

Impact of Resource Pooling on Capacity Utilization of the Mechanical Resources in Government Sector

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Abstract

Government organization of Uttar Pradesh Public Works Department (India) traditionally segregate mechanical resources such as machineries, tools and plants etc. into centralized functional divisions such as Road divisions, Bridge divisions, Building divisions, Maintenance divisions, Mechanical divisions, Electrical and Mechanical divisions, National Highways divisions, P.M.G.S.Y. divisions, World Bank divisions etc. This organizational model is framed based on the fact of specific nature of jobs performed by a division with a view of higher quality of work and efficiency. These mechanical resources are dedicated to the divisions to which they are allocated and perform the jobs related to that division only irrespective of the fact whether the division have scope of work or not. This model is challenged by the fact that higher resource utilization and greater efficiency is achieved when resources are centralized and could perform the jobs related to any division as and when the work is required. This paper examines work load characteristics of divisions to study the favourable conditions for centralization and decentralization of resources from resource utilization point of view.

Key Words: Mechanical resources in government organizations, Resource pooling, Capacity utilization.

Introduction

Government organizations are always under pressure to improve the quality of work i.e. the objective of the organization and decrease the operating cost by becoming more efficient. An organization can improve its performance and cut down the operating cost by efficiently organizing the execution of work. In government organization this is achieved by classifying different type of works performed by the government and grouping them according to their nature into individual departments thereby gaining efficiency in performance. Organizations, based on the specific nature of work performed by them become more specialized and gain efficiency in performance though focus of work.

In state of Uttar Pradesh (India), Public Works Department is concerned with construction and maintenance of different types of roads, bridges, buildings etc. across different districts of the state through different construction and maintenance divisions established at district level. At districts level, different mechanical resources are allocated to individual divisions based on nature of work performed by that division. In this paper we examine work load characteristics of divisions at district level to determine the conditions where dedicated mechanical resources are

more efficient and conversely where a common mechanical resource pool is more efficient from resource utilization point of view. This paper is organized as follows-

Resource Pooling

Cattani and Schmidt (2005) (1) had stated the pooling principle as, “*Pooling of customer demands along with pooling of resources used to fill those demands, may yield operational improvements*”. This principle leads to a conclusion that operational improvements may be achieved through resource pooling and forms a basis for this paper. The operational improvements through resource pooling may be sought in resource utilization and waiting time. To better understand the benefits of resource pooling, we need to compare a non pooled system with multiple sets of customer demands and multiple sets of resources with a pooled system where all demands and resources are pooled together to satisfy the customer demands.

Consider a Bank with dedicated counters for Cash Deposit, Cash with drawls, utility services, foreign exchange etc. A dedicated counter system is analogous to non pooled resource system. Here customers who arrive in the bank for any of the above mentioned services will join their respective counter queue and wait for their term to be processed by the counter server. The number of customers in every queue will vary depending upon the arrival rate of customers for specific service and respected service time. A situation may arrive when a long queue can be seen in front of Cash deposit counter where as the counter belonging to cash with drawl may be at rest due to no customer in front of the counter. This situation will result in Cash deposit server being busy and Cash with drawl server being idle, which is non beneficial for customer and bank as well, since long queue will result in longer waiting time to customer leading to increase in waiting cost and customer dissatisfaction, where as idleness of other server will lead to cost burden to bank associated with idleness of the server. Now consider the same bank with same number of counters serving to all types of customers irrespective of their specific needs i.e. customers are free to join any counter which can process all types of demands needed by a customer. This type of system is a pooled system where in different sets of resources are pooled to satisfy the needs of different sets of demands. In the case of pooled banking system, since every counter can process all types of customer demand, the average waiting time will reduce supported by the lower probability of all counters being busy when every counter server can process all types of demands, since waiting customer can be served by the idle server. Other than reduction in waiting time, there is one more benefit which could result from a pooled system, that is the greater utilization of the resources and even reduction in the number of servers required to fulfil the demand of the customers after verifying the actual requirement of servers needed. There may be other benefits resulting from the resource pooling but we limit ourselves to the resource utilization and optimizing the number of servers needed.

