Utilizing project management software in project scheduling: a case study

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Abstract. Project scheduling is the application of skills, techniques, and intuition acquired through knowledge and experience to develop effective schedule models. It is integrated with various project components, such as activities, resources, and logical relationships. This is a case study of project scheduling under resource-constrained in an aircraft industry. In order to successfully run a project should focus on the project accomplishing effort related to the deadline. When the schedule execution of activities does not meet the project scheduling plan, the entire project may take longer duration to achieve the deliverables. This paper presents a rearranged schedule compared to the current set. Utilizing project management software (PMS), the project can be finished in 91 days employing 12 operators. Microsoft Project is preferred for further evaluating and managing project scheduling solution. The data is treated automated and the leveling method is applied to compress the completion project time related to the scope of the study is the limited resources allocated. Leads and lags have been identified regarding the new schedule results. The project can be accomplished quickly enough using the rearranged schedule.

Keywords: project management software, project scheduling, limited resource

1. Introduction
A project is a temporary endeavor undertaken to create a unique product, service, or result [1]. More companies are clearly seeing the benefits of managing project in order to build organizational project management expertise: lower costs, greater efficiencies, improved customer and stakeholder satisfaction, and greater competitive advantage [2]. Project management performance, which evaluates success mostly based on budget, schedule, and requirement goals, becomes an indicator to project success. Benefits evaluation of a project performance through Benefits Realisation Management method shows a positive correlation to project success on the creation strategic value for the business [3]. Project management performance and integration management are linked with 17 components [4]. Integration management is consisted of development of project charter, knowledge integration, staff integration, supply chain integration, and integration of changes. Meanwhile, the project management performance are time, cost, quality, safety, and client satisfaction. The hypothesis regarding the relation reveals the strong interaction between integration and performance.

According to [5], a project success is measured by product and project quality, timeliness, budget compliance, and degree of customer satisfaction. Project management focuses on the ability to deliver the project’s product in scope, time, cost and quality known as the traditional iron triangle. Project scheduling and planning research started after the World War 2. Project scheduling provides a detailed plan that represents how and when the project will deliver the products, services, and results [1]. This is
a tool for communication, managing stakeholders’ expectation, and as a basis for performance reporting. Resources have become a factor contributing to the time and cost uncertainty. A project planning model considering time, budget, and resource constrained activity under uncertainty is developed using Monte Carlo [6]. The Monte Carlo simulation concept is applied to calculate project reliability. Thus, a project manager can evaluate his planning in order to meet the targeted time and cost. Schedule performance needs to be increased related to managerial efficiencies. A benchmarking model of 57 large projects is proposed evolving 5 categories: input upper outlier, optimal input, deficient input, and input lower outlier [7]. These 57 projects are selected and configured as Decision Making Units (DMUs) in a DEA (Data Envelopment Analysis) procedure that is integrated with PCA (Principal Component Analysis). In automobile D&R process in China, several projects developed simultaneously have led to resource conflict problems. It is required a new resource schedule method based on task priority, Critical chain method, and evidence reasoning in order to resolve the problems. This approach studied by [8] bring several benefits to the enterprise such as eliminate multitasking problem by ensuring one task undertaken at only a unit time.

The scheduling method presents the framework for schedule model creation. The most common scheduling methods, supported by all the major scheduling tools, are the precedence diagram method (PDM), Critical Path Method (CPM), and Critical Chain which is based on CPM [1]. Within these methods, there are various techniques such as rolling wave, PERT, Monte Carlo, integrated master scheduling, and agile. CPM and PERT research started in the late 1950s. They are an activity-on-node representation, both assuming unbounded availability of resources. CPM assumes deterministics duration of activities and PERT relates to uncertainty in activity durations. The Critical Path Method (CPM) provides a way for project managers to determine which tasks are critical (zero slack time) which tasks can be delayed as well as the duration delayed.

