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# Optimization of Chicken Farm Renovation Project Using PERT, CPM technique and POM-QM software

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**Abstract**
Construction is an important sector in every country to ensure the development of the nation. There are various issues in this industry, the most common of which being project delays and a limited budget. This research is based on construction data received from the Selangor Veterinary Department, especially the reconstruction of a large-scale modern chicken coop project involving a high number of workers and commercial machinery. Like any project, it encounters challenges related to time and cost constraints. The study employs the Program Evaluation and Review Technique (PERT) to delineate the project network, integrates the Critical Path Method (CPM) to identify critical paths, and applies project crashing with linear programming to optimise activity duration reduction and minimise costs. The utilisation of PERT yields an illustrative network diagram conducive to comprehensive analysis. The CPM computation determines a project completion time of 72 days, with a noteworthy 98.87% probability of achieving completion within 88 days. Each phase is individually analysed to enhance flexibility, and the CPM and PERT results indicate a completion time of 51 days for Phase 1 with a 98.80% probability and 19 days for Phase 2 with a 97.26% probability of completion within 28 days. Additionally, project crashes are implemented to further expedite the project. The project was successfully completed in 55 days at a cost of RM 16538.50. This study makes a big contribution to the construction sector in this country. At the same time, this study opens a new perspective on phased construction in project management. For future research, the other factor other that time constrain must be considered to achieve flexible and more meaningful result.

## 1. Introduction

The importance of construction in human progress has been demonstrated throughout history by the urbanization of ancient Mesopotamian towns [1]. In addition to offering safety, shelter, and necessary infrastructure, buildings also support the preservation of cultural heritage, the economy, and environmental concerns. Around the world, countries work to improve their infrastructure, especially in underdeveloped areas where building stimulates economic growth [2]. However, overseeing construction projects, particularly those of a big scale, presents a number of difficulties, highlighting the necessity of an effective project flow and a prompt completion date. Effective project management requires complicated coordination and knowledge to traverse complications at various construction stages, regardless of the size of the project a house or a skyscraper [3]. Challenges in project management, such as inaccurate time and cost estimation, along with improper planning, are common, especially in large-scale projects with significant resources and extended durations [4][5]. Cost considerations are paramount in project planning, with extensive research done before project initiation to ensure alignment with the budget [6]. A well-organized plan and schedule are crucial for orderly project implementation [7].

To address these issues, numerous mathematical techniques have been created, including PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method), which are widely used in project management. Project management entails planning, organizing, and coordinating resources to meet certain objectives within a set timeline [8]. PERT and CPM solve the project timeline problem by optimizing activities. They determine the critical path, activities that cannot be delayed, and slack activities that may be postponed without compromising project completion time. CPM identifies all [9] activities required for project completion by defining dependencies, predicting durations, and constructing task sequences [10]. PERT allows the estimation of activity durations considering uncertainty using optimistic, most probable, and pessimistic time estimates [11]. Early start ($ES$), early finish ($EF$), late start ($LS$), optimistic time ($a$), most likely time ($m$), and pessimistic time ($b$) are key notions in PERT and CPM [12].

Apart from these methods, a systematic way to reduce the duration of a project is to expedite its important activities through project crashing [13]. Project crashing is the analysis of the critical path and the identification of jobs that, if finished earlier, might shorten the project's duration [14]. Other previous studies were done in using forecasting method with the statistics technique in worldwide according to various fields of studies [15, 16, 17, 18].

This study's goals are to use the PERT technique to illustrate the network of activities related to renovation of a chicken farm, the CPM technique to identify critical and non-critical activities within the project, and the project crashing technique to reduce project duration and cost. Finally, this study is critical to the construction sector since it guarantees effective budget control while also expediting the completion of buildings.

## 2. Materials and Methods

### 2.1 Data Description

The data was obtained from the Selangor Veterinary Services Department. The project had two main parts: first, they worked on the structure, and second, they focused on the mechanical aspects. They made sure to finish the structure work completely in the first phase before moving on to the second. In the initial stage, they built and renovated the first floor of the farm. In the second phase, they started with wiring, then installed electrical appliances and necessary equipment for taking care of the chickens. The goal was to upgrade the farm and make it more modern and efficient.

