공정관리 2(LOB/TACT/LEAN), 원가관리 (구성/적산/견적)

건축시공 및 건설관리 입문 Introduction to Building Construction Engineering & Management

Moonseo Park

Professor, PhD

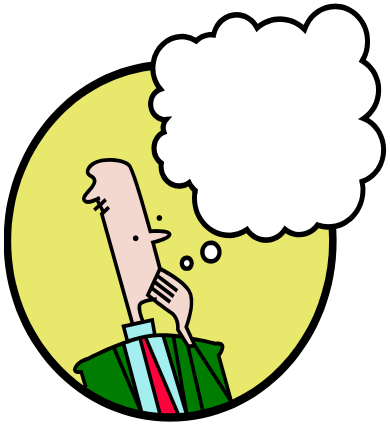
39동 433
Phone 880-5848, Fax 871-5518
E-mail: mspark@snu.ac.kr

Department of Architecture &
Architectural Engineering
College of Engineering
Seoul National University

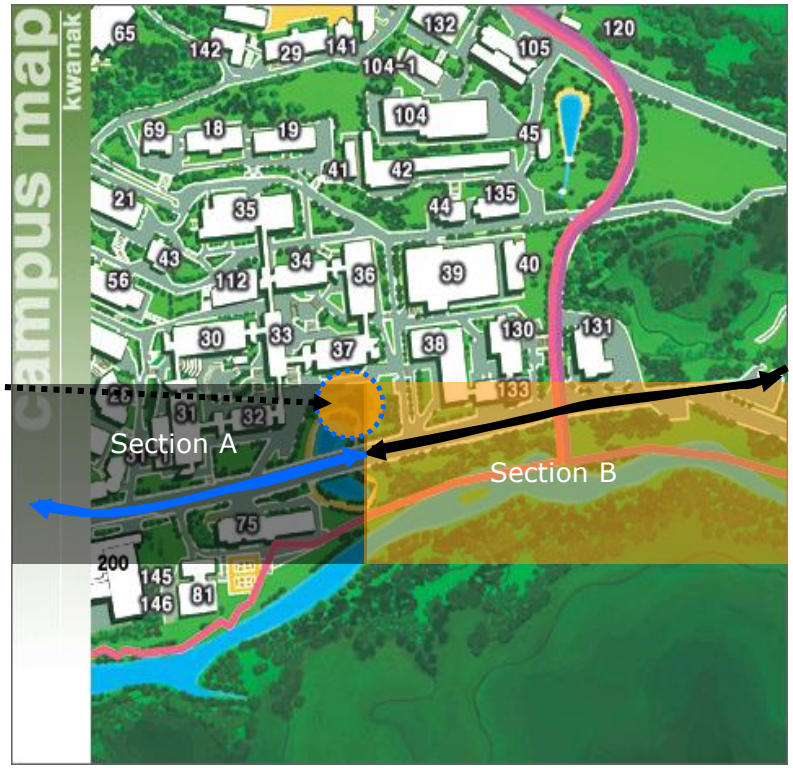
LOB

(Line of Balance/Linear Scheduling)

As part of the SNU IT Center project, a road pavement project is to be done in two sections, A and B. The project consists of three activities, each having different worker productivity. The entire project is now behind the schedule. Thus, 수교, the PM of this project is trying to find a more time-efficient way. He is thinking where to start the work. From Section A to B or from Section B to A ? How can you help him?



Project site for the proposed IT research center

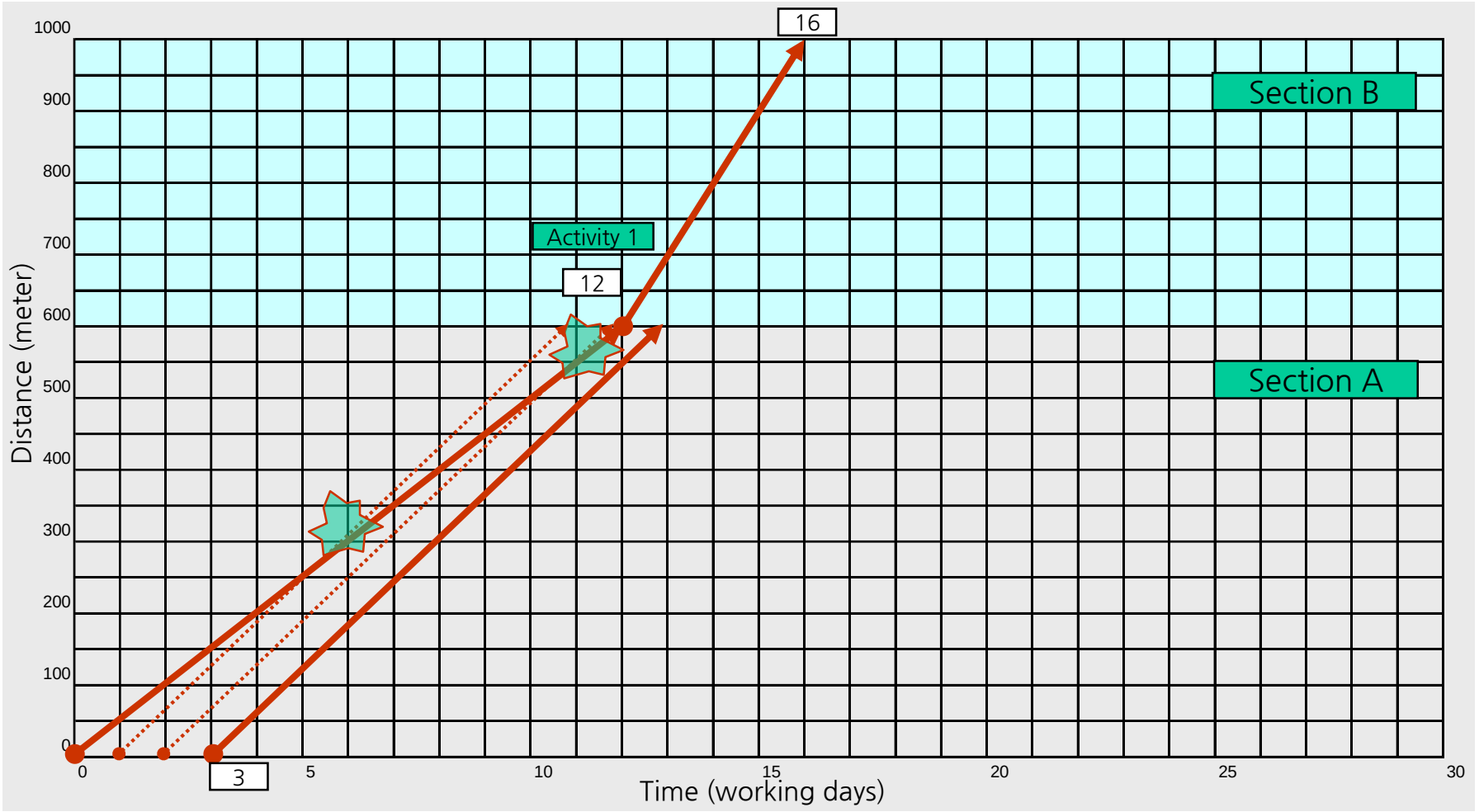


- The Project: installing pipeline for section A and B, which consists of three activities.

