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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 taking 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. 1st day, 1st 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

LINKING OF CASE STUDY

ID	Resource Name	Details	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1	2nd Half H2
	Unassigned	Work									
1	RMC plant	Work	299d	505d	210d	188d	215d	563d	100d		
	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		116d	131d	21d					
	merging span on portal pier frame with existing flyover deck (P21-27)	Work	28d	47d							
	Diaphragms	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						31d	25d		
	pier and pier cap (P9 -P1)	Work					29d	61d			
	cast in situ PSC box girder standards spans (8 nos.)	Work					26d	129d	25d		
	Diaphragms	Work						73d	39d		
	cast in situ PSC box girder obligatory span	Work					12d	78d			
	Diaphragms	Work						31d			
2	Transit Mixer	Work	1,342d	1,450d			800d	584d			
	pile boring including concreting (P14-P27 14 locations)	Work	188d	36d							
	pile caps(14nos.)	Work	66d	214d							
	pier and pier cap (P14 -P21)	Work	76d	244d							
	portal pile frames (p22-27)	Work	448d	224d							
	pile boring including concreting (AP1-AP10 10 locations)	Work	132d	28d							
	pile caps(10nos.)	Work	76d	324d							
	pier and pier cap (AP1 -AP7)	Work	20d	380d							
	portal pile frames (AP8-10)	Work	336d								
	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					116d	244d			
3	Concrete Pump/Boom placer	Work	638d	818d			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	38d	122d							
	portal pile frames (p22-27)	Work	224d	112d							
	pile caps(10nos.)	Work	38d	162d							
	pier and pier cap (AP1 -AP7)	Work	10d	190d							
	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	293d	210d	188d	157d	471d	100d		
	cast in situ PSC box girder standards spans (7 nos.)	Work	51d	130d	79d						
	Diaphragms	Work				120d	48d				
	cast in situ PSC box girder standards spans (6 nos.)	Work		116d	131d	21d					
	merging span on portal pier frame with existing flyover deck (P21-27)	Work	28d	47d							
	Diaphragms	Work				47d	45d				

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LINKING OF CASE STUDY

ID	Resource Name	Details	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1	2nd Half H2
	cast in situ PSC box girder standards spans (8 nos.)	Work					26d	129d	11d		
	Diaphragms	Work						31d	25d		
	cast in situ PSC box girder standards spans (8 nos.)	Work					26d	129d	25d		
	Diaphragms	Work						73d	39d		
	cast in situ PSC box girder obligatory span	Work					12d	78d			
	Diaphragms	Work						31d			
5	Hydraulic pile rig	Work	160d	32d			112d				
	pile boring including concreting (P14-P27 14 locations)	Work	94d	18d							
	pile boring including concreting (AP1-AP10 10 locations)	Work	66d	14d							
	pile boring including concreting (P9-P1 9 locations)	Work					40d				
	pile boring including concreting (P9-P1 9 locations)	Work					72d				
6	Ex 120 or equivalent excavator	Work	80d	16d			36d				
	pile boring including concreting (P14-P27 14 locations)	Work	47d	9d							
	pile boring including concreting (AP1-AP10 10 locations)	Work	33d	7d							
	pile boring including concreting (P9-P1 9 locations)	Work					36d				
7	Hydraulic dumper or tippers	Work	480d	96d			120d				
	pile boring including concreting (P14-P27 14 locations)	Work	282d	54d							
	pile boring including concreting (AP1-AP10 10 locations)	Work	198d	42d							
	pile boring including concreting (P9-P1 9 locations)	Work					120d				
8	JCB (Back hoe loader)	Work									
9	Prestressing jack with acceseries	Work	158d	586d	420d	376d	314d	942d	200d		
	cast in situ PSC box girder standards spans (7 nos.)	Work	102d	260d	158d						
	Diaphragms	Work				240d	96d				
	cast in situ PSC box girder standards spans (6 nos.)	Work		232d	262d	42d					
	merging span on portal pier frame with existing flyover deck (P21-27)	Work	56d	94d							
	Diaphragms	Work				94d	90d				
	cast in situ PSC box girder standards spans (8 nos.)	Work					52d	258d	22d		
	Diaphragms	Work						62d	50d		
	cast in situ PSC box girder standards spans (8 nos.)	Work					52d	258d	50d		
	Diaphragms	Work						146d	78d		
	cast in situ PSC box girder obligatory span	Work					24d	156d			
	Diaphragms	Work						62d			
10	cement	Work (b	42,639.93	89,933.28	42,203.83	41,559.5	96,934.84	203,776.78	25,210.83		
	FOUNDATION	Work (b	13,484.49	12,882.51							
	SUBSTRUCTURE	Work (b	10,674.96	5,814.04							
	SUPERSTRUCTURE	Work (b	7,445.9	18,979.74	19,125.74	18,833.75	9,781.87				
	FOUNDATION	Work (b	9,681.63	16,685.37							
	SUBSTRUCTURE	Work (b	1,352.94	15,136.06							
	SUPERSTRUCTURE	Work (b	0	20,435.56	23,078.09	22,725.76	7,927.59				
	FOUNDATION	Work (b					23,483.11	2,883.89			
	SUBSTRUCTURE	Work (b					7,969.68	8,519.32			
	SUPERSTRUCTURE	Work (b					10,713.01	53,153.02	10,300.97		
	FOUNDATION	Work (b					14,451.14	11,915.86			
	SUBSTRUCTURE	Work (b					5,313.12	11,175.88			
	SUPERSTRUCTURE	Work (b					9,939.91	49,317.23	14,909.86		
	SUPERSTRUCTURE	Work (b					7,355.4	66,811.6			

