PROJECT MANAGEMENT SYSTEMS THEORY TAUGHT THROUGH GAMES

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Abstract:

Project management systems are plagued with misunderstanding of Interdependence versus Independence, Finite versus Limited Capacity and Strategic versus Individual Safety. Lecture and research are ineffective at convincing members of the project management community to come together to overcome these serious obstacles. This article introduces three hands-on games that involve individuals in simple experiments that shift their understanding, highlight the solutions to these problems and allow them to teach others how to manage high performance projects.

1. Background.

The basic premises of the Theory of Constraints assume that people can think, they are good and systems are simple (*The Choice*, Eliyhau M. Goldratt, North River Press, 2009). Yet, there must be something missing. Why do good, thinking people have so much trouble with projects? After all, projects are simply a set of tasks which must all be done within some precedence order before the project is complete. What is missing? It must be something that is a hidden understanding of how project systems perform. Or, it must be something acting upon the project management system: good, thinking people that do things to actually make the problems worse.

This article addresses three specific problems that plague projects. 1. The overloading of project resources, 2. The embedding of too much safety in task estimates and, 3. The assignment of resources. Rather than try to discover the devastating effects of these three problems, try to explain the deep impacts in a lot of text, and then try to lecture on the correct action to take, let's play some games.

1.1. Value of Games.

Good games should be easy to play, easy to set-up, designed for a purpose, be flexible, have a specific purpose and provide deep understanding with-in a short time. Such games are fun to play and eye-opening to all who participate. Teaching games should bring the participants to discover the problems, the impact of the problems of the system and lead to self-discovery of the solution. While large projects can be complicated and overwhelming, a small and simple game (one that mimics the same behaviors as the larger system) can be sufficient for the inquisitive mind to make the needed changes in the real world system. The mind is a beautiful thing.

The description of the three games below seems long. It is verbose to help the reader soon become a leader of the games. Sorry for the length of the reading. However, once you have played the games and practiced just a bit, the games are much easier to play than to explain. Enjoy!

2. The Job Shop Game.

The purpose of the Job Shop Game is to show the need to choke the release of work to a system. The game is played with six people, one person releasing the work, four people acting as work centers and one person recording the performance of the Job Shop as a whole. During the game, participants learn for themselves the problems with too much work in the system and how to resolve these problems in order to become a fast, predictable team. The game takes about 30 minutes to play.

2.1 Set-up. Make ten copies of Figure 1. This sheet has four Job Order Cards on one page. Cut all the sheets in 4ths so there are 40 individual Job Order Cards (ten of each product type). Assign those acting as the four work centers a name (A, B, C or D). Arrange the four work centers in a square so they can easily pass the Job Order Cards from their work center to any work center (in a Job Shop, work flows in a haphazard fashion, not a linear flow-line like typical production). Have the person releasing work be on one side of the work center square and the person recording the performance at the other side of the square. Shuffle the 40 individual Job Order Cards and give them all to the person who will release the work to the work centers. The Order Card must flow through the assigned four work center operations in the order they appear on the Order Card (from top to bottom) before leaving the work centers and going to the last member of the group who records the flow time of the Order Card through the work centers.

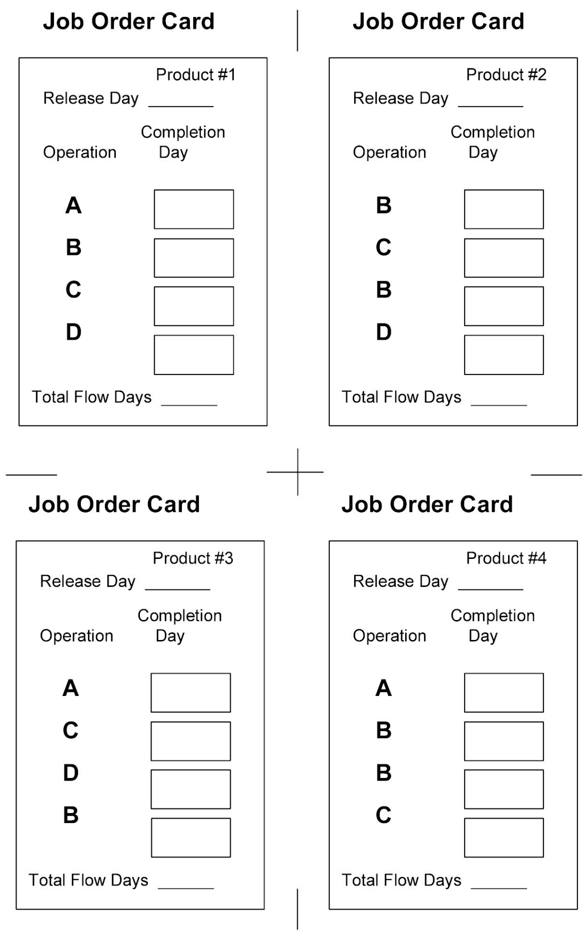

Figure 1. Job Order Cards for Four Products.

2.2 Playing the Game. The Job Shop Game is much easier to play than to explain. Each day has two parts. The Working Part, and the Passing Part. During the Working Part, each work center that has work to be done may write a number representing that day in the Day Complete box on the Job Order Card. After the Working Part is over (everyone who had work to do is done writing), there is the Passing Part of the day. The Job Shop Card is passed from the person who completed the work that day to the next work center operation in the order they appear (from top to bottom) on the individual Job Order Card. As an example, let’s follow the flow of a few Job Order Cards.

Assume the random shuffle has the first seven Job Order Cards in the stack of 40 to be Products 2, 3, 1, 1, 4, 3, 4 in that order. Here is how the processes would work:

Day 1. No one has any work except the releasing person. The releasing person writes 1 on the Release Day line of Job Order Card of Product #2. The Working Part of the day is now over. During the Passing Part of the day, the releasing person passes the card to work center B.

Day 2. During the Working Part of Day 2, the releasing person writes 2 on the Release Day line of Job Order Card Product #3. The work center B has the Job Shop Order Card for Product #2 released on Day 1 and writes 2 in the top box for Operation B. During the Passing Part of the day, the releasing person passes Product #3 to work center A. Work center B passes the Product #2 to work center C.

Day 3. During the Working Part of Day 3, the releasing person writes 3 on the Release Day line of Job Order Card Product #1. Work centers A and C both have work to do. Work center A writes 3 in the top box of the Product #3 which was released on Day 2. Work center C writes 3 in the second box of Product #2 which was released on Day 1. When all the Working Part of the Day is done, it is the Passing Part of the day. Work centers A and C (who did work that day) simultaneously pass their work to the next work center on the Job Order Card. A passes the Product #3 card to C. C passes the Product #2 card to B.

Writing all these transfers down in text is much more confusing than in just playing the game. But this will get you started. Table 1 show the flow of Job Shop Order Cards for the first seven days.

Table 1 Flow of Job Order Cards.

Day	Released Product	Work at Work Centers	Completed Work
1	#2		
2	#3	#2@B	
3	#1	#3@A, #2@C,	
4	#1	#1@A,#2@B,#3@C	
5	#4	#1@A#1@B,#3@D,#2@D	
6	#3	#4@A,#3@B,#1@B,#1@C,#2@D	
7	#4	#3@A,1@B,#4@B,#1@D	#2, #3

Table 1 shows the first seven days of the Job Shop Game with the work progressing. Note that on Day 5, work center D has two Job Order Cards (#2 released on Day 1 and #3 released on Day 2). And on Day 6, work center B has two Job Order cards (#3 and #1). However, work centers can only do one job per day. Allow those playing the game to determine how they will decide which work to do first, if there is more than one Job Order Card at the work center. In this example, work center D worked on Product #3 on Day 5, and then on Product #2 on Day 6. Work center B worked on Product #3 on Day 6 and Product #1 on Day 7. We also see that two Job Order Cards were completed on Day 6 and delivered during the Passing Part of Day 6 to the person measuring System Performance for accounting. They are available for plotting their flow time during Day 7. Figure 2 shows both completed Product #2 released on Day 1 and Product #3 released on Day 2. On these two Job Order Cards, the person measuring System Performance has calculated the Total Flow Days for each product (Total Flow Days = Day of Completing the Fourth Operation – Release Day). Product #2 took 5 days to flow through the Job Shop and Product #3 took 4 days to complete.

