Resource Levelling for a Construction Project

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Abstract: Resources are required to carry out specific tasks in a project, but the availability of resources within a given firm is always limited. While preparing the schedule structure, the Project Manager might schedule certain tasks in parallel. In such cases it might be possible that the same resource is being used in both the parallel tasks, while its availability is limited. This paper emphasises how the Project Manager could resolve such conflicts by using Resource levelling in modern softwares such as Microsoft Project and Oracle Primavera. Resource levelling as defined by PMBOK is a "technique in which start and finish dates are adjusted based on resource constraints with the goal of balancing demand for resources with the available supply." It basically refers to solving over-allocation of resources for the given project. A resource is over allocated when scheduled to perform more work than possible within the resource's schedule. Resource levelling may be simple in which the given tasks are delayed until the given resources are available or they can be complex where the given resource might be deployed on multiple projects throughout the company, thus requiring levelling to be done at the company level instead of the individual project. If levelling is done on tasks which are not present on the critical path, the given project will not be delayed, but if the given tasks are critical then the project would be delayed. Hence, Resource levelling is a complex issue which needs to be resolved in order to avoid delays in the project. This paper uses a case study in order to portray how resource levelling could be done using Microsoft Project and what its effects are on the duration of the entire project. Key Words: Resource, Levelling, Schedule, Over-allocation, Critical

I. Introduction

1.1 Resource Levelling

The network technique focuses on time element and assumes that unlimited resources are available for assigning to the activities to satisfy the time schedule. But when resources are limited, the 'critical path' and 'slack' lose their significance. Activity may be delayed due to non-availability of resources as well as due to change in the sequence of tasks. The process of distribution of available resources to meet the objectives of various activities constituting a project is called 'Resource Allocation' or 'Resource Loading'. This is done in a way so that the project completion schedule is least affected. The act of tasking a project with people assigned to a bunch of tasks and making it so that they don't have to work overtime is called Resource Levelling.

Step 1: Allocate resources serially in time. That is, start with the first time-period (e.g. 1^{st} day, 1^{st} week etc.) and schedule all activities possible with the available resources. Then move on to the next time-period and repeat the same.

Step 2: When several activities are assigned for the same resources, give preference to the activities with least slack.

Step 3: Reschedule non-critical activities if possible so as to free resources for the critical activities.

In this process, originally non-critical activities may become critical and the completion time of the project may be stretched. Critical path, i.e. a path comprising of activities with zero slack may not remain 'critical' in strict sense of the term. After completing resource leveling, resource smoothing may be carried out for further optimization of the problem. Resource smoothing does not change the duration of the project; it only works on the non critical activities.

1.2 Types of Resource leveling

1.2.1 Delaying the task

If a resource is not available for a given task, the given task would be delayed. The software would first perform the activity which is given higher priority in the software. By default the softwares give the same priority to all tasks. The priority for all the tasks may be assigned at the time of preparation of the schedule structure. To control which tasks take precedence over other tasks, user can set project priorities, so that if the user is working with a common pool of resources among multiple projects, the right projects and tasks take precedence.

1.2.2 Splitting

Certain types of work may be interrupted in between execution, instead of listing these tasks as two separate activities; the given task may be split in two or more segments. But it is a well-known fact that when resources have to switch tasks or projects mid-stream, they lose time as they have to re-orient themselves to the work.

1.2.3 Overtime

The given resources may have to work overtime in order to complete the given work. They are paid more wages than that for the standard work hours which is specified by Work Overtime factor. This can level the resources only up to a certain extent and not beyond that.

1.2.4 Levelling

This may be done in two ways, that is automatic levelling or manual levelling. Manual Leveling is always preferred over automatic leveling as it gives much more control in decision making. Automatic leveling gives no control to the user and the software levels all the resources. The only really useful method is the manual resource levelling. It is just impossible for an application to take into account all the possible conditions and restrictions from the real world projects in order to produce good results through an automatic levelling. Just in case the levelling is done automatically, the project manager needs to review the schedule in detail to ensure the automatic schedule makes sense.

