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Repetitive Projects Scheduling to Minimize Idle Time: A Case Study of Libyan Electricity Infrastructure Projects

Medhat Youssef[1, *], Alshger Abdallah Alshger Alshagmani[2], Mahmoud Malek Olwan[3]

[1]Department of Construction Engineering and Utilities, Faculty of Engineering, Zagazig University, Zagazig, Egypt
[2]General Electricity of Company of Libya, Tripoli, Libya
[3]Department of Civil Engineering, Higher Technological Institute, 10th of Ramadan City, Egypt

Email address:

med_most@yahoo.com (Medhat Youssef), MAIsmyel@eng.zu.edu.eg (Medhat Youssef),
asg.ash1609@gmail.com (Alshger Abdallah Alshger Alshagmani), mmmolwan@gmail.com (Mahmoud Malek Olwan)
[*]Corresponding author

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Abstract: Libyan reconstruction plan will start after the end of the current crisis, so effective management of resources is crucial as adopting time-cost optimizing tools. projects' success depends upon achieving their objectives, which makes project planning essential. Repetitive Scheduling Method (RSM) ensures continuous utilization of resources from location to location in linear projects to eliminate time waste. This study applied RSM in the electrical project scheduling of Sirt-Hone 400kv transmission project. A graph of crew's movement through locations without idle time was presented, leading to fast project delivery and providing more value to the owner. The scheduling was done for a single work crew's composition and production rate two times, one time assigning one contractor and the other time two contractors. The project duration in 1st case was 574 days with zero idle time, and in the 2nd case was 275 days with zero idle time. RSM facilitates it easy to perform several scheduling scenarios to compare idle time and project duration. The study is empirical evidence for production strategies based on Lean Construction principles in project scheduling using RSM. Libyan reconstruction plan will need an advanced scheduling approach as RSM for repetitive linear projects due to the scarcity of resources.

Keywords: Repetitive Construction Projects, Linear Scheduling Method, Continuous Resource Utilization, Repetitive Scheduling

1. Introduction

Effective project delivery is one of the most difficult challenges [24, 25]. Resource constraints are encountered in projects, which may limit the implementation of ideal schedules. Linear construction projects consist of a set of repeated activities in each location among the total length. After an activity is completed in one location, it is repeated in another location. Typically, linear construction projects are roadways, tunnels, and pipelines that involve repetitive operations. Projects containing a lot of repetitive activities are classified as repetitive projects, such as multi-story buildings, pipelines, highways, housing development projects, and linear electrical projects. Contractors often encounter projects that contain several identical or similar units, such as meters in pipelines, and stations on highways. These multi-unit projects are characterized by repeated activities, which in most instances arise from the subdivision of a generalized activity into specific activities associated with particular units [7]. There are projects with repetitive activities in horizontal alignment and projects with repetitive activities in vertical alignment, some repetitive project includes vertical and horizontal repetitive processes together [13, 12]. There are two types of Scheduling methods; network and linear scheduling methods (LSM). These scheduling methods are used in horizontal and vertical repetitive projects. The Linear Scheduling Method is one of the techniques that offer a practical way to model linear projects as well as an efficient framework to monitor their progress [10]. Also, creates a schedule in a coordinate system with a time axis and an axis that displays the amount of work produced at each station (location). The linear Schedule of a project is a plot of the repetitive activities' production rate in a time and location chart [3]. It also provides a tool to supervise the progress of the crew's production as they move along the project.

Effective planning, scheduling, and control of construction projects are necessary to reduce construction time, cost overruns, and disputes. These benefits accrue to the contractor, owner, suppliers, and workers in the form of improvements in productivity, quality, and resource utilization [15]. By using linear scheduling, a manager can determine how the planner intended the work to proceed. Even if the manager has little experience in construction, He can compare actual progress to planned progress from a cursory review of a linear schedule [18].

This case study aimed to optimize continuous resource utilization using an LSM schedule to minimize idle time and increase cost savings. This case study contained typical and atypical activities. In atypical activities, the duration varies from one unit to another due to different work quantities. The scheduling problem in repetitive projects lies in the constraints of continuous resource utilization from unit to unit as well as the technical constraints between activities. LSM attains work continuity not only between "unit and unit" but also between "activity and activity" when the activities employ the same crew. This study was based on real data collected from the General Electricity of Company of Libya (GECOL) for the planning and scheduling project of the Sirt-Hone 400kv transmission line to minimize the total idle time. Libya went through destructive events in the last decade [7]. After crisis resolution, the reconstruction phase will need an advanced scheduling approach as LSM for repetitive linear projects to control time and cost throughout the project life cycle from the beginning of the initial design until project delivery.

2. Literature Review: Repetitive Scheduling Method

2.1. Origin of Repetitive Scheduling Methods

The Repetitive Scheduling method (RSM) was introduced by [4, 3, 16]. Studies have been continued on the linear scheduling method for strengthen application as a powerful tool for repetitive project scheduling [20, 26]. Also, LSM represents a repetitive activity as a production line in a two-dimensional time and space graph, the horizontal axis represents time, and the vertical axis is the location of an activity or a crew. The slope of a production line represents its productivity rate. A production line may be a straight line or varying slopes according to production rates constant/varying, which is attributed to many factors. Previous research has shown that LSM allows a better representation of scheduling data than the conventional CPM or bar charts w.r.t time and space constraints, activity location, and productivity rates [23]. Work continuity should maintain to achieve efficiency in a linear project. In this regard, LSM is particularly useful in visualizing workflow, time, and other constraints. Therefore, a scheduler can easily adjust activity start time or balance production rates to achieve work continuity. Continuous resource utilization is not directly addressed by CPM, or by its resource-oriented extensions [8, 14].

