PROJECT MANAGEMENT
CENTER FOR EXCELLENCE
A.J. CLARK SCHOOL OF ENGINEERING
Civil & Environmental Engineering Department

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PROFIT MAXIMIZATION AND STRATEGIC MANAGEMENT FOR CONSTRUCTION PROJECTS

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Overview

- Resource Allocation Business as Usual
- Strategic and Business Attitude
- Modelling for Success
  - Mathematical Formulation of the Tool
  - Case Study and Results
- Questions?

Resource Allocation Business as Usual

WHAT IS IT AND WHY IS IT NO LONGER ACCEPTABLE?

Resource Allocation Business as Usual

- Traditionally projects are scheduled with an assumption that resources are limitless and available
- The main reason was the complexity of analysis and the trouble associated with losing the critical path

Strategic and Business Attitude

HOW TO MAKE IT BETTER?

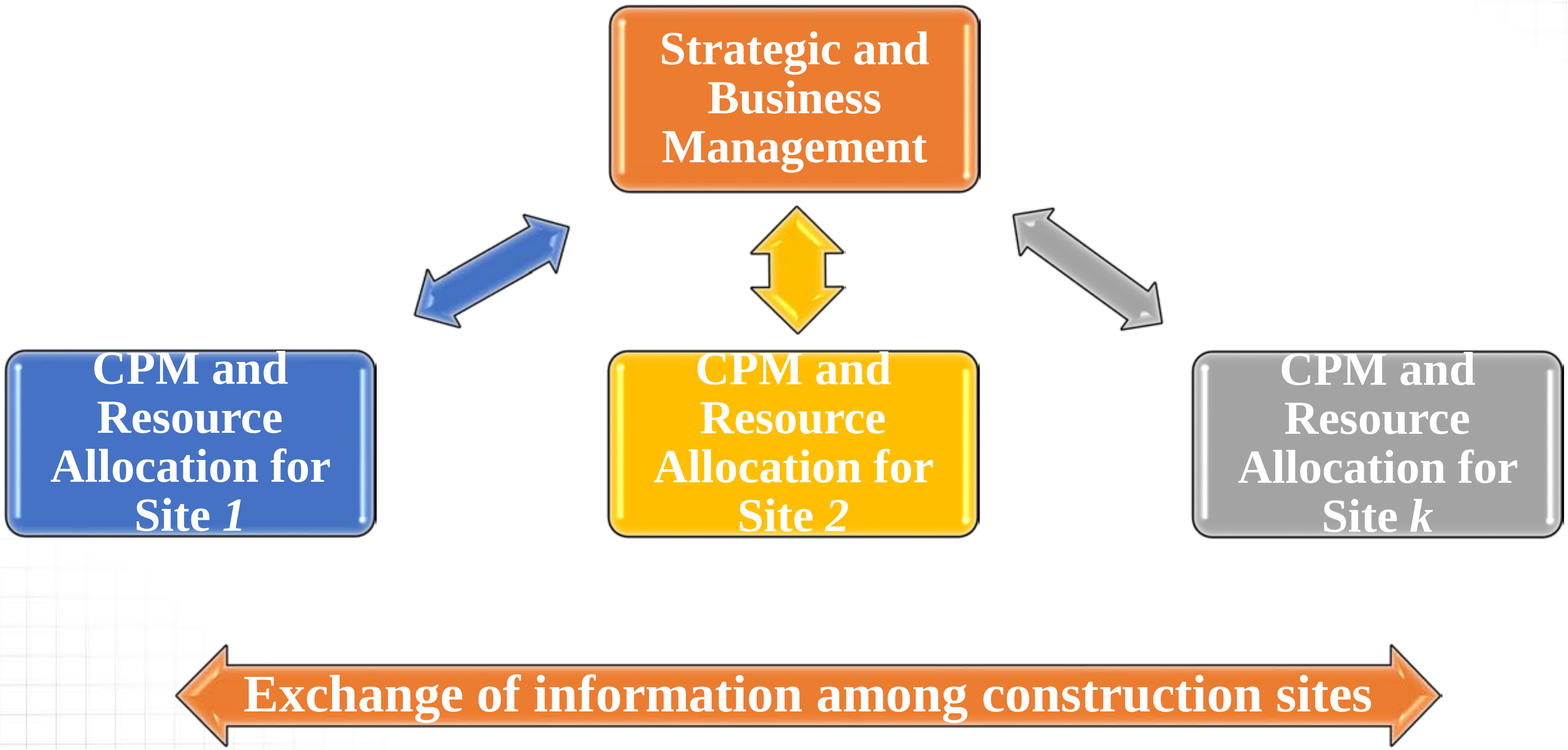
Competition

- Competition acts as a driving force in the industry and companies try to become more cost effective and profitable
- Competition also makes the margin of potential profit smaller and smaller.

