

Enhancing the Construction Parade of Trades Game

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An enhanced version of a learning exercise used in construction education is discussed in this paper. The Parade of Trades is a powerful learning tool showing the effects of dependency and variability in consecutive trades operating in a construction project. It has been commonly used to illustrate Lean Construction concepts, and implemented as a hands-on game without computerized elements. This manual approach has drawbacks such as a lack of mechanisms for expediting the game or falling back in case of player error. These limitations are minimized in this enhanced version, which incorporates software that can replicate and expand the manual game. It allows a wider range of playing possibilities and the collection of useful statistics that would be impractical to track or calculate during the discourse of the traditional version of the game.

Key Words: Construction education, educational games, lean construction, Parade of Trades game.

Introduction

There are significant differences in the effectiveness of the various teaching tools available to an educator. While lecturing and reading yield average learning retention rates of 5% and 10% respectively, practice by doing results in an average of 75% retention of the covered material (Weber, 2009). Games are excellent active learning tools for any instructor, and yet they tend to be the exception and not the rule in the teaching of higher education.

Computers are ubiquitous in education and in society in general, providing the means to explore possibilities that are impractical or impossible to address otherwise. But, developing a game that can convey the essence of a scenario in a teachable and enjoyable fashion is a difficult pursuit (Prensky, 2001). The quality of an educational game is manifest when it is used across several industries for over a decade and in groups ranging from field trades to seasoned professionals. This article centers on one of such cherished tools. The introduction of the computerized aspects discussed here has been done incrementally, expanding rather than replacing its traditional rules. This approach recognizes that for any individual a hands-on experience is an important component of learning-by-doing, and should be preserved as much as possible.

Objective

This paper describes an enhanced version of a popular game called The Parade of Trades (Tommelein et al., 1998) used to simulate the effects of dependency and variability in a construction project. Although its insights are applicable to any type of sequential performance, the game is commonly used by construction educators and trainers to explain core concepts of Lean Construction. Traditionally the game has been played manually, i.e. without any computerized component. The term *manual version* will be used throughout this article to describe the traditional form of the game, in contrast to the software-enhanced version described here.

The Parade of Trades is well discussed in the literature (e.g., Tommelein et. al, 1998, 1999a, 1999b, Ballard and Howell, 1998, Alarcon and Ashley, 1999), and therefore this paper discusses its traditional rules only to the extent necessary to understand the scope of the present enhancements.

Background

A construction project requires the sequential performance of multiple trades, in what has been called "a parade of trades" (Tommelein et al, 1998). A foundation requires of general excavation, which is followed by structural excavation, then by carpentry, then by reinforcement, then by concrete, and so on. Each of these steps is performed by different trades, using different tools and even working for different contractors. Each trade depends on the output of the previous one, both in defining its timing and the number of units ready for work.

As an example, consider a large subdivision with 5 trades performing the sequence of tasks described in the previous paragraph. Suppose that each trade can complete 5 units per week on average, but that this capacity can vary between 3 and 7 units per week. If the general excavation trade (Trade 1) completes 7 housing units in the first week, the structural excavation trade (Trade 2) can complete up to (and no more) than those 7 units until more are made available by its predecessor in subsequent weeks.

But, what happens if Trade 2 completes 3 units due to its inherent variability in production capacity? Trades 3, 4 and 5 will not be able to work on more than those 3 units, regardless of their production capacity. This strangling effect is cumulative. Trade 4's output is constrained by the minimum capacity achieved by any of the previous 3 trades, and Trade 5 will be constrained by all preceding 4 trades. Each trade increases this strangling effect to the trades following it in the parade. The excess capacity is wasted, and consequently the cost of the operation increases for the trade.

