# Resource-Driven Scheduling Implementation in Malaysian Construction Industry

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## ABSTRACT

Resource-driven scheduling techniques focus on resource. Their objective is to schedule activities so that a project dead line is met using predefined resource availability limits. This paper reports about the status of resource-driven scheduling implementation in Malaysian construction industry. An investigation Survey was conducted to determine the level of resource-driven scheduling and factors affecting the concerned implementation. Construction Firm registered under G7 (A Class), G6 (B class) and G5 (C class) were used in investigation. Data was analyzed by Statistical package SPSS to find the means and rank. Average index method was adapted to for the level of features of resource scheduling implementation and barrier to resource-driven scheduling. It is significant 59.65% firms are implementing resource-driven scheduling as partial. Also methods of project scheduling and resource options adopted were investigated. A Significant majority of construction firms (approximately 65%) adopt Microsoft project for scheduling. Study showed that the features of resource scheduling are being implemented at "Medium Level". Lack of understanding / awareness of concepts, lack of genuine commitment, lack of coordination of key personnel and Lack of coordination of constructors & consultants were found major factors that affect resource-driven scheduling. While, expensive to prepare is most contributing factor, no enforcement on schedules from authority, difficult to prepare and hurdles by personnel/authorities were found as major constraints in implementing resource driven scheduling.

*Keywords: Resource-Driven Scheduling, Planning & Scheduling, Construction Industry, Barriers to RDS, Resource Management, Resource Planning*

## 1.0    INTRODUCTION:

The construction industry is now a highly dynamic sector and one of the most complex industries. Money is always of special importance to those involved in construction projects and hence project completion within time limit is essential regardless of size and complexity of project as each day of delay in the completion of time constitutes a loss in revenue that can hardly be re covered. Therefore, construction schedule is required to be prepared.

In construction Industry, Scheduling is one of the most fundamental functions of construction project management [1] as it helps as a means of monitoring progress to ensure, the completion of project on time and within budget. Available planning and scheduling techniques that address construction projects can be classified into two basic categories, duration-driven and resource-driven. The critical path method (CPM) is a typical example of duration-driven techniques in which the basic inputs project activities, their durations and dependence relationships. Activity durations here are function of resources required (rather than available) to complete each activity. The CPM formulation, therefore, assumes that resources are not restricted in any sense. On the other hand, resource-driven techniques are more different and are focused on resources. Their objective is to schedule activities so that a project dead line is met using predefined resource availability limits. Line of balance and simulation are typical examples of resource-driven techniques [2].

## 2.0    WHY RESOURCE-DRIVEN SCHEDULING?

In construction industry, planning and scheduling has very much importance. Project schedules are invariably dynamic and uncertain [3]. Unfortunately, most discussions of scheduling in the project management arena focus largely on timing issues without taking into account the link between resource availability and capability and the project schedule [4]. Since the duration of each activity is dependent on the availability of resource, the problems arise when work proceeds without taking into account that how limited amount of labor, equipment and materials will impact the scheduling. When project schedules are developed without considering available, the resulting schedule may be misleading or impossible to achieve [5].  Resource related issues are frequently ignored even though they can affect project completion time [3].

Therefore, problem of scheduling activities under resource and precedence restriction with the objective of minimizing the total project, through put duration or the objective function is very important to perform the work as planned.

## 3.0    RELATED WORKS

### 3.1    Resource Planning and Resource Management

A construction project involves a group of activities to accomplish its goals within a specific amount time. Each activity requires certain resources, such as labor, materials, equipment, etc. to carry out assigned tasks and hence efficient resource management is a perquisite for its success [6].