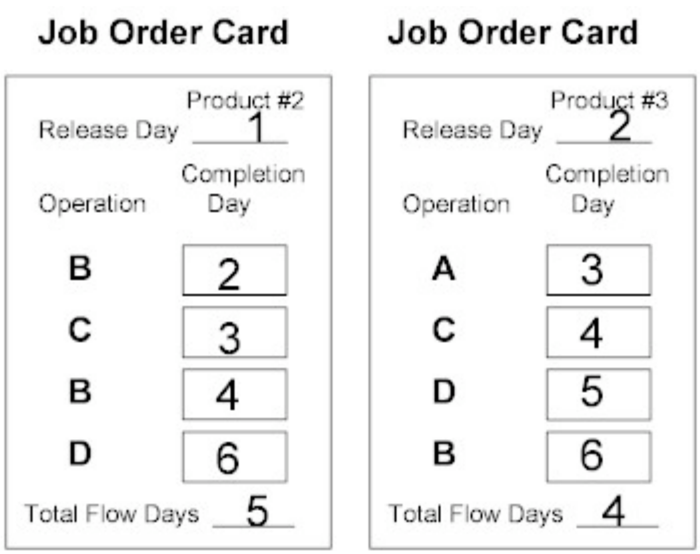

Figure 2. The Results of the First Two Completed Jobs from the Job Shop Game.

2.3 Recording Systemic Performance. The Job Shop Game is a busy one for those participating. It is hard to get a grasp of the system's performance without tracking the actual results. Plotting the trend of Total Flow Days, relative to the Day Released to the system, is helpful to see if system performance is changing. Constructing a histogram of the different Total Flow Days helps the players understand the variability in predicting future deliveries. Figure 3 shows the first two completed Job Order Cards with their Total Flow Days marked with black dots on the trend plot and as black squares on the histogram.

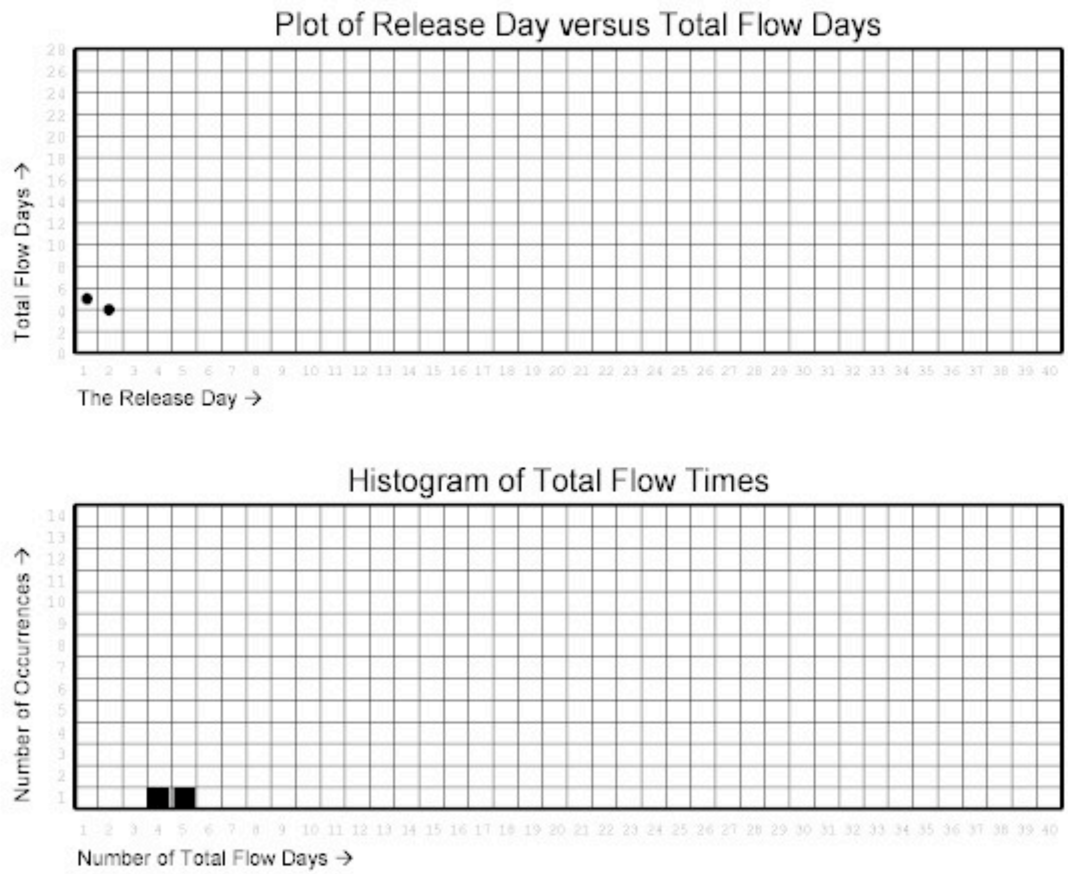

Figure 3. Plot of Trend and Histogram of Total Flow Days

2.4. Determining the Problem. Continue playing the Job Shop Game until Day 15. Ask: "How does the system look? What does the Plot of Release Day versus Total Flow Days and the Histogram of Total Flow Time show? When do you think the job to be released on Day 30 will be delivered?" At this point, the Plot and Histogram don't look too bad because almost half of the jobs haven't been completed and are not on the Plot. Let the group think about what is happening to the system and then move on releasing work each day until Day 20.

On Day 20, after the 20th Job Order Cards have been released, ask again: “How does the system look? What do the Plot and the Histogram show now? When do you think the job to be released on Day 30 will be delivered?” Have the group examine the system more closely. While the plot and histogram don’t look too bad, there is a serious problem with a back log of work at work center B. Have the work centers count how many B tasks are in the system. Figure 4 is a plot of a typical Job Shop Game where the releasing agent released one card per day for the first 40 days (all 40 Job Cards were released at one per day for 40 days), and then the game continued until all the 40 Jobs Cards were completed. Note the wide distribution of the Total Flow times. In this game, the Job Card released on Day 30 completed right on the dotted prediction flow line at 22 days (the Job Order released on Day 30 was completed on Day 52).

