adapting, updating, …)

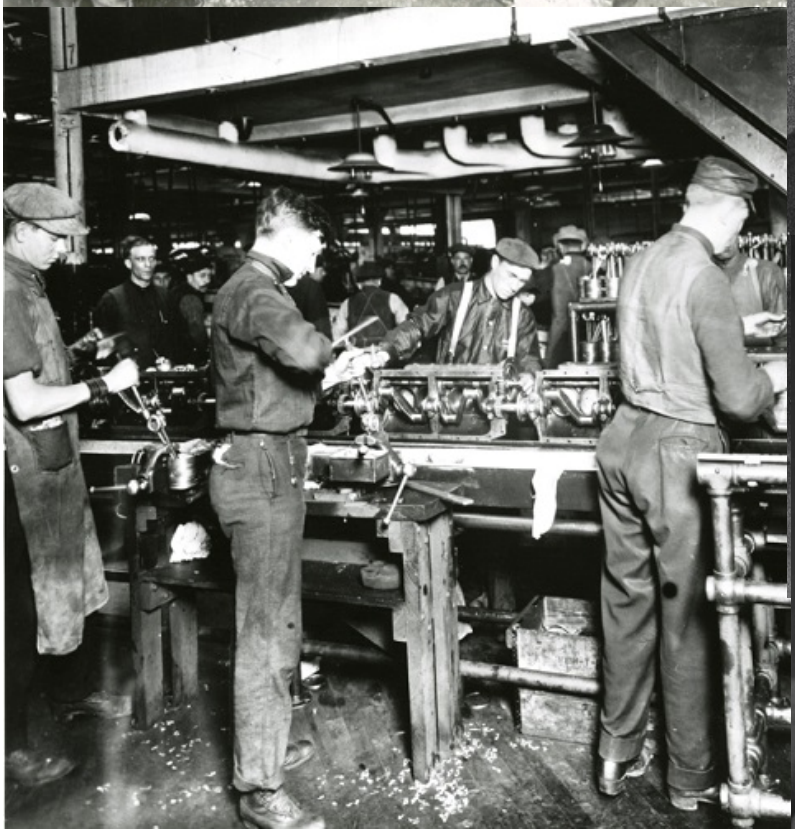
„Scientific Management”
Production Management Models, Operations Research

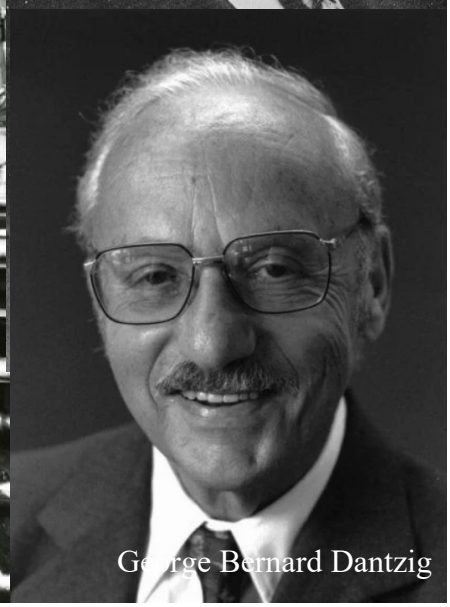


Henry Laurence Gantt



Frederick Winslow Taylor





George Bernard Dantzig

Time Plans

- **Models** to promote finding adequate and co-ordinated endeavours to realize the intended (construction) projects

- **Estimates**, bases to support decision making in relation of would-be contracts of executing (construction) projects

- Legally referable appendices of written contracts stating agreed **Schedules** of deliveries of (construction) projects

- **Baselines** to measure against the time-variances when executing (construction) projects

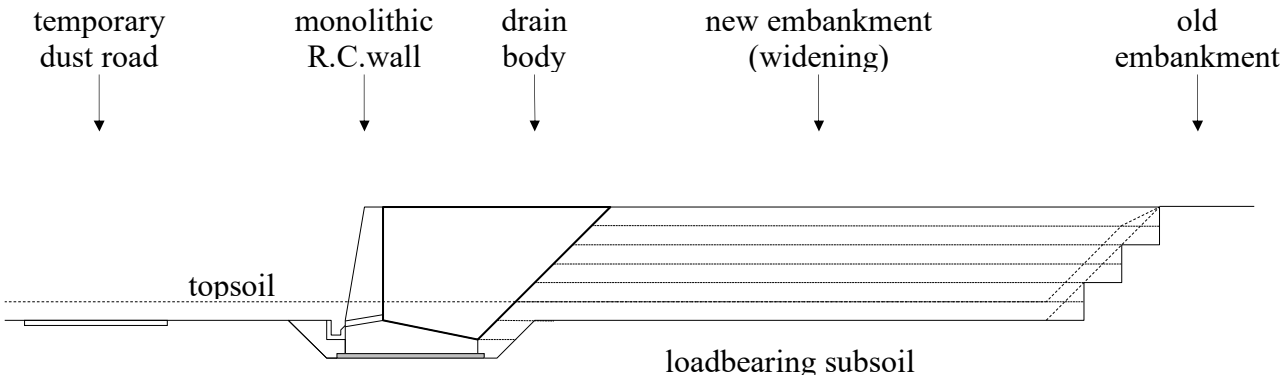
It has no sense to speak about time plans without considering resources needed to execute the given (construction) projects

BREAKING DOWN THE WORKS (WBS)

- Decision Actuality / Circumstances
- Decision Level / Responsibility
- Time-span / Term
- Function / Delivery
- Structure / Unit
- Technology / Contracting
- Measurability / Controlling
- Division / Management
- :
- Experience / Database

typical/frequent, quantified, qualified, …, accurately identified items with reference codes, structured

WORK BREAK-DOWN STRUCTURE (WBS)



01 Preparing the site
- 01-01 Cutting bushes and trees
- 01-03 Pre-liminary earthworks
  - 01-03-02 Demolishing and depositing top soil
  - 01-03-06 Stepping old embankment
  - 01-03-09 Levelling the ground
- 01-08 Constructing temporary access road
- 01-18 Constructing temporary supply lines

03 Mass earthworks
- 03-03 Excavating foundation ditch
- 03-05 Refilling ditch by wall
- 03-06 Constructing embankment
- 03-07 Constructing filter body
- 03-09 Levelling the ground

07 Concrete works
- 07-01 Blinding
- 07-04 Concreting foundation slab
- 07-06 Concreting wall
- 07-32 Constructing dewatering channels

11 Wood works
- 11-04 Formworking foundation slab
  - 11-04-02 Preparing formwork sheets
  - 11-04-05 Assembling and supporting
  - 11-04-11 Removing formwork
  - 11-04-12 Repairing formwork sheets
- 11-06 Formworking wall
  - 11-06-02 Preparing formwork sheets
  - 11-06-04 Assembling and supporting internal formwork
  - 11-06-06 Assembling external formwork
  - 11-06-09 Scaffolding and supporting external formwork
  - 11-06-11 Removing formwork
  - 11-06-12 Repairing formwork sheets

17 Steel works
- 17-02 Pre-fabricating reinforcement
  - 17-02-01 Cutting and bending
  - 17-02-03 Transporting
  - 17-02-05 Pre-assembling
- 17-04 Assembling foundation slab reinforcement
- 17-06 Assembling wall reinforcement

By Complexity: Production process (head of dep.)
(responsibility) Building process (site engineer)
Technology process (engineer)
Activity (foremen, groupleaders)
Motion (engineer + foremen)

RESOURCES

anything and everything
that is needed … and … restricted in access

M a t e r i a l

- Construction material (earth, wood, metal, concrete, …)
- Auxiliary structures (formwork, timber, scaffold, …)
- Fuel (gas, petrol, electricity, …)

H u m a n

- Management (leadership, know-how, authority, …)
- Skilled workers (mason, steel-fitter, carpenter, plumber, …)
- Labourers (unskilled, universal, trained workers, …)

E q u i p m e n t

- Heavy equipment (excavator, bulldozer, crane, truck, …)
- Auxiliary machinery (mixer, floater, finisher, pump, …)
- Power tools (cutter, drill, welding set, pin vibrator, …)

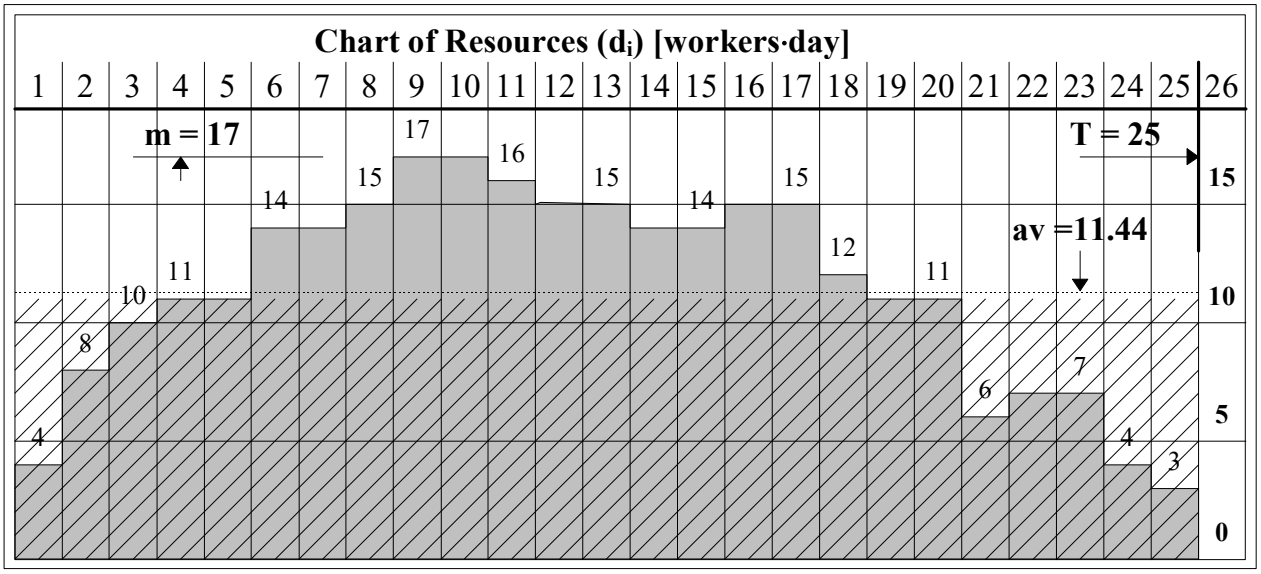
T i m e

A r e a

M o n e y

RESOURCE MANAGEMENT

Capacity-typed (not storable) resources



$$W = \sum_{i=1}^{T} d_i = \sum_{i=1}^{25} d_i = 286 \qquad av = \frac{W}{T} = \frac{286}{25} = 11.44 \qquad k = \frac{m}{av} = \frac{17}{11.44} \approx 1.486$$