Production scheduling tools extremely outperform compared to manual scheduling methods. Some organizations standardize on a specific software tool. Project management software (PMS) is required to support organizing, planning and managing resource in project management. They are capable of dealing with estimation, project scheduling, budget management, resource assignment, cooperation, communication, decision-making, quality management and administration system. Spreadsheet program Microsoft Excel 2016 and Microsoft Project 2016 are used for cost optimal time scheduling in construction [9]. Excel’s add-in solver was allowed to execute the cost optimization of example project time schedule applying the developed model. Afterwards, Microsoft Project software was employed for further organizing and presentation of optimized time scheduling solution. Using the CPM spreadsheet that implements the CPM/PERT algorithm in Excel can be easily operated than Ms. Project [10].

Regarding to scheduling, an aircraft industry, where this study is undertaken, has dealt with over schedule problem. It is found that the schedule execution does not meet the schedule plan. Based on data gained, the airplane of NC212i-199 version is manufactured for 155 days at station 1 started from March 01st until October 03rd, 2018. One of the main indicators affected the delaying is limited resources allocated. 6 process areas within station 1 have been assigned 2 operators each. Yet, the available resources are smaller than the resources required. Thus, this study aims to rearrange the project schedule under limited resource as well as analyse the critical tasks and critical path. Utilizing the project management software (PMS) Ms. Project, the current schedule has been evaluated and changed into a shorten schedule by leveling method. The critical tasks inform that they cannot be delayed related to accomplish the project on time. The study does not consider the cost, risks, and advanced technology indicators during the process. Our scope is reducing the completion time of the project employing 12 operators instead. The work breakdown structure (WBS) including the duration of each activity do not change either. They remain the same as the original schedule.

2. Method
This study is conducted based on a case study analyzed in an aircraft industry in Indonesia. It produces various type of aircraft to fulfill the needs of civil airlines, military operators and specific missions. Several problem occurred while producing the aircraft such as schedule planned missed due to resource-constrained. This study focuses on the NC212i-199 version scheduling particularly at station 1. It comprises 6 processes: landing gear (LG); door (DR); fuselage (FS); center wing (CW); sealant (SL);
and nose (NS). There are 100 activities spreading to 6 processes. 2 operators are assigned into each process. It means that 12 operators are employing in station 1. The research framework is shown in Figure 1 below.

**Figure 1. Research Framework**

In many cases, the number of resources that are expected to be available to accomplish an activity may determine the activity’s duration [1]. A change to a driving resource allocated to the activity will usually have an effect on the duration, yet it is not a simple linear relationship. Increasing the number of resources to twice the original number of the resources does not always reduce the time by half as it may increase extra duration due to risk. Moreover, at some point adding too many resources to the activity may increase duration due to knowledge transfer, learning curve, additional coordination, and other factors involved. Therefore, this study does not consider hiring more resource in terms of finishing the project faster, it is not required any changes to WBS either as the activity of producing the aircraft is a fixed activity based on company regulation. Both manually and auto task mode affect the overallocated tasks. This problem will be resolved by resource optimization. Resource optimization is used to adjust the start and finish date of activities to adjust planned resource use to be equal to or less than resource availability [1]. One technique applied to this study is Resource leveling. It is a technique which start and finish dates are adjusted based on resource constraints with the goal of balancing the demand for resources with the available supply. Resource leveling can be used when shared or critically required resources are available only at certain times or in limited quantities, or are overallocated. Several consideration of data processing are:

- The number of resources available are 12 operators with 2 operators of each task.
- The tasks and duration to produce the aircraft in station 1 are set by company.
- The tasks are sorted from the oldest to the newest date.
- The schedule given is processed on manually task mode, while the new schedule is on auto task mode.
- The overallocated tasks occurred will be resolved by leveling technique.
• Other factors in calculating duration as well as determining start and finish date are excluded such as cost and risk.
• Most activities dependencies are finish-to-start (FS), but 2 activities within fuselage (FS) process area are finish-to-finish (FF) dependencies.

Project constraints will affect the determination of leads and lags. It is a limiting factor that affect the execution of a project, program, portfolio or a process [1]. These includes: scope, schedule, budget, quality, resources, and risks. This study focuses on balancing the schedule and limited resources while others are excluded. These 2 different task modes have changed the completion time as well as the critical tasks and critical path. The results are analysed and evaluated based on several parameters: the completion time, critical tasks, critical path, and leads and lags.