Understanding the behavior and implications of sequential, linked production has been of interest not only to the construction industry but also to the manufacturing industry, where several simulations and games have been used to teach these concepts (Hilmola, 2006; Johnson and Drougas, 2002; Lambrecht et al, 2010; Umble and Umble, 2005). These games are similar to The Parade of Trades, although the scenarios and vocabulary are adjusted to the continuous assembly of parts typical of a manufacturing plant. E. Goldratt is widely credited as having first addressed the topic of sequential variable production in his management novel *The Goal* (Goldratt, 1992). The novel describes the scenario in a way that eventually inspired games such as The Parade of Trades.

Traditional Game Setup

A version of the Parade of Trades was developed and played by Greg Howell at the University of New Mexico as early as 1994. The most widely circulated form of the game has been discussed by Tommelein, Riley and Howell (1998) and Alarcon and Ashley (1999) among others. Variations and improvements have been introduced in the ensuing years, especially as implemented by the Lean Construction Institute for its training. However, the original basic setup is still in use and is valid for this discussion.

The traditional, manual game is played in rounds ("weeks") using groups of 5 members. Each member represents a sequential trade. A relatively large number of coins ("units"), for example 100, are sequentially processed by the 5 trades. Each trade processes each week the number of units determined by its production capacity for the week or the number ready for processing, as discussed below. Figure 1 shows the game setup.

The weekly production capacity of each trade is simulated by the throw of a specially marked die containing only two numbers such as 4 and 6 or 3 and 7 (3 faces marked with one number and the other 3 with the other) instead of the normal range from 1 to 6. Even though both instances yield the same average throw value of 5 (i.e., (4+6)/2 and (3+7)/2), the higher variability of the latter amplifies the bottleneck effect previously discussed.

Each round, or "week", is played by each trade by first determining its production capacity for the week by throwing the game's die. If a 3/7 die is used, the capacity for a week will be 3 units or 7 units. Assume that Trade 1 throws a 7 in Week 1. The player takes 7 units from the initial pile at its right and places the units in the pile to its left. The 7 units will be available for processing by Trade 2 in Week 2. When Trade 2 finds its weekly capacity by throwing the die, one of the following cases will apply.

1. If Trade 2 throws a 3, it will pass 3 coins to its left (i.e., Trade 3's inventory pile). The remaining 4 coins will be available for next week (Week 3), in addition to the coins passed by Trade 1 in the same Week 2 after Trade 2 has played.
2. If Trade 2 throws a 7, it will pass all coins to its left. The only coins available for Week 3 will be those passed by Trade 1 in Week 2.
3. For the remaining case, assume that Trade 1 throws a 3 in Week 1, and then Trade 2 throws a 7 in Week 2. In such case, Trade 2 has more capacity than available units. It will pass all units in its inventory (3) to the left and will waste the possibility to use the excess capacity of 4. In the real world, this mismatch would be costly for Trade 2.

The logic of the game requires that each week the die moves sequentially from Trade 5 to Trade 1, even though the units move from Trade 1 towards Trade 5. The game ends when all units have been processed by all trades, i.e., placed in the output pile of Trade 5 as shown in Figure 1.

