Seminar Series: In Architecture and the Built Environment

The University of Huddersfield

The Complete Guide to Serious Games & Simulations For Lean-Integrated Project Delivery

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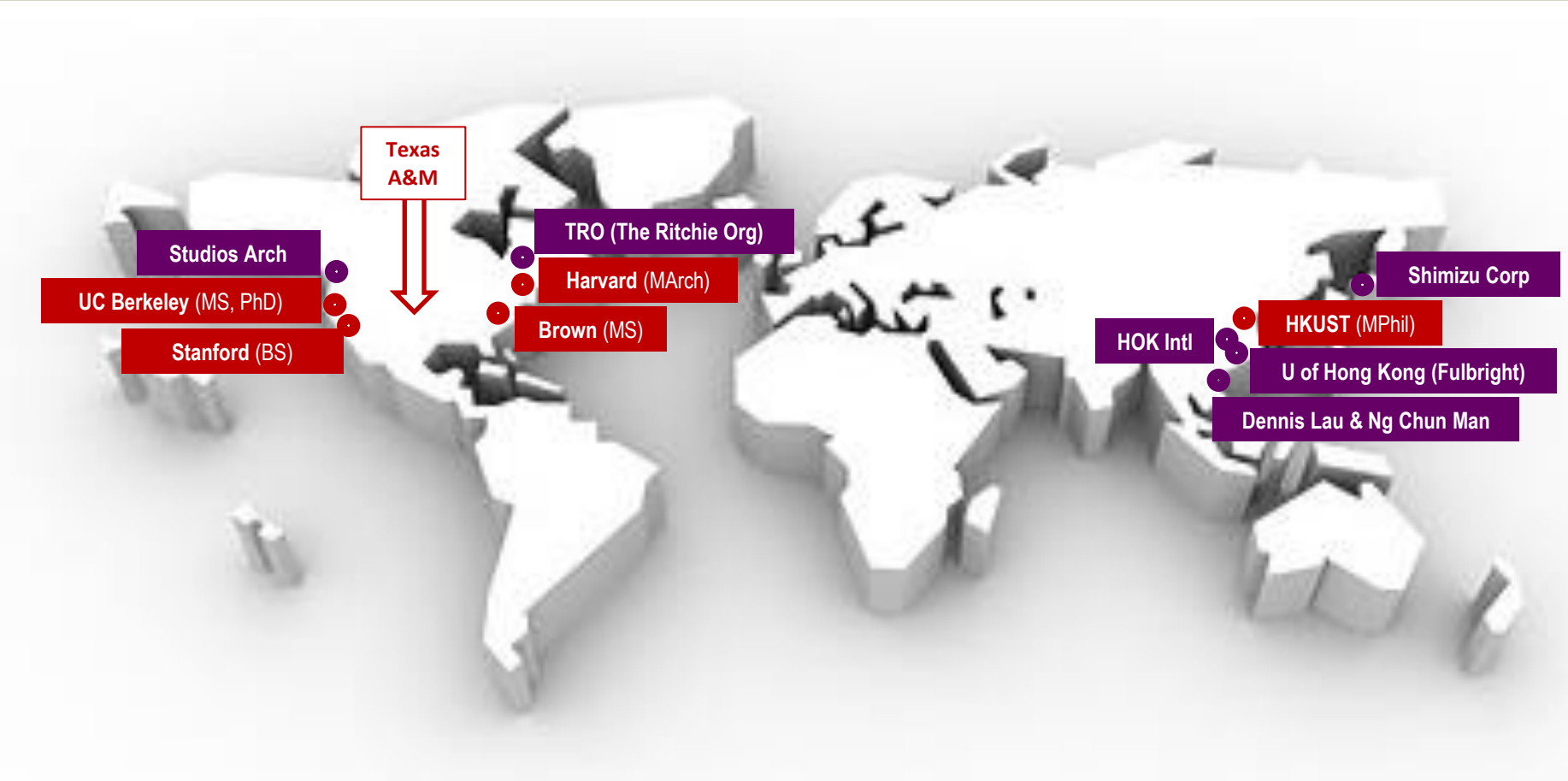
November 8, 2023

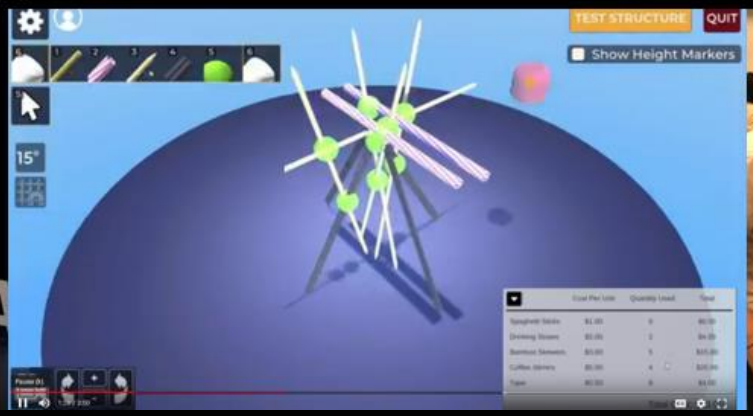
Acknowledgements to:

Dr. Ganesh Devkar
CEPT University, Ahmedabad, India

The Construction Industry Advisory Council (CIAC)
Department of Construction Science
Texas A&M University
College Station, TX USA

Education & Professional Experience





See videos about this research: https://www.youtube.com/watch?v=v8r5_RW9hIs&t=373s and https://www.youtube.com/watch?v=Xg9rWE3qj2M

Serious Games and Simulations for Lean-Integrated Project Delivery

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Today's Agenda

1) Brief **review of Lean** *(history & key concepts)*
2) Lean **simulations** *(their importance to developing a culture of Lean)*

1. Brief Review of Lean

History of Lean thought…

Might you be here?

Lean Construction:
Greg Howell, Lauri Koskela,
Glenn Ballard, Will Lichtig,
Iris Tommelein…

James P. Womack,
Jeffrey Liker


Eliyahu Goldratt

Taiichi Ohno

W. Edwards Deming

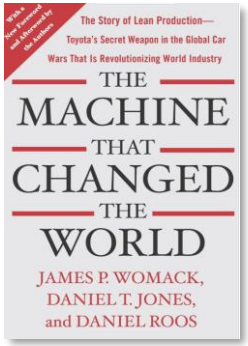
Lillian M. Gilbreth

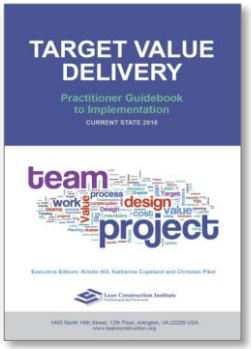
Frank B. Gilbreth

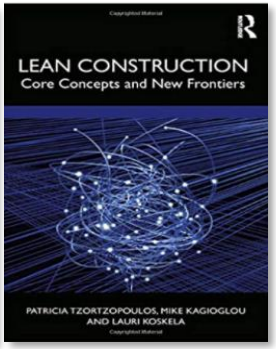
Henry Ford

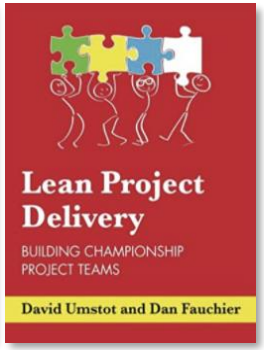
Frederick W. Taylor

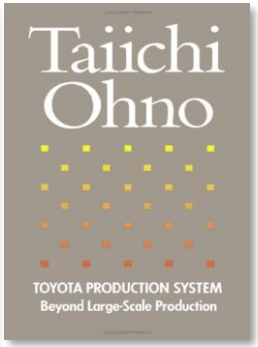
1800 1850 1900 1950 2000

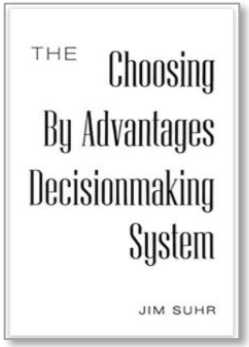


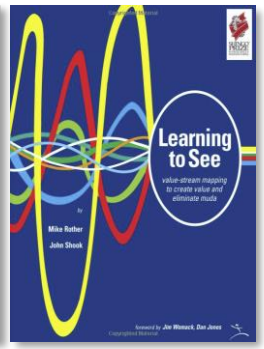


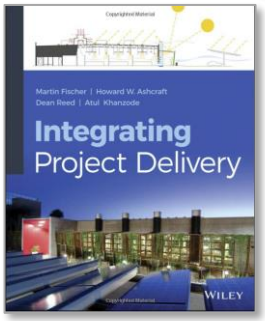


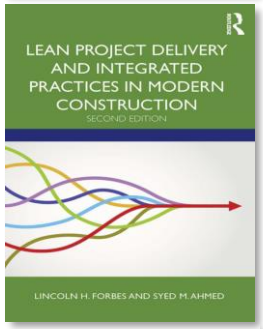


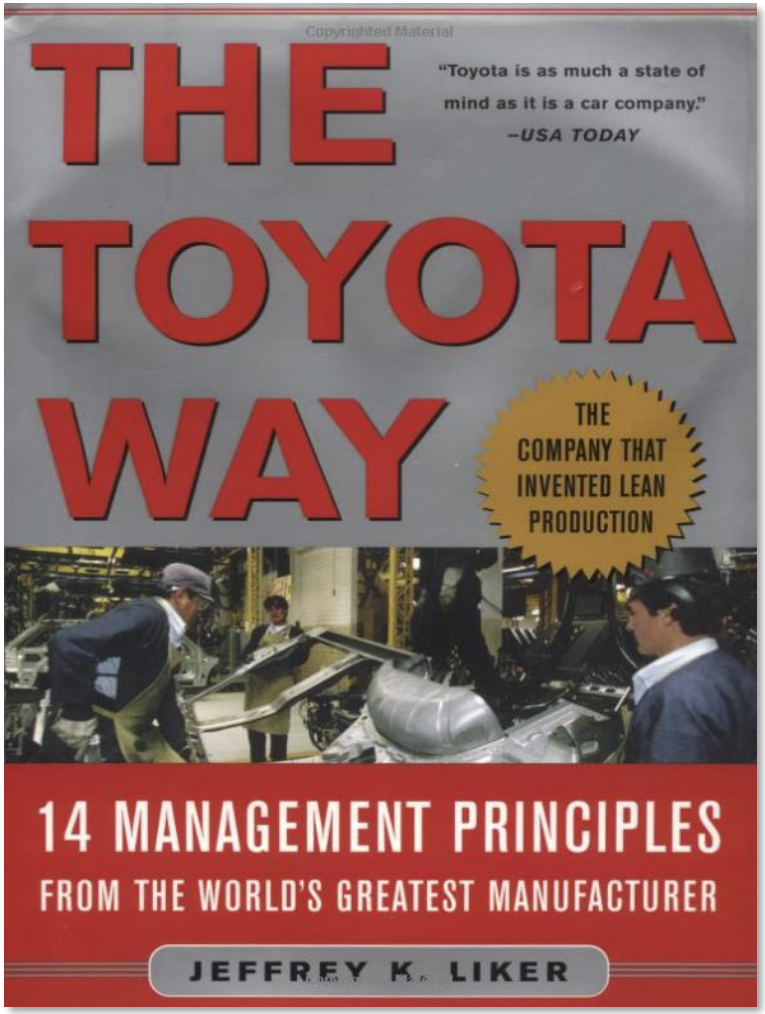












14 Principles of Toyota Way

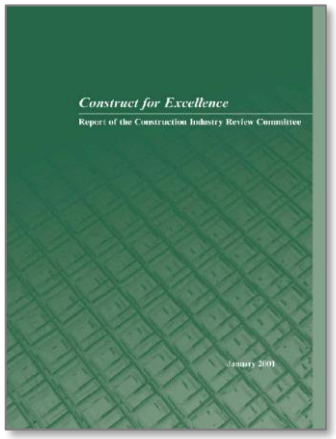
1. Long-term thinking
2. Continuous flow
3. Production "pull"
4. Workload levelling
5. Problem fixing culture
6. Improve through intermittent standardization
7. Visual control
8. Reliable technology
9. Grow lean leaders
10. Develop exceptional people
11. Respect your extended network
12. Go and see problems for yourself
13. Consensus decisions; Rapid implementation
14. Become a learning organization