Project resources provide the means of accomplishing the work objectives. Resource required to carry out activities on a project are determined by the type and quantity of work. Resources represent work force on a project in terms of various trades and operatives. For any project a number of resources are essential to accomplish the work. The process by which this is accomplished is resource planning. Resource planning and management is one of the most important ingredients for competitiveness and profitability in today's construction industry [7]. Resources are organizational assets. The planning of resources, which is of prime importance in generating a feasible scheduling, is one area in which problems are encountered [8]. Resource planning should take into consideration not only what is best for an individual project, but also what is best for organization as whole. Effective resource planning is also important when considering the impact of changes on the project schedule. The basic objective of resource planning and management is to supply and support the project so that established time objectives can be met and costs can be kept within the project budget [5]. Unanticipated overtime, schedule delays and the resulting cost over runs can all be symptomatic of planning and scheduling done without proper consideration for resources and their limits. Resources should be considered during the scheduling process in order to manage the construction project successfully [6]. If resource considerations are ignored during the project, they should always be considered after project completion when explaining poor schedule performance [5]. Therefore the proper management of construction resources plays a vital role in its successful execution [1].

## 3.2    Resource-Driven Scheduling Defined

Resource-driven scheduling is the plan that is limited by the available resources. Resource-driven scheduling is one of the most important issues of the construction management. Tasks whose durations are affected by addition or subtraction of resources are called resource-driven tasks. Note that in real world projects, this calculation is seldom so exact, because people have different skill levels and perform work at different speeds, two people never cut the time of a task exactly in half [9].

Unlike traditional scheduling techniques, resource-driven scheduling accounts directly for crew work continuity as well as resource availability to facilitate effective resource utilization [10]. However, resource-related issues such as constraints, availability, or in broader term resource allocation can cause delays yet their effects are typically neglected in those techniques [3].

## 3.3    Resource-Driven Scheduling Defined

There are five basic methods available for modelling the resources involved in the project cited by J. Gordon and A. Tulip, 1997 [11]. These include (i) resource aggregation, (ii) resource cumulating, (iii) resource allocation, (iv) resource smoothing, and (v) resource leveling.

**3.3.1    *Resource Aggregation:*** The simplest procedure of all of those scheduling resources is that of aggregation. It is a method of determining the total number of resource units required on a unit time basis throughout the life of the project. The most frequently used unit of time is the day [11]. Resource aggregation is the poor man's version of resource allocation [12].

An aggregation is a simple summation of the requirements for each resources time period to time period, throughout the life of the project with the project activities set at a defined state within their range of possible movement, For example, all the earliest start or all the latest start. This usually gives a peak for earliest start or a late peak for latest start [13].

**3.3.2** *Resource Cumulating:* The cumulating of the resource requirements for the two project conditions, of all at earliest start and all at latest start, can be used to give an indication of reasonable uniform requirement for each resource [13]. This approach provides a running accumulation of the resource requirements during the life of the project. The input to this process is the output of the aggregation calculation. In the cumulating the aggregation results are accumulated on a running basis [11].

**3.3.3** *Resource Allocation:* Resource allocation, also known as resource loading, is the process that breaks down work activities into the types and quantities of labor, equipment, and materials needed to perform the work. As a result, one is able to determine the anticipated resource needs, and plan accordingly. [14]. Resource allocation is used to provide a feasible schedule for the completion of the project within the management constraints. Resource allocation is used when there are definite limitations on the resources available. Resource allocation depends on a list of criteria for how to allocate limited resources within a specific period. The available resources need to be compared to the resource demanded by a given activity. When there are insufficient resources available, the activity has to be rescheduled to free necessary resources. In the case where two activities require the same resources simultaneously and there are insufficient resources to start both activities as planned, the activity with the highest priority will get the scarce resource first [15]. Therefore, the availability of resource of all types constitutes pre-requisite conditions for executing one activity [16].