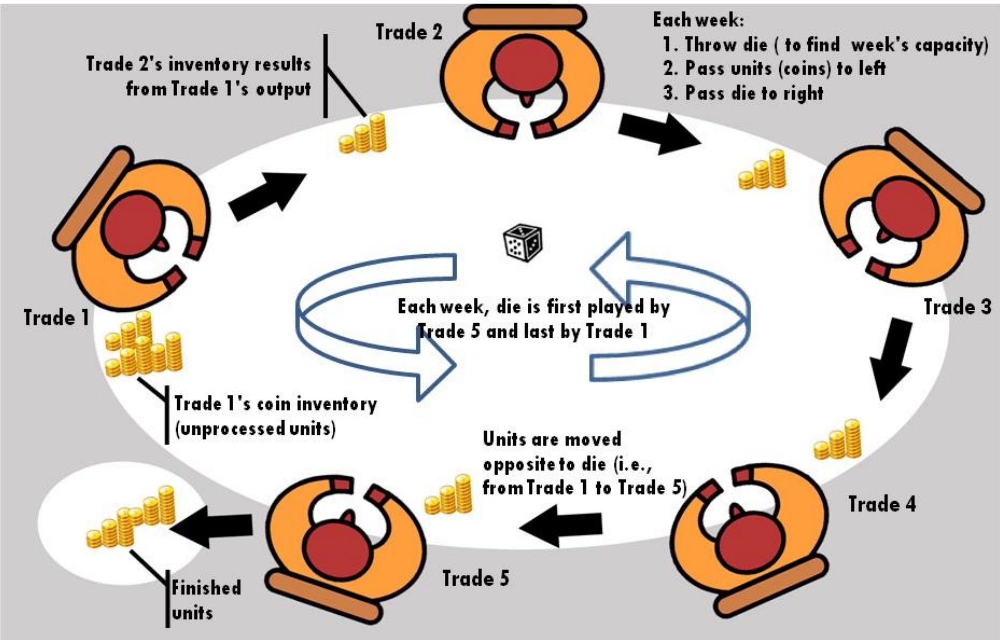


Figure 1: Traditional game setup

The final discussion of the game's results and its underlying theory are fundamental to its usefulness as a teaching tool. Participants are usually conscious of the increasing performance impairment created by the output variability of each preceding trade, but the differences created by the type of die used in the various groups can be surprising. The discussion of management implications and possible improvements make this game a memorable experience for its players. The Parade of Trades is frequently described by participants as transcendent to their comprehension of the need to stabilize productivity and to shield individual trade productivity as much as possible.

Drawbacks of the Traditional Manual Game

The Parade of Trades has been successfully played for more than a decade in its traditional form, which does not include a systematical computerized component other than ad-hoc presentation slides developed by trainers wanting to expedite the explanation of the game's rules. The game has been simulated by Tommelein et al. (1998, 1999) using Stroboscope (Martínez, 1996) and by Alarcón and Ashley (1999) using @Risk (© Palisade Corporation, Inc.). Choo and Tommelein (1999) developed a stand-alone simulation of the game that closely follows the input and output of the manual game. These software tools could be accommodated to become part of the game. However, they have been used primarily for discussing the statistical aspects of the game, and have not been made part of its flow.

There are significant drawbacks resulting from playing the Parade of Trades only by manual means. Although many of these limitations are applicable to any hands-on, computer-free game, the following list of drawbacks helps to understand the advantages of the enhancements presented here. Limitations of the manual version of the game include:

- *The mechanics of the game can be difficult to explain*. This is especially true for the first rounds of the game. As mentioned above, while the coins move from Trade 1 to Trade 5, the die must proceed each week from Trade 5 to Trade 1. The reasons for these opposite directions become clear after playing a few rounds, but they may appear counterintuitive at first. It is common to play a few practice rounds to explain the game's rules, lengthening the total time required for the game.
- *Players can make mistakes compromising some of the game lessons*. Each player keeps track of the capacity drawn by the throw of the die, passed coins and remaining inventory. It is relatively common to find at the end of the game that, for example, the number of coins accounted by one or more players does not add up to the actual number of coins used for the game, among other tracking mistakes.
- *Relatively large groups are needed for statistical insight*. To show the effect of the variability level, at least two groups are required, one playing with a die of small variability (e.g., 4/6) and the other playing with one of larger variability (e.g., 2/8). To account for chance in the results, at least two groups should use the same type of die. In summary, at least 15 persons (in 3 groups of 5) are required to obtain meaningful results. This is even more significant when 7 consecutive trades are used, as described in the next section.
- *The game must be played in its entirety to be meaningful*. A 100-unit game using a die marked with an average of 5 requires at least 25 weeks of play. The last 10 or 15 weeks add little to the understanding of the underlying principles of the game, and yet a game left before passing all coins would be essentially meaningless. This limitation has been addressed in recent variations of the game by reducing the amount of coins to pass, as described in the next section.
- *There is a lack of fallback strategies for mistakes or problems*. Mathematical mistakes are only one of the many mishaps that can happen during the game. For example, a player can shake the playing table or need to leave the room.