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

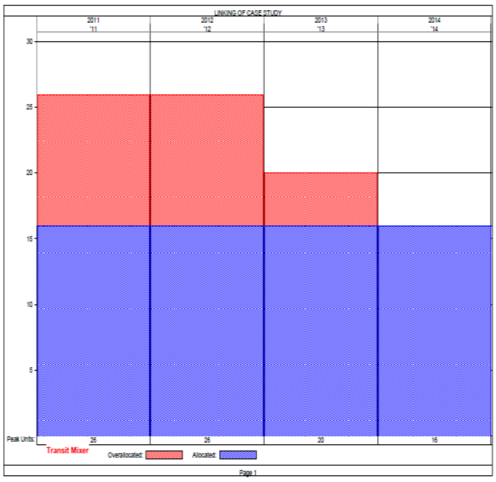


Fig- 2: Resource Graph of Transit Mixer showing over allocation

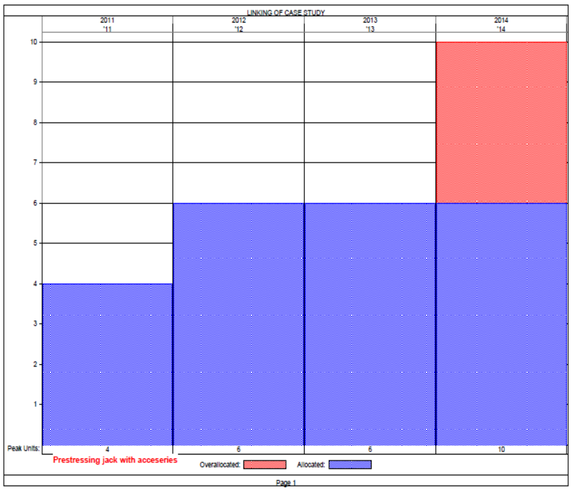


Fig- 3: Resource Graph of Prestressing jack showing over allocation

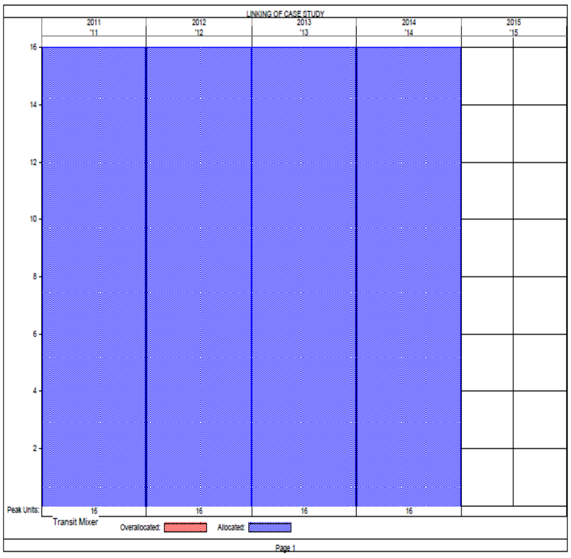


Fig- 4: Resource Graph of Transit Mixer after levelling

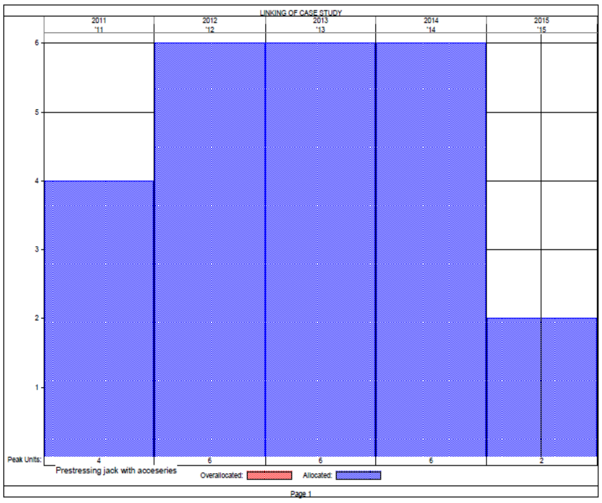


Fig- 5: Resource Graph of Prestressing Jack after levelling.