Therefore, allocating resources into the schedule is necessary to determine whether or not there is sufficient supply of resources on hand to perform the work as planned. By comparing the availability of the desired resources against the quantity of labor, equipment, or material required to work the schedule, one is able to manage resource use in the schedule. Therefore, it is very necessary to construct a resource schedule in order to indicate the type and quantity of resources and period for which they are required. [17]. By allocating the labor, equipment, and materials required to perform each individual task on the schedule, one is able to pre-plan the anticipated resource needs for each workday of the project before the schedule is put into action [14]. By comparing the availability of the desired resources against the quantity of labor, equipment, or material required to work the schedule, one is able to manage resource use in the schedule. Therefore, it is very necessary to construct a resource schedule in order to indicate the type and quantity of resources and period for which they are required [17]. If the supply on-hand exceeds the requirement, then the schedule can be worked as planned. If it is found that the demand exceeds supply, then steps need to be taken to ensure that the proper amount of resource will be on hand on the date needed [14].

In addition, it might not be a good strategy to acquire the demanded resources without planning for their effective utilization. Therefore, in order to manage a construction project successfully, resources should be allocated carefully throughout the project the project phase by considering demand, supply, and the effective utilization [6]. Efficient allocation of resources for construction planning activities requires construction

planning resource requirements to be determined on a cost-effective and value-adding basis [18]. The traditional solution of the resource allocation problem commences with the CPM analysis of the project network. Each activity is assumed to require a fixed quantity of resources, and the activity once started cannot be interrupted. An overall project duration is determined based on the assumption that resources are in abundance. Then a search is made for a schedule of activities such that resource requirements are met. Resource allocation schemes were integrated into the CPM, subsequently, to reschedule project activities in a way such that resource needs could be matched throughout the project life. Usually, this is done heuristically by shifting some activities competing for limited resources to other time periods when resources become available [2].

**3.3.4  Resource Smoothing***:* Resource smoothing is a technique to produce a feasible schedule within time constraint boundaries with a smooth (uniform) resource requirement profile or planned resource usage as possible [13]. In the allocation routines it is very difficult to produce a schedule, which is time- limited where the resource requirement does not suddenly explode into unacceptable dimensions. The smoothing procedure looks at the total project and works within the time frames of the project that has been set by the user. There are four steps in the cycle, which repeats until all activities have been scheduled:

> 1. Schedule any critical activities.
> 2. Find the most important activity yet to be scheduled.
> 3. Find the best place to schedule this activity, and do so.
> 4. Adjust the early and late times of the unscheduled activities to take account of this newly scheduled activity [11].

Smoothing does not require any prior resource scheduling to have take place. It does require start time and project duration to be defined and each resource to be assigned a priority for consideration. The procedure then schedules activities to give a smooth profile of resource usage as possible with the project time frame [13].

**3.3.5  *Resource Leveling:*** Resource Leveling is a part of broader topic of resource management [19]. It is a process of determining and minimizing the effect of low resource availability on schedule or on a way to resolve having much work assigned to resources i.e. resource over allocated [14]. If resources are adequate but the demand varies widely over the life of the project, it may be desirable to even out resource demand by delaying non-critical activities (using slack) to lower peak demand and increase resource utilization. This process is called resource leveling [20]. In other words, resource leveling is the process of positioning the activities of a network such that the use of project resources is minimized on a day-to-day basis [21]. In other words, the resource leveling technique attempts to reduce the sharp variations of resource demands, while maintaining the original project completion time [6]. To manipulate the daily resource requirements, resource leveling is implemented. In resource leveling the project duration of original critical path remains unchanged [22]. Resource leveling involves the delay of non-critical activities within their Total Float Limits to manipulate the daily resource requirements [14]. Therefore, Resource leveling can be defined as reallocation of total or free slack in activities to minimize fluctuation in the resource requirement profile [23]. It is a means of smoothing the resource histogram for a project. It reduces the peaks and valleys associated with staffing a project [24].