LSM is suitable for any construction project characterized by its repetitive nature and consists of activities repeatedly set sequentially at different locations. The activity's logic and technologically driven sequence are described by time/distance constraints. In addition, because resources are used sequentially, effective resource management is crucial in terms of project cost and duration. In addition, because of the division of the project into individual units, meeting intermediate unit delivery times is another issue in linear repetitive Projects [11, 17]. Searches of LSM have focused on early application in project scheduling, but uncertain events in project performance have not been fully addressed [2, 10]. Srisuwanrat and Ioannou studied the optimization of repetitive schedules when activity durations are probabilistic with two models to optimize work continuity and project cost by adjusting the repetitive activities' start time and considering only precedence logic between activities, and productivity rates per day following the normal distribution [19].

2.2. Activity Types and Logic Constraints

In LSM charts, there are two types of control constraints of unit-to-unit logic; one is a technical precedence constraint, and the other is a resource availability constraint. In the first instance, a particular work activity in the network of one unit must be followed by a similar work activity in a succeeding unit network to maintain the technical workflow between the units. In the second case, the resource assigned to an activity in one unit also must be assigned to a similar activity in the succeeding unit to ensure that the required resource for the first unit is free and available when the second unit scheduling starts. This does not guarantee that the resource is being continuously used between the two units [8, 11].

To derive a practical and effective schedule for repetitive projects, the main constraints that must apply are the precedence, resource availability, and resource continuity constraints. Precedence constraints ensure that activities will perform in technological construction orders, whereas resource availability constraints ensure the practical use of available resources. Resource continuity constraints are applied to maximize resource utilization by keeping resources working continuously without interruption. Accordingly, resource continuity constraints of these particular activities significantly affect the resource utilization of the overall project. The application of such crew work continuity during the scheduling of repetitive construction leads to the following managerial function: (i) maximize the benefits from the learning curve effect for each crew, which leads to time and cost savings (ii).

Minimize idle waiting intervals of equipment and labor. (iii) Minimize extra effort associated with work interruptions. (iv) Minimize the off-on movement of crews on a project once work has begun [17].

3. Case Study: Repetitive Scheduling Method Application

By following repetitive projects scheduling approach (LSM), in the real case study. The study aims to minimize work crew idle times in project Sirte – Houn 400 KV Transmission Line Single Circuit Project.

3.1. Project Description

Project name: Sirte–Houn 400 KV Transmission Line Single Circuit with length 287.4 km.

In this project, the contractor was responsible for the main line installation activities such as selecting suitable routes, obstacles on route surveying, bending, tower type selection, soil investigation, cut works, plain concrete and install fixed part of the tower, and Form Work for Reinforced Concrete... etc. The project data and information needed were collected from the General Electricity Company of Libya (GECOL). the project activities with their quantities and production rates. as shown in Table 1.

Table 1. *Quantities and production rates of activities.*

No.	Activity	Units	Total quantity	Production rate	Assigned crews
1	Select Suitable Route	Km	287.4049	18 km/day	1
2	Obstacles on Route Surveying	Km	287.4049	8.8 km/day	1
3	Tower Type Selection	Km	287.4049	9 km/day	1
4	Soil Investigation	Km	287.4049	2 km /day	1
5	Cut Works	m3	57641.6	89.6 m3/day	3
6	Plain Concrete and Install Fixed Part of Tower	m3	680.21	3 m3/day	1
7	Form Work for Reinforced Concrete	No.	667	3 /day	1
8	Install Footing Reinforcement Steel and Tower Base	No.	667	3 /day	1
9	Footing Reinforced Concrete Curing	m3	5067.28	22.6 m3/day	1
10	Remove Footing Form and Install it to Tower Base	No.	667	3 /day	1
11	Tower column Reinforced concrete curing	m3	3715.5	16.6 m3/day	1
12	Remove form work of column	No.	667	3 / day	1
13	Isolation Work for Base and Filling Work	m3	48248.76	75.4 m3/day	3
14	Tower steel Body collection and Installing	Ton	13521.9	13.3 ton/day	3
15	Install Different conductors and Wires	Km	287.4049	25 km/month	1
16	Install Communication optical ground wire (OPGW) Boxes	No.	82	4 /day	1
17	Cleaning work and project close out	Km	287.4049	9.5 km/day	1

The total project path distance is 287.4049 km, with 667 tower stations as shown in Figure 1. the tower models were different along the path as shown in Figures (2-a, 2-b, 2-c, and 2-d). Towers models range from types A, B, C, D, where tower type (A) is used for suspension wire in a straight line without an angle, and other tower types are used for wire tension with a straight line with an angle. Table 2, shows the model of the tower according to angle and purpose. Also, Table 3, Shows the towers stations number, the cumulative distance between towers, and tower models along the project path.

Throughout this study, the restrictions were constant construction production rate for each activity; using a single crew for each activity except activities No. 5, 13, and 14. In addition, all work will progress in the same direction, and a buffer time of one day between different activities execution was considered. To accomplish the mentioned objective above, a typical linear schedule was selected.

