Application of Project Time Management and Resource Management to a Novel Blended Wing Unmanned Aerial Vehicle (BWB UAV) Design

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Abstract

This paper explores the concept of project management and applies two knowledge areas of project management: project time management and project resource management to a typical Blended Wing Unmanned Aerial Vehicle (BWB UAV) model design and development project. After several literature studies on this concept, it was observed to the best of research knowledge that few studies exist concerning the practical application of these two techniques on an aerial vehicle. This paper therefore practically applies these two concepts to a novel designed BWB UAV project to investigate how project time and resource management can be applied to any UAV project step by step and its usefulness to the aviation project management world. Three tools (Critical Path Method, Gantt Chart, and Resource Leveling and Smoothing) are introduced and applied to the design project of the BWB UAV. After the application of these two techniques, it was observed that the techniques and result pattern agree well with the available literature. The project time and quality factors in the "iron triangle" were also examined however, the cost was not analyzed due to its broad scope of application. Design analysis steps are outlined, and the results are displayed with regards to the pressure distribution on the wing. It was observed that, the pressure is estimated to range between 900.0 - 110.0 kPa. A pressure difference is created at the bottom and top surface of the wing, and this will help produce lift agreeing with existing literature. For future applications, other techniques in the project management body of knowledge (PMBOK) like cost analysis, scope, risk, and quality among others could be studied.

## Subject Areas

Aerospace Engineering, General Management

1. Introduction

Roger [1] defines project management as the application of a class of tools and techniques like the Critical Path Method (CPM) and matrix organization to channel the utilization of diverse resources toward the accomplishment of a unique, complex, on-time task within time, cost and quality constraints which are known as the project constraints. These project constraints have over time been categorized into a conceptual figure known as the "Iron Triangle" as illustrated in **Figure 1** [2] [3] [4] [5]. It is called the iron triangle because, if there is a malfunctioning in all or any one of these constraints, there is the possibility of an emergence of a risk that may affect the cost, time and quality of the project [6] [7] [8] [9] [10]. Project time management as Rory [11] explains, forms a greater aspect of the project management body of knowledge (PMBOK) that comprises all the processes and activities that aid the project manager to finish the project on time. Finishing a project on time is one of the most crucial criteria for success in the mind of every project manager [12] [13] [14]. Every single project has to do with factors like human resources (materials), economics (money), machinery (equipment), and methods (technicalities), which can be controlled. However, one factor that cannot be fully controlled is "time" which the project manager would have to always catch up with when conducting activities. Estimating the number of resources needed for the project activity is a great task to perform to avoid resource overload. This is what calls for the concept of project resource management [15]. The main purpose of project resource management is to minimize the engineering construction under the assumption of ensuring that the project quality and construction period are not compromised [10]. It is therefore essential to assess the quantity and caliber of resources to be assigned to each activity before estimating the required resources. One useful tool employed for resource allocation and leveling of available resources is the resource histogram. It helps to allocate resources correctly and depicts the resource forecast within the Gantt Chart [10] [16] [17].

Moving to the civil aviation world, the invention of Unmanned Aerial Vehicles (UAVs) has now become a trend and a huge project to undertake for contemporary project managers. UAVs deliver vast opportunities in the aviation market and the world today in terms of the provision of cost-effective solutions for several uses that demand various capabilities for certain tasks involved. This is escalating the demand for UAVs, especially for civil applications and in the business world. As reported by Forecast International, a thousand UAVs of several types are manufactured every year with outcomes increasing to 1100 units
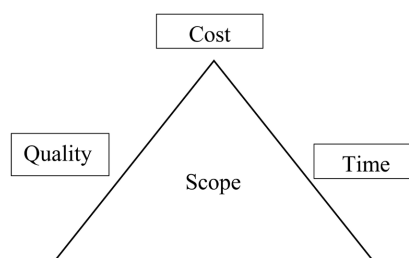
Figure 1. The iron triangle.

every two subsequent years. Production is predicted to reach an average of about 960 UAVs annually with a remaining nine-year prediction span of 2014-2023. The Defense Web and Forecast International mentioned that while the manufacture of UAVs is anticipated to remain comparatively stable over the next 10 years, the value of production progressively rose to about $942 million in 2014 and will reach a sum of about $2.3 billion in two years' time [18]. The application of UAVs now varies from place to place depending on the purpose for which it was built however, its application, development and management are quite complex. As a result, aerospace industries usually face the challenge of designing and developing robust projects in terms of the utilization and optimization of resources, time management, and improvement of project management practices [19]. This could be due to limited testing areas (simulation environment) for UAVs or a lack of project management framework. For this purpose, more stable and robust project management methods with practical applications and simulation approaches must be employed in the design and development process of UAVs. Although UAVs have numerous advantages like an absence of crew on board, top-notch imaging and live streaming, and control of environmental pollution among others, there is still room for optimization. An improvement of the geometry may have been a great way to improve performance characteristics of UAVs. This is where the concept of a Blended Wing Unmanned Aerial Vehicle (BWB UAV) comes in [20] [21]. Generally, this BWB UAV consists of a middle section which is the central body or the fuselage, and an outer section. The part in-between is the blending area where the center body freely blends into the wing geometry as shown in Figure 2. The BWB UAV comes with numerous aerodynamic, economic, and global advantages however being a new invention in the market today is somewhat an outstanding challenge because it is still gaining trust and expected to enter into service not earlier than the 2030s [22] Certainly, the UAVs have emerged as vital instruments for conducting many tasks both for personal and public benefits. However, building applications, workflows, and sequence of tasks that can robustly help to plan, design, build and operate UAVs and utilize them to meet certain demands still require the deployment of useful techniques. These demands are usually due to the absence of efficient technologies, resources, and management practices that could have been employed to develop the UAVs. Another cause for these challenges could be due to limited research work on the practical application of
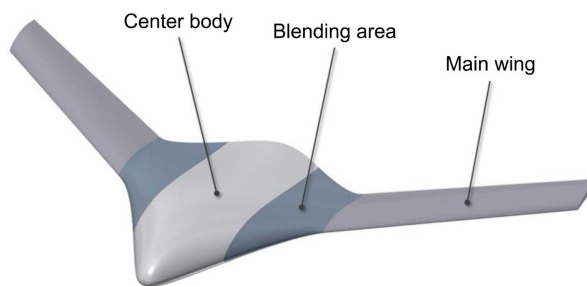
Figure 2. A typical UAV Blended Wing Body [20].

project management techniques like the Gantt Chart, Critical Path Method (CPM), Plan Evaluation and Review Technique (PERT), Resource Smoothing, Work Breakdown Structure (WBS), among others on UAV project designs. Practical applications help to build ideas for more applications, and this is where project management comes in.