The objective of resource leveling is to remove peaks and valleys from a schedule produced [11]. The resource schedule needs to be leveled for following reasons:

> ➢ The need to meet a physical limit of resources
> ➢ The need to maintain an even flow of resources [21], [26].
> ➢ To ensure that no resource is over allocated.
> ➢ Sometimes a number resource (people in most cases) is wanted to follow a logical pattern throughout the life of project. It is avoided that a number of people working on the project fluctuate widely day-to-day or from week-to-week. That would impose too many management and co-ordination problems. Resource leveling avoids this by ensuring that the numbers of resources working on a project at any time are fairly constant. The ideal project would have the number of people resources relatively level over the planning phase, building gradually to a maximum during the project work phases and decreasing through the closing phases. Such increases and decreases are manageable and expected in the life of well-planned project [19].

Resource leveling may not improve some high peaks or valleys. Resource leveling cannot resolve the case in which a high peak is beyond the resource availability [6]. Resource leveling problem arises from the project scenario in which the project duration is fixed [25] and when there are sufficient resources available [22]. The fluctuations of resource usage of labor, equipment, or materials can be very expensive. The expense that results from fluctuations in labor supply comes in the form of continuous training and lay-off of new employees, or in the mobilization and demobilization of construction equipment. Leveling the demand for resources helps minimize the large day-to-day fluctuations in the number of resources needed [21, 26, 14]. Hence, Resource leveling is used when there are enough resources but the fluctuation of resource usage need to be leveled. The project duration calculated by the critical path initially remains fixed. The leveling process is accomplished by the shifting only non-critical activities within their floats [15].

Resource leveling is a process that the project manager follows to schedule how each resource is allocated to activities in order to accomplish the work within scheduled start and finish dates of activity. Recall that the scheduled start and finish dates of every activity is constrained by project plan to lie entirely within their ES-LF window [19] and hence, Resource leveling may not improve the smoothness of resource usage beyond a certain level due to the fixed completion time [6].

## 4.0    DATA COLLECTION AND ANALYSIS

### 4.1    Survey Method

The study was conducted as a part of larger study of resource-driven scheduling implementation culture of contractors involved in Malaysian construction industry. Data was collected through a questionnaire administered to 200 firms. Firms were selected from top three classes of contractors of Malaysia i.e. G7, G6 and G5. These classes were selected for the study, because they constitute the most organized group of firms. They have regular offices and addresses as well as management structures that are readily accessible. A stratified sample was drawn from the list of contractors registered with CIDB and JKR Malaysia.

## 4.2    Data Analysis

Statistical Package for Social Science (SPSS) version 17 was used to analyze the data. The ranking of factors affecting resource-driven scheduling implementation was calculated based on the mean score and standard deviation. The higher the mean and lower standard deviation shows the higher is the ranking. The formula used for the mean rank calculation is;

$$M_R = \frac{\overline{R}}{M_{max}} n$$
(1)

Where $M_r$ is Mean Rank, $\overline{R}$ is Individual Mean Rank of effect, $R_{max}$ is the Maximum Individual Mean Rank of effect and n is the number of effects.

To analyze the data gathered regarding status of resource options/features and barriers to resource-driven scheduling, the research used frequency analysis and average index. The average index is calculated as follow [27-29].

$$\text{Average Index} = \frac{\sum a_i x_i}{\sum x_i}$$
(2)

Where,
a = constant expressing the weight given to i
x = variable expressing the frequency of response for i = 1, 2, 3

In order to determine the level of application of resource scheduling features in this study the classification of rating scale used is as follows:

| | |
|---|---|
| Highly Applied | 1.00 < Average Index < 1.50 |
| Medium Applied | 1.50 < Average Index < 2.50 |
| Little Applied | 2.50 < Average Index < 3.00 |

For the barriers/constraints against the implementation of resource-driven scheduling rating scales are as follows:

| | |
|---|---|
| Very Significant | 1.00 < Average Index < 1.50 |
| Significant | 1.50 < Average Index < 2.50 |
| Insignificant | 2.50 < Average Index < 3.00 |

## 4.3    Classification of Construction Firms

Construction firms in Malaysia (according to CIDB) report are categorized into seven financial classes according to the size of individual projects they can bid for government projects. Most private organizations also depend on this classification for contractor selection. This classification however, does not put any limit on number of jobs a firm can undertake in a year and thus the annual turnover. These classes are designated as G1, G2, G3, G4, G5, G6 and G7.The upper limits for fulfilling financial capacity and corresponding full time personnel resource criteria according to the contractor grade are given in table 1.