### 2.2 PERT

PERT, or Program Evaluation and Review Technique, is a handy tool in project management used for planning and controlling projects. It becomes particularly valuable when there's a lot of uncertainty about how much time each activity might take. PERT can help predict how long it will take to finish the project. In PERT, they use a beta probability distribution to estimate how long each activity might take. For every activity, they give three-time estimates: the "optimistic time" ($a$), which is the minimum time it might take under perfect conditions; the "most likely time" ($m$), which is the best guess based on typical situations and resources; and the "pessimistic time" ($b$), which is the maximum time it might take in the worst-case scenario. Based on 3 estimations, to calculate the expected time ($TE$), use formula (1)[19].

$$Te = \frac{(a + 4m + b)}{6} \tag{1}$$

### 2.3 CPM

Effective planning in project management requires a thorough grasp of the scheduling of events. The latest start time ($LS$) indicates the latest time at which an activity may begin without delaying the project, whereas the earliest start time ($ES$) indicates the earliest point at which an activity can begin. In a similar vein, the latest finish time ($LF$) indicates the latest time an activity must end to prevent project delays, while the earliest finish time ($EF$) indicates the earliest potential completion time for an activity. In project scheduling, the idea of slack is essential because it represents the flexibility or float time that may be allocated to non-essential work. The difference between an activity's late start ($LS$) and early start ($ES$) or late finish ($LF$) and early finish ($EF$) is used to compute slack ($S$) [20]. Positive slack implies flexibility, indicating the amount of time an activity can be delayed without impacting the project's completion date. On the other hand, zero slack identifies critical path activities where any delay influences the overall project timeline. This understanding and calculation of slack provide project managers with insights into the project's timeline flexibility and potential areas for adjustments without jeopardizing the completion date [21].

$$S = LS - ES = LF - EF \tag{2}$$

Changes in activities along the critical path can significantly impact the overall completion of a project. By analysing the variations in activities on this path, we can gain a better understanding of the uncertainties related to the project. To find the standard normal (Z), use equation (3) where $X$ is expected time and $V$ is variants, and then check the normal distribution table to find the corresponding probability. This method helps project managers systematically understand and manage uncertainties in critical path activities, providing a solid foundation for decision-making throughout the project's life.

$$Z = \frac{X - \Sigma Te}{\Sigma\sqrt{V_{critical}}} \tag{3}$$

In the context of project management, project crashing is a tactical approach intended to shorten a project's overall length by accelerating the completion of significant tasks or activities. Crashing is mostly used to shorten the project's total duration while maintaining the original goal and limitations. This approach is closely related to the Critical Path Method (CPM), in which project crashing is calculated using the CPM diagram as a fundamental tool. Using the critical route feature in the CPM framework, project managers can identify the most crucial activities that, if accelerated, will provide the greatest reduction in project length. [22] outlined a method that must be applied to calculate project crashes precisely. This academic elucidation underscores the strategic nature of project crashing as an instrument for time optimization while ensuring alignment with project objectives and constraints. Project crashing is calculated using this formula and the POM QM software (Fig. 1).

$$\frac{crash\ cost}{Time\ period} = \frac{Crash\ cost - Normal\ cost}{Normal\ time - Crash\ time} \tag{4}$$

