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SCHEDULING PROCESS: USING ONE-DAY SCHEDULING ON MULTI-FAMILY PROJECTS TO REDUCE DELIVERY TIME

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Abstract
The past fifty years has seen many changes in the construction process, but little has changed in the area of scheduling for most projects. There have been advances in the software used to manage schedules, but the same theories and practices have been used for decades. This process works well and will continue to be norm on most projects. Some home builders have incorporated a process "one-day scheduling." The process views the project as a linear sequence of days and identifies what activity is start and finish on that day. Several large home builders have found that the number of calendar days to construct an individual home as part of a large development has been reduced significantly, giving them a strategic advantage in the market. The following study looks at the implementation of a combination of traditional and "one-day scheduling" on multi-family residential projects as a method of schedule management, resource management, and cost control. The study reviews the management of the schedule during construction as well as the scheduling process. The end goal of any construction project is to deliver a project of the greatest value to the owner for the defined cost. The implementation of a method of scheduling which delivers a product more efficiently will conserve resources and enhance the goals of sustainable construction.

Keywords: Scheduling, Multi-family, Linear Scheduling

INTRODUCTION

Schedules and schedule management the core of the management process for construction projects. Activities are identified, defined, assigned durations, and linked by relationships to create a work flow and a critical path through the project that is effective and manageable. The Critical Path Method (CPM) works well on most projects and will continue to be norm.

Some residential contractors have changed their method of scheduling in an effort to be more competitive in the market. These contractors have adopted a scheduling method similar to production line scheduling, but instead of the product moving through as series of operations, the operations are moved through the product. The process is similar to the Linear Scheduling Method (LSM) and requires re-evaluating activities and the defining of activities and their durations (DiVosta Homes, 2002).

Proponents of LSM feel that the Critical Path Method (CPM) is not well suited to repetitive work, such as multiple housing units. The goal of LSM is to prevent interference between repetitive activities that progress linearly through the project. Interference is avoided by scheduling only one work process at a time in a defined area (Nunnally 2011).

One Day Scheduling (ODS) is derived from LSM. The following examines the development of ODS and its application in conjunction with CPM scheduling. Although residential construction is used as the context for the discussion, the principles can be applied to any repetitive process, whether there are several repetitive projects which stand on their own, or there is a group of similar and repetitive activities which are integral parts of larger projects.

BACKGROUND

LSM is based on the manufacturing process. In manufacturing, a product, such as a car or washing machine, would start out on the assembly line as one component, and move through the assembly line with additional components added until the final product is completed. The components are added during an operation (activity), and the operations (activities) are arranged in a sequence, with each operation completed before the next operations are started.

Although the current discussion is focused on residential construction, any repetitive function could benefit from LSM type scheduling. A recent hospital project in Florida had one hundred and seventy-eight patient rooms that were exactly the same. The contractor used prefabrication of components at an outside warehouse to facilitate the schedule. The assembly of the components used LSM type scheduling. The net result was valuable to the schedule and saw increased productivity of the workers. Part of the increase in productivity had to do with one trade not conflicting with another, as well as the repetitive nature of the work, and the ready access to all necessary materials and tools (Post 2010)

Since the manufacturing process is continuous, the movement of the line must be uniform. The uniform movement requires that each operation is performed in the same amount of time, referred to as standard time. Not every operation in the assembly process takes the same amount of time, so the activities need to "balanced" Balancing is the process of dividing up activities into multiple activities, all of which have the same duration as the standard time (Milas 1990). For example, if it takes two minutes for a worker to put on windshield wipers and eight minutes for one worker to put on the tires, the standard time could be placed at two minutes. The tire installation needs to be divided into four activities for the line to run smoothly. The four activities could occur sequentially or concurrently.

The speed is defined by the "standard time". The standard time is what is needed to complete each activity. The duration of the standard time is not the average time for an operation. Using the average time would result in about half of the operations failing to complete in the allotted time. The standard time is the duration required for the successful completing of each operation most of the time. As a result, the total time of production is longer than the minimum time that the product could be manufactured. The standard time is a balance between keeping the line moving all the time by have no time failures and line stoppage, and acknowledging and accepting some line stoppage to have a shorter standard time. The total duration of the assembly process is the total of moving and stationary time (Milas 1990).

