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Abstract

Constructing any project requires a multi-specialization experience in various fields, whether, cost controls, progress schedules and productivity measures. Productivity in construction is as essential as any major determinant of construction process flow. Recognition of perilous potential of loss in productivity is difficult to be obtained neither by cost reports nor by schedules solely.

This study presents some of new trends in measuring construction productivity at a specific construction site and develops ways for potential improvement, finally, it concludes by assessing an overall contractor work with some recommendations.

1 Introduction

In general, productivity signifies the measurement of how well an individual entity uses its resources to produce outputs from inputs. Moving beyond this general notion, a glance at the productivity literature and its various applications quickly reveals that there is neither a consensus as to the meaning nor a universally accepted measure of productivity. Attempts at productivity measurement have focused on the individual, the firm, selected industrial sectors, and even entire economies.

There are, however, a number of different productivity measures that are commonly used. Choosing between them usually depends on the purpose of the productivity measurement and the availability of data. In this study researchers used some of these measures, as the work sampling, five-minute rating, crew balance diagram, and process flow charts.

This study conducted is to a course of *Construction Productivity* in the Construction and Engineering Management in the college of environmental engineering at the King Fahad University of Petroleum and Minerals. This report is entirely oriented to scrutinize the construction productivity of a contractor and applying trends for the most promising activates to be improved, considerably, care was taking during the field study for the interference of work and intrusion in private contractor's information and data. A brief explanation on the aim of the study and how it was not to let the workforce feel uncomfortable about their jobs or statuses came to be a helpful tool which supported researchers throughout the study.

Data were collected whether by field video recording, filed walk-thru and interviews with members involved in the project. These approaches were further utilized in the analysis of the work productivity and supported factual information during investigating ways of improvement. The selection of activities was based on interviews made with project members prior to engaging in the study, both, project management team and field execution members.

2 Study methodology

Succinctly, the study presents a way in how to measure productivity of contractor's work in a specific construction site and develop ways for improving this productivity according to several trends adopted which would make an easier portray of the contractor's status. ***Figure 1*** shows the flowchart of the process including all trends, it aimed to give an overall picture of the nature of work been done, and, a final image of the overall assessment.

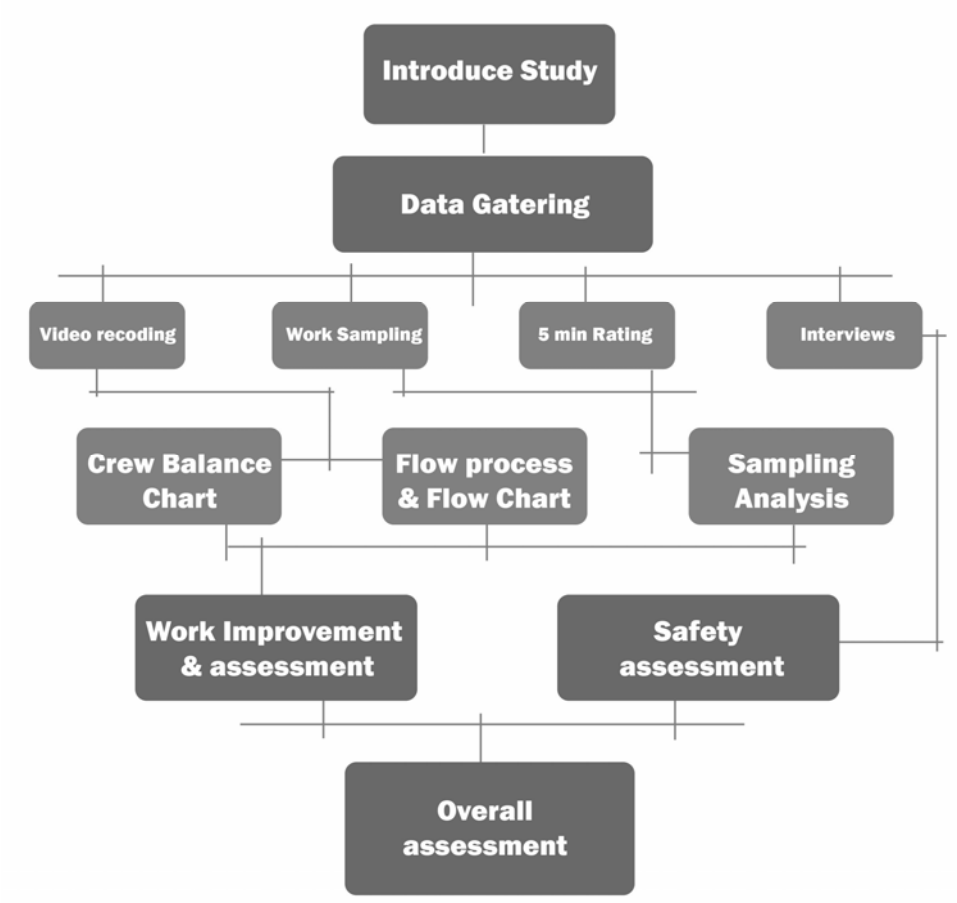

Fig.1 the flowchart of the process

Step 1**,** the research team begun by surveying project members opinions, including, project manager, site engineers, foremen and labors about the status of work and their own degree of satisfaction on work done.

Step 2**,** Study team took up this activity assuming that logically as long as it is the only major activity.

Step 3*,* Video-recording, study team squandered days on site to record the proposed activities.

Step 4, Process Flow Chart and Flow Diagram, a trend used to depict onsite situation showing available accesses, material flow and movement of work. After analyzing the graph, it showed some of the problems and areas for possible improvements.

Step 5, Crew Balance Diagram, where it is another trend for depicting relationships of onsite resource utilization, generally, between labors and equipment. Though, after depiction a horizontal relationship showed another possible way of improvement.