Source: Liker, J. (2004). *The Toyota Way*, McGraw-Hill, New York

Why Lean Construction Came About

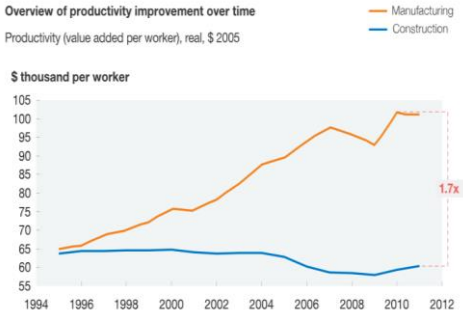
Challenges in construction project management that lead to experiments with Lean…

Latham & Egan Reports (UK)
1994 & 1998



Tang Report (Hong Kong)
2001

McKinsey Report (US)
2017



Source: McKinsey & Company

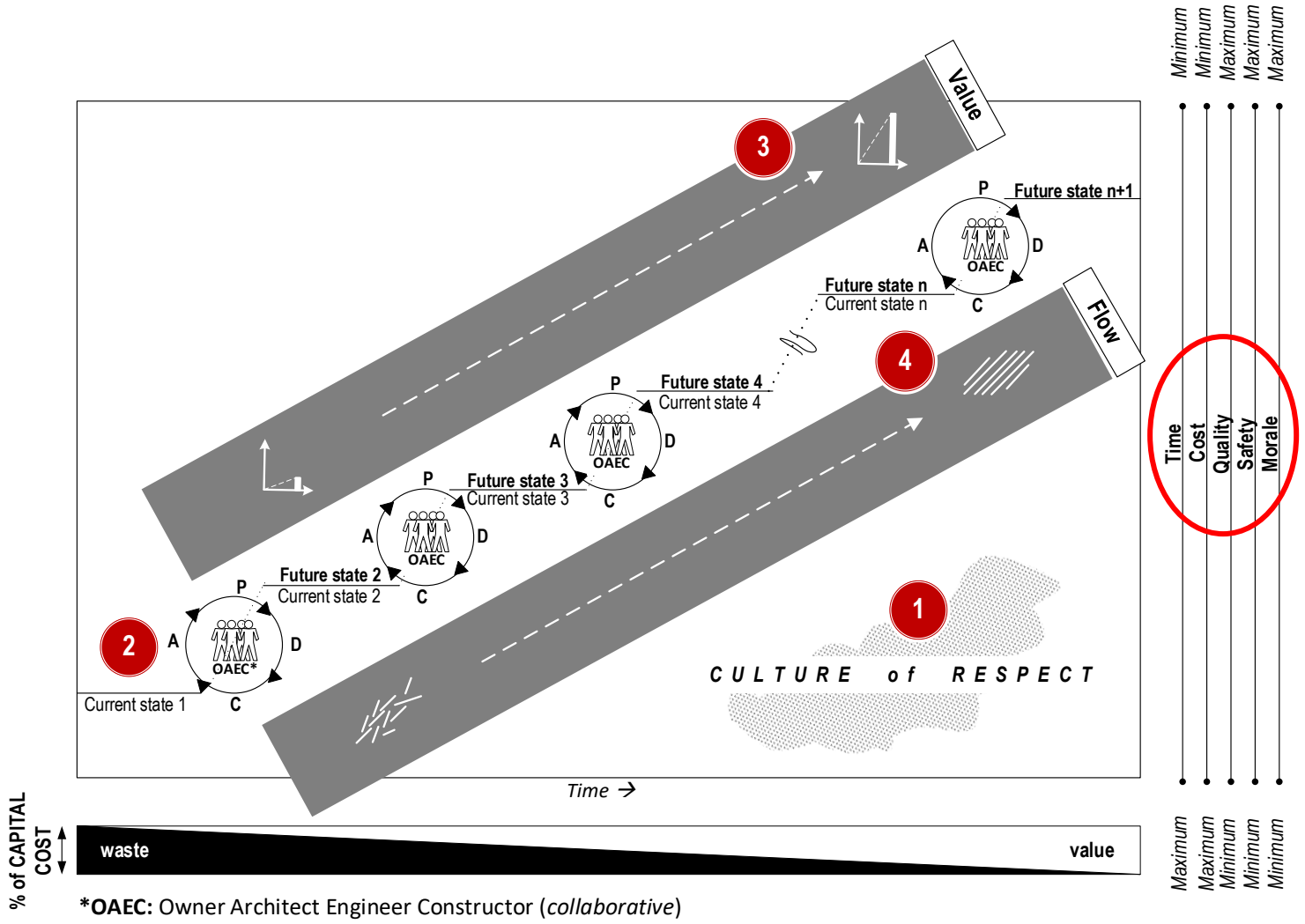
Productivity in construction significantly lags behind manufacturing

LCI's Definition of Lean Construction…

" **Culture of respect**
and **continuous improvement** *aimed at creating* **more value** *for the* customer *while identifying and* **eliminating waste**. "

--***Lean Construction Institute*** **Glossary**
https://www.leanconstruction.org/learning/education/glossary/#l

1. Culture of respect and **2. continuous improvement** aimed at **3.** creating **more value** for the customer while **4.** identifying and **eliminating waste**.



***OAEC:** Owner Architect Engineer Constructor (*collaborative*)

Adapted from: Rybkowski, Z. K., Abdelhamid, T., and Forbes, L. (2013). "On the back of a cocktail napkin: An exploration of graphic definitions of lean construction," *Proceedings of the 21th Annual Conference for the International Group for Lean Construction*; July 31-August 2, 2013: Fortaleza, Brazil, 83-92

Current Lean Practice: like the Blind Men and the Elephant

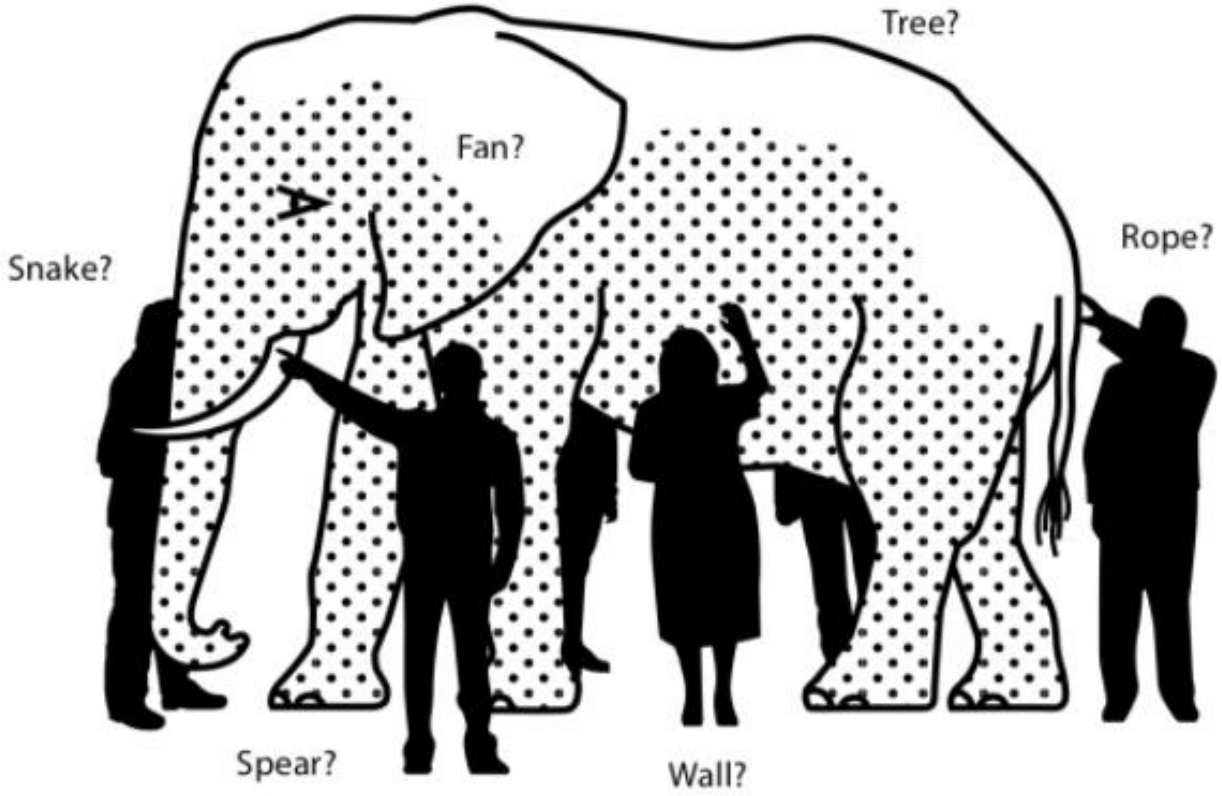
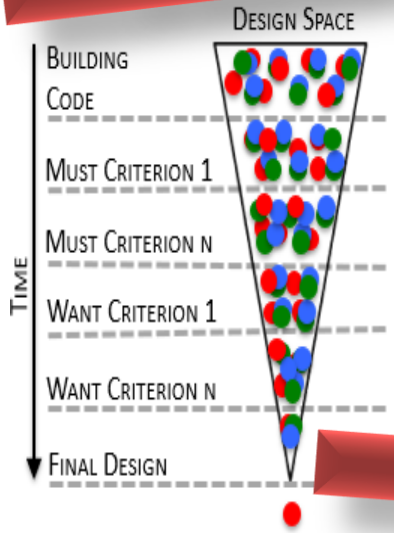


Image source: https://fs.blog/elephant/

Set-Based Design



Choosing by Advantages

Factor / Criterion	Incandescent: Attribute / Advantage	Import.	CFL (compact fluorescent): Attribute / Advantage	Import.	LED (light emitting diode): Attribute / Advantage	Import.
ENERGY EFFICIENCY *Higher lumens/watt preferred*	14 lm/W		60 lm/W 46 lm/W more than Alt 1	90	64 lm/W 50 lm/W more than Alt 1 *	100
SAFETY *No mercury content preferred*	No mercury 4 mg mercury/bulb more than Alt 2	10	4 mg mercury/bulb		No mercury 4 mg mercury/bulb more than Alt 2	10
LIGHT QUALITY *Higher CRI*	100 CRI CRI higher by 18 than Alt 2	50	82 CRI		93 CRI CRI higher by 9 than Alt 2	45
				90		**155**

* Determine & mark the most critical advantage

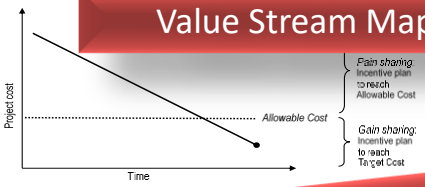
Pulse Reports

Rating is on a "1–7" scale: 1 representing "strongly disagree", 4 "neutral", 5 "slightly agree, 6 "moderately agree" ... Questions arranged in order of most agreement to least agreement for the current mon...