Activity	Productivity (meter/worker*day)	
	Section A (600m)	Section B (400m)
1	50	100
2	60	80
3	200	40

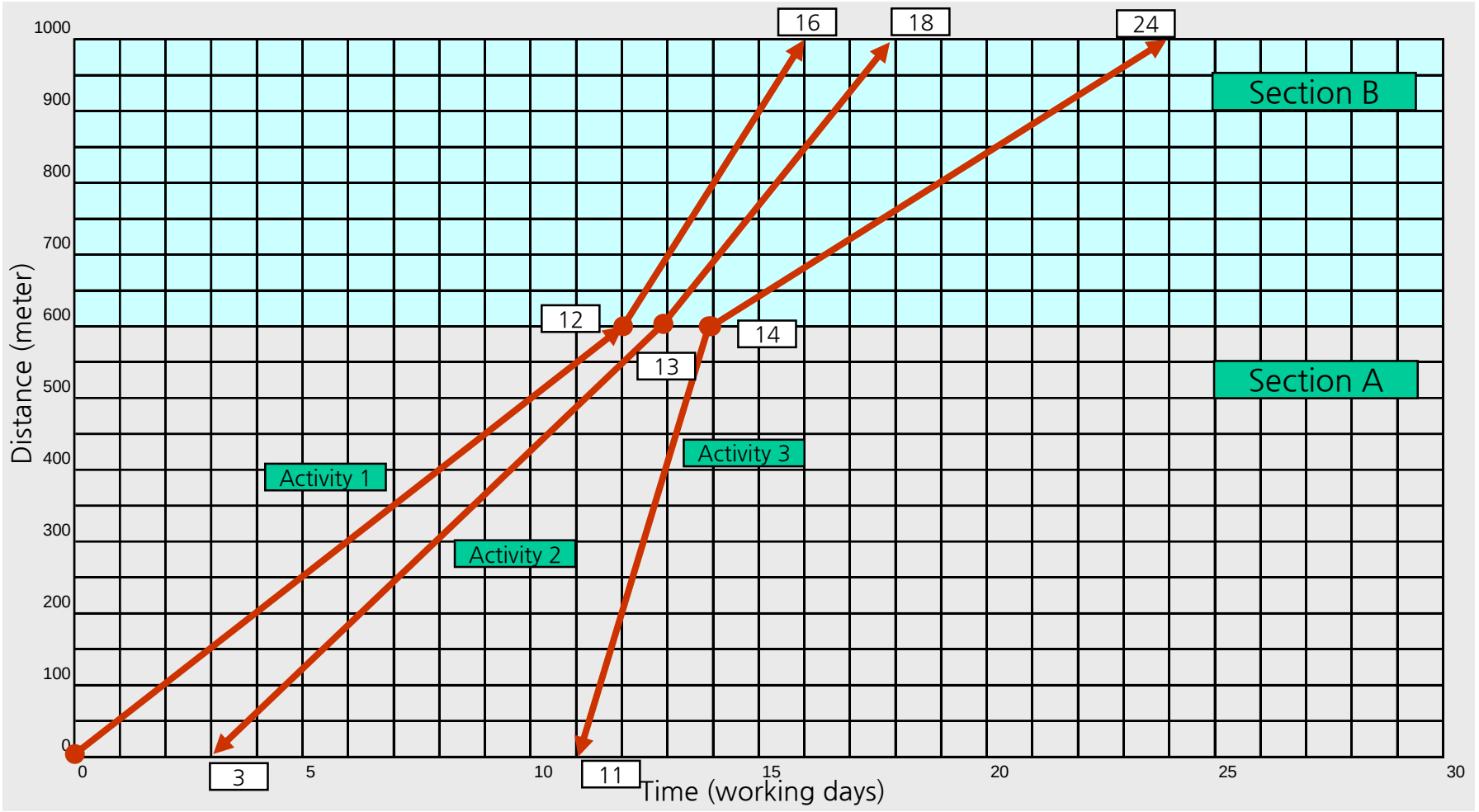
- Constraints
  - All activities must be performed continuously.
  - Only one crew is assigned for each activity.
  - A buffer of one working day must be assigned in between activities.

Work Proceeds from Section A to Section B (0m to 1000m)



Project Duration: 24 wd

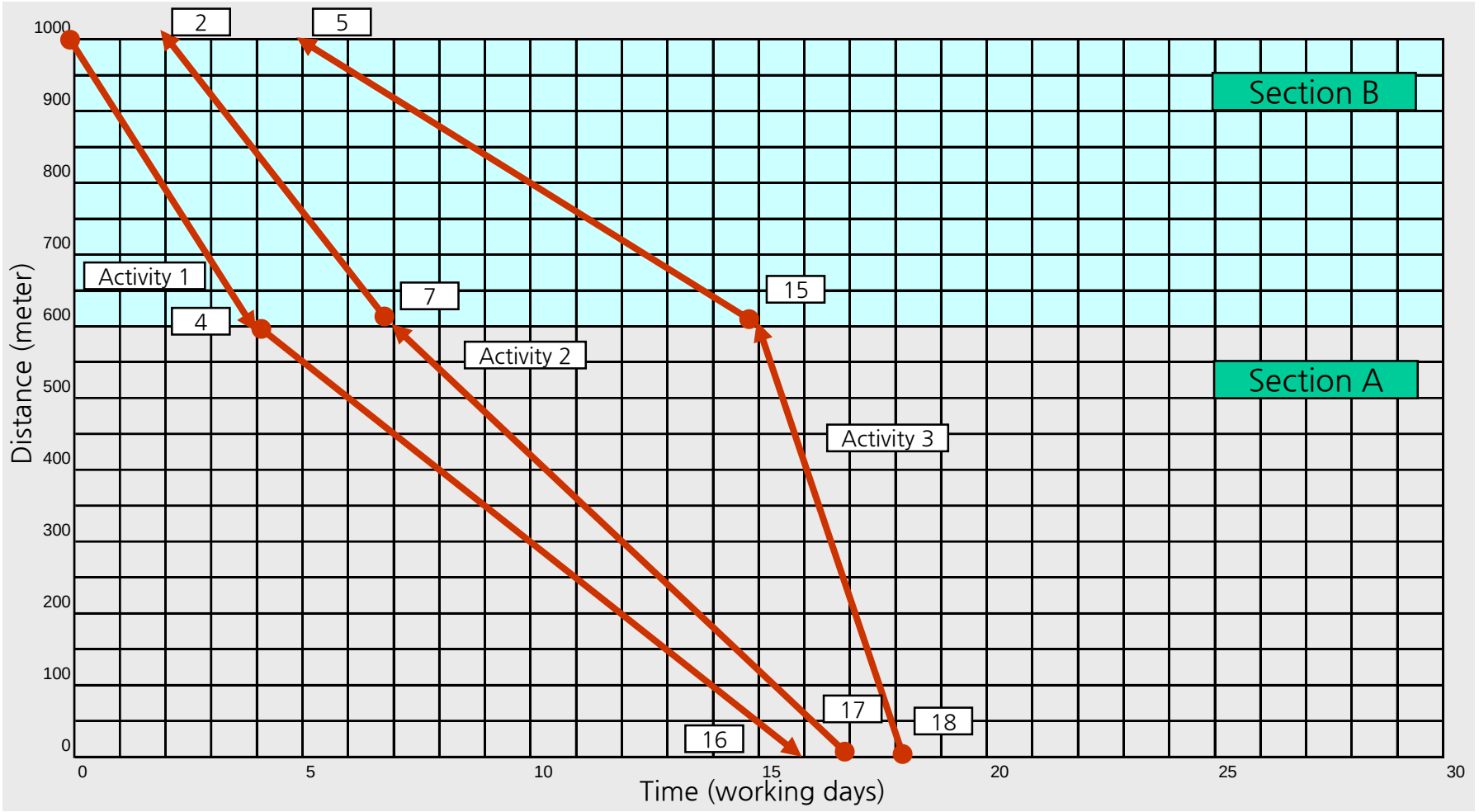
Direction of Planning not Work



Project Duration: 24 wd

Direction of Planning not Work

Work Proceeds from Section B to Section A (1000m to 0m)



Project Duration: 18 wd

A Linear Scheduling Practice

Linear Scheduling

A road pavement project is to be done in two sections A and B. The project consists of three activities, "1", "2", and "3". Considering the following activity durations and constraints,

