CREW FORMATION AND EVALUATION OF THEIR OUTPUT FOR SUB-BASE ACTIVITY IN ERA ASPHALT CONCRETE ROAD PROJECTS
CASE STUDAY IN
"SHASHEMENE-WONDOGENET-GEMETO ASPHALT CONCRETE ROAD PROJECT"

A Case Study Submitted in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Construction Engineering & Management at Jimma University, Jimma Institute of Technology, Department of Civil Engineering

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ABSTRACT

Construction productivity, which is measured by output per unit of resource, plays a key roll in the success of a construction project. High productivity leads to a lower cost to carryout a task or operation (YUN-YI SU; 2010). However, analyzing construction productivity is a challenging task because of the nature of construction field condition which contains complex resource flow that lacks the organized production lines of a manufacturing facility in a controlled and weather protected environment. Moreover, the wide variety of site condition has made the analysis difficult. Estimating actual output of resources from daily execution data can provide construction engineer with insightful information for productivity of resources on site. Estimating actual productivity is a key element in estimating the time and cost required to complete construction operations (Oglesby et al. 2002).

The primary purpose of this study is to conduct site observation to estimate actual out put of equipments and develop optimal crew formation for sub-base activity in road construction projects. This case study is conducted on shashemene-Wondogenet-Gemeto road up grading projects which is one of the Ethiopian Road Authority projects. The study is conducted on the road section from Km22+300.00 – Km23+300 for a total of 1km. Data is collected for actual out of equipments utilized in the operation. The actual output of equipments on site is used in composition the resources for optimal crew formation .The equipments utilized in this activity includes dozer, loader, grader, dump truck, water truck and pump. The day to day activities and the output of each equipment is registered by data collector and checked by the immediate foreman and site engineer. Data analysis is made for composition of equipments to eliminate idle hour or redundancy of equipments. Based on the analysis optimal and improved combination of these equipments is made and their combined out put is determined which is the standard crew output of sub-base activity.

According to the study and from the result of the analysis, the optimal crew formation for 1km of sub-base activity is one dozer, one loader, one grader, one loader five dump truck, one water truck and one pump. The combined out of the crew is 2,750m^3.

It is recommended that combination of equipments should be made by collecting and analyzing actual output of equipments on site and developing standard crew formation.

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CHAPTER ONE
INTRODUCTION

1.1 Background

Construction is the world's largest and one of most challenging industries (Michael Harber ;1988).Consequently, improving in the productivity of this industry will result in achieving lower construction cost and thus higher profit, which may translate into higher wages and ultimately higher standard of living.

The aim of every construction project sector is the completion of a project that meets the objective of time, cost and quality. However, the industry suffers from a no of problems that affect time, cost and quality performances (Ibrahim Mahamid; 2013).

Improper combination of resources which results in idle hour of equipments is one of the major factors that affect the successful completion of a project in time and cost. In order to avoid improper combination of equipments and to maximize the productivity, optimal crew formation should be formed. Crew formation is the term used for combination of equipments and allocating for execution of a particular task or activity.

Asphalt concrete pavement is one of the most widely used types of pavement all over the world in the road construction sector. As Ethiopia is investing huge amount of money for construction of asphalt concrete road projects to achieve the second growth and transformation programs, crew formation is crucial in timely and economically completion of road projects.

This study is conducted on crew formation of sub-base activity for Shashemene-Wendogenet-Gemeto Asphalt road project. Sub base is one of the pavement layers beneath the base-course in asphalt concrete pavement. The production of sub-base material needs heavy equipments like dozer and excavator. Loading, Hauling and placing of this material needs equipment like loader, dump trucks, grader, roller and water truck. These equipments will be combined and allocated for execution of this particular activity. The workforce to be used may vary but proper and optimal combination of these resources has to be made to avoid idle hours of equipments. In many road projects, there is unbalanced combination or grouping of these resources which results in idle hour of one or the other equipment. This idle hour of equipment will incur unnecessary additional cost to the contractor which finally affects the cash flow and intended profit from the project.

This study aims at identifying the equipments necessary for sub base activity and optimal composition of these equipments will be made to develop a standard crew formation and their combined output will be evaluated.

1.2 Statement of the problem

Ethiopia is investing a huge amount of money for the construction of road projects. Many new asphalt concrete road projects are being constructed in the country. In addition the government is working intensively on upgrading of the existing ones.