Question	Mean	Strongly Disagree (1)	Moderately Disagree (2)	Slightly Disagree (3)	Neutral (4)	Slightly Agree (5)	Moderately Agree (6)	Strongly Agree (7)
I am learning new processes and procedures.	6.5		1 2%			4 6%	19 29%	42 64%
The Cathedral Hill Hospital Project is headed in the right direction.	6.2		1 2%	2 3%	1 2%	4 6%	32 48%	27 40%
There has been an honest attempt to resolve project issues.	6.0		3 5%	2 3%	3 5%	5 7%	28 42%	26 39%
The project team members demonstrate a spirit of collaboration.	5.8	2 3%	1 2%	2 3%	1 2%	15 22%	20 30%	26 39%
The project team members trust one another.	5.5	1 2%	2 3%	3 5%	5 8%	8 12%	37 56%	10 15%
The project has a clearly articulated mission.	5.3	1 2%	3 5%	3 5%	10 15%	12 18%	22 33%	15 23%
We have the proper information technology/tools to complete our task.	5.3	1 2%	6 9%	7 11%	5 8%	8 12%	19 29%	20 30%
The project leadership structure is clear.	5.2	1 2%	4 6%	8 12%	7 11%	10 15%	22 33%	14 21%
In the last seven days, I have received recognition or praise for doing good work.	4.6	9 14%	9 14%		7 11%	8 13%	16 25%	14 22%
Our meetings are productive.	4.5	2 3%	6 9%	11 16%	12 18%	13 19%	20 30%	3 5%
The owner is accessible.	4.3	4 6%	8 13%	7 11%	16 25%	9 14%	15 24%	4 6%
Often I feel pressure to not "rock the boat" by speaking my mind about what's going on with the project.	3.2*	17 26%	14 22%	6 9%	8 12%	11 17%	6 9%	3 5%

**This item is reverse-scored; a low mean is preferred*

Value Stream Mapping



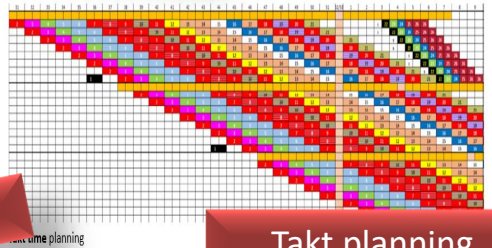
Target Value Design

Project Title ID: **Date:**
To: **From** (names of proposers)

Background What is the context of the problem and the need that must be addressed?	**PLAN:** Which countermeasure(s) will be implemented to address the identified root cause(s)?
Measurable **Current State** What is the current situation? This sets a measurable baseline.	**DO:** How will the proposed countermeasures be tactically implemented?
Measurable **Future State** What is the desired end result? This sets a measurable goal	**CHECK:** How and when will outcomes be measured and checked to see if they conform to expected results?
Bridging gap between Current and Future States Why does the current condition exist? Identify root cause using 5 Whys analysis and potential countermeasures in response to identified root cause.	**ACT:** How and when will adjustments be made if does not meet expected

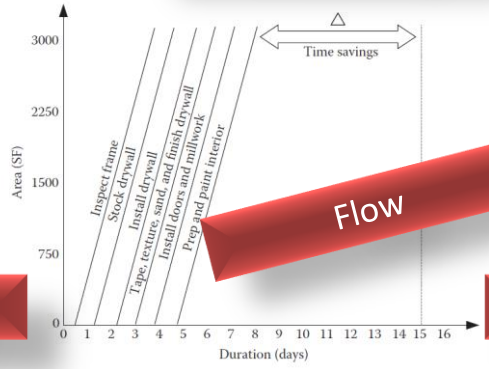
Supporting Document

A3 reports

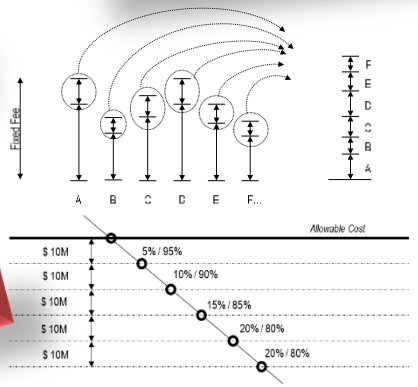


Takt planning

Last Planner System of Production Control



Flow



Pain-sharing / Gain sharing

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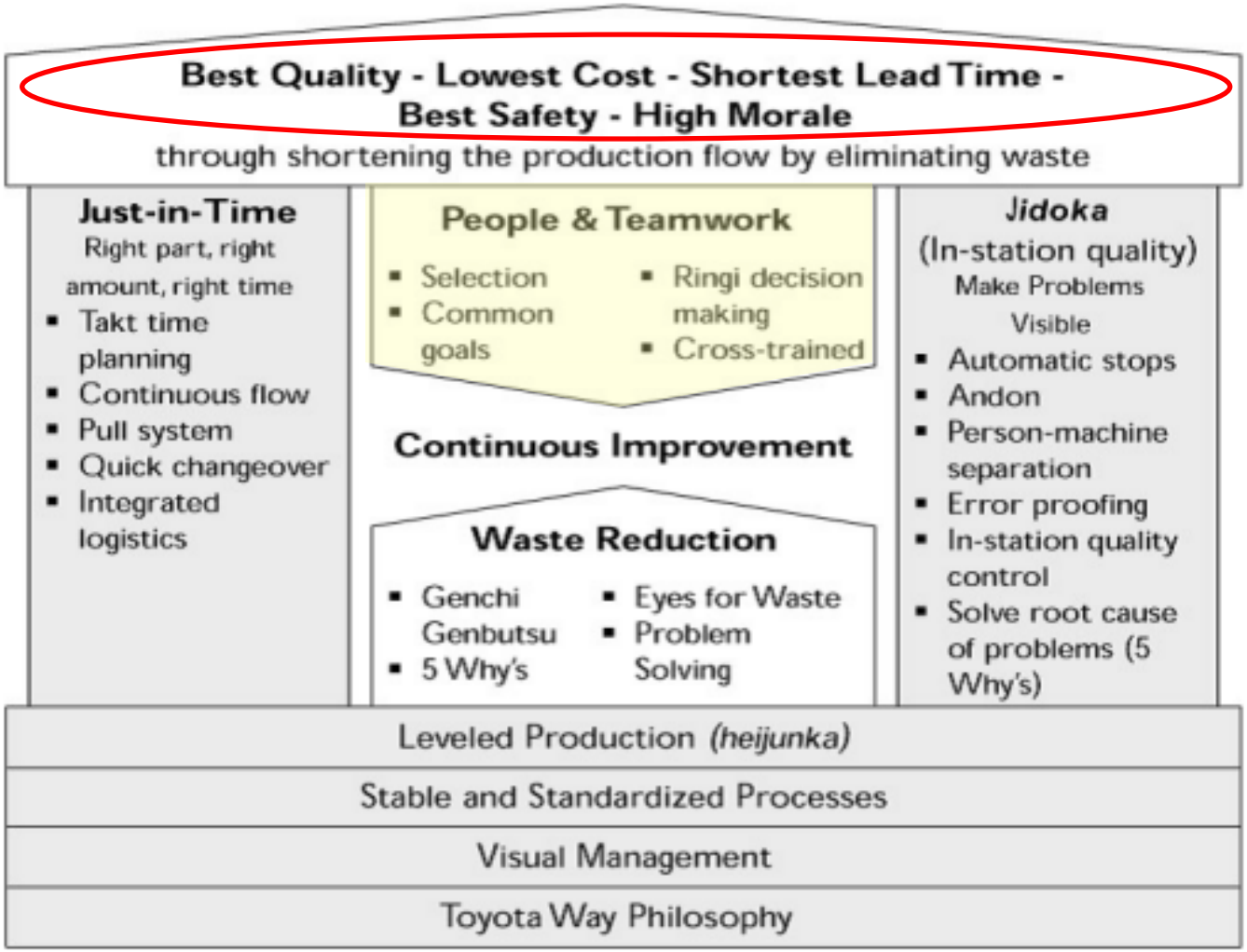
Image Credits- the ReAlignment Group of California, LLC http://danzpage.com/; Vatne, M. E, and Drevland, F.(2016). " Practical Benefits of Using Takt Time Planning: A Case Study." *Proc. 24th Ann. Conf. of the Int'l. Group for Lean Construction*, Boston, MA, USA, sect.6 pp. 173–182. Available at: www.iglc.net; Mi Sun An <sunm2an@email.tamu.edu>

How does Lean differ from other delivery methods?

How does Lean differ from other delivery methods?

LEAN is a

CULTURE of **INCLUSION** & **RESPECT**



"House of Lean"

Figure 3-3, p. 33, The Toyota Production System, Liker, J. (2004). *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*, McGraw-Hill, New York.

What does a culture of inclusion & respect look like?

With every pair of hands comes a free brain

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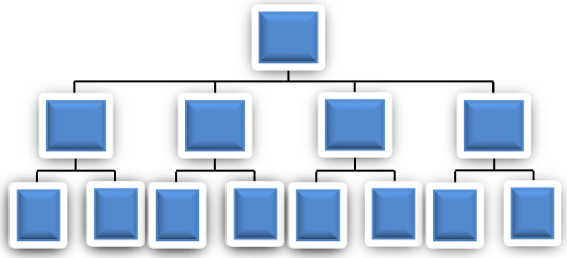
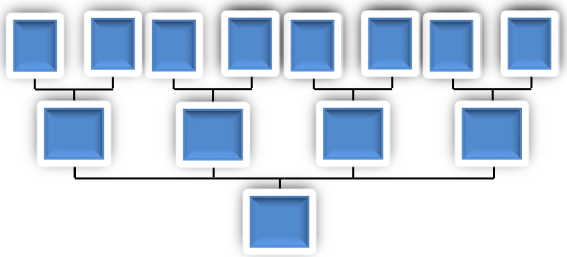
Image source: https://philosophicaldisquisitions.blogspot.com/2015/08/did-my-brain-make-me-do-it-neuroscience.html

What does a lean culture of inclusion and respect look like?

