"Using Manufacturing Techniques to Improve Scheduling and Resource Allocation for Repetitive Projects"

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Abstract

This paper makes a case for the use of repetitive manufacturing techniques (e.g. assembly line process, JIT) for repetitive projects. A sample project, building a children’s playground, is reviewed from the customer’s perspective using traditional project management techniques. The same project is assessed from a contractors’ perspective, using repetitive manufacturing techniques to improve scheduling and resource allocations.
Using Manufacturing Techniques to Improve Scheduling and Resource Allocation for Repetitive Projects

All projects, no matter how big or small, complex or simple, share common ground. For example, all projects have a start and finish date, and all require some sort of tracking. Also, effective communication is key to a successful project.

Traditional project management techniques such as Gantt and PERT/CPM flow processes, while useful for discrete projects, may not be the best methods for a contractor who performs the same project over and over again. Adaptation of repetitive manufacturing techniques such as assembly line manufacturing and just-in-time materials management can enable a contractor to gain the ability to time the project more accurately and expand operations while controlling resources. Also, by adopting the assembly line manufacturing structure during expansion, the contractor can move away from performing individual "projects" and avoid possible cost inefficiencies found in discrete project organization structures.

The purposes of this paper are threefold. First, the literature on general project management is reviewed. Second, a sample project, a playground renovation, is evaluated using traditional project management techniques. Third, the same project is assessed from a contractor's perspective, with the integration of appropriate repetitive manufacturing techniques.

GENERAL PROJECT MANAGEMENT

The complexity of projects today has spawned considerable literature on tools and guidelines to aid the project manager in making decisions, efficiently managing
resources, and completing the project on schedule. It is useful to discuss the techniques available to aid project teams in three areas: the project life cycle model, project staffing, and project communication.

**Project Life Cycle**

All projects go through a life cycle. Understanding this cycle can help the project team complete its goals. According to Gido and Clements, the project life cycle consists of four phases: identify a need, develop a proposed solution, perform the project, and terminate the project. (1, p. 8)

Projects begin when a specific need is identified. Performing a needs assessment helps a project manager clarify the specifics of the task to be accomplished. The needs assessment is an important part of the project process and should be as complete as possible.

A typical format used to conduct a needs assessment is a Request for Proposal (RFP). For in-house projects, the RFP may be as informal as a memo specifying the outcomes desired. However, many times the firm will not perform the project; an outside company will. The RFP provides the information needed for the outside company to bid and compete on the project that is specified in the RFP.

The second phase of a project is to develop a proposed solution. This is accomplished by either the in-house project team or by an outside company. Using the criteria from the RFP, the best proposal is chosen to be implemented.

After the proposal is selected, the project will be started. According to Gido and Clements, there are two phases involved with performing a project: "doing the detailed planning for the project and then implementing that plan to accomplish the project
objective”. (1, p. 64) Good up-front planning always pays off over the life of the project. There are many types of planning tools to help the project manager. Planning software is available to create Gantt timeline charts, Work Breakdown Structure, and PERT diagrams. All are helpful, but it is important to note that these are only tools, and cannot take the place of good planning.

Good planning, while useful, does not ensure project success. According to Wojciak, “many projects are planned well but seem to fail in the implementation stage... planning, in and of itself, does not dictate success.” Additionally, Wojciak notes several “keystones” for project success. They include effective communication, defining and understanding roles, knowing the difference between forcing and facilitating, and putting together the whole package. (10, p. 26) Every project should have a well defined scope, budget and timeline, and all of these features should work together and be monitored frequently for project success.

The last phase of any project is project termination. Every project should have an ending date. After the project is terminated, time should be allocated for assessment of the project. Actual versus planned performance should be compared for items such as budget, resources, and timelines. If the project is repeated in the future, the project team will be able to alter the budget, timelines and resources based on experience.

**Staffing a Project**

Assigning appropriate personnel to the appropriate tasks is an important aspect of project management. There are many ways to staff a project, and the major goal of any project is to ensure that the people who are on a project team bring unique characteristics that, when used together, complement one another to make the best use of resources.
In addition, successful project human resource management depends on understanding the different types of organizational structures. Basically, there are three main types of organizations utilized for projects: functional, project, and matrix. A functional type of organization separates each function of the organization within a hierarchy of management. Employees in the different functions rarely interact, and the project manager does not have complete control over the employees. Instead, for a project, the employees are “borrowed” for the time they are on the project. This type of organization works best when the project is in-house rather than for an external customer.