1.3 Process of Resource Leveling:

- i. Develop Work Breakdown Structure (WBS) to establish work elements constituting the project.
- ii. Determine inter-dependency among various work elements or activities/tasks and accordingly define logical sequence of the activities.
- iii. Quantify each work element in terms of time/other resources requirements.
- iv. Find out constraints, if any, external (e.g. government policies, law and order problem, inadequacies of infrastructure, etc.) and internal (e.g. poor choice of site, inadequacies in agreement with collaborators/consultants, technical incompetence, etc.).
- v. Review the work elements, their inter-dependencies and quantification, in the light of the identified constraints.
- vi. Develop a flow path of activities, satisfying the logic of interdependency of activities and constraints. Develop a time schedule of activities satisfying the logic of the flow path and time duration of the activities.
- vii. Check for any resource over-allocation either in the Resource Graph (Fig 2 to 9) or the Resource Sheet. (Fig 1) Any Over-allocations are indicated in red by the given software.
- viii. Level all the given resources to develop a revised schedule by using the leveling tool. The over-allocations indicated in red will no longer be seen on the software once this is done (Fig 10).

II. Case Study

This is a bridge construction project, where the schedule structure is prepared initially without considering any shortage in resources. Once the initial schedule is prepared, over allocations are checked for the resources. Resource over-allocation is resolved by carrying out manual levelling on the softwares. While carrying out resource levelling, some non critical activities turn into critical activities. The critical activities are given higher preference over the non critical activities. The following are the machineries which have been used on the site and are considered for resource levelling in this case study of the bridge project.

Table-1: Machineries used on site	
Transit Mixer	16
R.M.C. Plant	1
Concrete Pump	2
Tyre mounted crane	1
Hydraulic Pile Rig	2
Equivalent excavator	1
Hydraulic tipper and dumper	6
J.C.B.	2
Prestressing jacks	6