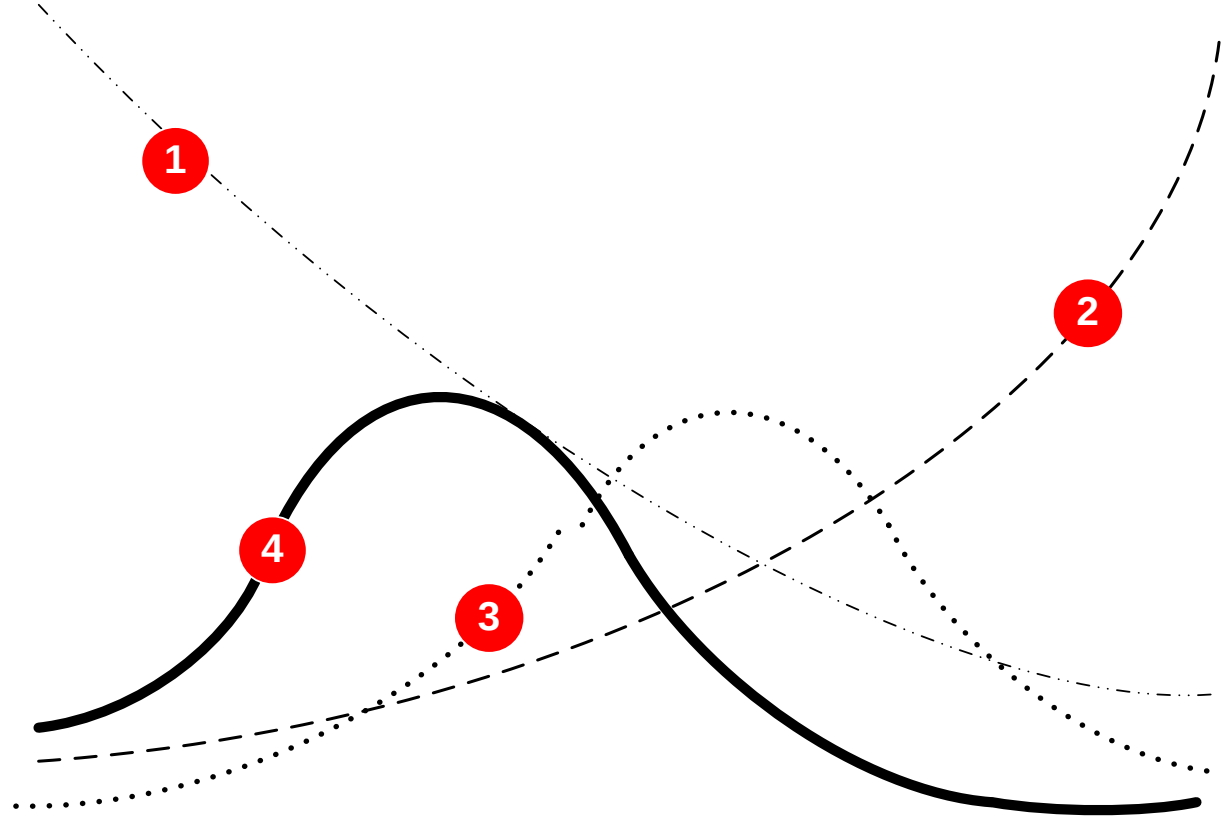


Traditional



Lean

The MacLeamy Curve



1 Ability to impact cost and function

2 Cost of design changes

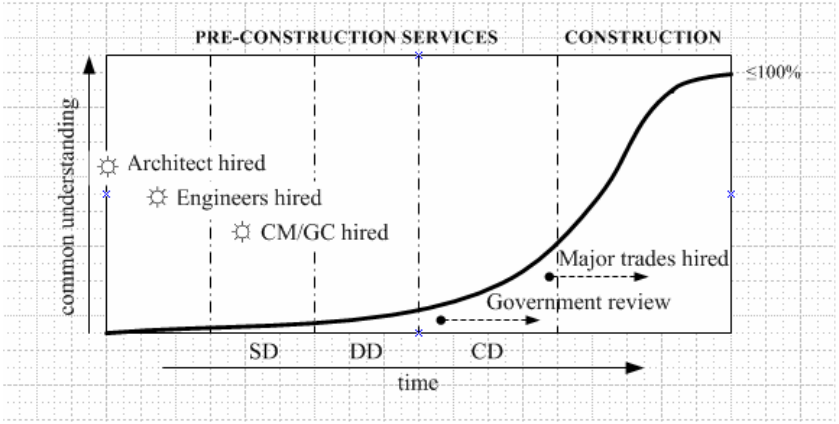
3 Traditional Design-Bid-Build process

4 Integrated Project Delivery Process

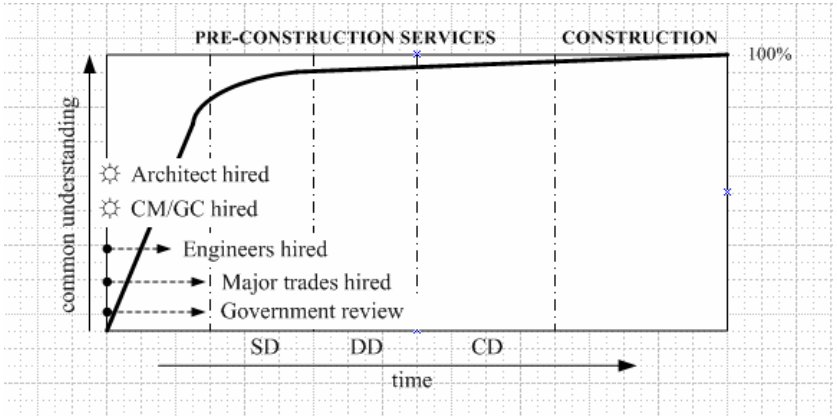
Predesign	Schematic Design	Design Development	Construction Documents	Agency Permit/ Bidding	Construction	TRADITIONAL DESIGN-BID BUILD
Conceptualization	Criteria Design	Detailed Design	Implementation Documents	Agency Coord/ Final Buyout	Construction	INTEGRATED DESIGN DELIVERY

Integrated Project Delivery

Adapted from: http://ohainc.com/news_detail.php?news_id=00031 (accessed on October 17, 2012)



Traditional



Lean

Shared project knowledge
by team members during typical Design-Bid-Build project delivery (top), and during Lean Project delivery (bottom), as speculated by Will Lichtig (2008).
Note that shared project understanding is much greater toward the beginning of a project during Lean Project delivery.

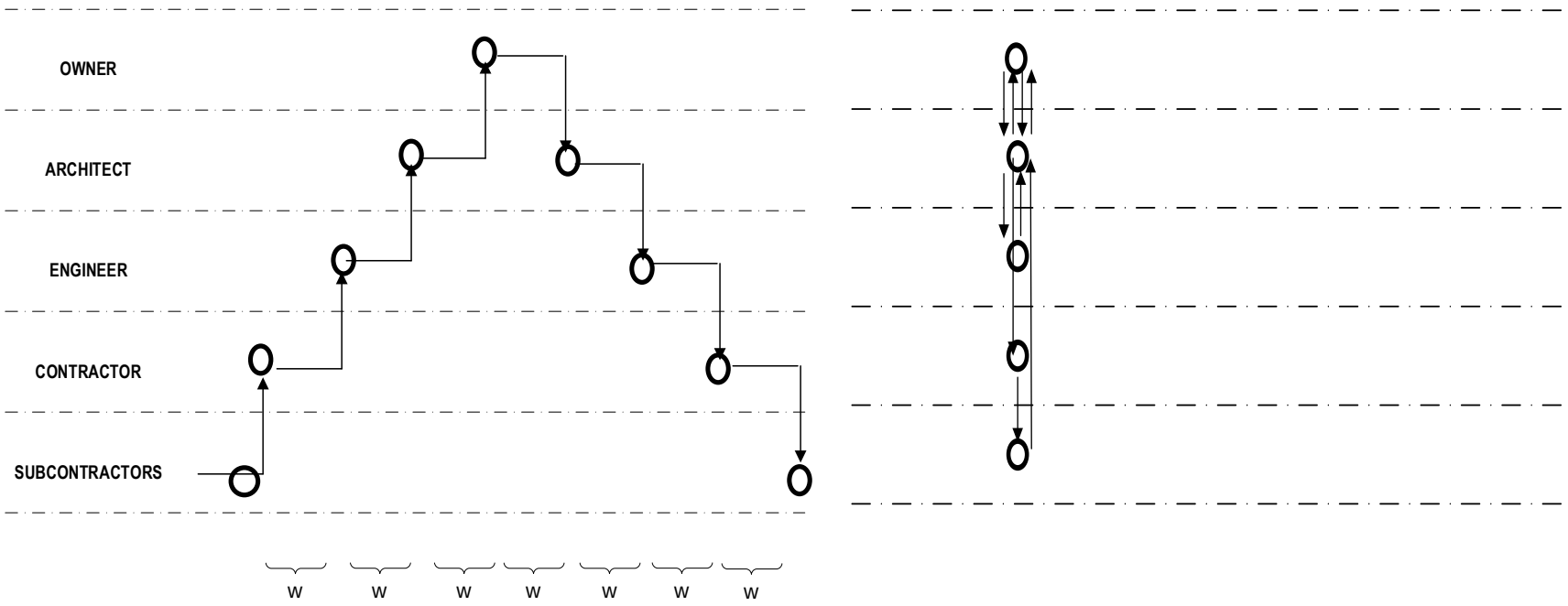
Shared Project Knowledge

Adapted from Lichtig (2008), as presented in Feng and Tommelein (2009).

Lichtig, W. (2008). *Common Understanding vs. Time*, McDonough Holland & Allen Attorneys at Law (Powerpoint presentation slides).
Feng, P. P., and Tommelein, I. D. (2009). *Modeling the Effect of Alternative Review Processes: Case Study of a State Permitting Agency*, Seattle, USA

Traditional

Lean-IPD

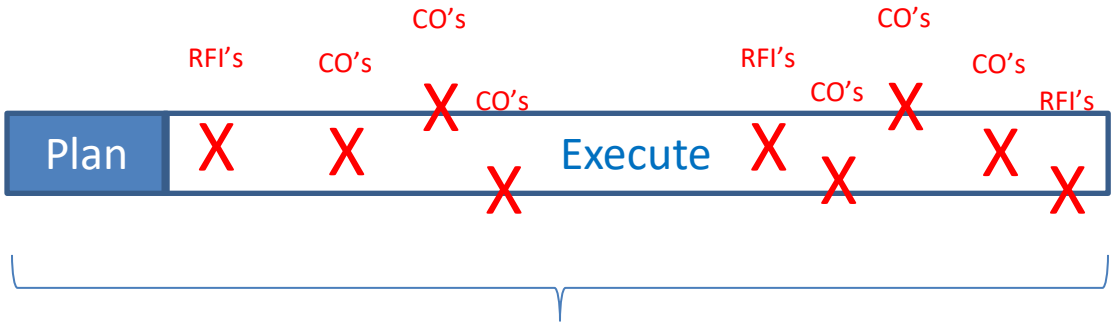


w=waste

Lean: Big Room Meeting

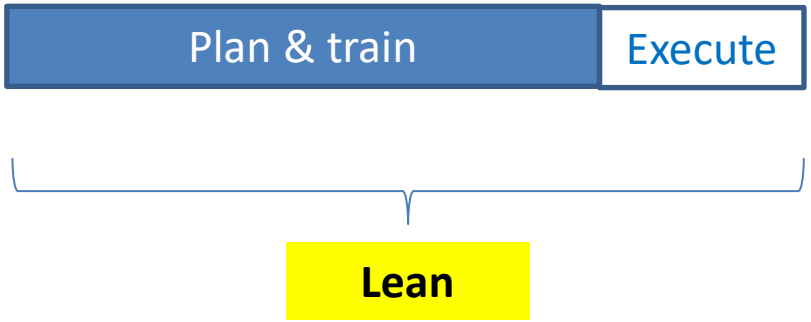
Travel path of an RFI in traditional (left) versus Lean (right) project delivery

Adapted from: Rybkowski, Z. K. (2009). "The Application of Root Cause Analysis and Target Value Design to Evidence-Based Design in the Capital Planning of Healthcare Facilities," Doctoral Dissertation, University of California, Berkeley, CA



Traditional

"Those who fail to plan, plan to fail."