Activity Durations

Activity	Duration (days)	
	Section A (2km)	Section B (4km)
1	20	5
2	10	10
3	5	20

Constraints

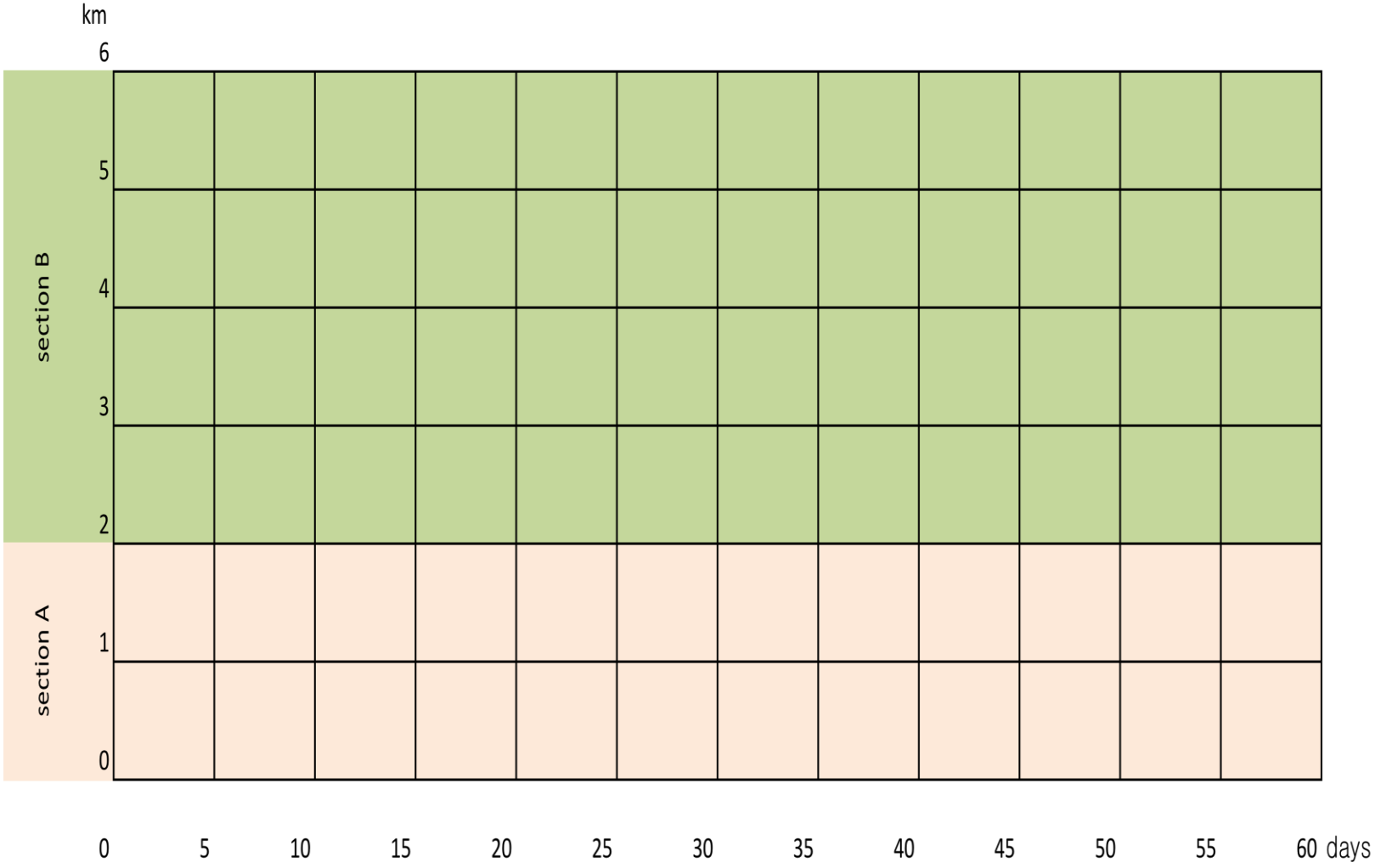
1) All activities should be performed continuously.

2) Five days of schedule buffering between activities is required.

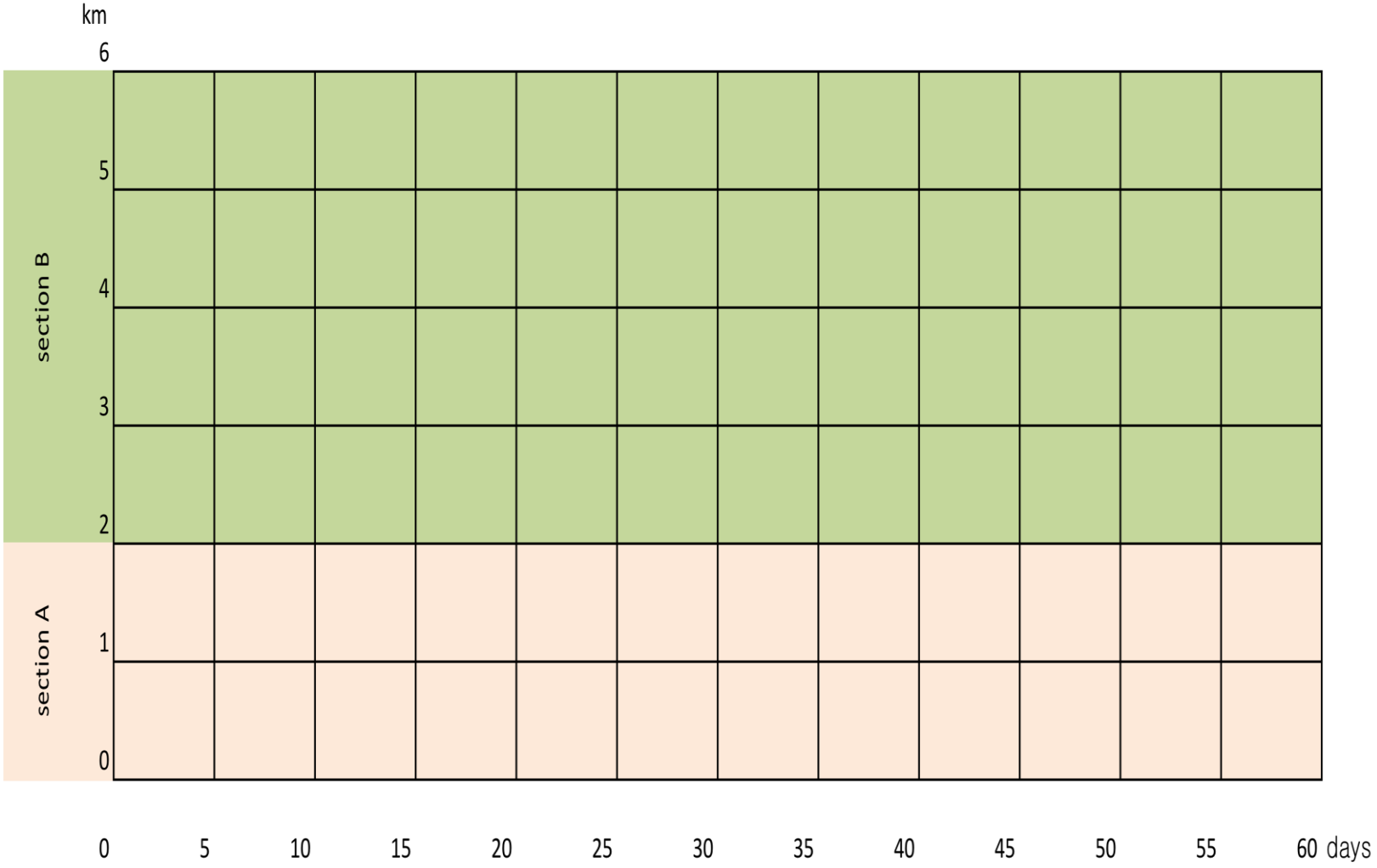
1) Draw a time-distance diagram as the work proceeds from section A to Section B.

2) Draw a time-distance diagram as the work proceeds from section B to Section A.