W = total work performed [workers·day]
T = total execution time [day]
d_i = daily work performed [workers·day]
i = day index

av = average of workers employed a day [workers]
m = maximum of workers employed a day [workers]
k = resource variency indicatrix

e.g.:

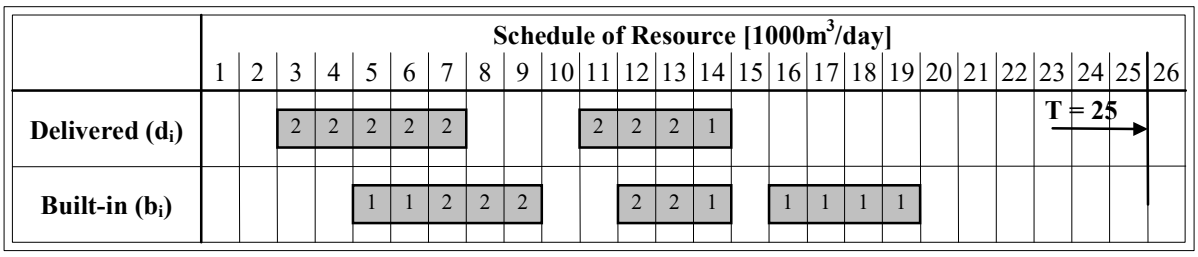
- Labour
- Equipment
- Electricity

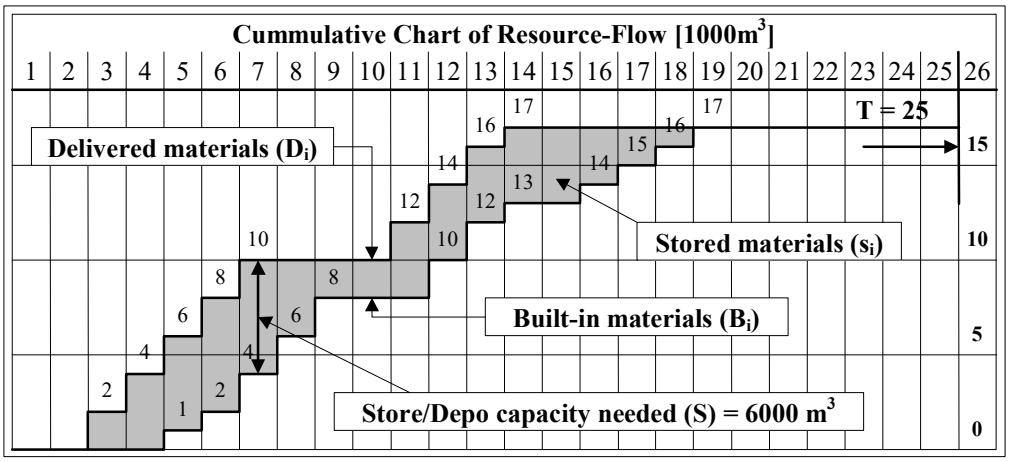
Loss in utilization can not be recovered

(Efficiency has great importance)

RESOURCE MANAGEMENT

Stock-typed (storable) resources





$$D_i = \sum_{j=1}^{i} d_j \qquad B_i = \sum_{j=1}^{i} b_j \qquad s_i = D_i - B_i \qquad S = \max_i \{ s_i \} \qquad i = 1,2, ...,T$$

D_i = cummulated amount of resource delivered by the day „i" [m^3] **i, j = day indices**

B_i = cummulated amount of resource built-in by the day „i" [m^3]

s_i = amount of resource to be stored on the day „i" [m^3] **S = store/depo capacity needed**

d_i = amount of resource delivered on the day „i" [m^3] **b_i = amount of resource built-in on the day „i" [m^3]**

e.g.:

- Material
- Structure
- Fuel

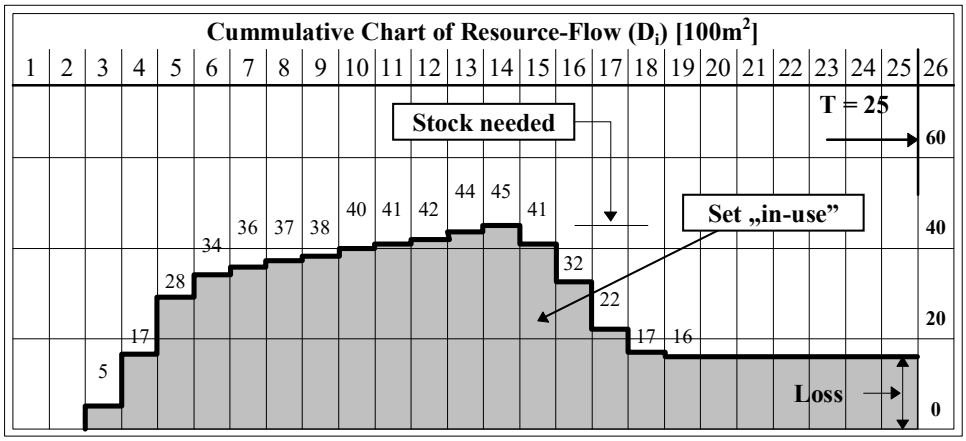
Transport and storage has great importance

(Top-time delivery can save money)

RESOURCE MANAGEMENT

Stock-typed (reusable) resources

Activity		Schedule of Resource Use (a_{ki}) [100m^2/day]																								
ID	Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	Internal formwork			5	5	5	5	5	5	5	5	5	5	5	5									T = 25			
2	External formwork				6	6	6	6	6	6	6	6	6	6	6	6											
3	Partitioning formwork				1			1			1			1			1										
4	Remove internal formw.						-5	-4	-5	-5	-4	-5	-5	-4	-5	-5	-4	-5									
5	Remove external formw.							-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5								
6	Remove partit. formw.							-1			-1			-1			-1			-1							



$$d_i = \sum_{k=1}^{n} a_{ki} \qquad D_i = \sum_{j=1}^{i} d_j \qquad S = \max_{i}\{D_i\} \qquad i = 1,2,\ldots,T$$

a_{ki} = set of resource assigned to (used at or produced by) activity „k" on day „i" [m^2] **i, j = day indices**

d_i = increment of set „in-use" on the day „i" [m^2] **k = activity index**

D_i = set „in-use" on the day „i" [m^2] **n = number of activities**

S = necessiated set (stock) of resource [m^2] **T = total execution time [day]**

e.g.:

- Top-Soil / Plantage
- Earth / Rubbish
- Auxiliary / Temporary Structures

Minimal loss (savings) has great importance

(Environment protection has preference)

S T A N D A R D S

Ways of establishing Standards

- Statistical analysis (bulk processing)
- Technical analysis (estimates)
- Hystorical analogies (comparision)
- Measuring performance (timing)

Basic types of Standards

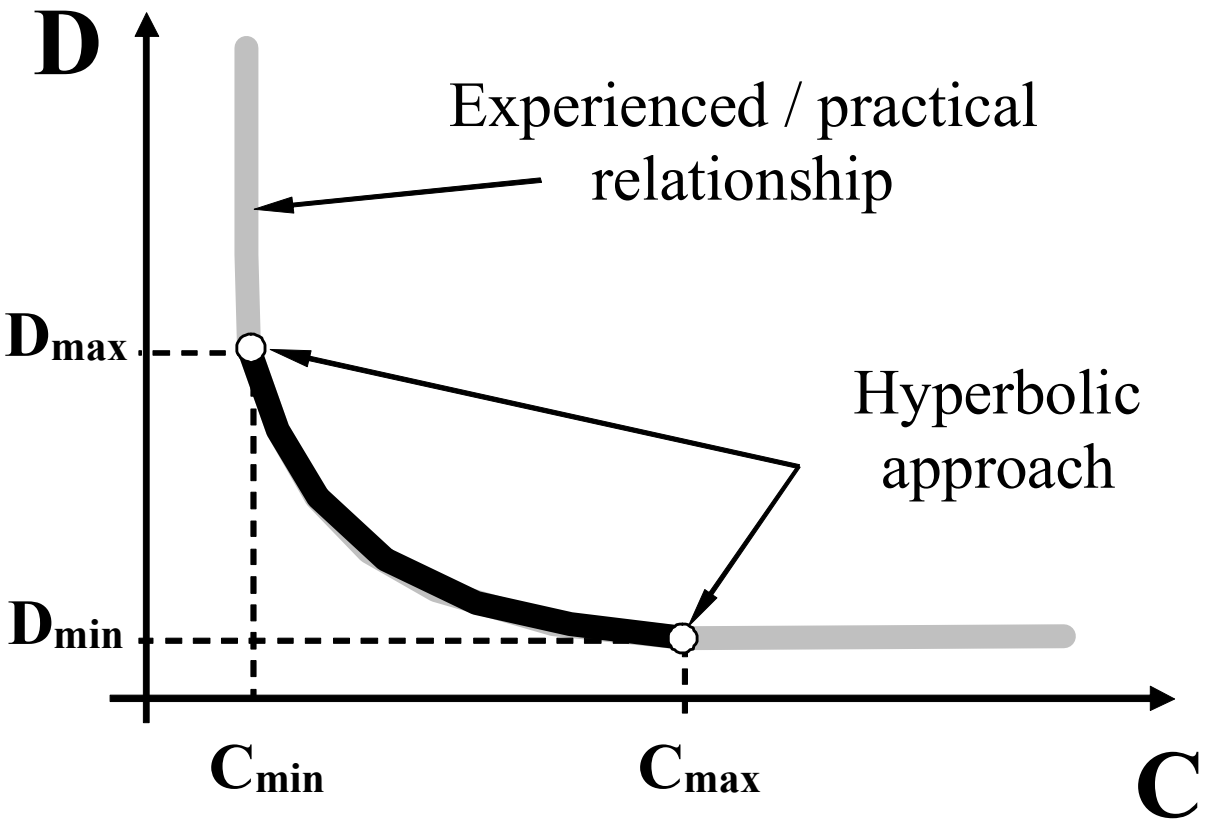
- Performance standard [time/unit] (h/m^3, h/to,..)
- Standard output [unit/time] (m^3/h, to/h, pcs/h,..)
- Material standard [volume/unit] (m^3/pc,..)
- Storage standard [volume/area] (pcs/m^2,..)
- Cost standard [cash/unit] ($/pcs, $/to, $/$m^2$,..)