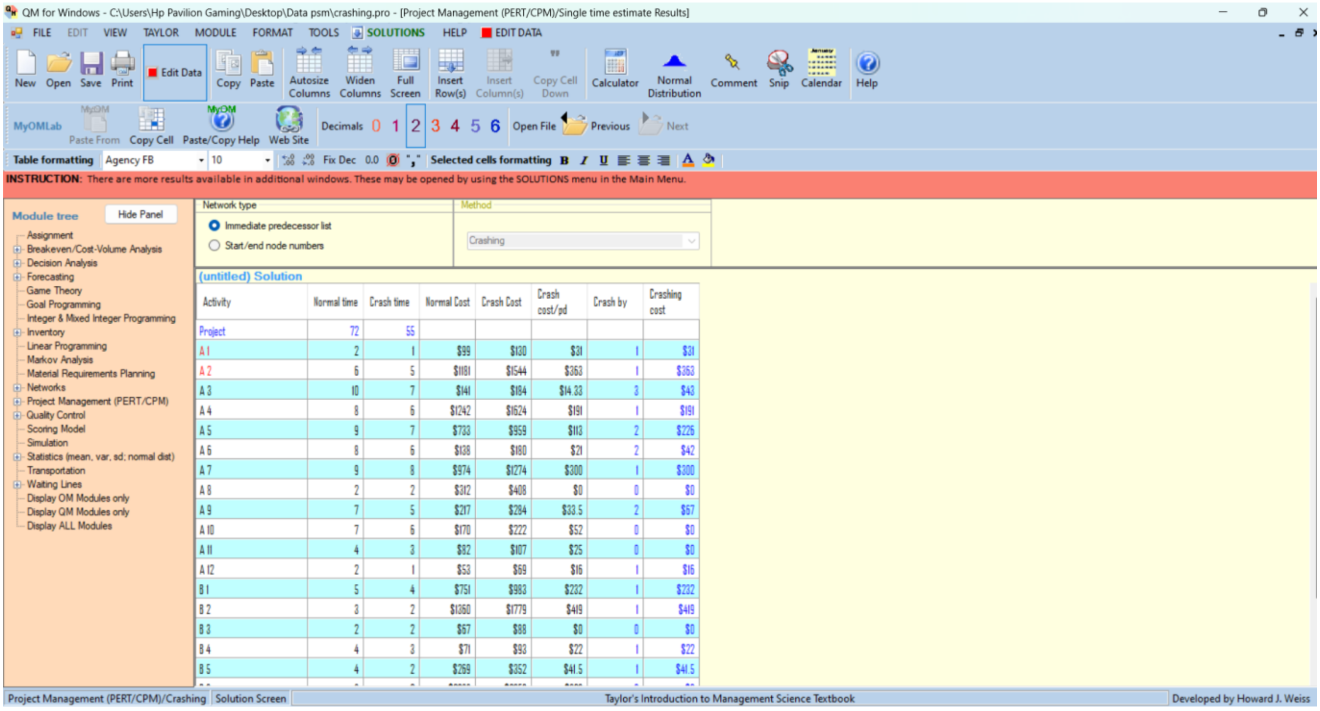


**Fig. 1** *POM QM*

## 3. Result and Discussion

This section had three main components that resulted in the whole project: phase 1 and phase 2 independently.

## 3.1 The Project of Chicken Coop

Illustrating the project network, identifying the critical path and activities, and estimating the probability of completing the overall project are the key objectives for this study.

### 3.1.1 Project Network for Chicken Coop

For phase 1: civil work, there are a total of 23 activities.