After several comprehensive literature studies on the implementation of these project management techniques, it was observed to the best of research knowledge that very little research work has been done concerning the very practical application of these two techniques typically for the design and development of UAV projects. Few exceptional works, however, like that of Bayliss and colleagues [23] who drew out a project timeline, and a work breakdown of task lists to design a UAV project. They proposed three design alternatives that deserve to be recognized. The goal of the work was to create an autonomous vehicle that detects basic shapes and transmits and receives information or signals to a ground station. The UAV design developed in that work however had a separate wing attached to the fuselage of the plane by a pylon. Sharon and colleagues [24] also presented a precise and simplified UAV case to support the assumption that the project and product are two interconnecting facets of systems engineering management. The authors applied the CPM to a typical UAV case study with twenty-three (23) tasks clearly showing their slacks and relationships. This was useful for the assessment of productivity; however, the work did not involve the design model of a typical UAV hence much work is needed. It was also observed in the paper that resource smoothing and leveling, a project resource management technique was not discussed. The work though excellent presented a simplified case of the model design of the UAV itself. The purpose of this study, therefore, is to build upon the few exceptional works mentioned above by designing a Blended Wing UAV model using Solid Works to investigate how project time and resource management could be applied this model and its usefulness to the aviation project management world in terms of cost, time, and quality. The work may be used as a reference for future simulation environments and tests for aviation project management tasks. The outline of the paper is as follows: 1) Introduction, 2) Relative theory of methodology, 3) Application of methodology and results, 4) The blended wing body unmanned aerial vehicle (BWB UAV) solid works technical design, 5) Discussion, 6) Conclusion.

2. Relative Theory of Methodology

2.1. Critical Path Method (CPM)

The CPM was developed in the late 1950s by James E. Kelly Jr. of Remington Rand Univas and Morgan R. Walker of DuPont and was employed as a management tool to improve the planning and control of their turnaround time [11]. CPM was originally set up to tackle the time-cost trade-off dilemma often presented to project managers while a complex relationship between project time-to-complete and cost-to-complete. The critical path method is recognized as one of the most useful project management techniques within the time management knowledge area that aids the project manager to determine the start and finish dates for all activities and the sequence of activities that form the critical path (slack = 0). The challenge for the project manager hence is to develop a framework known as the network diagram and perform CPM calculations to generate a reasonable timeline for the project [13]. After this understanding is gained, it is easy to prioritize the allocation of resources across a project plan. This requires much focus and accuracy as an error in calculation may lead to an error in float or no critical path at all. The critical path method will be applied in detail in section 3 for the (BWB UAV) design and development project. Calculation or mathematical application of the critical path is quite complex but feasible when done systematically and can be found in [11]. The steps include:

Step 1: Draw the network diagram.

Step 2: Insert activity times, calendar and project start time.

Step 3: Calculate forward pass and backward pass to determine activity start and finish dates.

Step 4: Calculate the activity float and identify the critical path.

Mathematically for forward pass calculations we have,

$$\text{Early Start}\,(\text{ES})\ \text{of succeding task} = \text{Early Finish}\,(\text{EF})\ \text{preceeding task} + 1 \quad (1)$$

$$
\begin{aligned}
&\text{Early Finish}\,(\text{EF})\ \text{of succeeding task} \\
&= \text{Early Start}\,(\text{ES})\ \text{of succeding task} + \text{Duration}\,(\text{DUR}) - 1
\end{aligned} \quad (2)
$$

Mathematically for backward pass we have,

$$\text{Late Finish}\,(\text{LF})\ \text{of last task} = \text{Early Finish}\,(\text{EF})\ \text{of last task} \quad (3)$$

$$\text{Late Finish}\,(\text{LF})\ \text{of preceeding task} = \text{Late Start}\,(\text{LS})\ \text{of suceeding task} - 1 \quad (4)$$

$$
\begin{aligned}
&\text{Late Start}\,(\text{LS})\ \text{of preceeding task} \\
&= \text{Late Finish}\,(\text{LF})\ \text{of preceeding task} - \text{Duration}\,(\text{DUR}) + 1
\end{aligned} \quad (5)
$$

$$\text{Float}\,(\text{Slack}) = \text{Late Finish}\,(\text{LF}) - \text{Early Finish}\,(\text{EF}) \quad (6)$$

2.2. The Gantt Chart

The Gantt Chart is an old-time unique technique in the project time management body of knowledge that enables the project manager to present the project schedule in an understandable bar-chart format. It helps to envision the project timeline by connecting its early start (ES) and early finish dates (EF). Further-

more, Gantt Chart is a common technique for depicting the phases and activities of a work breakdown structure and to ease the understanding of the general audience [25]. Gantt Chart was first created by Henry Gantt between 1861-1919 during the first world war which eventually became well known in the West around the years 1910-1915s [26]. It was the heart of scientific management usually employed for the monitoring of past performances of human and material resources. Today, it is recognized as the most simplified and robust tool for connecting project activities and durations [27]. One challenge with the use of Gantt Chart however is that although it can be easily understood by anyone when dealing with small projects, it is quite hectic for projects with more than 30 - 40 sequence of activities. This may be unsuitable for most desktop displays and even unbearable for manual users (drawing using tables and sheets).

2.3. Resource Leveling and Smoothing

The main purpose of project resource management is to minimize the engineering construction under the assumption of ensuring that the project quality and construction period is not compromised [28] [29]. In drawing the resource histogram, a Gantt Chart needs to be drawn and then followed by a resource histogram. The resource histogram helps to allocate resources correctly. Project resource management targets the dynamic management of resources correlated with scientific and reasonable resources to obtain efficient and safe production. The concept of resource overload, time-limited and resource-limited smoothing fall under a concept known as *resource optimization* [30]. Resource optimization is a resource related technique that helps to get rid of problems that come with major amendments of in resource usage. With resource optimization involved, all schedules, processes and methods are expected to match the available resources. It is a schedule network analysis that is extended to a schedule that is already analyzed with Critical Path Method. Resource Optimization techniques are divided into:

- Resource leveling: (Resource-limited scheduling);
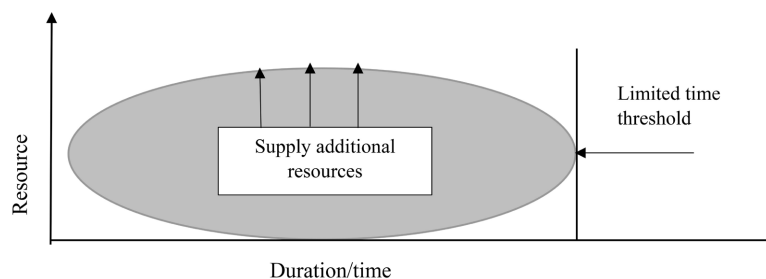- Resource smoothing: (Time-limited scheduling).

Figure 3 and Figure 4 give an illustration of resource limited and time-limited scheduling. Resource limited scheduling simply implies a situation where resource cannot be exceeded that means that in the event of resource overloads, certain planned activities would have to be delayed to equally distribute resources across the available time scheduled. Likewise for time limited scheduling, the finish date of the project should not be exceeded.