Adjusting Standards

l<1: Location factor (disadvantageous access)
(*position of equipment can not be optimal*)
t<1: Time efficiency factor (too much time loss)
(*much time to spend for technical breaks*)
… : … (…)
r<1: Resource factor (unfavorable material)
(*gluey or hard soil, sensitive structure*)

$$N_{eff} = N_{stnd} \cdot l \cdot t \cdot \ldots \cdot r$$

CAPACITY v. DURATION



V : volume [unit] *(of product)*

n : performance [time/unit] *(for a unit resource – labour)*
N : output [unit/time] *(for a unit resource – equipment)*

W : work [time] *(for a unit resource)*

C : capacity [unit] *(allocated resource units)*
D : duration [time] *(for resource units allocated)*

$$W = \frac{V}{N} \qquad W = V \cdot n \qquad D = \frac{W}{C}$$

SCHEDULE REPRESENTATIONS

α-numeric – Tabular - Timetable

Activity		Schedule			Resource			Remark
ID	Name	Time	Start	Finish	Crew	Machine	Cost	
1	Demolish top soil	2d	02.03.1998	04.03.1998		1 bullr	£250	Depo. on site
2	Stepping old slope	4d	03.03.1998	06.03.1998	10 labr		£900	h = 1m
3	Levelling ground	1d	05.03.1998	05.03.1998		1 gradr	£200	
4	Excavating ditch	2d	06.03.1998	09.03.1998	3 labr	1 excr	£430	15% by labr
5	Blinding	3d	09.03.1998	11.03.1998	5 labr		£530	
6	Formworking	3d	11.03.1998	13.03.1998	2 carpr		£850	
7	Reinforcement	5d	11.03.1998	17.03.1998	4 steelfr		£1410	prefabr. 35%

1Dimensonal – Bar Chart – Gantt Chart

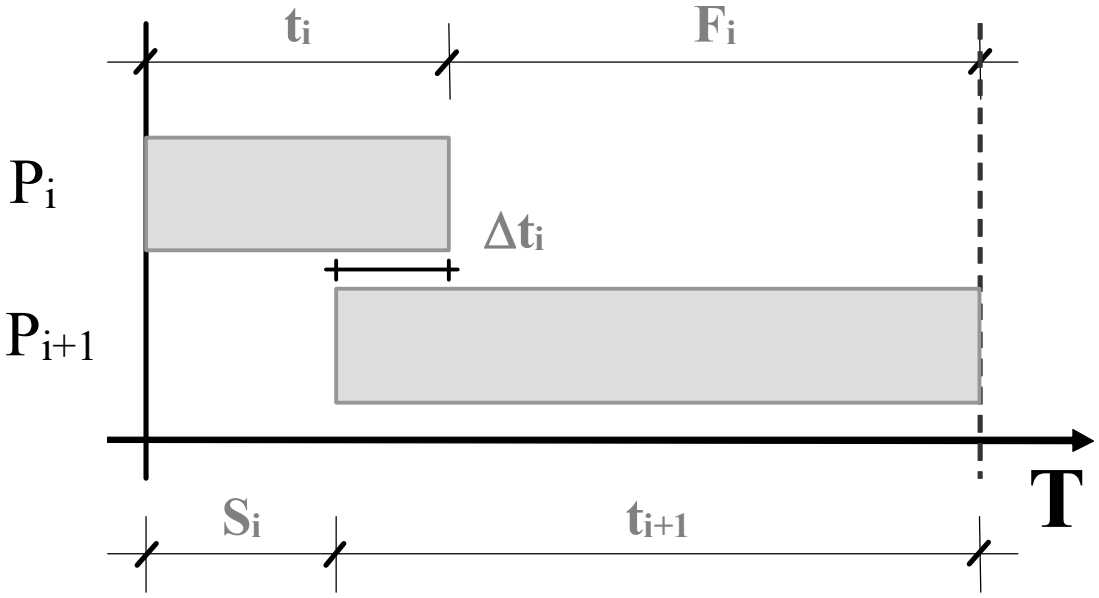
Activity				Working days																				
ID	Name	Time	Crew	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Demolish top soil	2d	1 bullr																						
2	Stepping old slope	4d	10 labr																						
3	Levelling ground	1d	1 gradr																						
4	Excavating ditch	2d	1 excr																						
5	Blinding	3d	5 labr																						
6	Formworking	3d	2 carpr																						
7	Reinforcement	5d	4 steelfr																						

2Dimensional – Linear Schedule - Cyclogram

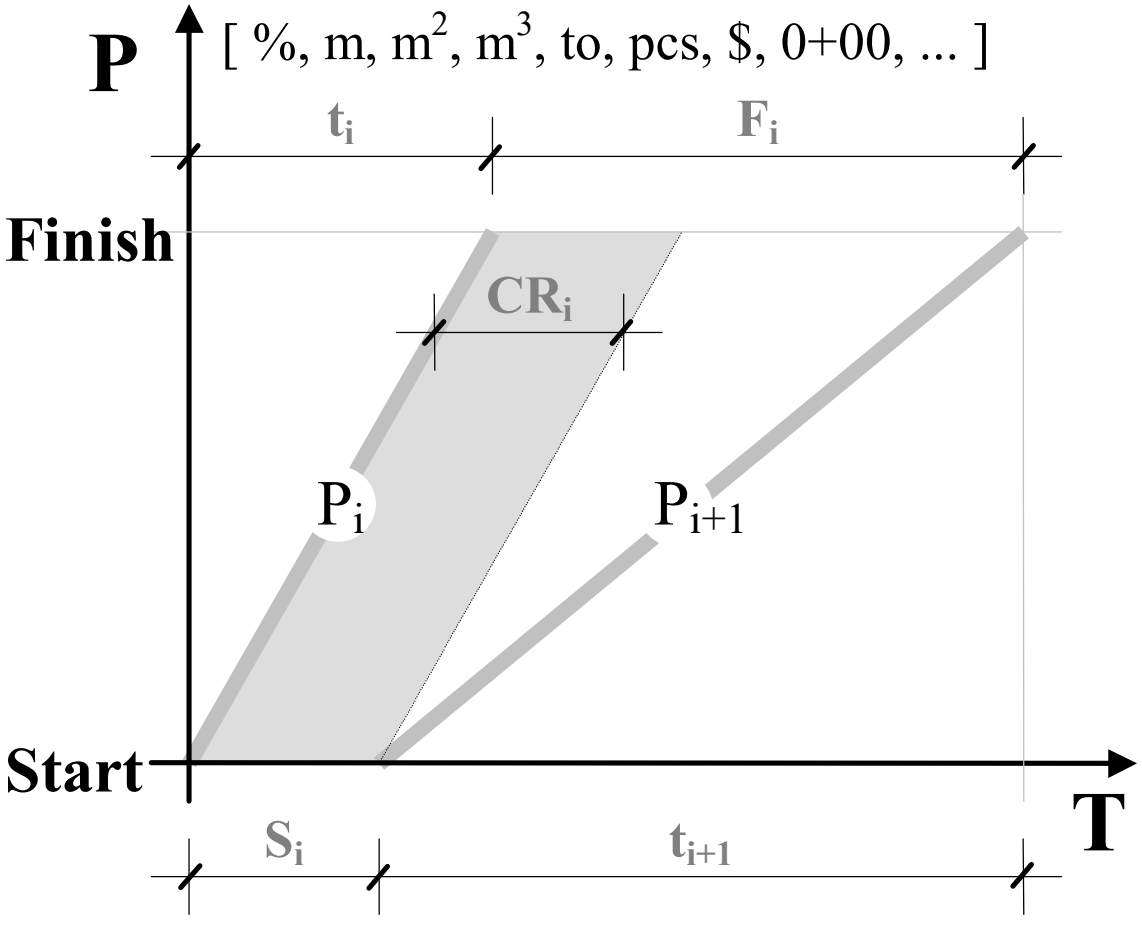
Activity					Working days																				
ID	Name	Time	Ini	Sect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Formworking slab	8d	fs	300																						
2	Reinforcing slab	12d	rs																							
3	Concreting slab	12d	cs	200																						
4	Demolishing formw.	4d	ds																							
5	Formworking wall	8d	fw																							
6	Reinforcing wall	12d	rw	100																						
7	Concreting wall	12d	cw																							
8	Demolishing formw.	4d	dw																							

Graphic Representations

1D – Bar Chart – Gantt Chart



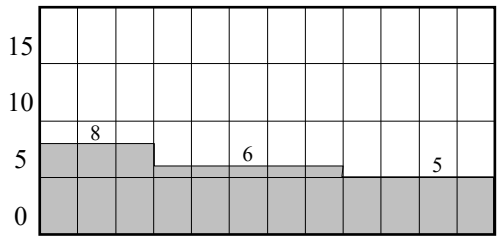
2D – Linear Schedule – Cyclogram



RELATIVE TIMING

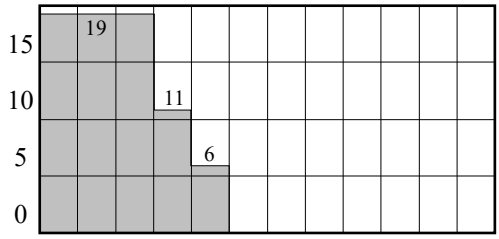
Consecutive Relations

Activity				Schedule											
ID	Name	Time	Crew	1	2	3	4	5	6	7	8	9	10	11	12
1	Excavate ditch	3d	8 labr	8											
2	Formworking	5d	6 carpr				6								
3	Reinforcement	4d	5 steelfr										5		