Step 6, Work sampling, to measure the overall contractor's performance another activity been considered to avoid being judgmental in a specific area solely. Tiling in a corridor of the main building was chosen as a work sampling application to measure the time and the effectiveness of work been done.

Step 7, Work Improvement and assessment, after combining all results adopted from previous steps a clear picture of the problem lead to be seen and a possible way of improvement was also presented with Crew Balance Diagram and Process Flow Chart with Flow Diagram.

Step 8, Safety assessment, the recognition of contractor's safety program was done using a check list which was answered by the contractor's safety manager, and study team – RC Engineer – evaluated it according to OSHA – Occupational Safety and Health Administration - Programs.

Step 9, Overall project assessment, after doing all previous steps a clear picture of the work status was evident, and, an overall assessment of the contractor's work was developed to show the idea this study was trying to deliver.

3 The Selected Project

3.1 Project description

The project simply is Construction of three elementary schools. Each elementary school has a gross building area of **4631 m²**, including a multipurpose hall of **573 m²**. The school has 25 typical class rooms. In addition it has general science labs. Language class rooms, computer rooms, art class room, library, administrative suite, health suite. More over, the girls' elementary school has home economics class room and buffet. The structure of the school building is composed of cast-in-place reinforced concrete foundation, Grade beam, columns, roof beams and slab. The building is provided with cast-in-site concrete roofing system. Multipurpose hall has pre-cast concrete double T's roof. The school has a guard apartment at the entrance and enclosed be decorative CMU boundary wall. In addition facilities such as car parks, shaded area and playgrounds are also provided. Fig2 shows the school front side view.

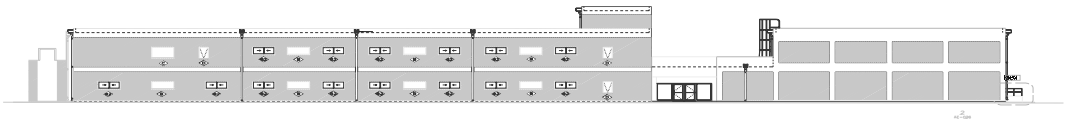

Fig.2 Building front view

The contractor who constructed the project was Abdulhamid A. Al-Mutawa and partners CO. in association with Tamimi CO. LTD.

3.2 Manpower

The key of any project is the manpower. The scope of the contract was constructing of three sites, manpower were moving from one site to another depending on the need of them onsite. The overall manpower of the project is shown in the following table:

		Site		
S/N	**Description/ Category**	**No.**	**N0.**	**No.**
A.	**Non-Manual**			
1	Project Manager		1	
2	Construction Manager		1	
3	Project Engineer		1	
4	Q.C Engineer		1	
5	Planning Engineer		1	
6	Civil Engineer		2	
7	Electrical Engineer		1	
8	Mechanical Engineer		1	
9	Precurment Engineer		1	
10	Safety Officer		1	
11	Surveyor		1	
12	Supervisor		6	
	Sub-Total		**18**	
B.	**Manual**	**Farouk**	**Dareen**	**Alhasa**
1	Foreman	1	1	1
2	Mason	11	15	15

3	Carpenter	3	4	3
4	Steel Fixer	5	4	4
5	Electrician	7	7	4
6	Plumper	3	4	2
7	Painter	4	2	2
8	Welder	1	0	0
9	Store Keeper	1	0	0
10	Time Keeper	1	0	0
11	Security	1	2	2
12	H.E Operator	1	1	1
13	Driver	2	1	0
14	Mechanic	1	0	0
15	Labor	65	36	31
	Sub-Total	**107**	**77**	**65**
C.	**Cub-contractor**	26	30	20
	Total Manpower		**343**	

Table.1 Manpower schedules in Jubail School project

3.3 Project Duration

The duration of the project was 88 weeks for the three schools. But, the one located in Dareen district handled over to contractor after eight months of the notice-to-proceed, because, the site was used by another company as temporary offices for another contract. This delay resulted the contract to be extended eight months further.

The following table shows the current situation of the three schools:

School	**Percentage Completed**
Al-Farouk	90
Al-Hasa	85
Dareen	10

Table 2 Project Completion Percentage

4 Data gathering

For data gathering process, first, we have to select the activities that will be studied. After the selection of the activities, we start gathering data, in this study the data

collection was done by video recording process. After that, the recording activity will be utilized for the data analysis.

The other way of collecting data will be sampling by walk through approach for all the sites for ten days to assure covering all activities with different time.

4.1 Activity selection

Team study selected criteria for the selection of potential activities:

1 Repetitive.

2 Less complexity.

3 Manual and equipment execution

4 Reasons behind delay.

5 Potential saving.

The study team explained these criteria to the project team to get their replies. Eventually, project members agreed that concrete work was the most critical work onsite which requires more man-hours susceptible to late work and equipment over consumption. The reasons behind it were explained due:

1 More labors.

2 More delays.

3 Expensive.

The second activity was selected by different way. Study team went through the actual construction plan to analyze the activities compatible with criteria.

4.2 Data Gathering

The data was collected by two ways. The first one was by video recording which was for the slab on grad concreting and terrazzo tile finishing. The second way of collecting data was sampling by using walk through approach which was for the three sites. The gathered data will be shown in different format as will be explained in the next few paragraphs.

4.2.1 Crew Balance Chart

The crew balance chart is an effective way to show the interrelationships among the activities of all members of a selected crew along with the equipment used. This study was to monitor operation of Pouring Concrete of slab on grad on Dareen school and measure the effectiveness of each worker in the crew and to show the interrelationships among with workers in this operation with the trucks and pumping machine used.

The crew dedicated for this operation consists of 20 workers in addition to one foreman, trucks and one pumping machine. The operation simply as follows:

1. The trucks will be registered once reaching the site location.
2. Slump test will be conducted to check the concrete property.
3. Switching to the pumping area and start pouring the concrete.
4. Then, pumping will be started.
5. Group1 was working for distributing concrete.
6. Group2 was working in leveling.
7. Group3 was watching.

