International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 4 Issue 9 ǁ Sep. 2016 ǁ PP.98-110

Designing way to deal with assign and assess execution affecting variables for prepared blended solid bunch plant under various impacts

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ABSTRACT: *Development of development movement on the planet exceptionally Egyptian development territories and prepared blended solid creation development essentially in super undertakings, for example, land projects, visit ism tasks and foundation projects, which they need great prepared blended cement. The fundamental target of this paper is to examine an unmistakable comprehension for estimating any solid group plant execution proportion by utilizing investigation of gathered information from all the more genuine solid cluster plants and deciding the best factors that have extraordinary effect on solid clump plants perfor-mance proportion. Anticipating the genuine future presentation proportion and creation rates for any solid cluster plant as per gatherings of successful elements is the fundamental area which is propose in this investigation utilizing shrewd displaying examination. Improve execution proportion of solid cluster plant was chosen due to its significance in development field by contemplating and examining the best factors. The investigation will be finished by gathering and concentrating enormous point by point information through beginning of 2012 till the finish of 2016 and it will be shown the time, amounts, distances and factors which influence ing solid bunch plants execution proportion. This paper will be separated into principle three gatherings, which are delineated as follows: (1) It was referenced the planning tables which is partitioned into three levels: (A) Field information recording sheet; (B) Field information handling sheet and (C) Field information investigation sheet to notice the most persuading factors that has enormous effect on solid bunch plant perfor-mance proportion. It was broke down and checked the solid cluster plant execution proportion by improving its best factors. (2) It was referenced how to investigate and utilize the gathered itemized information from field and classified their factors influencing solid cluster plant execution proportion and getting the connection between solid group plant execution proportion and every factor independently consider-ing all excess factors are blocked then all measurable examination were referenced, all relations were demonstrated to get extent relationship for every factor. (3) It was summed up the end.*

KEY WORD:*Ready mix concrete; Concrete batch plant; Construction projects; Productivity; Factors; Performance ratio and statistics package for social science (SPSS)*

I. OVERVIEW

Ref. [1] stated the companies of ready mixed concrete require for equipping themselves by latest equipment's, such as con- crete pumps, transit mixers and batch plants of concrete, which need additionally visualized management of production as Programmable Logic Controller (PLC) and softwares.Pumped concrete might defined as it is conveyed by pressure by flexible hose or rigid pipe and discharged directly into the required place. All mixed concrete transported to placement place by methods of pumping which are divided into three main types: (1) pneumatic pumps, (2) piston pumps and (3) squeeze pressure pumps. From practices of field right planning deliver concrete, line layout, pump locations, entire pumping operation and placing sequence will result for saving cost and time. Ready mixed concrete is passed through more ways such as handling material, concrete batching, concrete mixing, product loading on truck mixers and transport it to placingsite. Number of concrete batch plant, truck mixers and pumps typically the crucial elements inside the system. Concretebatchplants may additionally represent one of biggest periods for a contractor capital investments. The successful aim of construc- tion management is to complete any project within budget, at least available cost, on time and with high quality. Insufficient equipment management can be resulted from low production or/and idle equipment either of which can effect on projectcost and duration. Therefore, it is very important for construction managers, contractors and every person directly responsible for management of equipment, to be familiar with strategies for estimating equipment productivity for certain jobs.Ref.

[2] stated at ready mix concrete dispatching, common practices are to rely on human professionals of essential decision making for real time, additional investigations is suggested that mini- mize this optimality gap between optimization models and expert may be occurs because of critical situations experts agree higher cost of ready mixed concrete to ensure a stable dispatching system. To maximize profitability of ready mixed concrete companies, the experts of that field try to find conve- nient matches between available resources and demands [3]. Simulation is currently conventional inside the construction project management as a formal tool to solve related problems in construction. The key of modeling operations is to deter- mine productivity between needed resources and is to identify the sequences which are repeated during production level for construction projects [4].

II. PROBLEM STATEMENT

Performance ratio is productivity relative loss compared with some baseline periods and capability to perform tasks without wasting times and materials or the relative ratio between actual Production Rate abd ideal Production Rate [5] as presented in Eq. (1):

In this paper it was collected different detailed data from many concrete batch plants in Egypt, these data illustrates delivery quantities, transportation time and transportation dis- tance. Brainstorming was done using questionnaires to show factors affecting concrete batch plant performance ratio. Also, this study focuses on most effective variables that directly have a great affect on productivity, which was checked by Statistics Package for Social Science (SPSS) software.

III. PAPER OBJECTIVES ANDLAYOUT

Concrete batch plant is selected for this study because the RMC is sensitive part in the construction sector, it can be opti- mized to save time and cost. Major objective of this study is to focus on measuring concrete batch plant performance ratio. Also, sub objectives of this paper will provide, study and ana- lyze a clear understanding for: (1) Analyzing large scale of detailed data which is collected from more and different con- crete batch plants, this will be done through studying them during start of 2012 till the end of 2016; (2) Determining most effective factors affecting concrete batch plants performance ratiousingthreemainsheets:(A)Fielddatarecordingsheet;

(B) Field data processing sheet and (C) Field data analyzing sheet to monitor the most expected persuasive variables; (3) Classifying expected variables that affecting concrete batch plant performance ratio and predicting the relation between concrete batch plant performance ratio as dependant variable with each variable separately as independent variable consider- ing all remaining variables are obviated then more statistical analysis is suggested, all models were proved to get proportion correlation between each individual variable with concrete batch plant performance ratio; and (4) Summarization of conclusion.