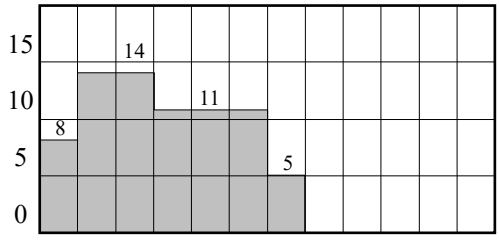
Parallel Relations

Activity				Schedule											
ID	Name	Time	Crew	1	2	3	4	5	6	7	8	9	10	11	12
1	Excavate ditch	3d	8 labr	8											
2	Formworking	5d	6 carpr	6											
3	Reinforcement	4d	5 steelfr	5											

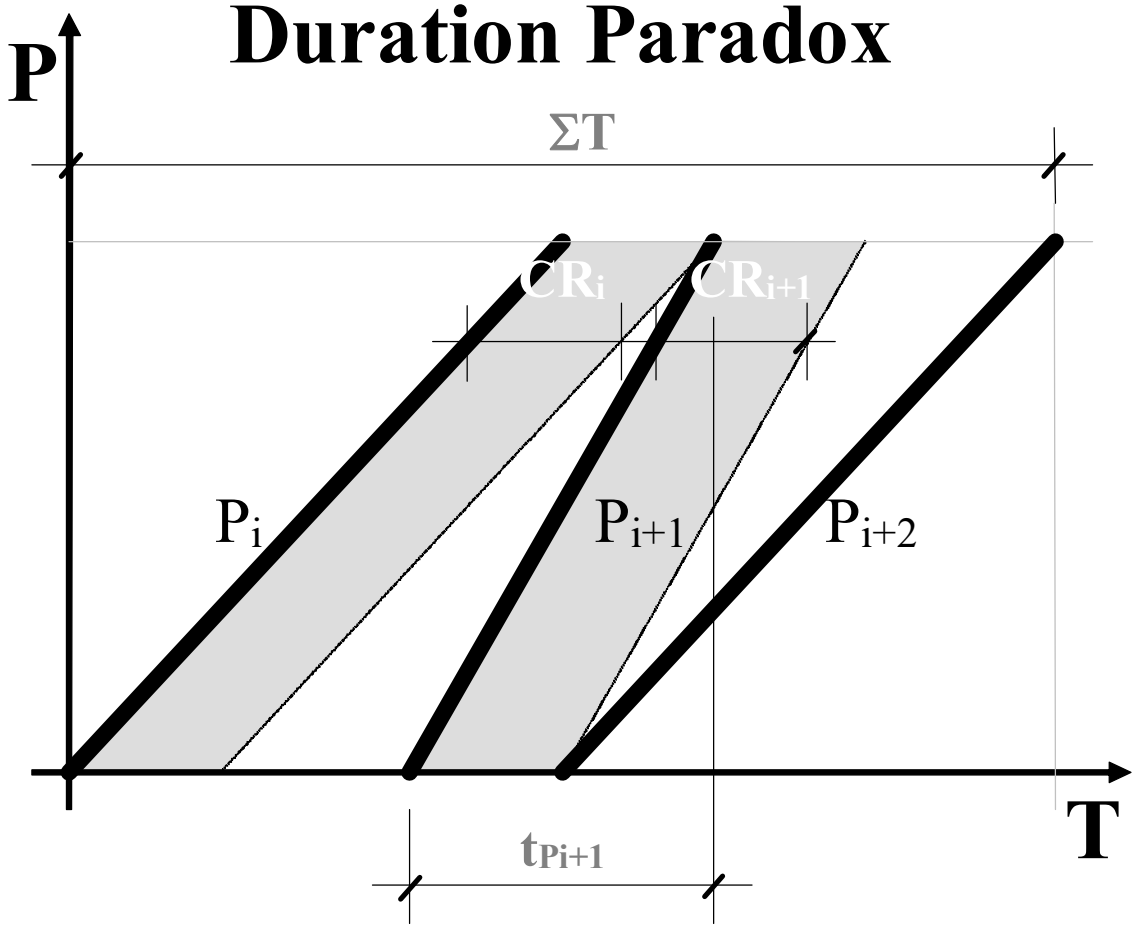


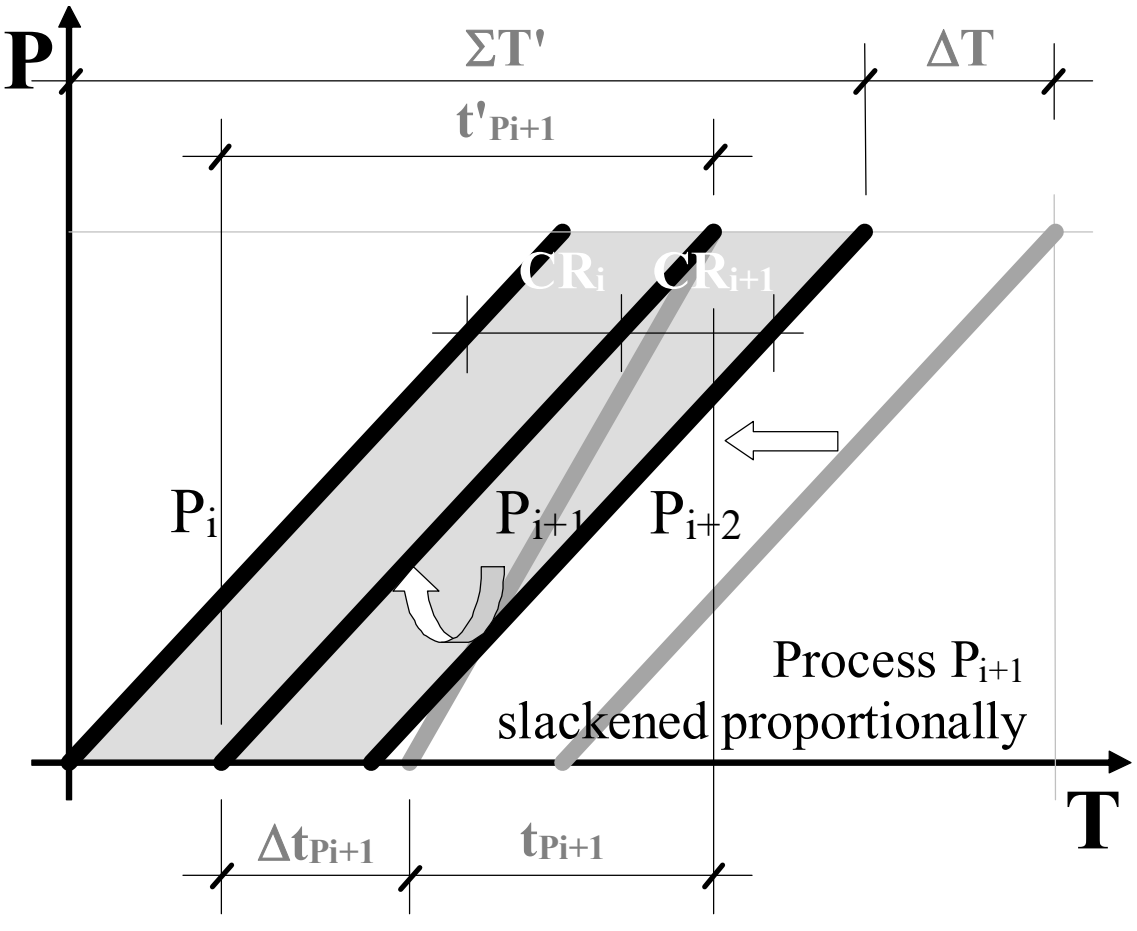
Overlapped Relations

Activity				Schedule											
ID	Name	Time	Crew	1	2	3	4	5	6	7	8	9	10	11	12
1	Excavate ditch	3d	8 labr	8											
2	Formworking	5d	6 carpr		6										
3	Reinforcement	4d	5 steelfr				5								