A project organization creates “mini-companies” for each project. According to Gido and Clements, “all the resources needed to accomplish each project are assigned full-time to work on that project. . . and the project-type organization is well positioned to be highly responsive to the project objective and customer needs because each project team is strictly dedicated to only one project.” (1, p. 142) While this may seem ideal for a company which works on projects regularly, it is possible that there may be cost inefficiencies associated with the project organization.

The matrix type of organization is a combination of the first two types of organizations. Employees work in functional areas of the company and may be “borrowed” for the time they work on the project. The matrix organization structure differs from the functional form. In this case, the project manager has direct control over project aspects whereas the project manager in the functional organization does not. In addition, there is more choice when reviewing the pool of employees to choose from a specific specialty to work on a project. Walter Meares states, “matrix management combines the project or project team forms with functional departmentation in a grid
where managers responsible for specific products or product lines tap the functional
groups for people." (3, p. 14) In this way, the matrix type of organization may utilize
employees' talents better. Further, Meares notes that "except for very special
circumstances, the matrix is the preferred choice for a dynamic, competitive company."
(3, p. 14)

Communication

The success of a project depends directly on the effectiveness of the project team.
It is well known that an effective team does not just happen. Team dynamics can make
or break a project. What are team dynamics? They not only include the stages of team
development as defined by B. W. Tuckman (form, storm, norm, and perform) (9), but
they also include team involvement in making decisions as well as motivation and
commitment. Generally, employees like to be involved in the decision making process.
It can give them a sense of ownership in the project, as well as providing the firm with
the employees' expertise thus resulting in a better decision.

Ralph Steinglass, an author in the area of building design and construction, notes
that projects where there has been no emphasis on team building encourages turf wars,
hard feelings, as well as adversarial relations among team members. Further, Steinglass
notes that project managers must first have top management support in order for team
building strategies to really work. (8) Then, the project managers can build on top
management's authority to actually make a cohesive team. In addition, giving
teammates ownership in a project and giving them input on timelines, resources needed,
and agreed upon outcomes, make the project go much smoother and provide a better
experience for everyone involved.
Ways to incorporate team commitment at the inception of the project may include a meeting directed toward “developing a set of common goals for the project, establishing lines of communication, defining authority and responsibility, and specifying the rules and protocols by which everyone will abide to accomplish the goals.”

A veteran project manager in the area of site management construction noted an important aspect missing from the project teams he oversaw: meaningful human involvement. The major reason for this missing link was that his employees were not involved in the decision making process of project components, and therefore never understood the scope of the project. (5) This can be addressed by paying attention to effective communication and asking for feedback from project team members. The project components -- the life cycle, staffing and communication -- all work together to ensure a successful project.

SAMPLE PROJECT USING TRADITIONAL PROJECT TECHNIQUES

This portion of the paper uses a playground renovation project as the basis for discussion of a project from the customer’s perspective. The projected is a one time, discrete event from the customer’s perspective and traditional project management techniques are used.

Traditional Project Life Cycle

A project for renovating a children’s playground on a university campus illustrates the project life cycle model discussed in the previous section. This project will need the services of an experienced contractor. But before a contractor can be assigned the job, the university must quantify what is needed, and obtain funding for the
project. This introductory process is phase one, or the needs assessment. The number of children using the equipment, the ages of the children, and safety concerns are important criteria for the design of the playground.

Also, determining the budget is a major consideration for the design of the playground. On a university campus, asking for funding requires an explanation of not only what, but why the funding is needed. For the playground, several benefits can be cited from the improvement of the playground. For example, a renovated playground may improve student retention rates and increase apartment occupancy. Also, the renovation will provide the children a safe alternative to the street as a playground. A third benefit is that playgrounds encourage growth and development of children, which in turn will help other skills during and after childhood.