There are three recognizable types of progressive assembly lines. The first is where the same product is produced. The second type is where two or more models an intermixed and run at the same time and use a predetermined and fixed sequence. The third type of progressive assembly line intermix two or more models, using varying sequences (Milas 1990). Construction of residential units would usually fall in the second category. Units may differ in many ways, but the sequencing would stay the same.

The LSM uses three steps in developing the schedule.

1. Determine the work activities
2. Estimate activity production rates, the same as in the CPM but the LSM uses the durations and the production rates to match the activity scope to the standard time.
3. Develop and activity sequence, similar to developing logical relationships. (Mubarak 2005)

The activities have a defined duration, and the activities are re-accruing. Over time, the productivity of crews may change, so adjustments are made to keep all the crews on schedule. Adjustments may involve extended hours, reduced hours, or adjusting the crew size (Mubarak 2005).

One-Day Scheduling (ODS) is an adaptation of LSM where the typical standard time is one work day, so activities have one day duration. Many construction operations take over one day to accomplish, so they must be broken down in separate activities, such as putting on the car's tires. Manufacturing refers to the process of breaking down activities as Dividing "Indivisible" Elements in order to create a standard time (Milas 1990). The defining of activities to be performed in a standard time of one day is accomplished through the collaboration between the general contractor and all the subcontractors.

A good example of how ODS works is shown by the experience of a construction company which has used the ODS since 2004. The example looks at how the company changed the way they schedule the gypsum installation and finishing in their homes.

Installing and finishing gypsum walls and ceilings have the following four elements:

- Hang
- Tape and bed
- Second coat of mud
- Finish coat
  (Gypsum 2007)

The company's previous scheduling method acknowledged that each element took about one day, and they allowed a fifth day to be sure that the gyp was completed before the next trade began their work. The gyp contractor agreed to provide more labor for larger homes to maintain the schedules. The gyp activity had a five-day duration on the schedule. Frequently, the gyp contractor failed to complete in five days and thus compromised the schedule.

Under ODS, Hunter Homes changed the schedule for gyp to:
Day 1 - Hang
Day 2 - Tape and bed
Day 3 - Second coat of mud
Day 4 - Finish coat
Day 5 - The trim carpenters begin

The subcontractor was required to be on schedule every day, and crews were adjusted by the subcontractor to make sure that the crews were successful every day. The change to ODS resulted in the gyp subcontractor completing their work in four days instead of five and being successful most of the time. Hunter Homes did not have statistics on the percent of successful completions for particular operations (Hunter Homes, 2006).

The previous example could have been accomplished by simply requiring the subcontractor to finish in four days, but the process was facilitated by the addition of more detailed control. Under the old system, the gyp contractor was not behind schedule until the end of the fifth day, which allowed little time for over-schedule work to be performed. Gyp work continuing into the sixth day would interfere with the trim carpenters. Under ODS, the contractor did not allow scheduled work to roll into the next workday. The process works for this contractor because of the commitment of the subcontractors and suppliers. The scheduling technique has resulted in advantages to the general contractor, the subcontractor, and the owners.

Advantages to General Contractors

There are several advantages that have been realized by companies who have adopted ODS. Traditional scheduling uses a heuristic approach to setting durations because of the number of variables that are present. The heuristic approach may actually be better that compiling large volumes of historic data and extrapolating durations, because the average duration will only be nearly correct, statistically, about 10% of the time. The heuristic approach lets the scheduler take into account some of the most important or predictable variables. ODS is used on repetitive projects, so historic data becomes more accurate.

Using shorter durations of one day, gives management a daily evaluation of the progress of each activity in the schedule, from first day until last. Inspections and jobsite monitoring are performed daily. Superintendents are able to look at a schedule and know what activity is being performed in each unit. The overhead is cut for the general contractor as managers and superintendents are able to manage more units in a year. The faster turn-around time improves the cash flow, which results in lower cost of internal financing. Finally, but most importantly, the subcontractors can charge less because the ODS increases the productivity of their crews and lowers their overhear cost.