Table 1: Financial Classification of Contractor

| Grade | Tending Capacity [RM] | Paid Up Capital / Net Capital worth [RM] |
|---|---|---|
| G7 | No Limit | 750,000.00 |
| G6 | Not exceeding 10 Million | 500,000.00 |
| G5 | Not exceeding 5 Million | 250,000.00 |
| G4 | Not exceeding 3 Million | 150,000.00 |
| G3 | Not exceeding 1 Million | 50,000.00 |
| G2 | Not exceeding 500,000.00 | 25,000.00 |
| G1 | Not exceeding 100,000.00 | 5,000.00 |
| Source: http://www.cidb.gov.my | | |

Questionnaires were delivered to the selected firms and arrangements were made to meet the officials involved in construction for collection of data and further interviews. The questionnaire consisted of fixed response questions including fixed alternative and multi-choice questions. There were also open-ended questions that allowed respondents to express thoughts and ideas not covered in the fixed format questions. All respondents were given freedom to answer the question, as they deemed appropriate. However, questions that needed clarification by some of the respondents were attended to, but in a manner that eliminated bias emanating from researcher's end.

The questionnaire was designated to meet set objectives. The first part dealt with general information. The second part dealt with method of scheduling, status and level of implementation of resource-driven scheduling features and factors affecting the concerned scheduling where as third section covered the identification the barriers/constraints against the implementation of resource-driven scheduling and their significance.

## 5.0    RESULTS AND DISCUSSION

### 5.1    Respondent Questionnaire

Questionnaire was distributed among the contractors of three classes of contractors i.e. G7, G6 and G5 as classified by CIDB Malaysia. As a result 36 responses were received from G7 contractors, 5 from G6 contractors and 16 from G5 contractors. Demographic results are tabulated in table 2.

Table 2: Respondent Demographics

| Class | No. of Responses | Percentage | Cumulative |
|---|---|---|---|
| G7 | 36 | 63.2 | 63.2 |
| G6 | 5 | 8.8 | 71.9 |
| G5 | 16 | 28 | 100 |

### 5.2    Method of Project Scheduling

The respondents were asked about for their firm regarding to implementation of method of project scheduling and status of resource-driven scheduling being adopted. A significant majority of respondents i.e 37 of 57 (64.9%) were found involved in implementation of Microsoft Project, where as another 10 of 57 (17.5%) respondents have been involved in implementation of Primavera Project Planner followed by third

largest majority 6 of 57 reponses (10.5%) using Gantt chart, where as 2 (5.3%) and 1 (1.75%) using simple Bar Chart and WBS respectively as shown in figure 1.
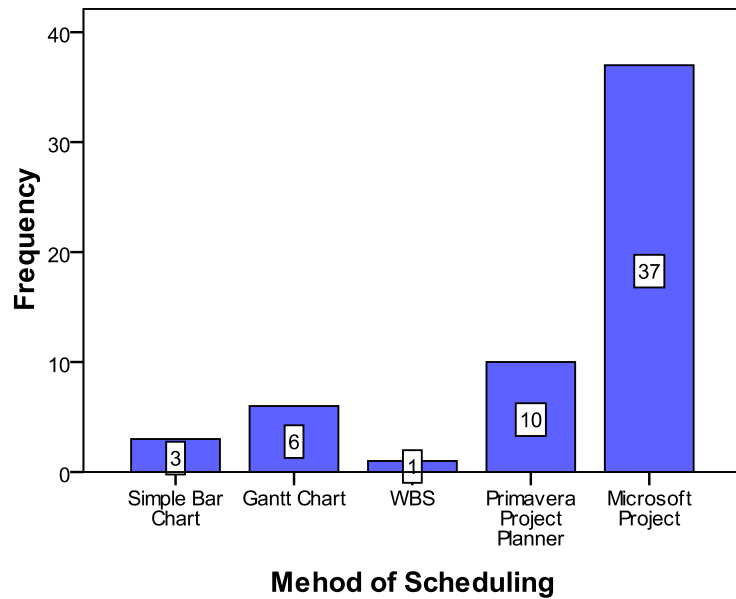


