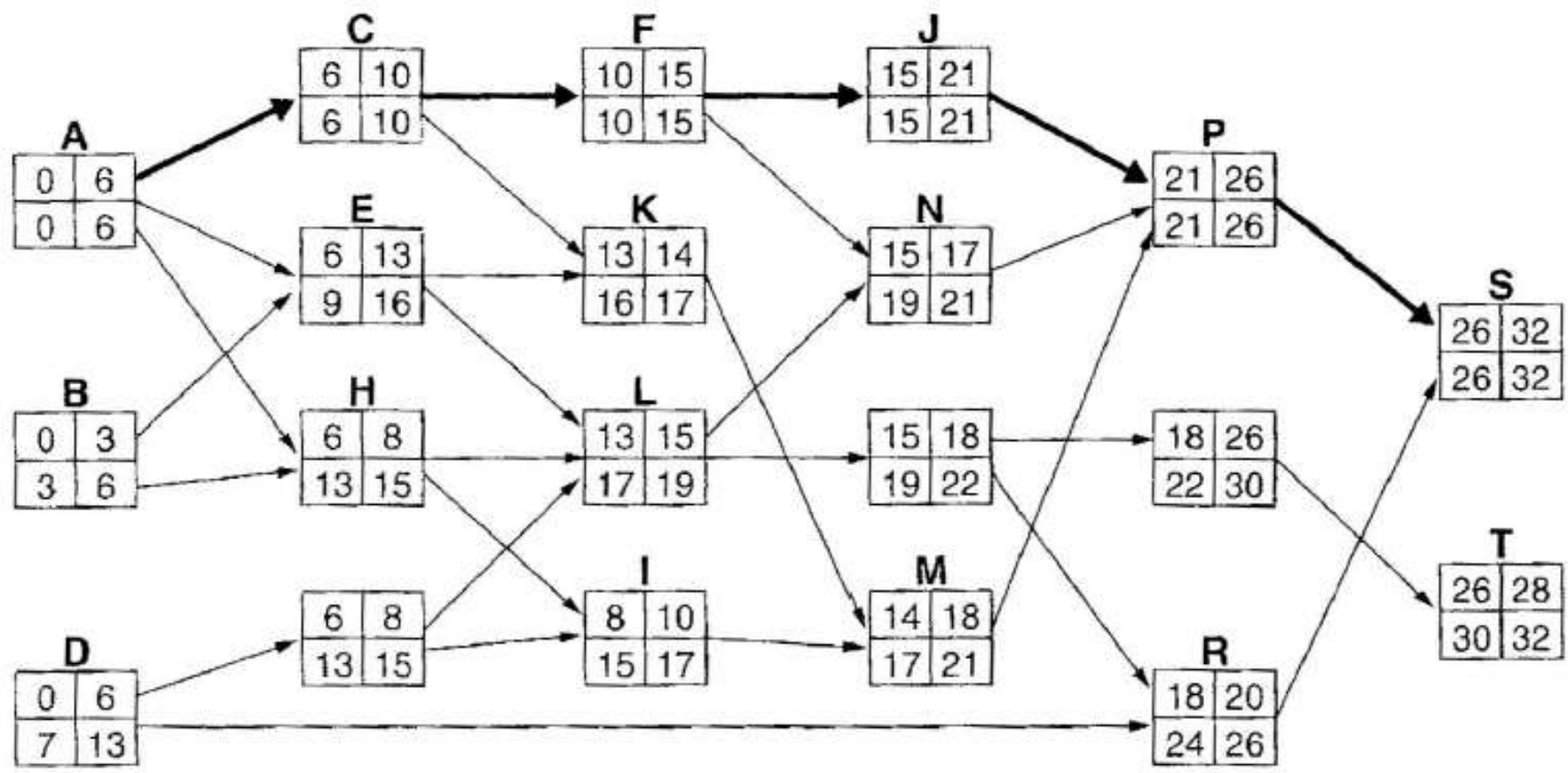
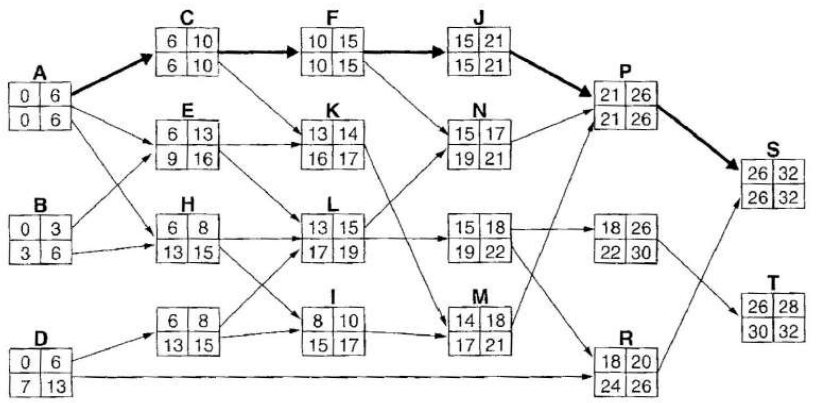