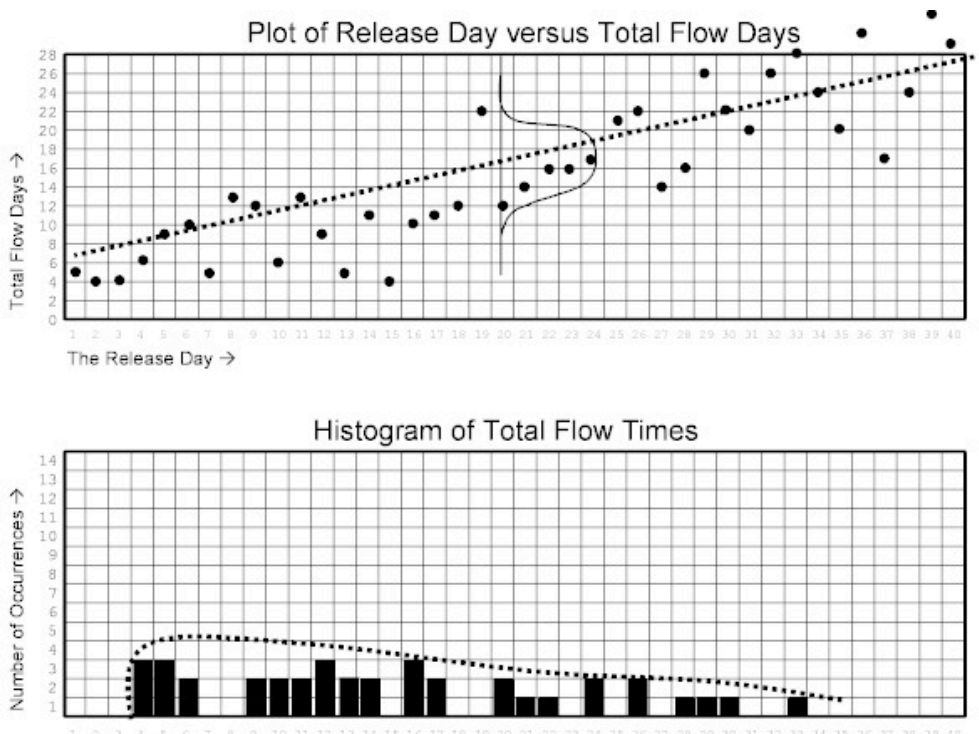

Figure 4. Plot and Histogram of Releasing On Job Card Each Day.

2.5. Learning Discussion. People learn best when they are in the middle of the problem they need to solve. Consider, “When will the job released today (on day 20) actually come out of the system?” If everyone treats it as an emergency, it could come out by day 25 but, if that happened, all the other work would have to wait. Lead a discussion on how to improve the system (for this discussion, work centers cannot do each other’s work). Ordering the type of jobs released can have only a temporary effect as, on average, the demand for the four types of products is about equal.

After some discussion ask, “If we continue to release new work every day, will we have more uncompleted B tasks in the system or fewer? Does it make sense to continue releasing more work into the system? And, if not, and we stop releasing new work, when should we start releasing work into the system again?”

2.6. Teaching Moment. Clearly, it makes little sense to continue releasing one new Job Order Card every day when the system is so back-logged with un-completed B tasks. The system Total Flow Time can only get worse and worse. We must chock back the release of work. Assign someone to act as CEO (an independent observer or one of the players –not B) to watch the system closely. Restart the game but do not release any new work on Day 21. Now, each day, ask the CEO if you should release new work or not. Continue playing day by day, each day asking the CEO the same question. Guide the group to help the CEO formalize the RULES FOR RELEASING new work or not. “What is the release of new work protecting? Why should it be protected? How should it be protected? What is the minimum protection necessary? How can we measure that (so the CEO doesn’t have to make the decision every day)?”

2.7. TOC Solution. The Theory of Constraints solution is to buffer the B work center without too much work but not too little. You can start with a buffer of 6 uncompleted B tasks released to the system. Each day before the Work Part of the day, count the number of empty boxes next to the B operations already released to the work centers; count all uncompleted B operations at all the work centers. If the number is 5 or less, release new work. If the number is 6 or more, do not release any work. This choking the release starting on Day 21 will block the release for some time. Eventually, the release of Job Cards will begin again. The release will be intermittent. The release will be at just the rate the B work center can complete B operations. While the queue of work moves all around among the work centers, B is always busy and never starved.

Figure 5 shows the dramatic change in the Plot and Histogram as a result of choking back the release of work[1]. In Figure 5, the Job Card released on Day 30 completes in 7 days or on Day 37. In fact, when the release of work is controlled, all future jobs can be promised in 8 days[2]. The shaded blocks in the Histogram show the very tight distribution of Total Flow Time with the chocked release.

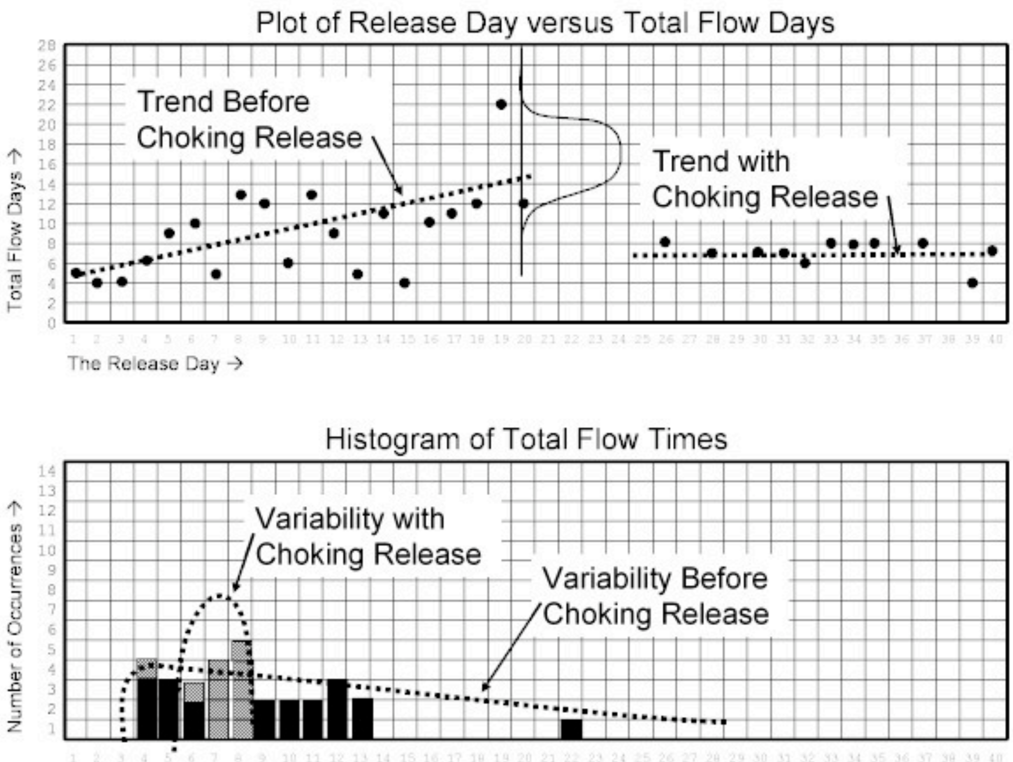

Figure 5. Dramatic Improvement in Total Flow Time and in Predictability of Delivery.

2.8. Summary. The results are clear. Discuss with your group the value of being able to predict the delivery of your Job Cards, and also the value of fast delivery to a customer. Consider the management improvement from knowing if you can accept new work or not (according to the

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[1] Choking back the release is called "Tying the Rope" in Drum-Buffer-Rope terminology.

[2] The Job Shop Game is deterministic. That is, there is no variability in the processes, only in the sequence of the cards released. Work center B is busy almost all the time. On average, there are six B tasks released every four days. So, the last card released will always complete at between 62 and 65 days. It is about the same completion time of the last card whether you release every day or choke the release (if you choke the release, the 40th card will be released about the 55th day). The real benefits from choking the release is the fast Total Flow Time, the predictable delivery date, knowing the real capacity of the system, and the ease of managing the system.

load on the constraint work center). More complete and advanced instructions for the Job Shop Game are available at: http://www.wsu.edu/~engrmgmt/holt/em530/JSGInstructions.pdf.

3. Sixes Game.

The Sixes Game deals with the problem of embedding too much safety in task duration estimates. In playing the game, the causes for embedding safety come to the surface. The impact of taking more aggressive estimates with a strategically-placed buffer dramatically changes the performance of the system as a whole.

The Sixes Game can be played quickly (about 20 minutes) or it can be extended to evaluate the impact of improved quality in the process.