The next crew balance chart representing the present method. The vertical bars are representing the total cycle time and the ordinate represents each group of men among the crew that doing the same task and the utilized equipments.(For more detail please see Video number 1)

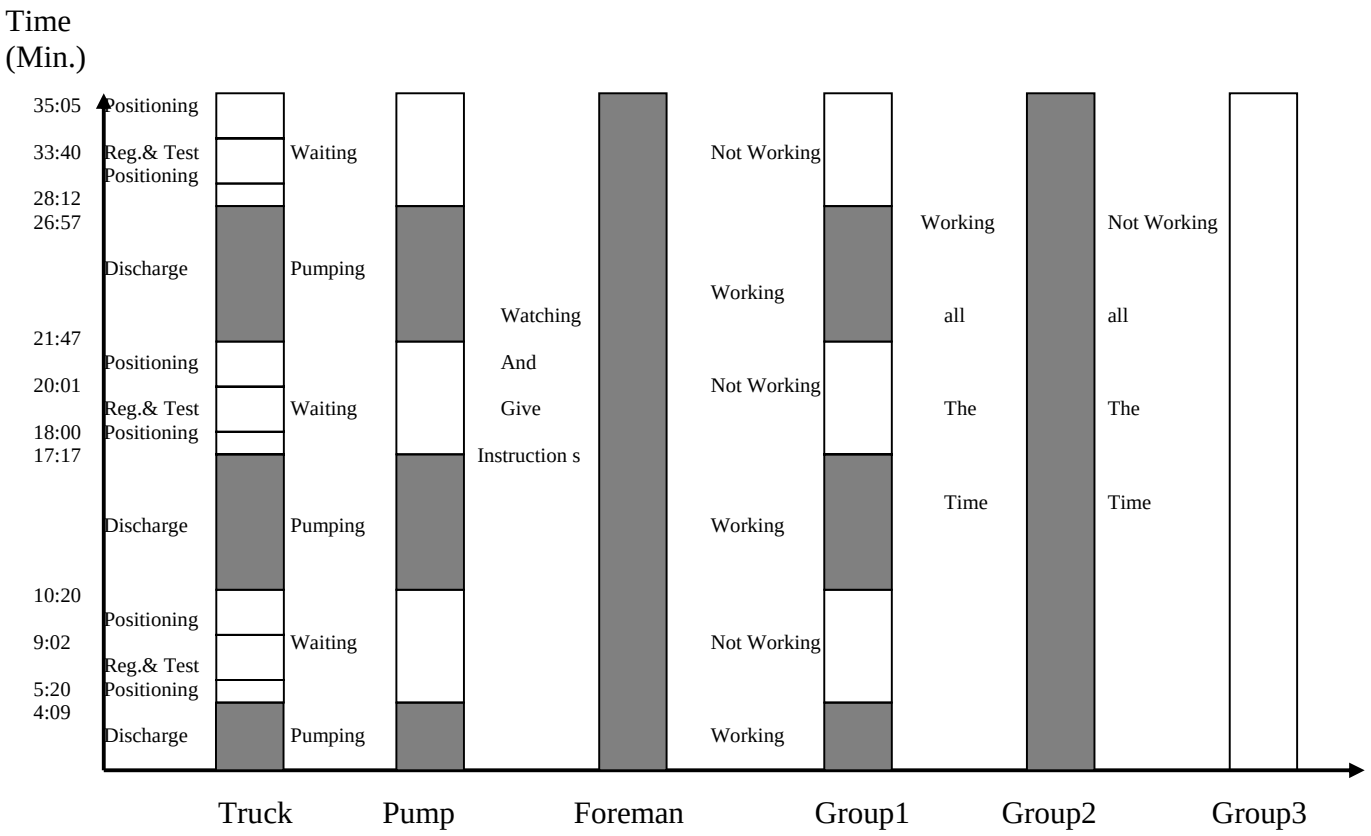

Fig.3 Crew Balance Chart for Slab on Grad Concreting on Dareen Site

To clarify the picture of the overall operation, the next figure will show the total of each activity with the average and the utilization percentage of each equipment and group.