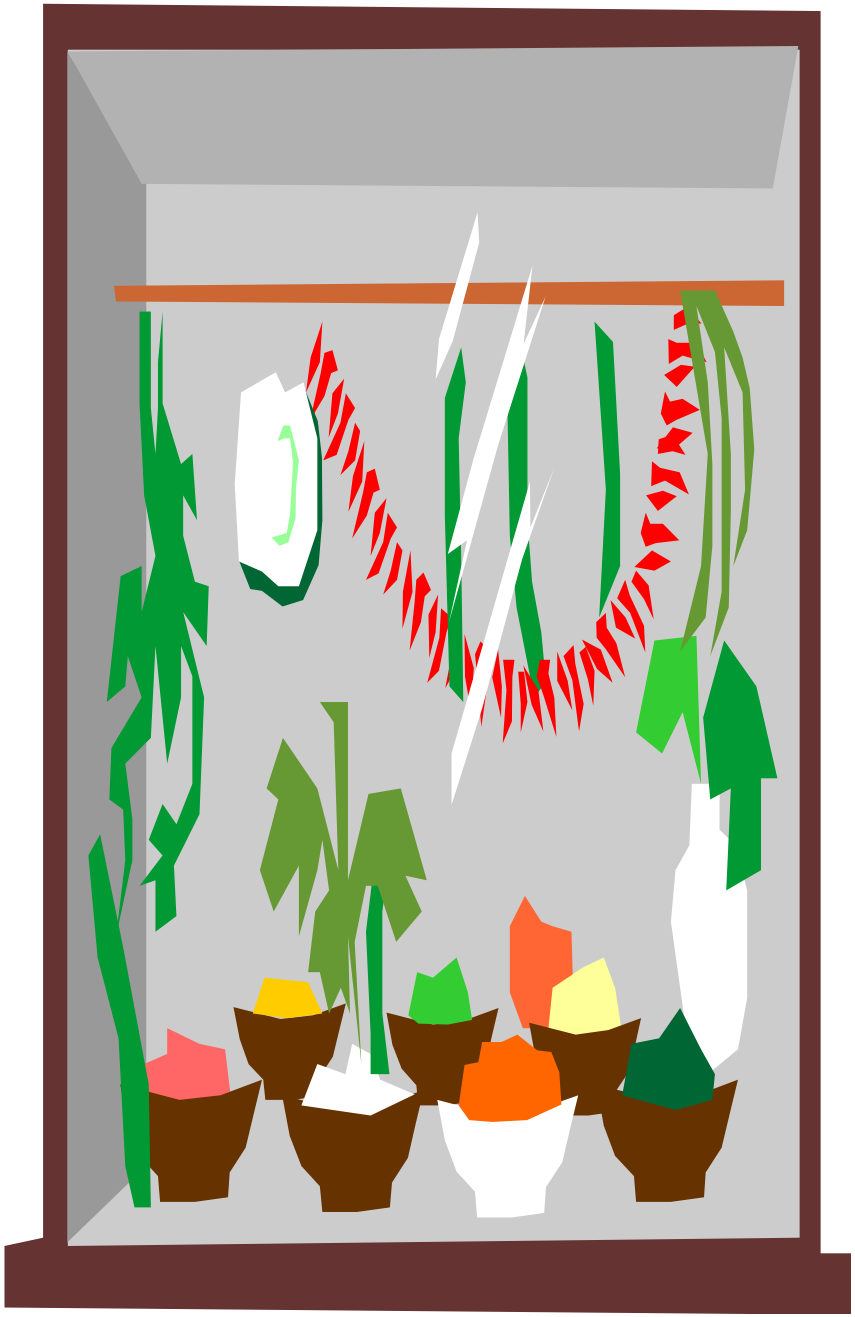
Work Proceeds from Section A to Section B (0 km to 6 km)



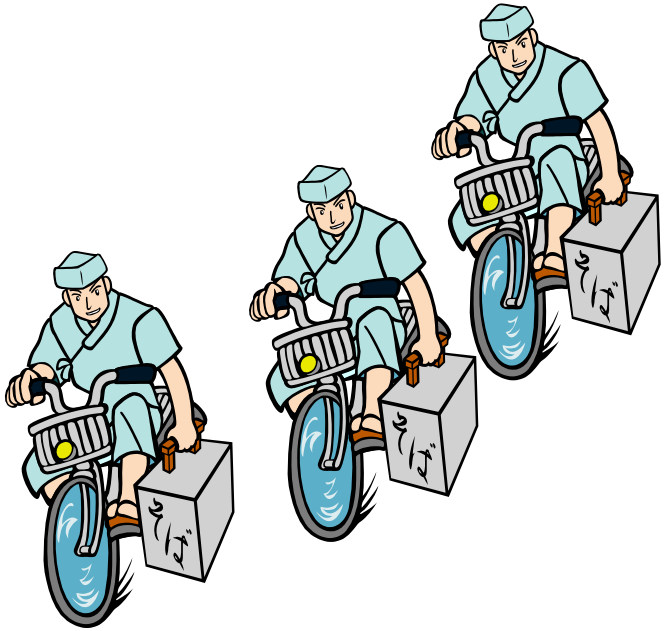
Work Proceeds from Section B to Section A (6 km to 0 km)



Lean Construction/TACT



번개




Flow


Push


Pull

What is “Lean”?

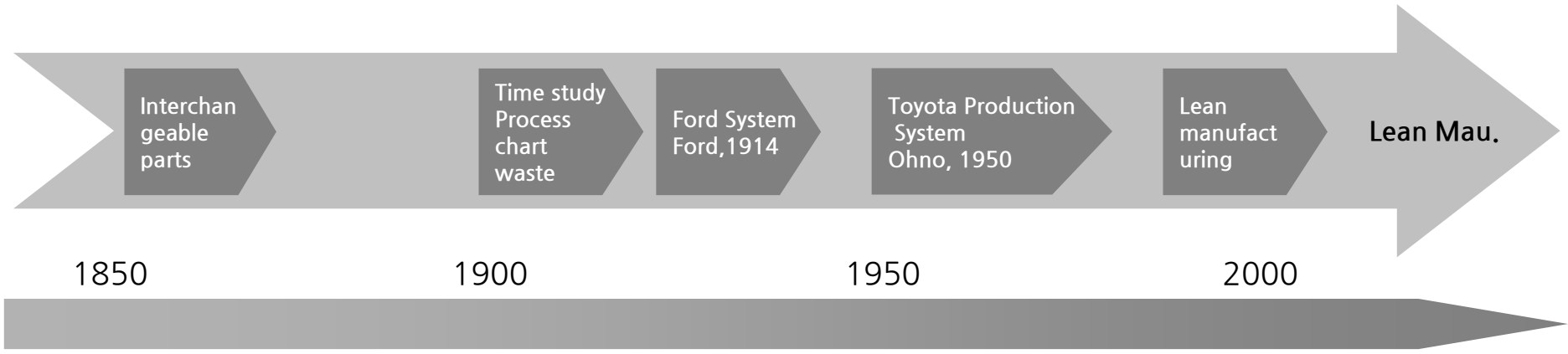
- **The Lean Idea**
  - Meet requirements of a unique customer
  - Deliver it instantly
  - Maintain no stock

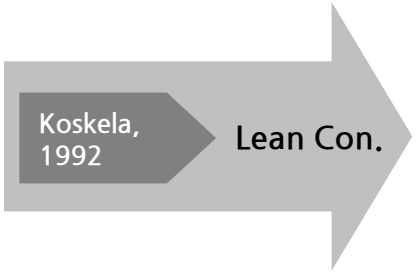
- “Give customers what they want, deliver it instantly, with no waste”

- **Lean production**

  a production philosophy which shortens the time line between the customer order and the product shipment by eliminating waste and maximizing value to the customer

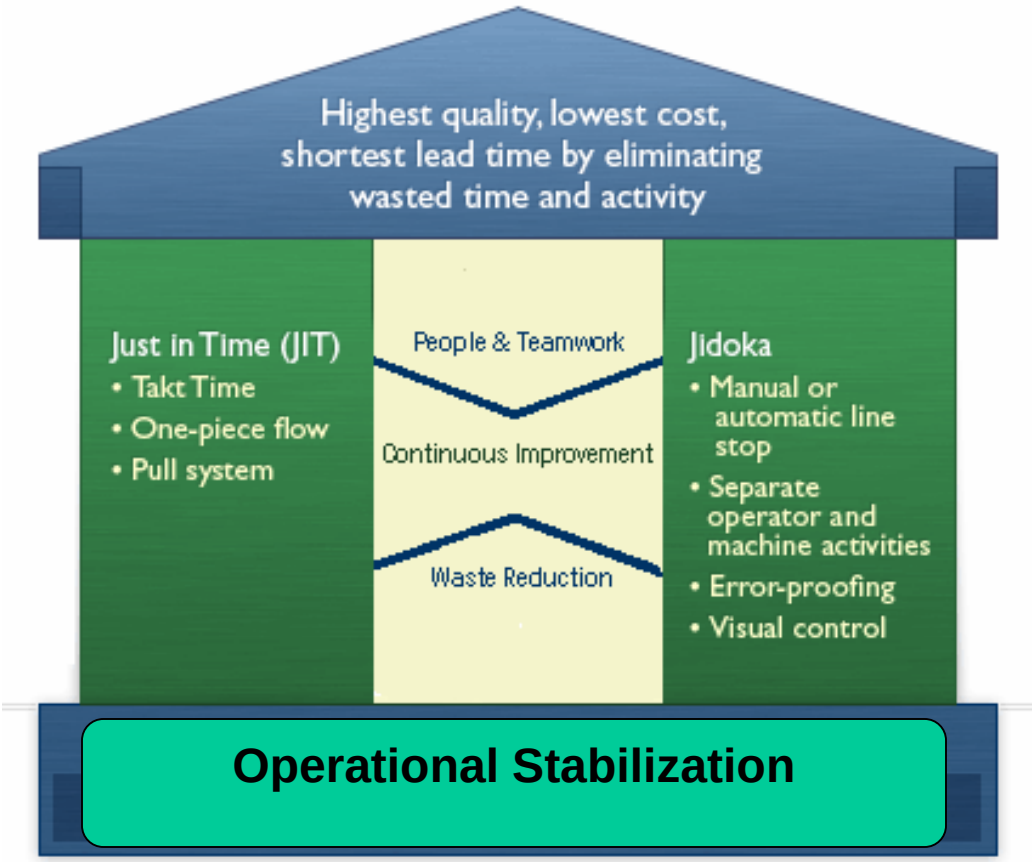
History of Lean





- Eli Whitney; interchangeable parts
- Frederick W. Taylor; Standardized work& Time study
- Frank Gilbreth; Process charts, motion study
- Lillian Gibreth; idea of “eliminating waste”
- Ford System,1914; assembly lines, flow lines, Manufacturing strategy
- Toyota Production System,1950, Ford idea+ Takt time, J-I-T
- Lean Production System American,1980’s
- “the machine that changed the world”, 1990
- Lean Construction,1992, Koskela