Lean

"Plan thoroughly, execute quickly."

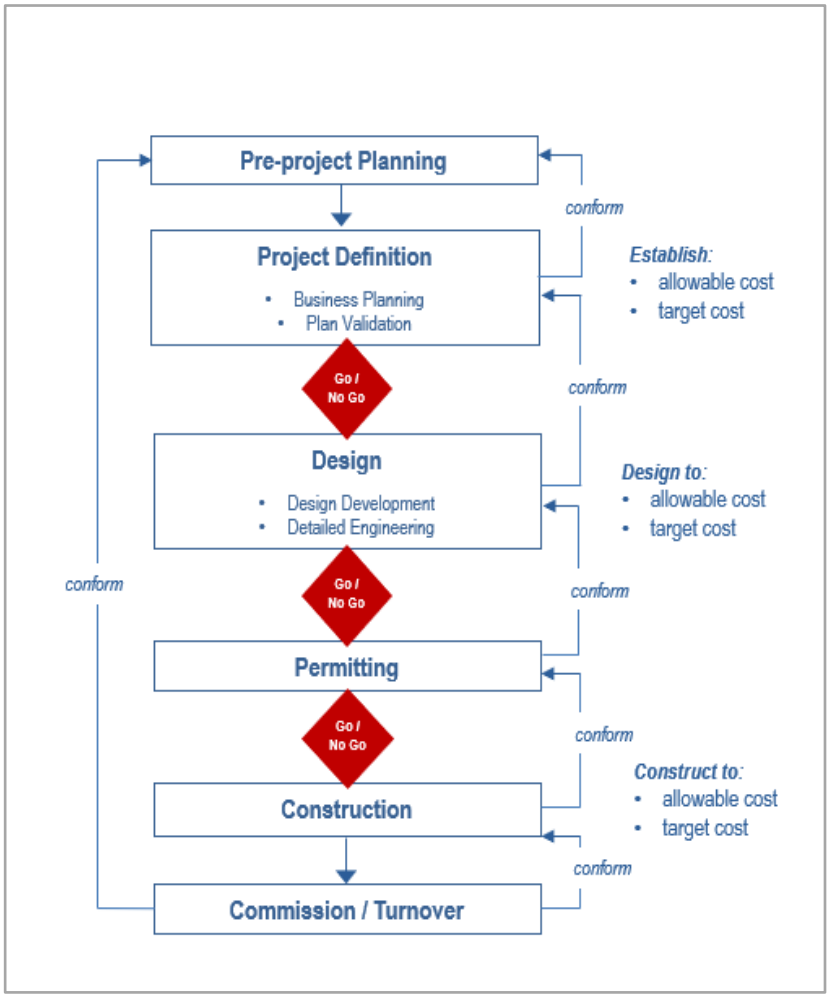
"Slow down to speed up."

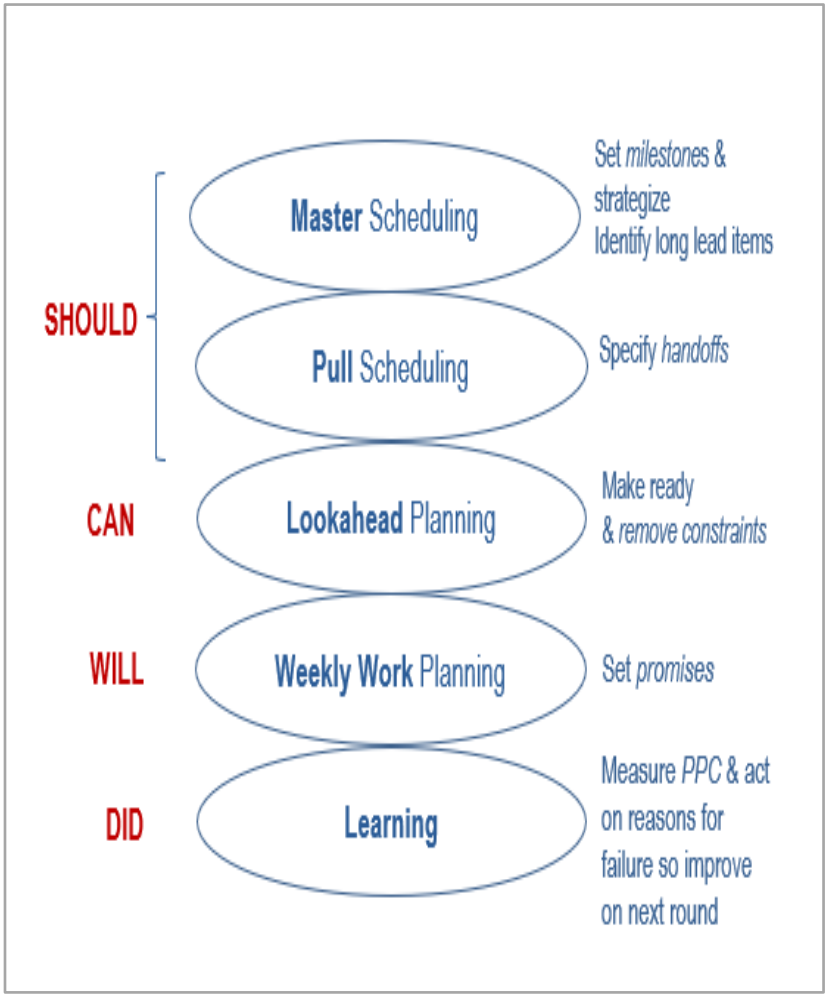
A culture of upfront planning

Lean embraces delivery from start to finish…

Target Value Delivery

Target Value Delivery





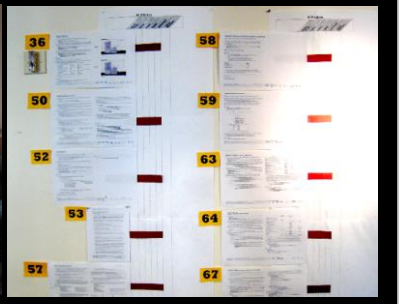
TVD:
Target Value Design

LPS:
Last Planner System™ of Production Control

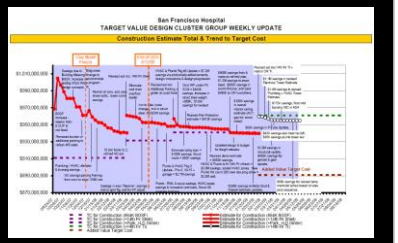
Ballard, G. (2000). "The Last Planner System of Production Control," Doctoral dissertation, University of Birmingham, Birmingham, UK

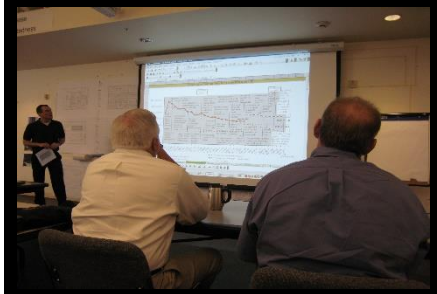
Ballard, G. (2008). "The Lean Project Delivery System: an Update." *Lean Construction Journal*, 1-19.

Target Value Delivery

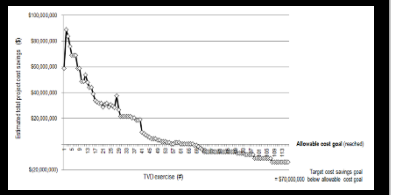


A3s from TVD Exercises, Cathedral Hill Hospital, San Francisco, CA (Rybkowski 2009)





Cost savings from TVD Exercises with scope changes, Cathedral Hill Hospital, San Francisco, CA (Rybkowski 2009)



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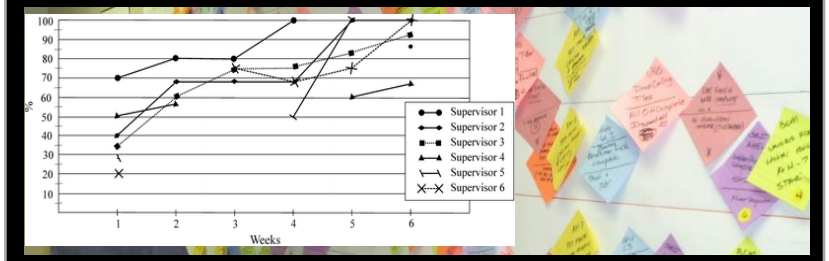

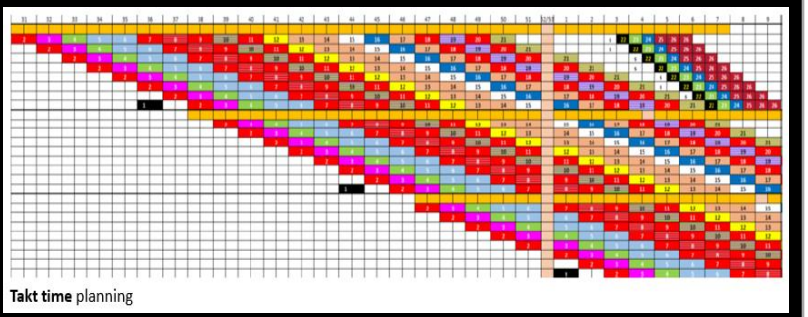

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Nieto-Morote, A. and Ruz-Vila, F. (2012) "Last Planner Control System Applied to a Chemical Plant Construction," *Journal of Construction Engineering and Management,* 138(2)
Source: Vatne, M. E, and Drevland, F.(2016)." Practical Benefits of Using Takt Time Planning: A Case Study." *Proc. 24th Ann. Conf. of the Int'l. Group for Lean Construction*, Boston, MA, USA, sect.6 pp. 173–182. Available at: <www.iglc.net>

TVD:
Target Value Design

LPS:
Last Planner System™ of Production Control

Zofia Rybkowski, PhD . Texas A&M University . zrybkowski@tamu.edu

Cost performance on some typical construction projects

Problematic construction projects (adapted from Forbes and Ahmed 2011, p. 57)

Name of Project	Budgeted cost ($ millions)	Final Cost ($ millions)	Growth of cost (%)
Hanford Nuclear Facility (2001)	715	1,600	120
Capitol Hill Visitor Center (2008)	265	621	134
Denver Airport (1995)	1,700	4,800	180
Boston Big Dig (2005)	2,600	14,600	460

Cost performance on construction projects using TVD

Examples of cost results following Target Value Design exercises on reduction of capital cost (Glenn Ballard, *personal communication*, 2012)

Name of Project (SF)	Market cost ($ millions)	Final Cost ($ millions)	Reduction of cost (%)
Project A (368,882 SF)	98,000,000	89,200,000	9.0
Project B (114,000 SF)	13,533,179	11,717,000	13.4
Project C (75,362 SF)	13,600,000	11,200,000	17.6
Project D: (230,000 SF)	22,000,000	17,900,000	18.6

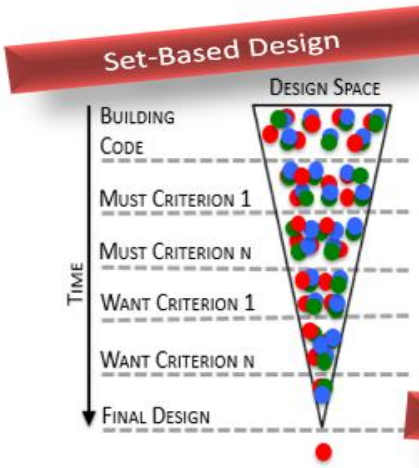
Cost performance comparing traditional versus TVD case studies

Adapted from: Forbes, L. H., and Ahmed, S. M. (2011). *Modern Construction: Lean Project Delivery and Integrated Practices*, CRC Press, Boca Raton.
Adapted from: Ballard, G. (personal communication, 2012)

2. Lean simulations

Training stakeholders in the use of **lean tools**
is *time-consuming*
& requires
"*buy-in*" from participants.