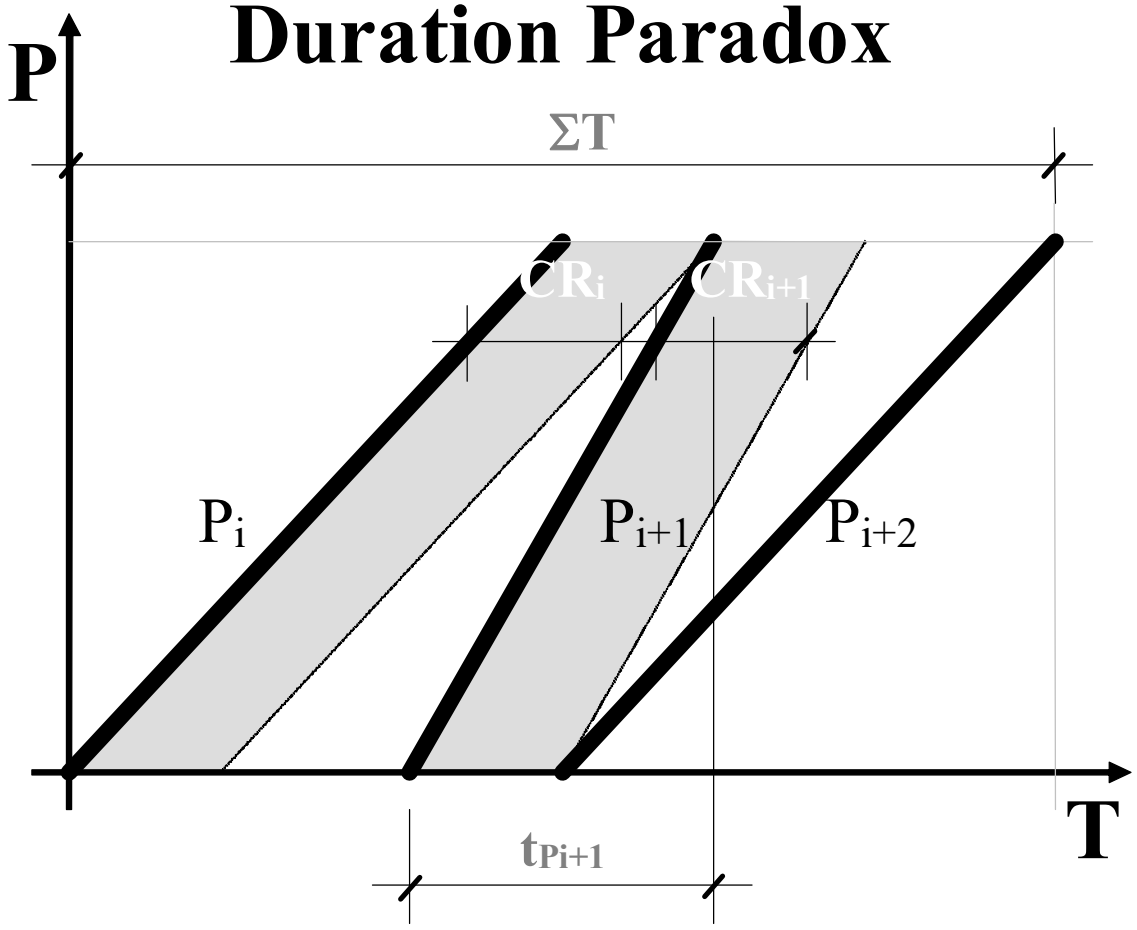


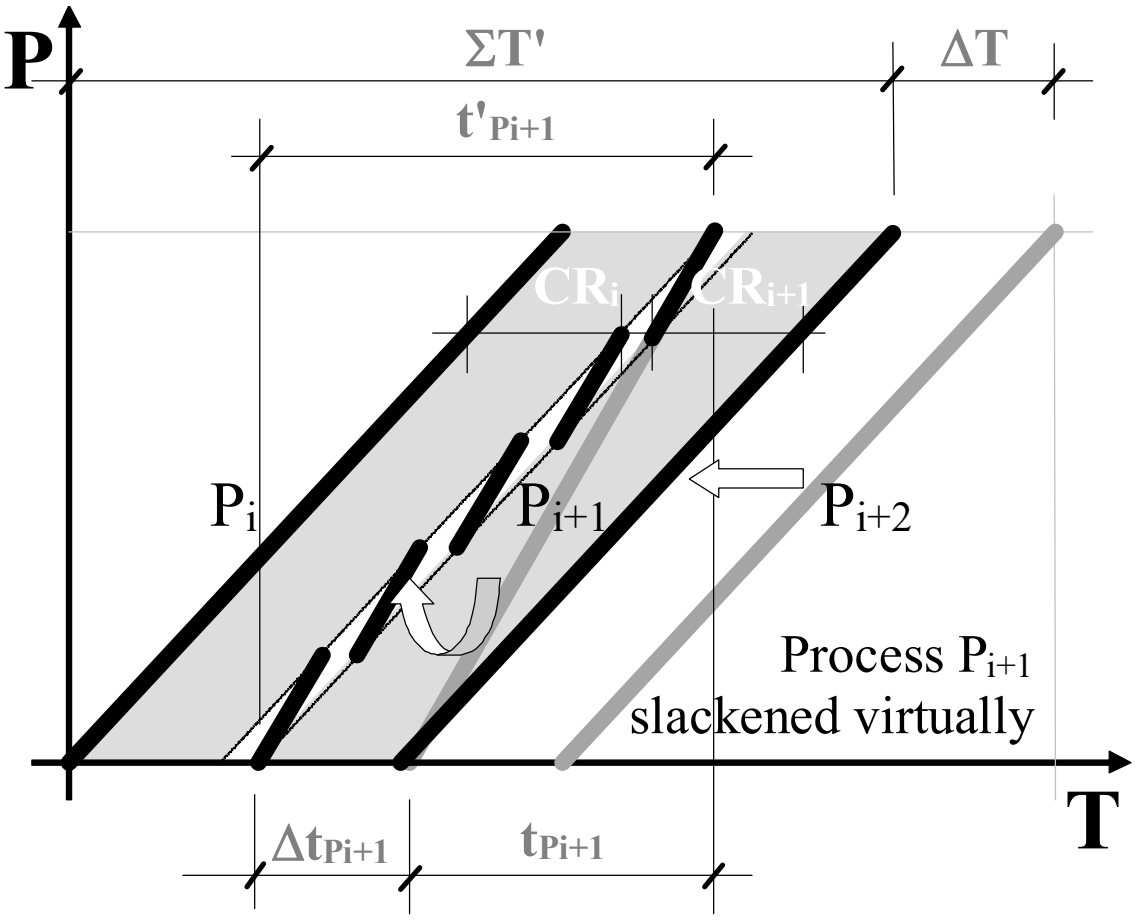
Duration Paradox



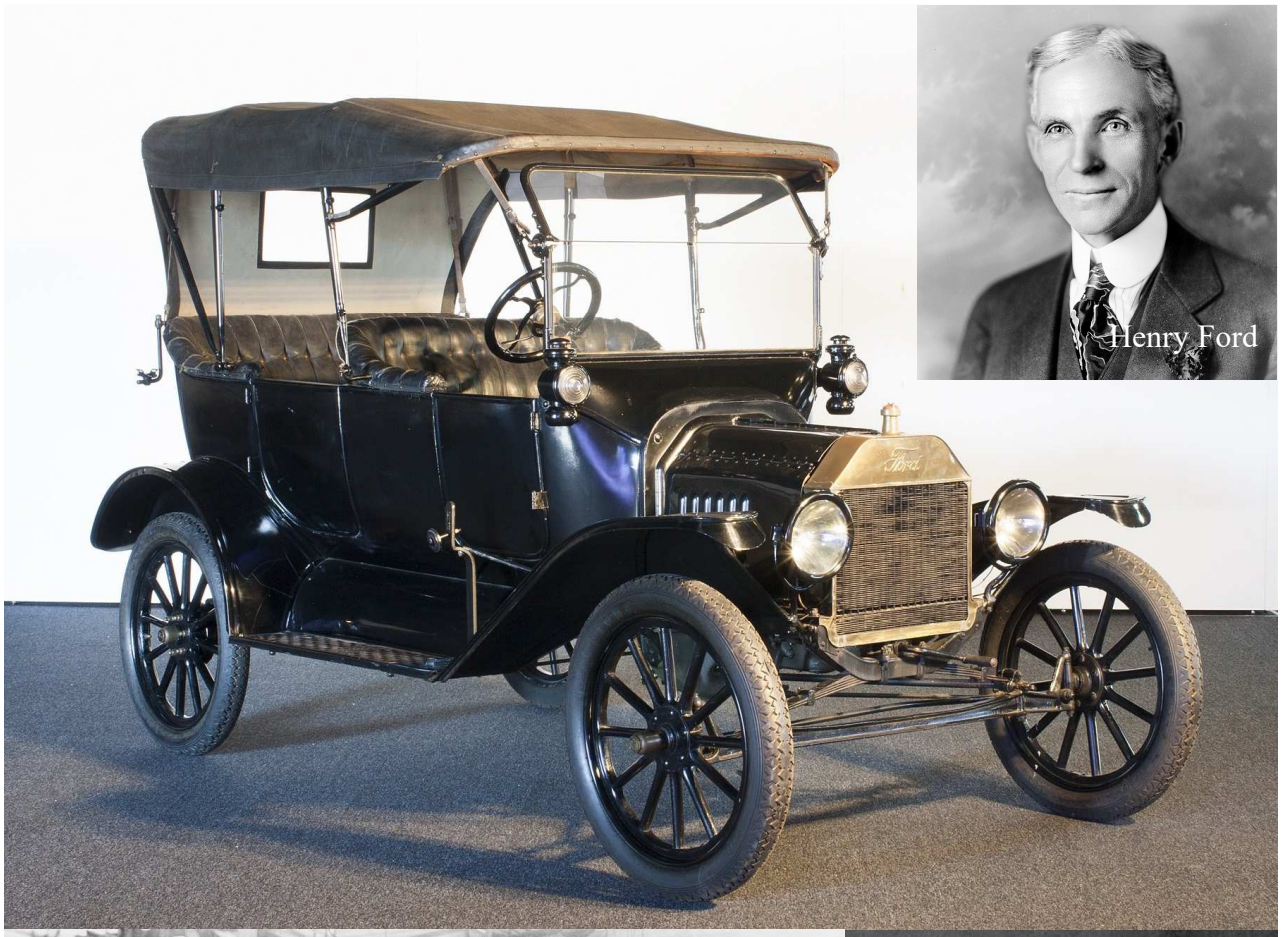


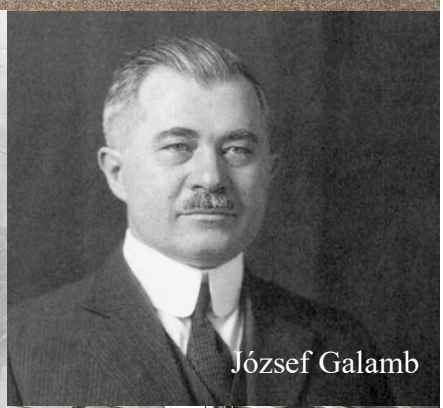
Duration Paradox

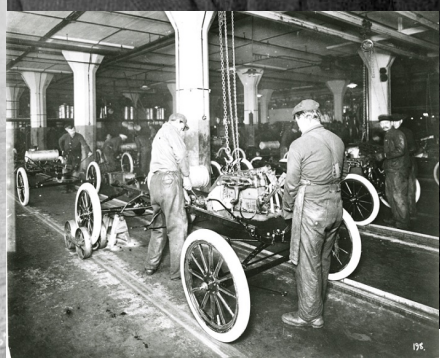




Top Effectivity: The Synchronized Belt (Mass Production)