Hopp, W.J. and Spearman (2000) (2) had stated that advantage of pooling is credited to the reduction in variability due to portfolio effect under the situations where the characteristics of non pooled resource system are identical. The characteristics of the service systems dictate the magnitude of pooling benefits.

Overview of Public Works Department of Uttar Pradesh

The Public Works Department of Government of Uttar Pradesh is structured in divisional frame work, which are generally differentiated based on geographical locations and nature of work performed by the division. In the department the nature of jobs performed by individual divisions belong to Roads, Buildings and Bridges construction/ maintenance etc.. The divisions are established across all the districts in the state. A district can have many divisions of same nature

or different nature based on the size of the district, quantum of work and type of work available in that district. Type and number of mechanical resources which are allocated to divisions are primarily based on the type of work and quantum of work the division is expected to handle in the future. These mechanical resources are dedicated in nature and can only be utilized by the same division irrespective of whether the division have work load or not. Most of the time it happens that a division is either overloaded by work or underutilized having less work load which results in either over utilization or under utilization of installed capacity of the mechanical resources.

The Mechanical Resources which are allocated to individual divisions are of same type performing different types of works in different divisions.

Divisions	Mechanical Resources
D1	Truck, Tipper, Road Roller, Tractor, Air Compressor, Water Tanker
D2	Tipper, Road Rollers, Paver Finisher, Hot Mix Plant, Loader
D3	Truck, Road Rollers, Loader, Tractor, Water Tanker
D4	Truck, Road Roller, Tractor, Water Tanker

The above arrangement illustrates a general allocation of mechanical resources to individual divisions D1, D2, D3 and D4 in a district to perform the work belonging to respective division. These divisions utilize above mechanical resources depending on their needs as and when required.

Capacity Utilization

Johansen (1968) (3) had stated *Capacity utilization* as the extent to which an enterprise or a nation actually uses its installed productive capacity. Thus, it refers to the relationship between actual output that 'is' produced with the installed equipment and the potential output which 'could' be produced with it, if capacity was fully utilized.

Capacity utilization of mechanical resources allocated to individual divisions in U.P.P.W.D. solely depend on following factors-

1. Quantum of work available in division to be performed by mechanical resources.
2. Availability of mechanical resources when required.
3. Availability of funds to carry out the work allotted to division.
4. Favourable working conditions for mechanical resources to perform the desired work.

Above 4 factors are directly responsible for capacity utilization of mechanical resources allocated in individual divisions. Since resources are capable to be fully utilized to their potential output, if there is any short fall of utilization, the same shall be immediately encountered and means to increase the utilization shall be adopted by the division.

Since government organizations are engaged mostly in welfare activities to the society and do not face any competition for their survival, least attention is paid to performance measures.

According to Maruchek and McClelland (1992) (4), capacity utilization plays a major role in improving profitability compared with other strategic variables including market share, inventory, vertical integration and industry growth. This inference was further supported by another research by Achi et al. (1996) (5) stating that excellent capacity management can boost average annual returns on invested capital by as much as 3–4%. Therefore, capacity determination and utilization is of prime importance for any organization.

Our study is concerned with capacity utilization of the mechanical resources, to get an insight of existing level of capacity utilization of mechanical resources of divisions, we analyse the annual performance reports of different divisions in a district with a view of finding a better solution for enhancement of capacity utilization.

Performance analysis of machines working under different divisions:

While doing performance analysis of mechanical resources working under different divisions, Hand Book on Road Construction Machinery, Published by the Indian Road Congress on behalf of the Government of India, Ministry of Shipping and Transport (Roads Wing), (1985) (6) is referred for calculation of standard performance of machines.

Below is the case of Mechanical Division, P.W.D., Allahabad in which the performance of the road rollers working under the same division are analyzed for 3 consecutive year viz.- 2009-10, 2010-11 and 2011-12.