In spite of the high importance of the construction sector in Ethiopia, the industry suffers from a number of problems that affect time, cost and quality performances. The first potential weakness is that contractors never build the same project under the same working conditions with the same resources. The main reason is most of the contractors do not have specific requirement with respect to the composition of resources and crew composition is made with the experience of construction engineer using his knowledge of the available resources, workload and budget. As a result when the output of most crew is analyzed, a wide range of performance level will be observed. Usually, contractors will incur significant amount of money for idle hour of equipments due to unbalanced combination of resources.

For example, in placing sub-base activity if the number of water trucks is not balanced with the number of grader (i.e. if the output of the water truck available on site is less than that of the grader), the grader has to wait until the water truck supply the required quantity of water. Consequently, the grader will be subjected to idle hours. This idle hour of grader will incur additional unnecessary cost. The same is true for other resources.

Knowing the actual output of equipments and proper combination of equipments could be used in improving the productivity and determining the required resources for execution of the activities. While there are many factors that will impact a construction's productivity, for this research the emphasis has been placed on determining the optimal crew formation based on actual site output of equipments.

The aim of this study is to identifying the equipments necessary for sub base activity and checks their actual productivity on site. Moreover, the paper presents optimal combination of the equipments to determine crew formation and set standard output of the crew.

1.3 Research Questions

- What are the resources to be used for execution of sub-base activity?
- What is the output of these resources independently?
- Which quantitative combination of these resources is optimal? For Example how many dump trucks should be assigned for hauling of sub-base material from source to the working place without making the loader idle? The same is true for other equipments.
- What will be the combined output of these resources?

1.4 Objective of the Study

1.4.1 General Objective of the study

The general objective of this study is to develop standard crew formation for sub-base activity which will result in most economical and efficient utilization of resources by avoiding any unbalanced composition of resources.

1.4.2 Specific Objectives of the Study

In addition to the general objective, the specific objective of the research through the case study is

- To identify the resources needed for sub base activity and evaluate their output independently.
- To make optimal composition of these resources in order to effectively and efficiently utilize the resources.

- To evaluate the combined output of the resources and set productivity standard for the crew.

CHAPTER TWO
LITERATURE REVIEW

2.1 Definition

Crew Formation-is the composition of resources to work as a team for execution of a particular activity.

Optimal Crew Formation- is the most effective and efficient composition of resources in execution of a particular activity by avoiding the possible idle hours of equipments.

Sub-base – Sub-base is one of the pavement layers beneath the base-course in Hot Mix Asphalt Pavement design. It enables traffic stress to be reduced to acceptable level to the sub-grade. It acts as a working platform for the construction of the upper pavement layers. (ERA Pavement Design Manual Volume II; 2013)

2.2 Crew Productivity

Crew formation is the selection of optimal resources, combine and evaluate their combined output to set productivity standard. Its main objective is to analyze utilization of equipment and eliminate any unnecessary or redundant equipment to save money and reduce wastage of resources. Selection and optimum use of available resources are critical tasks for project management teams in heavy civil engineering projects. (Osama Moselhi & Adel Alshibani; January 2006).

In order to improve the productivity, efficiency and safety of road construction project effective planning, tracking and controlling system should be made. The main goal of planning in road operation is: (1) optimize the use of available resources; (2) balance resource throughout the project duration; (3) select suitable equipment for the work at hand; (4) complete projects with least cost and with in the given targeted duration (Redda; 1990).In planning of a project, crew formation is mandatory in order to set productivity standard of each activity. Productivity standards provide the basis for comparing current productivity rate, and the estimation of the cost and duration of a proposed cost.

However, the construction process is often fraught due to improper combination of resources which results in poor crew formation. The first potential weakness is that contractors never build the same project under the same working conditions with the same resources (Michael Harber; 1988). The main reason is different contractors have different crew formation for the same activity which will result in different output.

An essential part of every highway construction project is the section which specifies the contact time allowed for the project (Hancher, Donn E., and James E. Rowings: June 1981).However lack of proper crew formation is one of the major factors that will affect the timely completion of a project and its subsequent profit. Being able to effectively utilize the workforce and equipment can improve productivity, reduce costs, and make efficient use of resources for the road construction (Robert W. Schober, Stefanie G. Brandenburg, And Lansford C. Bell ; August 2008).