3.1. Set-up. All that is needed is a fair die for each person in the game and a white board to display the results.

As part of the set-up, all the participants need to understand the performance of a fair die. Explain, "The fair die has six sides with dots ranging from 1 to 6 on the sides. Rolling the die one time gives a $1/6^{th}$ chance of showing any one of the sides. In the Sixes Game, we will each be rolling a fair die and trying to get a six. The probability of getting a six on the first roll is $1/6^{th}$. The probability of getting a six on the second roll is also $1/6^{th}$. The probability of not getting a six on the first roll is $5/6^{th}$ (or .8333). The probability of not getting a six on the second roll is also $5/6^{th}$. The probability of not getting a six on either the first or second roll is $5/6*5/6$ or $25/36^{th}$ (or .6944). The more times we roll, the chance of not getting a six gets lower and lower. We will surely get a six soon. But, how many rolls do you think it will take? Again, what is the minimum? What is the maximum number of rolls? What is the expected number?

"Since there is lots of confusion about how many rolls it will take to roll a six, let's just do a quick experiment to see what the process of rolling a six really looks like. Every one here roll your fair die and count the number of rolls it takes to get a six."

Plot the results of all the players. Make an 'X' mark for each player for the number of trials they reported. You will need at least 40 'X' marks to get an idea of how long it takes to roll a six. After plotting the first try, have everyone try to roll a six again for a second, third or more tries until you have at least 40 data points recorded on the histogram. Figure 6 is a typical histogram of 40 trials.

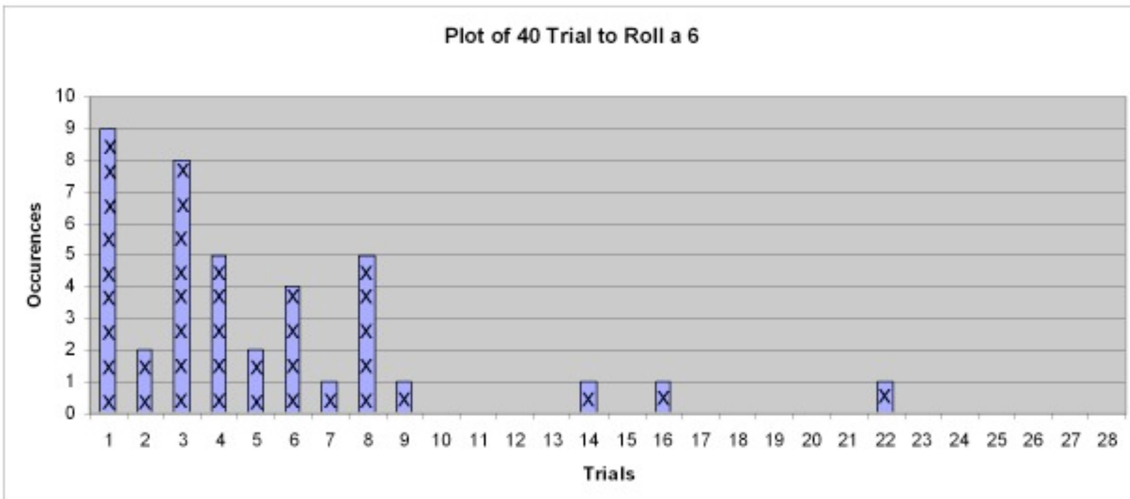

Figure 6. Histogram plot of the forty typical trials to roll a six.

Continue discussion about the shape of the histogram while you are plotting the data points after each round of trials. You can share, "It looks like rolling a six on the first roll looks to be the most likely outcome. There is a $1/6^{th}$ chance of succeeding. The other number of trials have less occurrences, Also note (as in Figure 6) there are several points (3 out of 40 for a 7.5% chance of exceeding 13 in Figure 6) that are a long way to the right. What do you think is the real maximum number of trials?[3]"

3.2 The Play. After the set-up, and drawing the histogram of trials similar to Figure 6, everyone is ready to estimate how long it will take them individually to roll a six. To make this realistic,

[3] Note to the leader of the Sixes game. During the Set-up period, everyone will be counting the rolls to get a six. Most will finish quickly (in six or less), but there will be the few who are having trouble getting a six. Point out the person having trouble. Make light hearted fun, "This person doesn't know how to roll dice!" Make sure everyone knows that rolling a six has nothing to do with the person rolling, "It is the SYSTEM!" Everyone there may have the same bad luck.

use a wager. Ask each player to put a sum of money on the table in front of them or to write the amount of their wager on a piece of paper (say $10 each). Tell them they are all working for you and you will pay them all $10 if they finish their job on-time. They are the ones who will estimate how many rolls of the die it will take to roll a six. They will determine what their 'on-time' time will be.

Ask the players what their estimate is. The answers may range from 1 to 40 trials, depending upon the individual player's perception of the taking risk of either earning $10 or losing $10.[4]

Explain, "All the players are in this together. So, we all need to use the same number to accommodate everyone." To make this easy, point to the histogram of the group trials you made, starting at the right side. Point at the highest number (say it is 22 like in Figure 6), "How many will play the game if you have 22 days to get a six (each roll counts as a day)?" Most, if not all hands should go up. Then, move to the left on the histogram and ask, "How many will play the game if you have only 21 days to get a six?" Continue sliding to the left asking the same question at 20, 19, 18, 17, 16 and so on. Most likely, some people will start pulling out of the wager somewhere when you get too low. Let's say that they start pulling out at 16 days. If the players don't have at least 16 trials to roll a six, then some of them won't play. Accept the group's level of comfort (16 trials or days) as the plan.

3.2.1. The First Round. Now, it is time to play the First Round of the game. Count the number of players in the group. Multiply the number of players (say 10) times the level of comfort (say 16 days) for a total of 10*16=160 days (we are assuming here that the work flows from one person to the next, and then the next, and so on, so it takes 160 days from start to finish).[5] To

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[4] The wager is similar to the risk a project management person faces each time they estimate their own task duration. An ethical person wants to deliver according to their promise. Delivering to promise is a reward, like receiving $10. Missing a promise is a disappointment, like losing $10. Individuals mentally make an estimation of what they can do to be successful. We will soon point out that the SYSTEM is the problem and even the best of players may not deliver to their promises all the time. In the end we hope everyone will ignore the estimate and work as hard as possible to meet the systemic goals.

[5] The Sixes Game works best with at least six players. If you have less than six, have each player act as two by playing the left hand and the right hand. There is no limit on the maximum

make the game faster, tell them you will count the number of days and they can all roll at the same time. Each person rolls once per day to see if they get a six. Once they get a six, they can stop rolling. The person leading the game counts the days from 1 to 16 as the players roll. After day 16 ask, "Has everyone finished? If yes, then the project completion took 16days time 10 people or 160 days. If not, then you have spent 160 days so far and need to continue counting until the last few players roll a six. Add those extra days on to the 160 days already consumed. The time to complete this first round then was 160+ days.

3.2.2. The Second Round. Now, let's play a Second Round, "Everyone willing to play again?" When they agree, tell them, "The previous customer was not happy. We took too long. He will only accept the project if we can deliver in 120 days (for this round everyone has only 12 days each for 10 people or 120 days). Do you think we can do it?"

Let the group discuss this. "Is it possible to complete in 120 days? If we only have 12 days to roll a six, some people will definitely not make it. So, if every one has only 12 days (10*12=120 days) and even one person is late, we will NOT make it. What should we do? Close the business? Or, give it a go?

"Since we can't decide with so much uncertainty, let's try it for practice, just to see what happens. Since this is practice only, put away your money (wager). We just want to see if it is possible."