Perhaps the greatest advantage to the process on One-Day Scheduling is the management process. The creation of detailed schedules which attempt to control the activities of all subcontractors on a daily basis would appear unmanageable. ODS allows this level of control only because of the repetitive nature of the subcontractors work and the involvement of the subcontractor in defining the activities to be performed in the standard time of one day.

Advantages to Subcontractors

The successful implementation of ODS requires coordination and cooperation from all subcontractors. As noted above, the subcontractors are a part of the decision process for setting the scope of the daily activities. This allows the subcontractors to allocate required resources. Subcontractors need to have sufficient resources to maintain the work flow as it is specified in the schedule. There are several benefits that the subcontractor receives for making the commitment to maintain the schedule.

First, the subcontractor builds a long term relationship with the contractor. Second, the repetition allows the subcontractor to identify costs and lower the risk due to unknown circumstances. Third, the subcontractor knows they will not have conflicts with other subcontractors trying to complete work on the same unit concurrently. Fourth, the subcontractor is able to level their resources and maximize the productivity of all the crews.

Leveling resources allows the subcontractor to have a defined number of workers for the general contractor. There is inefficiency in having to continually move workers from one

project to another. Having level resource requirements allows the subcontractors to keep workers productive and reduce turn-over due to changing labor needs.

Productivity of the workers can be increased. The elements that impact productivity are discussed in a following section, including the influence of ODS on some of the elements. The gyp subcontractor example shows the value of reduced duration on the calendar of five days to four days, allowing crews to complete five homes per month instead of four.

Advantages to Owners

There are two primary advantages that are received by the owners. First, and perhaps the most important, is that stringent schedule management promotes on-time delivery of the product. One of the accepted components of customer satisfaction is timely delivery. (Business Bear, 2011) The second advantage is the cost savings that can be passed down to the owner. The competitive nature of the construction industry requires successful companies to pass along savings realized through progressive management practices, while maintaining their profit margin which insures long term success.

Productivity

Since much of the strategic advantage of the ODS relies on the increased productivity of the workers, a discussion of productivity is in order. Since labor is about 33% of the construction cost, decreasing labor cost will benefit the project costs (Haskell 2004). The productivity of the workers has a direct impact on the cost and schedule, but the number of variables makes the measurement of productivity on construction projects is difficult.

"Send one boy to do a job and it will get done in one day. Send two boys and it will get done in a day. Send three boys and it will not get done at all." Lord Snowdon

Lord Snowdon points out that the allotment of additional resources may not increase productivity. The scope of work did not change, but the allocated resources changed with no increase in productivity. In fact, the productivity declined with the increase in resources.

Construction trades average about 32% productive time. The rest of the time is spent:

- Waiting 29%
- Traveling 13%
- Instructions 8%
- Tools and materials transportation 7%
- Late starts and early quits 6%
- Personal breaks 5%
    - (McCarthy 2008)

Productivity provides the greatest opportunity to reduce costs and reduce the schedule duration. A study in the United Kingdom was published through the Office of Government Commerce, showed that incorporating certain techniques resulted in efficiency gains of thirty percent in some public sector operations, while 30-50% improvements have been known in the private sector. (Clark 2010) Note that the gains were on specific projects not averages, but the study showed that significant gains are possible.

The methods used in the study are summarized by Sir Peter Greshom. "This is not rocket science - the basic principles are to: do the right things... (Eliminate unnecessary work), the

right way… (Use standard, streamlined processes), with the right people… (right skills, availability, location), using the right tools and equipment." (Clark 2010).

The *Mechanical Estimating Manual* lists sixteen factors that can impact labor productivity in construction (D'Amelio 2006). Examining several in relation to the four principles identified in Clark's study gives some reference in how some of the factors can be impacted by ODS.