This case study is aimed at crew formation for sub-base activity and determine the output to set productivity standard. According to Andrian, the main method used in the construction industry to develop and measure productivity standards are by using historical accounting data, or by analyzing a work process and then developing a scientific standard method. The accounting based standard is based on historical data that has been collected from past projects using the contractor's cost control system. The work study method is one of the scientific based standard technique in which randomly measuring and observing a portion or sample of a work crew is made (Adrian, James J.; 1987).In this study, the second method is used in which data is collected from site for actual output of equipments. Moreover, results from studies on highway construction projects has indicated that productivity can be measured and analyzed at the project level based upon the field data of construction operation and that this is the most effective way of measuring productivity across a large construction projects in the transportation industry (Ellis, Ralph D. and Lee, Seung-hyun ; 2006).

Construction of sub-base activities consists of different sequential tasks. The crew consists of production, loading, hauling, Spreading, showering units and compaction units.
Different heavy Equipments are assigned for execution of each unit or task of the activities. The equipment assigned and their function is explained below.

- *Production Unit*

- Dozer - is a tractor unit which has a blade attached to its front. The blade is used to cut, push and roll the material ahead of the tractor. The main purpose of this equipment is for production of material.

❖ *Loading Unit*

- Loader - It is a bucket mounted equipment used for loading of material

❖ *Hauling Unit*

- Dump truck – for hauling of material from production area to the placing area.

❖ *Mixing, Showering and Spreading Unit*

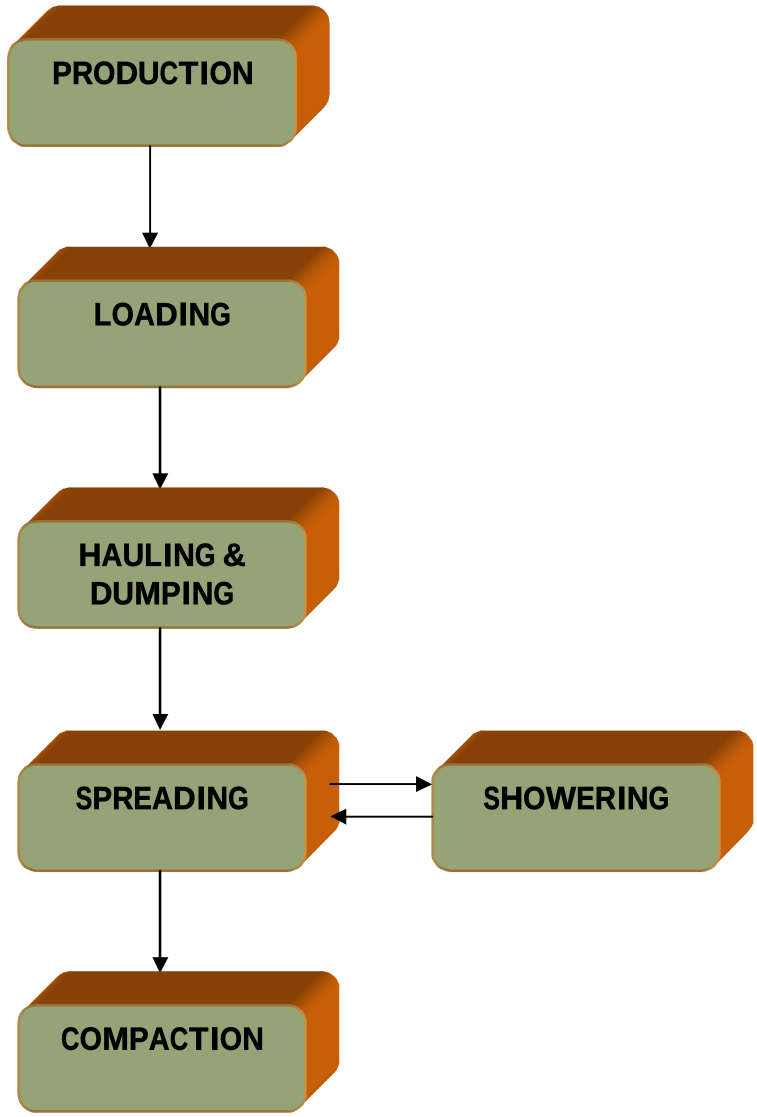
- Grader – is used for mixing and spreading of material to the required thickness. Water truck is used for showering to maintain the optimum moisture content of the material during mixing

❖ *Compaction Unit*

- Roller – used for compaction after spreading of the sub-base material is made.(R.L.Peurifoy, W.B Ledbetter and C.J. Schexnayder)

The following chart further explains the sequence of tasks involved in construction of sub-base activity.