Managing and Competing for Projects

- When companies have more than one project resource allocation may become more challenging.
- When combined with the requirements from stakeholders and financial limitations the decision-making becomes more challenging.

Schematic Representation



Modelling for Success

WHAT IS IMPORTANT AND HOW TO DO IT?

Mathematical Formulation of the Tool

- With Management Science applications along with carefully designed constraints informed decision-making becomes easier
- The key of success is to identify the limitations that actually make a difference in decision-making and formulate those as constraints

Mathematical Model

- First lets discuss unlimited resource availability case
- Next the limited availability will be discussed

Notation

I	=	set of origin where activity starts
J	=	set of destination where activity finishes, J* is the last element in the set
TD	=	total duration right hand sight value where necessary
R_k	=	construction resource types right hand sight value where necessary (e.g. material, labor, budget, time, stakeholder needs, sustainability, etc.) k∈K
R_{ijk}	=	usage of resource type k for activity ij i∈I, j∈J, k∈K
CC_{ij}	=	cost of crashing activity ij i∈I, j∈J
L_{ij}	=	right hand side value as limitation on crashing activity ij i∈I, j∈J
La_{ij}	=	estimate of the activity's crashing duration under the most favorable conditions
Lb_{ij}	=	estimate of the activity's crashing duration under the least favorable conditions
Lm_{ij}	=	most likely value for the activity's crashing duration
ta_{ij}	=	estimate of the activity's duration under the most favorable conditions
tb_{ij}	=	estimate of the activity's duration under the least favorable conditions
tm_{ij}	=	most likely value for the activity's duration

Notation

Decision variables

x_i and x_j	=	**start and finish times of activity ij, i∈I, j∈J**
CT_{ij}	=	crashing duration of activity ij, i∈I, j∈J where applied
Z	=	objective function value

Mathematical Model

- Objective function:

$$\min Z = x_{J*} - x_1 \qquad (1)$$

- Subject to:

$$x_j \geq x_i + t_{ij} \quad \forall\ i \in I,\ j \in J \qquad (2)$$

$$x_i\ and\ x_j\ URS \quad \forall\ i \in I,\ j \in J \qquad (3)$$

Mathematical Model - limits

- Objective function:

$$\min Z = \sum_0^{J*} CC_{ij} * CT_{ij} \qquad (4)$$

- Subject to:

$$CT_{ij} \leq L_{ij} \qquad \forall\ i \in I,\ j \in J \qquad (5)$$

$$x_j \geq x_i + t_{ij} - CT_{ij} \qquad \forall\ i \in I,\ j \in J \qquad (6)$$

$$x_{J*} - x_1 \leq TD \qquad \forall\ i \in I,\ j \in J \qquad (7)$$

$$CT_{ij} \geq 0 \qquad \forall\ i \in I,\ j \in J \qquad (8)$$

$$x_i \ and\ x_j\ URS \qquad \forall\ i \in I,\ j \in J \qquad (9)$$

Mathematical Model - combined

- Objective function:

$$\min Z = x_{J*} + \sum_{0}^{J*} CC_{ij} * CT_{ij} - x_1 \qquad (10)$$

- Subject to:

$$CT_{ij} \leq \frac{(La_{ij}+4Lm_{ij}+Lb_{ij})}{6} \qquad \forall\ i \in I,\ j \in J \qquad (11)$$

$$x_j \geq x_i + \frac{(ta_{ij}+4tm_{ij}+tb_{ij})}{6} - CT_{ij} \qquad \forall\ i \in I,\ j \in J \qquad (12)$$

$$x_{J*} - x_1 \leq TD \qquad \forall\ i \in I,\ j \in J \qquad (13)$$

$$CT_{ij} \geq 0 \qquad \forall\ i \in I,\ j \in J \qquad (14)$$

$$x_i\ and\ x_j\ URS \qquad \forall\ i \in I,\ j \in J \qquad (15)$$

Mathematical Model - SMCP

- Objective function of SMCP:

$$\min Z = x_{J*} + \sum_0^{J*} CC_{ij} * CT_{ij} + \sum_0^{J*} \dots \dots \dots - x_1 \quad (16)$$

