**original research article**

# COMPARATIVE ANALYSIS OF OILFIELD CHEMICAL OPERATIONS USING DETERMINISTIC AND STOCHASTIC MODELS

## Abstract

Efficient management of oilfield chemical operations is paramount for enhancing production, minimizing risks, and maximizing profitability in the oil and gas industry. This study presents a comprehensive comparative analysis of deterministic and stochastic modeling techniques to optimize oilfield chemical operations. Focusing on demulsifying and matrix acidizing operations in Nigeria, the research employed deterministic (Critical Path Method - CPM) and stochastic (Program Evaluation and Review Technique - PERT) models for analysis. Results demonstrate the deterministic model's ability to provide precise completion time estimates, while the stochastic model factors in uncertainties and variability, yielding slightly different but more flexible completion time predictions. Both models identify the Critical Path, yet the stochastic model offers probabilistic estimates, enhancing risk assessment and mitigation capabilities. Despite potentially longer completion times, the stochastic model emerges as the preferred option due to its adaptive approach and ability to incorporate uncertainties, ultimately improving project planning and risk management in oilfield operations. This study contributes to advancing optimization strategies in the industry, providing decision-makers with evidence-based insights to enhance operational efficiency and sustainability. By understanding the strengths and limitations of both modeling techniques, project managers can leverage the probabilistic insights offered by stochastic models to optimize project outcomes and effectively manage uncertainties in oilfield operations, contributing to improved operational efficiency, cost reduction, and enhanced productivity in the oil and gas industry.

KEY WORDS: Deterministic Model, Stochastic Model, Critical Path Method, oilfield chemical operations

## 1.0 Introduction

The forces of globalization and escalating competition have made it imperative to complete projects within designated timeframes and with available resources. Companies are seeking the best ways to execute projects successfully with minimal time and resources (Jiang et al., 2024; Korhonen et al. 2023). This has led to substantial investments in project management initiatives. Project management is a multifaceted discipline encompassing the planning, execution, and control of a set of tasks or activities aimed at achieving specific goals, constraints, and deliverables. Kerzner (2021) defines project management as the process of strategically managing and coordinating a company's resources to achieve defined objectives within a given timeframe. It is characterized by its systematic approach, structured methodologies, and various tools designed to ensure successful project completion.

Projects are strategic frameworks that maximize resource utilization to achieve specific objectives within a defined period (Zhao & Kim, 2022; Ferrer-Romero, 2018). Within projects, activities are interconnected in a structured order; certain tasks cannot commence until others are completed (Rençber, 2021). Project management ensures the successful execution of large-scale investment projects, achieving cost-effectiveness, meeting deadlines, and utilizing resources efficiently. Effective project management reduces resource wastage and mitigates cost and time overruns (Sarıca, 2016; Lee et al., 2023).In recent years, advancements in petroleum resource exploitation have significantly contributed to meeting global energy demands and driving economic growth. Petroleum exploration requires substantial capital investment, and companies aim to maximize returns. Hydrocarbon-bearing formations are vulnerable to damage and plugging from various natural or induced sources, which can drastically alter reservoir permeability and porosity. Proper drilling, completion, and intervention techniques are essential to maintain well productivity and reserve recovery, avoiding high costs of well maintenance and environmental management (Kruger, 2016; Al-Saraji et al., 2022). This demand for efficiency has driven research into optimized crude oil exploration techniques to maximize profitability.

The use of oilfield chemicals has been instrumental in addressing numerous challenges within the petroleum industry. These chemicals are applied across upstream and downstream sectors to stabilize drilling fluids under extreme conditions, prevent mud loss in diverse geological formations, offer corrosion protection, optimize drilling operations, and enhance oil recovery.The oil and gas industry is a cornerstone of global energy supply, driving economic growth and supporting numerous industries. However, the sector faces challenges in optimizing complex operations to ensure efficiency, safety, and profitability. Among these operations, oilfield chemical applications, such as demulsifying and matrix acidizing, are critical for sustaining and improving production levels. These processes involve specialized chemicals to manage operational challenges that may hinder hydrocarbon extraction efficiency (Patel & Roy, 2023; Jiang, 2024).Optimizing oilfield chemical operations is crucial for minimizing downtime, reducing costs, and mitigating risks associated with chemical usage. Increasingly, the industry is turning to mathematical modeling to simulate and predict outcomes of operational scenarios. Mathematical models provide insights into the interactions between chemicals, equipment, and reservoir conditions, aiding decision-making on chemical deployment strategies.Two primary types of models, deterministic and stochastic, are widely used. Deterministic models rely on fixed input parameters for predictable outcomes, providing a straightforward optimization approach (Li et al., 2023). Stochastic models, on the other hand, incorporate variability and uncertainty, reflecting the unpredictability of real-world conditions (Jiang, 2024). Both approaches have strengths, but their comparative effectiveness in oilfield chemical operations remains underexplored.

This study addresses this gap by analyzing deterministic and stochastic models in oilfield chemical operations, focusing on processes like demulsifying and matrix acidizing. The research aims to determine which modeling approach yields more accurate and reliable predictions for optimizing delivery times and operational efficiency. The findings offer valuable insights for decision-makers in the oil and gas industry, helping them adopt appropriate modeling techniques that enhance productivity while promoting safe and sustainable practices.

## 2.0 Methodology

The study focused on the project timelines of two distinct activities related to oilfield chemicals. The operations consist of demulsifying operation and matrix acidizing operation. The selection of these schedules was based on their characteristic of being single operations with multiple and comparable important activity routes. The project schedules were the company's standardized timetables that are utilized when carrying out the specified operations. These schedules were evaluated using deterministic (CPM) and stochastic (PERT) modeling. CPM and PERT are network planning methods. Network planning is a method of analyzing and describing a work diagram to estimate and establish the precise control of activity paths (Meflinda&Mahyarni, 2011).