Table-1: Machineries used on site

		-	P CASE ST 2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd H
ID	Resource Name	Details	H2	H1	H2	H1	H2	H1	H2	H1	H2
-	Unassigned	Work									
1	RMC plant	Work	2990	5050	2100	1880	2150	5630	1000		
-	pler and pler cap (P14 -P21)	Work	190	610			1.000				
	portal plie frames (p22-27)	Work	1126	550							-
	cast in situ PSC box order standards spans (7 nos.)	Work	510	1300	790						
	Diaphragms	Work				1200	480				-
	pler and pler cap (AP1 - AP7)	Work	50	950							
	portal plie frames (AP8-10)	Work	840								
	cast in situ PSC box oirder standards spans (6 nos.)	Work		1160	1310	210					
	merging span on portal pier frame with existing flyover deck (P21-27)	Work	280	470							
	Diaphraoms	Work				470	450				-
	pler and pler cap (P0 -P1)	Work					294	310			-
	cast in situ PSC box oirder standards spans (8 nos.)	Work					29d 26d	1290	110		
	Diaphraoms	Work	-					310	250		
	pler and pler cap (PQ -P1)	Work					290	610	6.00		-
	cast in situ PSC box oirder standards spans (8 nos.)	Work	-				260	1290	254		-
	Dianhraoms	Work					200	730	250		-
	cast in situ PSC box olider obligatory span	Work					120	780	390		-
	Diaphraoms	Work					120	310			-
2	Transit Mixer	Work	10000					5840			
4	plie boring including concreting (P14-P27 14 locations)	Work	1880	360			0000	0090			
	plie cans(14nos)	Work	660	2140							
	pler and pler cap (P14 -P21)	Work	760	2140							
	prer and prer cap (P14 -P21) portal plie frames (p22-27)	Work	4480	2440							-
	portal pile frames (p22-27) pile boring including concreting (AP1-AP10_10 locations)	Work									-
		Work	1320 760	28d 324d							-
	ple caps(10nos.)		760								
	pler and pler cap (AP1 - AP7)	Work	200	3800							-
	portal plie frames (AP8-10)	Work	3360								
	plie boring including concreting (P0-P1 0 locations)	Work					80d 1720				
	plie caps(9nos.)	Work						280			
	pler and pler cap (P9 -P1)	Work					1160	1240			
	plie boring including concreting (P0-P1 0 locations)	Work					1440				
	plie caps(pnos.)	Work					1720	1880			
	pler and pler cap (P9 -P1)	Work					1166	2446			
3	Concrete Pump/Boom placer	Work	6380	8180			4000	2920			
	plie boring including concreting (P14-P27 14 locations)	Work	940	180							
	plie caps(14nos.)	Work	66d	2140							
	pler and pler cap (P14 -P21)	Work	380	1220							
	portal plie frames (p22-27)	Work	2240	1120							
	plie caps/ 10nos.)	Work	380	1620							
	pler and pler cap (AP1 - AP7)	Work	100	1900							
	portal pile frames (AP8-10)	Work	1680								
	ple boring including concreting (P9-P1 9 locations)	Work					400				
_	ple caps/ goos.)	Work					86d	140			
	pler and pler cap (P9 -P1)	Work					580	620			
	plie boring including concreting (P9-P1 9 locations)	Work					720				1
	ple caps(pnos.)	Work					860	946			
	pler and pler cap (PQ -P1)	Work					580	1220			-
4	Gantry /Tyre mounted cranes	Work	796	2930	2106	1880	10001576	4710	1000		
	cast In situ PSC box girder standards spans (7 nos.)	Work	510	1300	790						1
	Diaphragms	Work	510	1300	790	1200	480				-
	cast in situ PSC box olider standards spans (6 nos.)	Work	-	1160	1310	210					-
	merging span on portal pier frame with existing flyover deck (P21-27)	Work	250	470	1310	210					-
	Diaphragms	Work	200	4/0		470	450				-
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Name Salt PSC box ginder standards spans (8 nos.) Salt PSC box ginder standards spans (8 nos.) Salt PSC box ginder oblaadon span Salt PSC box ginder oblaadon span Salt PSC box ginder oblaadon span phin no oma (nockling concreting (P14-P27 14 locations) oma (nockling concreting (PP4-P3 10 locations) suitar (PSC) (PP4-P3 14 locations) suitar (nockling concreting (PF4-P3 14 locations) ming (nockling concreting (PF4-P3	Details Work Work Work Work Work Work Work Work	2nd Half H2 160d 940 660 470 470 330 4800 2820	1st Haif H1 324 180 140 160 90 70	2nd Half H2	1st Half	2nd Half H2 250 120 1120 400 720 340	730 780 310	2nd Half H2 11d 250 25d 39d	1st Haf	2nd Ha H2
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aring including concreting (AP1-AP10_10 locations) aring including concreting (P0-P1 0 locations) hoe loader)	Work		540	-1-14-1-111111111	10101010101010101010			-16-1-1-11111111111	1-	
hoe loader)		1980	420							<u> </u>
hoe loader)		1900	420		-	1200				-
	Work	-				1200				
	Work	1580	5860	4200	3760	3140				_
					3200	2149	29425	2000		10000
n situ PSC box girder standards spans (7 nos.)	Work	1020	2600	1580						
ragms	Work				2400	960				
n situ PSC box girder standards spans (6 nos.)	Work		2320	2620	420					
		560	940							
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situ PSC box olrder standards spans (8 nos.)	Work					520		220		
raoms	Work							500		
situ PSC box olrder standards spans (8 nos.)	Work	-				520	2580	500		
raoms	Work						1460	786		
situ PSC box olider obligatory span	Work					240	1550			_
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						7,969.68	8,519.32			
	Work (b						14,909.86		
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	Situ PEO Dox girder standards spans (8 nos.) Signa PEO Dox girder obligatory span ragms Raymout Charles Raymout Charles Raymout Charles Raymout Charles Datation (Ref Raymout Ref Raymout Ref	Signing Work Sign PSC box grider standards spans (8 nos.) Work Sign PSC box grider standards spans (8 nos.) Work Sign PSC box grider standards spans (8 nos.) Work Sign PSC box grider oblgatory span Work <	vigans vigat sitp PSC box grider standards spans (8 nos.) vigat situ PSC box grider standards spans (8 nos.) vigat situ PSC box grider standards spans (8 nos.) vigat situ PSC box grider oblgatory span vigat spans box grider oblgatory span vigat span	Work Work Col 20010 2011 PSC box priver standards spans (§ nos.) Work Image: Col Image: Col </td <td>Work Unit <th< td=""><td>Signs Signs <th< td=""><td>Tagens Work Star 942 Star 943 Star <th< td=""><td>Tagens State <t< td=""><td>Tagens Work Display Sec <th< td=""><td>Tagents State <</td></th<></td></t<></td></th<></td></th<></td></th<></td>	Work Unit Unit <th< td=""><td>Signs Signs <th< td=""><td>Tagens Work Star 942 Star 943 Star <th< td=""><td>Tagens State <t< td=""><td>Tagens Work Display Sec <th< td=""><td>Tagents State <</td></th<></td></t<></td></th<></td></th<></td></th<>	Signs Signs <th< td=""><td>Tagens Work Star 942 Star 943 Star <th< td=""><td>Tagens State <t< td=""><td>Tagens Work Display Sec <th< td=""><td>Tagents State <</td></th<></td></t<></td></th<></td></th<>	Tagens Work Star 942 Star 943 Star Star <th< td=""><td>Tagens State <t< td=""><td>Tagens Work Display Sec <th< td=""><td>Tagents State <</td></th<></td></t<></td></th<>	Tagens State State <t< td=""><td>Tagens Work Display Sec <th< td=""><td>Tagents State <</td></th<></td></t<>	Tagens Work Display Sec Sec <th< td=""><td>Tagents State <</td></th<>	Tagents State <

Fig-1: Resource Sheet showing over allocation in red and the activities for which the resource is allocated.