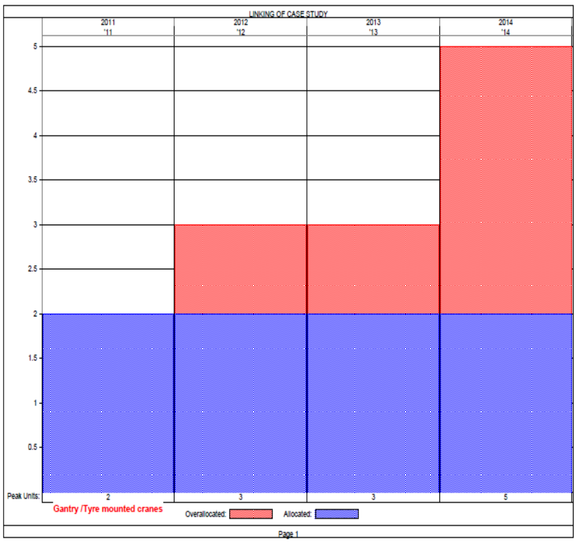


Fig- 6: Resource Graph of Tyre Mounted Crane showing over allocation

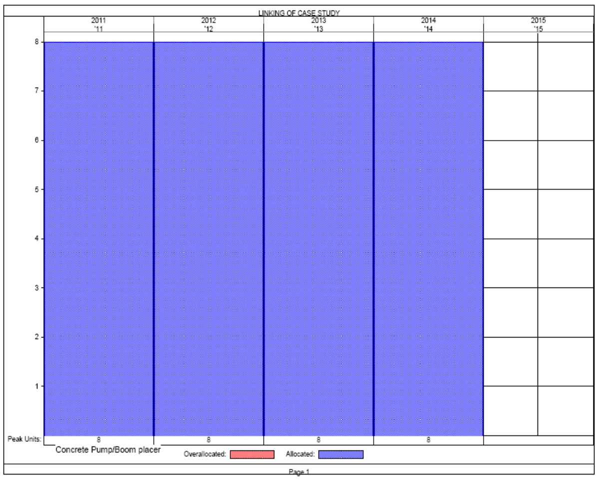


Fig- 7: Resource Graph of Concrete pump showing no over allocation

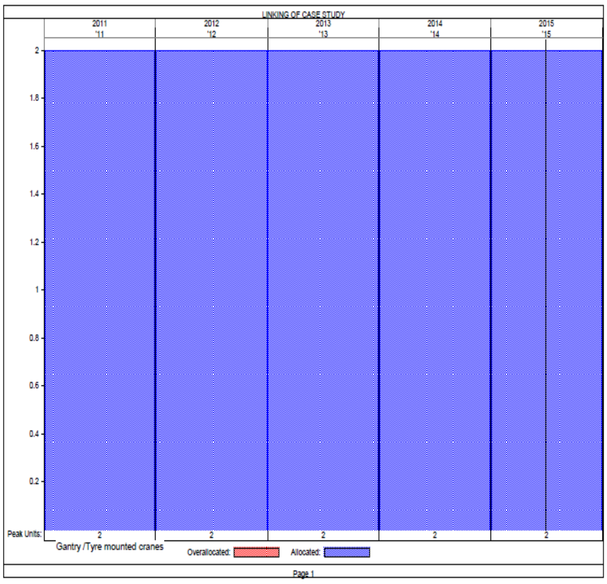
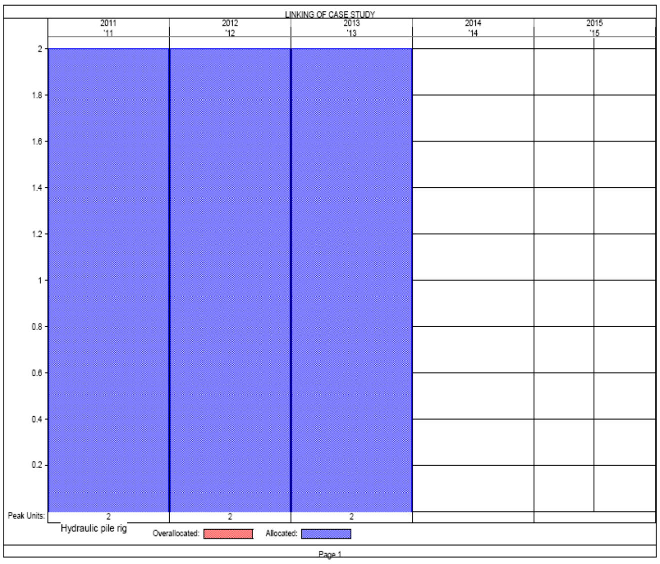


Fig- 8: Resource Graph of Tyre Mounted Crane after levelling



LINKING OF CASE STUDY

ID	Resource Name	Details	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1	2nd Half H2	1st Half 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		116d	131d	21d						
	merging span on portal pier frame with existing flyover deck (P21-27)	Work	28d	47d								
	Diaphragms	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					29d	61d				
	cast in situ PSC box girder standards spans (8 nos.)	Work					26d	129d	25d			
	Diaphragms	Work							65d	47d		
	cast in situ PSC box girder obligatory span	Work					12d	78d				
	Diaphragms	Work						31d				
2	Transit Mixer	Work	1,160d	1,428d	204d		768d	616d				
	pile boring including concreting (P14-P27 14 locations)	Work	188d	36d								
	pile caps(14nos.)	Work	56d	224d								
	pier and pier cap (P14 -P21)	Work	0d	320d								
	portal pile frames (p22-27)	Work	372d	300d								
	pile boring including concreting (AP1-AP10 10 locations)	Work	132d	28d								
	pile caps(10nos.)	Work	76d	324d								
	pier and pier cap (AP1 -AP7)	Work	0d	196d	204d							
	portal pile frames (AP8-10)	Work	336d									
	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	0d	160d								
	portal pile frames (p22-27)	Work	224d	112d								
	pile caps(10nos.)	Work	38d	162d								
	pier and pier cap (AP1 -AP7)	Work	0d	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	79d							
	Diaphragms	Work				120d	48d					