Figure 1: Method of Project Scheduling Adopted in Malaysian Construction Industry

Furthermore, study revealed that 59.6% respondents said that they adopt partially resource-driven scheduling and depend mostly on time-driven schedule. On the other hand 40.4% of responses showed that resource-driven scheduling is fully implemented in construction projects. Table 3 and figure 2 represents the results regarding the level and status of implementation of resource-driven scheduling.

Table 3: Status of Resource-Driven Scheduling Implementation

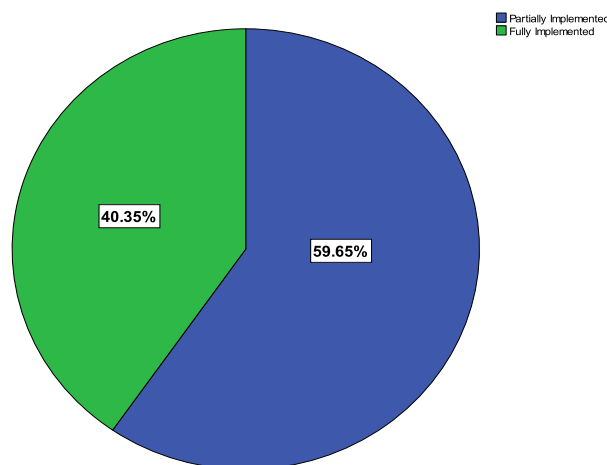| Status of Implementation | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|
| Partially | 34 | 59.65 | 59.65 |
| Fully | 23 | 40.35 | 100 |
| Total | 57 | 100 | |



Figure 2: Status of resource-driven scheduling

## 5.3 Factors Affecting Resource-Driven Scheduling Implementation

There are various factors that affect the resource-driven scheduling. In this regard the major factors identified with responded results in tabulated form are given in table 4.

Table 4: Factors Affecting Resource-Driven Scheduling Implementation

| Factors | Mean | S.D | Variance | Rank |
|---|---|---|---|---|
| Reluctance to allow construction review | 1.877 | 0.331 | 0.110 | 1 |
| Lack of genuine commitment | 1.860 | 0.350 | 0.123 | 2 |
| Lack of coordination of key personnel | 1.772 | 0.423 | 0.179 | 3 |
| Lack of coordination of constructors & consultants | 1.772 | 0.423 | 0.179 | 3 |
| Lack of experience | 1.737 | 0.444 | 0.197 | 4 |
| Lack of coordination of technical personnel | 1.737 | 0.444 | 0.197 | 4 |
| Lack of proper communication between decision | 1.684 | 0.469 | 0.22 | 5 |
| Lack of understanding /awareness of the concepts | 1.579 | 0.498 | 0.248 | 6 |

From the results it is very clear that respondents at large scale agree that lack of understanding / awareness of concepts was ranked is the major contributing factor affecting resource-driven scheduling implementation followed by lack of genuine commitment. Lack of coordination of key personnel and Lack of coordination of constructors & consultants were found as third major factors with same mean and SD.