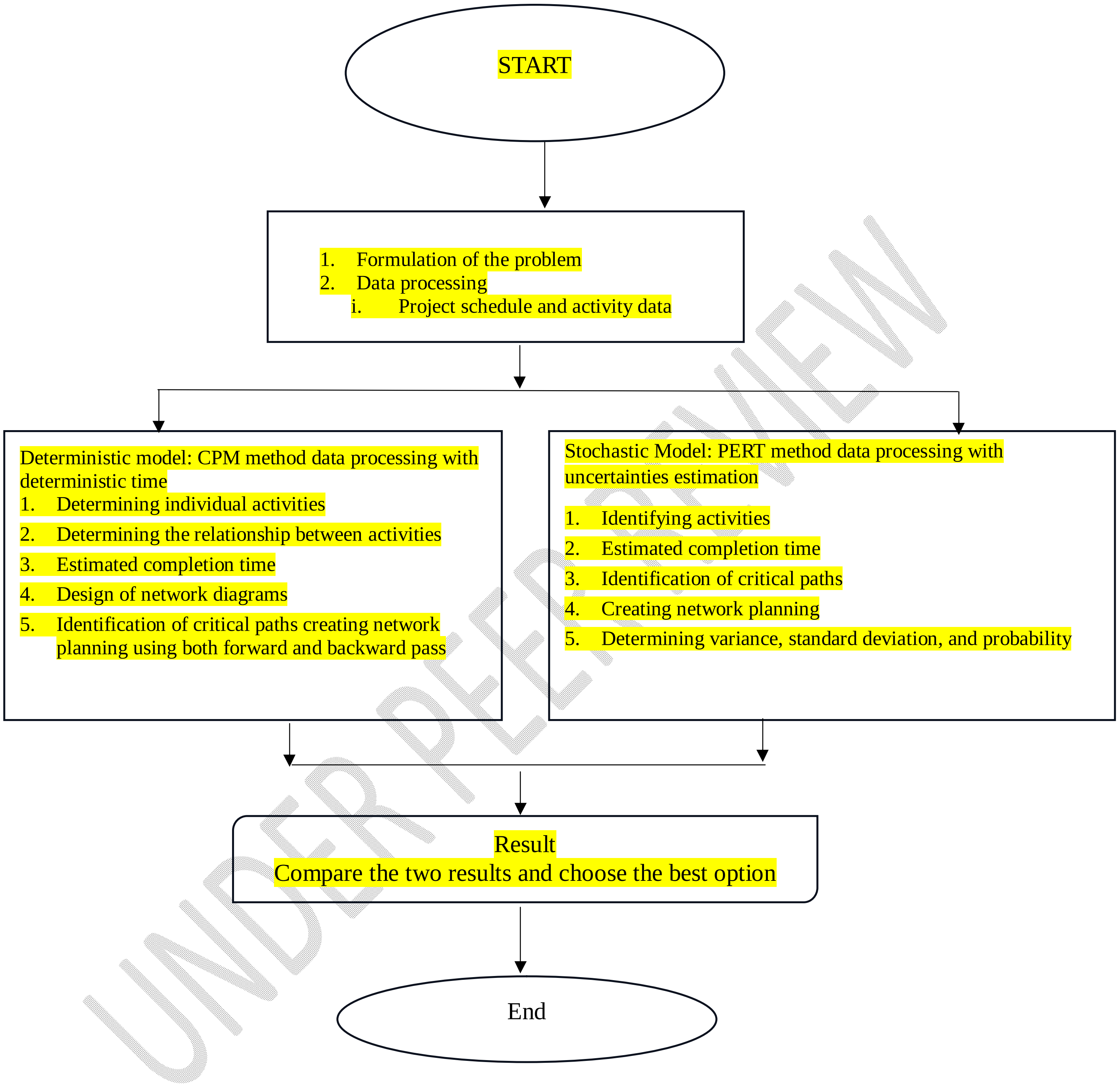


Figure 1: Design flowchart

## 2.1 Deterministic model

The Critical Path Model (CPM) was used as the deterministic model. The critical route refers to the sequence of actions inside a project that are anticipated to require the greatest amount of time to complete and is considered as the most commonly used project management tool in deterministic models (Kerzner, 2021). The CPM was estimated following the steps extensively described by Kerzner (2021). The steps are described below:

**Determination of the operation(s) as well as all the activities involved in performing the operation(s):** The first step in the sequence of steps described by Kerzner (2021) involves the identification of the operation as well as the activities involved in the operation. In the case of this study, all the activities involved in the two operations (matrix acidizing operation and demulsifying operation) as applicable.

**Identification of the antecedents and successors of each activity as well as the relationship among them:** following the identification of all the activities, the predecessors and followers of each activity in the process are identified and relationship determined.

**Construction of the network diagrams:** the network diagram that connects all the activities in the operation. This included all the possible paths that the operations can be achieved.

**Assignment of time estimates to each activity in the network diagram:** all the activities are assigned time.

**Calculation of the forward pass and backward pass:** for the forward pass, the early start and early finish for each activity was computed using the following guideline developed by Kerzner (2021).

ES= for each beginning activity

EF = ES+ duration of activity

ES of successor activities = maximum of EF time for all predecessor activities

Early finish time for the entire project is the largest early finish time of all activities

For the backward pass, the late start and late finish for each activity was computed using the following guideline developed by Kerzner (2021).

LF = project completion time for each "ending activity"

LS = LF- duration of activity

LF of predecessor activities = minimum of LS times of all successor activities

**Determination of the critical paths:** the critical paths in each operation are determined using both the longest route and the optimal analysis result (combination of forward and backward passes with no slack).

### Longest Route determination

The longest route method was used to determine the critical path using the following equation:

CPM = ΣT (summation of event time along critical path) (1)

CPM = $t_{cp}$=$\sum_{i=1}^{n} t_{cp}$ (2)

Where $\boldsymbol{t_{cp}}$is activity time along the critical path.

## 2.2 Stochastic Model

The study employed the probabilistic activities model (PERT) as the stochastic model. The PERT approach considers uncertainty while predicting the time of activities. This method is employed when the projected completion times for the activity are not provided, but certain data is available that describes the probability distribution for the potential range of completion times for the activity. The activities and their interrelation are clearly stated, but a certain level of ambiguity is still permitted during the period of the activities. Three-time estimates are used to reflect uncertainty and should be taken into account for each action (Kerzner, 2021). These are optimistic time, pessimistic time, and the most likely time.

**Optimistic time (a)**: To calculate the optimistic time for this study the researcher solicited the opinions and ideas of professional involved in performing the two operations as recommended by Johnson and Brown's (2023). Professional from the sampled site as well as external professionals' opinions were used to determine the optimistic time for each activity in the operations.

**Pessimistic time (b)**= To calculate the pessimistic time for this study the researcher solicited the opinions and ideas of professional involved in performing the two operations as recommended by Johnson and Brown's (2023). Professional from the sampled site as well as external professionals' opinions were used to determine the optimistic time for each activity in the operations.

**Most likely time (m)**= To calculate the most likely time for this study the researcher solicited the opinions and ideas of professional involved in performing the two operations as recommended by Johnson and Brown's (2023). Professional from the sampled site as well as external professionals' opinions were used to determine the optimistic time for each activity in the operations.

The professionals consisted of project managers, supervisors, coordinators, safety personnel, and operation leaders. Each time was arrived at after several hours of deliberation and brainstorming.

Furthermore, the following parameters were calculated using the underlisted equations:

**Expected mean time:** The anticipated average length of the critical path was additionally assessed to ascertain the longest possible duration of each operation. The mathematical formula for calculating the predicted mean time, as stated by Ihendeson, et. al., (2019), is as follows:

$$t_e = \frac{a+4m+b}{5} \qquad \text{(3) (Ihendeson, et. al., 2019)}$$

Where $t_e$ = Time estimate
$t_o$= a = Optimistic time
$t_m$ = b = most likely time
$t_p$ = c = pessimistic time
Standard deviation =$\sqrt{\sigma^2}$ = σ = $\frac{b-a}{6}$ (5) (Ihendeson, et. al., 2019)

The PERT model is express mathematically as:

$$\text{PERT (Z)} = \frac{X-E}{\sigma} \qquad \text{(6) (Ihendeson, et. al., 2019)}$$

Where

X= Due date

E= Expected date of completion

σ = standard deviation

For this study, the PERT (Project evaluation and review techniques) calculation was based on two possibilities. The first possibility is the probability of completing the specific operation between a day more than the PERT days and 5 days less than PERT days. The second possibility is the probability of completing the specific operation within the company allotted time for the operation. The objective time frame is the estimated time at which the project is expected to be completed within the given deadline. The chance of accomplishment in this study was calculated using the normal Z-test distribution table, assuming a 95% confidence interval.

### 2.3 Network Diagram

A network diagram displays the chronological order of all project operations. The sequences adhere to the precedence requirement. A network diagram was utilised in the study to illustrate the various potential routes through which the operations can be executed. The pathways were utilised to calculate the CPM (Critical Path Method) and PERT (Programme Evaluation and Review Technique) of both the deterministic and stochastic models.