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

LINKING OF CASE STUDY												
ID	Resource Name	Details	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1	2nd Half H2	1st Half H1
	cast in situ PSC box girder standards spans (6 nos.)	Work		116d	131d	21d						
	merging span on portal pier frame with existing flyover deck (P21-27)	Work	28d	14d	33d							
	Diaphragms	Work				47d	45d					
	cast in situ PSC box girder standards spans (8 nos.)	Work					26d	129d	11d			
	Diaphragms	Work							56d			
	cast in situ PSC box girder standards spans (8 nos.)	Work					14d	20d	132d	14d		
	Diaphragms	Work							65d	47d		
	cast in situ PSC box girder obligatory span	Work					12d	78d				
	Diaphragms	Work						31d				
5	Hydraulic pile rig	Work	94d	98d			112d					
	pile boring including concreting (P14-P27 14 locations)	Work	94d	18d								
	pile boring including concreting (AP1-AP10 10 locations)	Work	0d	80d								
	pile boring including concreting (P9-P1 9 locations)	Work					40d					
	pile boring including concreting (P9-P1 9 locations)	Work					72d					
6	Ex 120 or equivalent excavator	Work	80d	16d			36d					
	pile boring including concreting (P14-P27 14 locations)	Work	47d	9d								
	pile boring including concreting (AP1-AP10 10 locations)	Work	33d	7d								
	pile boring including concreting (P9-P1 9 locations)	Work					36d					
7	Hydraulic dumper or tippers	Work	480d	96d			120d					
	pile boring including concreting (P14-P27 14 locations)	Work	282d	54d								
	pile boring including concreting (AP1-AP10 10 locations)	Work	198d	42d								
	pile boring including concreting (P9-P1 9 locations)	Work					120d					
8	JCB (Back hoe loader)	Work										
9	Prestressing jack with acceseries	Work	158d	586d	420d	376d	314d	734d	314d	94d		
	cast in situ PSC box girder standards spans (7 nos.)	Work	102d	260d	158d							
	Diaphragms	Work				240d	96d					
	cast in situ PSC box girder standards spans (6 nos.)	Work		232d	262d	42d						
	merging span on portal pier frame with existing flyover deck (P21-27)	Work	56d	94d								
	Diaphragms	Work				94d	90d					
	cast in situ PSC box girder standards spans (8 nos.)	Work					52d	258d	22d			
	Diaphragms	Work							112d			
	cast in situ PSC box girder standards spans (8 nos.)	Work					52d	258d	50d			
	Diaphragms	Work							130d	94d		
	cast in situ PSC box girder obligatory span	Work					24d	156d				
	Diaphragms	Work						62d				
10	cement	Work (b	41,152.87	87,184.76	46,439.41	41,559.5	90,307.9	173,482…	51,695.24	10,436.67		
	FOUNDATION	Work (b	13,484.49	12,882.51								
	SUBSTRUCTURE	Work (b	9,187.9	7,301.1								
	SUPERSTRUCTURE	Work (b	7,445.9	18,979.74	19,125.74	18,833.75	9,781.87					
	FOUNDATION	Work (b	9,681.63	16,685.37								
	SUBSTRUCTURE	Work (b	1,352.94	10,900.48	4,235.57							
	SUPERSTRUCTURE	Work (b	0	20,435.56	23,078.09	22,725.76	7,927.59					
	FOUNDATION	Work (b					23,483.11	2,883.89				
	SUBSTRUCTURE	Work (b					7,969.68	8,519.32				
	SUPERSTRUCTURE	Work (b					8,686.23	43,097.04	22,383.73			
	FOUNDATION	Work (b					14,451.14	11,915.86				
	SUBSTRUCTURE	Work (b					4,879.4	11,609.6				
	SUPERSTRUCTURE	Work (b					5,773.48	28,645.34	29,311.51	10,436.67		
	SUPERSTRUCTURE	Work (b					7,355.4	66,811.6				

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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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