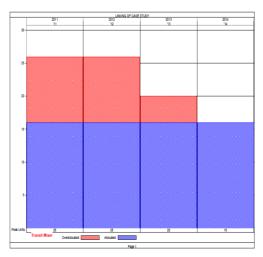


Fig- 2: Resource Graph of Transit Mixer showing over allocation

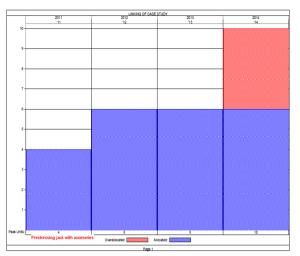


Fig- 3: Resource Graph of Prestressing jack showing over allocation

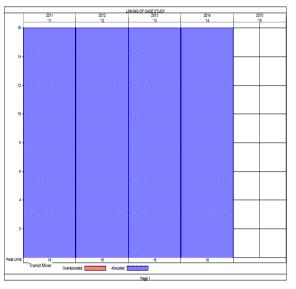


Fig- 4: Resource Graph of Transit Mixer after levelling

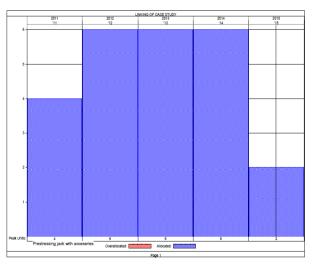


Fig- 5: Resource Graph of Prestressing Jack after levelling.

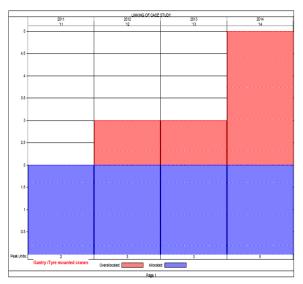


Fig- 6: Resource Graph of Tyre Mounted Crane showing over allocation

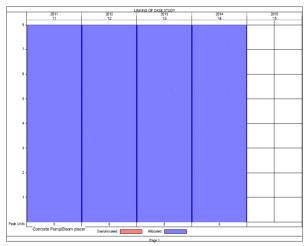


Fig- 7: Resource Graph of Concrete pump showing no over allocation

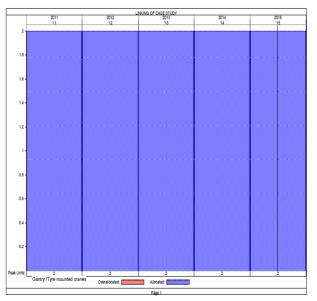
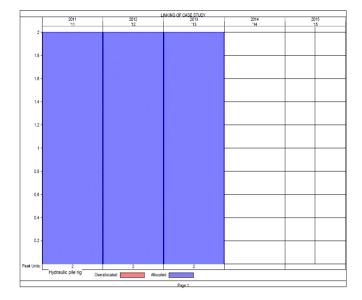