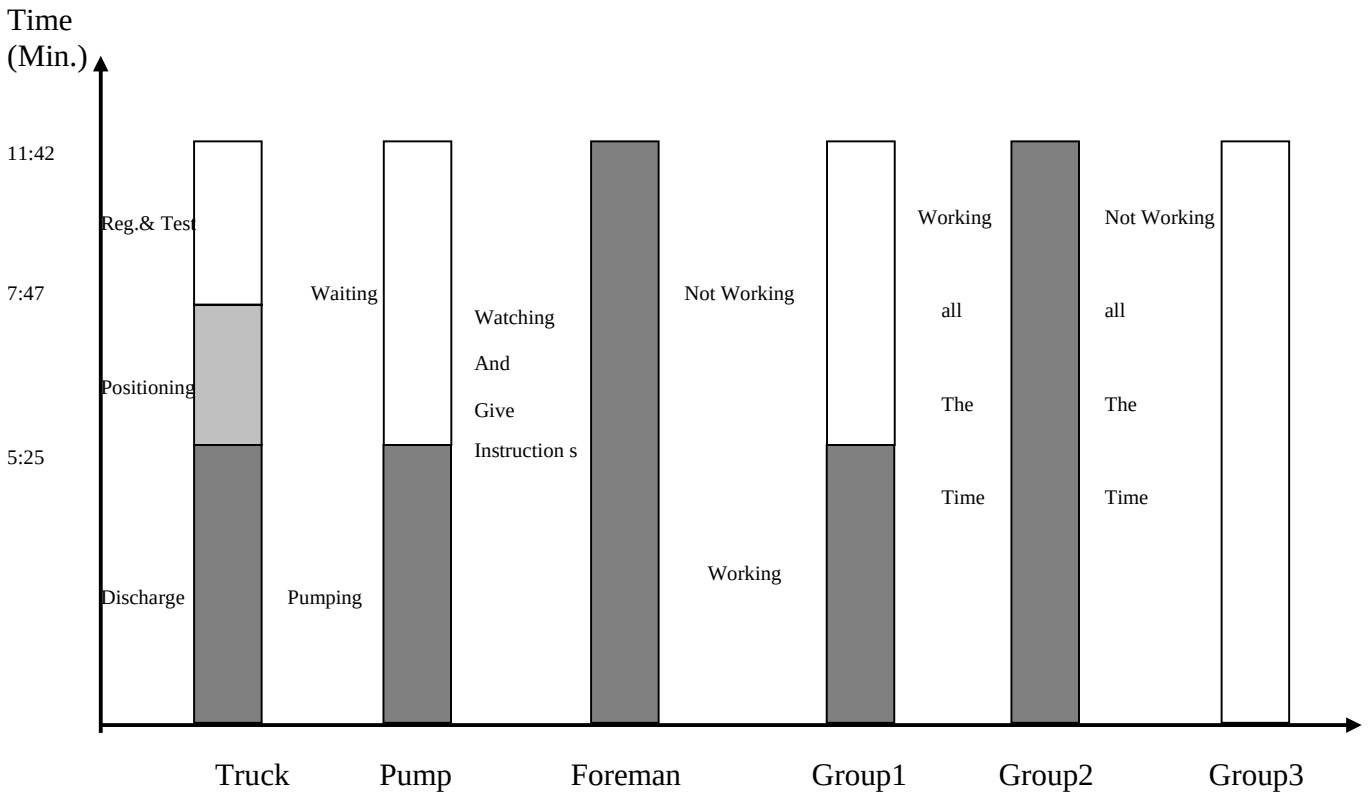

Fig.4 Crew Balance Chart of the Average Cycle for Slab on Grad Concrete

The following table will show the efficiency of each equipment and group.

Equipment & Group	Percentage
Truck	46
Pump	46
Foreman	100
Group1	46
Group2	100
Group3	0

Table3 Efficiency of the Equipment and the Group

4.2.2 Five Minutes Rating

The purpose of this technique is to create awareness of management of delays in the job, measure the effectiveness of a crew and to indicate where more through detailed observations or planning could result in savings.

Observations are not made at the instant but rather the craftsman is observed for a period of approximately 40 seconds to several minutes and observations are taken at interval of time "One minute is our study".

The observed crew consists of four workers performing filling tiles gapes . Results obtained are showing in table # 4.

Case1: Concrete Tiles Placement (filling the gapes of the tile)

Site: Al-Farouk Site

Job Description:

This job is very simple, the labor mixing gypsum with water. After that, they flash the mixture over the tiles and start to distribute it over the tiles to fill the gapes between the tiles.

TIME	WORKER # 1	WORKER # 2	WORKER # 3	WORKER # 4
14:11	√	√	√	√
14:12	X	√	√	√
14:13	√	X	√	√
14:14	X	√	X	√
14:15	X	√	√	√

Table 4: Observation Results for Case No 1.

Data Analysis:

Total number of observations = 20

Number of effective work = 15

Percentage of effectiveness = 15/20

= 75%

Case2: Pouring Concrete of Slab on Grad

Date:

Job Description: Observation was conducted for a crew consists of ten workers including their foreman. Workers are performing masonry work after pouring concrete. Observation results are showing in table # 5.

TIME	FORMAN	WKR #1	WKR #2	WKR #3	WKR #4	WKR #5	WKR #6	WKR #7	WKR #8	WKR #9
13:15	√	√	X	√	√	X	X	√	X	X
13:16	√	X	√	√	X	√	X	X	√	√
13:17	√	X	X	√	X	√	√	√	X	√
13:18	X	X	√	√	√	X	√	X	X	X
13:19	√	√	√	√	√	√	X	√	X	√

Table 5: Observation Results for Case No 2.

Data Analysis:

Total number of observations = 50

Number of effective work = 29

Percentage of effectiveness = 29/50 = **58%**

4.3 Flow Process Chart

Flow process chart is a way that makes a relation between the workers, materials, and the equipments. It shows the complete operation step by step from the beginning of the activity till the completion of activity. The processes that indicated in this chart are:

1- Transportation which means the movement of material, worker, or equipments.

2- Operation which means the activity to be done by the worker to achieve the final product of the activity.

3- Storage which means the permanent storage.

4- Inspection that done for equality or any other inspection.

By making the right description of any operation with above process we will have a clear picture about what is the activity and how can we improve it.

For our case we used the slab on grad operation to draw the flow process chart (For more detail please see video 1)

Flow Process Chart				Man	Equipment	Type
Chart no. 1 Sheet no. 1				Date :		
Project: Construction of Three Schools in Jubail Industrial City	Activity	Present		Proposed		Saving
	Operation	2				
	Transportation	2				
Method: Present	Delay					
Workers: 20	Inspection	1				
Observers: Ghazwi, Abdulraouf	Storage					
	Distance					
	Time					

Description	Qty.	Dis.	Time(min)	Symbol					Remarks
				○	⇨	D	□	▽	
The Truck Discharge concrete to the pump truck	1		5:25						For the concrete Truck
The Truck move to be ready of positioning	1		00:35						
Check the slump test	1		3:55						
The truck move to the pump position	1		1:47						
The Truck Discharge concrete to the pump truck	1		5:25						
Pump truck pumping the concrete	1		5:25						For the pump
Pump truck is waiting	1		6:17						
Pump truck is pumping the concrete	1		5:25						
Total			11:42	4	4	1	1		

Table 6 Flow process table of present operation (slab on grade concreting)