- Stacking of trades – ODS is very specific about only having one trade in a unit on any day.
- Morale and attitude – There is difficulty in quantifying morale and attitude, but there could be qualitative assessment based on stacking of trades, crew size efficiency, concurrent operations, site access, fatigue, overtime, logistics, and supervision. Improvements in one or more of these areas could improve morale and attitude.
- Reassignment of manpower (change orders) – Change orders cause a disruption in any schedule. ODS is as susceptible to disruption as any other scheduling method.
- Crew size inefficiency (over manning) – The basis of ODS is the adjustment of crew size to maximize production during a defined duration.
- Concurrent operations – ODS is resource centered, so crews are assigned to a single operation at any time, avoiding division of resources and lowering productivity.
- Dilution of supervision – Supervision is critical in any scheduling method, but ODS sets daily goals for each crew which is well communicated to each crew.
- Learning curve and Errors – ODS incorporates crews moving from one location to another and repeating the same tasks. Keeping continuity in the people in the crew keeps the learning curve low and minimizes errors. Errors may appear as successor activities are accomplished, but the errors will be related and adjustments made quickly.
- Site access – Site access is the key element in ODS as each trade will enter an area that is prepared to receive their work with no encumbrance.
- Logistics – The Logistics become more important but should be easier, because the rate of production is defined and the dates of material delivery can be verified by the schedule.
- Fatigue and Overtime – Fatigue is always a consideration for workers because the work is all physical. Crew sizes may need to be adjusted based on the time of year because productivity will change on extremely hot or cold days. Without a change in the crew size, overtime may be necessary, which is not productive over long periods of time.

The gains in productivity realized by users of ODS were primarily from:

- Not stacking trades
- Using proper crew size
- Lowering the learning curve
- Ensuring site access
- Standardizing logistics.

CASE STUDIES

There are three case studies that follow. The first two are brief commentaries on two home building companies that currently employ one day scheduling. The third is a case study showing how ODS can be used in conjunction with CPM scheduling for a multistory residential condominium project.

Case Study: DiVosta Homes
DiVosta Homes uses One-Day Scheduling, and has found the construction time has decreased, quality control is up, and costs are under control. The company builds single family homes in their own developments in Florida. In 2003, one of their subdivisions was starting two homes per day using ODS. The homes were in the $400,000 to $450,000 range, with limited options on the overall design.

The company has identified 45 distinct work activities (operations) on homes, from beginning to end. Each operation has one day duration for a crew, except for some short duration activities. On certain short duration activities, the crew was given two houses per day, so only one crew was needed. Activities that normally take multiple days are divided into two or more operations, using multiple crews moving each day or rotating starts. The company incorporates pre-planning and extensive staging to facilitate the crews' success. DiVosta Homes uses a combination of in-house forces and subcontractors. Each are managed as separate entities', with the expectations for both to meet the schedules and provide profit for the general contractor.

DiVosta Homes has been able to consistently deliver homes in 45 working days from the start date. The shorter delivery time cuts the management time on each home so each superintendent and project manager can oversee more homes in a year, cutting overhead for management of the projects. Subcontractors are able to train crews and maintain consistent work forces on the project, without having significant overtime or battling the stacking of crews. The company is also to turn over the projects to customers faster and improving the cash flow. Cash flow is very significant when the company is finishing two $450,000 homes per day. (DiVosta Homes 2002).

Case Study: Hunter Homes
Hunter Homes is a medium sized homebuilder in Huntsville, Alabama. The company sells homes from $125,000 to $250,000 and starts two homes per day for all their subdivisions. All the subdivisions are within the same geographic area, so the same subcontractors are generally used throughout the company. All work is subcontracted, and the total duration of the projects is 48 working days. The activities are all one day long, although, like DiVosta Homes, one contractor may accomplish short duration activities is less than a day, such as attic insulation, which is not critical on the schedule for other operations.

The management of Hunter Homes feels strongly that the schedule is key to their competitive edge in their market. Before using ODS they were at the same price per square foot as other builders in the area, but now have a lower base cost due to several factors, most notably the schedule (Hunter Homes 2006).

Case Study: Eagles Nest
A schedule for the Eagles Nest project uses a combination of CPM and ODS. The Eagles Nest is a six-story, eighteen units, residential condominium building with mid-range finishes. The frame of the building is structural steel with precast hollow-core concrete elevated decks. The CPM scheduling technique is used for the foundation, frame, windows, exterior doors, skin, elevator, and mechanical, electrical, and plumbing services that serve the entire building.

The interior build-out and finish of the units is scheduled as eighteen activities, one for each unit, and each activity is twenty-one days in duration. The first activity, or unit one, begins

when the exterior is closed in from the weather. Unit 2 will start on the next working day, and the start dates for each subsequent unit will start on succeeding days.