Fig- 8: Resource Graph of Tyre Mounted Crane after levelling



		Details	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Ha
D	Resource Name		H2	H1	H2	H1	H2	H1	H2	H1	H2	H1
	Unassigned	Work										
1	RMC plant	Work	299d	505d	210d	188d	215d	459d	157d	47d		
	pier and pier cap (P14 -P21)	Work	19d	61d								
	portal pile frames (p22-27)	Work	112d	56d								
	cast in situ PSC box girder standards spans (7 nos.)	Work	51d	130d	79d							
	Diaphragms	Work				120d	48d					
	pier and pier cap (AP1 - AP7)	Work	5d	95d								
	portal pile frames (AP8-10)	Work	84d									
	cast in situ PSC box girder standards spans (6 nos.)	Work		116c	131d	21d						
	merging span on portal pier frame with existing flyover deck (P21-27)	Work	28d	47d								
_	Diaphraoms	Work				47d	45d					
	pier and pier cap (P9 -P1)	Work					29d	31d				
	cast in situ PSC box girder standards spans (8 nos.)	Work					26d	129d	11d			
_	Diaphragms	Work							56d			
	pier and pier cap (P9 -P1)	Work	<u> </u>				29d	61d				
	cast in situ PSC box girder standards spans (8 nos.)	Work	<u> </u>				26d	129d	25d			
	Diaphragme	Work					200	1200	65d	47d		
-	cast in situ PSC box girder obligatory span	Work					12d	78d		470		
	Diaphragms	Work					140	31d				
2	Transit Mixer	Work	1,160d	1,428d	2044		768d	6164				
-	pile boring including concreting (P14-P27 14 locations)	Work	188d	360			1000	0100				
	pile caps(14nos.)	Work	56d	224d								
	pire caps(r4nos.) pier and pier cap (P14 -P21)	Work	00	3200								
_	portal pile frames (p22-27)	Work	372d	3200 300d								
	portai pile trames (p22-27) pile boring including concreting (AP1-AP10_10 locations)			280								
	pile bonng including concreting (AP1-AP10_10 locations) pile caps(10nos.)	Work	132d									
	pire caps(10nos.) pier and pier cap (AP1 - AP7)	Work	76d 0d	324d	204d							
	pier and pier cap (AP1 - AP7) portal pile frames (AP8-10)	Work	336d	1900	2040							
	portal pile frames (AP8-10)	Work	3366									
	pile boring including concreting (P9-P1 9 locations)	Work					80d					
	pile caps(9nos.)	Work					172d	28d				
	pier and pier cap (P9 -P1)	Work					116d	124d				
	pile boring including concreting (P9-P1 9 locations)	Work					144d					
	pile caps(9nos.)	Work					172d	188d				
	pier and pier cap (P9 -P1)	Work					84d	276d				
3	Concrete Pump/Boom placer	Work	590d	814d	52d		400d	292d				
	pile boring including concreting (P14-P27 14 locations)	Work	94d	18d								
	pile caps(14nos.)	Work	66d	214d								
	pier and pier cap (P14 -P21)	Work	Od	160d								
	portal pile frames (p22-27)	Work	224d	1120								
	pile caps(10nos.)	Work	38d	162d								
	pier and pier cap (AP1 - AP7)	Work	Od	148d	52d							
	portal pile frames (AP8-10)	Work	168d									
_	pile boring including concreting (P9-P1 9 locations)	Work					40d					
	pile caps(9nos.)	Work					86d	14d				
	pier and pier cap (P9 -P1)	Work					58d	62d				
	pile boring including concreting (P9-P1 9 locations)	Work					72d					
	pile caps(9nos.)	Work					86d	94d				
	pier and pier cap (P9 -P1)	Work					58d	122d				
4	Gantry /Tyre mounted cranes	Work	79d	260d	243d	188d	145d	258d	264d	61d		
	cast in situ PSC box girder standards spans (7 nos.)	Work	51d	130d	790							- and the second se
	Diaphragme	Work				120d	48d					

Fig- 9: Resource Graph of Hydraulic Pile Rig showing no over allocation

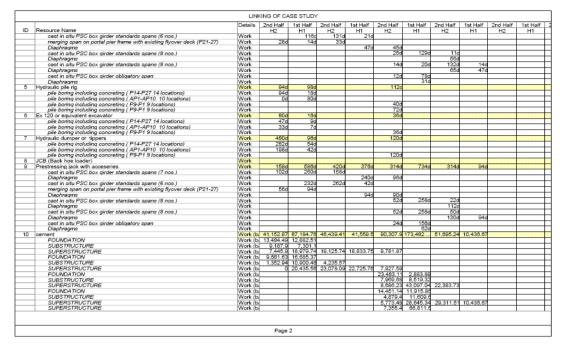


Fig- 10: Resource sheet after Resource Levelling

III. Conclusion

The initial schedule without resource levelling needs to be revised since there are over-allocations in the resources that have been used on the site. The resource over-allocation is thus rectified by resource levelling on Microsoft Project. The schedule may be further optimised by carrying out resource smoothing. The durations of the activities increase due to Resource Levelling but this step needs to be taken in order to resolve over-allocation of the resources present within a given firm. Certain changes can be made in the softwares such as Microsoft Project and Oracle Primavera wherein, activities consuming the same resource would not be allocated in parallel.

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