Figure 1: Sequence of tasks in sub-base activity



CHAPTER THREE
METHODOLOGY

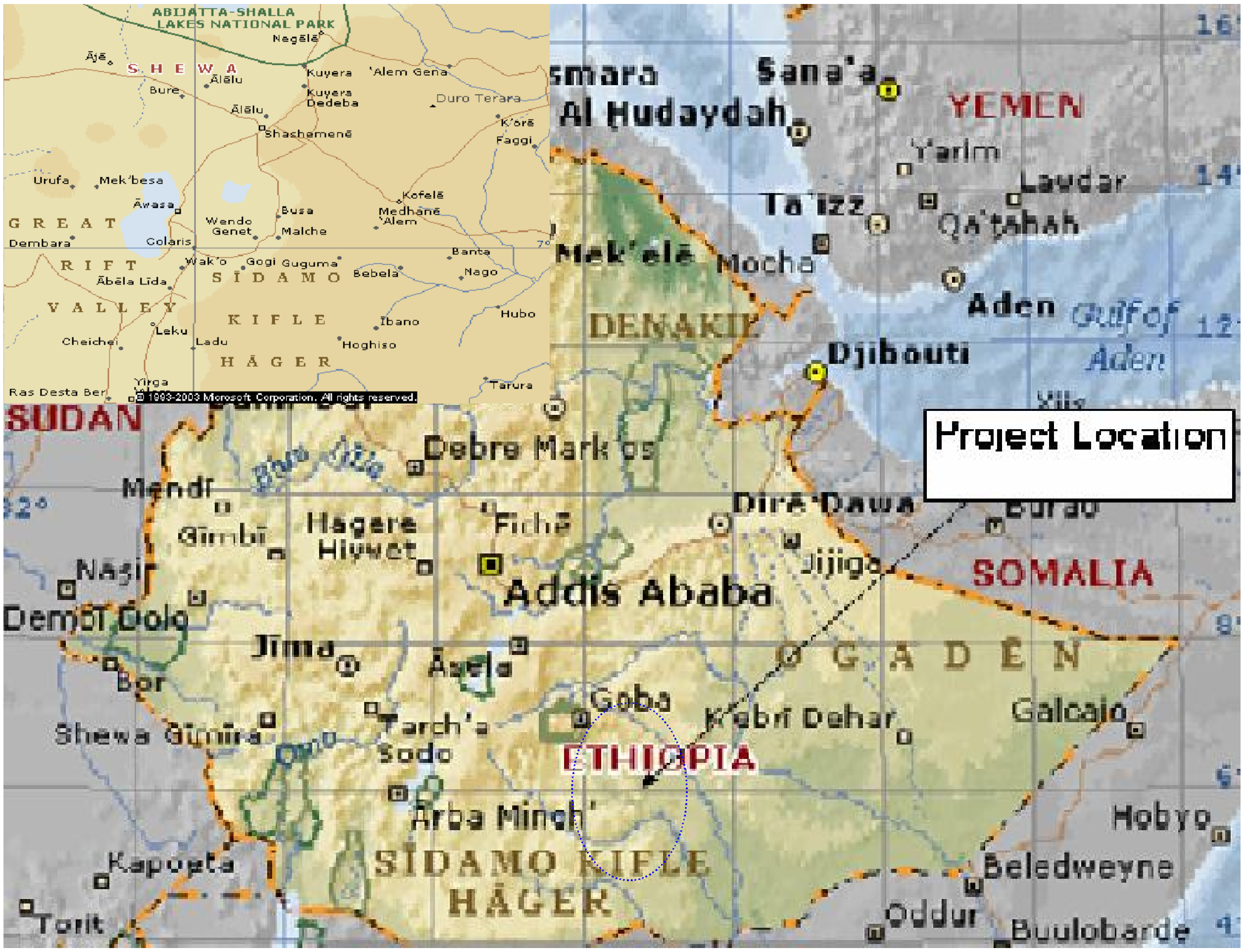
3.1 Introduction

This section deals on how the study will be conducted and specially the Source of data, method of data collection and analysis of the data. Daily work report format was prepared and distributed to the data collector. Data collector is assigned for each equipment allocated in the activity. Based on the collected data, data analyzing is made to find out the actual productivity of the equipments. To avoid irrelevance data, equipment idle hour due to breakdown or weather is not included.