Table 2. *Tower models with angle and purpose.*

Tower models	Angle		Tower Purpose
	From	To	
A	0	2	Suspension
B	3	30	Wire tension
C	31	60	Wire tension
D	61	90	Wire tension

Table 3. *Show some first & last stations no. and the distance between towers along the project path.*

Station	Tower type	Cum. distance	Station	Tower type	Cum. distance	Station	Tower type	Cum. distance	Station	Tower type	Cum. distance
1	DD21	0.0	2	CC24	245.55	3	CC24	598.82	4	DD24	862.06
5	AA27	1,219.39	6	BB30	1,645.16	7	SP72	2,039.43	8	SP72	2,557.52
9	BB42	2,753.41	10	AA30	3,180	11	BB27	3,535	12	DD27	3,920.34
660	A27	284,830.09	661	A27	285,230.09	662	A24	285,630.09	663	D18	286,009.31

* Number beside the tower symbols refer to the tower height up to the conductor

Figure 1. *Section from Libya map showing Sirte-Houn 400Kv Line route.*

(a)

(b)

(c)

(d)

Figure 2. *a: Tower models AA; b: Tower models BB, CC, DD; c: Tower models A; d: Tower models B, C, D.*

3.2. Project Activities Constraints

LSM may postpone the start of some activities to achieve uninterrupted resource (i.e. crews and equipment) usage and ensures continuous resource utilization. Also, it may decrease or increase the time buffers (floats) by which an activity can be delayed without delaying the project's completion. The following project constraints were considered:

1. Crews' composition was constant at each station and along the project path for each activity.
2. Resources (labor and equipment) crew has fixed composition, production rates, and work quantity was variable at different work locations.
3. Precedence relationships between activities, For Activities 1 to 4, any activity cannot start until the finish of the previous activity, i.e. activity 2 cannot start until activity 1 has been finished and accepted by the owner, activity 3 cannot start until activity 2 has been

finished, and activity 4 cannot start until activity 3 has been finished.

4. Consider a time buffer between the finish time of activity 12 and the start time of activity 13.
5. Activity 15 and 16 cannot start until all tower stations between the two tension towers are finished.
6. After the finish of activity 12 must be left for 28 days for concrete curing according to the consultancy notification.

3.3. Project Planning and Scheduling

The project was scheduled by using available Microsoft Excel as a part of the MS Office package, which is very simple and easy. Project data were entered in the spreadsheet by LSM concept in the following two cases.

In the first case, one contractor was assigned to the project (all project stations).

In the second case, two contractors were assigned, one contractor from station No. 1 to station 325 and the other contractor from station No. 325 to station No. 667.

In creating the linear schedules for all project activities, a minimum one-day buffer between activities was considered. In addition, the production rates were considered constant for the entire duration of each activity. Activity duration has calculated by knowing the production rates. the scheduling of Activities No. 1, 2, 3, 4, 15, 17 is a Linear curve, while the scheduling of activities No. 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16 are stepped stairs curves. By using Excel sheets activities duration was computed by dividing the work quantity at different tower stations by the production rates for each activity, and the calculated time was linked with the scheduling drawing figure automatically.

3.3.1. First Case: Project Scheduling Results

In a repetitive and linear construction project, maintaining a crew's continuous performance is essential to achieve the different activities because successor activities can only be performed after the predecessors are completed. In this case, one contractor was assigned to all project activities in all stations. Linear schedule for the project by using Excel spreadsheets to determine the start time (ST) and finish time (FT) for each activity as shown in Table 4 for station No. 1 to Station No. 8 and Table 5 for station No. 660 to Station No. 667. this is a part of the results for presentation purposes for the first case. For better visualization of the results, a graph for all activities on a large chart was presented, but here we can present a sample graph for the first four project stations as shown in Figure 3. Also, the last four project stations are shown in Figure 4, to demonstrate the start and finish times for each activity and the work continuity (no idle time). The total project duration, in this case, was 574 days.

3.3.2. Second Case: Project Scheduling Results

In this case, two contractors were assigned, the first contractor to construct the project activities from tower station No. 1 to tower station No. 325 with a total distance equal to 145.686 km. the second contractor to execute activities from station No. 325 to station No. 667 with a total distance equal to 141.7189 km. Table 6 shows the start and finish times for each activity from tower station No. 325 to station No. 332, Table 7 shows the start (ST) and finish times (FT) for each activity from station No. 660 to station No. 667 as a part of the results. Figure 5, shows the linear scheduling graph for the tower station No. 661 to station No. 667 for activities time calculated by Excel sheets, considering all scheduling constraints. the Total project duration in this case equal to 275 days.

Table 4. *First case, Scheduling times for Station No. 1 to Station No. 8.*

Tower Type		DD21	CC24	CC24	DD24	AA27	BB30	SP72	SP72
Station (No.)		1	2	3	4	5	6	7	8
Cumulative distance (m)		00.0	245.55	598.82	863.06	1219.39	1645.16	2039.43	2557.52
Work crew for items									
Rout selection	ST	0.00	0.01	0.03	0.05	0.07	0.09	0.11	0.14
	FT	0.01	0.03	0.05	0.07	0.09	0.11	0.14	0.15
Surveying work for obstacles	ST	8.09	8.12	8.16	8.19	8.23	8.28	8.33	8.38
	FT	8.12	8.16	8.19	8.23	8.28	8.33	8.38	8.41
Tower type selection	ST	24.65	24.68	24.72	24.74	24.78	24.83	24.88	24.93
	FT	24.68	24.72	24.74	24.78	24.83	24.88	24.93	24.95
Soil investigation	ST	40.84	40.96	41.14	41.27	41.45	41.66	41.86	42.12
	FT	40.96	41.14	41.27	41.45	41.66	41.86	42.12	42.21
Cut works	ST	44.19	46.21	48.22	50.42	50.94	52.68	53.73	54.75
	FT	46.21	48.22	50.42	50.94	52.68	53.73	54.75	56.50
Plain concrete	ST	47.43	49.68	51.92	54.35	54.93	56.88	58.04	59.20
	FT	49.68	51.92	54.35	54.93	56.88	58.04	59.20	61.15
Install form work for footing	ST	88.00	88.00	88.00	89.00	89.00	89.00	90.00	90.00
	FT	88.00	88.00	89.00	89.00	89.00	90.00	90.00	90.00
Steel work for footing and column	ST	89.00	89.00	89.00	90.00	90.00	90.00	91.00	91.00
	FT	89.00	89.00	90.00	90.00	90.00	91.00	91.00	91.00
R. concrete pouring for footing	ST	92.90	95.44	97.98	100.88	101.26	103.32	104.45	105.57
	FT	95.44	97.98	100.88	101.26	103.32	104.45	105.57	107.63