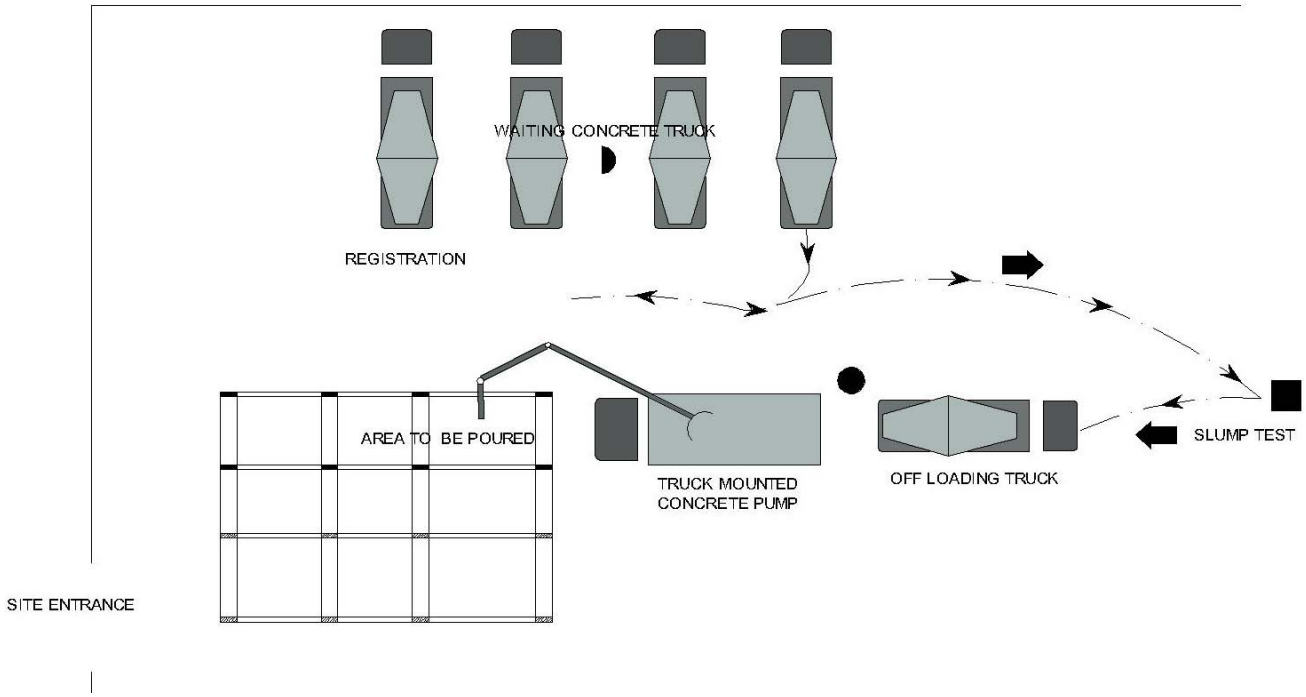

Fig 5: Flow Process Diagram (actual)

4.3.1 Sampling (By productivity rating)

The data of this part was collected during ten days. The observation covered all three sites and during different time of the day i.e (mooring till the end of the day). The sample size was 400 observations to have 5% error and 95% confident level.

The observations divided to three divisions:

1- Effective work which add value directly to the basic work such as fixing door.

2- Essential contribution which doesn't add value to the basic work but it is important to do the basic work such as handling material

3- Ineffective work which doesn't add any value to the basic work and doesn't needed to complete the basic work such as rest.

The following table shows the result of the sampling process.

Ser	Effective	Essential	Ineffective	Ser	Effective	Essential	Ineffective
1	√			201	√		
2	√			202			√
3			√	203	√		
4			√	204	√		
5		√		205		√	
6	√			206			√

7	√			207	√		
8	√			208			√
9	√			209			√
10			√	210	√		
11			√	211	√		
12		√		212	√		
13	√			213		√	
14	√			214			√
15			√	215	√		
16	√			216			√
17		√		217			√
18	√			218	√		
19			√	219	√		
20	√			220	√		
21	√			221		√	
22			√	222	√		
23	√	√		223			√
24			√	224	√		
25	√			225			√
26	√			226			√
27			√	227			√
28		√		228		√	
29	√			229			√
30			√	230	√		
31	√			231			√
32			√	232			√
33	√			233			√
34	√			234	√		
35	√			235			√
36		√		236			√
37			√	237		√	
38	√			238			√
39			√	239	√		
40		√		240	√		
41	√			241			√
42			√	242		√	
43	√			243			√
44	√			244			√
45			√	245			√
46			√	246	√		
47		√		247			√
48	√			248			√
49			√	249		√	
50			√	250			√
51	√			251	√		
52	√			252	√		
53		√		253	√		

54			√	254			√
55	√			255			√
56			√	256		√	
57			√	257			√
58	√			258	√		
59		√		259	√		
60	√			260			√
61			√	261		√	
62			√	262			√
63	√			263			√
64		√		264	√		
65			√	265			√
66	√			266			√
67	√			267			√
68			√	268		√	
69			√	269		√	
70			√	270			√
71			√	271	√		
72	√			272			√
73	√			273			√
74		√		274			√
75			√	275			√
76	√			276			√
77	√			277			√
78	√			278		√	
79			√	279		√	
80			√	280			√
81		√		281			√
82			√	282	√		
83			√	283			√
84			√	284		√	
85		√		285			√
86			√	286	√		
87	√			287			√
88	√			288			√
89	√			289		√	
90			√	290			√
91			√	291			√
92			√	292	√		
93	√			293	√		
94		√		294		√	
95			√	295		√	
96		√		296			√
97	√			297			√
98			√	298			
99			√	299		√	
100			√	300			√