Traditional Game Evolution

The manual, non-computer assisted version of the game described so far has evolved over the more than 10 years of continuous use in higher education and professional training. These evolutionary changes, which do not appear to have been scholarly documented, do not contradict the points discussed in this paper. Differences with the original version described by Tommelein et al. (1998) include:

- *Trades are more commonly described by name, instead of simply assigning numbers to each one*. Trade names such as Concrete, Mason, Façade and so on can assist in framing the scenario mimicked by the game.
- *Seven consecutive trades are used, instead of 5*. The total capacity of the system and other statistics commonly kept now are proportional to the number of players, and the higher number of trades makes clearer the contrast between various die types.
- *Only 35 units are processed, instead of the 100 or 50*. This lower number is offset by also using dice with a lower marked-face average. The traditionally used average of 5.0 resulted from dice marked, for example, with 4s and 6s or 3s and 7s. The newer dice have an average of 3.5, and are marked with, for example, 3s and 4s or 2s and 5s. Some dice have more than 2 face values, but keep the same average of 3.5.
- *Forms have been simplified and tailored to each trade position*. For example, Trade 2's customized tracking form does not have a line to fill for Week 1, since the first week that it can play is Week 2. Group summary statistics have been similarly tailored and simplified.

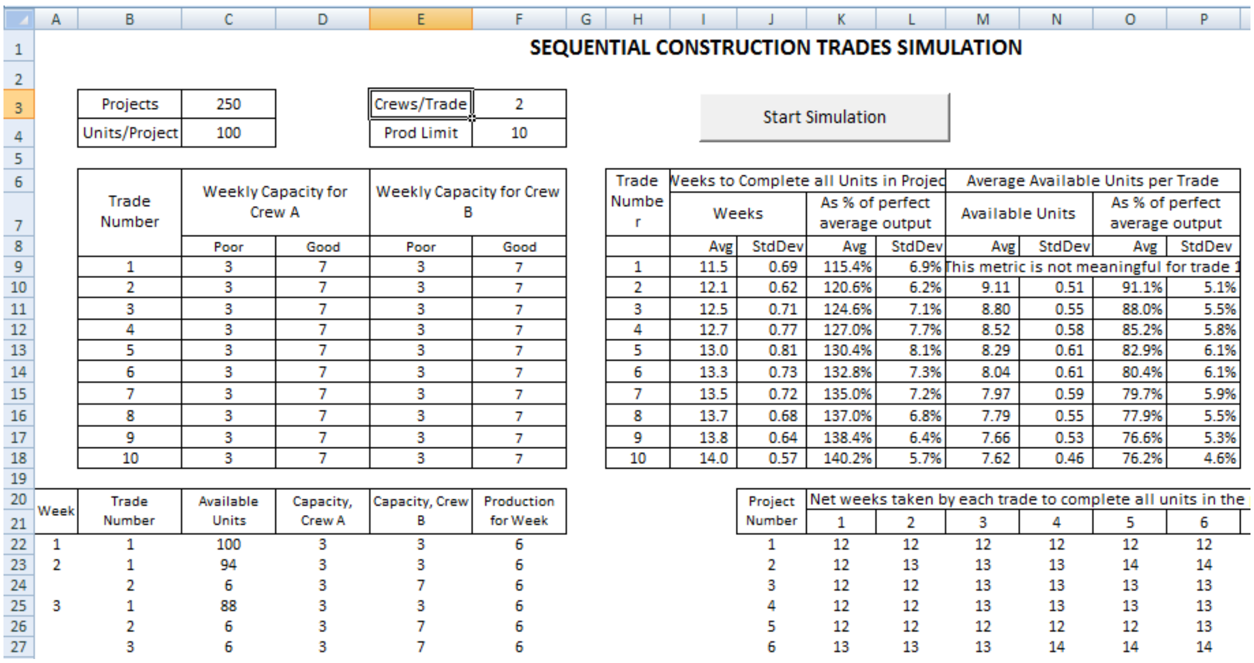
Software-Assisted Game Enhancements

Many of the current limitations of the manual game discussed so far can be improved by the concurrent use of a computer software package closely mimicking the traditional, manual, version. Such enabling software was developed by this article's author. It is not intended as a replacement to the manual game, but as a means to expedite and enhance it. The use of computer software leads to a much wider range of playing possibilities and the collection of useful statistics that would be impractical to keep or calculate during the discourse of the manual version of the game.