Tower Type		DD21	CC24	CC24	DD24	AA27	BB30	SP72	SP72
Remove footing form work and install column form	ST	132.00	132.00	132.00	133.00	133.00	133.00	134.00	134.00
	FT	132.00	132.00	133.00	133.00	133.00	134.00	134.00	134.00
R. Concrete pouring for column	ST	134.81	135.65	136.49	138.30	138.90	139.63	140.35	141.07
	FT	135.65	136.49	138.30	138.90	139.63	140.35	141.07	141.80
Remove form work of column	ST	143.00	143.00	143.00	144.00	144.00	144.00	145.00	145.00
	FT	143.00	143.00	144.00	144.00	144.00	145.00	145.00	145.00
Concrete painting and fill work	ST	146.13	148.17	150.20	152.33	152.86	154.64	155.69	156.72
	FT	148.17	150.20	152.33	152.86	154.64	155.69	156.72	158.49
Tower steel collection and install	ST	154.78	157.28	159.78	162.68	163.36	165.82	168.31	170.80
	FT	157.28	159.78	162.68	163.36	165.82	168.31	170.80	173.69
Install conductors and OPGW	ST	178.00	178.29	178.72	179.03	179.46	179.97	180.45	181.07
	FT	178.29	178.72	179.03	179.46	179.97	180.45	181.07	181.30
Install and welding works for OPGW Box	ST	343.00	343.02	343.04	343.06	343.09	343.12	343.15	343.18
	FT	343.02	343.04	343.06	343.09	343.12	343.15	343.18	343.20
Clean work and project closeout	ST	344.00	344.03	344.06	344.09	344.13	344.17	344.21	344.27
	FT	344.03	344.06	344.09	344.13	344.17	344.21	344.27	344.29

Table 5. *First case, Scheduling times for Station No. 660 to station No. 667.*

Tower Type		A27	A27	A24	D18	A30	A54	A54	D39
Station (No.)		660	661	662	663	664	665	666	667
Work crew for items									
Rout selection	ST	15.85	15.87	15.89	15.91	15.93	15.96	15.98	15.99
	FT	15.87	15.89	15.91	15.93	15.96	15.98	15.99	16.00
Surveying work for obstacles	ST	48.40	48.45	48.49	48.53	48.58	48.63	48.67	48.69
	FT	48.45	48.49	48.53	48.58	48.63	48.67	48.69	48.72
Tower type selection	ST	80.38	80.43	80.47	80.52	80.56	80.61	80.64	80.67
	FT	80.43	80.47	80.52	80.56	80.61	80.64	80.67	80.70
Soil investigation	ST	223.28	223.48	223.68	223.87	224.07	224.31	224.45	224.57
	FT	223.48	223.68	223.87	224.07	224.31	224.45	224.57	224.69
Cut works	ST	299.48	299.87	300.26	301.83	302.22	302.74	303.26	304.83
	FT	299.87	300.26	301.83	302.22	302.74	303.26	304.83	306.39
Plain concrete	ST	314.04	314.36	314.69	316.05	316.37	316.82	317.27	318.64
	FT	314.36	314.69	316.05	316.37	316.82	317.27	318.64	320.00
Install form work for footing	ST	345.00	346.00	346.00	346.00	347.00	347.00	347.00	348.00
	FT	346.00	346.00	346.00	347.00	347.00	347.00	348.00	348.00
Steel work for footing and column	ST	346.00	347.00	347.00	347.00	348.00	348.00	348.00	349.00
	FT	347.00	347.00	347.00	348.00	348.00	348.00	349.00	349.00
R. concrete pouring for footing	ST	347.73	348.00	348.27	349.82	350.08	350.35	350.61	352.22
	FT	348.00	348.27	349.82	350.08	350.35	350.61	352.22	353.82
Remove footing form work and install column form	ST	388.00	389.00	389.00	389.00	390.00	390.00	390.00	391.00
	FT	389.00	389.00	389.00	390.00	390.00	390.00	391.00	391.00
R. Concrete pouring for column	ST	390.12	390.39	390.66	391.39	391.66	392.38	393.10	393.83
	FT	390.39	390.66	391.39	391.66	392.38	393.10	393.83	394.55
Remove form work of column	ST	400.00	401.00	401.00	401.00	402.00	402.00	402.00	403.00
	FT	401.00	401.00	401.00	402.00	402.00	402.00	403.00	403.00
Concrete painting and fill work	ST	398.73	399.14	399.55	401.17	401.58	402.11	402.64	404.26
	FT	399.14	399.55	401.17	401.58	402.11	402.64	404.26	405.88
Tower steel collection and install	ST	523.13	523.54	523.91	524.97	525.42	526.30	527.18	528.89
	FT	523.54	523.91	524.97	525.42	526.30	527.18	528.89	530.61
Install conductors and OPGW	ST	558.27	558.75	559.23	559.68	560.16	560.73	561.06	561.36
	FT	558.75	559.23	559.68	560.16	560.73	561.06	561.36	561.65
Install and welding works for OPGW Box	ST	562.37	562.40	562.43	562.46	562.49	562.52	562.54	562.56
	FT	562.40	562.43	562.46	562.49	562.52	562.54	562.56	562.57
Clean work and project closeout	ST	573.02	573.07	573.11	573.15	573.19	573.24	573.27	573.29
	FT	573.07	573.11	573.15	573.19	573.24	573.27	573.29	573.32