Multi-Skilled Resource Allocation

Activity Name	Duration (days)	Predecessor Activities	Resource Requirements per Day					
			R1	R2	R3	R4	R5	R6
A	6	---	5	2	2	2	7	4
B	3	---	3	5	2	3	9	6
C	4	A	2	4	4	2	3	1
D	6	---	5	4	3	5	5	4
E	7	A, B	3	5	2	3	8	0
F	5	C	4	1	4	9	2	5
G	2	D	4	1	4	3	9	8
H	2	A, B	5	5	4	0	9	1
I	2	G, H	3	2	4	3	4	2
J	6	F	1	5	4	6	7	3
K	1	C, E	3	3	2	4	5	1
L	2	E, G, H	3	2	2	8	3	4
M	4	I, K	2	2	2	2	4	8
N	2	F, L	1	4	4	3	4	1
O	3	L	5	5	4	6	2	3
P	5	J, M, N	3	2	3	4	7	8
Q	8	O	4	5	4	2	3	4
R	2	D, O	5	3	3	3	7	8
S	6	P, R	2	4	6	2	3	4
T	2	Q	1	6	2	7	5	2
Daily Resource Limits			7	10	10	16	18	13



Time	Eligible Activities	Resources						Late Start	Duration	Decision	Finish Time
		R1=7	R2=10	R3=10	R4=16	R5=18	R6=13				
0	A	5	2	2	2	7	4	0	6	Start	6
	B	3	5	2	3	9	6	6	3	Delay	-
	D	5	4	3	5	5	4	7	6	Delay	-
6	B	3	5	2	3	9	6	6	3	Start	9
	C	2	4	4	2	3	1	6	4	Start	10
	D	5	4	3	5	5	4	7	6	Delay	-
9	C	2	4	4	2	3	1	---	---	Continue	10
	D	5	4	3	5	5	4	7	6	Start	15
	E	3	5	2	3	8	0	9	7	Delay	-
	H	5	5	4	0	9	1	13	2	Delay	-
10	D	5	4	3	5	5	4	---	---	Continue	15
	E	3	5	2	3	8	0	9	7	Delay	-
	F	4	1	4	9	2	5	10	5	Delay	-
	H	5	5	4	0	9	1	13	2	Delay	-
15	E	3	5	2	3	8	0	9	7	Start	22
	F	4	1	4	9	2	5	10	5	Start	20
	G	4	1	4	3	9	8	13	2	Delay	-
	H	5	5	4	0	9	1	13	2	Delay	-