After the funding is approved, the university must request bids from contractors. This is done by posting RFP’s. An RFP submitted to outside firms, such as contractors, must detail in specific terms what the client wants to be performed. All pertinent information should be included in the RFP including a detailed description of the work to be performed, all deliverables, due dates, schedules, and payment terms. In this case, the RFP serves two purposes: it forces the university to clarify their needs and it allows the contractor to make an informed bid on the project.

Contractors bid on the project in the second phase of the project: develop a proposed solution. With the RFP in hand, the contractor can prepare an informed proposal for the project, including sections on technical aspects, their management style and all associated costs. Proposals from contractors enable the university to see how well the contractor understands the need, and their solution to that need.
Firms have many ways of evaluating a contracted bid. The most widely used analysis of the bid is the cost. Usually, the contractor who provides the lowest bid is awarded the contract. But cost analysis is not the only way to evaluate contracted bids. Analyzing the contractor’s qualifications, experience on similar projects, and assessing their proposed timelines and costs are important too. Clients should beware of bids that come in too low. (4) The likelihood of the contractor using substandard materials, cheaper labor and the possibility of cutting corners during the project may be more prevalent when the bid is abnormally low.

Once the bid is awarded, the contractor begins the planning phase of the project. Planning a renovation of a playground includes everything from the start (site preparation) to the end (installation of playground equipment) of the project. One of the most widely used tools in the planning phase is the Gantt chart, which details events of the project, in the chronological order they should be done.

Depending on the agreed upon mode of communication, the contractor will supply a layout of the playground. Also, the contractor should communicate regularly with the university on any special needs they have. For this particular project, there is a city sewer cap located in the playground area which requires special treatment. The contractor must also notify the appropriate city officials as necessary. In addition, the contractor must coordinate the delivery of site preparation materials, as well as human resources needed to complete the project.

For this study, a contractor (Company X) who builds playgrounds was interviewed about their process for building a typical playground. Company X is a small playground manufacturer headquartered in the Houston, Texas area. They specialize in
building modular, multi-level playgrounds. They have been in business for seven years and have approximately 20 design, sales and support employees (in four locations around Houston) and 1 manufacturing site with 10 employees. Playgrounds are ordered as job numbers with scheduling priority on a first-in, first-out basis.

This contractor often prepares proposals for community and apartment playgrounds. Proposals include a diagram of the product, the duration of the project (simple Gantt timeline), and price. Also, upon request, photographs of other completed playgrounds are included for the customer to view, mainly to address any questions about their expertise in playground construction.

After the contract is signed, the contractor will schedule a meeting with the client to work out specific details, like the color of playground parts. According to Company X, the complete playground process lead time after the sale is six weeks. The process includes ordering all materials, forming and painting playground pieces at the manufacturing site, and building the playground on the customer’s site. From the customer’s perspective, the six weeks is blocked out on a Gantt chart as manufacturing and installation. The contractor’s Gantt chart is much more detailed. After installation, the project is complete. Company X guarantees their product, and they schedule a follow up visit one year after installation. As one can see, this project fits into the traditional project life cycle model. From the RFP to project completion, both the customer and the contractor work together for project completion.
SAMPLE PROJECT USING
REPETITIVE MANUFACTURING TECHNIQUES

Some projects, like the children's playground, tend to be repetitive in nature from the contractors perspective. One playground installation is similar to another. Planning and scheduling the playground installation may use many tools designed for project management, such as Gantt charts and work breakdown schedules. However, when a contractor specializes in this type of operation, the repetitive nature of the project leads one to view the project more like repetitive manufacturing than a traditional project.

From the interview with the CEO of Company X, it is clear that this company does not view the project of building a playground in the same way as the customer. Company X utilizes traditional project management techniques up to a point. When the project enters the manufacturing area, it deviates from a traditional project and instead takes on a new form -- repetitive manufacturing.

Currently, the manufacturing employees are assigned the projects by job number on a first-in, first-out basis. Since there are only 10 employees, they are cross-trained in every area and each can step in and help when another employee is out. Usually, only one employee will work on one playground at a time, following it through the entire manufacturing process (shaping the pieces, sanding, painting, and packaging for shipment). Two employees may work together if the playground is a large one.