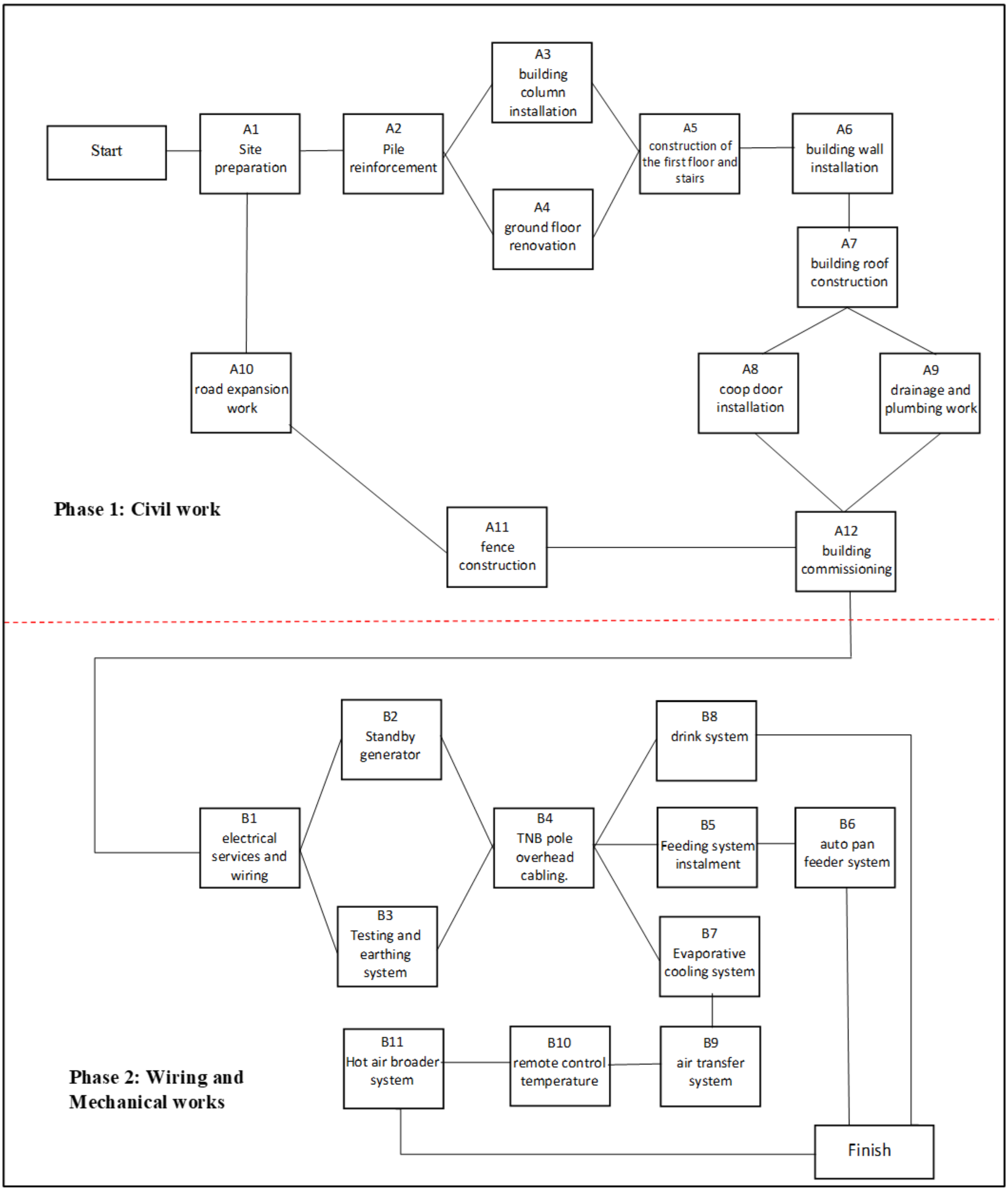


**Fig. 2** *PERT network diagram for chicken coop*

Fig. 1 shows how the entire project comes together. It illustrates the PERT network diagram, combining both phase 1 (Civil work) and phase 2 (wiring and machine work). In phase 1, things kick off with activity A1 and wrap up with activity A12. On the other hand, phase 2 starts with activity B1 and goes through B9. Each phase goes through its analysis separately before everything is combined into the overall project.

## 3.2 Critical Path and Activities for Phase 1: Civil work and Phase 2

Fig. 2 and Fig. 3 clearly shows the duration, earliest start (*ES*) time, earliest finish (*EF*) time, latest start (*LS*) time, latest finish (*LF*) time, and slack time for each.

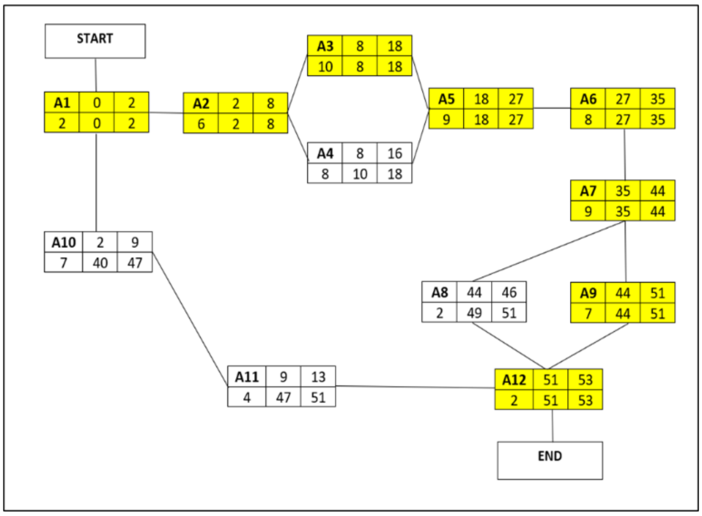


**Fig. 3** *CPM network diagram for phase 1*

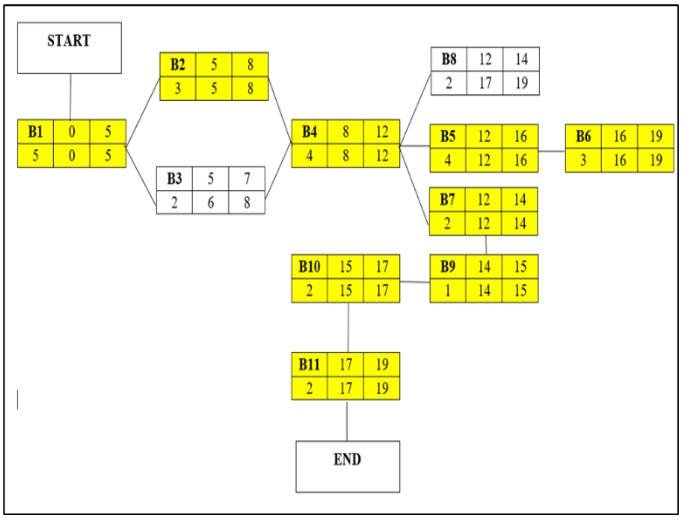


**Fig. 4** *CPM network diagram for phase 2*

These important tasks, shown in the image above, are critical, as any delays in their execution result in corresponding delays in the overall project timeframe. Managing and understanding these critical paths is crucial for maintaining project timelines. The crucial route for Phase 1 is A1-A2-A3-A5-A6-A7-A9-A12, which takes 53 days to complete. Meanwhile, to Phase 2, the start with electrical services and wiring (B1) is followed by the installation of the hot air border system (B6) and the auto pan feeder system (B11). Phase 2 has two critical paths is B1-B2-B4-B5-B6, and B1-B2-B4-B7-B9-B10-B11 that requires 19 days to complete.

### 3.2.1 Probability of Completion Time for Phase 1

The PERT method employs three-time estimates, which are optimistic time (*a*), most likely time (*m*), and pessimistic time (*b*). Using equations (1) and (2), the PERT method calculates the expected time and variances. The results are presented in Table 1.