This paper is categorized into main seven groups as follows:

(1) Introduction; (2) Literature Review; (3) Methodology of Data Source, Field Measurement; (4) Collecting Data and Analyze its Effect on Concrete batch Plant Performance Ratio using Statistics Package for Social Science (SPSS)software.

IV. PAPER METHODOLOGY

The main aim of this paper is to determine some main objec- tives as follows: (1) Selecting some different concrete batch plants in Egypt and determine design capacity of them. (2) Getting hourly/daily information data for: (a) concrete quanti- ties,(b)triptime,(c)boringlocation,(d)selectingequipment, (e) determining variables, (f) projects and (g) designing tables to tabulate collected data. (3) Collecting data since 2012 till 2016 and was made the comparison between average actual productivity with theoretical capacity. (4) Making detailed studyandanalysisforcollecteddatausingSPSSsoftwaretoassure which variables affect concrete batch plants perfor- mance ratio.

V. DESIGNING TABLES

1.1. Field recording datasheet

A questionnaires are prepared to give data for fourty effective variables that have direct impact on concrete batch plants per- formance ratio. Table 1 presents the sample of daily collected data from concrete batch plant for more of different construc- tion projects. This table contain: (1) projects ID, (2) truck number, (3) driver name, (4) boring place, (5) cement quantity,

(6) cement type, (7) concrete quantity, (8) cycle time and (9)timingschedule.

1.2. Field processing datasheet

The processing data sheet was designed for analyzing and pre- dicting concrete batch plant

performance ratio as presented in Table 2.

Table 2shoes the data analysis detailed summary of all recourses in selected concrete batch plants with different pro- jects. The table contains: (1) projects ID, (2) boring date, (3) cycle time, (4) daily quantity of concrete, (5) actual productiv- ity, (6) theoretical productivity, (7) concrete batch plant performance ratio and (8) allvariables affecting the performanceratio.

Where: Actual Time for operating concrete batch plant was major groups: (1) factors related to job conditions, (2) factors related to management conditions, and (3) factors related to equipment, where the major variables affecting concrete batch plants performance ratio were categorized into three major groups as presented in the following subsections.

6.1. Group (A) concrete batch plant variables

This group was broken down into seventeen variables as fol- lows: (1) concrete batch manager efficiency (X_1) which was expressed as a percentage; (2) batch plant operator efficiency (X_2) which was expressed as a percentage; (3) truck mixersdri- vers efficiency (X_3) which was expressed as a percentage, (4) concrete pump operator efficiency (X_4) which was expressed as a percentage; (5) concrete pump efficiency (X_5) which was expressed as a percentage either new one that give efficiencyis equal to 95% or old one that give efficiency is equal to 75%; (6) procurement plan efficiency (X_6) such as plans which provide cement, sand, gravel, etc. to fill the needs ofRMC

which was expressed as a percentage, (7) batch plant market planefficiency (X_7) that it was presented asapercentageifcon- crete batch plant is worked in maximum capacity or not as shown in Eq.(4).

Batch plant market plan efficiency

RðActual Quantities per dayÞ / ðtheoretical capacity per dayÞ 100 2

(8) truckmixersefficiency(X_8)thatwasstatedinEq.(5).

T12 m 0:9 þ T10 m 0:85 þ T6 m 0:75

measured per minutes; Actual Quantity of concrete was mea- sured by cubic meter per each day, actual production rate was calculated by get the ratio between actual quantity per

Truck mixers efficiency ¼

T12þT10þT6

ð3Þ

cubic meter over actual time per hr., theoretical capacity is the ideal production rate for the concrete batch plant which was assumed to be constant from manuals; PR concrete batch plant performance ratio which was calculated as a ratio between actual production rate over ideal production rate; X_1, X_2,.. ., X_n are variables that affecting concrete batch plant performanceratioasdeclaredinTable3.

VI. VARIABLES AFFECTING CONCRETE BATCH PLANTS PERFORMANCERATIO

Refs. [5–7] determined the general factors affecting construc- tion equipment productivity which were classified into three where T_{12} is the number of concrete truck mixers its capacityis equal to 12 m^3 that has corresponding efficiency is equal to 90%; T_{10} is the number of concrete truck mixers its capacity is equal to 10 m^3 that has corresponding efficiency is equal to 85%; T_6 is the number of concrete truck mixers its capacity isequalto6m^3thathas75%correspondingefficiency.

(9) 12m^3concretetruckmixersnumberthatusedfortrans- portating concrete from batch plant to sites (X_9); (10) 10 m^3 concrete truck mixers number that used for transportating concrete from batch plant to sites (X_{10}); (11) 6 m^3 concrete truck mixers number that used for transportating concrete from batch plant to sites (X_{11}); (12) concrete pumpsnumber

Table 1 Concrete batch Plant information for all studied projects.