101	√			301	√		
102	√			302	√		
103		√		303		√	
104			√	304			√
105		√		305	√		
106	√			306			√
107	√			307		√	
108	√			308			√
109		√		309			√
110			√	310	√		
111	√			311			√
112	√			312			√
113		√		313	√		
114			√	314		√	
115	√			315			√
116			√	316		√	
117			√	317			√
118	√			318	√		
119	√			319	√		
120		√		320			√
121	√			321		√	
122			√	322			√
123	√			323	√		
124	√			324	√		
125			√	325			√
126		√		326			√
127	√			327			√
128	√			328			√
129			√	329		√	
130			√	330		√	
131		√		331			√
132	√			332	√		
133			√	333	√		
134			√	334	√		
135		√		335			√
136	√			336		√	
137		√		337			√
138		√		338			√
139	√			339	√		
140			√	340			√
141			√	341			√
142			√	342			√
143		√		343	√		
144	√			344			√
145	√			345		√	
146	√			346			√
147	√			347			√

148	√			348	√		
149			√	349		√	
150			√	350			√
151	√			351			√
152		√		352			√
153			√	353		√	
154			√	354		√	
155	√			355			√
156			√	356			√
157		√		357	√		
158	√			358	√		
159	√			359	√		
160			√	360		√	
161			√	361			√
162	√			362			√
163	√			363	√		
164			√	364			√
165	√			365		√	
166		√		366			√
167			√	367	√		
168	√			368			√
169			√	369		√	
170	√			370		√	
171	√			371	√		
172	√			372		√	
173	√			373			√
174			√	374			√
175			√	375	√		
176			√	376			√
177		√		377		√	
178	√			378	√		
179	√			379	√		
180			√	380			√
181			√	381			√
182			√	382	√		
183			√	383	√		
184		√		384		√	
185	√			385			√
186	√			386			√
187			√	387	√		
188			√	388		√	
189			√	389		√	
190			√	390			√
191			√	391	√		
192	√			392			√
193	√			393			√
194		√		394			√

195			√	395			√
196			√	396		√	
197			√	397	√		
198	√			398	√		
199	√	√		399	√		
200			√	400			√

Table 6: Observation sampling

The result of the sampling was, that, 146 workers was engaged in an effective work, 73 were helping in a contributory effective and 181 were to be found ineffective.

$$\text{The labor utilization factor} = \frac{\text{Effective work} + .25 \text{ X essential contribution work}}{\text{Total Observations}} \text{ X } 100$$

$$= \frac{146 \text{ X } .25\ (73)}{400} \text{ X } 100 = 41\%$$

$$\text{Field rating index} = \frac{\text{Effective work} + \text{essential contribution work}}{\text{Total Observations}} + 10 = .6475$$

Field rating index= 64.75 %

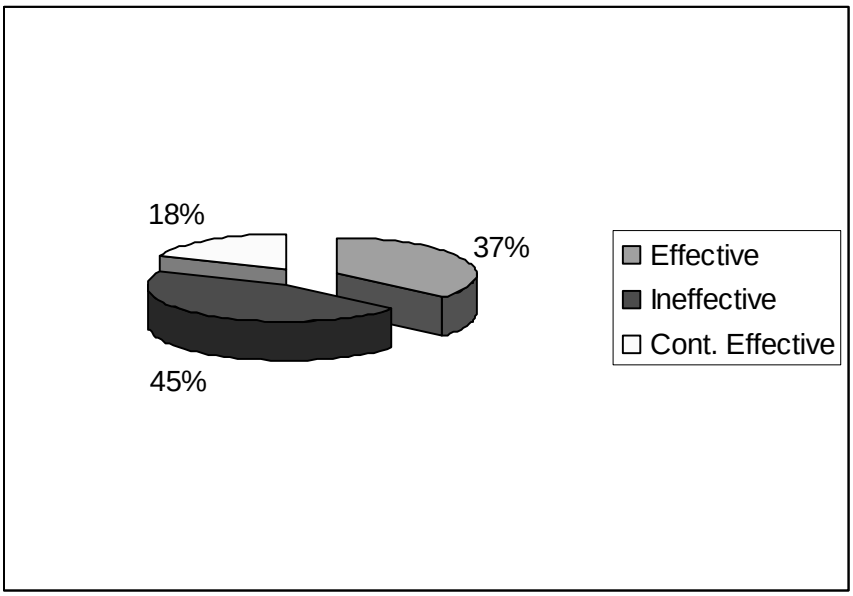

Figure 6. A pie chart showing status of workers found in the study

5 Work Improvement and assessment

5.1 Data Analysis

The analysis of the data was done by watching the video tape for several times at different speeds, also, integrating the charts of crew balance and flow process with it to have a clear illustration of the work.

5.2 Improvement and assessment

5.2.1 Crew balance Chart

Looking in precise to the present crew balance chart and the provided video, one can notice the followings:

No	Observations	Recommendation
1	The number of workers was high and it was clear that most of them were not working effectively; some of them were doing nothing where others were sleeping.	It is recommended to reduce the number of workers to 10 workers including the foreman instead of 20 workers.
2	Trucks spent long periods of time for registration and performing slump tests before switching for concrete pouring.	Trucks were ordered in straight line and both registration and slump test were conducted together at the same time while trucks were waiting. Then, engagement to pour concrete.

Table 7 The improvement

The following chart was the result of implementation of our recommendations.