And…there are a lot of lean tools that require *willing collaboration from stakeholders*!

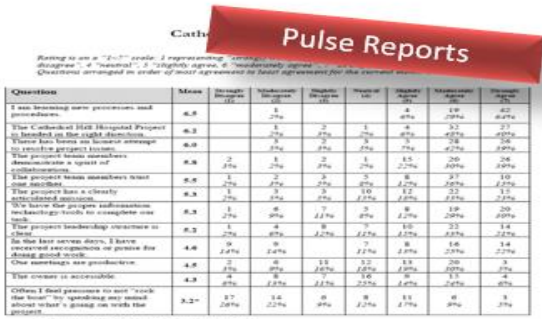


Set-Based Design

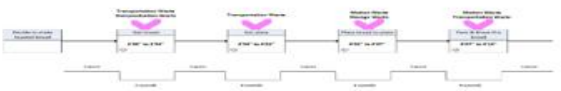
Factor / Criterion	Incandescent: Attribute / Advantage	Import.	CFL (compact fluorescent): Attribute / Advantage	Import.	LED (light emitting diode): Attribute / Advantage	Import.
ENERGY EFFICIENCY *Higher lumens/watt preferred*	14 lm/W		60 lm/W 46 lm/W more than Alt 1	90	64 lm/W 50 lm/W more than Alt 1 *	100
SAFETY *No mercury content preferred*	No mercury 4 mg mercury/bulb more than Alt 2	10	4 mg mercury/bulb		No mercury 4 mg mercury/bulb more than Alt 2	10
LIGHT QUALITY *Higher CRI*	100 CRI CRI higher by 18 than Alt 2	50	82 CRI		93 CRI CRI higher by 9 than Alt 2	45
		90				155

* Determine & mark the most critical advantage

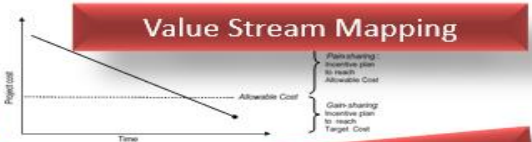
Choosing by Advantages



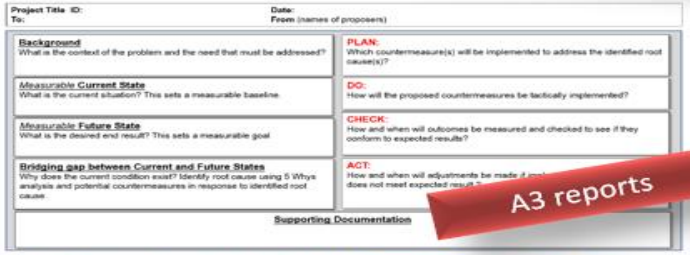
Pulse Reports



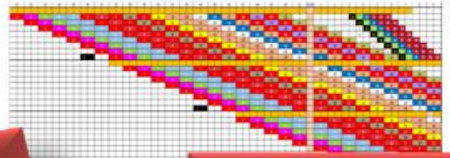
Value Stream Mapping



Target Value Design

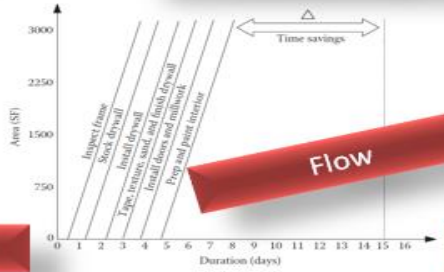


A3 reports

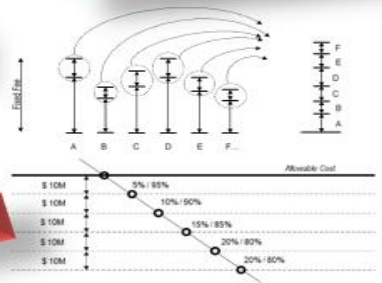


Takt planning

Last Planner System of Production Control



Flow



Risk Sharing

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Lean simulations used to quickly teach lean concepts & tools have emerged from within the lean community itself.

Examples of Lean Simulations

- from ***Academia:*** Examples of simulations that have and have been developed and tested by **academic researchers** include:

  - **Silent Squares** (Bavelas 1973)
  - **Parade of Trades** (Tommelein and Riley 1999)
  - **LEAPCON simulation** (Sacks 2007)
  - **Marshmallow Tower TVD simulation** (Rybkowski et al. 2016)

- from ***Industry*:** LCI estimated about **100 US-based construction companies** use simulations to teach lean to their employees (Kristin Hill, personal communication, February 5, 2021). Examples of simulations that have emerged from industry include:

  - **The Lego™ Airplane Game** (Visionary Products Inc. 2008)
  - **Wood Block Tower Exercise**, DPR/Turner (George Zettel, Turner, *personal communication*, November 2, 2020)

- Lean principles can be **difficult** to grasp conceptually
  (Liker 2004, Tzortzopoulos et al. 2020)
- Action research of lean on construction sites is helpful, but **controlled scientific experimentation on sites is nearly impossible,** due to confounding variables.
- **Lean simulations offer the types of controlled laboratory conditions usually found in physical and biological sciences** (Rybkowski et al. 2012; Verma 2003).
- Lean simulations therefore impart an **"aha moment"** to participants and give confidence to those who teach lean (Rybkowski et al. 2020; Verma 2003).
- They tend to be enjoyable to play and can help unify the stakeholder team.

Universities use simulations to teach critical key lean concepts to students.

Tsao et al. (2013)

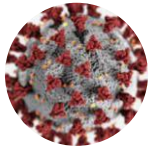
OVERVIEW *Instructor*	*U. Cincinnati* *Tsao*	*Arizona State* *Mitropoulos*	*San Diego St* *Alves*	*S. Illinois U.* *Azambuja*	*Amer. U. Beir.* *Hamzeh*	*Ill. Inst. Tech.* *Moches*	*Texas A&M* *Rybkowski*
SIMULATIONS							
5S Game							X
Airplane Game	X		X	X	X		X
Cocktail Napkin							X
Cups Game		X				X	
Delta Design	X						
Deming s Red-Bead							X
Helium Stick	X				X		
Leapcon				X		X	
Magic Tarp	X						
Maroon-White					Variant		X
Origami Game	X						
Parade Game	X	X	X	X	X	X	X
Radioactive Popcorn				X			
Silent Squares			X	X	X	X	
TVD Game							X
Win As Much As	X				X	X	

Rybkowski, Forbes, and Tsao. (2018)

OVERVIEW *Instructor*	*N Carolina St* *Liu*	*Virginia Tech* *Muir*	*Colorado St* *Senior*	*Michigan St* *Abdelhamid*	*Pittsburg St* *Levens*
SIMULATIONS					
5S Game				X	
Airplane Game	X	X		X	
Cocktail Napkin					
Cups Game					
Delta Design				X	
Deming s Red-Bead			X	X	
Helium Stick	X				
Leapcon				X	
Magic Tarp					
Maroon-White				X	
Origami Game					
Parade Game	X	X	X	X	X
Radioactive Popcorn					
Silent Squares	X	X		X	
TVD Game				X	
Win As Much As			X	X	
Additional:					
Ball Game				X	X
DPR Block Tower		X			X
Gemba Walk		X			
Last Planner (AGC)				X	
Leadership Styles				X	X
Lego Hotel/Tower				X	X
Light Fixtures			X	X	
Make-a-Card				Variant	X
Marshmallow Challenge				X	
NASA Survive/ Moon				Variant	X
No./Task Switching				X	
Oops	X				
Original Dice Game				X	
Prison Door Case				X	
Repairman					
Villego	X			X	X

Growth of lean simulations

But then...



- On March 11, 2020, director general of WHO declared the spread of COVID-19 to be a **global pandemic**, transmitted to over 110 countries and territories.
- Many universities and lean consultants around the world transitioned to **on-line or hybrid** format.
- A lean consultant in Germany send an **email appeal** to educators and consultants to figure out how to take lean simulations online (Annett Schöttle, personal communication, March 21, 2020).
- **The appeal represented an urgent need (gap) to fill.**

At **Texas A&M** we started the group **APLSO**

(*Administering and Playing Lean Simulations On-Line*)

- APLSO participants decided to **meet on Zoom for 90 minutes at the same time every Monday from March 30 until the start of the fall 2020** when meetings became **monthly,** which we continue to do.
- Requests to join **spread by word-of-mouth** and were directed to Texas A&M's organizer (Rybkowski); admission was **intentionally open and welcoming**—those who showed interest were invited and given Zoom access.
- All sessions must be interactive and include 15 minute **plus/delta session** at the end.

At first participants converted pre-existing simulations, but eventually completely novel ones started to emerge as well.

Some examples...

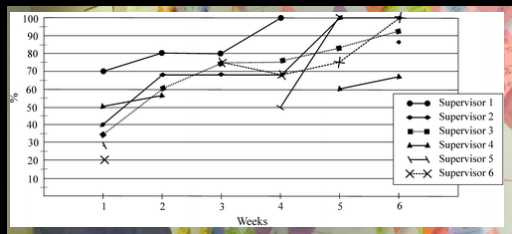
In person simulation

Parade of Trades Simulation

Source photos: Colin Milberg (https://leanconstruction.org/pages/parade-of-trades-simulation/)
Aliko Sunawang from *Pexels* (https://medium.com/10x-curiosity/dice-game-make-more-production-f9766258510a);
Credit: Tommelein, I.D. and Riley, D.R. (1999) 'Parade Game: Impact of workflow variability on trade performance,' Journal of Construction Engineering & Management, 125 (5), pp. 304–310.