3. Application of Methodology and Results

This section applies CPM, Gantt Chart, and Resource Leveling and Smoothing Technique (RLST) to schedule and develop the novel blended wing unmanned aerial vehicle (BWB UAV) model. Firstly, the project task list table is drawn and then followed by a project graph (CPM analysis and Gantt Chart). Thirdly, the RLST is applied. Finally, the BWB UAV is technically designed and analysed
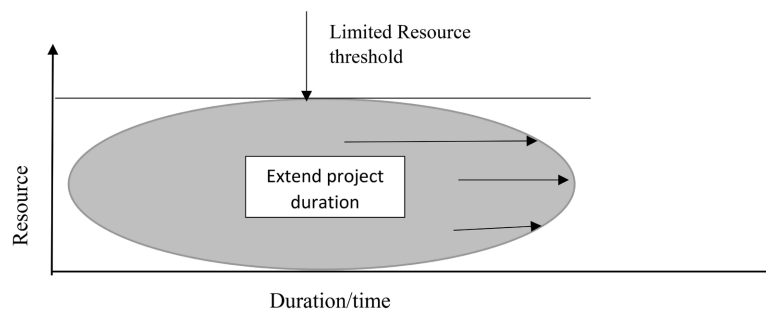
Figure 3. Resource limited scheduling. The arrows towards the right shows that project duration can be extended. Horizontal line shows the limit of the resources available.


Figure 4. Time limited scheduling. Arrows facing upwards signifies that, additional resources can be applied. Vertical line on the right marks the limit of time (end date cannot be extended).

with Solid Works Software. For the sake of the scope of this paper, few details about the technical design will be discussed.

3.1. Project Tasks Table Formulation

The tasks to be performed in building the BWB UAV design project are listed in Table 1 where "Task No" in the first column, represents *task number.* The immediate predecessors in the third column help to identify which tasks should be performed first and last. The application of a network flow diagram in CPM analysis will help to better visualize this. The values of the parameters in the table are randomly given. However, a correlation sequence line is drawn using the *xcorr* function in MATLAB® software to test their applicability. This is shown in Figure 5. The correlation sequence line in this figure is simply a measure of the extent to which the tasks and the durations are co-dependent. Details about correlation analysis can be found in [31] [32]. With the correlation sequence line, the heaviness of the tasks can be observed. The vertical line (slanted right) rising from task 1 (preliminary paper sketch) to task 2 (wing and empennage design investigation & study) shows the increase in duration from 1 to 2 days. This implies that task 2 demands more attention hence a positive rise (positive correlation) is observed. Same analysis can be done for the negative correlation from task 5 (Avionics suite investigation & study) to task 6 (Rotor investigation and study) and other decreasing lines for the remaining tasks in Figure 5. The constant lines observed between task 2 and 4 for example, depicts a moderate work duty as the duration for each tasks remains the same. A similar analysis can also

be done for other constant lines in the figure. With this, the project manager can appropriately allocate and verify the tasks to ensure that every task is given the due attention and effort.
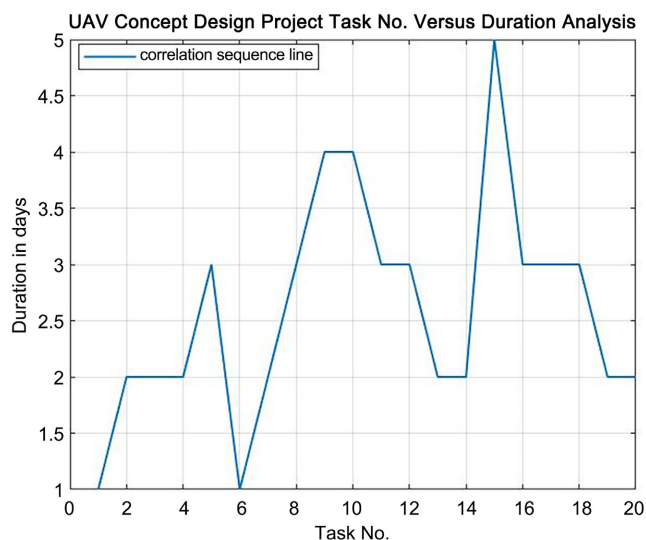
Figure 5. A correlation sequence between the tasks and the duration needed to complete the project. The rising of the curve signifies a positive correlation. Horizontal lines imply a constant (moderate) correlation and a sharp decrease in line to the right means a negative correlation.

Table 1. BWB UAV project task list and activity table.

Task No.	Description	Immediate Predecessors	Duration/[days]
1	Preliminary paper sketch	1	1
2	Wing and empennage design investigation & study	1	2
3	Fuselage design investigation & study	8	2
4	BWB UAV assembly and payload investigation & study	1	2
5	Avionics suite investigation & study	1	3
6	Rotor investigation and study	2	1
7	Engine design investigation & study	4	2
8	Conceptual design alternatives	5	3
9	Solid Works Modeling and design	1	4
10	Structural Analysis	7	4
11	Verification and Testing	10	3
12	Solid Works Flow Simulation	11	3
13	Special Component Research and Ordering	9	2
14	Assembly of parts	3	2
15	Flight Testing	12	5
16	Cost Analysis	17	3
17	Report presentation and seminars	13	3
18	Engineering drawings	11	3
19	Distribution of drawings	16	2
20	Making of posters	14, 15, 18, 19	2

Task 1 through task 20 must be sequentially performed within the specified durations randomly allocated in Table 1 to achieve good results. It is recommended that tasks 1-8 and tasks 13-20 be undertaken in real-life applications as they may involve thorough discussion among project managers and software model designers. Hence, only task 9 to task 12 is performed in detail in this paper(See section 4).

3.2. CPM Analysis Calculations

The calculations are done from the data provided in Table 1 with an ES value randomly selected as 1 for task No. 1 for simplicity as shown in Table 2. According to [11], there are two types of calculations, the forward pass calculations, and backward pass calculations. The forward pass helps with calculating the early start (ES) dates and early finish dates (EF) for all the activities while the backward pass determines the activity's late start (LS) and late finish (LF) dates. For example, the forward and backward pass calculation for task No. 1 and No. 2 can be calculated as:

From Table 2, given that ES = 1 for task No. 1; Duration (DUR) = 1, the forward pass calculation by referring to Equation (2) is given by:

$$\text{Early Finish}\left(\text{EF}\right) \text{ of task No.1} = 1 + 1 - 1 = 1 \tag{7}$$

Table 2. BWB UAV project task activity tabular report.