## 3.0 Result

### Demulsifying Operation

**Table 1: Activity duration for a typical demulsifying operation with their respective durations**

| S/N | Activity | Activity code | Activity duration (day) | Activity Code | Immediate predecessor |
|---|---|---|---|---|---|
| 1 | Process that involves analysing several chemicals available for this operation and choosing the appropriate chemical that is compatible with the target reservoir and can deliver expected result. | $Z_{i}$ | 6 | $Z_{i}$ | - |
| 2 | Drawing up acquisition contract and receiving bids from company vendors, deciding the purchasing vendor, issuing of purchasing contract to qualified vendor and receiving of the purchased chemicals from the chosen vendor | $Z_{ii}$ | 4 | $Z_{ii}$ | $Z_{i}$ |
| 3 | Preparation of site, mobilization of equipment to site, and readying the site for operation | $Z_{iii}$ | 3 | $Z_{iii}$ | $Z_{ii}$ |
| 4 | Personnel training, HSE certification and induction | $Z_{iv}$ | 6 | $Z_{iv}$ | $Z_{i}$, $Z_{iii}$ |
| 5 | Preparation of chemicals according to requirements and specifications, and performing all the necessary test. Performing quality control and quality assurance on the prepared chemicals. | $Z_{v}$ | 7 | $Z_{v}$ | $Z_{iii,}$ $Z_{iv}$ |
| 6 | Preparation the target well for the operation. This involves flushing, cleaning and pressurizing the well. | $Z_{vi}$ | 5 | $Z_{vi}$ | $Z_{v}$ |
| 7 | Performing the operation through the application of chemicals | $Z_{vii}$ | 7 | $Z_{vii}$ | $Z_{iii}$, $Z_{iv,}$ $Z_{vi}$ |
| 8 | Testing and assessment of the well to determine if the operation aim has been achieved | $Z_{viii}$ | 5 | $Z_{viii}$ | $Z_{vii}$ |
| 9 | Demobilization | $Z_{ix}$ | 3 | $Z_{ix}$ | $Z_{viii}$ |
| 10 | Closing report | $Z_{x}$ | 3 | $Z_{x}$ | $Z_{ix}$ |