Scheduling the jobs through the manufacturing process is done with a large calendar wipe board hung on a wall in the manufacturing area. The calendar format mirrors a Gantt chart, and works well for this company because of the simplicity and
short duration cycle of each project. The calendar lists the job number and the employee assigned to it, and each employee is allotted the time it takes to complete the playground in the manufacturing area. After the playground is built, another crew is needed to do site preparation and playground installation, thus completing the project.

Company X has already formed a basis for repetitive project management. They have divided the company into three areas: design, sales, and support; manufacturing; and installation. It is the manufacturing and installation areas that can utilize the techniques proposed for repetitive projects.

**Repetitive Project Model**

Rehab Reda, the developer of the repetitive project model (RPM), proposes three approaches to repetitive construction projects. They are a network technique (such as PERT or CPM), a graphical technique (activity time cost curve), and an analytical technique (linear programming) (6). Together with these three techniques are some company specific constraints such as a constant production rate and continuity of work crew. The objective of the RPM is to "maintain a constant production rate, and find a schedule for each activity that will finish the project at a feasible duration and at a minimum project direct cost."

Using this thought process, the playground contractor can view the repetitive nature of building playgrounds in a new light. The constant production rate constraint included in the RPM can be further incorporated into assembly line manufacturing.

**Assembly Line Manufacturing Process**

Many small scale contractors may not have the tools of RPM (such as linear programming) readily available to them. However, if their output is a repetitive project,
there is still a way to utilize the assembly line format in their business. Paul Hinkley, a project management consultant, has determined a way to view a repetitive project from the assembly line perspective. In assembly line manufacturing, the overall job is divided into different sub-parts. These sub-parts are work areas that do the same thing over and over, and as the product moves down the assembly line, more sub-parts are added to make a completed item. (2) It may be useful to develop modular bills of materials (BOM) for those sub-parts which are common to more than one end item. The modular BOM would facilitate the ordering of materials, management of lead times, and scheduling of production.

A major goal of assembly line management is to minimize the amount of time at each station and to equalize the times at each station so that there is a smooth flow along the assembly line as well as a minimal amount of delay between stations. Traditional assembly line balancing techniques can be utilized to increase the efficiency of the operation. Hinkley utilizes the assembly line approach for repetitive parts of large projects, such as building a highway, pipeline, or multiple floors of a high-rise building. Also, Hinkley notes that many times, it is not the product that is moving down the assembly line (i.e. fixed position layout), it is the human resources. This type of approach can increase the firms flexibility in utilizing its human resources.

While Hinkley applies the assembly line approach only to those tasks in a project that are repetitive, some projects can be viewed as total repetitive projects. For example, when the contractor builds a playground, the individual tasks to build a specific playground are not repetitive, but building a playground over and over is repetitive.
Generically, the project manager can break down the project into sub-parts. Next, he can estimate the amount of time in each sub-part. Beginning with the subset with the longest time, the manager can look at the item and decide if time can be shortened by using more manpower. If he can shorten the sub-part, it is done. This is done until all sub-parts are not only allotted the shortest time possible, but they have relatively the same duration. After the sub-parts are identified and time frames set, the project manager can then begin to chart the project, using the repetition cycle instead of a Gantt chart format. The project manager must check for resource allocations and possible conflicts in equipment and manpower assignments. The end result duplicates a balanced assembly line that can handle multiple projects at the same time.

In our example playground project, Company X currently assigns one employee to each job order. This employee performs all aspects of the manufacturing process. The assignment linear programming model could be used in such operations to optimize the assignment of projects to individual employees. An advantage to this general form of assignment process is that it is very easy to assign human resources to jobs. However, there are several disadvantages to this type of resource allocation. Employees working on individual projects may need to use the same manufacturing tools if the individual job orders are at the same stage in the manufacturing process. The overlap causes at least partial work stoppage until the equipment becomes available. Also, there may be very little coordination among manufacturing staff using the one staff member per job order. Some employees may have improved techniques for accomplishing tasks that may never be shared. In addition, employees who work solo may hinder company communication.
Thus, Company X may not be prepared for growth using their current manufacturing techniques.