Activities for each unit – each activity has a standard duration of one day.

1. Interior Partitions
2. Ductwork for HVAC Main Ducts (Two Days – two crews)
3. Ductwork for HVAC Branch and Return Ducts (Two Days – two crews)
4. Plumbing rough-in
5. Electrical RI- Place device boxes, Meter Base, Panel and feed Panel (Two Days – two crews)
6. Electrical RI- Pull wire to boxes and home runs (Two Days – two crews)
7. Insulation
8. Hang Gyp (Gyp Contractor has a crew for each of the four steps)
9. Tape and Bed Gyp
10. Second Coat Gyp
11. Finish Coat Gyp
12. Interior doors, base, and window trim
13. Prime walls and trim (Painting - Three Days – Three crews)
14. First Coat of paint on walls and trim
15. Bathroom and Kitchen Cabinets
16. HVAC finish
17. Electrical Finish
18. Plumbing Finish
19. Hard flooring in kitchen and Bath (One Crew – second day requires only one hour labor)
20. Grouting Flooring (one hour labor – 24 hour duration for setting)
21. Finish coat of paint on walls and trim

When two crews are specified, such as for the HVAC contractor, the activities can be handled in two ways. The first day's activities are completed by the first crew and the second day's activities completed by a second crew. Alternatively, crew one could work both days and complete the entire scope for the two days, while the second crew comes in the second day and completes all work in the second unit. The crews would leap-frog through the schedule completed every other unit.

The schedule for the interior of the building is a very simplistic schedule which shows the activity by number, which is being performed in each unit on each day. Table 1 shows part of the ODS for the eighteen units. The actual dates for the activities would be added from the master CPM schedule. The duration of the interior work would be eighteen consecutive work days, with the last unit starting on day eighteen and continuing for twenty-one days, for thirty-eight work days to completion.

The simplicity of the schedule creates the power as a management tool. One immediately notices that there is planned activity in each unit each day. Although this may be the goal of many builders, ODS provides a tool to manage the performance of the subcontractors. The methodology of creating the ODS from the manufacturing standpoint, where failure to meet the schedule and stop the assembly line is the unusual, not the norm, is based on the buy-in from all subcontractors, starting with the input on the activity creation and continuing to the commitment on the success.

Table 1
One-Day Schedule for the Build-Out and Finishes

Unit	Activity in Each Unit Each Day																					
1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
2		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
3			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
4				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
5					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
6						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
7							1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
8								1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
9									1	2	3	4	5	6	7	8	9	10	11	12	13	14
10										1	2	3	4	5	6	7	8	9	10	11	12	13
11											1	2	3	4	5	6	7	8	9	10	11	12
12												1	2	3	4	5	6	7	8	9	10	11
13													1	2	3	4	5	6	7	8	9	10
14														1	2	3	4	5	6	7	8	9
15															1	2	3	4	5	6	7	8
16																1	2	3	4	5	6	7
17																	1	2	3	4	5	6
18																		1	2	3	4	5

CONCLUSION

One-Day Scheduling is not revolutionary and it is not applicable for every type of project. ODS does work for large residential contractors and is applicable for other types of project that contain many highly repetitive sequences of activities. Traditional construction scheduling defines activities to be accomplished by in-house forces or subcontractors, without defining the resources required to accomplish the work in the time frame defined. ODS has an understanding of the crew sizes and equipment required and uses that information in setting the work required for the day in the schedule.

The work to be accomplished on any day in the schedule is agreed upon by the subcontractor and the general contractor to assure that the production required is achievable every day. It is possible to reduce the duration of the building process due partially because there is progress every day. Additionally, subcontractors are the sole trade in the unit during the activity, which, along with additional benefits, improves productivity. With increased productivity come lower costs and shorter schedules. There are benefits to the general contractor, the subcontractor, and the owner, which result from the schedule management and productivity.

The critical component to the success of ODS is the collaboration of subcontractors and subcontractors on the design of the schedule and creating the scope of work for each day. Upfront planning can be the key to success. Low bid contracting may not be a successful model. Negotiated bidding would provide a better contracting platform for success, as the schedule and activities are part of the contractual agreement.

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