3. Result and Discussion

3.1 The completion time

The original schedule is processed using manually schedule mode while the new schedule is rearranged in auto schedule mode. For both schedules, there are 12 operators assigned with 2 operators each. They work 8 hours a day on weekdays. The processes can be seen in the following Table 1.

| Code | Work Specification | Process Area | Resources | Activities |
|------|--------------------|--------------|-----------|------------|
| LG   | Mechanic           | Landing Gear | 2         | 2          |
| DR   | Mechanic           | Door         | 2         | 13         |
| CW   | Mechanic           | Center Wing  | 2         | 7          |
| FS   | Mechanic           | Fuselage     | 2         | 31         |
| SL   | Sealant Mechanic   | All process  | 2         | 6          |
| NS   | Mechanic           | Nose         | 2         | 41         |
| TOTAL|                    | 6 processes  | 12 resources | 100        |

Sealant (SL) activities are part of Nose (NS) and Fuselage (FS) process area. Mixing sealant is conducted once in fuselage, while other 5 mixing sealant activities are done in nose. The original schedule starts on March 01st and finishes on October 03rd, 2018. It takes 155 days to accomplish the project. The auto schedule has reduced the duration to 91 days. Ms. Project automatically calculate the start, finish, and duration values for each task based on dependencies, constraints, calendar, and other factors. In the calculating process, one constraint considered is the resources allocation for each activity. It is assumed that 2 operators set in every activity. The example of several activities is shown in Figure 2 and 3.

Based on data, installation of passenger door in door process area and installation of heating system in fuselage area are conducted on the first day of the project, March 01st, 2018. The activities are sorted by the oldest to newest date. Installation of tube for hydraulic system in nose is the last activity accomplished on October 02nd – 03rd, 2018. It is found 4 overallocated activities: installation of supports for hydraulic system in nose [NS] and installation mechanic at transformer and transmitter in nose [NS] started on June 05th; installation of pulley support in center wing [CW] and installation of tube for hydraulic system in nose [NS] are on June 20th.
Due to the leveling technique using manually task mode, installation of pulley support in center wing has changed from 1 day to 2 days. Now, the duration total turns to 156 days. Comparing to auto task mode integrated with leveling technique, the new schedule has been reduced 65 days into 91 days. We do not find any task duration changed using this mode. It is proposed to complete the project from March 01st to July 05th, 2018.

3.2 Critical path
The critical path is the sequence of activities that represents the longest path through a project, that determines the shortest possible project duration. It is normally characterized by zero total float or total slack on the critical path. The total slack contains the amount of time a task’s finish date can be delayed without delaying the project’s finish date. Ms. Project shows the critical task in red. There is only one critical task found among 100 activities in the original schedule that is installation of tubes for hydraulic system in nose process area. This task is the latest conducted within the schedule. Furthermore, around 16 activities have free slack 0. Free slack is the number of days that an activity can have before it starts delaying the next (successor) activity. For example, attachment of right ramp seat in door process area has total slack of 143 days but no free slack. It cannot be delayed otherwise the successor of installation of switch and label ramp door area will be delayed as well.

Based on the result on auto task mode for new schedule, there are 4 critical tasks with the shortest possible project duration of 9 days. 16 activities of 0 free slack have been identified. The following Table 2 and 3 shows the free slack and critical activities of both original and new schedule.
### Table 2. Free slack activities