ID	Driver name	Truck No.	Location	Cement type	Cement quantity	Receipt no.	Go out time	Quantity (m^3)	Return back time	Total time (h)
1	Awad Mahmoud	8652	Bourtage Misr	Anti.	400	23,588	9:20	6	10:20	1:00
2	Aly	8259	Elsafa	Nor.	250	23,589	9:50	10	11:15	1:25

	Mahmoud								
3	Mohamed	8654	Bourta Antige	Anti.	400	23,590	10:00	12	11:10	1:10
4	Sharaf Mansour	8572	AboKhalifa	Misr Nor.	250	23,591	10:10	10	11:40	1:30
5	Selim Ahmed Elshafey	432	AboKhalifa	Nor.	250	23,592	10:45	12	12:05	1:20

Table 2 Concrete batch Plant information for all selected projects with effective variables.

ID	Date	Act. time by Min.	Act. quantity	Act. production rate	Ideal production rate	Eff. %	X_1	X_2	X_3	X_4	X_{27}
1	2015/01/01	415	218	31.52	35	90.05	0.90	0.90	0.90	0.80	14.00
2	2015/01/02	290	35	7.24	35	20.69	0.60	0.60	0.70	0.90	14.00
3	2015/01/04	255	102	24.00	35	68.57	0.70	0.70	0.80	0.80	15.00
4	2015/01/05	95	36	22.74	35	64.96	0.60	0.90	0.90	0.90	14.00
5	2015/01/06	110	31	16.91	35	48.31	0.60	0.60	0.80	0.80	13.00

(X_{12}) that used for casting; (13) machines maintenance effi- ciency in the plant (X_{13}) which was expressed as a percentage, (14) workers bonus system inside batch plant (X_{14}) which was expressed as EGP for every trip; (15) raw material transporta- tion method from washing area to the concrete batch area and washing plant efficiency (X_{15}) which was expressed as a per- centage, (16) average distance between construction projects and concrete batch plant (X_{16}) that was presented in Eq. (6).seven effective variables and classified into 14 qualitative vari- ables and 13 quantitative variables as presented in Table 3:

6.4. Variablesclassification

These variables should categorize into two parts according to their measuring classifications.

$$\text{Average Distance} = \frac{RðQmdÞ}{RQ} \quad ð4Þ$$

6.4.1. Qualitativevariables

These variables are not having measurable values; they are

where d: is distance between concrete batch plants and con- struction projects; Q: is concrete truck mixer quantity per a trip;andRQ:isthequantityofusedconcreteperday.

(17) construction projects schedules (X_{17}) that supply the concrete referring to daily concrete quantities production.

6.2. Group (B) roadvariables

Itwasbrokendownintosixvariables:(18) sitesnumber, which aregivesorder forusing RMC(X_{18}),(19)plantsafetywitheffi- ciency (X_{19}) which was expressed as a percentage, (20) site arrangement (X_{20}) which was expressed as a percentage, (21) casteditemstypes (X_{21}) whichwasexpressedasapercentage,

(22) communications between site crews (X_{22}) which was expressed as a percentage, (23) machines damages number (X_{23}) which was expressed as a number. and X_{26}). They were expressed by using one of four choices: Excellent, Good, Medium, or Poor and were converted to equivalent percentage 90%, 80%, 70%, or 60%.

6.3. Group (C) projectvariables

APR¼ $\overset{P}{}$ðA:Prod:÷T:Prod:Þ

ð5Þ

6.4.2. Quantitativevariables

Thesevariablesarehavingmeasurablevalues;theyare(X_5,X_7, X_8,X_9,X_{10},X_{11},X_{12},X_{14},X_{16},X_{17},X_{18},X_{23},andX_{27}).

VII. RELATION BETWEEN CONCRETE BATCHPLANT PERFORMANCE RATIO WITH ALL VARIABLES

Graphical relationships were showed in this section to demon- strate effect of all variables on concrete batch plant perfor- mance ratio. The average of concretebatch plant performance ratio wasprovedasshowninEq.(5):

$$APR¼ \frac{\overset{P}{}ðA:Prod:÷T:Prod:Þ}{N} \qquad ð5Þ$$

It was broken down into four variables: (24) roads quality (X_{24}), which was expressed as a percentage, (25) traffic condi- tions (X_{25}) which was expressed as a percentage, (26) weather conditions (X_{26}) which was expressed as a percentage, and(27) averagetemperature(X_{26})itwasmeasuredbyCelsius.

By studying these factors that will lead to maximize con- crete batch plant performance ratio, Concreting procedures that consist of mixing concrete, transporting concrete and placing concrete are the major operations in construction pro- jects. This study started from early of 2012 till end of 2016 to monitor concrete quantities, distances, times, and transporta- tion system. As mentioned before more variables affect con- crete batch plant performance ratio. These variables were concluded tofortyvariables,theymightbereducedtotwenty where APR is the average of all performance ratios; A. Prod. is the Actual Productivity that was collected all data from field;
T. Prod. is the concrete batch plant Theoretical Productivity which was assumed constant for each one; N is the daily records number.