Table 1 – Performance of Road Rollers working under Mechanical Division, P.W.D., Allahabad

Sr. No.	Name of the M/c	2009-2010		2010-2011		2011-2012		Summary(from 2009-10 to 2011-12)			
		Performance	% age utilization	Performance	% age utilization	Performance	% age utilization	Performance	Avg. Performance/ Yr.	Std. Performance/ Yr (As per MOST)	Avg. % age utilization of M/c per Yr
1	Road Roller-2395	596.25	49.69%	635.75	52.98%	384.75	32.06%	1616.75	538.92	1200	44.91%
2	Road Roller-2396	622.00	51.83%	630.75	52.56%	395.75	32.98%	1648.50	549.50	1200	45.79%
3	Vibratory Roller-961	509.25	42.44%	607.75	50.65%	338.00	28.17%	1455.00	485.00	1200	40.42%

As we can analyze, for 3 consecutive years the road rollers working under Mechanical division, P.W.D., Allahabad are much underutilized to their installed capacity. Now the performance of the trucks working under Mechanical Division, P.W.D., Allahabad is analyzed during 2009-10, 10-11 and 11-12 and the results are as under –

Table 2 – Performance of trucks working under Mechanical Division, P.W.D., Allahabad

Sr. No.	Name of the M/c	2009-2010		2010-2011		2011-2012		Summary(from 2009-10 to 2011-12)			
		Performance (Kms)	% age utilization	Performance (Kms)	% age utilization	Performance (Kms)	% age utilization	Performance (Kms)	Avg. Performance/ Yr.	Std. Performance/ Yr (As per MOST)	Avg. % age utilization of M/c per Yr
1	Truck -9002	14123	56.49%	14336	57.34%	8304	33.22%	36763	12254	25000 Kms	49.02%
2	Truck -9115	13120	52.48%	15311	61.24%	5366	21.46%	33797	11266		45.06%
3	Truck -9347	13400	53.60%	14964	59.86%	9000	36.00%	37364	12455		49.82%
4	Truck -597	12800	51.20%	8908	35.63%	9417	37.67%	31125	10375		41.50%
5	Truck -9668	12700	50.80%	14378	57.55%	8120	32.48%	35198	11733		46.93%
6	Truck -8025	11606	46.42%	13226	52.90%	9991	39.96%	34823	11608		46.43%
7	Truck -8026	11785	47.14%	15954	63.82%	8641	34.56%	36380	12127		48.51%

As we can analyze, for 3 consecutive years the trucks working under Mechanical division, P.W.D., Allahabad are much underutilized to their installed capacity.

The above performance analysis relates to a single division at Allahabad district. To establish a relationship of performance of the similar kind of machines working under other divisions of

district Allahabad, we need to analyze the performance of machines working in other divisions also.

Below is the case of Provincial Division, P.W.D., Allahabad in which the performance of the road rollers working under the same division are analyzed for 3 consecutive year viz.- 2009-10, 2010-11 and 2011-12 are analyzed and the results are as under –

Table 3 – Performance of Road Rollers working under Provincial Division, P.W.D., Allahabad

Sr. No	Name of the M/c	2009-2010		2010-2011		2011-2012		Summary(from 2009-10 to 2011-12)			
		Performance	% age utilization	Performance	% age utilization	Performance	% age utilization	Performance	Avg. Performance/Yr.	Std. Performance(Hr)/Yr (As per MOST)	Avg. % age utilization of M/c per Yr
1	Road Roller 3338	519.00	43.25 %	432.00	36.00%	607.00	50.58%	1558.00	519°20'	1200	43.28%
2	Road Roller 2148	773.00	64.42 %	654.00	54.50%	548.00	45.67%	1975.00	658°20'		54.86%
3	Road Roller 10581	557.00	46.42 %	502.00	41.83%	487.00	40.58%	1546.00	515°20'		42.94%
4	Road Roller 3337	895.50	74.63 %	589.00	49.08%	539.00	44.92%	2023.50	674°30'		56.21%
5	Road Roller 4211	640.00	53.33 %	499.00	41.58%	571.00	47.58%	1710.00	570°		47.50%
6	Road Roller 10560	915.50	76.29 %	687.00	57.25%	603.50	50.29%	2206.00	735°20'		61.28%
7	Road Roller 10578	1221.00	101.7 %	702.00	58.50%	460.00	38.33%	2383.00	794°20'		66.19%
8	Road Roller 258	391.50	32.63 %	411.00	34.25%	499.00	41.58%	1301.50	433°50'		36.15%
9	Road Roller 22488	540.00	45.00 %	571.00	47.58%	557.00	46.42%	1668.00	556°		46.33%
10	Road Roller 5588	691.00	57.58 %	381.00	31.75%	643.00	53.58%	1715.00	571°40'		47.64%
11	Road Roller 11310	859.00	71.58 %	639.00	53.25%	703.00	58.58%	2201.00	733°40'		61.14%