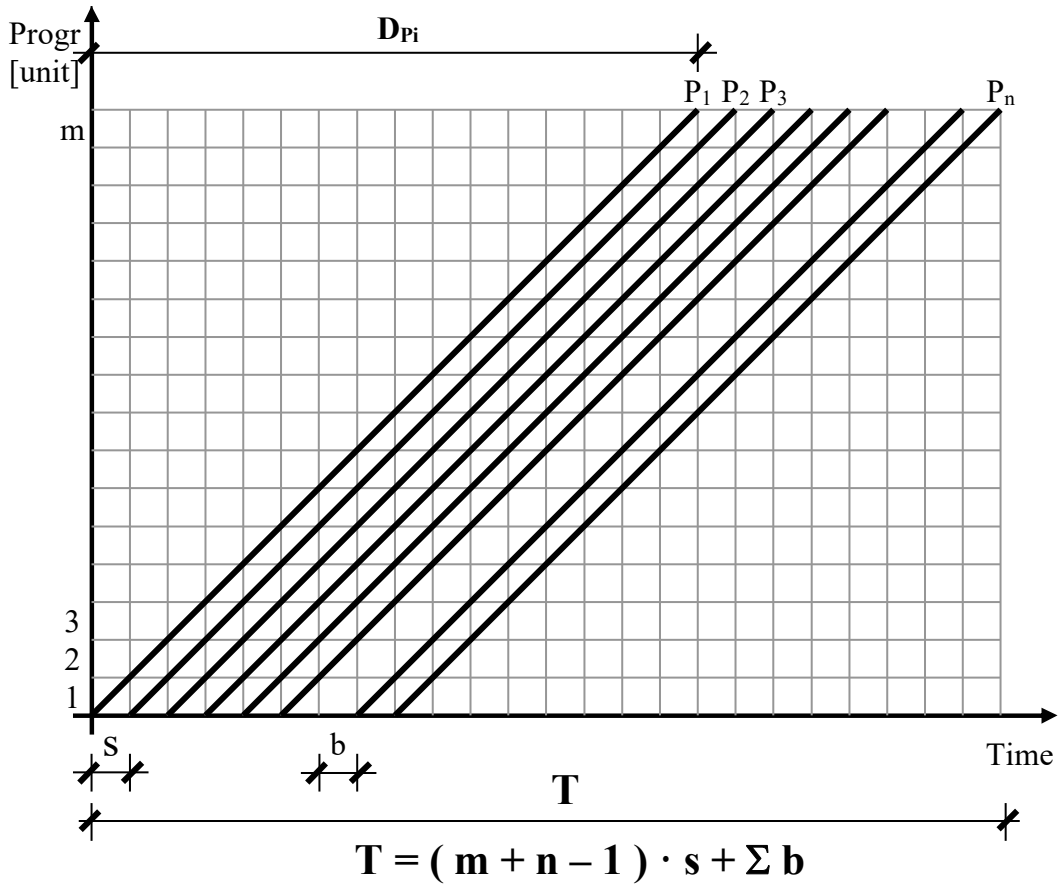




Synchronization

(the ultimate parallels)

U.S.: Ford, Model-T, Mass Production
"Belt-System Manufacturing"



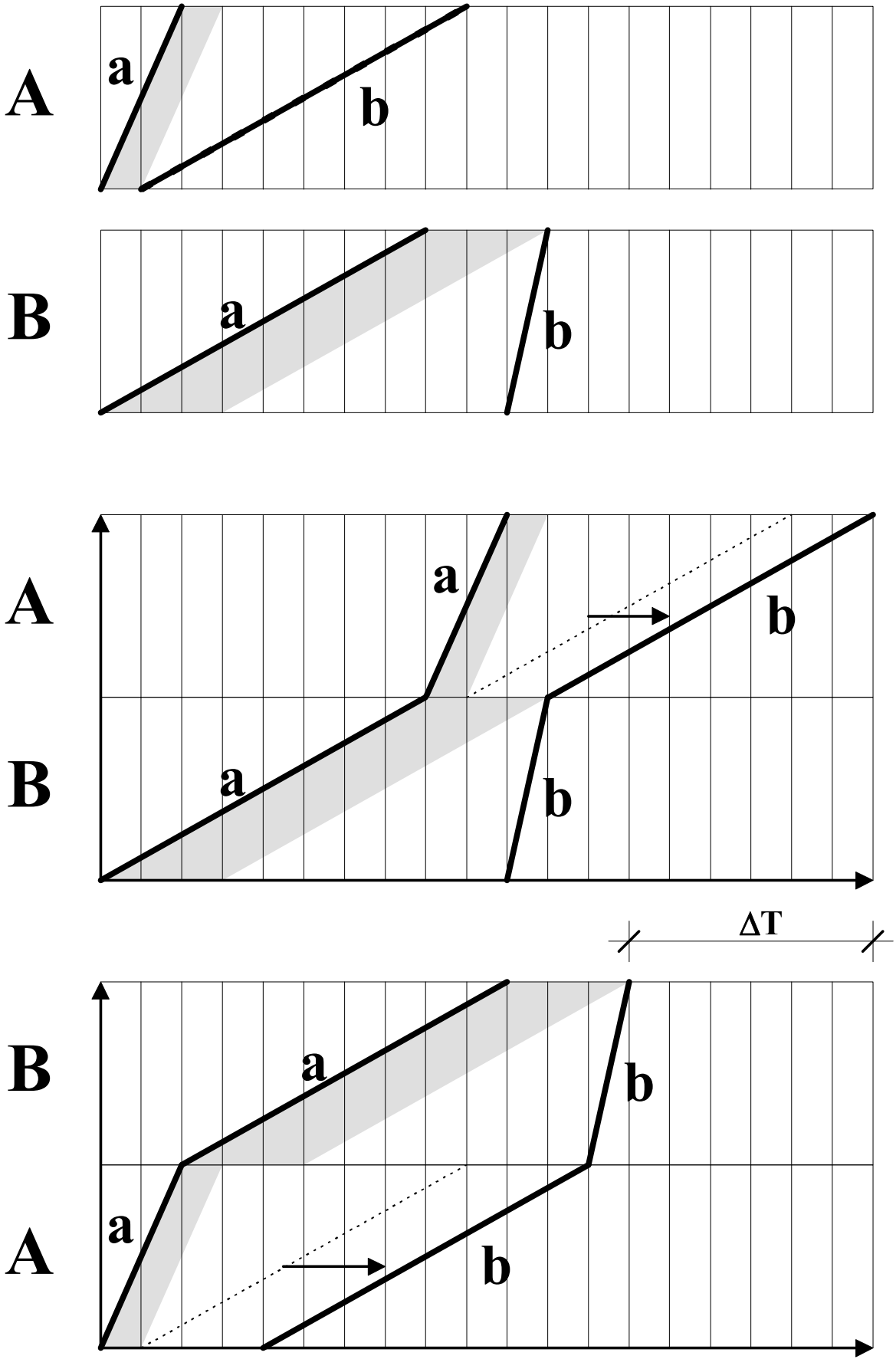
$$T = (m + n - 1) \cdot s + \Sigma b$$

H i s t o r i c a l R e l a t i o n s

Belt-System Construction / Industrialization
After-War (II) Reconstruction
(Lack of Resources / Bulk of Needs)

Typical: Linear structures, Infrastructure
(highway, railway, public utilities, etc.)

SEQUENCING



Dynamic Time-Models Scheduling Networks

Analogies in Graph-techniques and Applied Mathematics

- The Longest Path Problem
- Potentials' Problem (Linear Programming)

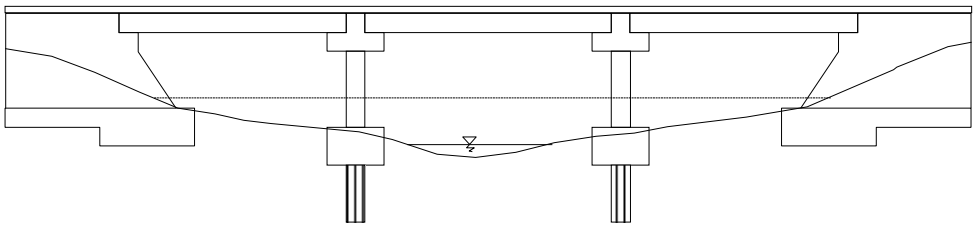
(All components should be involved. We look for the dominant flows of activities and track the potential consequences of eventual changes)