- Subject to:

$$CT_{ij} \le \frac{(La_{ij}+4Lm_{ij}+Lb_{ij})}{6} \quad \forall\ i \in I,\ j \in J \quad (17)$$

$$x_j \ge x_i + \frac{(ta_{ij}+4tm_{ij}+tb_{ij})}{6} - CT_{ij} \quad \forall\ i \in I,\ j \in J \quad (18)$$

$$x_{J*} - x_1 \le TD \quad \forall\ i \in I,\ j \in J \quad (19)$$

$$\dots \dots R_{ijk} \dots \dots \le \dots R_k \dots \quad \forall\ i \in I,\ j \in J \quad (20')$$

$$CT_{ij} \ge 0 \quad \forall\ i \in I,\ j \in J \quad (21)$$

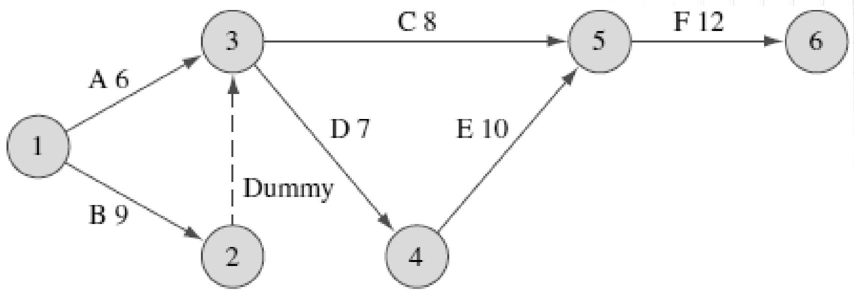
$$\mathrm{TPD} = (x_{J*} - x_1) \quad (22)$$

$$TPCC = \sum_0^{J*} CC_{ij} * CT_{ij} \quad (23)$$

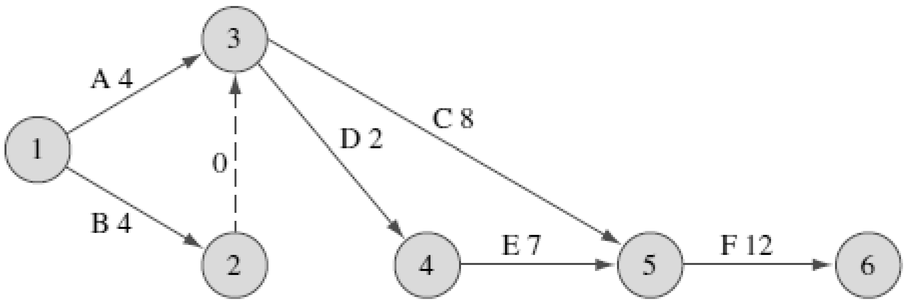
$$x_i \ and\ x_j\ URS \quad \forall\ i \in I,\ j \in J \quad (24)$$

Case Study and Results

Activity	Predecessors	Duration in Days
A	None	6
B	None	9
C	A and B	8
D	A and B	7
E	D	10
F	C and E	12



Activity	Crashing Cost Per Day ($)	Limit on Crashing Duration (Days)
A	10	5
B	20	5
C	3	5
D	30	5
E	40	5
F	50	5



Case Study and Results

Activity	Predecessors	Duration in Days		
		ta	tb	tm
A	None	5	13	9
B	None	2	10	6
C	A and B	3	13	8
D	A and B	1	13	7
E	D	8	12	10
F	C and E	9	15	12

LP OPTIMUM FOUND AT STEP 11

OBJECTIVE FUNCTION VALUE IS 415

VARIABLE	VALUE	REDUCED COST	VARIABLE	VALUE	REDUCED COST
X6	25	0	F	0	10
X1	0	0	X3	4	0
A	2	0	X2	4	0
B	5	0	X5	13	0
C	0	3	X4	6	0
D	5	0	TPD	25	0
E	3	0	TPCC	390	0

Case Study and Results

- Objective function value of SMCP as discussed above is not intuitive
- Values for Total Project Duration (TPD) and Total Project Crashing Cost (TPCC) (shaded cells) are reported as 25 days consistent with the constraint for duration limitation
- $390 as crashing cost

Case Study and Results

ROW	SLACK OR SURPLUS	DUAL PRICES	ROW	SLACK OR SURPLUS	DUAL PRICES
2)	3	0.00000	10)	6	0.00000
3)	0	10.00000	11)	0	-6.66667
4)	5	0.00000	12)	0	-6.66667
5)	0	10.00000	13)	0	-6.66667
6)	2	0.00000	14)	0	-30.00000
7)	5	0.00000	15)	0	39.00000
8)	0	-1.66667	16)	0	0.00000
9)	0	-5.00000	17)	0	0.00000

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QUESTIONS?