Company X can benefit from the assembly line approach. The entire process of building a playground can be divided into subparts. These tasks can be assigned to employees who will "specialize" in that area only. As playground orders are generated, the manufacturing team breaks down the manufacturing process into sub parts, and more than one playground may be in the assembly line process without an overlap of manufacturing machinery. The tasks may be divided as follows: one crew is forming and shaping the pieces, one crew is painting, and another crew may be preparing them for delivery. On the installation side, one crew may only work on site preparation, and another crew may actually install the playground. This way there is no lag time between orders, and everyone is kept busy.

Table 1 illustrates how an assembly line process can be begun for the playground manufacturer. Suppose there are six tasks to building a playground, with one-week time durations for each task. If there are six work teams specializing in Task 1 – Task 6, then by Week 6, the firm will be at full production, with each work team assigned to a different project. Also, with this schedule, there is one playground completed each week.
**TABLE 1.**

Sample Assembly Line format for Playground Manufacturer.

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Week 7</th>
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</table>

Example of Tasks:
Task 1 – Order and receive materials
Task 2 – Form and build playground uprights
Task 3 – Form and build playground add-ons
Task 4 – Paint and cure playground units
Task 5 – Package and get playground ready for shipping
Task 6 – Site prep, playground installation

For planning the manufacturing process, PERT diagrams may be helpful. The PERT diagram is a visual tool for determining the order that the playground must go through to be complete. Management, with the input of manufacturing employees, can determine activities and time lines for each workstation. By involving manufacturing employees in this process, management gains two benefits. First, employees who are actually doing the work can offer expertise and ideas about shortening the process time.
Second, involving employees can indeed foster trust, communication, and improve a team atmosphere in the manufacturing team.

The calendar format currently used to schedule employees can be replaced by a repetitive cycle format (refer to TABLE 1), although the calendar itself can still be used. The new format can display the job number and work team assigned. The problem of overlapping both human and materials resources is automatically removed using the new process.

This type of schedule makes it easy to add work as the number of orders is increased. For example, this schedule can be easily doubled with each work team assigned to two projects each week (with additional human resources, of course). Traditional job shop scheduling heuristics [e.g. first come, first served (FCFS), shortest processing time (SPT), critical ratio (CR), due date (DD)] could be used to improve the efficiency of the release of jobs to the work teams.

Figure 1 illustrates how work can be added with the addition of resources. For example, Task 2 requires two employees. If the project load is doubled, then the task would require 4 employees, but the work is done in the same time period. This process can be repeated for every task.
FIGURE 1.
Sample work team on Task 2 using Assembly Line format.

Week 2
Work Team 2
Form and build playground uprights on Project 1 (2 employees)

Week 3
Work Team 2
Form and build playground uprights on Project 2 (2 employees)

Week 4
Work Team 2
Form and build playground uprights on Project 3 (2 employees)

Work Team 3
Playground sent to Work Team 3 for forming and building playground add-ons (3 employees)

Work Team 3
Playground sent to Work Team 3 for forming and building playground add-ons (3 employees)

Sample Assembly Line process if work teams were doubled because of additional workload.

Week 2
Work Team 2
Form and build playground uprights on Project 1, Project n (4 employees)

Week 3
Work Team 2
Form and build playground uprights on Project 2, Project n (4 employees)

Work Team 3
Project 1, Project n sent to Work Team 3 for forming and building playground add-ons (6 employees)

Week 4
Work Team 2
Form and build playground uprights on Project 3, Project n (4 employees)

Work Team 3
Project 2, Project n sent to Work Team 3 for forming and building playground add-ons (6 employees)
What are the benefits of using this type of model for repetitive projects? First, there is a learning curve in repetition. The more that a repetitive motion is done, the more kinks that will be removed and the time duration for each activity will be lessened. Also, employees can be trained and “specialize” in one or a smaller number of tasks. This makes the project easy to understand, simplifies employee training and facilitates monitoring of project activities. Also, by having employees specialize, they can offer input and knowledge in their area of specialization to make future projects more cost effective. In addition, this type of layout may offer more room for growth, allowing the company to add resources where needed in the assembly line process.