| Original Schedule |
|-------------------|
| Task Name | Duration | Start | Finish | Pred | Successors |
| ATTACHMENT OF RIGHT RAMP SEAT [DR2] | 3 days | Mon 3/5/18 | Wed 3/7/18 | 7 |
| INST. OF SWITCH & LABEL RAMP DOOR AREA [DR2] | 1 day | Thu 3/8/18 | Thu 3/8/18 | 5 | 9 |
| INST. OF LOCKING SYSTEM ON RAMP DOOR [DR2] | 1 day | Thu 3/22/18 | Thu 3/22/18 | 14 | 18 |
| INSTL OF ANTENNA SPT ON FUSELAGE AREA [FS2] | 4 days | Mon 4/2/18 | Thu 4/5/18 | 25FF |
| INST. OF TUBES & HOSES ON MAIN LANDING [LG2] | 1 day | Wed 5/30/18 | Wed 5/30/18 | 51 |
| INSTALLATION OF CENTER WING TO FUSELAGE [CW2] | 2 days | Wed 5/30/18 | Thu 5/31/18 | 64,57,68,66,61 |
| INSTALLATION SUPPORT OF INSTRUMENT PRESS [NS2] | 1 day | Wed 5/30/18 | Wed 5/30/18 | 52 |
| INSTALLATION OF SUPPORT ASSY FOR ENGINE [CW2] | 2 days | Fri 6/1/18 | Mon 6/4/18 | 48 | 64,57 |
| INSTALLATION SUPPORT OF INSTRUMENT PANEL [NS2] | 1 day | Mon 6/4/18 | Mon 6/4/18 | 62,73,97 |
| INSTL OF JOINING PART ON CTRW WING [CW2] | 3 days | Tue 6/5/18 | Thu 6/7/18 | 48,53 | 68,66,61 |
| INST. OF SUPPORTS FOR HYDRAULIC SYSTEM [FS2] | 2 days | Tue 6/5/18 | Wed 6/6/18 | 52 | 60 |
| INSTALLATION OF TUBES FOR HYDRAULIC SYST [NS2] | 1 day | Mon 6/11/18 | Mon 6/11/18 | 58 | 63 |
| INSTALLATION OF TUBES FOR HYDRAULIC SYST [NS2] | 2 days | Thu 7/5/18 | Fri 7/6/18 | 72 | 76 |
| INSTALLATION OF TUBES FOR HYDRAULIC SYST [NS2] | 2 days | Mon 7/23/18 | Tue 7/24/18 | 76 | 80 |
| INSTALLATION OF WINDSHIELD [NS2] | 2 days | Thu 8/2/18 | Fri 8/3/18 | 78 | 84 |
| INSTALLATION OF TUBES FOR HYDRAULIC SYST [NS2] | 2 days | Tue 10/2/18 | Wed 10/3/18 | 52 |

| New Schedule |
|---------------|
| Task Name | Duration | Start | Finish | Predecessors | Successors |
| INSTL OF PASSENGER DOOR [DR2] | 2 days | Fri 3/16/18 | Mon 3/19/18 | 42 |
| INSTALLATION OF HEATING SYSTEM IN FUSELAGE [FS2] | 1 day | Thu 3/1/18 | Thu 3/1/18 | 6 |
| RECEIVING OF THE FUSELAGE [FS2] | 1 day | Fri 3/2/18 | Fri 3/2/18 | 8,13,38,39,86 |
| ATTACHMENT OF RIGHT RAMP SEAT [DR2] | 3 days | Thu 3/1/18 | Mon 3/5/18 | 7 |
| INSTL OF VENTILATION SYSTEM IN FUSELAGE [FS2] | 3 days | Wed 3/7/18 | Wed 3/7/18 | 3 | 45 |
| INST. OF SWITCH & LABEL RAMP DOOR AREA [DR2] | 1 day | Tue 3/6/18 | Tue 3/6/18 | 5 | 9 |
| INSTALLATION OF SUPPORTS FOR LH TAPESTRI [FS2] | 2 days | Fri 3/9/18 | Fri 3/9/18 | 43 |
| INST. OF REAR DOOR / PORT DOOR EQUIPPED | 2 days | Thu 3/8/18 | Thu 3/8/18 | 7 | 14 |
| INST. OF TUBES FOR HYDRAULIC SYSTEM [FS2] | 2 days | Fri 3/16/18 | Mon 3/19/18 | 41 |
| INSTALLATION OF MICRO SWITCH IN DOOR [DR2] | 1 day | Fri 3/9/18 | Fri 3/9/18 | 16 |
| INSTL. HINGE AND FITTING OF PILOT DOOR [DR2] | 2 days | Mon 3/12/18 | Tue 3/13/18 | 21 |
| INSTALLATION OF SUPPORTS FOR RH TAPESTRI | 2 days | Tue 3/20/18 | Wed 3/21/18 | 4 | 44 |
| INSTALLATION OF FORWARD DOOR / RAMP DOOR [DR2] | 2 days | Thu 3/15/18 | Thu 3/15/18 | 9 | 17 |
| MAKE HOLES & INSTL SPT FOR ROUTING FSLG [FS2] | 6 days | Thu 3/29/18 | Thu 3/29/18 | 46 |
| INSTALLATION OF EMERGENCY EXIT DOOR [DR2] | 2 days | Wed 3/21/18 | Wed 3/21/18 | 11 | 23 |
| INST. OF LOCKING SYSTEM ON RAMP DOOR [DR2] | 1 day | Thu 3/22/18 | Thu 3/22/18 | 14 | 18 |