**Table 1** *Project variance for each activity in phase 1*

| Activates code | Activity description (Critical activity) | Duration a | m | b | Expected Time (Te) | Variance |
|---|---|---|---|---|---|---|
| A1 | Site preparation | 1 | 2 | 3 | 2.0000 | 0.1111 |
| A2 | Pile reinforcement | 5 | 6 | 8 | 6.1667 | 0.2500 |
| A3 | Building column installation | 6 | 10 | 14 | 10.0000 | 1.7778 |
| A5 | Construction of the first floor and stairs | 6 | 9 | 12 | 9.0000 | 1.0000 |
| A6 | Building wall installation | 5 | 8 | 15 | 8.6667 | 2.7778 |
| A7 | Building roof construction | 5 | 9 | 12 | 8.8333 | 1.3611 |
| A9 | Drainage and plumbing work | 5 | 7 | 9 | 7.0000 | 0.4444 |
| A12 | Building commissioning | 1 | 2 | 3 | 2.0000 | 0.1111 |
| | Total | | | | 53.6667 | 7.8333 |

Based on the project file, the expected completion time for phase one is 60 and the actual time finish is 74. Therefore, the obtained z value is:

$$Z = (X - \Sigma Te)/(\Sigma\sqrt{(V\_critical)}) = (60 - 53.667)/\sqrt{7.833} = 2.2627$$

After the z value is determined, an important step in statistical analysis involves the use of a z-score table. Where the z value is 2.2627, it is found that this corresponds to a probability of 0.9880. When this probability is converted into a percentage, it is observed that there is a very high likelihood of 98.80%. In practical terms, it is indicated that there is a strong probability that a project will be completed within 60 days or less. Through the utilization of project crashing methods, it can be confidently stated that Phase 1 can be completed on time within the specified 60-day period.

### 3.2.2 Probability of Completion Time for Phase 2

**Table 2** *Project variance for each activity in phase 2*

| Activity | Activity description | Duration | | | Expected Time (Te) | Variance |
|---|---|---|---|---|---|---|
| | | a | m | b | | |
| B1 | Electrical services and wiring | 2 | 5 | 5 | 4.5000 | 0.2500 |
| B2 | Standby generator | 1 | 3 | 5 | 3.0000 | 0.4444 |
| B4 | TNB pole overhead cabling. | 2 | 4 | 5 | 3.8333 | 0.2500 |
| B5 | Feeding system instalment | 2 | 4 | 6 | 4.0000 | 0.4444 |
| B6 | Auto pan feeder system | 1 | 3 | 4 | 2.8333 | 0.2500 |
| B7 | Evaporative cooling system | 1 | 2 | 4 | 2.1667 | 0.2500 |
| B9 | Air transfer system | 0.5 | 1 | 1 | 0.9167 | 0.0069 |
| B10 | Remote control temperature | 1 | 2 | 3 | 2.0000 | 0.1111 |
| B11 | Hot air broader system | 1 | 2 | 3 | 2.0000 | 0.1111 |
| Total | | | | | 25.2500 | 2.1181 |

Based on the project file, the expected completion time for phase 1 is 28 meanwhile the actual time of finish is 30. Therefore, the obtained z value is:

$$Z = (X - \Sigma Te)/(\Sigma\sqrt{(V\_critical)}) = (28 - 25.2500)/\sqrt{2.1181} = 1.9239$$

After the z value is determined, an important step in statistical analysis involves the use of a z-score table. Where the z value is 1.9239, it is found that this corresponds to a probability of 0.9726. When this probability is converted into a percentage, it is observed that there is a very high likelihood of 97.26%. In practical terms, it is indicated that there is a strong probability that a project will be completed within 28 days or less. Through the utilization of project crashing methods, it can be confidently stated that Phase 2 can be completed on time within the specified 28-day period.

## 3.3 Critical Path and Activities for Whole project

Fig. 4 clearly shows the duration, earliest start ($ES$) time, earliest finish ($EF$) time, latest start ($LS$) time, latest finish ($LF$) time, and slack time for each activity in the kitchen renovation project.