Play this round the same as the First Round. Call out the days with everyone rolling once each day. After day 12, ask if everyone has rolled a six. Most likely at least one person will not have completed. Make it clear, "If everyone has their 12 days, and someone has bad luck and goes over 12 days, we cannot succeed."[6]

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number. The example here is based on ten players. You can do the math to accommodate any number of players.

[6] Note to Leader. If by some luck every one has finished by day 12, the accept the contract and try to deliver. There is a 50/50 chance that with ten people playing, someone will exceed 12 days. Most likely, you will not be able to consistently deliver in 120 days if everyone is given 12 days; someone will go more than 12 days.

At the end of the Second Round, the group has a pretty good understanding (while probably not verbalized) that most people are finishing much earlier than the maximum allowed time. They may even be telling you they can do better and don't need the full 16 or 12 days (they have too much safety). The third round will test their intuition.

3.2.3. The Third Round. Time for the Third Round. Continue the discussion. Help the group notice that a lot of the players finished very early (in 1, 2 or three days), yet we were counting them as using up 12 or 16 days. If we didn't have to give everyone the same number of days, we might do better. Be cause of the SYSTEM (the die), we can't control who will only have to roll for a few rolls and who will have to roll a lot of times. But, maybe the aggregate will be much less.

For the Third Round, let's remove all safety. We do this by just letting everyone roll and counting the days until they roll a six. After everyone has rolled a six, we add up the completion times of all players. The number will be amazingly low in comparison to the First and Second Rounds (for ten people, the Third Round is usually between 55 and 85 days). However, this Third Round has no safety; not a good idea.

3.3. The TOC Solution. Critical Chain Project Management recognizes that safety allocated to individual tasks is often wasted. CCPM takes the safe estimates and divides them in half. One half is allotted to the task; and the other half is aggregated with all the other safety removed from individual tasks. With the aggregation, only about half as much safety is needed. So, half of the aggregated safety is added back at the end of the project as a safety buffer. The result is a project delivery date that is 3/4th of the original schedule. With the task estimates cut in half, the project length is half as long, but it doesn't have much safety. Adding back half of the safety removed (that's one half of the time removed from the tasks), the result is a project target completion date that is 25% shorter and yet highly likely (95%) to succeed.

To test the TOC Solution, let's return to our safe estimate of 16 days per person. If we cut the 16 days in half and give each person only 8 days to complete their task, many will be late. To protect the SYSTEM of many people trying to roll sixes using fair dice and taking more than 8 days, we will add 50% of our safety back in at the end. In other words, with 10 people, we give each task 8 days to complete their task. That is 10*8 =80 days. We removed 80 days of safety from our earlier 160 day estimate. We will now add back half of the safety removed (80 days of safety *50% =40 days) for a total of 80 days of tasks and 40 days of safety. We expect to complete the project in 120 days or less 95% of the time.

3.3.1. The Fourth Round. For this round, we will test the CCPM solution described above. We will give each player 8 days. If they are late, we will add all the late days to the project.

Count the days as in the First Round. Everyone rolls the dice once each day. After day 8 (80 days for 10 people spent so far) find out how many players have not rolled a six. From this point, add each additional day rolled by those still rolling (one day per person rolling) to the 80 days. Continue counting days until all the players have rolled a six. Total the number of days. The total number of days will be well below 120 days (there is a 5% probability of exceeding 120 days).[7]

After the success of the Fourth Round, ask the question, “Wow, that was great! I wonder how low we can go? For the Fourth Round we started at 16 days from the First Round and cut them in half to 8 days and did well. Remember back on the Second Round where we started with only 12 day estimates. What would happen if we cut those estimates in half to 6 days? Would that work?

“Let’s give it a try. Everyone will have only six days to do their task. That will be 10*6 or 60 days. We will add a systemic buffer of ½ expected duration to protect the system. If we plan 60 days, the systemic buffer (project buffer) will be 30 days or a total of 90 days. Let’s play.”

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[7] Note that in this round the minimum time would be 80 days (ten players allowed 8 days each). While this is not the preferred way of CCPM, the Sixes Game is trying to gain cooperation from people to give up their safety. Allowing 8 days to roll a six is still a lot of safety. Playing the game with multiple rounds incrementally moves the intelligent player to understand how the SYSTEM needs the safety, but individual tasks do not.

3.3.2. The Fifth Round. For this Fifth Round, count the days as before. After day 6, ask how many have not completed. Count the 60 days for everyone who has worked so far. Then, continue counting for those who have not rolled a six yet. Add one day per player rolling each day. Continue rolling until all players have rolled a six. You will be less than 90 day 95% of the time.

3.4 The bottom-line. When protective capacity is spread through every individual task, we lose the benefit of aggregation. By individuals yielding even a portion of their personal safety, and by putting a portion (50%) of that safety at the strategic location (at the end of the project), tremendous reduction in project durations happen WITHOUT CHANGING THE SYSTEM. We are still rolling a six sided die.

For the benefit of the leader, the theoretical distribution of the number of expected success per day (the generation of the Histogram discussed above) is shown in Figure 7.

Figure 7. Histogram of the Number of Rolls to get a Six.

Figure 7 shows the probability of having a success on any one of the trial days. What is more important to a project manager is the inverse, the number of days it will take to complete a task. Figure 8 Shows the distribution of the number of trials (days) it will take to roll a six. While the mode is between 5 and 6, the long tail to the right pushes the median to about 9 and the mean over 10. This distribution in Figure 8 is the same as a Beta Distribution with alpha=.8 and beta =.9 from 0 to 29.[8]

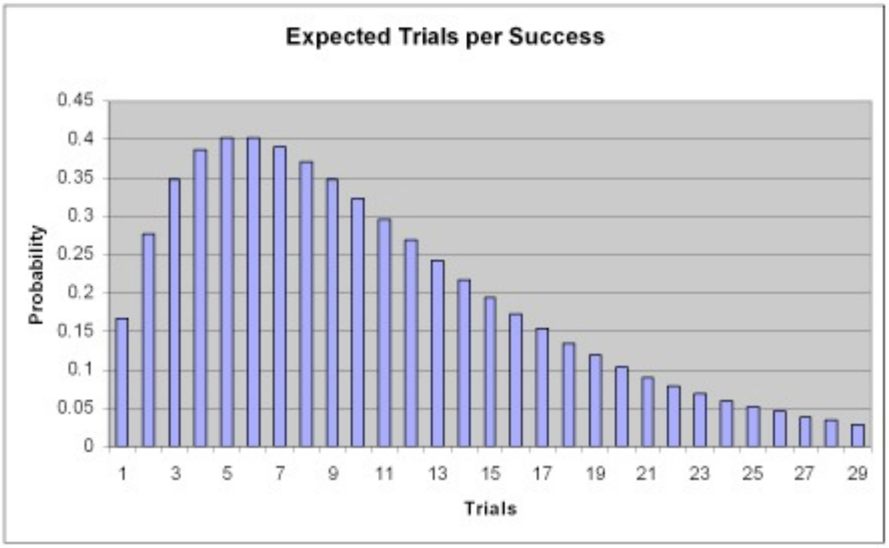

Figure 8. Distribution of the Expected Number of Trials to Roll a Six.

3.5 An Additional Discovery. After playing the Sixes Game for these many rounds, the group may still wonder if there can be more improvements. While CCPM does dramatically reduce the project completion times, there is another improvement that can be easily modeled using the Sixes Game.

In CCPM, there are many things that improve the first pass yield in a task. The absence of bad multi-tasking (distractions and delays) improves first pass yield. Having everything needed available before having to start a task, improves first pass yield. Not having a mandatory completion time reduces the number of problems passed on from task to task. Communicating Time Remaining and getting additional resources for help when needed also improve first pass yield.