The use of critical path calculation is to determine the earliest possible completion of the project. In other word, it can be called the driving path to project completion. Analysis of the critical path requires several assumptions, including the following: all tasks are known, all links are accurate, all estimates are accurate, and other non-critical paths may have small amount of slack. In this study, all tasks and links are based on the data given by company. The estimation of other factors such as duration are provided as well. In terms of small amount of slack, there are only 2 activities of less than 10 days total slack. The rest, excluded the critical task, is between 10 to 150 days total slack. Most of the non-critical
paths have big amount of slack. It can be confusing as the critical task found is only one among 100 tasks. Different results are showed on auto task mode for new schedule. The non-critical paths have vary total slack from 3 to 89 days. This is not small amount of slack, yet it is smaller than the original schedule result. Despite this potential problem, the critical path analysis using auto task mode provides the project manager a good indication of where to focus attention.

Table 3. Critical tasks comparison

| Original Schedule                                                                 |
|----------------------------------------------------------------------------------|
| Task Name                                                                        | Duration | Start  | Finish | Pred | Success |
| INSTALLATION OF TUBES FOR HYDRAULIC SYST [NS2]                                 | 2 days   | 10/2/18| 10/3/18| 52   |         |

| New Schedule                                                                     |
|----------------------------------------------------------------------------------|
| Task Name                                                                        | Duration | Start  | Finish | Pred | Success |
| INSTALLATION SUPPORT OF INSTRUMENT PANEL [NS2]                                  | 1 day    | 3/2/18 | 3/2/18 | 62   | 73,97    |
| INSTL SUPPORT AT MECH. ELECT. NOSE AREA [NS2]                                   | 2 days   | 3/28/18| 3/29/18| 56   | 77       |
| INST. OF ELECTRIC EQUIPMENT ON FRAME 3-5 [NS2]                                  | 4 days   | 4/10/18| 4/13/18| 73   | 100      |
| INSTL. OF FUEL CONTROL UNIT ON FR.C4F-5F [NS2]                                  | 3 days   | 7/3/18 | 7/5/18 | 77   |         |

3.3 Leads and lags
In project schedule management, sequence activities are the next step after define activities. Sequence activities is the process of identifying and documenting relationship among the project activities. The key benefit is defining the logical sequence of work to obtain the greatest efficiency given all project constraints. One technique used is leads and lags. A lead is the amount of time a successor activity can be advanced with respect to a predecessor activity. Conversely, a lag is the amount of time a successor activity will be delayed with respect to a predecessor activity. Leads and lags are essential for making a good project. They are the basic building blocks of scheduling. We try to identify the leads and lags of each activity based on the start, finish date and free slack information showed in new schedule. Most activity has lags due to limited resources of each area. An example of calculating leads and lags in door area are documented in Table 4 and Figure 4.