Activity Name	Duration (days)	Resource Requirements per Day					
		R1	R2	R3	R4	R5	R6
A	6	5	2	2	2	7	4
B	3	3	5	2	3	9	6
C	4	2	4	4	2	3	1
D	6	5	4	3	5	5	4
E	7	3	5	2	3	8	0
F	5	4	1	4	9	2	5
G	4	1	1	4	3	9	8
H	5	5	5	4	0	9	1
I	3	5	2	3	8	0	9
J	6	2	2	4	2	3	7
K	1	4	1	4	9	2	5
L	2	4	3	4	2	3	1
M	1	4	1	4	9	2	5
N	2	4	3	4	2	3	1
O	2	4	3	4	2	3	1
P	5	4	1	4	9	2	5
Q	3	5	2	3	8	0	9
R	2	4	3	4	2	3	1
S	6	5	2	2	2	7	4
T	2	4	3	4	2	3	1
U	8	3	5	2	3	8	0
V	2	4	3	4	2	3	1

Time	Eligible Activities	Resources						Late Start	Duration	Decision	Finish Time
		R1=7	R2=10	R3=10	R4=16	R5=18	R6=13				
20	E	3	5	2	3	8	0	—	—	Continue	22
	G	4	1	4	3	9	8	13	2	Start	22
	H	5	5	4	0	9	1	13	2	Delay	-
	J	1	5	4	6	7	3	15	6	Delay	-
22	H	5	5	4	0	9	1	13	2	Start	24
	J	1	5	4	6	7	3	15	6	Start	28
	K	3	3	2	4	5	1	16	1	Delay	-
24	J	1	5	4	6	7	3	—	—	Continue	28
	I	3	2	4	3	4	2	15	2	Start	26
	K	3	3	2	4	5	1	16	1	Start	25
	L	3	2	2	8	3	4	17	2	Delay	-
25	I	3	2	4	3	4	2	—	—	Continue	26
	J	1	5	4	6	7	3	—	—	Continue	28
	L	3	2	2	8	3	4	17	2	Delay	-
26	J	1	5	4	6	7	3	—	—	Continue	28
	L	3	2	2	8	3	4	17	2	Start	28
	M	2	2	2	2	4	8	17	4	Delay	-
28	M	2	2	2	2	4	8	17	4	Start	32
	N	1	4	4	3	4	1	19	2	Start	30
	O	5	5	4	6	2	3	19	3	Delay	-
30	M	2	2	2	2	4	8	—	—	Continue	32
	O	5	5	4	6	2	3	19	3	Start	33

Time	Eligible Activities	Resources						Late Start	Duration	Decision	Finish Time
		R1=7	R2=10	R3=10	R4=16	R5=18	R6=13				
32	O	5	5	4	6	2	3	—	—	Continue	33
	P	3	2	3	4	7	8	21	5	Delay	-
33	P	3	2	3	4	7	8	21	5	Start	38
	Q	4	5	4	2	3	4	22	8	Start	41
	R	5	3	3	3	2	8	24	2	Delay	-
38	Q	4	5	4	2	3	4	—	—	Continue	41
	R	5	3	3	3	2	8	24	2	Delay	-
41	R	5	3	3	3	7	8	24	2	Start	43
	T	1	6	2	7	5	2	30	2	Start	43
43	S	2	4	6	2	3	4	26	6	Start	49

- Scheduling with constrained resources, particularly skilled labor, is a major challenge for almost all construction projects. One of the promising solutions to this problem is to develop methods that optimize or better utilize the skilled workers already in the industry. Most resource allocation techniques, such as the heuristic procedure described earlier, assume single-skilled resources. To improve existing solutions, we will introduce some modifications to this heuristic procedure to consider multi-skilled resources.