In most mature CCPM groups, using CCPM improves the first pass yield on individual tasks. CCPM changes the underlying distributions of the SYSTEM. We can mimic this change in the Sixes Game by improving the probability of rolling a six. By ignoring a 1 (not counting the roll

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[8] It is interesting to note that the Beta Distribution (the distribution used for typical project tasks) is really the same as a repetitive effort to succeed with a low first pass yield.

if a 1 is rolled), the probability of rolling a six jumps from 1 in 6 to 1 in 5 or from 16.6% to 20%. While this may not sound like much improvement, what happens is that the long tail to the right is cut off. The probability of taking a really long time to roll a six is dramatically reduced. Using the revised 5 sided die, a group of ten players can reduce their planned task duration time to 5 days each or for 50 days total for all ten and a 25 day buffer to complete 95% of the time in 75 days.

Further improvements (going to a four sided die by ignoring both 1's and 2's) can even shorten projects even more. As the system gets better and better, task durations can shorten. When this happens, always retain a project buffer of at least 50% of the task estimates. Additional information about the Sixes Game is available at:
http://www.wsu.edu/~engrmgmt/holt/em530/SixesGame.pdf.

4. The Assembly Game.

In the Sixes Game, we discussed a long chain of players each trying to roll a six. We learned a lot. There is another part to projects that also requires our attention: Assembly. Projects always have sub-projects or feeder chains of activities. Often, there is a situation (such as at a milestone) when many, many things must all come together at the same time. CCPM does an excellent job of providing just the right amount of feeder buffer for feeding chains. And, CCPM does it in such a way that the feeding chains offer even more protection towards the end of the project where is it needed the most (see the advanced applications of the Sixes Game).

But, there is still something to be learned about the effective allocation of limited resources to the project tasks. How should this be done? When should it be done? What kind of benefits does it provide?

This time, we will play the Assembly Game. It only takes about 10 minutes.

4.1. Set-up. The Assembly Game is easy to play. All you need are six players with two coins each[9]. In the Assembly Game, the six players will each do their own task with the goal of making an Assembly at the end of day six.

4.2. Instructions. In the Assembly Game, each player is given a task. They are to finish that task so the Assembly can take place. All six players need to complete before the Assembly can happen. The Assembly is planned to happen immediately after day six. If the Assembly happens on time, the group receives $100,000 for a delivering a successful project on time. For each day late, the group receives $20,000 less (that is $80,000 for delivering on day 7, $60,000 for delivery on day 8, and so on).

4.3. The Task. Each player has two coins. Each player can flip one coin each day of the game. The task is to flip the coins (one a day) until two heads are flipped. After flipping the coins with the results of two heads, the task is complete.

The probability of flipping a fair coin resulting in the head side up is 50%. The probability of not getting a head is also 50%. Getting two heads in a row is $0.5 * 0.5 = 0.25$. There is a 75% chance of getting exactly one head or no heads. The object of the game is to have two heads. What are the odds of a single person flipping coins to get two heads in six days or less? This is getting complicated. Figure 9 is the distribution of 500 attempts to flip two heads. There is about a 90% chance for an individual flipping coins of obtaining two heads in six days or less. Rarely, it will take more than six days.

[9]If you don't have six people, use six different denominations of coins. Have two coins of each denomination and they can become the six players.

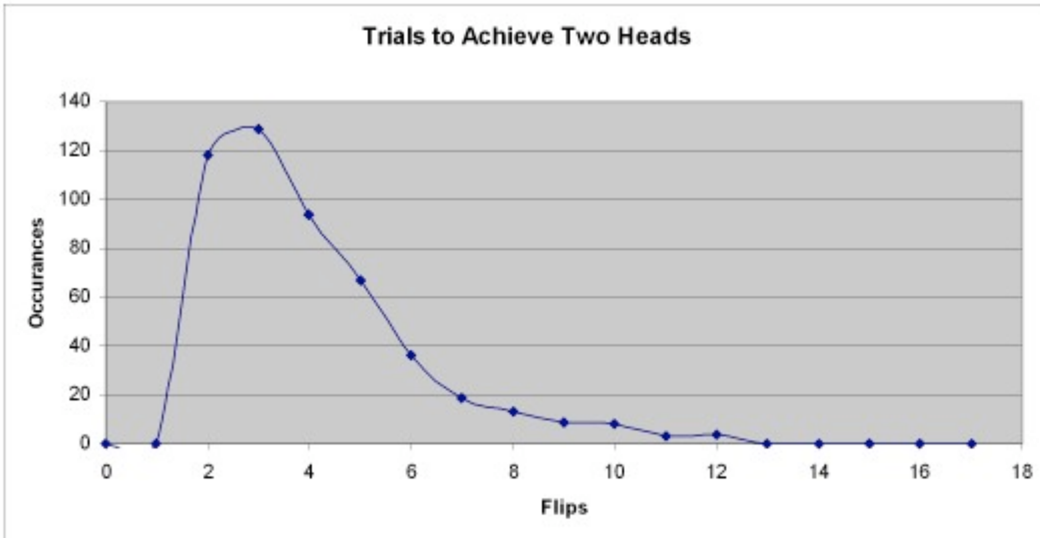

Figure 9. Distribution of the Number of Flips to Obtain Two Heads from 500 trials.

4.4. The Play. Bring the players close together so they can see each other. The leader calls out the number of the day. On the first day, some players will flip a head. On the second day, you may have a player flip a second head. Once a player has two heads, they don't need to flip any longer. Keep calling out days until all players have two heads or it is Day Five. After Day Five, make a big deal out of the Day Six flipping, "This is IT! We either make good money or lose our profit all on this roll. We have spent $80,000 doing this project. If all six of you have each flipped two heads on day six, we will make $20,000. If we don't, the most we can hope for is to recover our costs by completing on Day Seven. OK! Here it is, Day Six."

Evaluate the Game after Day Six. Did you earn the $100,000? If so, you made $20,000 and can play again! If not, then play to Day Seven or longer if needed. Realize that if it takes Day Eight or longer, you are losing money. Maybe you should not be in this project business. Figure 10 shows the results of 100 trials of six people trying to make the Assembly by flipping coins. About 50% of the time, the Assembly can be made. Note that there were four times in 100 that it took more than 9 days!

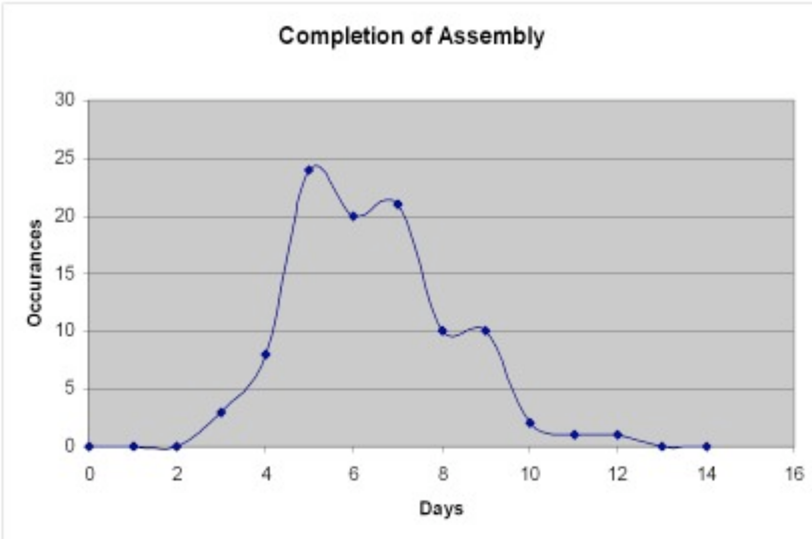

Figure 10. Assembly Day Results of 100 Assembly Games

Play the Assembly Game a few more times so everyone understands the problem. It is not an individual player who has trouble flipping coins to get heads, it is a system that requires sometimes many tries to get two heads. And, it is the system that requires everyone to complete on Day Six. In general, 50% of the time, the Assembly will be late, 20% of the time, it will take 8 or more days. To be 95% certain of completing, you need 10 days of flipping coins.