The expanded version of the parade game requires the same supplies (other than computers) used for the manual version. It uses the same coins and especially marked dice, along with the same forms for tracking each trade's performance. There is no need for written explanations of the game's setup, which is replaced by visual explanations with the software.

The new software

Figure 2 shows the layout of critical parts of the software user interface. It runs in MS Excel™, and was written in Microsoft Visual Basic for Applications (VBA). Formulas and code are compatible with MS Excel 97 or more recent versions. However, it must be run in Excel 2007 or more recent versions for proper cell display. Most cells are protected without a password, to preserve the integrity of the various formulas while allowing for customization or simple exploration by users.



SEQUENTIAL CONSTRUCTION TRADES SIMULATION

Projects	250
Units/Project	100

Crews/Trade	2
Prod Limit	10

Start Simulation

Trade Number	Weekly Capacity for Crew A		Weekly Capacity for Crew B	
	Poor	Good	Poor	Good
1	3	7	3	7
2	3	7	3	7
3	3	7	3	7
4	3	7	3	7
5	3	7	3	7
6	3	7	3	7
7	3	7	3	7
8	3	7	3	7
9	3	7	3	7
10	3	7	3	7

Trade Number	Weeks to Complete all Units in Projec				Average Available Units per Trade			
	Weeks		As % of perfect average output		Available Units		As % of perfect average output	
	Avg	StdDev	Avg	StdDev	Avg	StdDev	Avg	StdDev
1	11.5	0.69	115.4%	6.9%	This metric is not meaningful for trade 1			
2	12.1	0.62	120.6%	6.2%	9.11	0.51	91.1%	5.1%
3	12.5	0.71	124.6%	7.1%	8.80	0.55	88.0%	5.5%
4	12.7	0.77	127.0%	7.7%	8.52	0.58	85.2%	5.8%
5	13.0	0.81	130.4%	8.1%	8.29	0.61	82.9%	6.1%
6	13.3	0.73	132.8%	7.3%	8.04	0.61	80.4%	6.1%
7	13.5	0.72	135.0%	7.2%	7.97	0.59	79.7%	5.9%
8	13.7	0.68	137.0%	6.8%	7.79	0.55	77.9%	5.5%
9	13.8	0.64	138.4%	6.4%	7.66	0.53	76.6%	5.3%
10	14.0	0.57	140.2%	5.7%	7.62	0.46	76.2%	4.6%

Week	Trade Number	Available Units	Capacity, Crew A	Capacity, Crew B	Production for Week
1	1	100	3	3	6
2	1	94	3	3	6
	2	6	3	7	6
3	1	88	3	3	6
	2	6	3	7	6
	3	6	3	7	6

Project Number	Net weeks taken by each trade to complete all units in the					
	1	2	3	4	5	6
1	12	12	12	12	12	12
2	12	13	13	13	14	14
3	12	12	13	13	13	13
4	12	12	13	13	13	13
5	12	12	12	12	12	13
6	13	13	13	14	14	14

Figure 2: Software user interface

As shown in Figure 2, several parameters can be set by the user, as follows.