7.1. Relationbetweenmanagerefficiency(X_1)andbatchplant performanceratio

Concrete batch manager efficiency impacts on concrete batch plant performance ratio, when concrete batch plant manager efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and Poor manager efficiency produces an averageconcrete

No.	Factor	Definition	Type
X_1	Concrete batchmanagere□ciency	Itwasexpressedbyusingonefromfourchoices:ExcellentorGoodor Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_2	Batch plantoperatore□ciency	Itwasexpressedbyusingonefromfourchoices:ExcellentorGoodor Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_3	Truck mixersdriverse□ciency	Itwasexpressedbyusingonefromthreechoices:ExcellentorGoodor Medium	Qualitative (0.9 or 0.8 or 0.7)
X_4	Concrete pumpoperatore□ciency	Itwasexpressedbyusingonefromthreechoices:ExcellentorGoodor Medium	Qualitative (0.9 or 0.8 or 0.7)
X_5	Concretepumpe□ciency	Itwasexpressedbyusingonefromtwochoices:newoneoroldone	Quantitative (0.95 or 0.75)
X_6	Procurementplane□ciency	Itwasexpressedbyusingfourchoices:ExcellentorGoodorMediumor Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_7	Batch plant marketplane□ciency	It was calculated as a ratio between quantities of used concrete per dayover theoretical capacity per day	Quantitative See Eq. (2)
X_8	Truck mixerse□ciency	It was calculated as a weighted average e□ciency by putting 90% for 12m^3 trucks, 85% for 10 m^3 trucks, 75% for 6 m^3 trucks	Quantitative See Eq. (3)
X_9	12 m^3 Concrete truckmixersnumber	Counted which it usedfortransportation	Quantitative Counted
X_{10}	10 m^3 Concrete truckmixersnumber	Counted which it usedfortransportation	Quantitative Counted
X_{11}	6 m^3 Concrete truckmixersnumber	Counted which it usedfortransportation	Quantitative Counted
X_{12}	Concretepumpsnumber	Counted which it usedforcasting	Quantitative Counted
X_{13}	Machinesmaintenancee□ciency	Itwasexpressedbyusingonefromfourchoices:ExcellentorGoodor Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_{14}	Workersbonus system	Extra cost to workers per each tripby(EGP)	Quantitative
X_{15}	Raw material transportation method and washing plant e□ciency	Itwasexpressedbyusingonefromfourchoices:ExcellentorGoodor Medium orPoor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_{16}	Average distance between construction projects and concrete batch plant	It was calculatedby(km)	Quantitative See Eq. (4)
X_{17}	Constructionprojectsschedules	Itwascalculatedforneededquantitiesofconcreteby(m^3)	Quantitative Calculated
X_{18}	Sites number, which are gives order for using RMC	It was calculatedby(number)	Quantitative Counted
X_{19}	Plant safetywithe□ciency	Arrangementmethodsandschedulesfortrucksanditwasexpressedby using one from three choices: Excellent or Good or Medium or Poor	Qualitative (0.9 or 0.8 or 0.7)
X_{20}	Sitearrangement	Itwasexpressedbyusingonefromthreechoices:ExcellentorGoodor Medium	Qualitative (0.9 or 0.8 or 0.7)
X_{21}	Casted items types (raft – columns – slabs – etc.)	Itwasexpressedbyusingonefromfourchoices:ExcellentorGoodor Medium orPoor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_{22}	Sitecrewscommunications	Itwasexpressedbyusingonefromfourchoices:ExcellentorGoodor Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_{23}	Machinesdamagesnumber	Number of trucks damages andpumpsdamages	Quantitative Counted
X_{24}	Roads quality (bumpy–slopes)	Itwasexpressedbyusingonefromfourchoices:ExcellentorGoodor Medium orPoor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_{25}	Tra□cconditions	It was expressed by using one from four choices: Excellent or Good or Medium orPoor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)

Table 3 Selected variables information.

Table 3 (*continued*)

No.	Factor	Definition	Type
X_{26}	Weather conditions (humidity –rain– Excellent or Good or wind)	It was expressed by using one from four choices: Medium orPoor	Qualitative (0.9 or 0.8 or 0.7 or0.6)
X_{27}	Average	It was measured by	Quantitativ

batch plant performance ratio as 88.192, 74.656, 61.120 and 47.584% respectively. The efficiency of batch plant manager has major effect on concrete batch plant performance ratio.

PR ¼ —33:632 þ135:360X_1 ð6Þ

Eq. (6)was developed and it presents a relationship between manager efficiency (X_1) with concrete batch plantper- formance ratio by using SPSS considering all remaining vari- ables wereobviated.

7.2. Relationbetweenoperatorefficiency(X_2)andbatchplant performanceratio

7.4.Relationbetweenconcretepumpoperatorefficiency(X_4) and batch plant performanceratio

Concrete pump operator efficiency impacts on concrete batch plant performance ratio, when concrete pump operator effi- ciency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good and Medium pump operator efficiency produces an average concrete batch plant performance ratio as 66.928, 64.109 and 61.291%respec- tively. When site labors do not use pump that will give batch plant performance ratio is equal to 41.561%. The efficiencyof concrete pump operator has minor effect on concrete batchplant performanceratio.

Concretebatchplantoperatorefficiencyimpactsonconcretebatchplantperformanceratio,whenconcretebatchp lant

PR¼41:561þ28:185X_4

ð9Þ

operator efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and Poor operator efficiency produces an average concrete batch plant performance ratio as 84.184, 70.719

57.254 and 43.789% respectively. The efficiency of batch plant operator has major effect on concrete batch plant performance ratio.