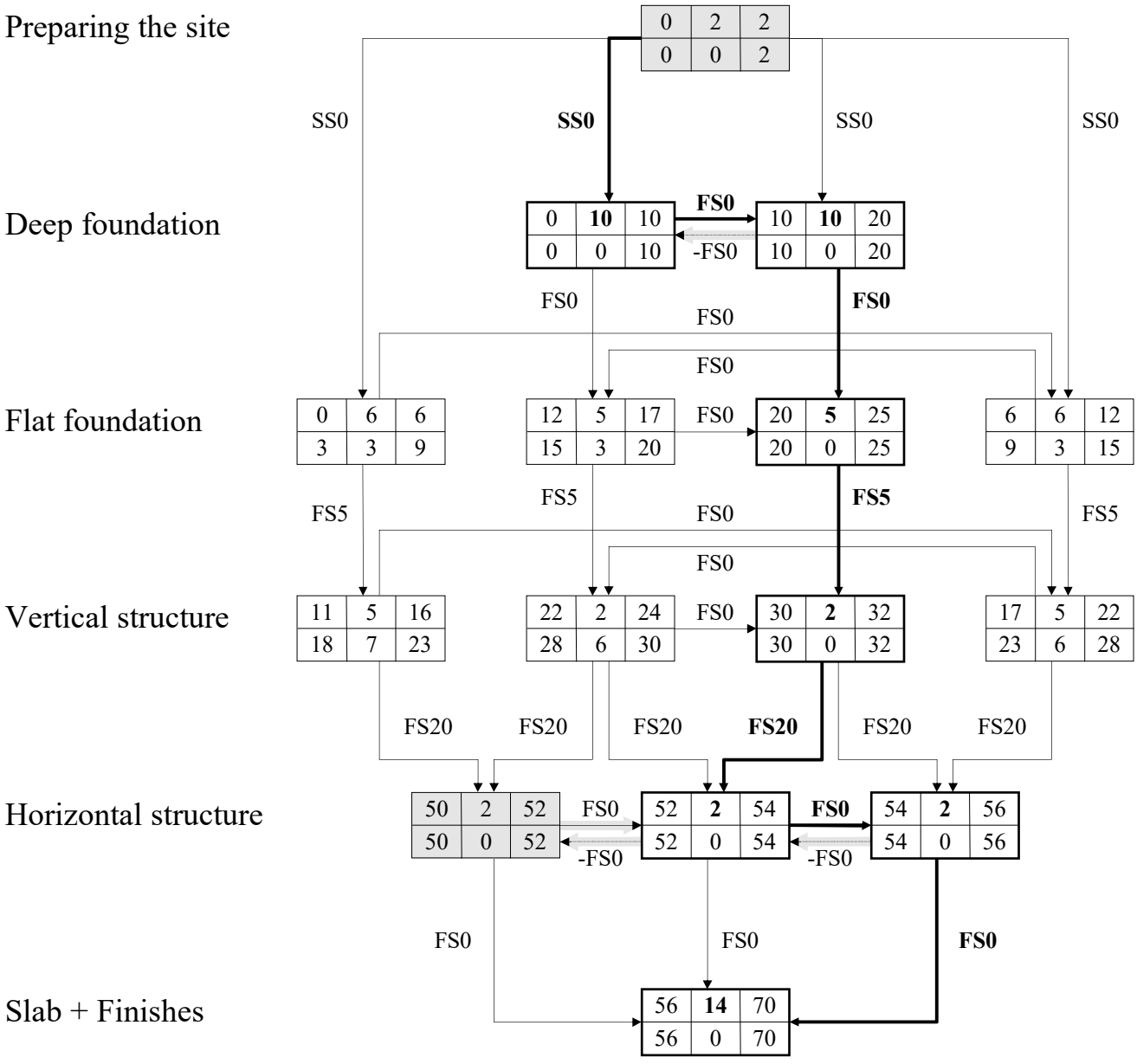
Network techniques

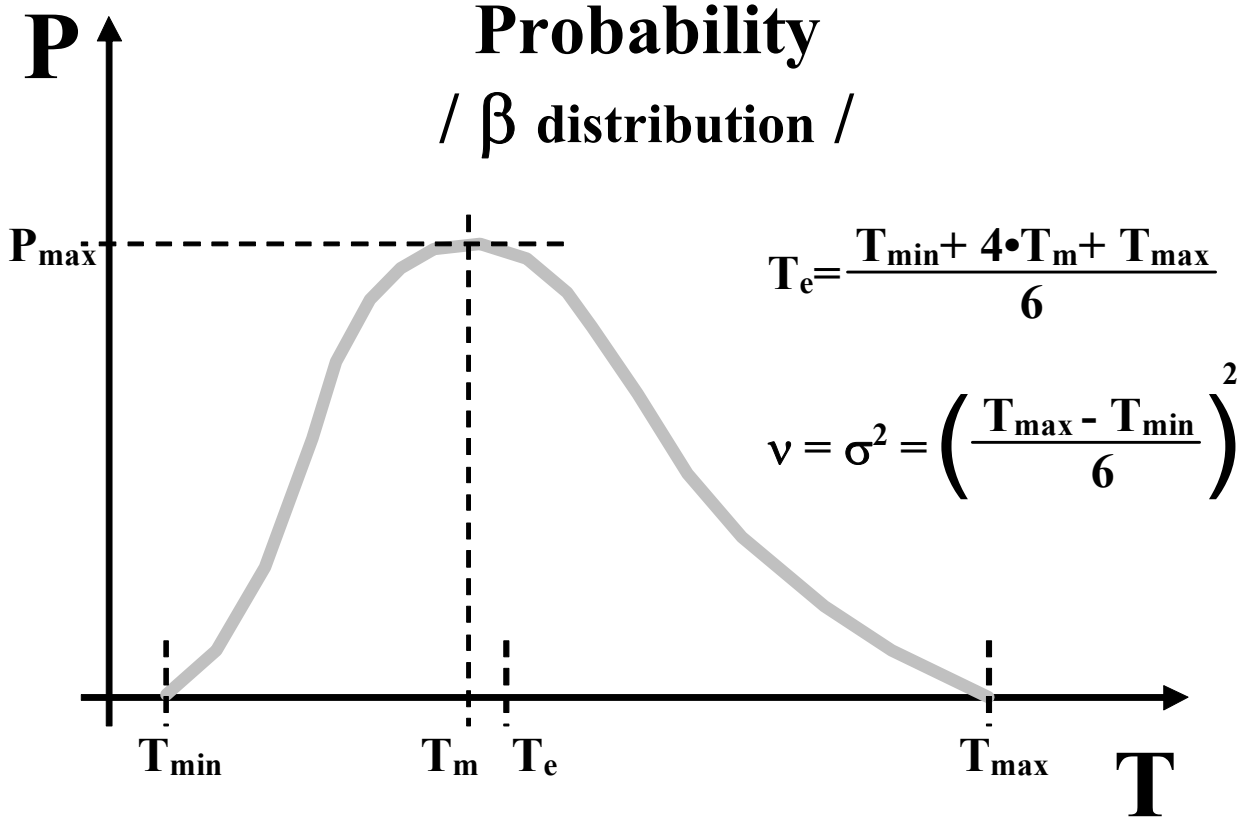
(differing correspondences and joint algorithms)

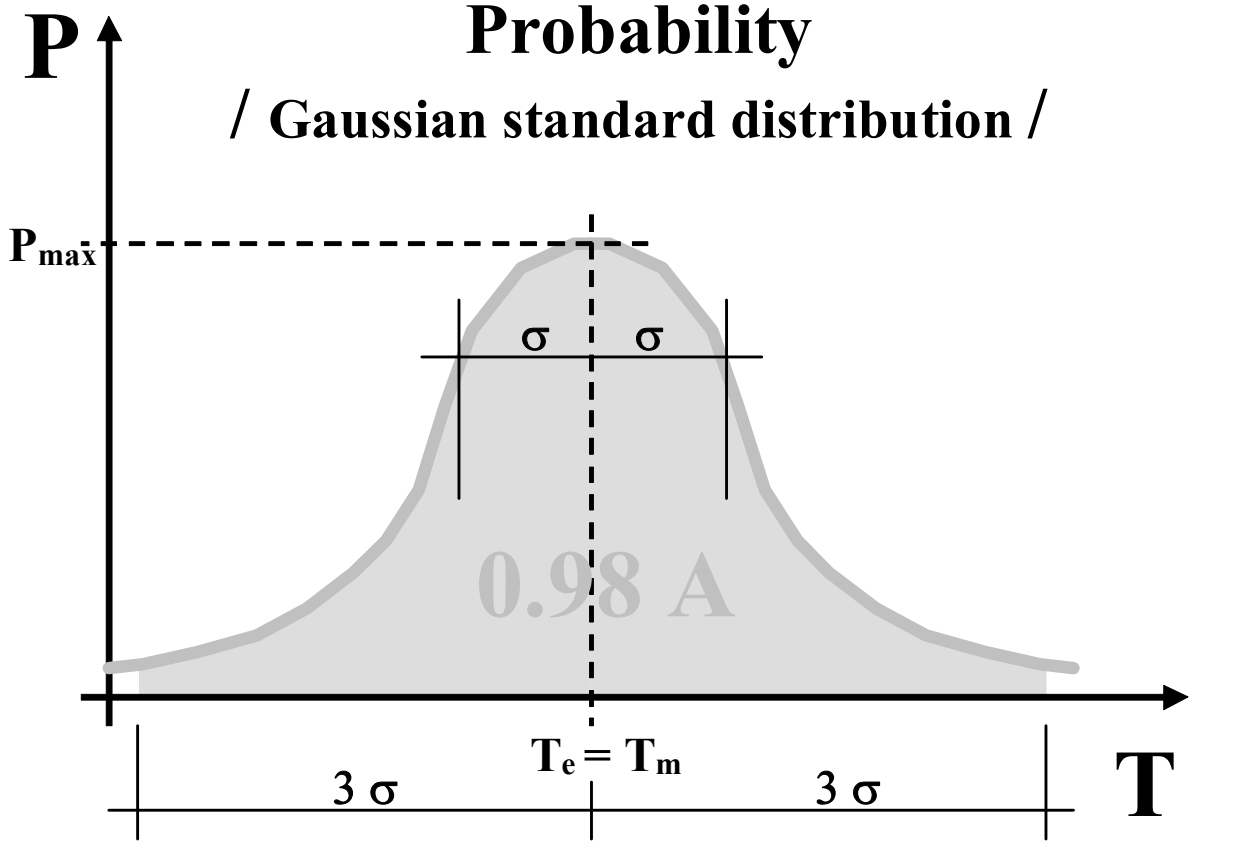
- $PERT^{time}$
- CPM^{time}
- CPM^{cost}
- CPM^{ladder}
- MPM^{time}/PDM^{time}
- MPM^{cost}
- GTM *(General Time Model)*