Example application in Industry:

Last Planner™ System of Production Control



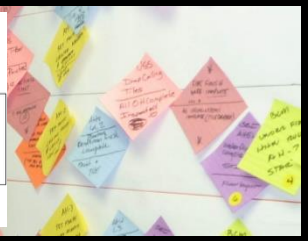


Image Credits- the ReAlignment Group of California, LLC <http://danzpage.com/>;
Nieto-Morote, A. and Ruz-Vila, F. (2012) "Last Planner Control System Applied to a Chemical Plant Construction," *Journal of Construction Engineering and Management,* 138(2)

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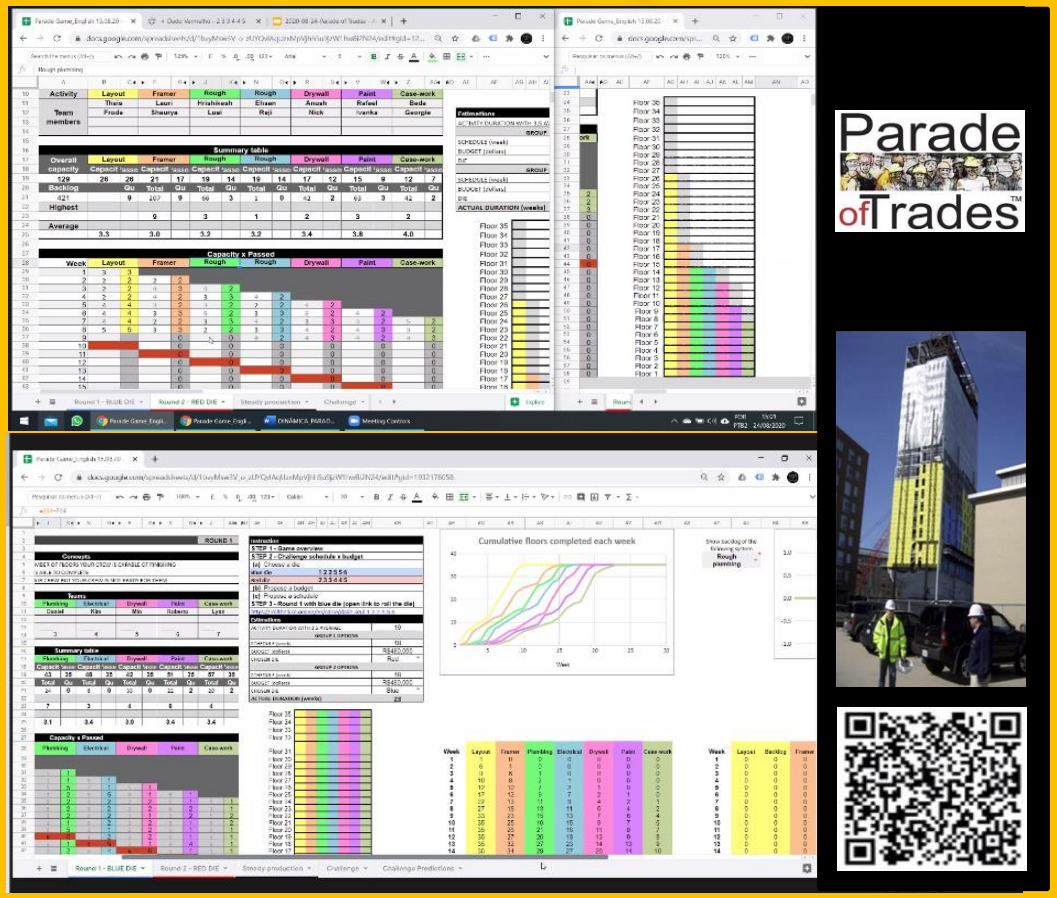
On-line version

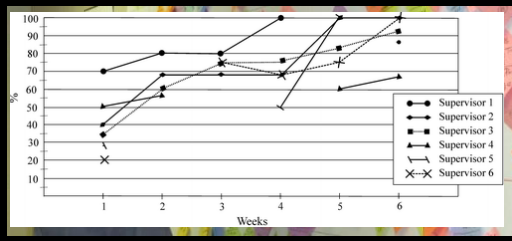
Parade of Trades Simulation

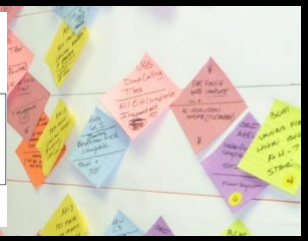


Developers: Colin Milberg colin@askmassociates.com, Ryan Popp<ryan@askmassociates.com & Cynthia Tsao <cynthia@navilean.com>

Example application in Industry:

Last Planner™ System of Production Control





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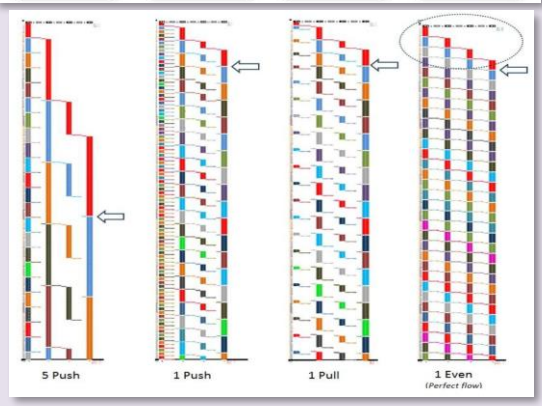
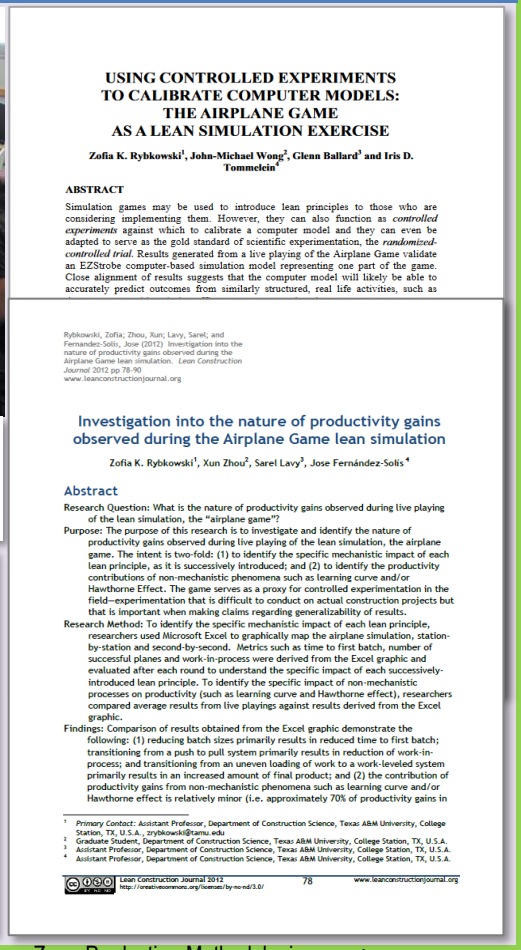
In person simulation

Lego™ Airplane Simulation





USING CONTROLLED EXPERIMENTS TO CALIBRATE COMPUTER MODELS: THE AIRPLANE GAME AS A LEAN SIMULATION EXERCISE

Zofia K. Rybkowski[1], John-Michael Wong[2], Glenn Ballard[3] and Iris D. Tommelein[4]

ABSTRACT

Simulation games may be used to introduce lean principles to those who are considering implementing them. However, they can also function as *controlled experiments* against which to calibrate a computer model and they can even be adapted to serve as the gold standard of scientific experimentation, the *randomized-controlled trial*. Results generated from a live playing of the Airplane Game validate an EZStrobe computer-based simulation model representing one part of the game. Close alignment of results suggests that the computer model will likely be able to accurately predict outcomes from similarly structured, real life activities, such as

Rybkowski, Zofia; Zhou, Xun; Lavy, Sarel; and Fernandez-Solis, Jose (2012). Investigation into the nature of productivity gains observed during the Airplane Game lean simulation. *Lean Construction Journal* 2012 pp 78-90
www.leanconstructionjournal.org

Investigation into the nature of productivity gains observed during the Airplane Game lean simulation

Zofia K. Rybkowski[1], Xun Zhou[2], Sarel Lavy[3], Jose Fernández-Solís[4]

Abstract

Research Question: What is the nature of productivity gains observed during live playing of the lean simulation, the "airplane game"?

Purpose: The purpose of this research is to investigate and identify the nature of productivity gains observed during live playing of the lean simulation, the airplane game. The intent is two-fold: (1) to identify the specific mechanistic impact of each lean principle, as it is successively introduced; and (2) to identify the productivity contributions of non-mechanistic phenomena such as learning curve and/or Hawthorne Effect. The game serves as a proxy for controlled experimentation in the field—experimentation that is difficult to conduct on actual construction projects but that is important when making claims regarding generalizability of results.

Research Method: To identify the specific mechanistic impact of each lean principle, researchers used Microsoft Excel to graphically map the airplane simulation, station-by-station and second-by-second. Metrics such as time to first batch, number of successful planes and work-in-process were derived from the Excel graphic and evaluated after each round to understand the specific impact of each successively-introduced lean principle. To identify the specific impact of non-mechanistic processes on productivity (such as learning curve and Hawthorne effect), researchers compared average results from live playings against results derived from the Excel graphic.

Findings: Comparison of results obtained from the Excel graphic demonstrate the following: (1) reducing batch sizes primarily results in reduced time to first batch; transitioning from a push to pull system primarily results in reduction of work-in-process; and transitioning from an uneven loading of work to a work-leveled system primarily results in an increased amount of final product; and (2) the contribution of productivity gains from non-mechanistic phenomena such as learning curve and/or Hawthorne effect is relatively minor (i.e. approximately 70% of productivity gains in

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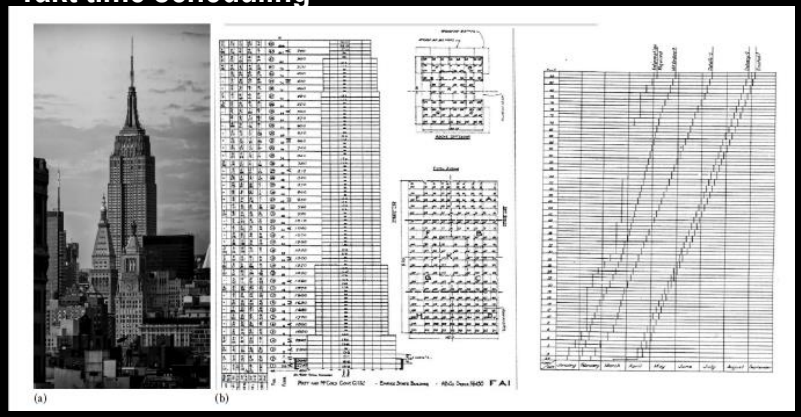
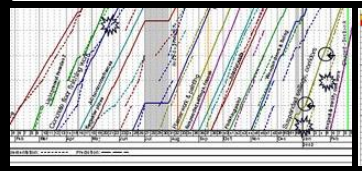
[2] Graduate Student, Department of Construction Science, Texas A&M University, College Station, TX, U.S.A.
[3] Assistant Professor, Department of Construction Science, Texas A&M University, College Station, TX, U.S.A.
[4] Assistant Professor, Department of Construction Science, Texas A&M University, College Station, TX, U.S.A.

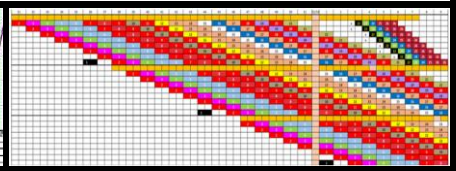
Source: Visionary Products: <https://store.lean-zone.com/Lean-Zone-Production-Methodologies.aspx>
Research study: Rybkowski, Z. K., Zhou, X., Lavy, S. and Fernández-Solís, J. (2012). "Investigation into the nature of productivity gains observed during the Airplane Game lean simulation," *Lean Construction Journal,* 78-90.