PR ¼ —37:002 þ134:651X_2 ð7Þ

Eq. (7)was developed and it presents a relationship between operator efficiency (X_2) with concrete batch plant per- formance ratio by using SPSS considering all remaining vari- ables wereobviated.

7.3.Relationbetweendriverefficiency(X_3)andbatchplant performanceratio

Truck mixers drivers efficiency impacts on concrete batch plant performance ratio, when truck mixers drivers efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good and Medium truck mixers drivers efficiency produces an average concrete batch plant performance ratio as 79.532, 56.766 and 34.001% respec- tively (3). The efficiency of truck mixers drivers has major effectonconcretebatchplantperformanceratio.

PR ¼ —125:357 þ227:654X_3 ð8Þ

Eq. (8)was developed and it presents a relationship between truck mixers drivers efficiency (X_3) with concrete batch plant performance ratio by using SPSS considering all remaining variables wereobviated.

Eq. (9)was developed and it presents a relationship between concrete pump operator efficiency (X_4) with concrete batch plant performance ratio by using SPSS considering all remaining variables wereobviated.

7.5. Relationbetweenconcretepumpefficiency(X_5)andbatch plant performanceratio

Concretepumpefficiencyimpactsonconcretebatchplantperformanceratio,whenconcretepumpefficiencyi ncreases,con- cretebatchplantperformanceratiowillincreasewithoutsame rate. When (X_5= 1 then PR = 39.296) & (X_5= 0.9 then PR = 39.264) & (X_5= 0.8 then PR = 39.232) & (X_5=0.7 thenPR=39.2)and(X_5=0thenPR=38.975%).Theeffi- ciencyofconcretepumphasminoreffectonconcretebatch plant performanceratio.

PR ¼ 38:975þ0:321X_5 ð10Þ

Eq. (10)was developed and it presents a relationship between concrete pump efficiency (X_5) with concrete batch plant performance ratio by using SPSS considering all remain- ing variables were obviated.

7.6. Relationbetweenprocurementplanefficiency(X_6)and batch plant performanceratio

Procurement plan efficiency impacts on concrete batch plant performance ratio, when procurement plan efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor procurementplanefficiencyproducesanaverageconcretebatch plant performance ratio as 96.114, 78.878, 61.641 and 44.405% respectively. The efficiency procurement plan has major effect on concrete batch plant performance ratio.

PR ¼ —59:015þ172:366X_6 ð11Þ

Eq. (11)was developed and it presents a relationship between procurement plan efficiency (X_6) with

concrete batch plant performance ratio by SPSS considering all remaining variables were obviated.

7.7. Relation between batch plant market plan efficiency (X_7) and plant performanceratio

Batchplantmarketplanefficiencyimpactsonconcretebatch plant performance ratio, when batch plant market plan effi-ciency increases, concrete batch plant performance ratiowill increase without same rate. When (X_7= 100 then PR = 84.024) & (X_7= 75 then PR = 74.099) &(X_7= 50 thenPR=64.174)and(X_7=0thenPR=44.32%).Theeffi-ciencyofbatchplantmarketplanhasverymajoreffectoncon-crete batch plant performanceratio.

PR ¼ 44:324þ0:397X_7 ð12Þ

Eq. (12)was developed and it presents a relationship between batch plant market plan efficiency (X_7) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.8. Relationbetweentruckmixersefficiency(X_8)andbatch plant performanceratio

Truck mixers efficiency impacts on concrete batch plant per- formance ratio, when truck mixers efficiency increases, con- crete batch plant performance ratio will increase without Eq. (14)was developed and it presents a relationship between 12 m^3 concrete truck mixers number (X_9) with con- crete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.10. Relation between 10 m^3 concrete truck mixers number (X_{10}) and plant performanceratio

10m^3concretetruckmixersnumberimpactsonconcretebatch plant performance ratio, when 12 m^3 concrete truck mixers numberincreases,concretebatchplantperformanceratiowill increase without same rate. When (X_{10}= 4.0 then PR = 90.04) & (X_{10}= 3.0 then PR = 79.775) & (X_{10}=2.0 thenPR=69.51)and(X_{10}=1.0thenPR=59.248%).The

10m^3concretetruckmixersnumberhasmajoreffectoncon- crete batch plant performanceratio.

PR ¼ 48:980þ10:265X_{10} ð15Þ

Eq. (15)was developed and it presents a relationship between 10 m^3 concrete truck mixers number (X_{10}) with con- crete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.11. Relation between 6 m^3 concrete truck mixers number (X_{11}) and plant performanceratio

6 m^3 concrete truck mixers number does not impact on con-cretebatchplantperformanceratio,when6m^3concretetruck mixers number increases, concrete batch plant performance ratio will negligible increase without same rate. When(X_{11}= 2.0 then PR = 62.874) and (X_{11}= 1.0then

PR = 62.82%). The 6 m^3 concrete truck mixers number has negligible effect on concrete batch plant performance ratio.

samerate.When(X_8=1.0thenPR=89.716)&(X_8=0.90 then PR = 67.778) & (X_8= 0.80 then PR = 45.839)&

PR¼462:766þ0:054X_{11}

ð16Þ

(X_8= 0.70 then PR = 23.90) and (X_8= 0.60 then PR=1.962%).Theefficiencyoftruckmixershasmajoreffect on concrete batch plant performanceratio.