## 5.4 Resource-Driven Scheduling Features

As majority of respondents agreed upon the implementation of commercial scheduling packages i.e. Microsoft Project and Primavera project Planner in construction projects which facilitate the resource scheduling at different levels. Depending on the size and complexity of the project and type of the work, these packages offer various features to implement. The respondents were asked for companies regarding to these features of resource scheduling with the degree of implementation. Table 5 presents the responses regarding to the implementation of resource-driven scheduling features and their level of implementation.

Table 5: Level of Implementation of Resource-Driven Scheduling Features

| Features | HA | MA | LA | AI |
|---|---|---|---|---|
| Resource option | 11 | 22 | 9 | 2.0 |
| Resource calendar | 12 | 24 | 5 | 1. 8 |
| Assigning resources to activity | 19 | 13 | 10 | 1.8 |
| Resource priority | 21 | 10 | 12 | 1.8 |
| Resource leveling | 12 | 17 | 13 | 2.0 |
| Resource smoothing | 11 | 17 | 13 | 2.0 |
| Resource splitting | 4 | 18 | 17 | 2.3 |
| Resource stretching | 6 | 16 | 19 | 2.3 |
| Resource crunching option | 3 | 11 | 23 | 2.5 |

From table 5, it can be viewed that average index of all features of resource-driven is between 1.50 to 2.50 i.e. all the features are being implemented at "Medium Level".

### 5.5    Barriers Checklist Against Implemenation Of Resource-Driven Scheduling

As construction industry is complex in nature and construction projects are unique, hence the practitioners face various constraints and barriers while trying to run project smoothly in order to complete within estimated and scheduled time. The respondents were asked about the most common and frequently faced barriers, which affect the resource-driven scheduling at large scale to implement in construction industry. Table 6 represents the tabulated results regarding to the barrier and constraints.

Table 6: Results for Barrier/ Constraints Checklist.

| Barrier/Checklist | VS | SI | IS | AI |
|---|---|---|---|---|
| Expensive to prepare | 5 | 19 | 21 | 2.4 |
| No enforcement on schedules from authority | 7 | 25 | 10 | 2.1 |
| Difficult to prepare | 13 | 20 | 15 | 2.0 |
| Hurdles by personnel/authorities | 8 | 28 | 8 | 2.0 |
| Impediments due to interference | 9 | 22 | 8 | 2.0 |
| Has no guidance to follow concerning preparation | 14 | 23 | 11 | 1.9 |
| Too many numbers of resources | 16 | 25 | 7 | 1.8 |
| Not every one know and understand project schedule | 22 | 23 | 6 | 1.7 |
| Complexity of the project | 23 | 24 | 4 | 1.6 |

Table 6 shows that all the checklist factors are significant constraints to implementing resource-driven scheduling. However, expensive to prepare is most contributing factor with average index of 2.4 followed by no enforcement on schedules from authority. Difficult to prepare and hurdles by personnel/authorities were found as third major constraints.

### 6.0    CONCLUSION

Study was carried to investigate the status of resource-driven scheduling in construction industry of Malaysia through questionnaire survey. Survey was carried out among the contractors of top 3 grades i.e. G7, G6 and G5. From the study it was revealed that resource-driven scheduling is being practiced in construction industry but majority is implementing it as partial. It was observed from the survey results that ratio of adoption of commercial packages is increasing but majority of firms is implementing Microsoft Project, however, Primavera Project Planner has not become so popular is use in construction industry as compared to Microsoft project. From the investigation it was found that 59.65% respondents claimed to implement resource-driven scheduling as partially while 40.35% implement resource-driven scheduling fully. However, all the features of resource scheduling are being implemented at "Medium Level".

Respondents show that lack of understanding / awareness of concepts, lack of genuine commitment, lack of coordination of key personnel and Lack of coordination of constructors & consultants were major factors that affect resource-driven scheduling. While, expensive to prepare is most contributing factor, no enforcement on schedules

from authority, difficult to prepare and hurdles by personnel/authorities were found as major constraints in implementing resource driven scheduling.

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