**Networkdiagrams**

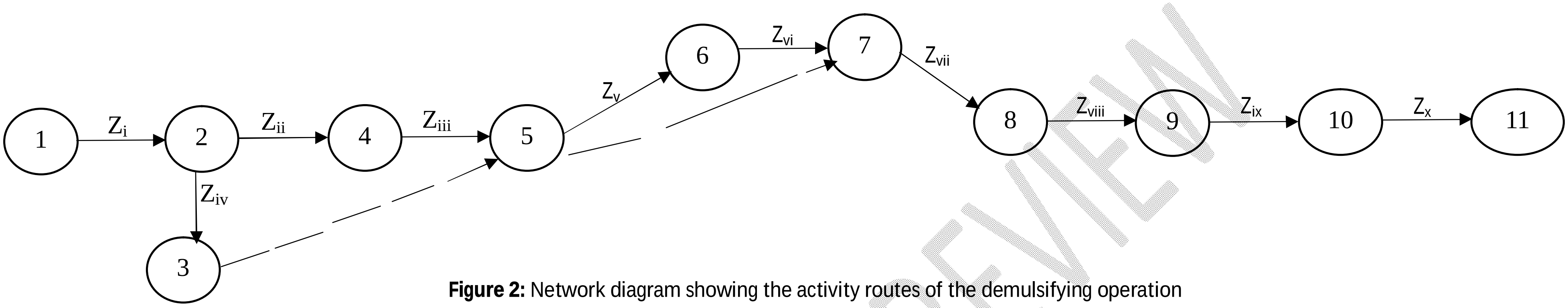


**Figure 2:** Network diagram showing the activity routes of the demulsifying operation

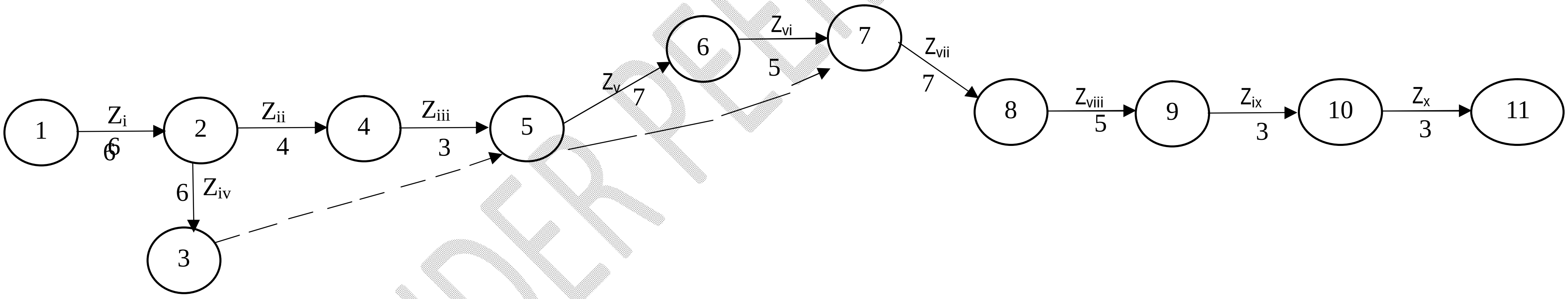


**Figure 3:** Network diagram showing the activities routes and duration of the demulsifying operation

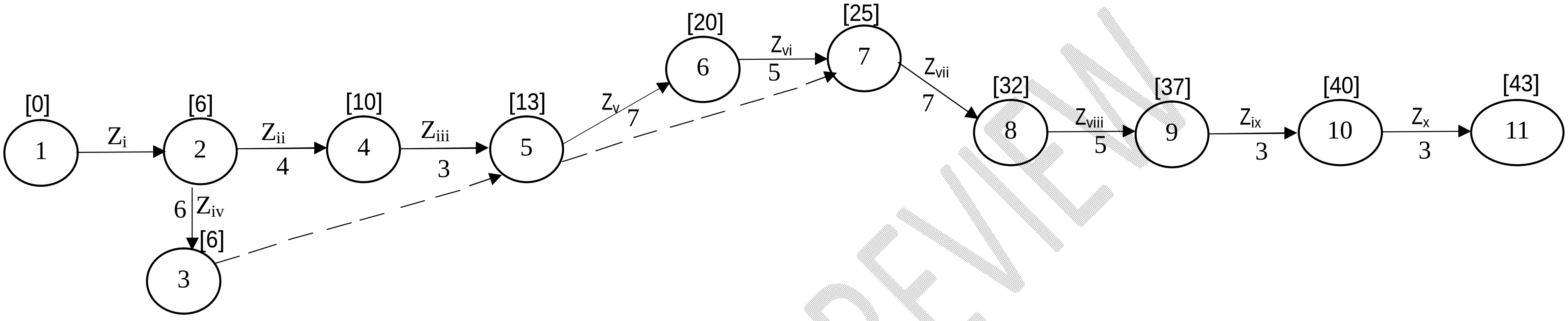


**Figure 4:** Network diagram showing the forward pass computation path of activities

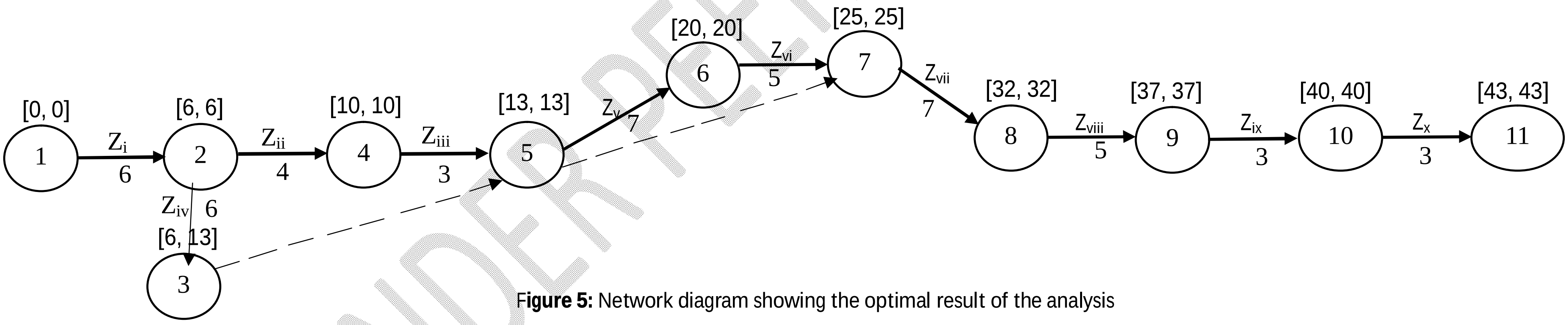


**Figure 5:** Network diagram showing the optimal result of the analysis

Using both the longest route, and the forward and backward pass criteria, the Critical Path of the demulsifying operation (shown in bold arrows) is 43 days.

## Matrix Acidizing operation

**Table2: Activity duration for matrix acidizing operation with their respective durations**

| S/N | Activity | Activity code | Activity duration (day) | Activity code | Immediate predecessor |
|---|---|---|---|---|---|
| 1 | Analysis of the reservoir to be acidified in order to characterize the reservoir as well as locate and identify formation where the operation will be beneficial | $Y_i$ | 15 | $Y_i$ | - |
| 2 | Cleaning up of the wellbore to remove debris, drilling mud, and other materials that have accumulated overtime | $Y_{ii}$ | 3 | $Y_{ii}$ | $Y_i$ |
| 3 | Process that involves analysing several acids and surfactants available for this operation and choosing the appropriate acid and surfactants that are compatible with the target reservoir and can deliver expected result. | $Y_{iii}$ | 8 | $Y_{iii}$ | $Y_{i,}$ $Y_{ii}$ |
| 4 | Design of injection system and determination of injection point | $Y_{iv}$ | 6 | $Y_{iv}$ | $Y_{iii}$ |
| 5 | Personnel training, HSE certification and induction | $Y_v$ | 5 | $Y_v$ | $Y_{iv}$ |
| 6 | Pre-flushing of well for effective acidizing operation | $Y_{vi}$ | 3 | $Y_{vi}$ | $Y_v$, $Y_{iv}$ |
| 7 | Preparation of chemicals according to requirements and specifications, and performing all the necessary test. Performing quality control and quality assurance on the prepared chemicals. | $Y_{vii}$ | 5 | $Y_{vii}$ | $Y_{vi}$ |
| 8 | Injection of the prepared acid into the wellbore and reservoir | $Y_{viii}$ | 3 | $Y_{viii}$ | $Y_{vii}$ |
| 9 | Reaction period: Allowing for sufficient time for the acid to react with the formation and dissolve minerals, scale, or other materials that may be restricting flow. | $Y_{ix}$ | 3 | $Y_{ix}$ | $Y_{viii}$ |
| 10 | Post-flush: Inject a post-flush fluid to remove residual acid and reaction by-products from the wellbore and reservoir | $Y_x$ | 2 | $Y_x$ | $Y_{ix}$ |
| 11 | Performing flow back on the well to recover fluids and assess the success of the acid acidizing treatment as well as monitoring of the well | $Y_{xi}$ | 2 | $Y_{xi}$ | $Y_x$ |
| 12 | Testing and assessment of the well to determine if the operation aim has been achieved | $Y_{xii}$ | 5 | $Y_{xii}$ | $Y_{xi}$ |
| 13 | Demobilization | $Y_{xiii}$ | 3 | $Y_{xiii}$ | $Y_{xii}$ |
| 14 | Closing report | $Y_{xiv}$ | 5 | $Y_{xiv}$ | $Y_{xii}$ |