PR ¼ —129:67þ219:386X_8 ð13Þ

Eq. (13)was developed and it presents a relationship between truck mixers efficiency (X_8) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.9. Relation between 12 m^3 concrete truck mixers number (X_9) and plant performance ratio

12m^3concretetruckmixersnumberimpactsonconcretebatch plant performance ratio, when 12 m^3 concrete truck mixers numberincreases,concretebatchplantperformanceratiowill increase without same rate. When (X_9= 8.0 then PR = 95.473) & (X_9= 7.0 then PR = 87.996) & (X_9=4.0 thenPR=65.565)and(X_9=1.0thenPR=43.134%).The

Eq. (16) was developed as relationship between 6 m^3 con- crete truck mixers number (X_{11}) with concrete batch plant per- formance ratio using SPSS considering all remaining variables were obviated.

7.12. Relation between concrete pumps number (X_{12}) and batch plant performanceratio

Concretepumpsnumberimpactsonconcretebatchplantper-formanceratio,whenconcretepumpsnumberincreases,con- crete batch plant performance ratio will

increase without same rate. When (X_{12}= 2.0 then PR = 84.103) & (X_{12}= 1.0 then PR = 62.158) and (X_{12}= 0.0 then
PR=40.213%).Theconcretepumpsnumberhasmajoreffect on concrete batch plant performanceratio.
PR ¼ 40:213þ21:945X_{12} ð17Þ
Eq. (17)was developed and it presents a relationship
12 m^3 concrete truck mixers number has very major effect on
between concrete pumps number (X
$_{12}$) with concrete batch

concrete batch plant performance ratio.
PR ¼ 35:657þ7:477X_9 ð14Þ
plant performance ratio by using SPSS considering all remain- ing variables were obviated.

7.13. Relation between machines maintenance efficiency (X_{13}) and plant performanceratio

Machines maintenance efficiency impacts on concrete batchplant performance ratio, when machines maintenance effi- ciency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor machines maintenance efficiency produces an aver- age concrete batch plant performance ratio as 65.85, 60.760, 55.666 and 550.571% respectively. The machines maintenance efficiency has minor effect on concrete batch plant perfor- manceratio.

PR ¼ 20:002þ50:948X_{13} ð18Þ
Eq. (18)was developed and it presents a relationship between machines maintenance efficiency (X_{13}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.14. Relation between workers bonus system (X_{14}) and batch plant performanceratio
Workersbonussystemimpactsonconcretebatchplantperformanceratio,whenworkersbonussystemincreas es,concrete batchplantperformanceratiowillincreasewithoutsamerate.When (X_{14}= 185 then PR = 99.374) & (X_{14}= 150 then PR = 88.664) & (X_{14}= 100 then PR = 73.364)and
(X_{14}=5thenPR=44.294%).Theworkersbonussystem
hasmajoreffectonconcretebatchplantperformanceratio.

PR ¼ 42:764þ0:306X_{14} ð19Þ
Eq. (19)was developed and it presents a relationship between workers bonus system (X_{14}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.15. Relationbetweenwashingplantefficiency(X_{15})andbatch plant performanceratio

Raw material transportation method and washing plant effi- ciency impacts on concrete batch plant performance ratio, when raw material transportation method and washing plant efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good and Med- ium raw material transportation method and washing plant efficiency produces an average concrete batch plant perfor- mance ratio as 78.25, 55.475 and 32.699% respectively. The raw material transportation method and washing plant effi- ciency has major effect on concrete batch plant performance ratio.

7.16. Relationbetweenaveragedistancebetweenbatch&projects (X_{16}) and performanceratio
Averagedistancebetweenconstructionprojectsandconcrete batch plant impacts on concrete batch plant performance ratio,whenaveragedistancebetweenconstructionprojects andconcretebatchplantincreases,concretebatchplantper- formance ratio will decrease without same rate. When (X_{16}= 100 then PR = 34.67) & (X_{16}= 75 then PR=43.595)&(X_{16}=50thenPR=52.52)&(X_{16}=29
then PR = 60.017) & (X_{16}= 25 then PR = 61.445) and (X_{16}=0.50thenPR=70.192%).Theaverage distance betweenconstructionprojectsandconcretebatchplanthas medium effect on concrete batch plant performance ratio, thebestdistancerangebetweenconcretebatchplantandpro- jectsisrangedbetween(0.5:29km)togivetheacceptablecon- crete batch plant performanceratio.
PR ¼ 70:370—0:357X_{16} ð21Þ
Eq. (21)was developed and it presents a relationship between average distance between construction projects and concrete batch plant (X_{16}) with plant performance ratio by using SPSS considering all remaining variables wereobviated.