As we can analyze, for 3 consecutive years the road rollers working under Provincial division, P.W.D., Allahabad are much underutilized to their installed capacity.

Now the performance of the Trucks working under Provincial Division, P.W.D., Allahabad is analyzed during 2009-10, 10-11 and 11-12 and the results are as under –

Table 4 – Performance of Trucks working under Provincial Division, P.W.D., Allahabad

Sr. No	Name of the M/c	2009-2010		2010-2011		2011-2012		Summary(from 2009-10 to 2011-12)			
		Performance (Kms)	% age utilization	Performance (Kms)	% age utilization	Performance (Kms)	% age utilization	Performance (Kms)	Avg. Performance/Yr.	Std. Performance(Km)/Yr As per MOST)	Avg. % age utilization of M/c per Yr
1	Truck-0039	6200	24.80%	15640	62.56%	7725	30.90%	29565	9855	25000	39.42%
2	Truck-9342	2500	10.00%	15408	61.63%	5012	20.05%	22920	7640		30.56%
3	Truck-9316	10313	41.25%	19524	78.10%	9240	36.96%	39077	13026		52.10%
4	Truck-2041	10634	42.54%	7572	30.29%	9987	39.95%	28193	9398		37.59%

As we can analyze, for 3 consecutive years the Trucks working under Provincial division, P.W.D., Allahabad are much underutilized to their installed capacity.

Below is the analysis of the road rollers working under Provincial division, P.W.D., Kaushambi-

Table 5 – Performance of Road Rollers working under Provincial Division, P.W.D., Kaushambi

Sr. No.	Name of the M/c	2009-2010		2010-2011		2011-2012		Summary(from 2009-10 to 2011-12)			
		Performance	% age utilization	Performance	% age utilization	Performance	% age utilization	Performance	Avg. Performance/Yr.	Std. Performance/Yr (As per MOST)	Avg. % age utilization of M/c per Yr
1	Road Roller 1225	519.00	43.25%	394.00	32.83%	459.50	38.29%	1372.50	457.50	1200	38.13%
2	Road Roller 1335	1004.00	83.67%	1281.00	106.75%	851.50	70.96%	3136.50	1045.50		87.13%
3	Road Roller 72492	1105.00	92.08%	633.50	52.79%	408.00	34.00%	2146.50	715.50		59.63%
4	Road Roller 30267	398.50	33.21%	636.00	53.00%	136.00	11.33%	1170.50	390.17		32.51%
5	Road Roller 3339	719.50	59.96%	697.00	58.08%	254.50	21.21%	1671.00	557.00		46.42%
6	Road Roller 10582	611.00	50.92%	589.00	49.08%	798.00	66.50%	1998.00	666.00		55.50%
7	Road Roller 11284	1075.50	89.63%	1183.50	98.63%	636.00	53.00%	2895.00	965.00		80.42%
8	Road Roller 25078	793.50	66.13%	1084.50	90.38%	464.50	38.71%	2342.50	780.83		65.07%
9	Road Roller 1981	853.50	71.13%	821.50	68.46%	274.00	22.83%	1949.00	649.67		54.14%

Table 6 – Performance of Trucks working under Provincial Division, P.W.D., Kaushambi