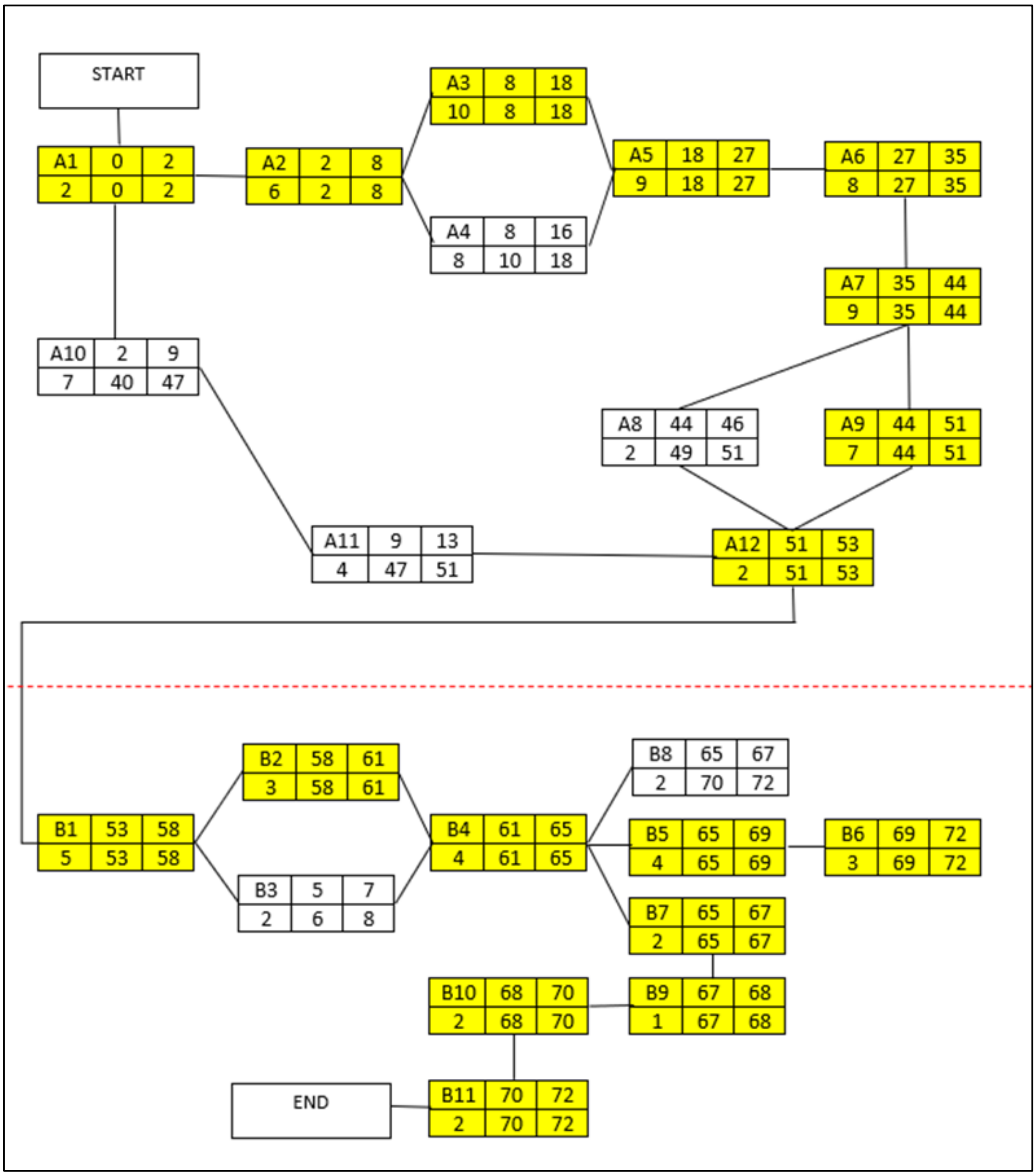


**Fig. 5** *CPM network diagram for case study 2*

Phases 1 and 2 of the chicken coop projects combine to create a complete project. Phase 1's "building commission" (A12) and Phase 2's "electrical services and wiring" (B1) are seamlessly connected because of the PERT diagram's incorporation of activities from both phases to show this integration. This a link indicates that B1 starts on day 51 instead of day zero, showing a transition from the end of A12 to the beginning of B1. With reference to Fig. 4, the yellow activities represent essential tasks that have no slack, highlighting their significance in the project schedule. There are 17 essential tasks in all that must be completed successfully for the project to be completed.

### 3.3.1 Probability of Completion Time for whole phase

The expected time and variance of the PERT method were calculated by applying equations (1) and (2), as detailed in Table 3.