3.2 Research Area

This research is conducted on shashemene-Wondogenet-Gemeto Asphalt road project which is one of the major Ethiopian Roads Authority projects. The project is suited in Southern part of Ethiopia 250Km away from Addis Ababa. The project is aimed at linking the cash crop area in Sidama zone to the main arterial road from Addis Ababa-Hawassa. The total project length is 36Km.

Figure 2: Project Location



3.3 Source of Data

The construction of sub-base activity consists of different sequence of tasks from production up to placing. The crew consists of production units, loading units, hauling units, mixing, showering and spreading units and compaction units. Site survey is made and data is collected for actual out of equipments assigned in all units of the above mentioned tasks.

Table 1: Material Source and their Location

Material Source	*Location(Station)*	*Remark*
Sub-base Material	26+425.000	Borrow Material Source
Water Source	24+333.503	Wedessa River

This paper is made in the road section from Km 22+300 – Km 23+300. According to the pavement design of the project, the sub-base thickness is 27cm.The average hauling distance of sub-base material is 3.63km (From Source @Km 26+425 to Km 22+800) and the average hauling distance of water is 1.53Km(From Source @Km 24+333.503 to Km 22+800.00).

Table 2: Task Description and Equipment used

Activity Description	*Equipment Used*	*Equipment Model*	*Capacity*
Production	Dozer	D8R	
Loading	Loader	CAT	
Hauling	Dump Truck	UD Truck	14m^3
Showering	Water Truck	UD Shower Truck	14,000lit
Mixing and Placing	Grader	CAT 140H	
Compaction	Roller	DYNAPAC	

3.4 Data Collection Method

Data collection is often a difficult task because it is nearly impossible to observe and record all the details of ongoing construction work. As a result, the existing objective of any data collection technique is to approximate, as accurate as possible, what is taking in the field (YUN-YI SU; 2010).Several conventional technique have been well employed for gathering data to support construction productivity analysis (Oglesby; 1989).Among the techniques direct observation is used in which data is collected for all the equipments assigned in the task by data collector. The daily report format consists of the equipment type, equipment model, working hours and other related information for each equipment. The data collected is cheeked by the immediate foreman and site engineer of the project.

Production Unit – The driving resource in production unit is Dozer. Daily productivity of Dozer for normal working hours is collected.

Loading Unit – The actual time needed for loading of each dump truck is calculated by taking data for beginning and end of loading.

Hauling Unit - Data was collected for hauling start (@ Borrow Pit) and finish (@ Spreading station) of each dump truck. The objective of this data is to calculate the average loading and unloading speed of the dump trucks.

Mixing and Spreading Unit – The daily out put of grader for normal working hour is collected. It includes the total hour for mixing and spreading of material. From the pavement design the sub-base thickness is 27.5cm. According to the specification the minimum compacted thickness is 10cm and the maximum is 20cm (ERA Specification; 2013).From the operation observed mixing and spreading is made in two layers. The first layer is 12.5cm and the second layer is 15cm and data will be collected accordingly.

Showering Unit – From the operation observed on site, the time for showering is negligible compared to the grader working hour. It is found that the hauling distance and pumping time is the major factor that will affect the number of water trucks.

Compaction Unit – This task is executed after mixing and spreading is completed. From the observation made the time needed for accomplishing of this task too short compared to the grader working hour. Therefore, the number of roller is dependent on the number of grader.

Pumping – Based on the data for Start and finishing time of pumping to fill the water truck, the total time of pumping is calculated.

3.5 Data Analysis

Site survey was made for the entire unit in sub-base placing activity. The data collected was organized according to unit or task of activities. Based on the observation made the actual output of equipment in each unit is checked and the average out put is calculated. Once the average output is obtained improved equipment allocation is made and crew formation is developed. Summary of the average productivity rate of equipment and their hourly output is shown below.