Sr. No	Name of the M/c	2009-2010		2010-2011		2011-2012		Summary(from 2009-10 to 2011-12)			
		Performance (Kms)	% age utilization	Performance (Kms)	% age utilization	Performance (Kms)	% age utilization	Performance (Kms)	Avg. Performance/Yr.	Std. Performance/Yr (As per MOST)	Avg. % age utilization of M/c per Yr
1	Truck-0035	8339	33.36%	3305	13.22%	1782	7.13%	13426	4475	25000	17.90%

Performance summary: Now summarizing the performance of m/cs for 3 consecutive years i.e. from 2009 to 2012 belonging to three divisions as below-
RoadRollers:

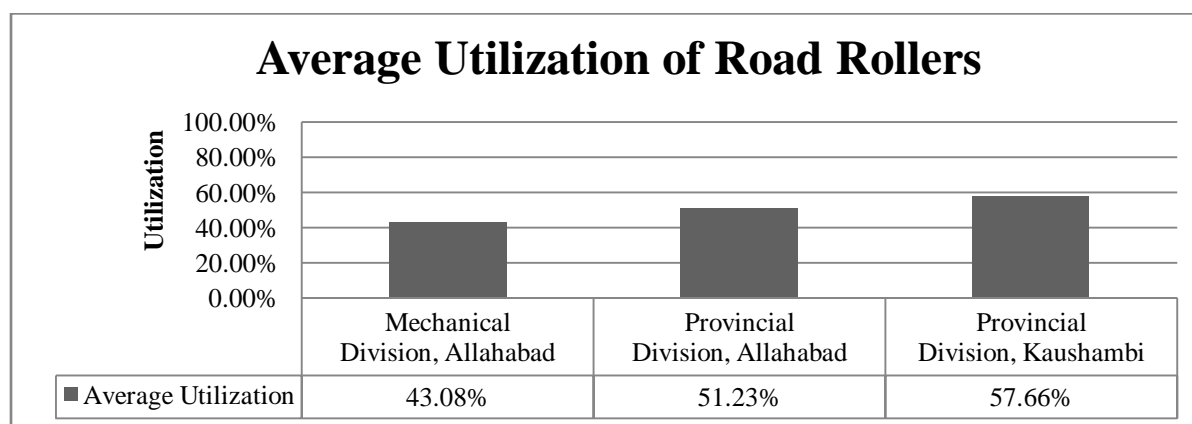


Figure – 1 Average utilization of Road Rollers of three divisions

Average performance from above data for Road Rollers employed under above 3 division -

$$= (43.08\% + 51.23\% + 57.66\%) / 3$$

$$= 50.65 \%$$

Trucks:

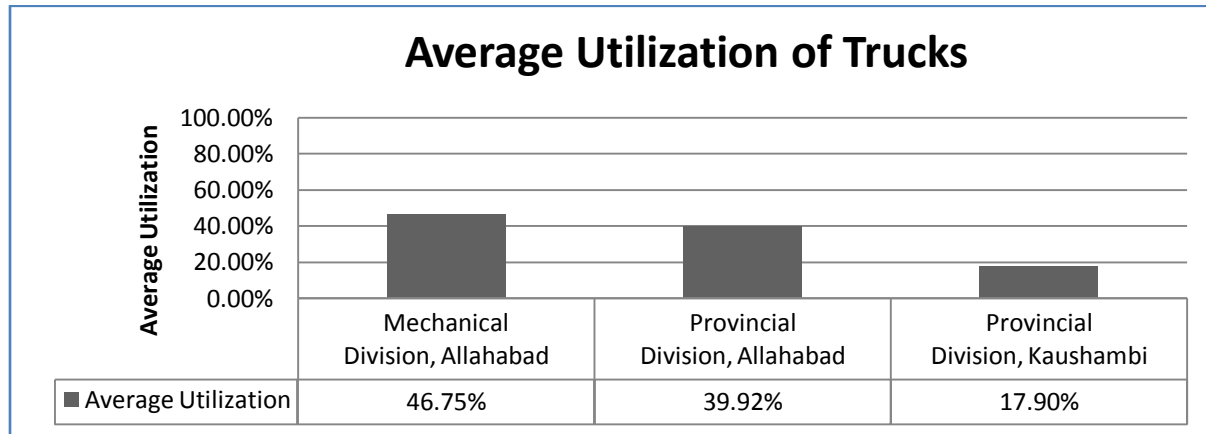


Figure – 2 Average utilization of Trucks of three divisions

Average performance from above data for Trucks employed under 3 divisions -

$$= (46.75\% + 39.92\% + 17.90\%) / 3 = 34.86\%$$

Analysis Result:

This analysis represent that the divisions having their own dedicated resources (machines) independently are not utilizing their installed capacities to fullest thereby wasting the capacity. From the analysis of above performance data, we can conclude that the road rollers employed under three divisions had an average performance of 50.65 % and trucks with an average performance of 34.86 % which are of course very low to their installed capacity resulting in huge amount of cost burden shouldered by the government. The impact of the cost can be calculated as below during three years –

The average performance of road rollers belonging to 3 divisions is equal to 50.65 % resulting in idle capacity $100.00 - 50.66 = 49.35\%$. The total no. of road rollers employed under three divisions are 23 with an overall performance of 50.65% which depicts that with $23 \times 50.65\% = 11.65\%$ say 12 nos. of road rollers were good enough to meet the work load with about 100% performance, so $23 - 12 = 11$ nos. of road rollers could have been either transferred to some other divisions to meet their work load or else these three divisions could have survived with employing 12 nos. of road rollers only thereby saving the total product cost of 11 road rollers and associated cost of wages of staff, other overheads and expenses, similarly for trucks also we can calculate as the total 12 no. of tippers working under three divisions with average performance of 34.86 % depict that $12 \times 34.86\% = 4.18$ say 4 Nos. of trucks were good enough to meet the work load of all three divisions resulting in about 100 % utilization of their installed capacity and thereby reducing the cost burden associated with additional $12 - 4 = 8$ nos. of trucks employed under three divisions.

The factors which are responsible for utilization of mechanical resources as discussed earlier, the appropriateness of resource allocation to any division is highly influenced by work availability. If consistently for 3 years, a division is running with low work load, to avoid resource wastage, the resource shall be shifted to some other division where work is available to utilize these resources. Considering the cost related with a resource, it can be classified in two heads, Fixed and Variable cost. Fixed cost is independent of the m/c utilization and emphasis shall be given to cut down this cost burden by making the m/c functional throughout the year thereby justifying this fixed cost on the work. For optimum resource utilization resources shall be shifted to other division where work is available to be performed by the resources.

Shifting of resource from one division to other requires numerous approvals, sanctions, statements and reasoning by concerned and responsible authorities and thereby consumes healthy amount of time keeping resources idle during the pendency of the shifting decisions. Again since unavailability of work load in a particular division is a temporary phase and later on the same division may be flooded with loads of work and hence would require resources back to perform the jobs in the parent division. In addition, shifting of resources attracts shifting cost required to transport resources from one division/ place to other division/ place. So the shifting of resources may not yield a solution for optimum resource utilization.

Dedicated Resource allocation

The resource allocation system which is followed by the department of U.P.P.W.D. at present is dedicated in nature, i.e. the resources which are allocated to individual divisions shall support the work load of that division only irrespective of the fact whether that division contains enough work to fully utilize the installed capacity of the resources or not. All the resources are owned by the government and are primarily responsible to support the government work, the divisions lack dynamism in auto allocation of resources in accordance to variable work load of different divisions. Consider a situation where a district has many divisions under the same department with mechanical resources allocated to every individual division to support the functioning of that division, not to forget that all the resources are owned by the same department. Since resource allocation is dedicated i.e. resources will perform the jobs of their parent divisions only, there could be three situations regarding the utilization of the resources under dedicated resource system –