4.5. The Feeder Buffer Solution. When there is an Assembly, CCPM separates the Assembly by pushing all but one of the Assembly tasks to start earlier in time. CCPM adds a feeder buffer of 50% so the earlier tasks will have a good chance of completing before the last single task is completed. Figure 11 shows how the Assembly Game is modified to insert the feeder buffer. Let's assume it is actually possible to push five of the tasks back in time to begin Day Minus Three.

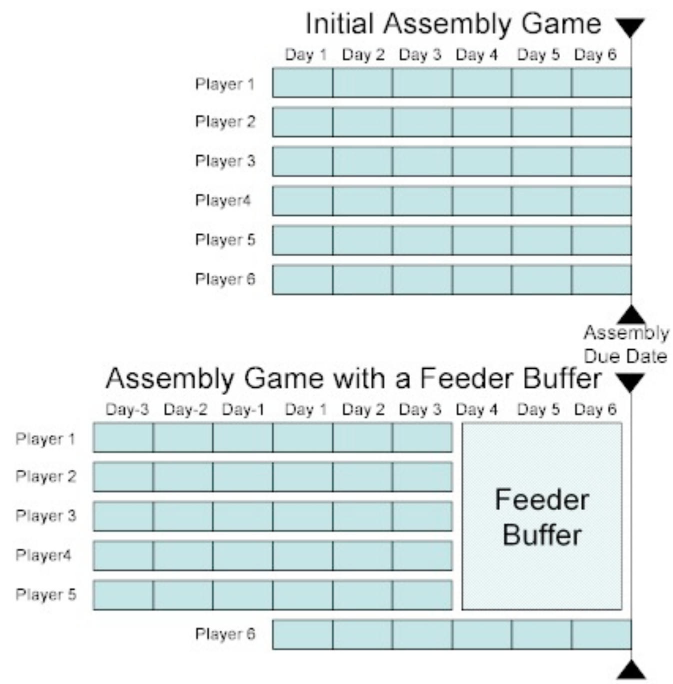

Figure 11. Changing the Assembly Game to Allow Feeder Buffers.

Playing the Assembly Game with a Feeder Buffer necessitates players 1, 2, 3, 4 and 5 to begin on Day Minus 3. Play this scenario and see how well the group does. Clearly, players 1 through 5 have a better chance of flipping two heads by Day Six (They have nine days to do it).

What did your group achieve? If they made the $100,000, then play again. See if it was just random chance or if they can actually make the Assembly after Day Six most of the time. Most likely you will. There is an 85% chance the group will complete by the Assembly Due Date. But, there is a 15% chance you will not. Figure 12 shows the typical results of 100 Assembly Games using the CCPM Feeder buffer technique. Notice there were many more early completions, but there is still a tail to the right. While not specifically shown 10% of the time the completion date for the Assembly was determined by one of the five early start tasks that finished after Day Six and after Player 6.

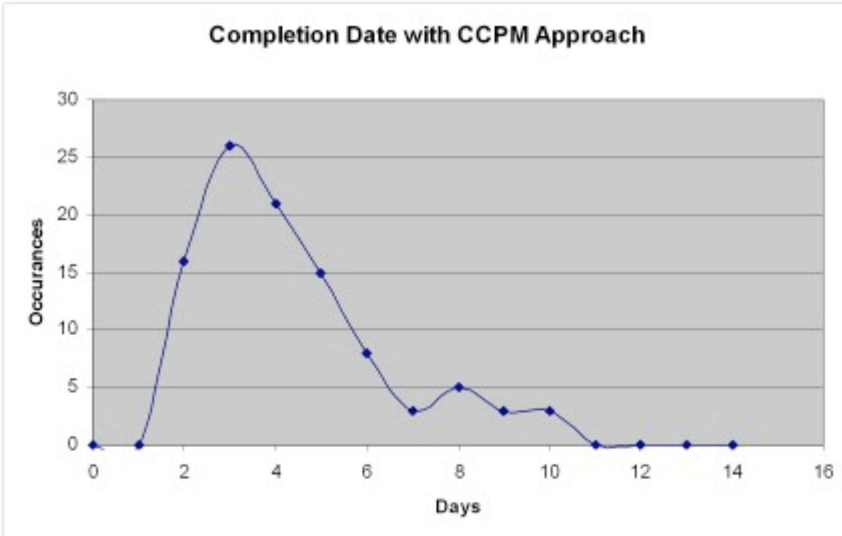

Figure 12 Distribution of Completion of the Assembly with the Feeder Buffer Approach.

The CCPM Feeder Buffer helped a great deal. If we had a full project, and not just these six tasks, there probably would have been enough protection elsewhere in the project to protect the 15% of the time the CCPM Feeder Buffer approach was late.

But, what if the Assembly Game is your job? What if you have to do the six parallel tasks in the Assembly Game, and you cannot offset five of the tasks by three days? What can you do then?

4.5. The Resource Bench. Let's consider another option for management of our resources. In most cases where pressing work is required, the most expert people are assigned to the difficult tasks. This would surely be the case in the Assembly Game where delivery on Day Six was essential. In such pressing environments, the novice person rarely gets to participate. This can be a real problem when there are many novices and few experts. How will the novices learn? What will happen when the experts are not available or retire? Is there any way to improve the system when the experts are all so busy they don't have time to evaluate the SYSTEM and find what is causing the problems?

Let's consider a counter-intuitive solution. It's called the Resource Bench. In general, the Resource Bench is a reserve work force that is not normally involved in the day to day work. The Resource Bench is made up of about 20% of the work force. They are the best experts. In terms of the Assembly Game, one could say, “A real expert can flip a coin and get heads 80% of the time!” To make it easy in this Assembly Game, we will have the Resource Bench made up of just normal people who flip coins at 50% heads. Also, we will use two persons on the Resource Bench (for 33% rather than 20%).

The Resource Bench has several responsibilities. They watch the SYSTEM and see what is going right and what is going wrong. They use their expertise to figure out how to improve the system. They are also responsible for applying their expertise, but only participate in routine activities at the time when their expertise is essential. They are also responsible for training the novices.

There are several problems. The experts have a hard time holding themselves back from doing the urgent work and, they don’t like spending too much time training novices.

4.6. Managing the Resource Bench. Figure 13 is a pictorial representation of the Assembly Game with the Resource Bench added. The Resource Bench is placed along side the regular work. In this case, there are six players who are playing the Assembly Game. The Resource Bench has no assignment during the first three days of the Game.
Beginning on Day 4, the two members of the Resource Bench (who each have one coin), can join any one of the players, 1 through 6, who has not yet flipped two heads.

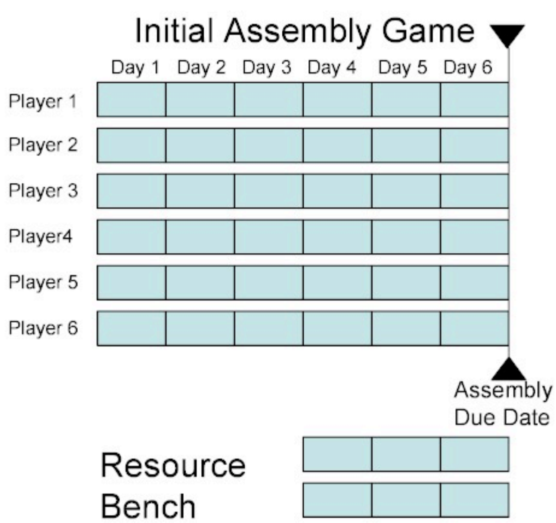

Figure 13. The Assembly Game with the Resource Bench Added.