Improving
Resource
Allocation
Utilizing
Multi-skilled
Resources

- A simple representation of the multiskill of resources can be in the form of a substitution rule, as follows: $2 R4 = 1 R2$; meaning that two of resource R4 are required to substitute a shortage of one R2 resource. One important assumption made here is that a rule applies to all members of its resources (e.g., if 2 steel fixers = 1 carpenter, then any two steel fixers can substitute one carpenter). This assumption becomes reasonable when a training mechanism is implemented for resources to be used in multiskill work assignments.

$$(2 R5 = 1 R1)$$

Time	Eligible Activity	Resources						Late Start	Duration	Decision	Finish Time	Substitution Rule Used
		R1=7	R2=10	R3=10	R4=16	R5=18	R6=13					
0	A	5	2	2	2	7	4	0	6	Start	6	2 R5 = 1 R1
	B	3-1	5	2	3	9+2	6	6	3	Start	3	
	D	5	4	3	5	5	4	7	6	Delay	-	
3	A	5	2	2	2	7	4	0	6	Continue	6	2 R5 = 1 R1
	D	5-3	4	3	5	5+6	4	7	6	Start	9	
6	D	5	4	3	5	5	4	7	6	Continue	9	
	C	2	4	4	2	3	1	6	4	Start	10	
	E	3	5	2	3	8	0	9	7	Delay	-	
	H	5	5	4	0	9	1	13	2	Delay	-	
9	C	2	4	4	2	3	1	6	4	Continue	10	
	E	3	5	2	3	8	0	9	7	Start	16	
	H	5	5	4	0	9	1	13	2	Delay	-	
	G	4	1	4	3	9	8	13	2	Delay	-	
10	E	3	5	2	3	8	0	9	7	Continue	16	
	F	4	1	4	9	2	5	10	5	Start	15	
	G	4	1	4	3	9	8	13	2	Delay	-	
	H	5	5	4	0	9	1	13	2	Delay	-	
15	E	3	5	2	3	8	0	9	7	Continue	16	
	G	4	1	4	3	9	8	13	2	Start	17	
	H	5	5	4	0	9	1	13	2	Delay	-	
	J	1	5	4	6	7	3	15	6	Delay	-	

16	G	4	1	4	3	9	8	13	2	Continue	17
	H	5	5	4	0	9	1	13	2	Delay	-
	J	1	5	4	6	7	3	15	6	Start	-
	K	3	3	2	4	5	1	16	1	Delay	22
17	J	1	5	4	6	7	3	15	6	Continue	22
	H	5	5	4	0	9	1	13	2	Start	19
	K	3	3	2	4	5	1	16	1	Delay	-
19	J	1	5	4	6	7	3	15	6	Continue	22
	I	3	2	4	3	4	2	15	2	Start	21
	K	3	3	2	4	5	1	16	1	Start	20
	L	3	2	2	8	3	4	17	2	Delay	-
20	I	3	2	4	3	4	2	15	2	Continue	21
	J	1	5	4	6	7	3	15	6	Continue	22
	L	3	2	2	8	3	4	17	2	Delay	-
21	J	1	5	4	6	7	3	15	6	Continue	22
	L	3	2	2	8	3	4	17	2	Start	23
	M	2	2	2	2	4	8	17	4	Delay	-
22	L	3	2	2	8	3	4	17	2	Continue	23
	M	2	2	2	2	4	8	17	4	Start	26
23	M	2	2	2	2	4	8	17	4	Continue	26
	N	1	4	4	3	4	1	19	2	Start	25
	O	5	5	4	6	2	3	19	3	Delay	-
25	M	2	2	2	2	4	8	17	4	Continue	26
	O	5	5	4	6	2	3	19	3	Start	28

26	O	5	5	4	6	2	3	19	3	Continue Start	28	2 R5 = 1 R1
	P	3-1	2	3	4	7+2	8	21	5		31	
28	P	3	2	3	4	7	8	21	5	Continue Start Delay	31	
	Q	4	5	4	2	3	4	22	8		36	
	R	5	3	3	3	7	8	24	2		-	
31	Q	4	5	4	2	3	4	22	8	Continue Start	36	2 R5 = 1 R1
	R	5-2	3	3	3	7+4	8	24	2		33	
33	Q	4	5	4	2	3	4	22	8	Continue Start	36	
	S	2	4	6	2	3	4	26	6		39	
36	S	2	4	6	2	3	4	26	6	Continue Start	39	
	T	1	6	2	7	5	2	30	2		38	