**Table 3** *Project variance for each activity in whole project*

| Activates code | Activity description | Duration a | m | b | Expected (TE) | Variance |
|---|---|---|---|---|---|---|
| A1 | Site preparation | 1 | 2 | 3 | 2.0000 | 0.1111 |
| A2 | Pile reinforcement | 5 | 6 | 8 | 6.1667 | 0.2500 |
| A3 | building Column installation | 6 | 10 | 14 | 10.0000 | 1.7778 |
| A5 | Construction of the first floor and stairs | 6 | 9 | 12 | 9.0000 | 1.0000 |
| A6 | Building wall installation | 5 | 8 | 15 | 8.6667 | 2.7778 |
| A7 | Building roof construction | 5 | 9 | 12 | 8.8333 | 1.3611 |
| A9 | Drainage and plumbing work | 5 | 7 | 9 | 7.0000 | 0.4444 |
| A12 | Building commissioning | 1 | 2 | 3 | 2.0000 | 0.1111 |
| B1 | Electrical services and wiring | 2 | 5 | 5 | 4.5000 | 0.2500 |
| B2 | Standby generator | 1 | 3 | 5 | 3.0000 | 0.4444 |
| B4 | TNB pole overhead cabling. | 2 | 4 | 5 | 3.8333 | 0.2500 |
| B5 | Feeding system instalment | 2 | 4 | 6 | 4.0000 | 0.4444 |
| B6 | Auto pan feeder system | 1 | 3 | 4 | 2.8333 | 0.2500 |
| B7 | Evaporative cooling system | 1 | 2 | 4 | 2.1667 | 0.2500 |
| B9 | Air transfer system | 0.5 | 1 | 1 | 0.9167 | 0.0069 |
| B10 | Remote control temperature | 1 | 2 | 3 | 2.0000 | 0.1111 |
| B11 | Hot air broader system | 1 | 2 | 3 | 2.0000 | 0.1111 |
| Total | | | | | 78.9167 | 9.9514 |

From the project file of this project, the expected completion time for phase one is 88 days and the actual time finish is 104. Therefore, the obtained z value is:

$$Z = \ (X - \Sigma Te)/(\Sigma\sqrt{}(V\_critical\ )) = \ (88 - 78.9167\ )/\sqrt{}9.9514 = 2.8797$$

After the z value is determined, an important step in statistical analysis involves the use of a z-score table. Where the z value is 2.8797, it is found that this corresponds to a probability of 0.9887. When this probability is converted into a percentage, it is observed that there is a very high likelihood of 98.87%. In practical terms, it is indicated that there is a strong probability that a project will be completed within 28 days or less. Through the utilisation of project crashing methods, it can be confidently stated that the whole project can be completed on time within the specified 88-day period.

## 3.4 Project Crashing for project chicken coop.

Meeting project deadlines is the primary goal of project crashes. Project crashing becomes necessary in our chicken coop project since the original schedule was less than the real amount of time needed to finish. Even though there was originally a plan for earlier completion, delays have been caused by unforeseen circumstances such as bad weather, physical barriers, and the difficult journey to the building site. The project timetable will inevitably be extended by these unanticipated events. Therefore, putting projects crashing into practice is a good way to make sure that the deadline is met.

**Table 4** *Project crashing*

| Activity | Normal time | Crash time | Normal Cost (RM) | Crash Cost (RM) | Crash cost/pd (RM) | Crash by | Crashing cost (RM) |
|---|---|---|---|---|---|---|---|
| Projects | 72 | 55 | | | | | |
| A1 | 2 | 1 | 99.00 | 130.00 | 31.00 | 1 | 31.00 |
| A2 | 6 | 5 | 1181.00 | 1544.00 | 363.00 | 1 | 363.00 |
| A3 | 10 | 7 | 141.00 | 184.00 | 14.33 | 3 | 43.00 |
| A4 | 8 | 6 | 1242.00 | 1624.00 | 191.00 | 1 | 191.00 |
| A5 | 9 | 7 | 733.00 | 959.00 | 113.00 | 2 | 226.00 |
| A6 | 8 | 6 | 138.00 | 180.00 | 21.00 | 2 | 42.00 |
| A7 | 9 | 8 | 974.00 | 1274.00 | 300.00 | 1 | 300.00 |
| A8 | 2 | 2 | 312.00 | 408.00 | 0.00 | 0 | 0.00 |
| A9 | 7 | 5 | 217.00 | 284.00 | 33.50 | 2 | 67.00 |
| A10 | 7 | 6 | 170.00 | 222.00 | 52.00 | 0 | 0.00 |
| A11 | 4 | 3 | 82.00 | 107.00 | 25.00 | 0 | 0.00 |
| A12 | 2 | 1 | 53.00 | 69.00 | 16.00 | 1 | 16.00 |
| B1 | 5 | 4 | 751.00 | 983.00 | 232.00 | 1 | 232.00 |
| B2 | 3 | 2 | 1360.00 | 1779.00 | 419.00 | 1 | 419.00 |
| B3 | 2 | 2 | 67.00 | 88.00 | 0.00 | 0 | 0.00 |
| B4 | 4 | 3 | 71.00 | 93.00 | 22.00 | 1 | 22.00 |
| B5 | 4 | 2 | 269.00 | 352.00 | 41.50 | 1 | 41.50 |
| B6 | 3 | 2 | 2033.00 | 2659.00 | 626.00 | 0 | 0.00 |
| B7 | 2 | 2 | 1368.00 | 1789.00 | 0.00 | 0 | 0.00 |
| B8 | 2 | 1 | 882.00 | 1154.00 | 272.00 | 0 | 0.00 |
| B9 | 1 | 1 | 538.00 | 704.00 | 0.00 | 0 | 0.00 |
| B10 | 2 | 1 | 286.00 | 374.00 | 88.00 | 1 | 88.00 |
| B11 | 2 | 2 | 1490.00 | 1948.00 | 0.00 | 0 | 0.00 |
| Totals | | | 14457.00 | | | | 2081.50 |