3.5.1 Production Unit Output

The equipment used in production of sub-base material is dozer. From the data, the actual average daily output of Dozer is;

Table 3: Dozer Actual Productivity

Equipment	Model	Unit	Actual Productivity	Actual Working Hour (Hrs)	Remark
Dozer	D8R	m^3	862	8hr	Avg. output in 8hr

The hourly output is;

= 862/8= 107.75m^3/hr

= 107.75*0.80=*86.20* m^3/hr

Utilization factor=*0.80*

3.5.2 Loading Unit Output

The equipment used for loading of sub-base material is Loader. The actual average daily output is;

Table 4: Loader Actual Productivity

Equipment	Model	Unit	Actual Productivity	Actual Working Hour (Min)	Remark
Loader	CAT	m^3	14	5.72	Average loading time

The hourly output is;

=14/5.72*60 =146.85m^3/hr

=146.85*.80 =*117.48* m^3/hr (Utilization factor=*0.80*)

3.5.3 Dumping Unit Output

The dump truck used for hauling of sub-base material is UD with hauling capacity of 14m^3.From the collected data, the average actual loading speed and unloading speed of the dump trucks is;

Loading Speed = 27.21Km/hr (Average loading speed)

Unloading Speed = 32.28Km/hr (Average unloading speed)

Loading Time = 5.72min (Average loading time)

Unloading Time = 3.84 min (Average unloading time)

3.5.4 Spreading Unit Output

The equipment used in spreading of sub-base material is Grader. From the data, the actual average daily output of Grader is;

Table 5: Grader Actual Productivity

Equipment	Model	Unit	Actual Productivity	Actual Working Hour (Hrs)	Remark
Grader	CAT-140H	m^3	481.43	8hr	Avg. output in 8hr

The hourly output is

$$=481.43/8 = 60.18 m^3/hr$$

$$=60.18*.80 = \underline{\underline{48.144}}\ m^3/hr$$

Utilization factor=*0.80*

3.5.5 Showering Unit Output

The shower truck used for hauling of water is UD with a capacity of 14,000 lit.

From the collected data, the average actual loading speed and unloading speed of the shower trucks is

Loading Speed = 17.2Km/hrs (Average loading speed)

Unloading Speed = 20.28Km/hrs (Average unloading speed)

Pumping time = 24.5min (Average time for pumping of water to the water truck)

3.6 Work Load Computation

Based on the data analysis from the actual out of equipments, the crew formation for the sub-base activity is made. This case study is made specifically in the road section from Km 22+300 - Km 23+300 for a total length of 1km. According to the pavement design of the project, the sub-base thickness is 27cm and the cross-section of the road is 10m including shoulder.

- The average hauling distance of sub-base material is 3.63km (From Source @Km 26+425 to Km 22+800).
- The average hauling distance of water is 1.53Km (From Source @Km 24+333.503 to Km 22+800).

3.6.1 Material Production Quantity

❖ Total Quantity required is

=L*W*T*CF

=1000*10*.275*1.30=*3575.0*m^3

Where

L: length of the road to be placed

W: Cross-sectional width of the road

T: Thickness of sub-base layer

CF: Compaction Factor

❖ Considering Wastage Factor of 1.1

= 3575*1.10 = ***3932.50***m^3

Total Quantity required **=** ***3932.50****m^3*

3.6.2 Material Loading Quantity

❖ Total Quantity required –

=L*W*T*CF

=1000*10*.275*1.30=***3,575.0***m^3

3.6.3 Material Spreading Quantity

- Volume of Spreading (compacted volume)

  = L*W*T

  $=1000*10*.275 = \underline{\underline{\mathbf{2{,}750}}}m^3$

3.7 Equipment Allocation and Optimization

Table 6: Equipment Allocation

Task	*Work load*		*Driving Resource*	*Actual Hourly Output(m^3)*	*Working Hours required(hrs)*	*No. of days*	*Remark*
	Qty.	*Unit*					
Production	3932.5	m^3	Dozer	86.24	45.60	6	With One Dozer production will be completed in 6days
Loading	3575.0	m^3	Loader	117.52	30.42	4	With One Loader Loading will be completed in 4days
Mixing and Spreading	2750.0	m^3	Grader	48.144	57.12	7	With One Grader Mixing and Spreading will be completed in 7days

❖ Since the output of loader is higher than the dozer, loading has to be started after 2days of production and both activities will simultaneously completed 4days after loading is started.