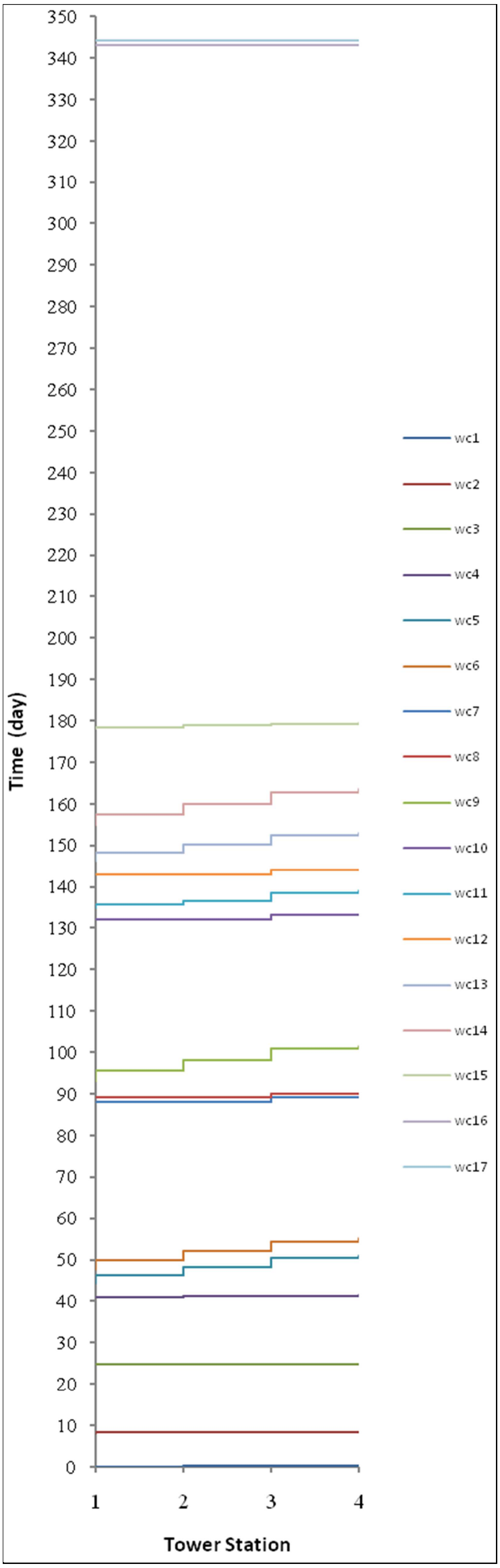

Figure 3. *The first four stations scheduling.*

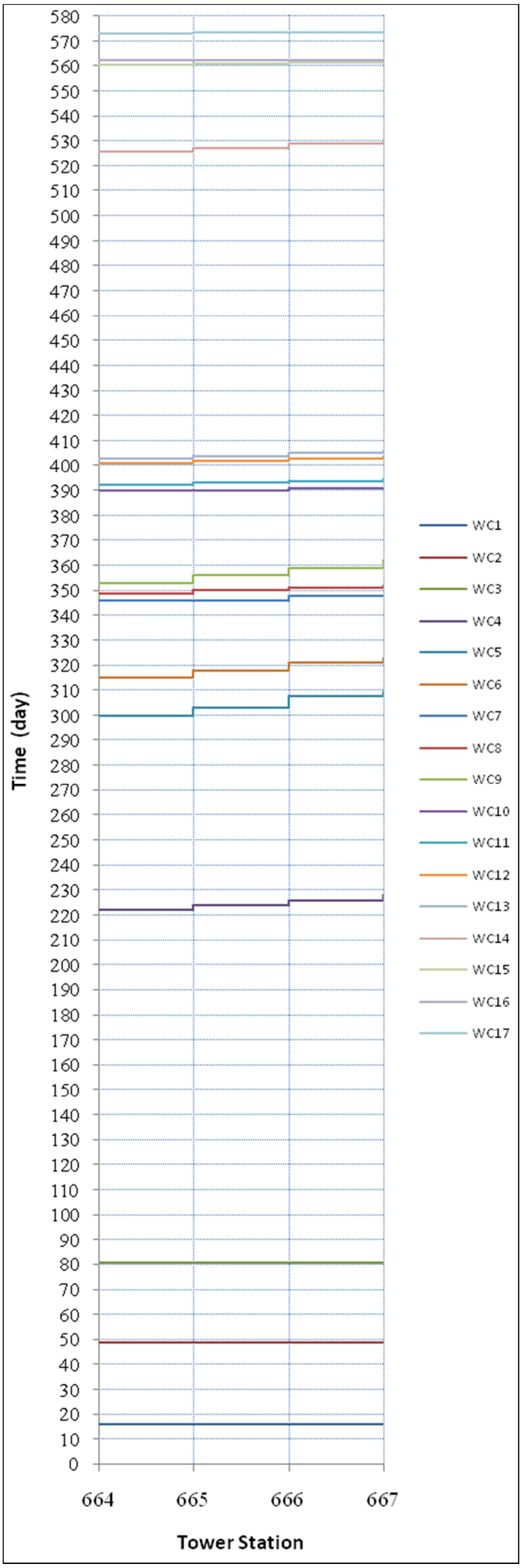

Figure 4. *The last four stations scheduling.*

Table 6. *The second case, Scheduling times for tower station No. 325 to Station No. 332.*