1. Units per project. This parameter is the equivalent of the total number of coins passed in the manual game (typically, 35 to 100 coins are passed in the manual game). A small amount of coins can bias the statistical results, since a steady state would not be achieved. The software allows up to 1,000 units per project.
2. Number of projects. As a matter of practicality, in the manual version of the game a group of players can complete the game only once in any particular session. In contrast, the software allows playing the same game many times over by specifying a number of "projects". If 500 projects are specified, the results will show average statistics for each trade as if the game had been played 500 consecutive times. This removes the "luck" factor from results and is the underlying rationale for any discrete-event Monte Carlo simulation such as this one.

3. Weekly production capacity. This is the equivalent of the specially marked dice used by each group in the manual game. Akin to these marked dice, the weekly capacity of each crew can be either “poor” or “good” (for example, 3 or 7, 4 or 6). Each trade within the group can assume different good and bad capacity limits (i.e., each trade can use a different “die”), although the default mimics the manual game by assuming the same capacity limits for all trades within a group.
4. Crews per trade. Each trade can have up to 2 crews. This means that if the maximum capacity for a particular group is 7 units/week (i.e., players use a die marked with 3 and 7), a trade with 2 crews could have a capacity of up to 7+7 = 14 units/week. The combined capacity could also be 3+3 and 3+7 units per week
5. Production limit. The weekly production allowed to any trade can be restricted to a predefined amount. Even if a trade has a capacity of, say, 14 units in a particular week, the production can be limited to, for example, 10 units. This feature is common in manufacturing industry versions of the game emphasizing the management of work flow (e.g., Umble and Umble, 2005).

The number of sequential trades has been increased to 10, instead of the 5 to 7 trades usually used in the manual version of the game.

Playing the enhanced game

A flowchart showing how the game is played is shown in Figure 3. As it can be seen, there are four distinct stages in the game.

1. Preliminaries. The principles and mechanics of the game are explained concurrently to all groups, using the software to explain the mechanics of the first weeks of play.
2. Manually playing the game, similarly to its traditional form. This stage is considered crucial for making the simulation a true hands-on experience, but since the software alleviates the need for statistical accuracy, only 50 coins are used.
3. When the manual part is concluded, each group conducts a number of what-if experiments using the simulation software. For example, each group repeats their game in the computer (using the same die and number of units), and compares the results of the manual game and software-based simulation. Groups are also asked to consider new scenarios, such as using two crews per trade and processing more units per project.
4. Similarly to the traditional manual game, the last part of the game consists on a final discussion involving all groups. Typical topics include expected and surprising results; how the simulation relates to practical situations in the field; and how the detrimental effects of variability and dependencies could be allayed.

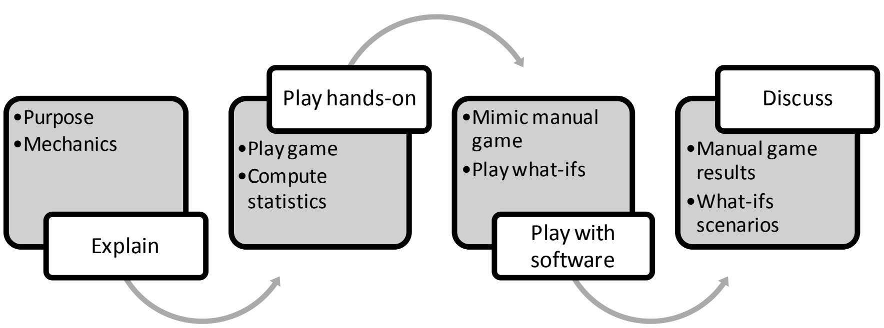


Figure 3: Playing the enhanced game

The software allows for a wide range of scenarios that can be explored with the group at large, including the use of different dice for trades within one group, or a discussion of charts provided by the software. For example, Figure 4 shows how the net number of weeks required for processing all units increase with the position of the trade in the parade, while the standard deviation of the variability does not.