After implementing project crashing, the project was able to significantly reduce its original duration, which was set at 72 days. Using beneficial crashing procedures, the project schedule was reduced to 55 days with a cost of RM 2081.5. This additional cost is the fee paid for faster completion.

To achieve this shorter schedule, the durations of 15 of the 23 activities were reduced. Several activities were effectively cut during the project's first phase. For example, Activity A3 was reduced by three days, A5 and A6 by two days each, while Activities A1, A2, A4, A7, A9, and A12 were all reduced by one day each. These changes combined helped to streamline Phase 1 of the project.

Similarly, in Phase 2, activities were reduced. Activities B1, B2, B4, B5, and B10 were all reduced by one day each. It's worth noting that the values connected with each activity indicate the greatest feasible reduction in length, showing the most efficient use of crashing approaches.

In summary, the successful implementation of project crashing not only demonstrated the project's flexibility in achieving a faster completion but also highlighted the specific activities and phases that underwent modifications. The trade-off of incurring additional costs for a significantly reduced timeline showcases the strategic decision-making involved in project management.

### 3.4.1 Comparison of Performance of Project Crashing Result with the Current Project Cost and Completion Time

Tables 5 and 6 show the results of project crashes for phases 1, 2, and the whole project in comparison to the current project cost and completion time.

**Table 5** *Comparison table in project completion time*

| Activity | Normal Time | Crash Time | Difference Time |
|---|---|---|---|
| Phase 1 | 53 | 40 | 13 |
| Phase 2 | 19 | 15 | 4 |
| Whole project | 72 | 55 | 17 |

**Table 6** *Comparison table in project cost*

| Activity | Normal Cost (RM) | Crash Cost (RM) | Total Cost (RM) |
|---|---|---|---|
| Phase 1 | 5342.00 | 1279.00 | 6621.00 |
| Phase 2 | 9915.00 | 802.5.00 | 10717.50 |
| Whole project | 14457.00 | 2081.50 | 16538.50 |

The comparison between the current project scenario and the proposed results after the project crashed reveals substantial improvements. The completion time for Phase 1, Phase 2, and the entire project has been effectively reduced by 13 days, 4 days, and 17 days, respectively. However, this time, efficiency comes with an associated cost increase. While the total project cost rises from RM 14457 to RM 16538.5 due to extra resources, the detailed breakdown indicates additional costs of RM 6621 and RM 10717.5 for Phase 1 and Phase 2, respectively. This trade-off underscores the project's strategic decision to expedite completion, utilizing additional resources at an increased cost to achieve a more efficient timeline.

## 4. Conclusion

Based on the result of this study all the 3 objectives had been achieved for objective 1, the project renovation of the chicken farm was effectively illustrated using the PERT technique. All the activities of chicken be illustrated in network diagram. Next for objective 2, the CPM technique successfully identified critical and non-critical activities within the chicken farm project. There are 7 critical activities for phase one and 9 critical activities for phase 2, it makes 16 critical activities in the project renovation of chicken farm. Lastly for objective 3, project crashing effectively minimize the total cost required to shorten the specific duration of the renovation project. The duration of day can minimize is 17 days with cost added RM 2081.50. However, the study has limitations, primarily focusing on time and cost and neglecting other influential factors in construction timelines. Future research should adopt a multifactorial approach, considering variables like workforce size and equipment efficiency for a more accurate understanding. This would enhance the applicability of findings in real-world construction scenarios. In conclusion, the study recommends future researchers broaden their analyses to encompass a wider range of factors, offering a more comprehensive perspective on construction project management dynamics. This study will also help increase the supply of chicken meat by helping build a chicken coop [23].

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

*The authors confirm contribution to the paper as follows:* ***study conception and design, data collection, analysis, and interpretation of results****: Muhammad Haziq Faris Abdul Halim;* ***draft manuscript preparation****: Muhammad Haziq Faris Abdul Halim and Siti Noor Asyikin Mohd Razali. All authors reviewed the results and approved the final version of the manuscript.*

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