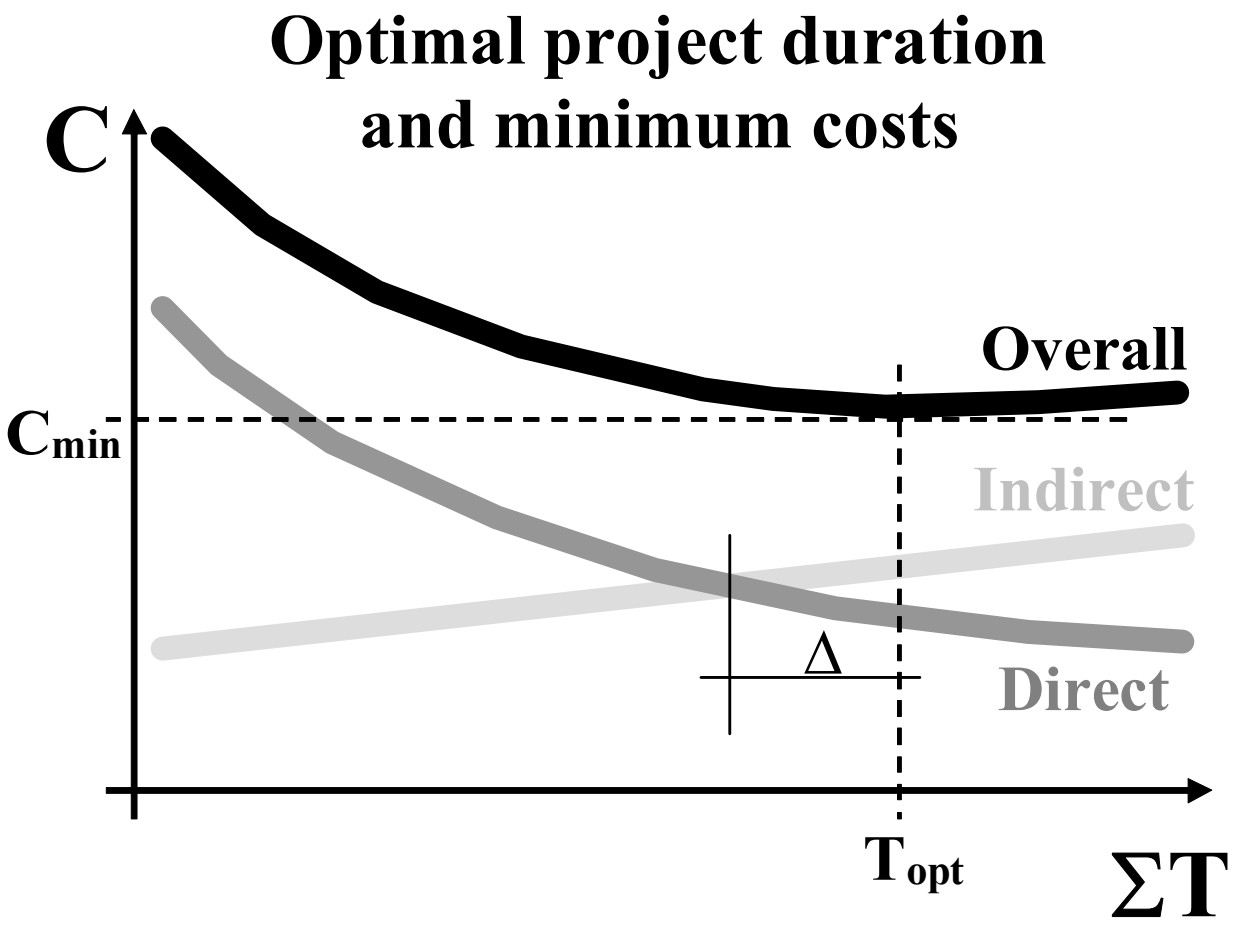
e.g. an MPM time-model

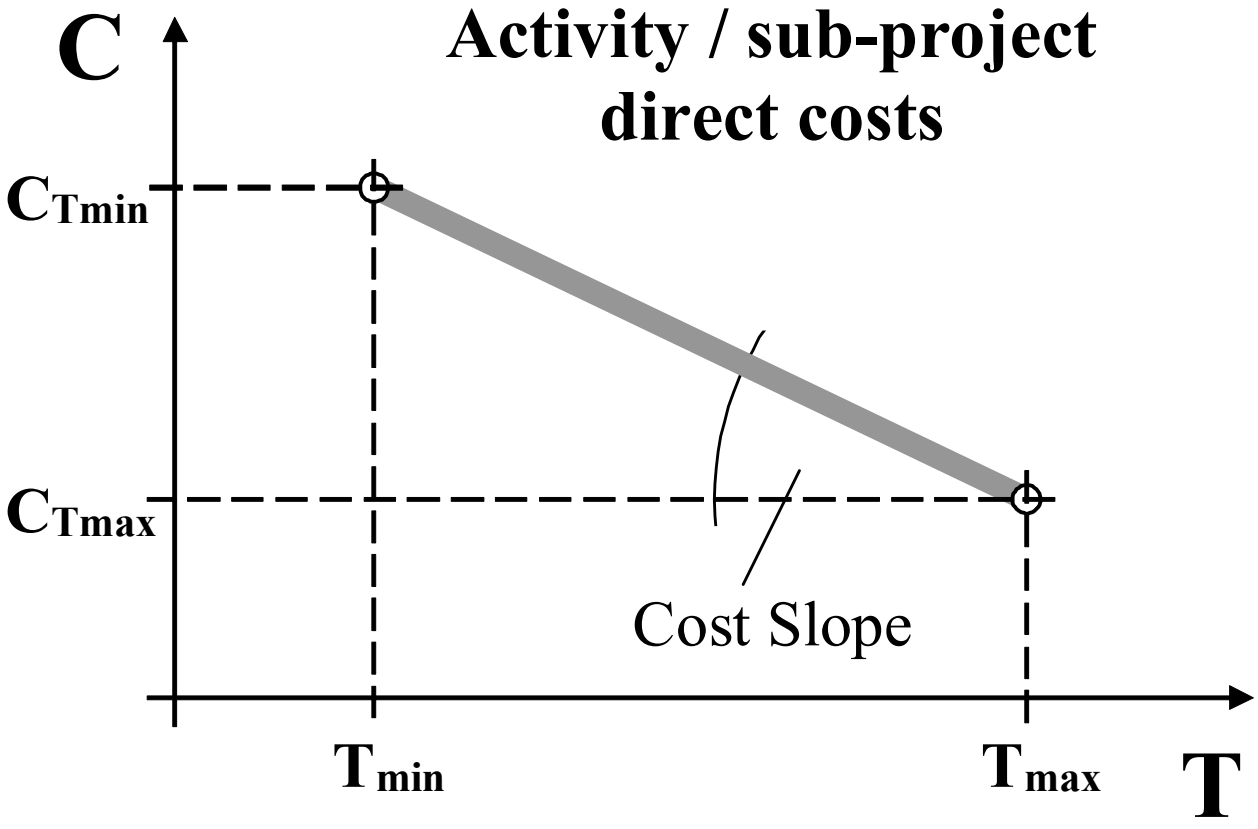




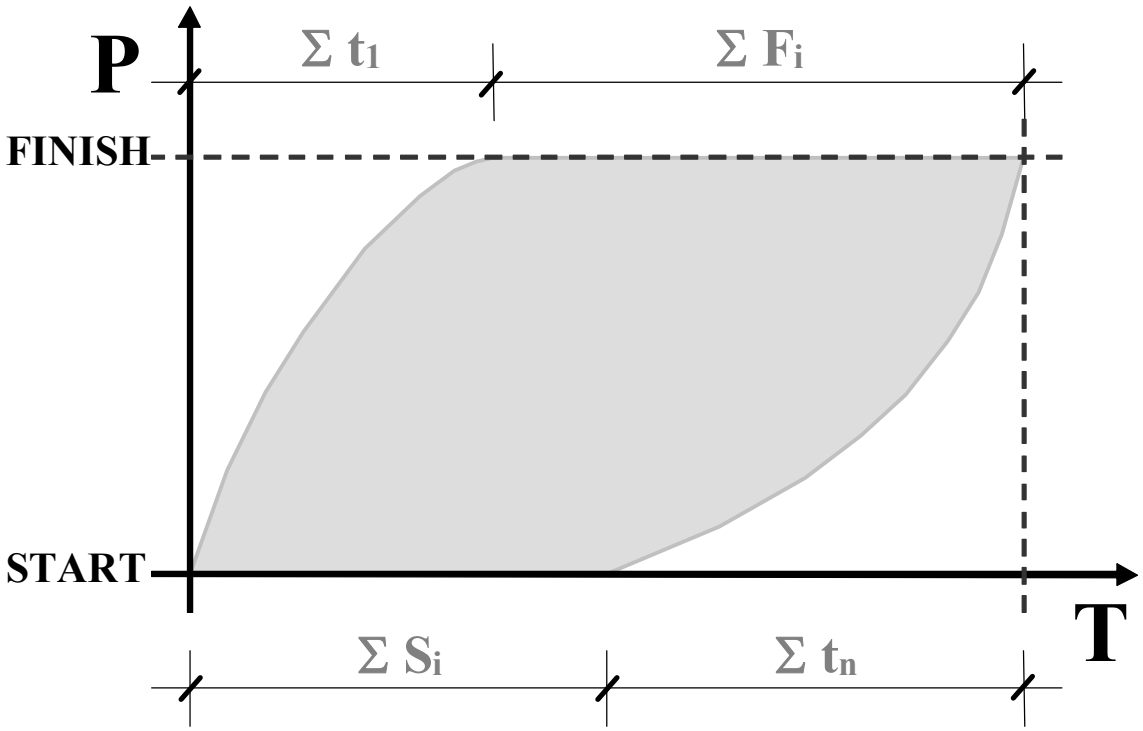

Probability
/ β distribution /
P
Pmax
Tmin
Tm
Te
Tmax
T
$T_e = \frac{T_{min} + 4 \cdot T_m + T_{max}}{6}$
$\nu = \sigma^2 = \left(\frac{T_{max} - T_{min}}{6} \right)^2$


Probability
/ Gaussian standard distribution /
P
Pmax
σ
σ
0.98 A
Te = Tm
3 σ
3 σ
T


Optimal project duration
and minimum costs
C
Overall
Cmin
Indirect
Δ
Direct
Topt
ΣT


C
Activity / sub-project
direct costs
CTmin
CTmax
Cost Slope
Tmin
Tmax
T

Project Schedule



Project Direct Costs / CPM^{cost} /