1. Resource capacity is fully utilized

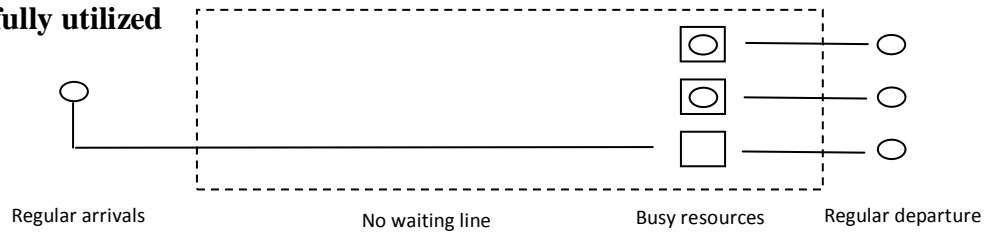


Figure – 3 Optimum work load division

2. Resource capacity is underutilized

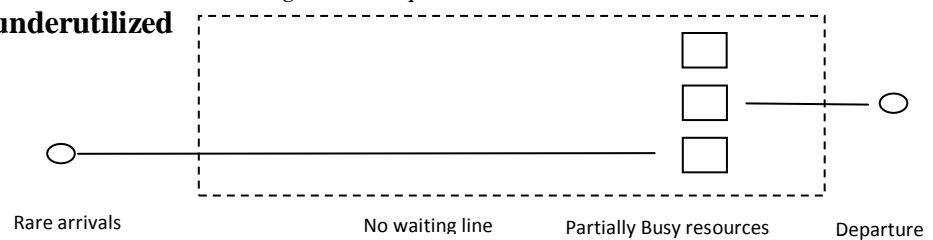


Figure – 4 Low work load division

3. Resource capacity is over utilized

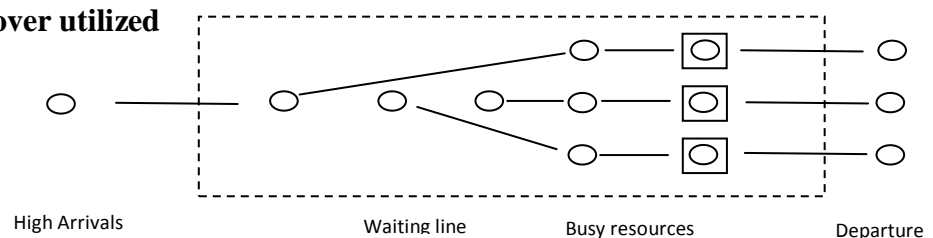


Figure – 5 Excess work load division

Common Resource Pool System

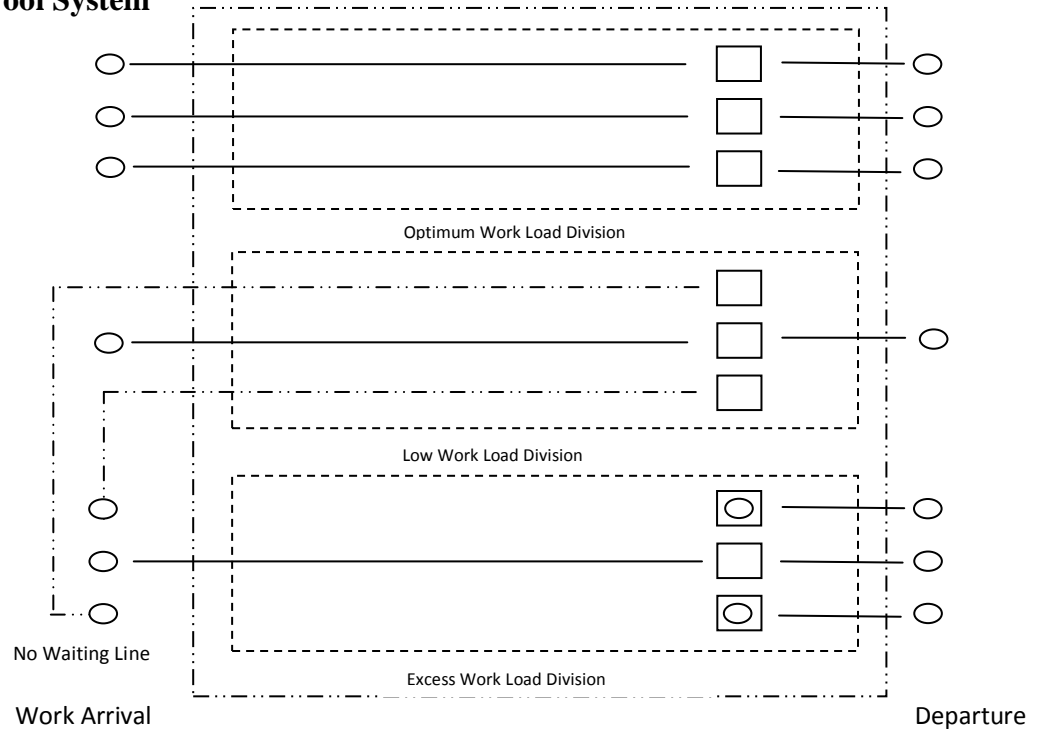


Figure – 6 Centralized resource pool system

Cattani and Schmidt (1) state that Pooling helps to mitigate the curse of variability and server pooling leads to greater server utilization. This principle guides to develop a better approach towards existing resource allocation. Figure-6 represents an ideal situation where dedicated resources belonging to individual divisions are pooled in a centralized system and are free to perform the jobs belonging to any division whenever any job comes to them.

Example

The benefit of centralized resource pool system can be well understood by following example- Consider a District 'X' with 6 numbers of divisions, working with dedicated resources allocated to individual divisions. The characteristics of different divisions, their work load, installed capacity of resources and existing utilization of resources is shown in the table-7. In the example, the total installed capacity of the resources in district 'X' is 7680 hours, where as the actual work load available is 6800 hours only. From the table-7 the effective resource utilization of the district 'X' is 82.55 % with a further scope of improvement of capacity utilization of the resources in the district 'X'. The excess work load of the division no. 1 and 6 which is 25.00 % and 10.94 % respectively, under dedicated resource allocation system is performed by some hired agency other than the department due to the fact that the dedicated resources of division 1 and 6 were busy, while during the same period, in the same district, the dedicated resources of division no. 3, 4 and 5 were underutilized and were free to take care of extra work load belonging to division 1 and 6. Under above situation, total work load of the district could have been performed by the total available resources of the district, since work load is much below to the installed capacity of the resources, if the resources were centrally allocated in the district and were free to support the work load belonging to any division of the district.