4.6.1. Time for Analysis. During the first half of the expected task time for players 1 through 6, the two persons on the Resource Bench observe them. They have three days to see the methods, processes, good and bad things happening with the normal players. The two on the Resource Bench can analyze the problems and decide how to make improvements.

4.6.2. Just-in-Time Training. Beginning on Day 4, one person from the Resource Bench will join one of the players from 1-6 who is having trouble flipping heads. At that time, the player is anxious to learn and has some experience with the problem. The player is ready to receive additional guidance and learn quickly. The person from the Resource Bench can easily and effectively teach the exact principles and techniques that the player needs at a time when the player really needs it and can learn the most in the least time.

4.6.3. Trimming the Right Side Tail. Beginning on Day 4, the person from the Resource Bench joins a player in need and, together, they now flip two coins per day (one coin from the player and one coin from the Resource Bench person). For this simple Assembly Game, we will assume the Resource Bench has the same probability of flipping a head as the regular players. The probability of both the player and the Resource Bench person flipping tails on one day is $0.5*0.5=0.25$. That means there is a 75% chance that one or the other (or both) will flip a head. The Resource Bench person stays with the player until the player's flips and the Resource Bench's flips add up to two heads for that player. Then the Resource Bench person is available to work with another player in need. Figure 14 shows the distribution of dates of Assembly resulting from having a Resource Bench of two persons are available to assist with the routine work being done by the six players on Days Four, Five and Six.. There is a better than 90% chance of completing the Assembly on Day Six.

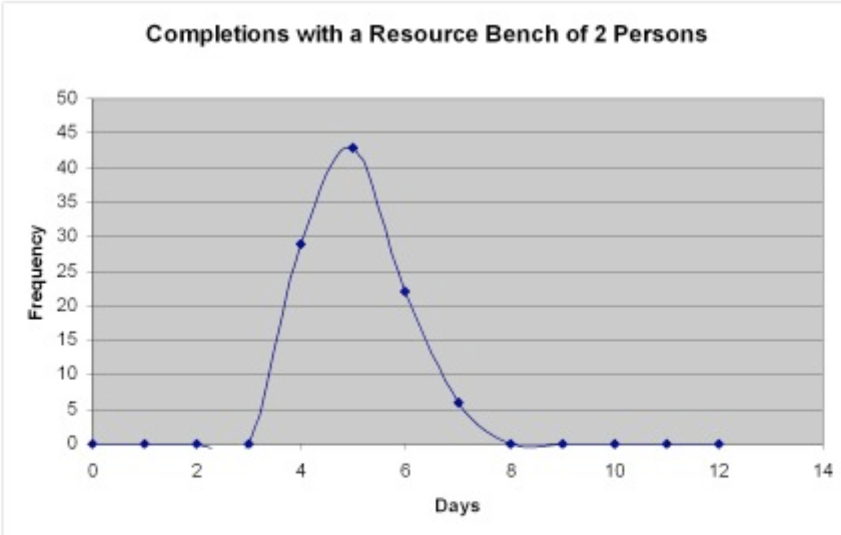

Figure 14. Distribution of Assembly Days with Two Persons Assisting from the Resource Bench.

The results with having two additional resources available on the Resource Bench, as shown in Figure 14, are markedly different than the results with players 1 through 6 working on their own as shown in Figure 10. It is worthwhile to note that while the Resource Bench could have been used with two persons for three days for each of the 100 Assembly Games played with the Resource Bench available, as reported in Figure 14 (that is the Resource Bench was schedule to be available for 2*3*100 = 600 days of potential contribution to the players), the Resource Bench actually participated with the players for only 350 flips (just over 50% of their scheduled time). This means that the Resource Bench, while they really did contribute to a significant improvement in on-time Assembly, were really occupied in flipping coins only about 25% of the time. That is, 75% of the time, the Resource Bench was available for process improvement. Those on the Resource Bench should be those with the most experience and expertise.

4.6.4. Assembly Must Be Made On Day Six. What happens if we are in a situation where Assembly absolutely has to be made on Day Six. The Resource Bench, as good as it was, is not enough. What else could be done? Well, there are some of the players 1 through 6 who were lucky and flipped their two heads early and were not flipping for the whole six days. Perhaps they could help. This is called the Full Bench Press.

4.6.5. The Full Bench Press. While the Full Bench Press is not recommended[10], it may be needed from time to time. In the Full Bench Press ALL players 1 through 6 flip a coin every day for the full six days. If any player completes his two heads early, then that player can join any other player who has not yet completed two heads. In other words, each player acts as a Resource Bench asset, and they can do it even on Day Three (if they flipped two heads on Day One and Day Two) when the Resource Bench is not scheduled. The Resource Bench acts the same way in the Full Bench Press as it did previously; they observe for the first three days, and are scheduled to assist with the last three days. Figure 15 shows the distribution of Assembly times under the Full Bench Press approach.

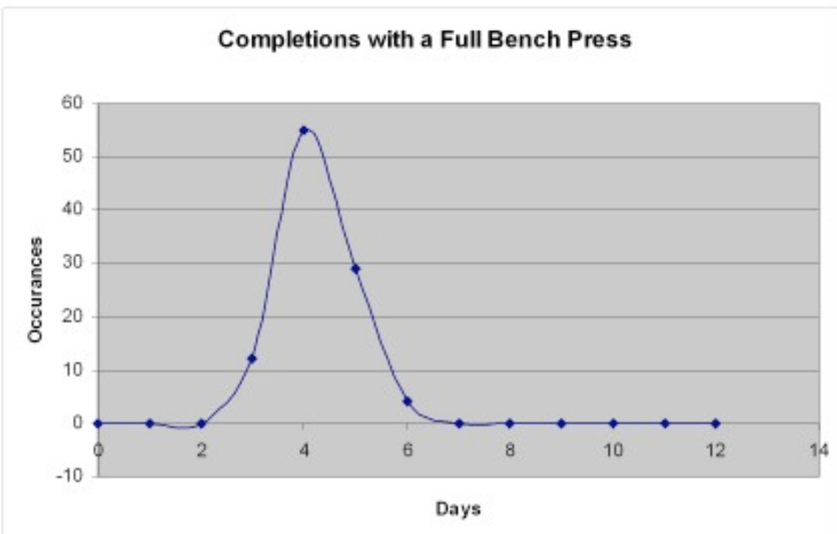

Figure 15. Distribution of Assembly Completion Times under the Full Bench Press Approach.

In figure 15, 100 Full Bench Press Assembly Games were played to produce the distribution. In testing this approach, about 1 time in 1000, the Full Bench Press completed the Assembly after Day Six. This is virtual certainty of completion on Day Six or before. Of the 600 days the Resource Bench was schedule to be available for the 100 Assembly Games reported in Figure 15, the Resource Bench actually flipped coins for only 250 days. Again, the Resource Bench was available about 75% of the time to continue their focus on systemic improvement. More

[10] Working people continuously for any period of time degrades their capability over time. While a pit crew can work miracles on a car in seconds during a race, they can't work at that rate for an hour.

information on the Assembly Game is available at
http://www.wsu.edu/~engrmgmt/holt/em530/Assembly.pdf.

5. Final Note.

Dr Holt has found these simple games invaluable in teaching systems theory. Please use them with reference to the source. There are many different ways to modify and expand the applications of these games. They work as well teaching Boy Scouts or teaching Rocket Scientists; although the teachers approach does make a difference.

If you find an interesting adaptation and would like to share it with the rest of the world, please contribute it in written form to jholt@wsu.edu where it can be added to the library of excellent ideas. Include your name and contact information is you desire credit for a new discovery.

Keep Thinking!
Dr Holt