Tower Type		**B24**	**A27**	**A30**	**A27**	**A27**	**A27**	**A27**	**A24**
Station		325	326	327	328	329	330	331	332
Work crew for items									
Rout selection	ST	0.00	0.02	0.05	0.07	0.09	0.12	0.14	0.14
	FT	0.02	0.05	0.07	0.09	0.12	0.14	0.14	0.16
Surveying work for obstacles	ST	7.93	7.98	8.03	8.08	8.13	8.18	8.23	8.23
	FT	7.98	8.03	8.08	8.13	8.18	8.23	8.23	8.27
Tower type selection	ST	24.12	24.17	24.22	24.27	24.31	24.36	24.41	24.41
	FT	24.17	24.22	24.27	24.31	24.36	24.41	24.41	24.45
Soil investigation	ST	40.09	40.29	40.53	40.73	40.93	41.16	41.37	41.37
	FT	40.29	40.53	40.73	40.93	41.16	41.37	41.37	41.56
Cut works	ST	41.92	42.31	42.70	43.09	43.48	43.87	44.25	44.25
	FT	42.31	42.70	43.09	43.48	43.87	44.25	44.25	44.64
Plain concrete	ST	52.77	53.09	53.42	53.74	54.06	54.39	54.71	54.71
	FT	53.09	53.42	53.74	54.06	54.39	54.71	54.71	55.03
Install form work for footing	ST	60.00	60.00	60.00	61.00	61.00	61.00	62.00	62.00
	FT	60.00	60.00	61.00	61.00	61.00	62.00	62.00	62.00
Steel work for footing and column	ST	61.00	61.00	61.00	62.00	62.00	62.00	63.00	63.00
	FT	61.00	61.00	62.00	62.00	62.00	63.00	63.00	63.00
R. concrete pouring for footing	ST	63.72	63.99	64.25	64.52	64.78	65.05	65.31	65.31
	FT	63.99	64.25	64.52	64.78	65.05	65.31	65.31	65.58
Remove footing form work and	ST	67.00	67.00	67.00	68.00	68.00	68.00	69.00	69.00
install column form	FT	67.00	67.00	68.00	68.00	68.00	69.00	69.00	69.00
R. Concrete pouring for column	ST	70.72	70.99	71.27	71.54	71.81	72.08	72.35	72.35
	FT	70.99	71.27	71.54	71.81	72.08	72.35	72.35	72.62
Remove form work of column	ST	75.00	75.00	75.00	76.00	76.00	76.00	77.00	77.00
	FT	75.00	75.00	76.00	76.00	76.00	77.00	77.00	77.00
Concrete painting and fill work	ST	85.95	86.36	86.77	87.18	87.59	87.99	88.40	88.40
	FT	86.36	86.77	87.18	87.59	87.99	88.40	88.40	88.81
Tower steel collection and install	ST	93.65	94.06	94.50	94.91	95.31	95.71	96.09	96.09
	FT	94.06	94.50	94.91	95.31	95.71	96.09	96.09	96.53
Install conductors and OPGW	ST	95.42	95.91	96.47	96.96	97.44	97.98	98.50	98.50
	FT	95.91	96.47	96.96	97.44	97.98	98.50	98.50	98.94
Install and welding works for OPGW Box	ST	258.03	258.05	258.09	258.12	258.15	258.18	258.21	258.21
	FT	258.05	258.09	258.12	258.15	258.18	258.21	258.21	258.23
Clean work and project closeout	ST	259.04	259.08	259.13	259.17	259.21	259.26	259.31	259.31
	FT	259.08	259.13	259.17	259.21	259.26	259.31	259.31	259.35

Table 7. *Second case, Scheduling times for Station No. 660 to Station No. 667.*

Tower Type		**A27**	**A27**	**A24**	**D18**	**A30**	**A54**	**A54**	**D39**
Station		660	661	662	663	664	665	666	667
Work crew for items									
Rout selection	ST	7.75	7.77	7.80	7.82	7.84	7.87	7.88	7.90
	FT	7.77	7.80	7.82	7.84	7.87	7.88	7.90	7.91
Surveying work for obstacles	ST	23.79	23.84	23.88	23.93	23.97	24.02	24.06	24.08
	FT	23.84	23.88	23.93	23.97	24.02	24.06	24.08	24.11
Tower type selection	ST	39.63	39.67	39.72	39.76	39.80	39.85	39.89	39.91
	FT	39.67	39.72	39.76	39.80	39.85	39.89	39.91	39.94
Soil investigation	ST	109.86	110.06	110.26	110.45	110.65	110.88	111.02	111.14
	FT	110.06	110.26	110.45	110.65	110.88	111.02	111.14	111.27
Cut works	ST	146.17	146.55	146.94	148.51	148.90	149.42	149.94	151.51
	FT	146.55	146.94	148.51	148.90	149.42	149.94	151.51	153.08
Plain concrete	ST	158.89	159.22	159.54	160.90	161.23	161.68	162.13	163.49
	FT	159.22	159.54	160.90	161.23	161.68	162.13	163.49	164.85
Install form work for footing	ST	171.00	172.00	172.00	172.00	173.00	173.00	173.00	174.00
	FT	172.00	172.00	172.00	173.00	173.00	173.00	174.00	174.00
Steel work for footing and column	ST	172.00	173.00	173.00	173.00	174.00	174.00	174.00	175.00
	FT	173.00	173.00	173.00	174.00	174.00	174.00	175.00	175.00
R. concrete pouring for footing	ST	172.98	173.25	173.51	174.07	174.33	174.59	174.86	175.46
	FT	173.25	173.51	174.07	174.33	174.59	174.86	175.46	176.07
Remove footing form work	ST	178.00	179.00	179.00	179.00	180.00	180.00	180.00	181.00
and install column form	FT	179.00	179.00	179.00	180.00	180.00	180.00	181.00	181.00
R. Concrete pouring for column	ST	183.22	183.49	183.77	184.49	184.76	185.48	186.20	186.93
	FT	183.49	183.77	184.49	184.76	185.48	186.20	186.93	187.65
Remove form work of column	ST	186.00	187.00	187.00	187.00	188.00	188.00	188.00	189.00
	FT	187.00	187.00	187.00	188.00	188.00	188.00	189.00	189.00