Depending on the rate of growth and how that growth is managed, chaos may result when too many orders are accepted. That’s where Just-in-Time (JIT) manufacturing can be beneficial. JIT was developed to reduce work in progress which lowers overall production costs. Materials that are not needed immediately are not ordered immediately. Instead, they are only ordered to arrive at the exact moment they are needed. This reduces the need for extra storage space as well as freeing up cash flow. Spencer and Cox note that for companies who specialize in custom products, the likelihood that a true JIT system can be incorporated is reduced. (7) However, companies who specialize in custom built products with many common components such as the playground manufacturer, can still utilize these techniques.

According to Spencer and Cox, JIT works best when there is a stable master production schedule in place. The longer a set schedule is in place, the better. The MPS is also useful to avoid finished goods build up. In addition, it is important for orders to be released on a regular basis. (7) This may not hold true for the playground manufacturer
where business may be seasonal. Because of the custom nature of the business, it is impossible to schedule very far ahead and have a stable MPS. However, the basis of every playground is the same; what makes playgrounds unique are the add-ons and colors. Therefore, it is possible to gauge at least the first step of every order.

Communication

Communication is very important in the JIT and assembly line work environment. There must be some kind of Kanban or signaling system in place for work teams to know when to initiate and move work. Knowledgeable work teams know exactly when their portion of the playground will hit their area, and what the timing of materials receipt must be well coordinated. For Company X, the calendar board that displays the job number and the date the job is scheduled to be in a work team's area may be sufficient for this purpose.

Assigning work teams who are responsible for the ordering and completion of their portion of the playground does more than just assign work. It may foster independence and give ownership, which promotes loyalty among staff. Providing employees the autonomy to schedule and improve their work will in turn improve scheduling all around. In addition, as the company continues to grow and more orders are generated, additional specialization can be utilized.

Challenges to the Assembly Line Approach

There are some concerns with viewing projects as an assembly line process. First, if one part of the assembly line process is delayed, the whole process can become backed up or possibly shut down. For example, if inclement weather delays the installation of the playground, it may sit in a warehouse until it can be installed. This warehouse may
not have the capacity to hold additional materials, and in effect may shut down the manufacturing process or at least delay it.

Also, a holdup in supply of materials may also delay the assembly line process. There is much literature on avoiding the delay of essential materials in Just-in-Time literature. One way to avoid delays in delivery of materials is to have more than one supplier who can supply materials quickly. A better way may be to establish a partnership with a single, highly reliable supplier.

In addition, the contractor may find that his business is seasonal. Playground demand tends to peak during the summer months. Depending on the number of playground building orders that are placed, employees may find themselves with nothing to do for periods of time. Companies deal with this by branching out into complementary or counter-cyclical activities. The playground manufacturer may decide that the tools used to build playgrounds can also be used to manufacture picnic tables, benches and barbeque pits. These projects can be easily incorporated into the assembly line process using repetitive manufacturing skills as well as JIT techniques.

**CONCLUSION**

General project techniques such as the project life cycle model, staffing and communication are important to any project. In addition, good planning before a project is begun can save time and costly resources later in the project. Also, it is important to know and understand project team dynamics, because many times the project will only be successful when the right team is working together.
Most project management literature is geared towards discrete projects. Project crashing, and resource leveling are tools used to shorten project time and costs. For the university, renovating a playground is a discrete project. It is unlikely that a similar project will be managed quickly after this one is completed. Therefore, for the university, traditional project techniques are acceptable.

For the contractor that builds playgrounds, or any small scale repetitive project, certainly traditional project management techniques can be utilized for control of projects. However, the company that specializes in repetitive construction may be able to use a combination of assembly line management and Just-in-Time management techniques and have better results. The main reason to use assembly line management is for growth. With the contractor accepting more repetitive jobs, the process can be divided into equal time length sub-parts. Employees assigned to specific areas of every project will gain expertise from the repetition process. Using these employees' talents fosters increased communication and teamwork. Additionally, the calendar format can aid the contractor when orders are doubled due to expansion. Thus, the assembly line process combined with JIT resource scheduling will place the contractor in a better place to not only to schedule projects, but expand and grow while controlling resources.
REFERENCES