**Networkdiagrams**

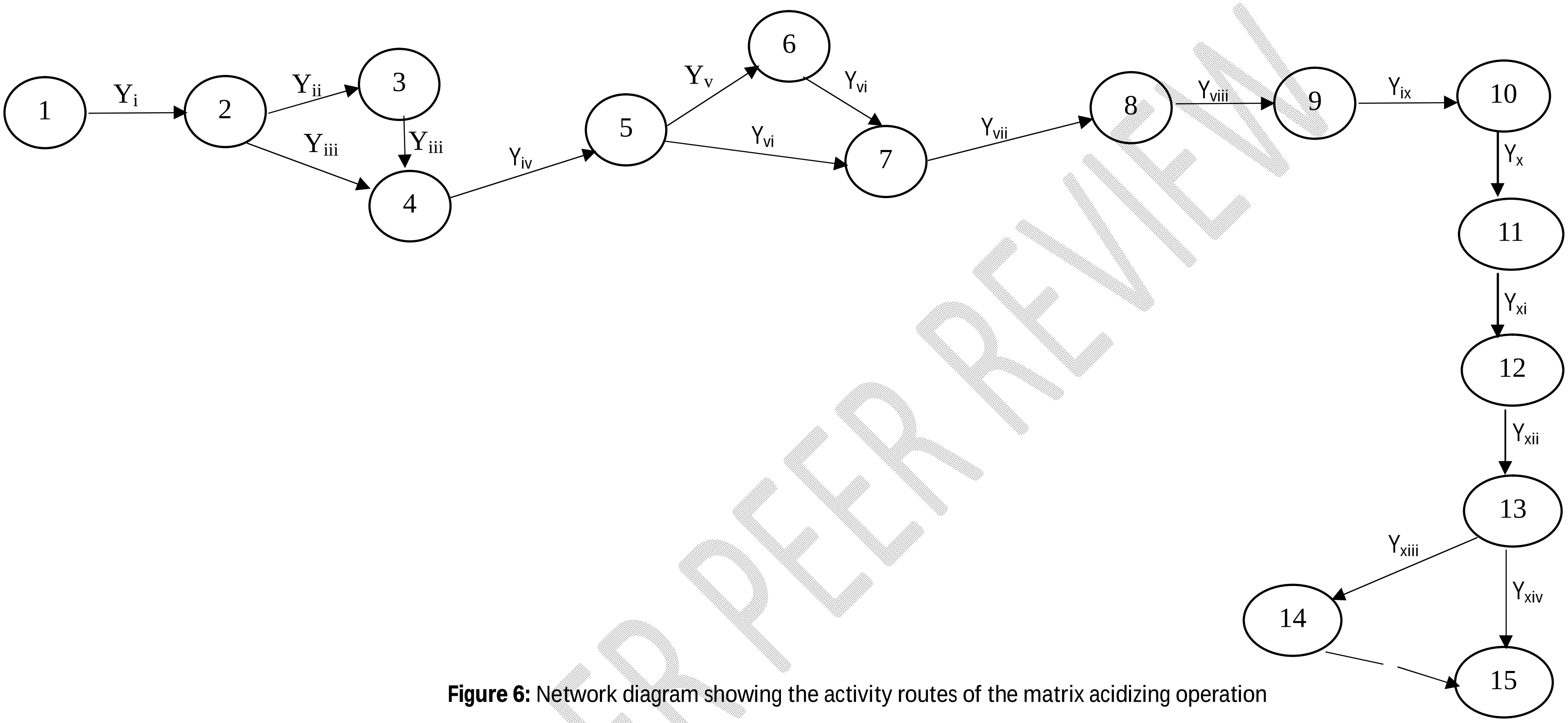


**Figure 6:** Network diagram showing the activity routes of the matrix acidizing operation

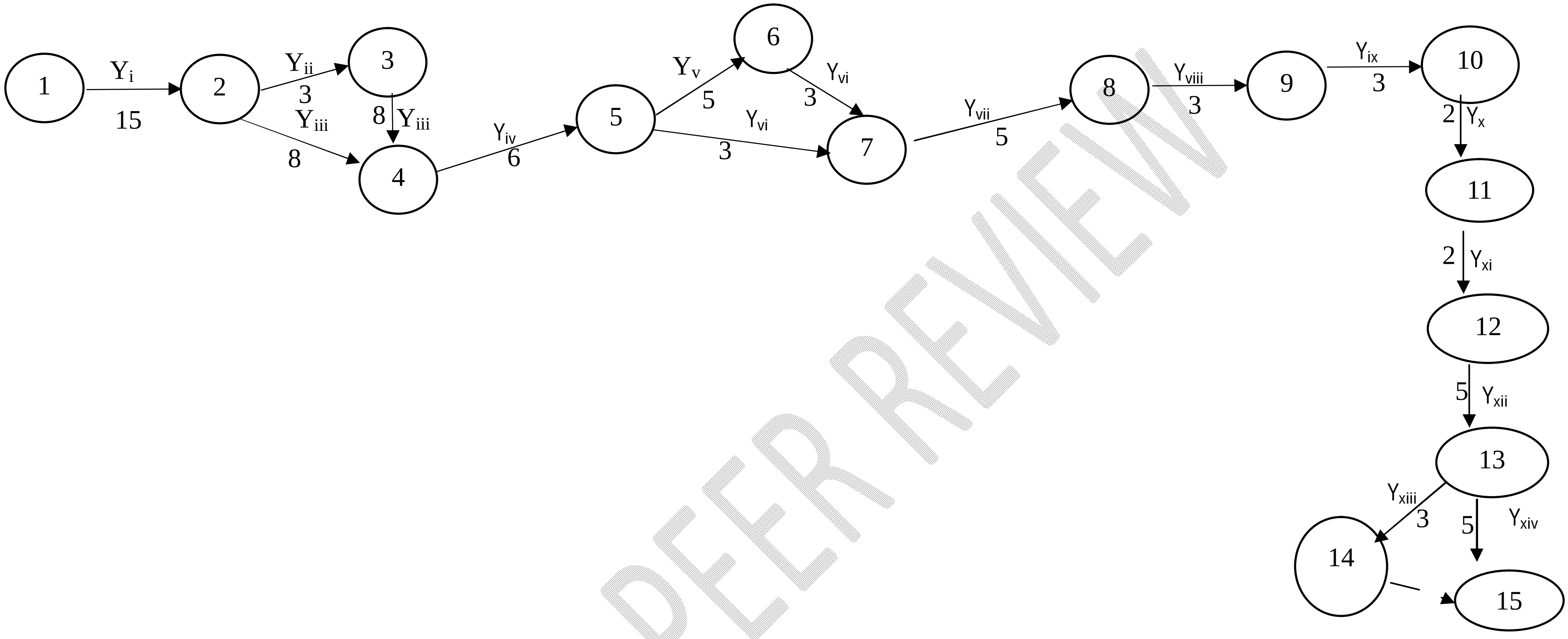
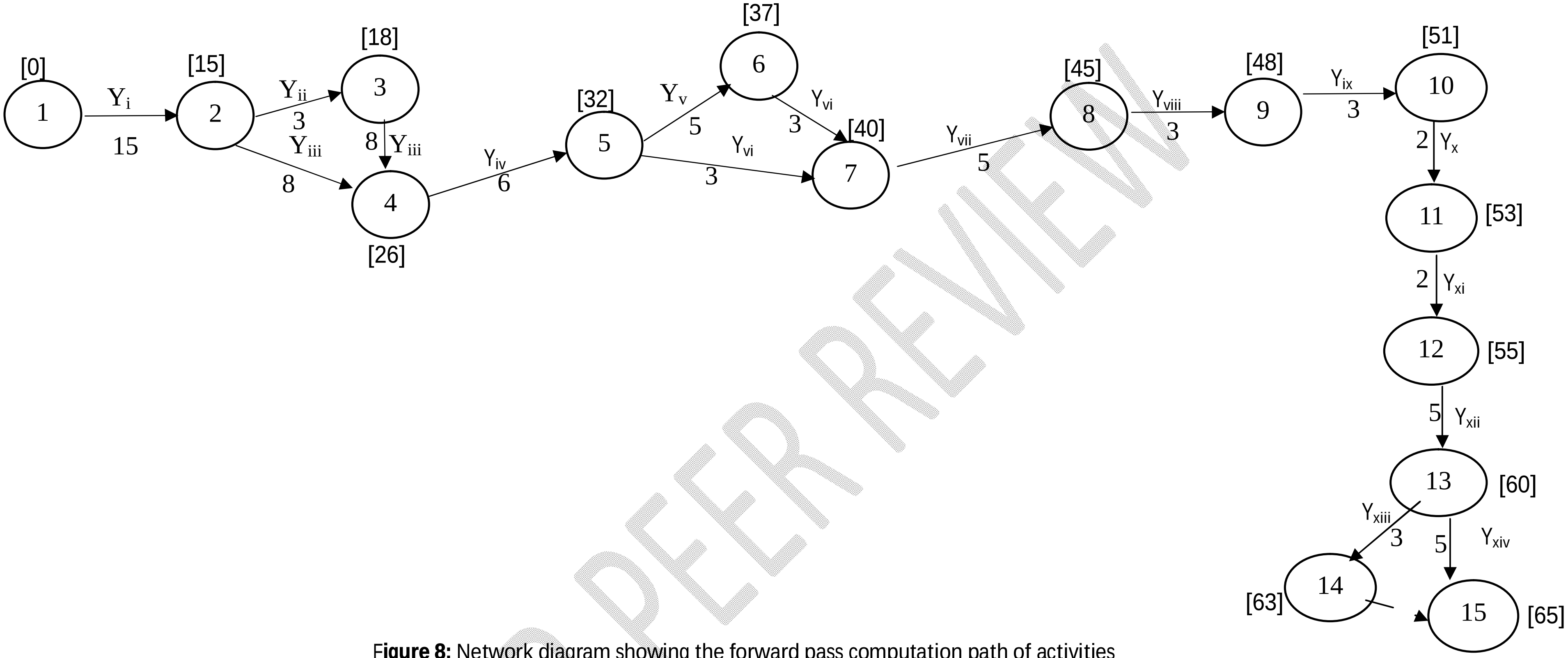


**Figure 7:** Network diagram showing the activities routes and duration of the matrix acidizing operation



F**igure 8:** Network diagram showing the forward pass computation path of activities