Task No.	Duration [DUR]	EarlyStart [ES]	EarlyFinish [EF]	LateStart [LS]	LateFinish [LF]	Float [F]
1	1	1	1	1	1	0
2	2	2	3	3	4	1
3	2	8	9	12	13	4
4	2	2	3	2	3	0
5	3	2	4	6	8	4
6	1	4	4	5	5	1
7	2	4	5	4	5	0
8	3	5	7	9	11	4
9	4	2	5	4	7	2
10	4	6	9	6	9	0
11	3	10	12	10	12	0
12	3	6	8	8	10	2
13	2	5	6	6	7	1
14	2	10	11	14	15	4
15	5	9	13	11	15	2
16	3	10	12	11	13	1
17	3	7	9	8	10	1
18	3	13	15	13	15	0
19	2	13	14	14	15	1
20	2	16	17	16	17	0

Now, pass EF of task No. 1 = 1 forward to task No. 2 that is, the early start of task No. 2 referring to Equation (1) gives:

$$\text{Early Start}(\text{ES}) \text{ of task No.2} = \text{Early Finish}(\text{EF}) \text{ of task No.1} + 1 = 1 + 1 = 2 \quad (8)$$

It should be noted that for forward pass, the greatest value of EF should be passed to the next task if there are more than one EFs. For task No. 1 there is only one EF hence it is directly passed to task No. 2.

$$\text{Early Finish}(\text{EF}) \text{ of task No.2} = 2 + 2 - 1 = 3 \quad (9)$$

The calculation continues similarly throughout the analysis until the EF of the last task which is task No. 20 is calculated. For this task, we have four (4) different EFs from task No. 15, 14, 18 and 19 respectively (See Figure 6) to be passed to task No. 20. For this case we need to select the greatest EF which is coming from task No. 18.

Now, pass EF of task No. 18 = 15, forward to task No. 20 that is, the early start of task No. 20 will then be:

$$\begin{aligned} &\text{Early Start}(\text{ES}) \text{ of task No.20} \\ &= \text{Early Finish}(\text{EF}) \text{ of task No.18} + 1 = 15 + 1 = 16 \end{aligned} \quad (10)$$

$$\begin{aligned} &\text{Early Finish}(\text{EF}) \text{ of task No.20} \\ &= \text{Early Start}(\text{ES}) \text{ of task No.20} + \text{Duration}(\text{DUR}) - 1 = 16 + 2 - 1 = 17 \end{aligned} \quad (11)$$

For backward pass calculation, we start from the last task and move backwards. The early finish is always equal to the late finish for the last task in backward pass calculation.

$$\begin{aligned} &\text{Late Finish}(\text{LF}) \text{ of task No.20} \\ &= \text{Early Finish}(\text{EF}) \text{ of last task}(\text{task No.20}) = 17 \end{aligned} \quad (12)$$

$$\begin{aligned} &\text{Late Start}(\text{LS}) \text{ of task No.20} \\ &= \text{Late Finish}(\text{LF}) \text{ of task No.20} - \text{Duration}(\text{DUR}) + 1 = 17 - 2 + 1 = 16 \end{aligned} \quad (13)$$

The float calculation is given by:

$$\begin{aligned} &\text{Float}(\text{Slack}) \text{ of task No.20} \\ &= \text{Late Start}(\text{ES}) - \text{Early Start}(\text{ES}) \\ &= \text{Late Finish}(\text{ES}) - \text{Early Finish}(\text{ES}) = 0 \end{aligned} \quad (14)$$

The slack for task No. 20 is zero meaning that it lies on the critical path. Similar analysis and calculations are done for the rests of the tasks until the all the elements in the key are calculated. The path that has all zeros as floats will be identified as the critical path. One way to identify whether the calculation is accurate is when the first and last activity have a float of zero. After calculation, the values for the early start, finish, late start, finish, and float of the activities are tabulated in the project task activity tabular report. These are shown in Table 2. Figure 6 shows the network diagram drawn after critical path analysis. The "key" on the right side of the figure helps to identify what the numbers in each box imply. The red horizontal line signifies the path where the float is zero and this is known as the critical path.
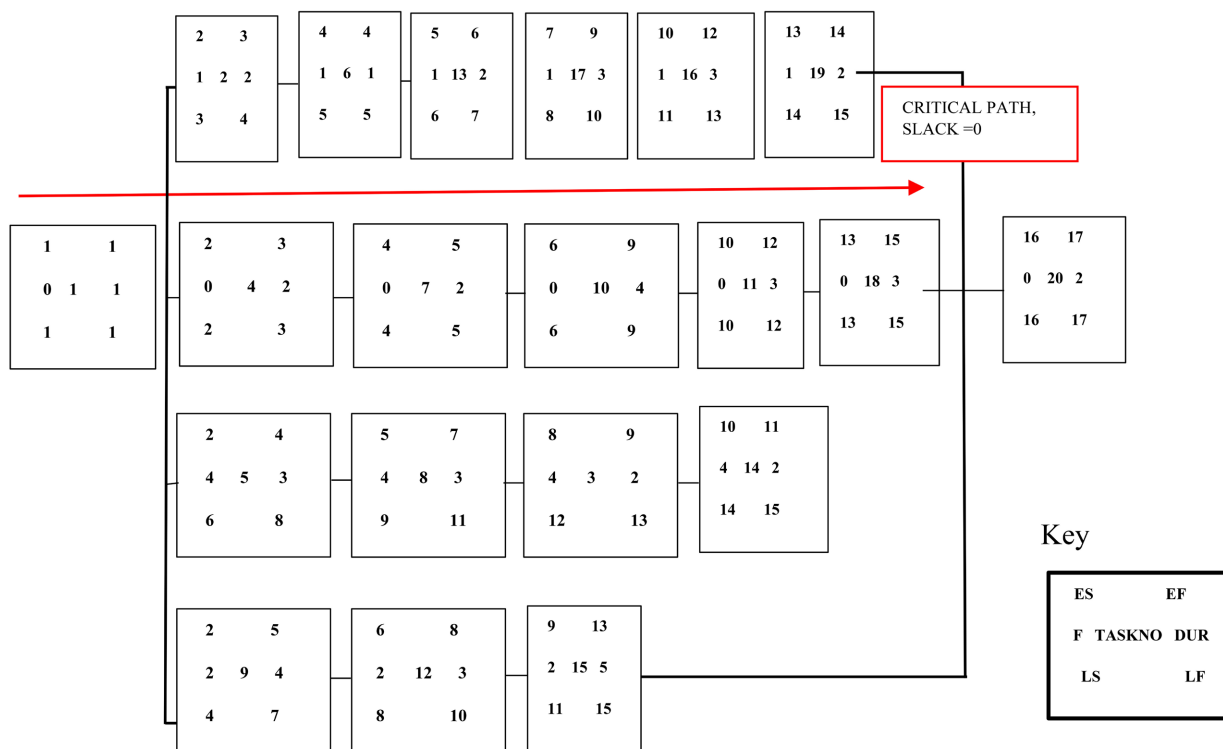
Figure 6. Network diagram of the critical path analysis showing the early start, early finish, late start, late finish, floats, duration, and task number at the center.

3.3. The Gantt Chart Table Formulation

Gantt chart helps to identify your slack times and which activities need to be sped up or slowed down. It helps to extensively overview the early start and early finish of the project and what should be included in the replanning phase of the project schedule. It is usually drawn to connect the Early Start (ES) and Early Finish (EF) of the project dates. Table 3 below is a Gantt Chart drawn for the BWB UAV project using the results obtained from calculation in section 3.2.

From Table 3, the Gantt Chart, the early start and early finish dates relate to the solid green lines. The red dotted lines represent the floats or slack times that is the delay period of the task. Though there seems to be more delays than expected the tasks on the critical path (task 1, 4, 7, 10, 11, 18 and 20) are untouched making the project feasible, hence they can start on time and finish on time. The delays in the heavy tasks like task No.9 (Solid Works Modeling and design) and No.12 (Solid Works Flow Simulation) may be useful for revision, inspection and optimization hence would not cause much trouble to the project.