House of Toyota (TPS)



Muda (Waste)

Muri (Overburden)

Mura (Variability)

Pull vs. Push

Pulling

Initiating the delivery of input based on the readiness of the process into which they will enter for transformation into outputs

Pushing

Releasing materials, information, or directives possibly according to a plan but irrespectively of whether or not the downstream process is ready to process them

Push system schedules the release of work based on demand
Pull system authorizes the release of work based on system status

from Hopp and Spearman 1996 P.317

Flow

- A term used to describe the throughput of an entire process (set of activities)
- Seven flows towards the perfect execution of a work package
  - **Previous work**
  - **Space**
  - **Crew**
  - **Equipment**
  - **Information**
  - **Materials**
  - **External condition**

(koskela, 2000)

- Flow=Work flow (material, equipment, information) +Labor flow

Work flow

• The movement of information and materials through a network of production units, each of which processes them before releasing to those downstream.
• The movement of materials, information, and equipment through a system
(Womack and Jones, 1996)

Labor flow

• involves the tracking and allocation of the labor resource to various tasks and work assignment
• The interaction of the crew with other crew and other work

Times

- Cycle time

  The time it takes a product to go from beginning to end of a production process

- Idle time

- Waiting time

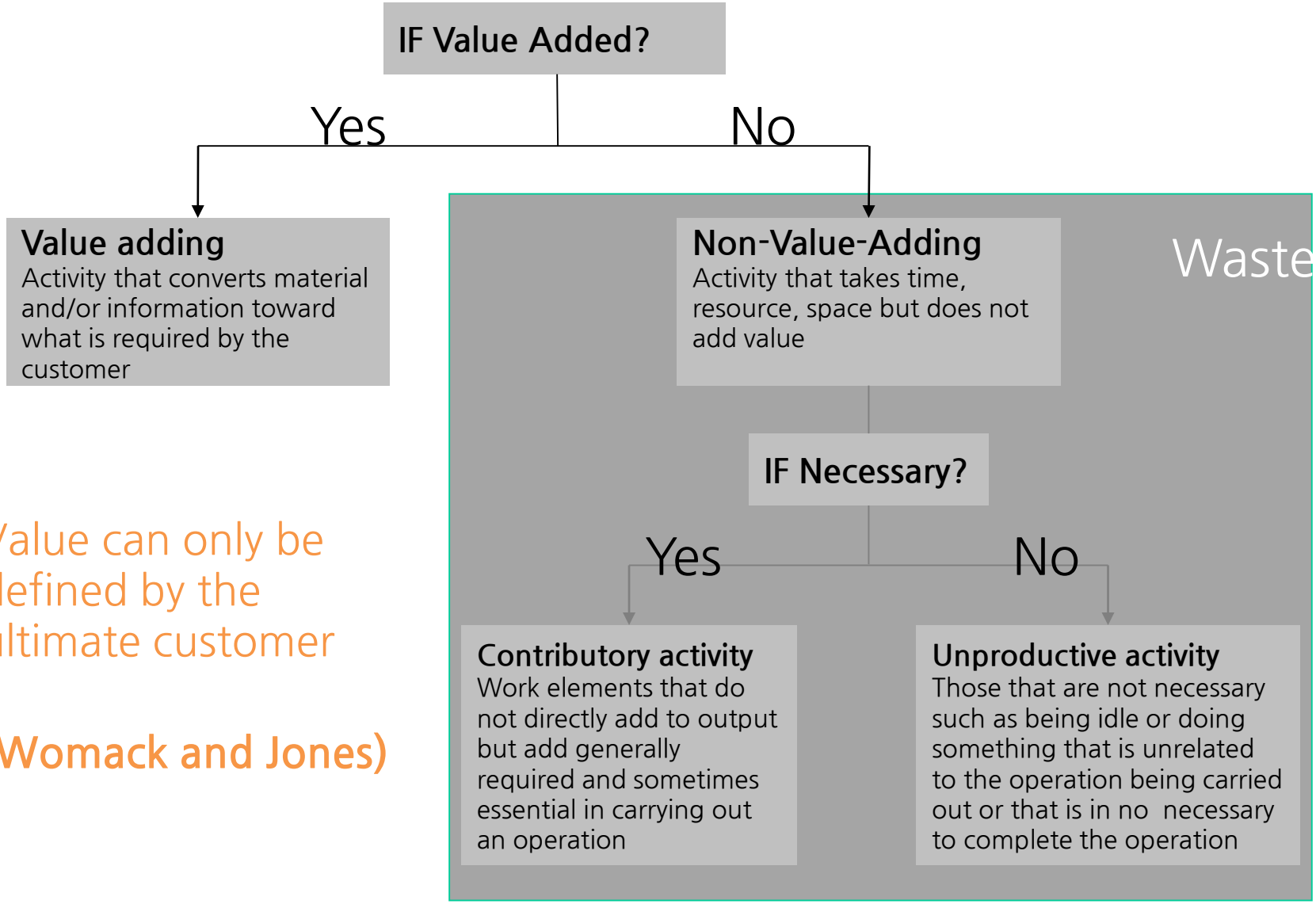
- Traveling time

- Takt time

  The time in which a unit must be produced in order to match the rate of customer demand

$$\text{Takt Time} = \frac{\text{Available Time}}{\text{Unit Demand}}$$

Value



Value can only be defined by the ultimate customer

(Womack and Jones)