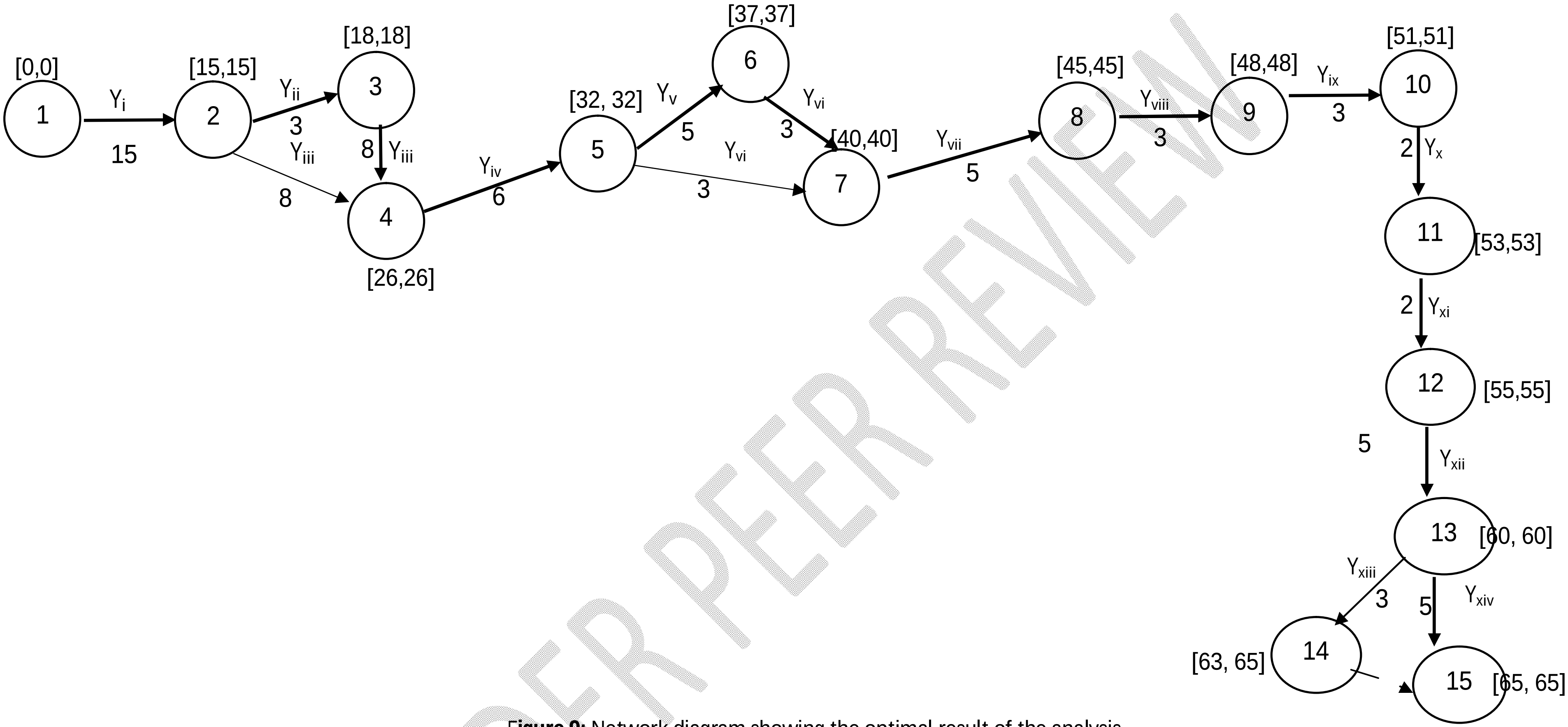


**Figure 9:** Network diagram showing the optimal result of the analysis

Using both the longest route, and the forward and backward pass criteria, the Critical Path of the matric acidizing operation (shown in bold arrows) is 65 days.

### Stochastic Model

### Demulsifying operation

For the PERT analysis, the critical path, as determined by the Critical Path Method, was analysed. This was done in order to ascertain whether the project will be completed within the calculated time.

**Table3: PERT of demulsifying operation (expected mean time, and standard deviation**

| Activity code | Optimistic (a) | Pessimistic (b) | Most likely (m) | $t_e$ | σ |
|---|---|---|---|---|---|
| $Z_i$ | 4 | 9 | 6 | 6.166667 | 0.833333 |
| $Z_{ii}$ | 2 | 6 | 4 | 4 | 0.666667 |
| $Z_{iii}$ | 1 | 5 | 3 | 3 | 0.666667 |
| $Z_v$ | 5 | 10 | 7 | 7.166667 | 0.833333 |
| $Z_{vi}$ | 3 | 7 | 5 | 5 | 0.666667 |
| $Z_{vii}$ | 5 | 9 | 7 | 7 | 0.666667 |
| $Z_{viii}$ | 3 | 8 | 5 | 5.166667 | 0.833333 |
| $Z_{ix}$ | 1 | 5 | 3 | 3 | 0.666667 |
| $Z_x$ | 1 | 5 | 3 | 3 | 0.666667 |
| | | | | 43.5 | 6.5 |

$\Sigma\ t_{e\,=}$ 43.5=44, $\Sigma\sigma$ = 6.5

The probability of completing the demulsifying operation at the 45 days (a day more than the 43 days) and also the 5 days less than ($Z_{40}$) the estimated day is calculated as follows:

For 45 days, PERT ($Z_{45}$) = $\frac{45-44}{6.5}$= 0.153

$Z_{44}$= 0.15

From the normal distribution table; $Z_{45}$ of 0.15 has a probability of 0.55962 which is 55.9%.

PERT ($Z_{40}$) = $\frac{40-45}{6.5}$= -0.77

Z= -0.77

From the normal distribution table; $Z_{38}$ of -0.77 has a probability of 0.22065 which is 22.1%.

Furthermore, the probability of completing the demulsifying operation between 44 and 39 days is estimated as:

= 55.9-21.1= 34.8%

$Z_{45\text{-}40}$ = 34.8%

Furthermore, the company target for the completion of the demulsifying operation is 50 days. Using the PERT analysis, the probability of the company completing the operation in 50 days or less can therefore be calculated as:

PERT ($Z_{50}$) = $\frac{50-44}{6.5}$= 0.92

Z= 0.92

From the normal distribution table; $Z_{50}$ of 0.92 has a probability of 0.82121which is 82.1%.