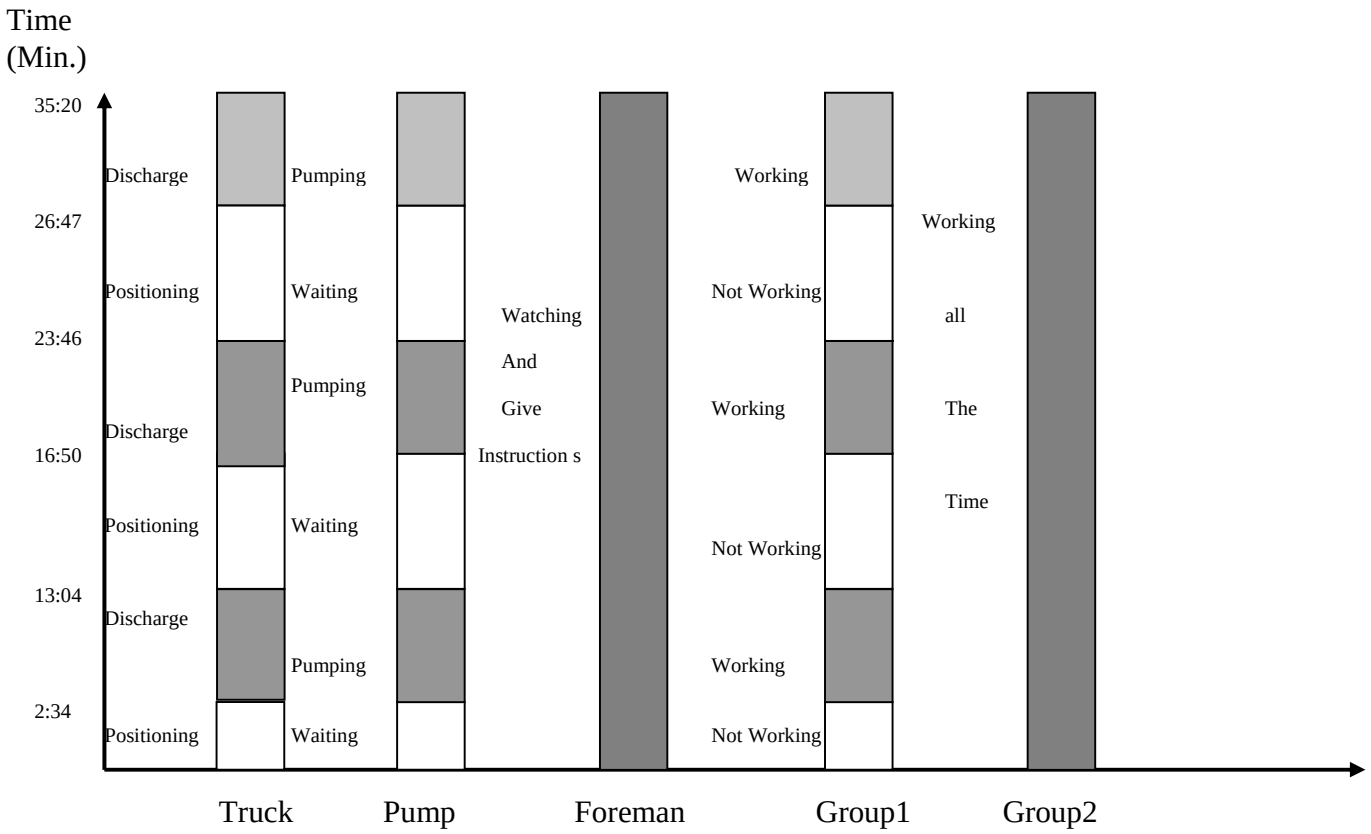

Fig.7 Improved of Crow Balance Chart

The following table will show the efficiency of each equipment and group.

Equipment & Group	Percentage
Truck	81
Pump	81
Foreman	100
Group1	81
Group2	100

Table 8. Efficiency of the Equipment and the Group

5.3 Flow Process Chart

For the same operation we applied the flow process chart with the same recommendations. The process become as the next table

Flow Process Chart Type				Man	Equipment
Chart no. 1 Sheet no. 1			Date :		
Project: Construction of Three Schools in Jubail Industrial City	Activity	Present	Proposed	Saving	
	Operation	2			
	Transportation	1			
Method: Improved	Delay				
Workers: 20	Inspection				
Observers: Ghazwi, Abdulraouf	Storage				
	Distance				
	Time				

Description	Qty.	Dis.	Time(min)	Symbol					Remarks
				○	⇨	D	□	▽	
The Truck Discharge concrete to the pump truck	1		8:39	○					For the concrete Truck
The Truck move to be ready of positioning	1		3:01		⇨				
Check the slump test	1		8:39	○					
Pump truck pumping the concrete	1		8:39	○					For the pump
Pump truck is waiting	1		3:01			D			
Pump truck is pumping the concrete	1		8:39	○					
Total			11:40	4	4	1	1		