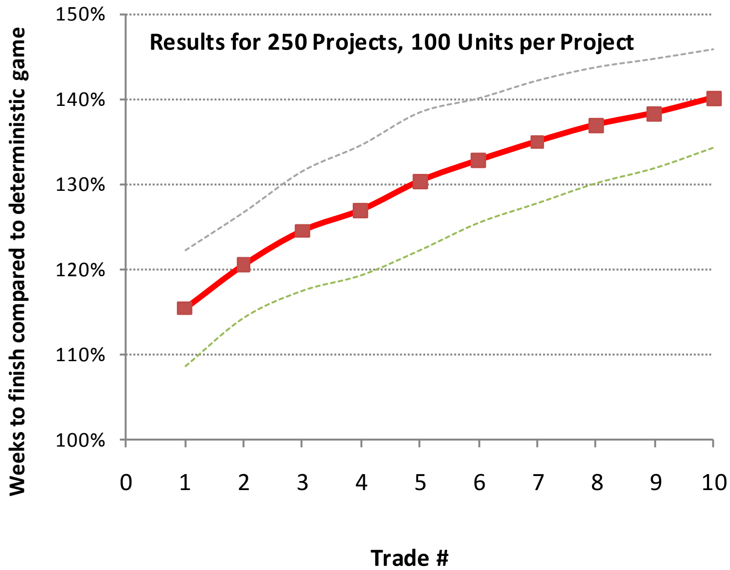


Figure 4: Example of chart provided by the software

Some statistics produced by the software are innovative, and lead to a richer exploration and discussion. One of these metrics is the *Percent from perfect average output*, defined as the ratio between the number of weeks that a trade takes to process all units and the minimum number without variability or dependence. If a trade takes 12 weeks to process 50 units with an average die capacity of 5 units/week, this metric is 12/(50/5) = 1.2 or 120%. *Percent from perfect average output* is an example of the many other statistics that are either available in the software's current form, or could be developed by any user with a knowledge of MS Excel's functions.

Feedback from implementation

The enhancements described here have been tested by the author in two academic settings, namely in masters-level courses at Colorado State University and Universidad Panamericana at Guadalajara, Mexico. The 4-hour session at Universidad Panamericana involved 22 students, and held in Spanish. The session at Colorado State University was 3-hours long and had 7 participants. In both instances, the main topic of the session was Lean Construction.

In both cases, the two initial steps of the game, which essentially comprise the traditional manual version, were played in about 30 minutes, against the 40-45 minutes typically taken to explain, play and develop statistics for the manual game. The what-if part was intertwined with the game's final discussion. This last step was much longer than the time typically allocated to it when playing the traditional version of the game, since students were engaged for more than an hour in the discussion. While this small sample does not allow a statistical validation of the enhancements described here, it is clear that so far they have been enthusiastically received by the game players.

Conclusion

Most of the enhancements to the Parade of Trades discussed here are incremental and afforded by the software tool introduced here. The larger number of virtual trades and processed units and the ability to average the results of a large number of simulated instances of the game do not depart from the basics currently used in the manual version of the game. These features do provide, however, a better separation of the true statistical behavior of the consecutive players compared to the random and sometimes strange results that the luck of the draw – quite literarily – can introduce in a single instance of the game. Moreover, the software serves as an excellent fallback strategy for finishing the game when an unexpected event happens.

The software introduces many new possibilities to the game. For example, it allows the use of dice with different variability or average. This is an important scenario, overlooked by traditional forms of the game. Other features are entirely new and virtually impossible to play by hand, such as using two crews per trade or limiting the trade weekly output.

Initial reactions to the game indicate that players appreciate the extended time for exploring scenarios, although a controlled comparison of the traditional and new versions still needs to be performed. Continuous improvement is central to lean construction, which has adopted the parade of Trade as a favorite educational tool. It is very likely that the present enhancements will continue to evolve along with the manual version of the game.

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