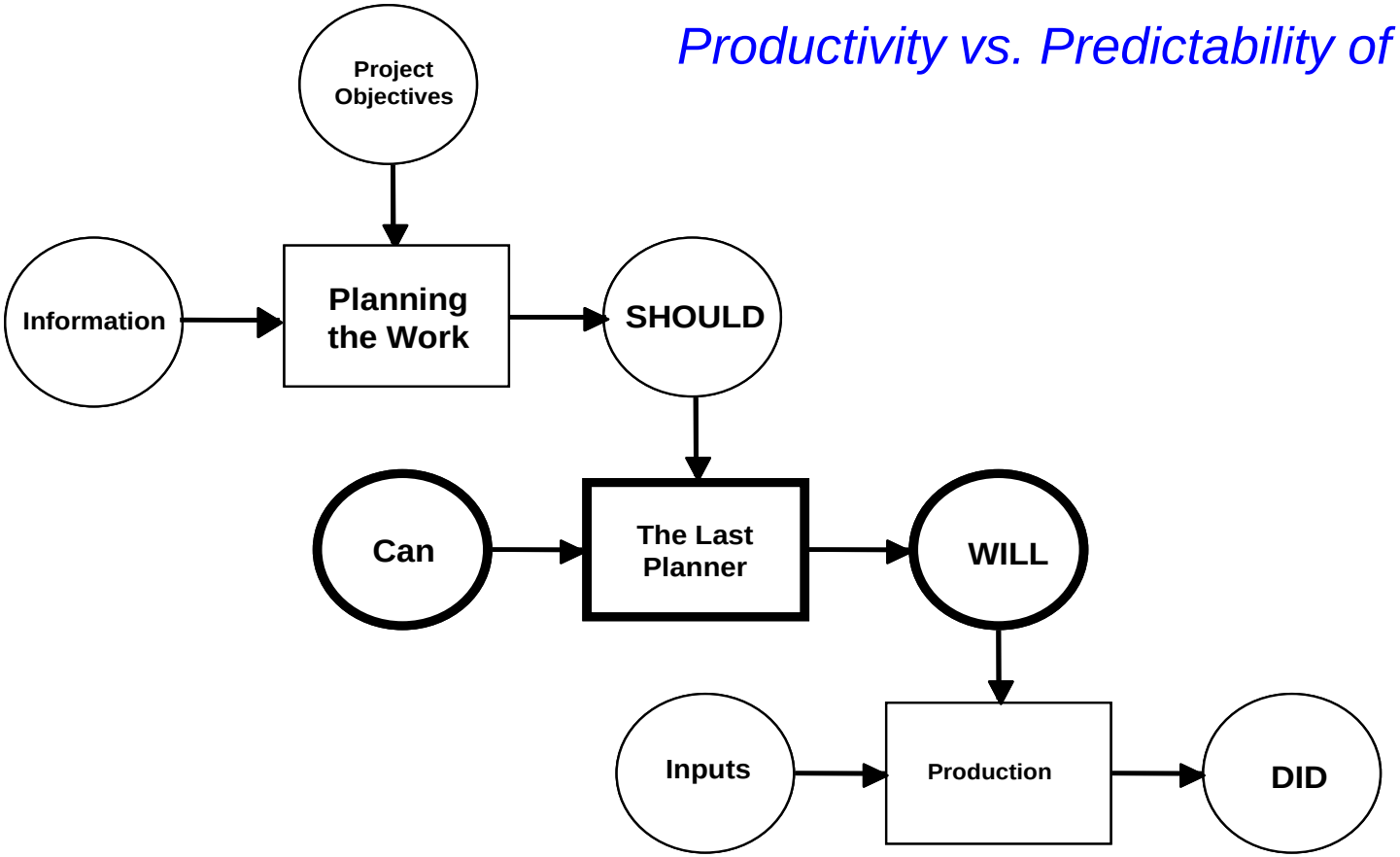
Lean Construction

A comprehensive management approach
to project delivery based on
organized set of principles & tools
that enable project delivery teams
to stabilize project workflow.

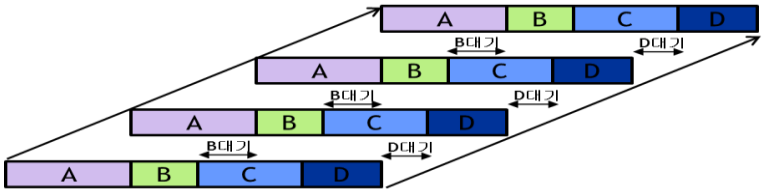
Last Planner System

Planning Reliability (Work Flow Control)
Lean Construction (1992, 2000 Ballard)

Productivity vs. Predictability of Flow

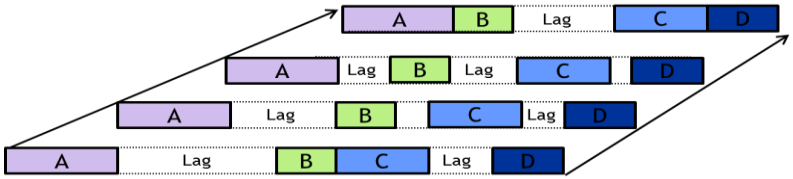


Tact 공정관리



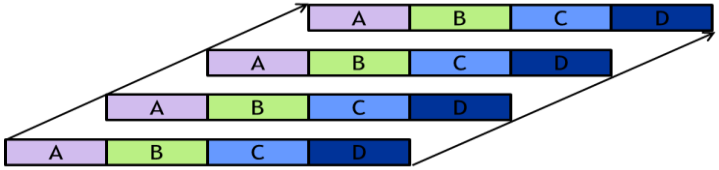
1. **형식적 택트형**

협력사 위주의 생산보다는 **주관사 위주의** 생산



2. **불완전 택트형**

주관사의 생산보다는 **협력사의 효율 위주**로 관리



3. **완전 택트형**

시간적, 공간적 조건이 모두 완전하게 성립

→ **가용한 자원 내**에서 추구

택트공정 관리 원리

동기화 : 작업구역 및 공종 세분화

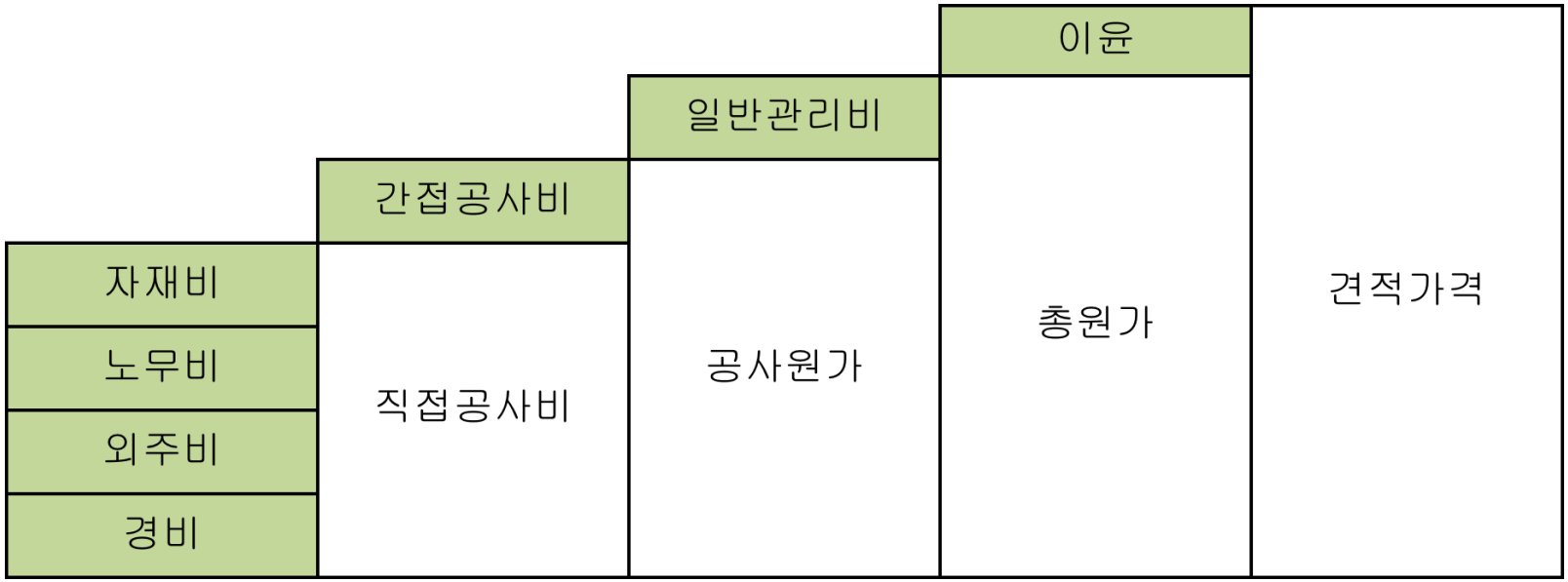
다공구 : 자원공급 및 작업시간의 일치화

원가관리

As Part of the Project Financial Plan

- Construction Cost Estimate: a specific indication of the construction related costs, which gives vital information
  - to the owner: to verify the project economic viability and cash flow needs.
  - to the designer: to confirm the viability of its design and to meet the projected investment.
  - to the contractor: to set up the potential profit.

원가의 구성



Typical Project Financial Plan Items

- Land Cost: purchase or Lease
  (Existing Facilities Acquisition Cost and Site Clearance Cost)

- Construction Cost:
  - Hard Cost: construction material, manpower, equipment
  - Soft Cost: design and engineering, general contractor fees, infra fee, contingencies (depending on delivery systems, it may not be included in construction cost)

- Other Cost and Expenses: organization and development costs, project management fees, pre-opening expenses

- Financing Cost

- Working Capital

Direct Costs vs. Indirect Costs

- Direct Costs

  Can be directly attributed to a recognized work item

- Indirect Costs

  Cannot be directly attributed to a recognized work item

Examples of Direct/Indirect Costs

Priced Items / Cost Items	Con'c Floors	Building 3	Site 08	Firm
Salary of Receptionists at Home Office	I	I	I	D
Water Consumption during April at site 08	I	I	D	D
Rent of Concrete Pump for Building 3	I	D	D	D
Re-bar Placement on the Third Floor of Building 3	D	D	D	D

Major Components of a Priced Item

- Direct Costs
- Site Overhead
- Home Office Overhead
- Profit and Contingencies
- Financing Costs

Indirect Costs
(depending on pricing)

Common Types of Direct Cost Items

- Labor
- Material
- Equipment
- Forms, Scaffolds, and Special Tools
- Subcontractors

Site Overhead Expenses

- Salaries: Project Manager, Superintendent, Foremen, Gate-man, Other Personnel
- Housekeeping: Site Offices, Temporary Roads, Fences, Signs, Waste Disposal, etc.
- Services: Water, Electricity, Telephone, Insurance, etc.