3.4. Resource Leveling and Smoothing Analysis

This section will briefly apply resource leveling and smoothing to the BWB UAV project based on the allocation of resources provided in the resource in Table 4 and a new Gantt chart from the previous one in section 3.3 will be drawn. The resource histogram will be drawn for the tasks on the critical path only using the *bar* function in MATLAB®. From the Gantt chart in Table 5, there are no re-

source overloads hence it presents the simplified form of the resource histogram to be drawn. The total number of resources required to perform the tasks on the critical path is 5 as arbitrarily allocated. The project manager can in the same manner decide the suitable number of resources needed for resource allocation. There are no resource overloads hence there is no need to perform resource smoothing or leveling. The resource histogram is shown below in Figure 7.

Table 3. Gantt chart of the BWB UAV project.

Task No.	Mon 1	Tue 2	Wed 3	Thu 4	Fri 5	Sat 6	Sun 7	Mon 8	Tue 9	Wed 10	Thu 11	Fri 12	Sat 13	Sun 14	Mon 15	Tues 16	Wed 17
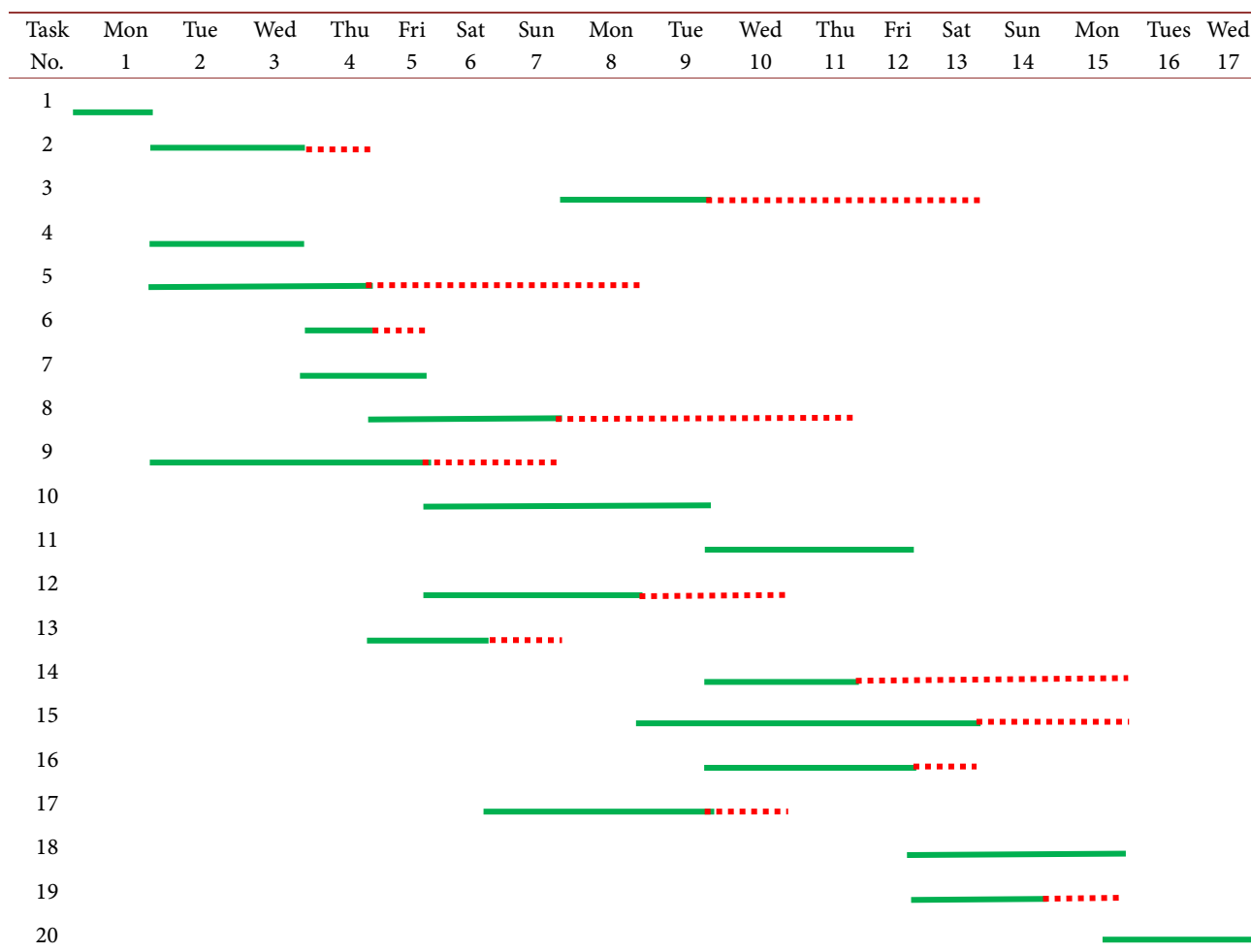
Table 4. BWB UAV Resource table of critical tasks.

Task No.	Description	Start Date (ES)	Finish Date (EF)	Resources per day
1	Preliminary paper sketch	1	1	5
4	BWB UAV assembly and payload investigation & study	2	3	2, 1
7	Engine design investigation & study	4	5	2, 2
10	Structural Analysis	6	9	3, 2, 1, 1
11	Verification and Testing	10	12	1, 2, 1
18	Engineering drawings	13	15	2, 1, 2,
20	Making of posters	16	17	5, 4

Table 5. Gantt chart of critical tasks for resource histogram.

Task No.	Mon 1	Tue 2	Wed 3	Thu 4	Fri 5	Sat 6	Sun 7	Mon 8	Tue 9	Wed 10	Thu 11	Fri 12	Sat 13	Sun 14	Mon 15	Tues 16	Wed 17
1	5																
4		2	1														
7				2	2												
10						3	2	1	1								
11										1	2	1					
18													2	1	2		
20																5	4
Sum	5	2	1	2	2	3	2	1	1	1	2	1	2	1	2	5	4
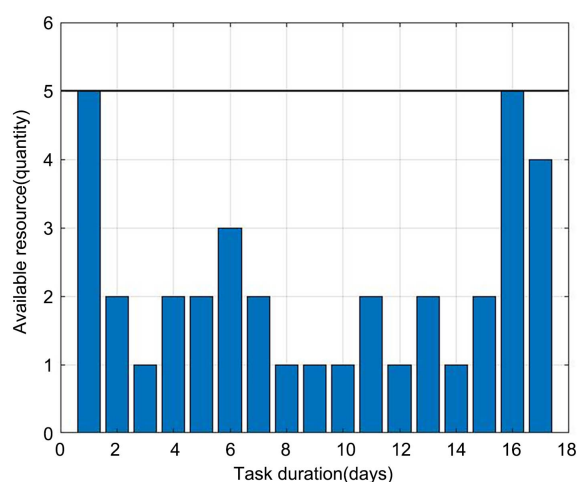
Figure 7. A resource histogram plot of the critical task duration against the available resources. The highest bar (limit in black horizontal line) represents the maximum resource available hence there is no resource overload observed.