Table 7: Dump truck Analysis

Description	*Unit*	*Quantity*	*Remark*
Total Quantity	m^3	3575	
Dump truck Capacity	m^3	14	UD 14m3 Capacity
Total Quantity in trucks	Truck no	256	
Hauling Distance	Km	3.63	
Loading Speed	Km/hr	27.21	From data collected
Unloading Speed	Km/hr	32.28	From data collected
Average Speed	Km/hr	29.75	
Hauling Time	Min	14.64	
Loading Time	Min	5.72	From data collected
Unloading Time	Min	3.84	From data collected
Total time/trip	Min	24.2	
No. of Trip/ day	Trip	19	
Utilization factor		0.80	
Adjusted no. of trip/day	Trip	16	
Loader productivity/day in trucks	Truck no	67	Considering utilization factor =0.8
No of trucks needed/day	Truck no	5	
No. of days to complete the work	Day	4	

- The number of roller is dependent on the number of grader. The roller will be subjected to idle hour until spreading is completed. In addition, the time needed for compaction is negligible compared to the grader time. Therefore, one roller is sufficient for one grader according to the site observation.
- The number of water trucks should be balanced with the number of grader .From the site survey, the critical time in showering unit is the hauling time from the source and the return time. It is the major factor in deciding the number of water trucks. If the shower truck is delayed the grader will be subjected to idle time due to shortage of water for mixing. However, the average hauling distance is 1.53Km which is short and the total time taken from the daily report data is only 37min including the time to return, hauling time and pumping time .Therefore, one shower truck is sufficient for one grader in this case.

CHAPTER FOUR
CONCLUSION AND RECOMMENDATION

4.1 Conclusion

In order to maximize the efficiency and productivity of the workforce for sub-base activity, the research has attempted to identify optimal crew composition. The daily work reports are the primary entry point for data in this study. However, these reports do not include all the information that may impact the crew out put due to limitation of data. For example the number of traffic is not uniform throughout the day and may have a drastic impact on crew productivity, especially on hauling activity. The performance of the driver or operator may vary for the same type of trucks or equipments. To a fill the gap in variability of equipment productivity of the same type and to consider the actual working condition, average output is taken for productivity measurement.

From the result of the study, It is identified that the equipment required for execution of sub-base activity is dozer, loader, grader, roller, dump truck, water truck and water pump. The actual productivity of the equipments and the optimal crew composition is listed below. According to the analysis the output of the crew formation is *2,750m*$^{3.}$

Table 8: Equipment Productivity

Equipment	*Model*	*Unit*	*Hourly output*
Dozer	D8R	m^3	86.24
Loader	CAT	m^3	117.52
Grader	CAT-140H	m^3	48.144

Table 9: Dump truck Productivity

Parameter	*Unit*	*Productivity*
Loading Speed	Km/hr	27.21
Unloading Speed	Km/hr	32.28
Loading Time	Min	5.72
Unloading Time	Min	3.84

Table 10: Water truck Productivity

Parameter	*Unit*	*Productivity*
Loading Speed	Km/hr	17.2
Unloading Speed	Km/hr	20.28
Pumping Time	Min	24.5

Table 10: Water Pump Productivity

Parameter	*Unit*	*Productivity*
Pumping Volume	Lit	14,000
Pumping Time	Min	24.5

Table 6: Optimal Crew Formation

Equipment	No	Total Working Time (Hrs)	Working days	Remark
Dozer	1	45.60	6	One dozer operator and one ass. operator is needed
Loader	1	30.42	4	One loader operator and one ass. operator is needed
Grader	1	57.12	7	One grader operator and one ass. operator is needed
Roller	1	7	7	One roller operator is needed.
Equipment	**No**	**Working days**		**Remark**
Dump truck	5	4		Five dump truck driver is needed
Water truck	1	7		One water truck driver is needed
Pump	1	7		One water pump operator is needed

From the site observation, the number of dump truck assigned in this particular activity is Seven, but according to the result of the study Five dump trucks is sufficient and two dump trucks may be assigned in other tasks.

4.2 Recommendation

While attempting to achieve the objective of the research, several lessons learned from the case studies.

- Poor productivity causes delay and cost overrun of project, therefore proper crew formation should be developed to utilize the available resources efficiently and to maximize the productivity.

- It is recommended that crew actual productivity shall be used as a basis in planning and monitoring of a project in order to acquire realistic estimate of productivity and for a better project evaluation.

APPENDIXES

Appendix A: Daily Report Summary Sheet

Appendix B: Typical Section

Appendix C: Research Photo

Appendix D: Daily Report Format

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