**Matrix Acidizing operation**

**Table4: PERT of Matrix Acidizing operation (expected mean time, and standard deviation**

| Activity code | Optimistic (a) | Pessimistic (b) | Most likely (m) | $t_e=\frac{a+4m+b}{6}$ | $\sigma=\frac{b-a}{6}$ |
|---|---|---|---|---|---|
| $Y_i$ | 12 | 18 | 15 | 15 | 1 |
| $Y_{ii}$ | 1 | 5 | 3 | 3 | 0.666667 |
| $Y_{iii}$ | 4 | 10 | 8 | 7.666667 | 1 |
| $Y_{iv}$ | 4 | 9 | 6 | 6.166667 | 0.833333 |
| $Y_v$ | 3 | 7 | 5 | 5 | 0.666667 |
| $Y_{vi}$ | 1 | 5 | 3 | 3 | 0.666667 |
| $Y_{vii}$ | 3 | 7 | 5 | 5 | 0.666667 |
| $Y_{viii}$ | 1 | 5 | 3 | 3 | 0.666667 |
| $Y_{ix}$ | 1 | 5 | 3 | 3 | 0.666667 |
| $Y_x$ | 1 | 5 | 2 | 2.333333 | 0.666667 |
| $Y_{xi}$ | 1 | 4 | 2 | 2.166667 | 0.5 |
| $Y_{xii}$ | 3 | 8 | 5 | 5.166667 | 0.833333 |
| $Y_{xiv}$ | 3 | 7 | 5 | 5 | 0.666667 |
| | | | | 65.5 | 9.5 |

$\Sigma t_e$= 65.5which can be rounded up to 66 days

$\Sigma\sigma$ = 9.5

The probability of completing the matrix acidizing operation within the 67 days (a day more than the 66 days) and 61 days (5 days less than the estimated day) is calculated as follows:

PERT ($Z_{67}$) = $\frac{67-66}{9.5}$= 0.105

Z= 0.11

From the normal distribution table; $Z_{67}$ of 0.11 has a probability of 0.54380 which is 54.4%.

PERT ($Z_{61}$) = $\frac{61-66}{9.5}$= -0.526

Z= -0.53

From the normal distribution table; $Z_{60}$ of -0.57 has a probability of 0.29806which is 29.8%.Furthermore, the probability of completing the matrix acidizing operation between 66 and 60 days is estimated as:

$Z_{67-61} = Z_{67} – Z_{61}$= 54.4-29.8= 24.6%

$Z_{67-61}$ = 24.6%

Furthermore, the company target for the completion of the matrix acidizing operation is 70 days. Using the PERT analysis, the probability of the company completing the operation in 70 days or less can therefore be calculated as:

PERT ($Z_{70}$) = $\frac{70-66}{9.5}$= 0.421

Z= 0.42

From the normal distribution table; $Z_{70}$ of 0.57 has a probability of 0.66276 which is 66.3%.

**Comparative analysis of the deterministic and the stochastic models**

**Table5: Comparison of the deterministic and the stochastic model results**

| **S/n** | **Operation** | **Deterministic duration days** | **Stochastic duration** | **Difference in days** |
|---|---|---|---|---|
| **1** | Demulsifying operation | 43 | 44 | 1 |
| **2** | Matrix acidizing operation | 65 | 66 | 1 |

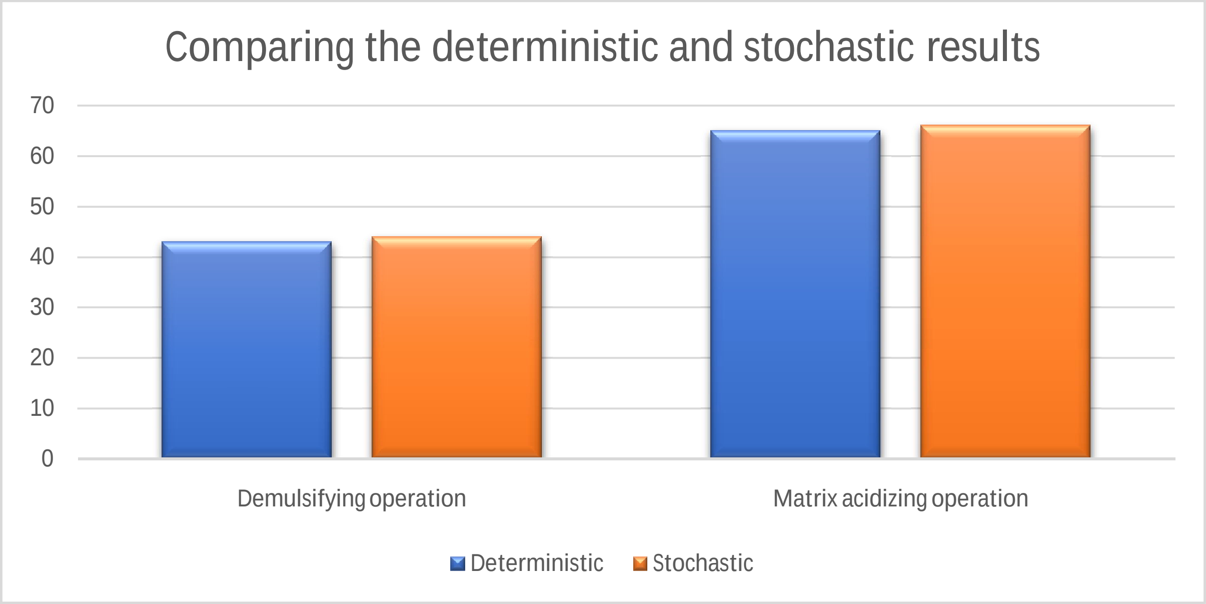


Figure 10: Comparison of the deterministic model and stochastic model results

In project management, the choice between deterministic and stochastic models for estimating operation durations is a critical decision that can impact project planning and execution. Deterministic models provide a fixed value for the duration of each activity, assuming no variability or uncertainty in the process. On the other hand, stochastic models consider the probabilistic nature of activities, taking into account factors such as contingencies, downtime, force majeure events, and other unplanned disruptions that can affect the duration of operations.

Table5 in the research findings illustrates the comparison between deterministic and stochastic models in estimating operation durations. The deterministic model yields shorter durations for each operation compared to the stochastic model. This is attributed to the deterministic model's reliance on specific, predetermined values for activity durations, without accounting for uncertainties or variations that may occur during project execution. The stochastic model, by incorporating probabilistic elements, offers a more comprehensive approach to estimating operation durations. It allows for a range of possible outcomes, considering the likelihood of activities being completed ahead of schedule or exceeding the allocated time frame. This flexibility in the stochastic model enables project managers to account for unforeseen events, such as equipment breakdowns, environmental disruptions, or other unexpected delays that can impact project timelines.

While the deterministic model provides a more straightforward and deterministic approach to estimating operation durations, the stochastic model offers a more realistic and robust framework that considers the inherent uncertainties in construction projects. The slight differences in operation durations (less than 1 day) between the two models, as observed in the study, suggest that both approaches can be effectively utilized in practice. Ultimately, the choice between deterministic and stochastic models should be based on the specific characteristics of the project, the level of uncertainty involved, and the desired level of risk management. Project managers need to carefully evaluate the trade-offs between simplicity and complexity, accuracy and flexibility, to select the most appropriate model for estimating operation durations in construction projects.

## 4.0 Discussion

### Delivery time of performing two distinct well operations (matrix acidizing operation, demulsifying operation) using deterministic model

The study results indicate that the durations of 65 days for matrix acidizing and 43 days for demulsifying, was identified as the Critical Path using both the longest route and the forward and backward pass criteria. The Critical Path method is a fundamental technique in project management that determines the longest sequence of dependent tasks, which collectively dictate the minimum time required to complete a project (Han et al., 2021). By applying the forward pass to calculate the earliest start and finish times for each task and the backward pass to determine the latest start and finish times, project managers can precisely identify the Critical Path. In project management, the Critical Path analysis involves identifying all the tasks required to complete a project, determining their dependencies, estimating the duration of each task, and ultimately identifying the Critical Path. The Critical Path method is a crucial tool in project management that helps identify the sequence of tasks that collectively determine the minimum time required to complete a project (Muzio et al., 2021). It is essential as any delays in tasks along this path will directly impact the overall project timeline. The significance of the identified Critical Paths in the two operations cannot be understated. It implies that any delays or extensions in the tasks comprising these paths will directly influence the overall duration of the operations. This implies that project managers can focus their attention on monitoring and managing the tasks along the critical path to ensure that the projects stay on schedule. Additionally, resources can be allocated efficiently to expedite the completion of critical tasks and mitigate any potential delays. The study's findings regarding the Critical Path for the operations highlight the importance of effective project management techniques in ensuring timely and successful project completion. By leveraging the Critical Path method and its associated criteria, project managers can streamline operations, optimize resource utilization, and proactively address any challenges that may arise during the project lifecycle (Han et al., 2021).