Tower Type		A27	A27	A24	D18	A30	A54	A54	D39
Concrete painting and fill work	ST	189.22	189.63	190.03	191.66	192.06	192.60	193.13	194.75
	FT	189.63	190.03	191.66	192.06	192.60	193.13	194.75	196.36
Tower steel collection and install	ST	251.52	251.93	252.30	253.36	253.81	254.69	255.57	257.29
	FT	251.93	252.30	253.36	253.81	254.69	255.57	257.29	259.00
Install conductors and OPGW	ST	262.87	263.35	263.83	264.28	264.76	265.33	265.66	265.96
	FT	263.35	263.83	264.28	264.76	265.33	265.66	265.96	266.25
Install and welding works for OPGW Box	ST	267.99	268.02	268.05	268.08	268.10	268.14	268.16	268.18
	FT	268.02	268.05	268.08	268.10	268.14	268.16	268.18	268.19
Clean work and project closeout	ST	273.73	273.77	273.81	273.85	273.89	273.94	273.97	274.00
	FT	273.77	273.81	273.85	273.89	273.94	273.97	274.00	274.02

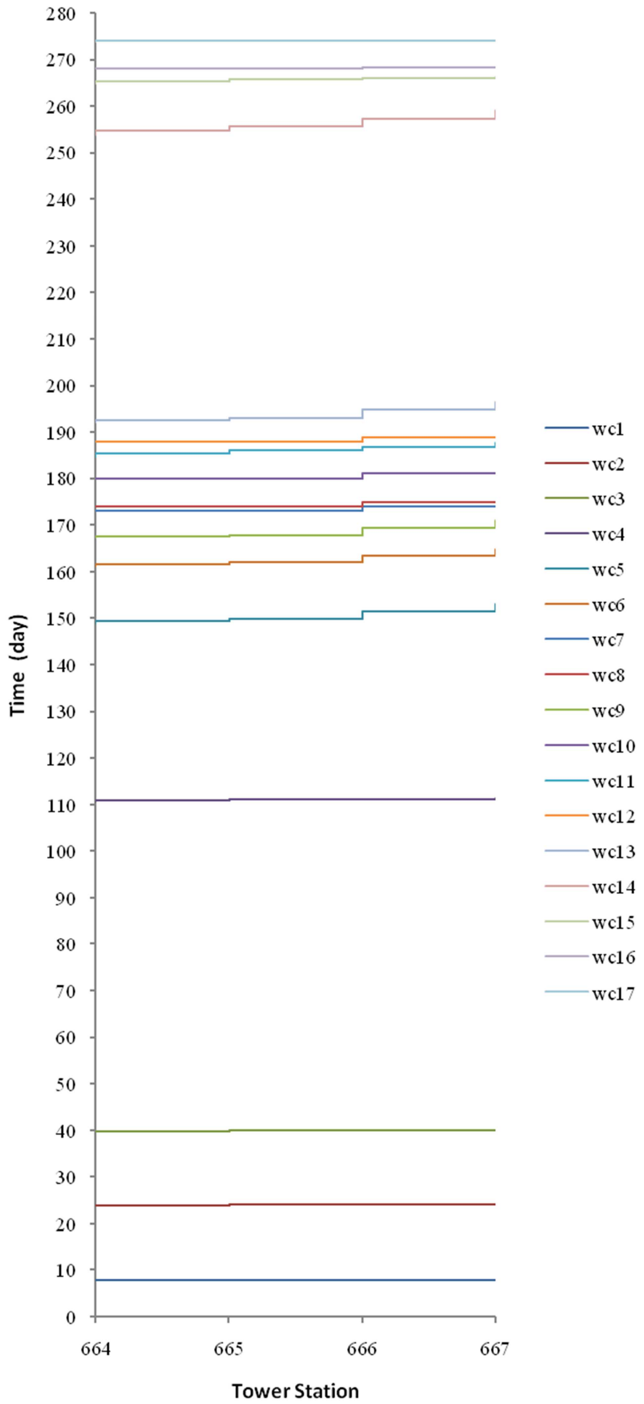

***Figure 5.** ST and FT times for activities and total project duration, 2nd case.*

4. Results Discussions

This study introduces repetitive and linear scheduling methods for a construction project: Sirte – Houn 400 KV Transmission Line Project in Libya. Actual data was collected from the General Electricity of Company of Libya (GECOL) and used to generate a project schedule using an Excel spreadsheet as a simple tool. This project schedule requires ensuring uninterrupted and linear progress of the activities. Linear scheduling was developed with a deterministic approach. i.e., in this case, activity durations were determined as a single value, usually the most likely duration, by dividing the total activity quantity by the work crew production rate. All project activities are similar in 667 stations along the total project distance of 287,404.9 km. Through the results, LSM minimized the idle time to reach zero in the two cases studied, which achieved the best utilization of available resources. Project duration in the 1st case was 574 days with zero idle time, and in the 2nd case was 275 days with zero idle time. In addition, the project planner can perform and check several scenarios during the planning and scheduling period to effectively compare idle time and project duration. The project activities, progress, follows up, and updating becomes easy. In addition, activities progress was facilitated and made more rigorous.

5. Conclusion

In the next decades after the Libya crisis, Libyan reconstruction will start for infrastructure projects in most sectors. Due to the poor history value of the Libyan construction industry from previous searches [1, 6, 7, 21, 27], it needs to adopt more advanced managing techniques for different management knowledge such as planning techniques, cost estimation and controls, value engineering, resources management, reengineering, supply change management, and sustainability. This study contributes to simplifying the application of the Repetitive Projects Scheduling approach as an empirical case study. The Libyan reconstruction phase will need an advanced scheduling approach as RSM for repetitive linear projects due to the scarcity of resources in the current economic state.