4. The Blended Wing Body Unmanned Aerial Vehicle (BWB UAV) Solidworks Technical Design

This section briefly introduces the complete model design of the BWB UAV designed by Anda using SolidWorks Software [33]. Task 9, 10, 11 and 12 from Table 1 will be executed here. The complete model shows six views: the top, front, rear, left, right and bottom view. This prototype design is just a simplified by-product of the application of project time and resource management. This is included as a framework by which future aviation project managers can refer to for planning, designing and building their aerial design projects. More information about a detailed blended BWB UAV design can be found in [34].

4.1. Design Process

In the design process, the project task number 9 (Solid Works Modeling and Design) is executed here. As indicated in Table 1, the task should take the average

software user about 4 days to finish a very perfect model. However this is based on the experience of the designer. An expert could finish in one day. After the five steps are complete, the model is put into six views as shown in Figure 8. The steps to designing the BWB UAV in solidworks software are listed below:

Step 1: Sketch the NACA 2412 airfoil with the airfoil data provided by the aerodynamics group [35].

Step 2: Follow the steps shown in the design tutorial introduced by Anda to design the right wing of the aerial vehicle.

Step 3: After the right wing is done, adjust the airfoil shape sketched in step1 by increasing the thickness of the leading edge. Exit the sketch bench and move to step 4.

Step 4: Follow the steps to design the empennage and the engine (with nacelle) on the right wing. Mark out the lines for the control surfaces (flaps, slats, ailerons, spoilers) of the wing.

Step 5: After the right wing is done, use the mirror tab in solidworks to duplicate it on the left side to finish the design.

(a) Top View   **(b) Bottom View**

(c) Rear View   **(d) Front View**

(e) Right View   **(f) Left View**
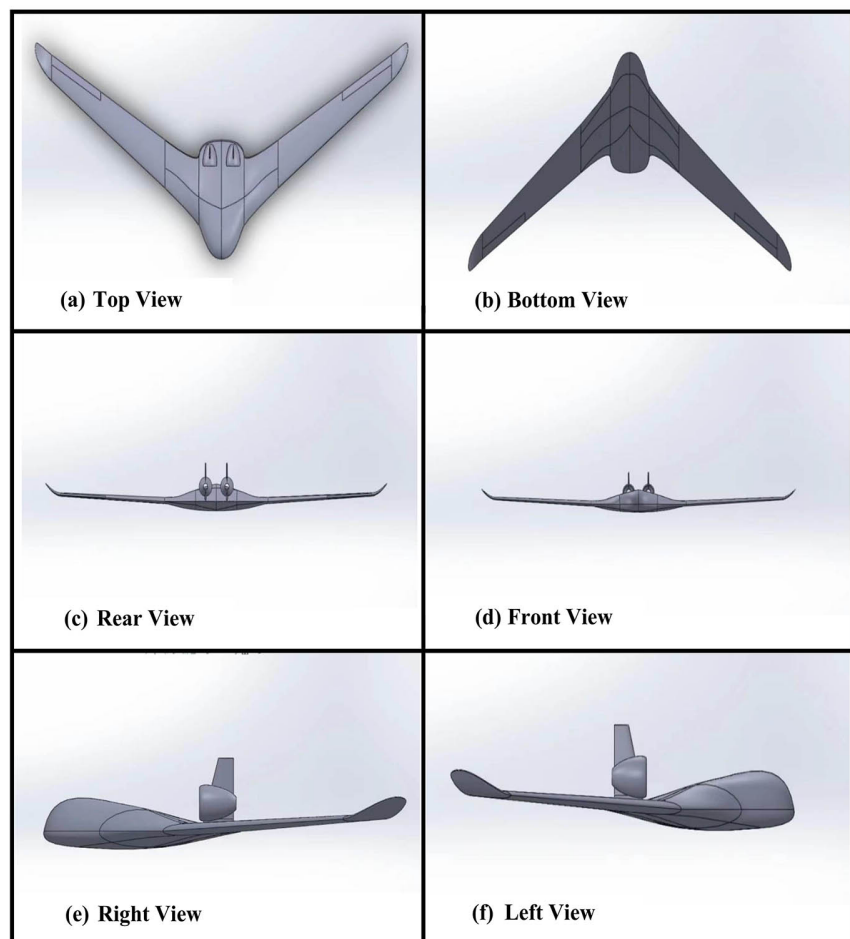
Figure 8. The six views of the blended wing body blended wing body unmanned aerial vehicle (BWB UAV) Views: (a) Top View, (b) Bottom View, (c) Rear View, (d) Front View, (e) Right View and (f) Left View.

4.2. Design Analysis and Results

4.2.1. Design Analysis Steps

This section executes task 12 (Solidworks flow simulation) as listed in Table 1. The model is simulated aerodynamically using solidworks software. It is verified and tested by animating the air flow movement on the aerial vehicle to identify the areas where pressure is more concentrated. Details of the analysis steps and design guide can be found in [36] [37]. The steps outlined in this study are:

Step 1: The flow simulation tab is selected on SolidWorks software and the unit system together with the analysis type, the fluid type (air is selected for this case), internal and ambient conditions and the wall conditions as shown in Figure 9.
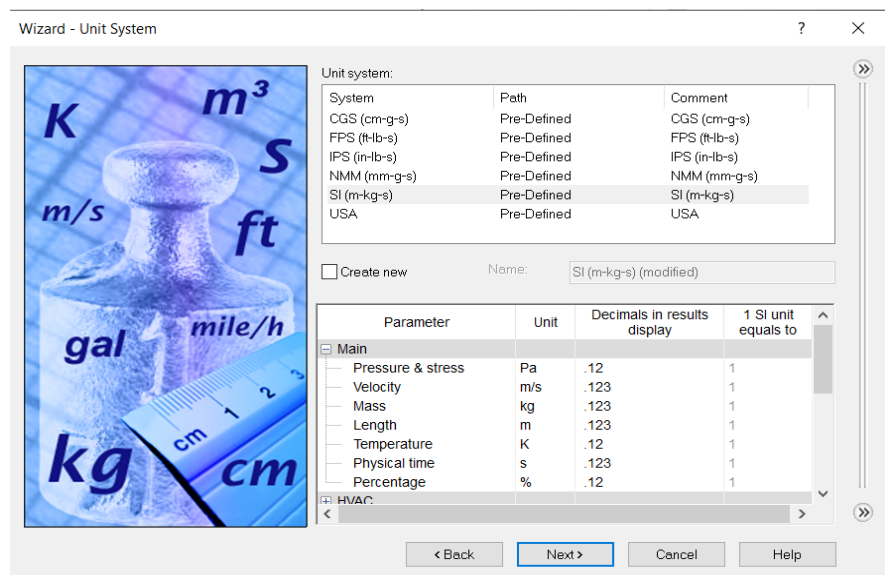
(a)
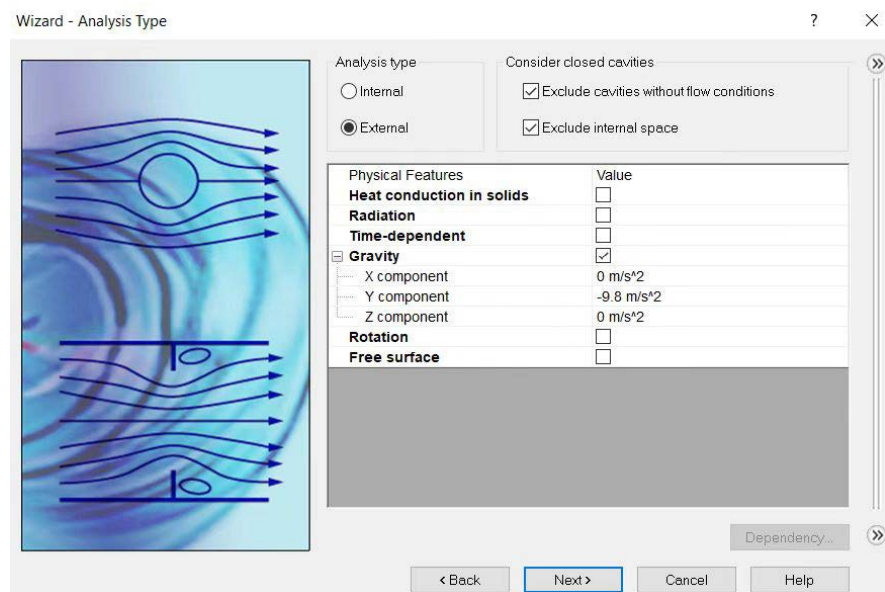
(b)
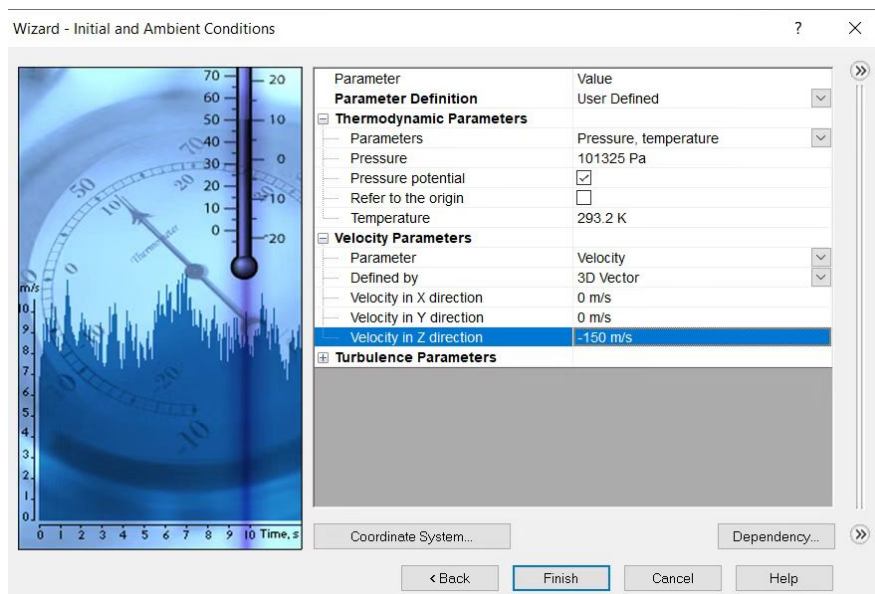
(c)
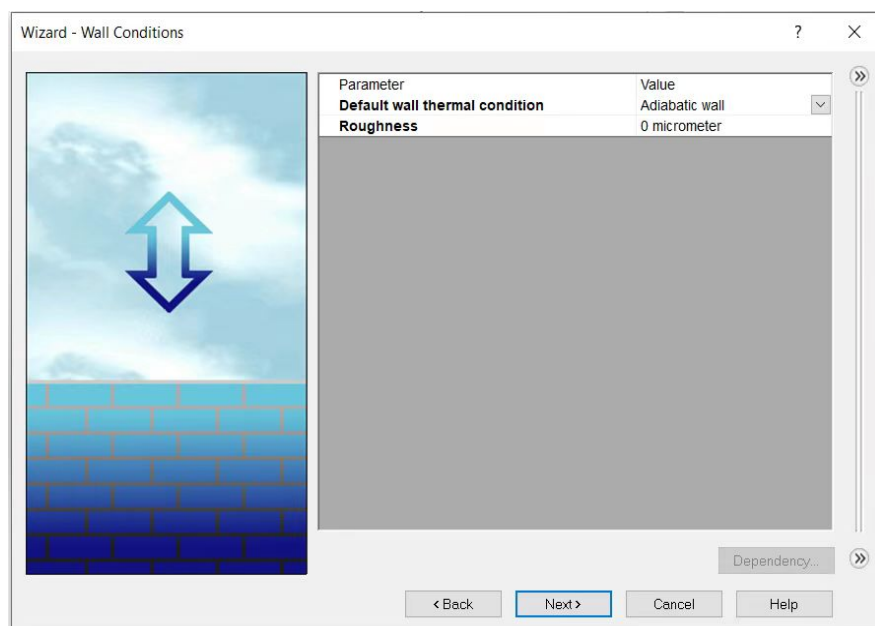
(d)

Figure 9. Selection of flow simulation parameters. (a) Select the unit system: SI (m-kg-s), (b) Choose the analysis type: External and consider all closed cavity options, (c) Inlet and ambient conditions: Pressure is 101,325 Pa and Velocity in Z direction is −150 m/s. Chosen according to coordinate direction and (d) Select default wall conditions as shown.

Step 2: The model is then automatically set into a computational domain (in form of a rectangular box) and the geometry of the model is set.

Step 3: Suitable parameters from the input data option on the left pane of the working area are selected. They are: total pressure, temperature, velocity (in x, y, z directions), force in the direction (lift-force), and friction force in Z direction are selected.

Step 4: The default mesh type is applied with no changes.

Step 5: The study is then run. A solver page will display displaying the calculation of the respective parameters and the results are displayed. **Figure 10** just shows the results for pressure and however, many other parameters like velocity and temperature can be studied.

4.2.2. Design Analysis Results

Figure 11 below shows the results from the solver in SolidWorks and the total number of simulation iteration was 212 which the displays pressure distribution on the left wing. The results may differ in real applications and more accurate results can be obtained for real life applications. The red circled area in the zoomed figure shows the area on the wing where the pressure is more concentrated. This is appreciable since a lot of pressure is generally generated on a wing to produce the lift in an aerial vehicle hence agreeing well with available literature. Details about aerodynamic analysis of an aerial wing can be found in [38]. That paper also used the NACA 2412 airfoil hence the study would be useful for future work.