Table 4. Activities in door are

| Activity                          | Description                  | Duration | Start   | Finish   | Pred | Successors | Free Slack |
|-----------------------------------|------------------------------|----------|---------|----------|------|------------|------------|
| 1                                 | INSTL OF PASSENGER DOOR [DR2]| 2 days   | Fri 3/10/18 | Mon 3/15/18 | 41   | 0 days     |            |
| 4                                 | ATTACHMENT OF RIGHT RAMP SEAT [DR2]| 3 days | Thu 3/3/18 | Mon 3/5/18 | 6    | 0 days     |            |
| 6                                 | INST. OF SWITCH & LABEL RAMP DOOR AREA [DR2]| 1 day | Tue 3/6/18 | Tue 3/6/18 | 8    | 0 days     |            |
| 8                                 | INST. OF REAR DOOR / PORT DOOR EQUIPPED [DR2]| 2 days | Wed 3/7/18 | Thu 3/8/18 | 4    | 0 days     |            |
| 10                                | INSTALLATION OF MICROSWITCH IN DOOR [DR2]| 1 day | Fri 3/9/18 | Fri 3/9/18 | 6    | 0 days     |            |
| 11                                | INSTL. HINGE AND FITTING OF PILOT DOOR [DR2]| 2 days | Mon 3/12/18 | Tue 3/13/18 | 6    | 0 days     |            |
| 13                                | INSTALLATION OF FORWARD DOOR / RAMP DOOR [DR2]| 2 days | Wed 3/14/18 | Thu 3/15/18 | 10   | 0 days     |            |
| 15                                | INSTALLATION OF EMERGENCY EXIT DOOR [DR2]| 2 days | Wed 3/20/18 | Wed 3/21/18 | 17   | 0 days     |            |
| 16                                | INST. OF LOCKING SYSTEM ON RAMP DOOR [DR2]| 1 day | Thu 3/22/18 | Thu 3/22/18 | 15   | 0 days     |            |
| 17                                | INST. OF SUPPORT AND RAILS ON RAMP DOOR [DR2]| 1 day | Fri 3/25/18 | Fri 3/25/18 | 16   | 0 days     |            |
| 18                                | INSTL.RUBB PROFILE FR. OF EMERGENCY DOOR [DR2]| 1 day | Mon 3/26/18 | Mon 3/26/18 | 73   | 0 days     |            |
| 20                                | INSTALLATION OF PILOT DOOR [DR2]| 2 days | Tue 3/27/18 | Wed 3/28/18 | 17   | 0 days     |            |
| 22                                | INSTALLATION OF LOCK ON LH DOOR [DR2]| 1 day | Fri 3/29/18 | Thu 3/29/18 | 15   | 0 days     |            |
The scheduled Start (S) of 15 is 6 days after (+6 days) the scheduled Finish (F) of 10. Mathematical representation of lags: \(15(S) = 10(F) + 6\) days; \(22(S) = 15(F) + 5\) days; \(20(S) = 11(F) + 9\) days. Leads and lags can be estimated accurately in the future schedule planning. Many scheduling experts do not use them including this aircraft industry where the study is undertaken.

4. Conclusion

The activities in a project must be completed in a certain period of time, typically the activities in the critical path. This has led the project manager adjusting the resource to ensure the completion time is on schedule. For some projects, the limited resources allocated becomes a factor considered in estimating the schedule. The available resources may be less than resources required to do the tasks. Resources are precious to be spent in the best and most efficient way possible. It is all about the ability to meet customer demand under uncertainties occurred.

Manually and auto task mode will be interchangeable. It depends on the complexity of the project. Since the original schedule has been defined by the company, it is treated as manually task mode in Ms. Project. The new schedule uses the auto task mode. They give different completion time of duration. For several projects, they are hybrid application. Yet, either manual or auto, each is influenced by project constraints, project assumption, and project dependencies. The concept of leads and lags has many practical applications in Project Scheduling. Sometimes they are mandatory due to the project constraints or environmental reasons. In this case, the project constraints of resource have driven lags determination. For further research, other project management softwares can be applied to get a better result. Cost optimization using mathematical modeling can be integrated with project software application including other constraints such as budget and risks constraints. Understanding project assumptions, project constraints, and project dependencies in terms of project scheduling management particularly resource-constrained project scheduling will create a successfully project completion.

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