Home Office Overhead Expenses

- Salaries: Top Managers, Regional Managers, Office Personnel, Technical and Supporting Staffs (e.g.., cost estimators, in-house architectural engineers), etc.
- Outsourcing Services: Special consultants, Lawyers, CPAs, Advertising Firms, Lobbyists, etc.
- Headquarter Operation and Maintenance: Office Rent, Furniture, Electricity, Telephone, Water, Insurance, etc.
- Centralized Services: Equipment Yard, Material and Tool Center, Fleet of Company Cars and Trucks, etc.

Common Mark-Up Categories

- Planned Profit: usually added as a flat percentage on all items (sometimes with differentiation between self performed work and sub-contracted work, or according to types of work)

- Escalation: considered for expected annual inflation

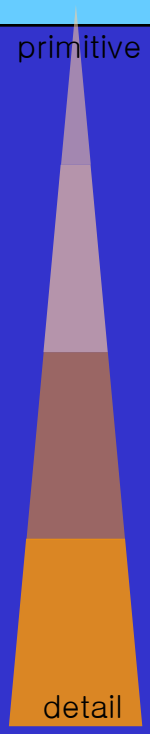
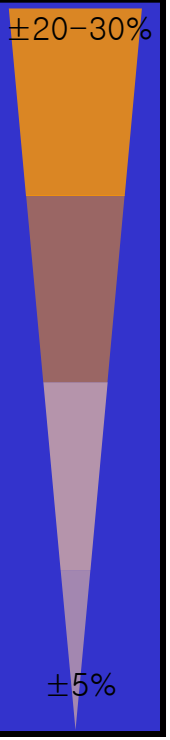
- Contingencies: added for unexpected, non-reimbursable expenses (e.g., rework due to errors, slowdown due to weather conditions, unexpected wastes, under-insured damages, work strikes, warranty work in the future, etc.)

Common Mark-Up Categories

- Financing Expenses: supposed to compensate expected interest payments (or conceptual interests) for negative cash flow periods.

- Panic Factors: for designers or owners of bad reputation (“trouble makers” on the contract).

Types of Cost Estimating

Types of Estimate	Purposes	Design Progress	Accuracy
Feasibility Studies	Determine the project financial feasibility		
Appropriation	Obtain project funding		
Capital Cost or Budget	Control project budget		
Definitive	Final cost prediction		

구분	단계	유형/방법
개산견적 (approximate estimate)	개념단계 (conceptual satge) 기본단계 (preliminary stage)	order of magnitude
		cost indexes method (비용지수법)
		cost capacity method (비용용량법)
		factor estimating method (계수견적법)
		parameter estimating method (변수견적법)
		base unit price method (기본단가법)
상세견적 (detailed estimates)	상세단계 (detailed stage) : 입찰, 시공계획	final estimates (최종견적)
		definitive estimates (명세견적)
		bid estimates (입찰견적)

비용지수법 (cost indexes method)

- Cost index: 다른 시간과 장소에서의 비용정보를 조정하는 데 사용 물량산출
- 과거에 수행된 시설물의 공사비용을 현재의 금전가치에 맞도록 환산
- CPI (Consumer Price Index) is a good example

Formula for total cost

$$Ct = C_0 (I_t / I_0)$$

- Ct = estimated cost at present time t
- C_0 = cost at previous time t_0
- I_t = index value at time t
- I_0 = index value at base time 0

Example

- Problem: Estimate the total cost of labor today in US dollars for a maritime construction project using data from a similar project in Europe completed in 1998.
- Labor index, 1998: 789.6 Cost in 1998: €3.9 million
- Labor index, current: 1165.8 Currently, 1 € = 1.5 US$

- **Solution: Let t = today and 0 = 1998 base**

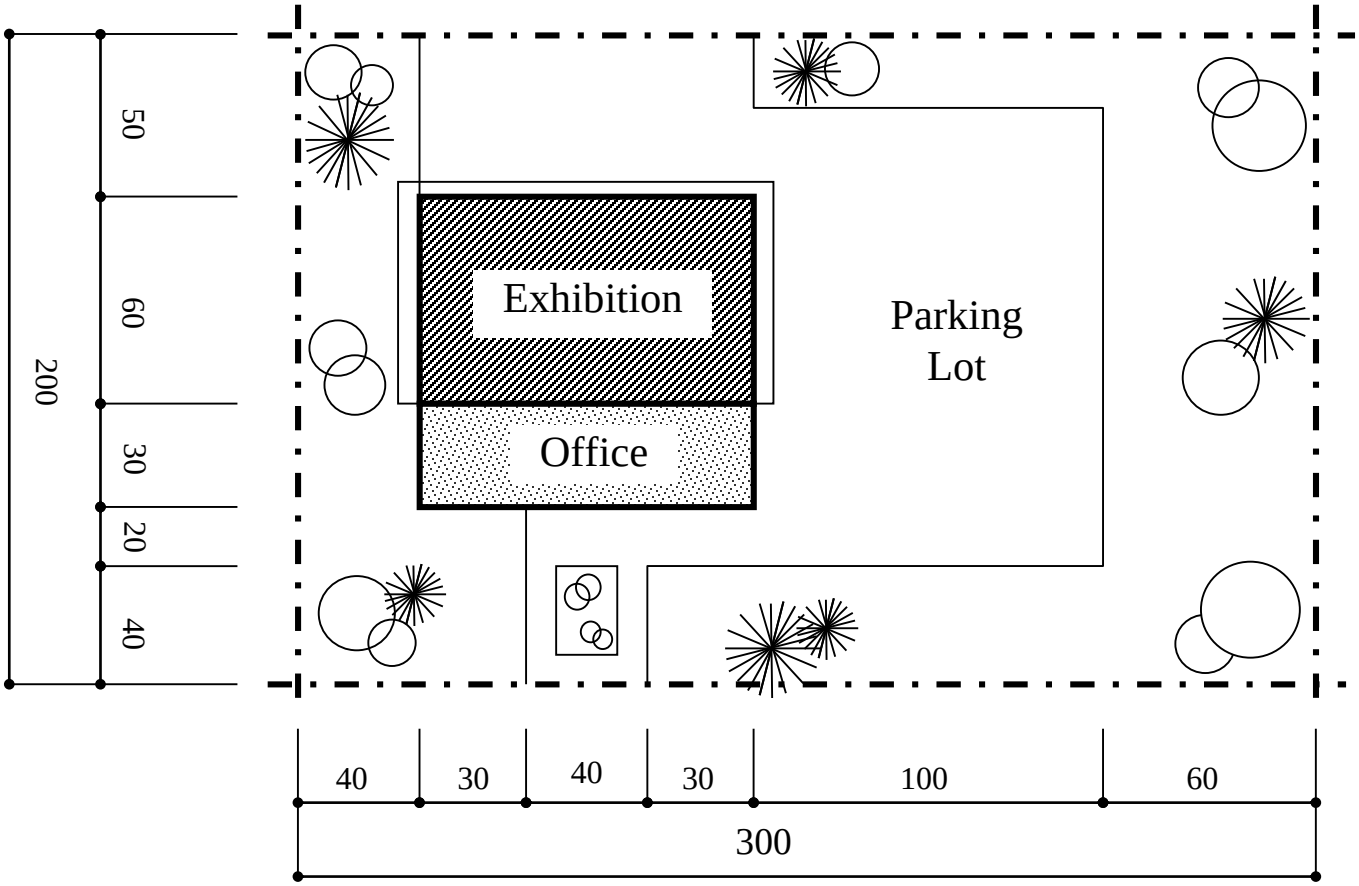
$$C_t = 3.9 \text{ million} \times (1165.8/789.6) = €5.76 \text{ million}$$
$$= €5.76 \times 1.5 = \$8.64 \text{ million}$$

변수견적법 (Parameter Estimating Method)

- 변수견적법은 프로젝트의 크기 또는 범위에 영향을 주는 설계변수에 근거한다.
- 건축, 토목, 설비, 전기 등 각 시스템에 대한 비용은 설계변수의 수량과 각 변수의 수량단위에 대하여 견적된 시스템 비용을 곱하여 계산한다.
- 따라서 프로젝트의 전체 비용은 프로젝트를 구성하는 모든 시스템들의 비용을 합하여 구해진다.
- 이 방법은 적어도 각 변수의 수량을 산출하기에 충분한 기본 도면이 필요하다.