Table 9 Flow Process of improved operation

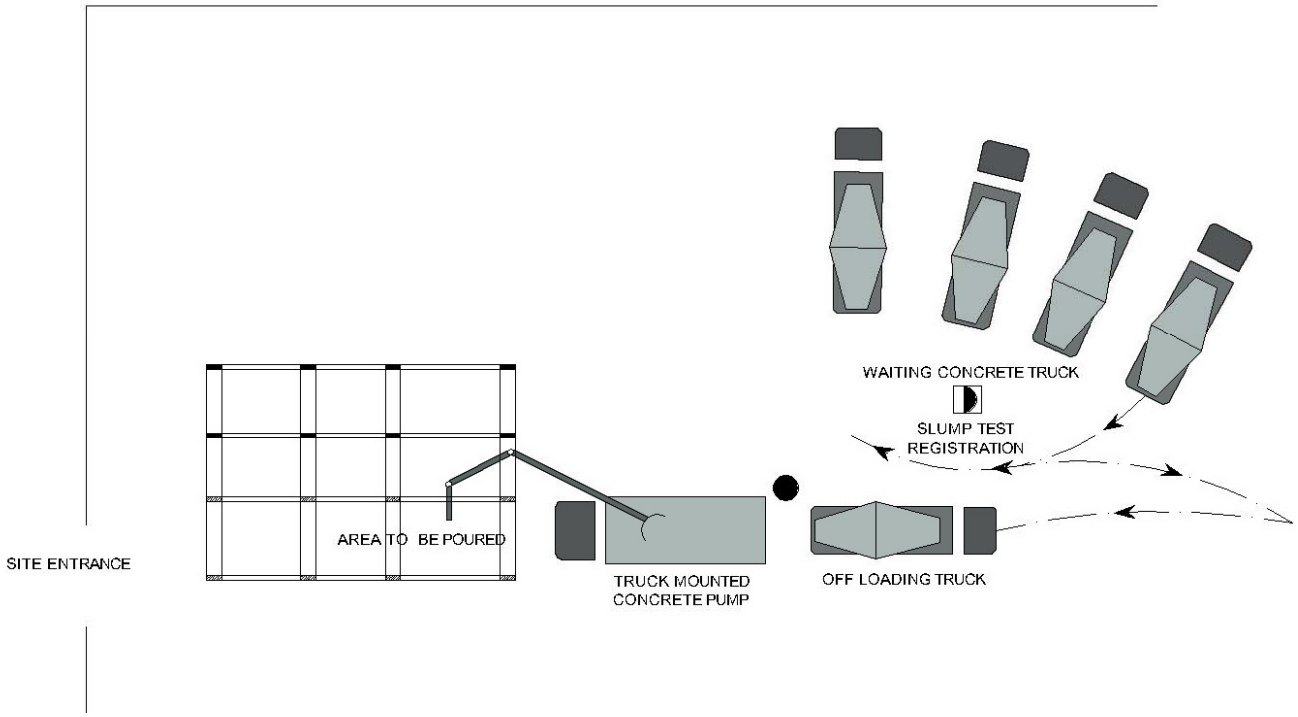

Figure 8. Flow Process Chart (improved)

5.3.1 Overall Work Assessment

The following points are the main findings of the team during this study:

1- It was clear to see over manning in both concrete work, and tile installation.
2- Foremen were not enough to monitor labors where there an average of 100 labors/ foreman.
3- There was no good plan for testing concrete which cause a delay of the truck.
4- There was no plan for concrete truck parking which may reduce the time of truck positioning.
5- The labors efficiency is little low due to overtime (7:00 AM to 10:00PM with two hours rest only)
6- The project main office was in Al-Farouk site which means high productivity on this site where the other site was less productive due to lack of monitoring.

6 Safety assessment

The assessment of the safety in the project were done by an interview made with the on-site safety manager, answers were been taking and then been manipulated by the study team based on OSHA standards applied by RC Safety Department.

6.1 Housekeeping

The housekeeping was generally accepted by the contractor's safety manager, where, the study team implemented that housekeeping was not done properly and periodic cleaning wasn't acceptable, although, passageways and walkways were to be considered free of hazardous tripping debris at a reasonable illumination level. Organization of site was considered before the construction of the project starts, where, material storage area, area for disposals and separated hazardous materials area was provided.

6.2 Structures

One of the major problems affecting construction safety is that it is dependent on temporary structures which need proper design and installation to prevent accidents within the project to occur. Willingly, project safety manager applied the basic prevention techniques and provided necessary materials and tools to prevent accidents from temporary structures to occur, scaffolds and railings, safe ladders, platforms, hooks and belts, walkways and gates. Even though, a lack of personal protective equipment was noticeable to all workers and a lack of proper scaffold installation was sometimes observed.

6.3 Signs and tools

To alert users/workers to the danger of materials or positions it is a habit in any project to provide tapes, tags and signs to show the level of danger the user/worker is working around. The site was equipped with some of the essential signs and tags; unfortunately, it was not as much as required contractor could put

more time in evaluating them. Some areas were hazardous, such as, electrical conduits and conductors.

Certainly, tools in any construction project have a continuous daily use, condition and storage and they are as much critical as any construction equipment, one of the essential determinants of the quality of work is the tool the work is performed with. Onsite tools were merely convenient to study team and its use, condition and storage to some degree forgotten.

6.4 Welding and cutting

Welding is a risky activity necessary when joining steel bars together and have a negative effect among workers due to the sparks it creates during the welding process. Generally, onsite welding and cutting operations were done properly and in a safe manner.

6.5 Carnes

The difficulty of erecting cranes, its dangerous positions, the weight it carries and the height of it makes as one of the most dangerous equipment in construction processes. The management realized that as much as they needed the crane onsite as much as they have to maintain it in a safe manner. Onsite facts, such as, power lines location, position of crane and behavior of people around were considerably good. Periodical maintenance and assurance of crane performance were seldom done to keep it working as safe as possible.

6.6 Fire prevention

The enemy of building construction and the most difficult vulnerability to be rectified is the case of fire. Risky actions, like location of fuel tanks, electric pumps grounding and location heating devices were suitable and properly located, but, danger alerts coming from flammables, smoking or dangerous liquids were not prevented onsite. Though, fire extinguishers were not identifiably located were even maintained.

6.7 First Aids

In case of hazard a well First aid system is required, signs showing emergency numbers and site male-nurse is necessarily required. And contractor did provide an equipped male-nurse but didn't provide signs showing emergency numbers to workers.

6.8 Miscellaneous

Other small activities to prevent hazards or accidents is as much as important as previous points are; personal protective equipment, proper ventilation and lighting, drinking water and rest rooms were provided and maintained daily onsite

7 Conclusion and recommendations

From previous headings it is obvious that the contractor lacked an external eye to see his progress, where, a huge difference could have been engaged in their work if they have realized the situation.

The study team experienced in this example an actual application of new trends in construction productivity, none of the less, it was found out that it wouldn't be so hard to adopt these trends and apply it in any project. Hereby, the team suggested some recommendations contractor may apply to enhance his work:

- Always think about how to be more engaged into productive work
- Concentrate on repetitive high cost activities
- Avoid over manning at congested areas
- Draw a diagram showing each phase and activity
- Measure productivity onsite and compare it with cost reports and progress schedules
- Provide a good working environment for workers i.e. consider, lighting, noise and heat
- Think how to be in a safe position avoid risky activities
- Always think how to motivate your people and not let them feel alienated