ORCID

Medhat Youssef: 0000-0002-0876-0659

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References

[1] Abuzaid Salah and Steve Bloomer 2014. Problems Related to Construction and Building Materials in Libya. KICEM Journal of Construction Engineering and Project Management Online ISSN 2233-9582 http://dx.doi.org/10.6106/JCEPM.2014.4.4.001

[2] Aiyin Jiang, Bin Cheng, Ian Flood and Raymond Issa, 2006. "Modified Linear Scheduling in Scheduling Multiple Utility Line Construction Project." Joint Int. Conference on Computing and Decision Making in Civil and Building Eng., Montréal, Canada.

[3] Andersson, N., & Christensen, K., 2007. Practical Implications of Location-Based Scheduling. In CME25: Construction Management and Economics: past, present and future Taylor and Francis Group.

[4] Carr, R. I.; Meyer, W. L. (1974) "Planning Construction of Repetitive Building Units." J. Constr. Div., ASCE, 100 (CO3) 403-412.

[5] Chrzanowski, E. N.; Johnston, D. W. (1986) "Application of Linear Scheduling." J. Constr. Eng. Manage., ASCE, 112 (4) 476-491.

[6] EL-Hasia, A. M. (2005). *The effects of state's construction procurement policy implementation on the outcome of local construction projects: the Libyan case*. University of Salford (United Kingdom).

[7] Elsonoki, M. M., Yunus, R., Yunus, S. R., & Hamid, A. R. A. (2020, May). The adoption of value engineering practices in the Libyan construction industry. In *IOP Conference Series: Earth and Environmental Science* (Vol. 498, No. 1, p. 012099). IOP Publishing.

[8] I-TUNG Yang and Photios G. Ioannou, 2002. "Stochastic analysis on project duration under the requirement of continuous resource utilization." *Proceedings IGLC-10, Gramado, Brazil*.

[9] I-TUNG Yang and Photios G. Ioannou, 2004. "Scheduling system with focus on practical concerns in repetitive projects." Constr. Management and Economics, 619–630.

[10] Iulian Trofin, 2004. "Impact of Uncertainty on Construction Project Performance Using Linear Scheduling." Master Thesis, University of Florida.

[11] Kallantzis, A. and Lambropoulos, S., 2004. "Critical path determination by incorporation minimum and maximum time and distance constraints into linear scheduling." Eng. Constr. and Arch. Manage., Vol. 11, No. 3, pp. 211-222.

[12] Kang, L. S., Park, I. C., & Lee, B. H. (2001). Optimal schedule planning for multiple, repetitive construction process. Journal of Construction Engineering and Management, 127 (5), 382–390. https://doi.org/10.1061/(ASCE)0733-9364(2001)127:5(382)

[13] M. Khanzadi, S. Dabirian and K. Zia Ghazvini, 2003. "Developing The LSM_{VPR} scheduling Method for Scheduling Highway Construction Projects Based on Effective Factors On Embankment Activity Productivity." Int. J. Optim. Civil Eng., 3 (4): 601-616.

[14] Marco A. Bragadin, and Kalle Kahkonen, 2011. "Heuristic solution for resource scheduling for repetitive Construction projects." Management and Innovation for a Sustainable Built Environment, Amsterdam, the Netherlands.

[15] Mattila, K. G., & Abraham, D. M. (1998). Resource leveling of linear schedules using integer linear programming. Journal of construction engineering and management, 124 (3), 232-244.

[16] Robert B. Harris and Photios G. Ioannou, 1998. "Scheduling Projects with Repeating Activities." J. Constr. Eng. Manage., Vol. 124, No. 4.

[17] Sherif Mohamed Hafez, 2004. "Practical limitations of line-of-balance in scheduling repetitive construction units." Faculty of Eng., Alexandria University, Egypt, Alexandria Eng. J., Vol. 43, No. 5, 653-661.

[18] Sims, S. L. (1998). *An Analysis of the Use of Linear Scheduling Techniques in the Construction Industry*. FLORIDA UNIV GAINESVILLE DEPT OF CIVILENGINEERING.

[19] Srisuwanrat, C., and Ioannou, P. G., 2007. "The Investigation of Lead-time Buffering under Uncertainty using Simulation and Cost Optimization." Proceedings IGLC-15, Ann Arbor, MI.

[20] Su, Y., & Lucko, G. (2016). Linear scheduling with multiple crews based on line of balance and productivity scheduling method with singularity functions. Automation in Construction, 70, 38-50. doi: 10.1016/j.autcon.2016.05.011.

[21] Tahir, H. A. (2015). A project control framework for the Libyan construction industry. Sheffield Hallam University (United Kingdom).

[22] Weixin Wang, Xu Wang, Xianlong Ge, and Yandong He (2013). "Resource continuity constraints in repetitive project scheduling." J. of Information & Computational Science 5619–5628, http://www.joics.com.

[23] Yamin, R. A., and Harmelink, D. J., 2001. "Comparison of Linear Scheduling Method (LSM) and Critical Path Method (CPM)". J. Constr. Eng. & Manage., ASCE, Vol. 127 (5), pp. 374–381.

[24] Youssef Medhat, Mohamed Saad Eldin Mohamed & Abdelraoff Ali Shokri Balah, 2022. Fuzzy model for Libyan construction projects delivery system selection, International Journal of Construction Management, DOI: 10.1080/15623599.2022.2113629.

[25] Youssef, M. A., Gamal, A., & Abdelhamid, S. A. G. (2017). Libyan construction projects delivery systems: empirical comparison between design-build and design-bid-build. *Eng Appl Sci*, *2* (1), 17-21.

[26] Tang, Y., Liu, R., Wang, F., Sun, Q., & Kandil, A. A. (2018). Scheduling optimization of linear schedule with constraint programming. *Computer-Aided Civil and Infrastructure Engineering*, *33* (2), 124-151.

[27] Youssef, M., AlDeep, S. M. H., & Olwan, M. M. (2023). Value engineering: Case study of Libyan educational buildings. *Alexandria Engineering Journal*, *76*, 735-746.