Table 7 – Performance of mechanical resources of District 'X' with six divisions under dedicated resource system

Division No.	Type of Division	Total Working hours available in a year (8 hrs/day x 20 days a month x 8 months in a year)	Work load hours required in year	Work load in excess or below in % of total resource hours available	% utilization of resources	Remarks
1	Excess work	1280	1600	+ 25.00 %	100.00	Additional resources reqd.
2	Balance work	1280	1280	0.00 %	100.00	Balance resource allocation
3	Low work	1280	800	- 37.50 %	62.50	Resources to be shifted
4	Low work	1280	725	- 43.36 %	56.64	Resources to be shifted
5	Low work	1280	975	- 23.83 %	76.17	Resources to be shifted
6	Excess work	1280	1420	+ 10.94 %	100.00	Additional resources reqd.
	Total	7680 Hrs.	6800 Hrs.		82.55	

Conclusions

A solution to above situation is to change to Centralized resource pool system, where resources are centrally located and can be utilized by any of the divisions of that district depending on the priority of the work and availability of the resources. The resources can be allocated to respective work directly thus maximizing the resource utilization, completing the work within the stipulated time period and averting the resource idleness resulting in minimization of cost impact related with resources.

Scope for future research

This paper is written keeping in view the existing resource allocation procedure followed by the department of U.P.P.W.D. at present. This paper reflects the trend of resource utilization in the past and suggest an alternate method of resource allocation to improve the resource utilization. Further micro level analysis is required to stress upon the key factors which are responsible for under utilization of the resources. This paper does not consider the work arrival rates and their processing time. Analysis related to resource unavailability due to their break down and its impact on utilization is left as future scope. A detailed queuing model representing the existing resource allocation system shall be made to simulate for optimum resource utilization. Future scope shall accommodate the cost impact caused due to misappropriations of resource allocation resulting in underutilization of the resources.

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