7.17. Relation between construction projects schedules (X_{17}) and batch plant performanceratio

Constructionprojectsschedulesimpactsonconcretebatchplantperformanceratio,whenconstructionproj ectsschedulesincreases,concretebatchplantperformanceratiowillincrease withoutsamerate.When(X_{17}=375.0thenPR=97.575)& (X_{17}= 285.0 then PR = 84.795) & (X_{17}= 140.0 then PR=64.205)&(X_{17}=35.0thenPR=49.295)and (X_{17}= 2.0 then PR = 44.609%). The construction projects concretequantitiesscheduleshasverymajoreffectonconcrete batch plant performance ratio, the best daily demand of con- crete that should be produced are ranged between (285.0:375.0 m^3/day) to get optimized concrete batch plant performanceratio.

PR ¼ 44:325þ0:142X_{17} ð22Þ

Eq. (22)was developed and it presents a relationship between construction projects concrete quantities schedules (X_{17}) with batch plant performance ratio by using SPSS con- sidering all remaining variables were obviated.

7.18. Relation between sites number (X_{18}) and batch plant performanceratio

Number of sites, which are gives order for using RMC impacts on concrete batch plant performance ratio, when number of sites increases, concrete batch plant performance ratio will

PR¼—126:727þ227:752X_{15}
ð20Þ
increase without same rate. When (X_{18}= 10.0then PR=89.426)&(X_{18}=8.0thenPR=82.558)&(X_{18}=6.0

Eq. (20)was developed and it presents a relationship between raw material transportation method and washingplant efficiency (X_{15}) with batch plant performance ratio by using SPSS considering all remaining variables wereobviated.

thenPR=75.69)&(X_{18}=4.0thenPR=68.822)and (X_{18}= 2.0 then PR = 61.954%). The sites number whichareneedRMChasmediumeffectonconcretebatchplantperformanceratio,thegoodnumberprojects areranged(4.0–6.0projects/day) to get optimized concrete batch plant perfor- mance ratio.

PR ¼ 55:086þ3:434X_{18} ð23Þ

Eq. (23)was developed and it presents a relationship between daily sites number (X_{18}) with batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.19. Relation between plant safety with efficiency (X_{19}) andbatch plant performanceratio

Plant safety with efficiency impacts on concrete batch plant performance ratio, when plant safety with efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good and Medium plant safety with efficiency produces an average concrete batch plant perfor- mance ratio as 67.899, 40.071 and 12.242% respectively. The plant safety with efficiency has major effect on concrete batch plant performance ratio.

PR¼—182:559þ278:287X_{19} ð24Þ

Eq. (24)was developed and it presents a relationship between daily sites number (X_{19}) with batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.20. Relation between site arrangement (X_{20}) and concrete batch plant performanceratio

Site arrangement impacts on concrete batch plant performance ratio, when site arrangement increases, concrete batch plant performance ratio will increase without same rate. The Excel- lent, Good and Medium site arrangement produces an average concrete batch plant performance ratio as 71.628, 54.730 and 37.832% respectively. Site arrangement has major effect on concrete batch plant performance ratio.

PR¼—80:453þ168:979X_{20} ð25Þ

Eq. (25)was developed and it presents a relationship between site arrangement (X_{20}) with concrete batch plant per- formance ratio by using SPSS considering all remaining vari- ables were obviated.

7.21. Relation between casted items types (X_{21}) and concrete batch plant performanceratio

Casted items types impacts on concrete batch plant perfor- mance ratio, when casted items types increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor casted items types pro- duces an average concrete batch plant performance ratio as 65.855, 60.760, 55.666 and 50.571% respectively. The items typesthatwillbecasted(raft–columns–slabs–etc.)hasmed- iumeffectonconcretebatchplantperformanceratio.

PR¼—55:295þ147:942X_{21} ð26Þ

Eq. (26)was developed and it presents a relationship between casted items types (X_{21}) with concrete batch plantper- formance ratio by using SPSS considering all remaining vari- ables wereobviated.

7.22. Relation between site crews communications (X_{22}) and batch plant performanceratio

Site crews communications impacts on concrete batch plant performance ratio, when site crews communications increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor casted items types produces an average concrete batch plant perfor- mance ratio as 87.642, 66.474, 45.307 and 24.139% respec- tively. The site crews communications has very major effect on concrete batch plant performanceratio.

PR¼—102:866þ211:675X_{22} ð27Þ

Eq. (27)was developed and it presents a relationship between site crews communications (X_{22}) with concrete batch plant performance ratio by using SPSS considering all remain- ing variables were obviated.

7.23. Relation between machines damages number (X_{23}) and batch plant performanceratio

Machinesdamagesnumberimpactsonconcretebatchplant performanceratio,whenmachinesdamagesnumberincreases, concrete batch plant performance ratio will decreasewithout same rate. When (X_{23}= 3.0 then PR = 48.822) & (X_{23}= 2.0 then PR = 52.909) & (X_{23}= 1.0 then PR=56.996)and(X_{23}=0.0 thenPR=61.083%).The machines damages number has very minor effect on concrete batch plant performance ratio.

PR ¼ 61:083—4:087X_{23} ð28Þ

Eq. (28)was developed and it presents a relationship between machines damages number (X_{23}) with concrete batch plant performance ratio by using SPSS considering all remain- ing variables were obviated.

7.24. Relation between roads quality (X_{24}) and concrete batch plant performanceratio

Roads quality impacts on concrete batch plant performance ratio, when roads quality increases, concrete batch plant per- formance ratio will increase without same rate. The Excellent, Good, Medium and poor roads quality produces an average concrete batch plant performance ratio as 64.280, 62.580, 60.879 and 59.179% respectively. The roads quality has very minor effect on concrete batch plant performance ratio.