- 이 방법은 각 비용요소에 대한 개별적인 계수를 만들기에 적합한 과거 실적자료가 존재하고 각 요소들이 과거 건설공사 비용요소와 유사하다는 가정하에 신뢰할 만한 견적을 제공한다고 볼 수 있다.

Example



Design Parameter Available	Office Building	Exhibit Building
1. Area of Site	60,000 m^2	-
2. Gross enclosed floor area	18,000 m^2	6,000 m^2
3. Gross supported area	18,000 m^2	-
4. Basement floor area	3,000 m^2	-
5. Roof area	3,000 m^2	6,500 m^2
6. Net finished area	15,000 m^2	2,000 m^2
7. Length of exterior wall	1,560 m	220 m
8. Paving area	20,000 m^2	5,000 m^2

Buildings / Cost Elements	Office Building				Exhibit Building			
	Par	Unit Cost (₩1,000)	Total Cost (₩1,000)	%	Par	Unit Cost (₩1,000)	Total Cost (₩1,000)	%
Sitework / Utilities								
Clearing / Grubbing	1	0.10	6,000	0.20	-	-	-	
Excavation	4	10.80	32,400	1.07	-	-	-	
Paving	8	3.09	61,800	2.03	8	3.09	15,450	2.40
Utilities	2	2.34	41,400	1.36	2	1.71	10,260	1.55
Landscaping	1	0.45	27,000	0.89	-	-	-	
Structural								
Caissons / Piping	3	3.60	64,800	2.13	-	-	-	
Foundation	3	6.90	124,200	4.08	5	7.47	48,555	7.35
Structural framing	3	17.70	318,600	10.48	5	9.90	64,350	9.75
Floor slabs	2	12.30	221,400	7.28	2	14.10	84,600	12.81
Architectural								
Exterior walls	7	261.00	407,160	13.39	7	96.30	21,186	3.21
Roof / Water proof	5	6.60	19,800	0.65	5	6.15	39,975	6.05
Vertical circulation	3	5.61	100,980	3.32	-	-	-	
Interior partitions	2	4.89	88,020	2.89	6	4.05	8,100	1.23
Floor finishes	6	6.69	100,350	3.30	6	2.85	5,700	0.86
Wall / Column finishes	6	3.42	51,300	1.69	6	3.69	7,380	1.12
Ceiling finishes	6	4.95	74,250	2.44	6	4.77	9,540	1.44
Carpentry	6	1.05	15,750	0.52	6	0.90	1,800	0.27
Misc. trades	6	3.90	58,500	1.92	6	1.35	2,700	0.41
Mechanical Systems								
HVAC	2	14.70	264,600	8.70	2	18.48	110,880	16.79
Plumbing	2	10.44	181,980	5.99	2	6.51	39,060	5.92
Fire protections	2	6.30	113,400	3.73	2	5.94	35,640	5.40
Electrical System								
Distribution	2	7.80	140,400	4.62	2	3.69	22,140	3.35
Fixtures	2	6.75	121,500	4.00	2	5.67	34,020	5.15
General OH	2	22.50	405,000	13.32	2	16.50	99,000	14.99
Total	3,040,590				660,336			

기본단가법(Base Unit Price Method)

- 각 건설공사의 기본단위에 대한 비용자료, 예를 들어 건물 바닥의 단위면적, 건물의 단위체적 등에 근거하여 비용을 산출하는 방법을 말한다.
- 비용공식은 제안된 건설공사에 대하여 상대적으로 정확한 기본단가를 얻기 위하여 몇몇의 관련된 속성에 근거하여 통계적인 추론에 의해서 발전될 수 있다.

Ex) 단위면적당 단가에 의한 방법

- 건축물의 단위면적당 비용을 산출하기 위하여 과거 유사한 건축물의 공사 비용자료 또는 비용 참고문헌을 이용한다.
- 견적된 단가는 제안된 건축물의 지리적 위치, 크기, 예상되는 수량 등을 고려하여 조정된 다음 연면적과 곱해져서 전체 비용을 산출하게 된다.

견적의절차

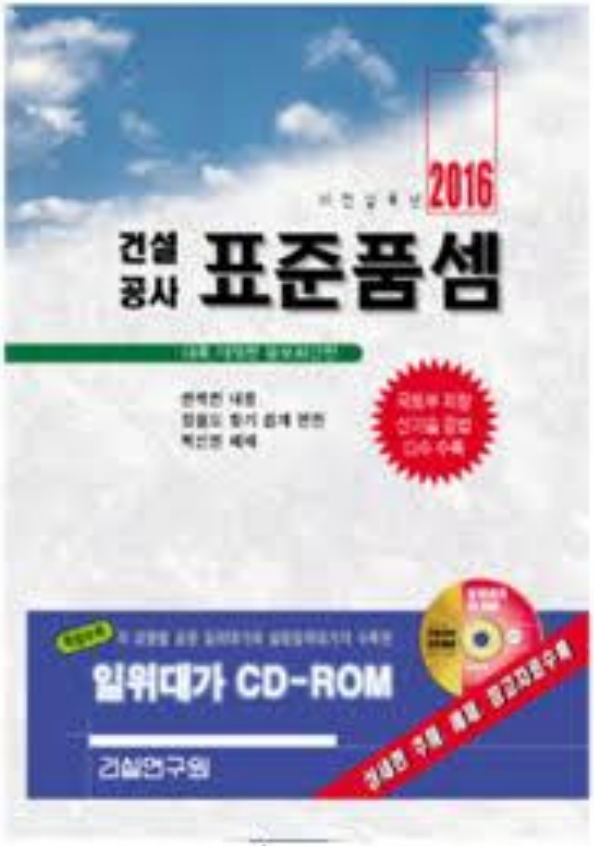
- 물량산출 (take-off)

- 일위대가 산정 (unit cost calculation, costing):
  - 복합단가: 재료비 +가공설치비
  - 단위작업 (자재+노무)의 가격 x 품의 수량 (품셈)

- 공사비 계산 (cost calculation, pricing)
  - 공종별 수량 X 단가 (from 일위대가)

<표 13-32> 모르타르 바름품 (표준품셈) : ㎡당

바 탕	장 소	바름두께	미장공 (인)	보통인부(인)	비 고
콘크리트 및 벽돌	바닥	15~24㎜	0.05	0.05	줄눈무
		24~30㎜	0.09	0.09	줄눈유
	벽	초벌 바름	0.03	0.03	2회바르기는 초벌과 마감 바르기 적용
		재벌 바름	0.05	0.05	
		마감 바름	0.05	0.05	



일 위 대 가 표

공사명 : 중량구조물

명 칭	규 격	수 량	단위	합 계		노 무 비		재 료 비		경 비	
				단 가	금 액	단 가	금 액	단 가	금 액	단 가	금 액
제 1 호표											
중량구조물설치	(850~1150kg미만)		개								
특별인부		0.05	인	66,422	3,985	66,422	3,985				
보통인부		0.19	인	52,585	9,991	52,585	9,991				
기구손료	인건비의 %	2.	%	13,976	279			13,976	279		
크레인	(트럭 10ton)	0.61	시간	56,768	34,627	30,167	18,401	5,391	3,288	21,210	12,
합 계					48,882		32,377		3,567		12,
제 2 호표											
중량구조물설치	(1150~1500kg미만)		개								
특별인부		0.07	인	66,422	4,649	66,422	4,649				
보통인부		0.24	인	52,585	12,620	52,585	12,620				
기구손료	인건비의 %	2.	%	17,269	345			17,269	345		
크레인	(트럭 10ton)	0.76	시간	56,768	43,142	30,167	22,926	5,391	4,097	21,210	16,
합 계					60,756		40,195		4,442		16,
제 3 호표											
중량구조물설치	(1500~2000kg미만)		개								
특별인부		0.09	인	66,422	5,977	66,422	5,977				
보통인부		0.3	인	52,585	15,775	52,585	15,775				
기구손료	인건비의 %	2.	%	21,752	435			21,752	435		
크레인	(트럭 10ton)	0.96	시간	56,768	54,496	30,167	28,960	5,391	5,175	21,210	20,
합 계					76,683		50,712		5,610		20,
제 4 호표											
중량구조물설치	(2000~2500kg미만)		개								
특별인부		0.11	인	66,422	7,306	66,422	7,306				
보통인부		0.38	인	52,585	19,982	52,585	19,982				
기구손료	인건비의 %	2.	%	27,289	545			27,289	545		
크레인	(트럭 10ton)	1.2	시간	56,768	68,121	30,167	36,200	5,391	6,469	21,210	25,

Assignment 2: 물량산출