(a)

(b)

Figure 10. Setting of computational domain parameters. (a) Step 2 and (b) Step 3.
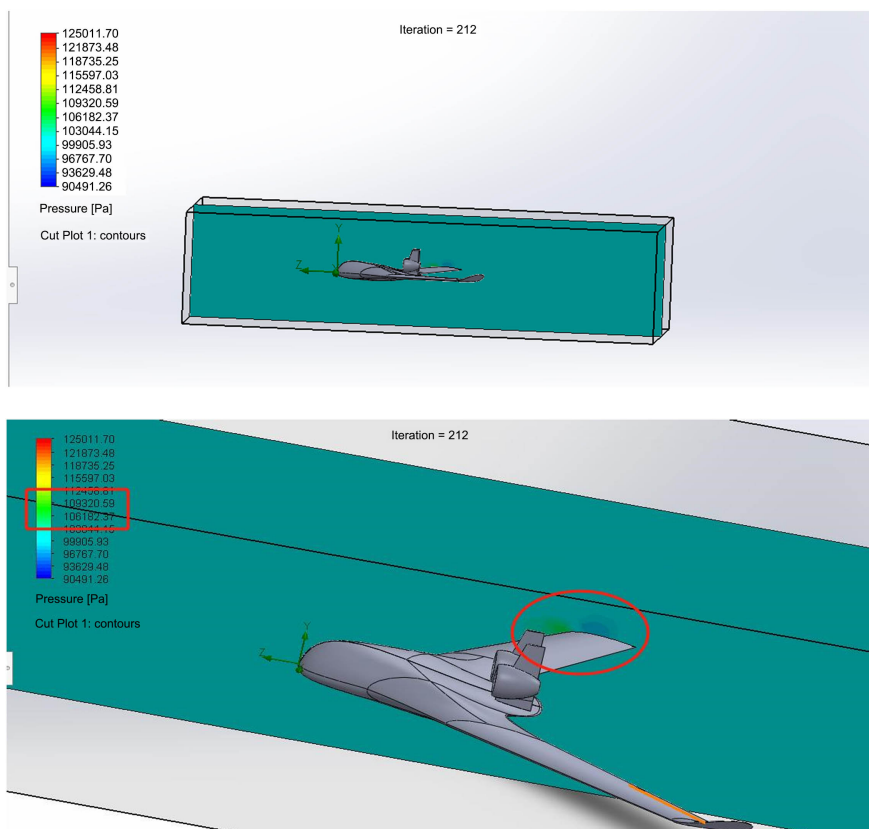
Figure 11. Pressure distribution on BWB UAV wing. The pressure is estimated to range between 900.0 - 110.0 kPa. A pressure difference is created at the bottom and top surface of the wing to produce lift.

5. Discussion

Project management is a significant concept that cannot be overlooked when building projects like the Blended Wing Body Unmanned Aerial Vehicle (BWB UAV). The BWB UAV is an advanced geometry of the UAV that comes with several advantages and a few demerits as it is still new to the aviation world. Project management embodies several knowledge areas of which two are studied in this paper that is time and resource. Project time management deals with a clear understanding of the type, nature, magnitude, and intensities of the activities involved in a project and then schedules these activities to fulfill several deadlines and goals. The main purpose of project resource management on the other hand is to reduce the engineering construction under the assumption of ensuring that the project quality and construction period is not compromised. It is therefore essential to assess the quantity and caliber of resources to be assigned to each activity before estimating the required resources. One useful tool used for resource allocation and leveling of available required resources is the resource histogram. It helps to allocate resources correctly and depicts the resource forecast within the Gantt Chart.

Regarding the practical application of the two project management techniques mentioned above, it was observed to the best of research knowledge that very lit-

tle research work has been done when it comes to designing and building UAV projects. However, there were few exceptional works found like the research works in [23] [24]. Based on this conclusion, the paper was aimed at building upon the few exceptional works by investigating how project time and resource management could be applied to any UAV project using a typical BWB UAV as a model. Another purpose was to study its usefulness to the aviation project management world in terms of cost, time, and quality. The main work was completed in section 2 which deals with the methodology and results. In that section, the CPM, Gantt Chart and Resource Leveling and Smoothing Technique (RLST) to schedule and develop the novel blended wing unmanned aerial vehicle (BWB UAV) model were employed. For the project graph, 20 tasks were developed and visualized using the *xcorr* function in MATLAB* and it was observed that positive, negative, and constant correlations help the project manager appropriately allocate time and energy into making sure that every task is given the due attention. The network diagram is drawn after the CPM calculations and the critical path is observed. Two heavy tasks (task No. 9 and task No. 12) from Table 1 and the Gantt Chart Table 2 did not fall in the critical path that means that there would be some delays in the project. However, it was argued that this may be useful for revision, inspection and optimization hence would not cause much trouble to the project. The resource histogram for the critical tasks was drawn and there were no overloads hence a simple analysis was made concluding that the maximum number of resources needed are 5 in total. Finally, the BWB UAV which was technically designed by Anda with Solid Works Software was introduced. Design process and analysis steps are outlined, and the results are displayed with regards to the pressure distribution on the wing. It was observed that, the pressure is estimated to range between 900.0 - 110.0 kPa. A pressure difference is created at the bottom and top surface of the wing and this will help produce lift [39].

Techniques applied in this paper agree well with previous literature and the project time and quality factor could be achieved. The cost effectiveness however was not examined in this work hence should be considered for future work. The innovation here is the step-by-step approach to planning the project, applying the two project management techniques to designing and developing a typical BWB UAV model and then actualizing it by presenting a complete design. It should be noted however that more work can be done concerning the application of other techniques in the project management body of knowledge (PMBOK) like cost analysis, scope, risk, quality among others. Besides the CPM analysis, PERT analysis could also be employed to study its usefulness to the project. Moreover, a resource histogram could be drawn with the tasks that have non-zero floats so that resource leveling, and smoothing can be examined.

6. Conclusion

The role of project management in UAVs is simply to provide an organized

framework for designing and developing robust projects in terms of the utilization and optimization of resources, time management, and improvement of project management practices. After several literature studies on this concept, it was observed to the best of research knowledge that little research work is available concerning the very practical application of time and resource management on an aerial vehicle. This paper hence was aimed at investigating how these two techniques could be applied to a typical BWB UAV model. After applying the three tools (Critical Path Method, Gantt Chart, and Resource Leveling and Smoothing) it was observed that the approach agreed well with previous literature and the project time and quality factor could be achieved. Finally, the design process and analysis steps are outlined, and the results are displayed with regards to the pressure distribution on the wing. It was observed that the pressure is estimated to range between 900.0 - 110.0 kPa. A pressure difference is created at the bottom and top surface of the wing and this will help produce lift. These techniques therefore can be applied to any UAV project to build a robust framework for aviation project management tasks in terms of cost, time, and quality. The cost effectiveness however was not examined in this work hence should be considered for future work. It should be noted however that more work can be done concerning the application of other techniques in the project management body of knowledge (PMBOK) like cost analysis, scope, risk, quality among others. This work may be used as a reference for future simulation environments and tests for building optimized aviation project management tasks.

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Conflicts of Interest

The author declares no conflicts of interest.

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