### Delivery time of performing two distinct well operations (matrix acidizing operation, and demulsifying operation) using stochastic model

The stochastic models presented for the delivery times of the demulsifying and matrix acidizing operations provide valuable insights into the variability and uncertainty associated with project completion times. The delivery time for the demulsifying operation is determined to be 44 days, with a probability of 34.8% for completion between 39 and 44 days and an 82.1% probability of finishing in less than 50 days. On the other hand, the matrix acidizing operation has a delivery time of 66 days, with a 54.4% probability of completion between 61 and 67 days and a 66.3% probability of finishing in less than 70 days. Unlike deterministic models, which provide fixed estimates of project completion times, stochastic models incorporate variability and uncertainty inherent in real-world scenarios. They offer a range of possible outcomes along with probabilities associated with each outcome, providing a more comprehensive understanding of project timelines. By utilizing a stochastic model, the study acknowledges the dynamic nature of oil and gas operations, where various factors such as weather conditions, equipment availability, and unforeseen challenges can influence project timelines. The stochastic model offers a probabilistic view of project timelines, aiding project managers in assessing and managing risks associated with project scheduling and execution (Vlysidis&Kaznessis, 2018). By evaluating the probabilities of completing operations within specific time frames, decision-makers can make informed choices regarding resource allocation, project timelines, and risk mitigation strategies. The model provides a basis for understanding the likelihood of meeting project deadlines and can assist in optimizing project schedules to enhance overall project performance (Lock, 2020).

For this study, the stochastic model predicts a delivery time of 44 days for the demulsifying operation. This estimate provides a central point within a range of possible outcomes, reflecting the average completion time considering all potential variables. The probability of completing the demulsifying operation between 44 and 39 days is 34.8%. This probability distribution illustrates the likelihood of achieving specific milestones within the project timeline, allowing project managers to assess the feasibility of meeting intermediate deadlines. Furthermore, the probability of delivering the project in less than 50 days is 82.1%. This high probability suggests a relatively high level of confidence in meeting the overall project deadline, indicating efficient planning and execution of the demulsifying operation. In contrast, the stochastic model predicts a longer delivery time of 66 days for the matrix acidizing operation. This extended duration reflects the complexity and intricacies involved in this particular operation, which may include factors such as reservoir characteristics and wellbore conditions. The probability of completing the matrix acidizing operation between 61 and 67 days is 54.4%. This probability distribution indicates a moderate likelihood of achieving specific milestones within the project timeline, highlighting the inherent variability in project execution. Despite the longer delivery time, the probability of delivering the project in less than 70 days is 66.3%. While slightly lower than that of the demulsifying operation, this probability still signifies a reasonable likelihood of meeting the overall project deadline, albeit with a margin of uncertainty due to the longer duration of the matrix acidizing operation.

The implication of this result for project management is that the stochastic model results offer critical insights for project managers in terms of planning, resource allocation, and risk management. By understanding the range of possible outcomes and associated probabilities, project managers can make informed decisions to optimize project timelines and minimize the impact of uncertainties. Additionally, these findings underscore the importance of contingency planning and flexibility in project scheduling. Recognizing the inherent variability in project execution allows for the implementation of adaptive strategies to mitigate risks and address unforeseen challenges as they arise. In conclusion, the utilization of stochastic models in project management, as demonstrated in the context of the demulsifying and matrix acidizing operations, offers a systematic approach to handling uncertainties and variability in project timelines. By including probabilistic assessments into project planning and execution, organizations can enhance their ability to deliver projects on time and within budget, ultimately improving project outcomes and stakeholder satisfaction (Abdulla & Al-Hashimi,2019; Banerjee et al., 2017).

**Comparative analysis of the two models (deterministic and stochastic model) in order to ascertain which model would be best suited for oilfield deliverable operation evaluation.**

Using the deterministic model, the demulsifying operation was calculated to be completed in 43 days while the matrix acidizing operation completion time is 65 days. However, with the stochastic model, the demulsifying operation is expected to be completed in 44 days with the matrix acidizing operation completion time being 66 days. This shows that the stochastic model prediction is one day more than the deterministic model prediction in both the matrix acidizing and demulsifying operations. This difference can be attributed to the fact that deterministic model employs an approach that provides a single estimate of project completion time based on predetermined task durations. While in contrast, the stochastic model adopts a probabilistic approach, considering variability and uncertainty in project parameters. Also, while both models identify the critical path, which represents the sequence of tasks with the longest duration and determines the overall project timeline; the stochastic model provides additional insights into the probability distribution of project completion times.

Additionally, the deterministic model CPA provides precise estimates of project completion times but may overlook uncertainties and variations. On the other hand, the stochastic model offers a range of possible outcomes and associated probabilities, allowing for a more flexible and adaptive approach to project management. Conclusively, while both CPA and stochastic models offer insights into project completion timelines, they differ in their approach to uncertainty and variability. CPA provides deterministic estimates based on predetermined task durations, while the stochastic model offers probabilistic estimates considering variability and uncertainty. By understanding the strengths and limitations of each approach, project managers can make informed decisions to optimize project outcomes and mitigate risks effectively. Based on the foregoing, the use of stochastic model in determining the best model in planning for the project management of the oil deliverable operations considered in the study. Although, it has added to the completion days of the operations; its incorporation of probabilities and uncertainties makes it better option.

## 5.0 Conclusion

The comparison between the deterministic and stochastic models in evaluating oilfield deliverable operations reveals distinct advantages and considerations for project management. The deterministic model, employed in this study, provided specific completion times of 43 days for the demulsifying operation and 65 days for the matrix acidizing operation. In contrast, the stochastic model predicted completion times of 44 days for demulsifying and 66 days for matrix acidizing, indicating a slight deviation from the deterministic estimates. The deterministic model, such as Critical Path Analysis (CPA), offers precise estimates of project completion times based on predetermined task durations. However, it may overlook uncertainties and variations inherent in project execution. On the other hand, the stochastic model incorporates probabilistic elements, considering variability and uncertainty in project parameters. By providing a range of possible outcomes and associated probabilities, the stochastic model offers a more flexible and adaptive approach to project management, allowing for better risk assessment and mitigation strategies. Both models identify the Critical Path, which represents the sequence of tasks with the longest duration and determines the overall project timeline. While the deterministic model focuses on fixed estimates, the stochastic model offers insights into the probability distribution of project completion times, enabling project managers to make informed decisions based on the likelihood of meeting project deadlines. In conclusion, the stochastic model emerges as a preferred option for planning oilfield deliverable operations due to its incorporation of probabilities and uncertainties. Although it may slightly extend the completion days of operations compared to deterministic models, the stochastic model’s ability to account for variability and provide probabilistic estimates enhances project planning and risk management. By understanding the strengths and limitations of both models, project managers can leverage the probabilistic insights offered by stochastic models to optimize project outcomes and navigate uncertainties effectively in oilfield operations.

## Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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