PR ¼ 48:975þ17:006X_{24} ð29Þ

Eq. (29)was developed and it presents a relationship between roads quality (X_{24}) with concrete batch plant perfor- mance ratio by using SPSS considering all remaining variables were obviated.

7.25. Relation between traffic conditions (X_{25}) and concrete batch plant performanceratio

Traffic conditions impacts on concrete batch plant perfor- mance ratio, when traffic conditions increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor roads quality produces anaverageconcretebatchplantperformanceratioas88.192,74656, 61.120 and 47.584% respectively. The traffic condi- tions has very major effect on concrete batch plant perfor- mance ratio.

PR¼—33:632þ135:360X_{25} ð30Þ

Eq. (30)was developed as a relationship between traffic conditions (X_{25}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.26. Relation between weather conditions (X_{26}) and concrete batch plant performanceratio

Weather conditions impacts on concrete batch plant perfor- mance ratio, when weather conditions increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor weather conditions produces an average concrete batch plant performance ratio as 67.832, 64.274, 60.715 and 57.157% respectively. The weather conditions has very minor effect on concrete batch plant performanceratio.

PR ¼ 35:808þ35:582X_{26} ð31Þ

Eq. (31)was developed and it presents a relationship between weather conditions (X_{26}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.27. Relation between average temperature (X_{27}) andconcrete batch plant performanceratio

Averagetemperatureimpactsonconcretebatchplantperfor- mance ratio, when average temperature increases, concrete batchplantperformanceratiowilldecreasewithoutsamerate. Changes of temperature affect both concrete batch plant equipmentperformanceratioandmanpower,alltemperatures were recorded at studied period. When (X_{27}= 40 then PR=42.89)&(X_{27}=30thenPR=48.19)&(X_{27}=20then

PR = 53.49) and (X_{27}= 11 then PR = 58.26%). Average temperature has minor effect on concrete batch plant perfor- mance ratio, a suitable temperature is ranged between (10.0:20.0 °C) to optimize concrete batch plant performance ratio.

PR ¼ 64:090—0:53X_{27} ð32Þ

Eq. (32)was developed and it presents a relationship between average temperature (X_{27}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated, this equation is valued between 10 and 50Celsius.

In previous sub sections it was mentioned how to collect data from construction fields, to classify variables affecting concrete batch plant performance ratio, to analyze the data and results, to estimate the relation between each variable sep- arately with concrete batch plant performance ratio consider- ing remaining variables are obviated, to mention statistical analysis, finally to prove models and find the proportion cor- relation per eachvariable.

VIII. CONCLUSION

In this paper, it was concluded engineering approach to allo- cate and evaluate effective variables that is affecting concrete batch plant performance ratio under different effects and are listed and ranked in descending order respectively as: (truck mixerseffi ciency,batchplantmarketplanefficiency,truckmix- ers drivers efficiency, weather conditions, communications between site crews, casted items types, batch plant operator efficiency, raw material transportation method from washing area to the concrete batch area and washing plant efficiency, machines maintenance efficiency in the plant, and concrete batch manager efficiency) based on questionnaires results and collected data analysis. Each effective variable values were studied carefully and final study results were mentioned as fol- lows: (1) Concrete batch plant performance ratio increases when(managerefficiency,operatorefficiency,driverefficiency, concrete pump operator efficiency, procurement plan effi- ciency,marketingplanefficiency,truckmixerseffi ciency,num- ber of 12 m^3 capacity truck mixers, number of 10 m^3 capacity truck mixers, pumps number, regular equipment maintenance efficiency,pumpsefficiency,washingplantefficiency)increase, (2) weighted average distance between projects and concrete batch plant impacts on concrete batch plant performanceratio, when the distance increases; concrete batch plant perfor- mance ratio will decrease; it was studied a acceptable distance between projects and concrete batch plant and it should be ranged between (0.5:29 km), (3) projects schedules and orders of concrete quantities affecting concrete batch plant perfor- mance ratio, when it increases, concrete batch plant perfor- mance ratio will increase; it was studied optimaldaily concrete quantities range that should to be produced is ranged between (285:375 m^3), (4) daily projects orders number affect- ing concrete batch plant performance ratio, when it increases, concrete batch plant performance ratio will increase; it was studied optimal daily projects orders number should be ranged between(4:6projects),(5)itemstypesthatwillbecastedeffects on concrete batch plant performance ratio, when items types that will be casted are same and easy, concrete batch plant per- formance ratio will increase, (6) communication between site crews impact on concrete batch plant performance ratio, when it is a good communication, concrete batch plant performance ratio will increase, (7) unexpected damages impacts on con- crete batch plant performance ratio, when it increases, con- crete batch plant performance ratio will decrease, (8) roads quality effects on concrete batch plant performance ratio, when they are good, concrete batch plant performance ratio will increase, (9) traffic conditions influences on concrete batch plant performance ratio, when it is not crowded, concrete batch plant performance ratio will increase, (10) weather con- ditions effects on concrete batch plant performanceratio, when it is good weather, concrete batch plant performance ratio willincrease.

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