Example application in Industry:

Takt time scheduling







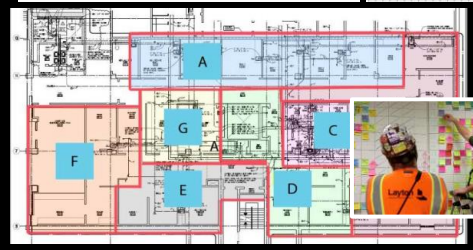
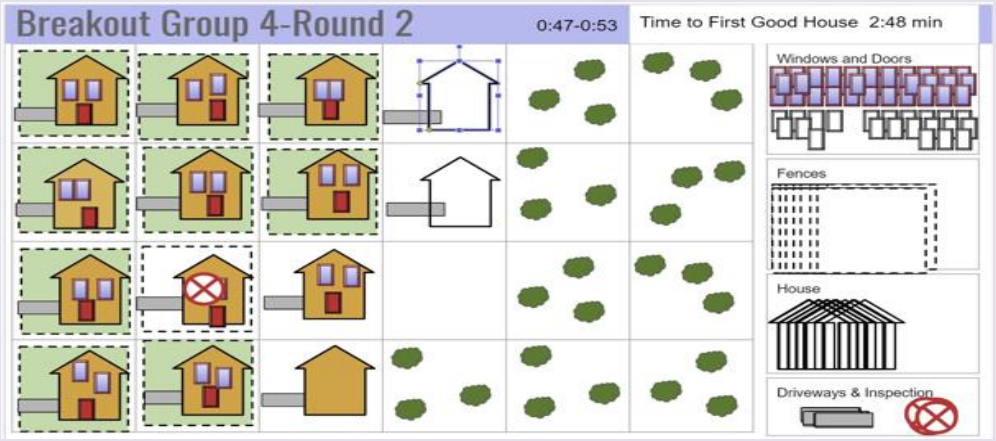


Image sources: Last Planner System of Production Control, HOAR Construction, Last Planner® System <https://www.youtube.com/watch?v=kUT-9WiYyso>,
16th *LCI Congress*, Oct. 7-10, 2014,
Kankainen J., and Seppanen, O. (2003). "A line-of-balance based schedule planning and controlling system," *Proceedings of the 11th International Group for Lean Construction*, Blacksburg, VA

On-line version

Batch-Pull Balance Simulation



Data Summary

WIP = TH X CT

Reducing batch/WIP lowers CT
Pull prevents overproduction by controlling WIP
TH is determined by the bottleneck

Team Yellow Breakout Group 1	Good Homes	Failed Homes	Time to First Good Home	Work in Process
Phase 1	1	3	4:46	8
Phase 2	16	2	1:24	5
Phase 3	Result	Result	Result	Result

Team Green - Breakout Room 2	Good Homes	Failed Homes	Time to First Good Home	Work in Process
Phase 1	10	2	3:29	12
Phase 2	14	4	1:24	6
Phase 3	Result	Result	Result	Result

Team Blue - Breakout Room 4	Good Homes	Failed Homes	Time to First Good Home	Work in Process
Phase 1	4	0	4:52	20
Phase 2	5	1	2:48	5
Phase 3	Result	Result	Result	Result

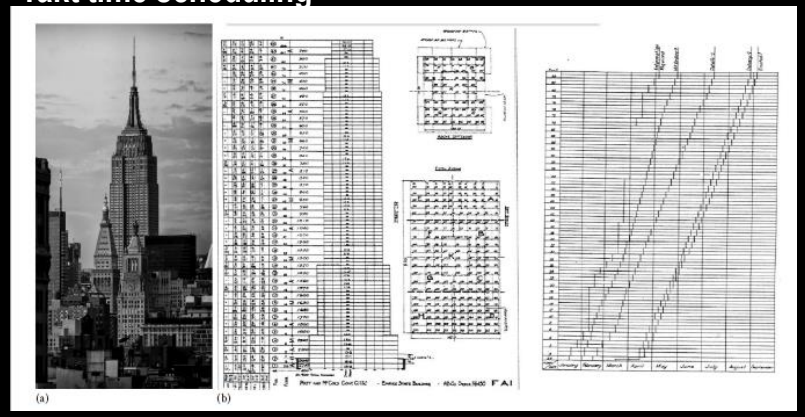
Team Red - Breakout Room 3	Good Homes	Failed Homes	Time to First Good Home	Work in Process
Phase 1	16	0	2:22	8
Phase 2	19	0	1:10	2
Phase 3	Result	Result	Result	Result

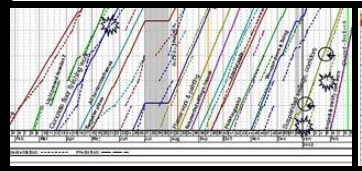
Team Blue - Breakout Room 5	Good Homes	Failed Homes	Time to First Good Home	Work in Process
Phase 1	Result	Result	Result	Result
Phase 2	Result	Result	Result	Result
Phase 3	Result	Result	Result	Result

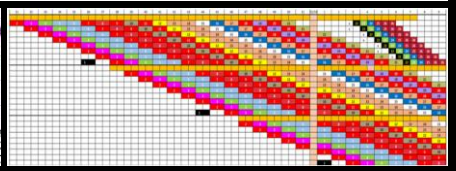
Source: Colin Milberg <colin@askmassociates.com>, Ryan Popp <ryan@askmassociates.com & Cynthia Tsao <cynthia@navilean.com>

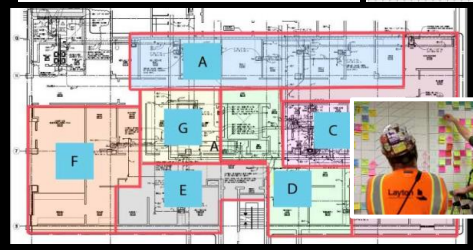
Example application in Industry:

Takt time scheduling









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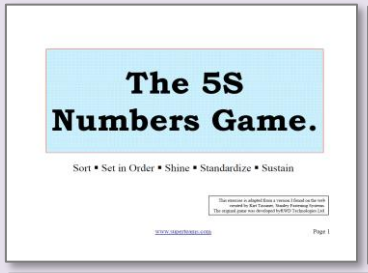
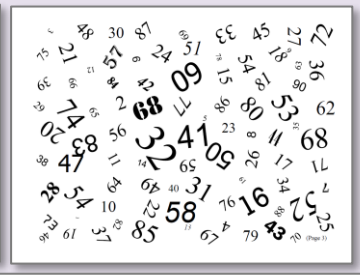
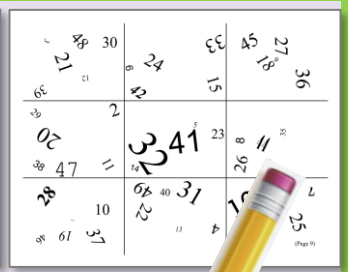
Kankainen J., and Seppanen, O. (2003). "A line-of-balance based schedule planning and controlling system," *Proceedings of the 11th International Group for Lean Construction*, Blacksburg, VA

In person simulation

5S Simulation







Numbers from 1 to 49

1	2	3	4	5	6	7	8		10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32		34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	

Adapted from <www.superteams.com> (PDF)

Before 5S | **After 5S**

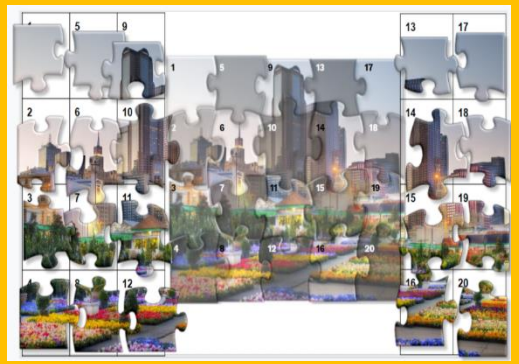
McNew, T. (July 26, 2011). "TD Industries: Lean Transformation," presentation delivered to Texas A&M University, College Station, TX

On-line version

5S Simulation







5S:

- Sort
- Set in Order
- Shine
- Standardize
- Sustain

Source: Obulam, R. and Rybkowski, Z. K. (2021). "Development and testing of the 5S puzzle game" *Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC29)*, Alarcon, L.F. and González, V.A. (eds.), Lima, Peru, pp. 309–319.

Before 5S | **After 5S**



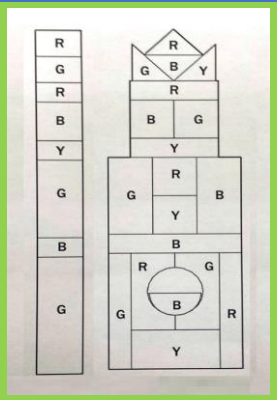


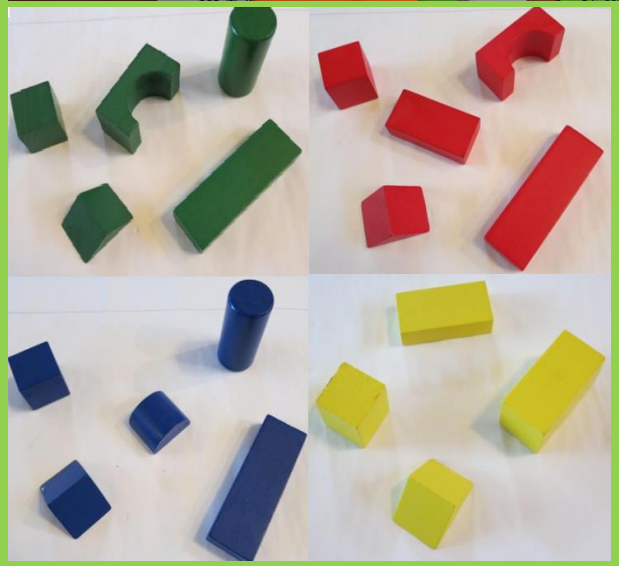
McNew, T. (July 26, 2011). "TD Industries: Lean Transformation," presentation delivered to Texas A&M University, College Station, TX

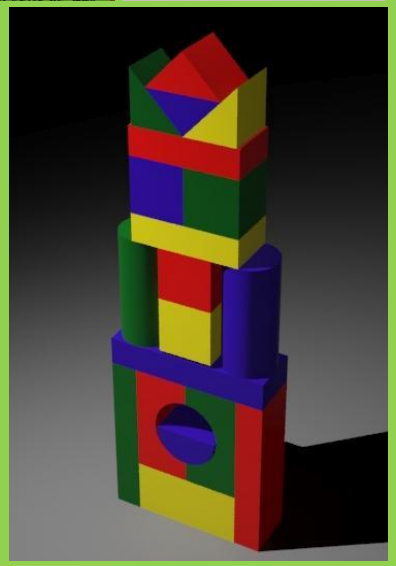
Zofia Rybkowski, PhD . Texas A&M University . zrybkowski@tamu.edu

In person simulation

DPR/Turner Tower Simulation







Adapted from DPR for DPR/Turner Joint Venture. George Zettel: <gzettel@tcco.com>

Example application in Industry:

Last Planner™ System of Production Control

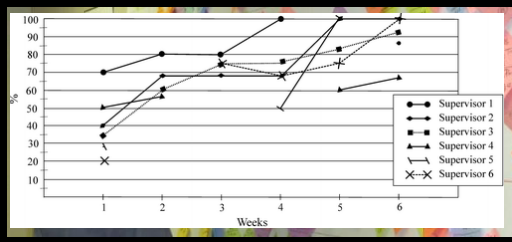
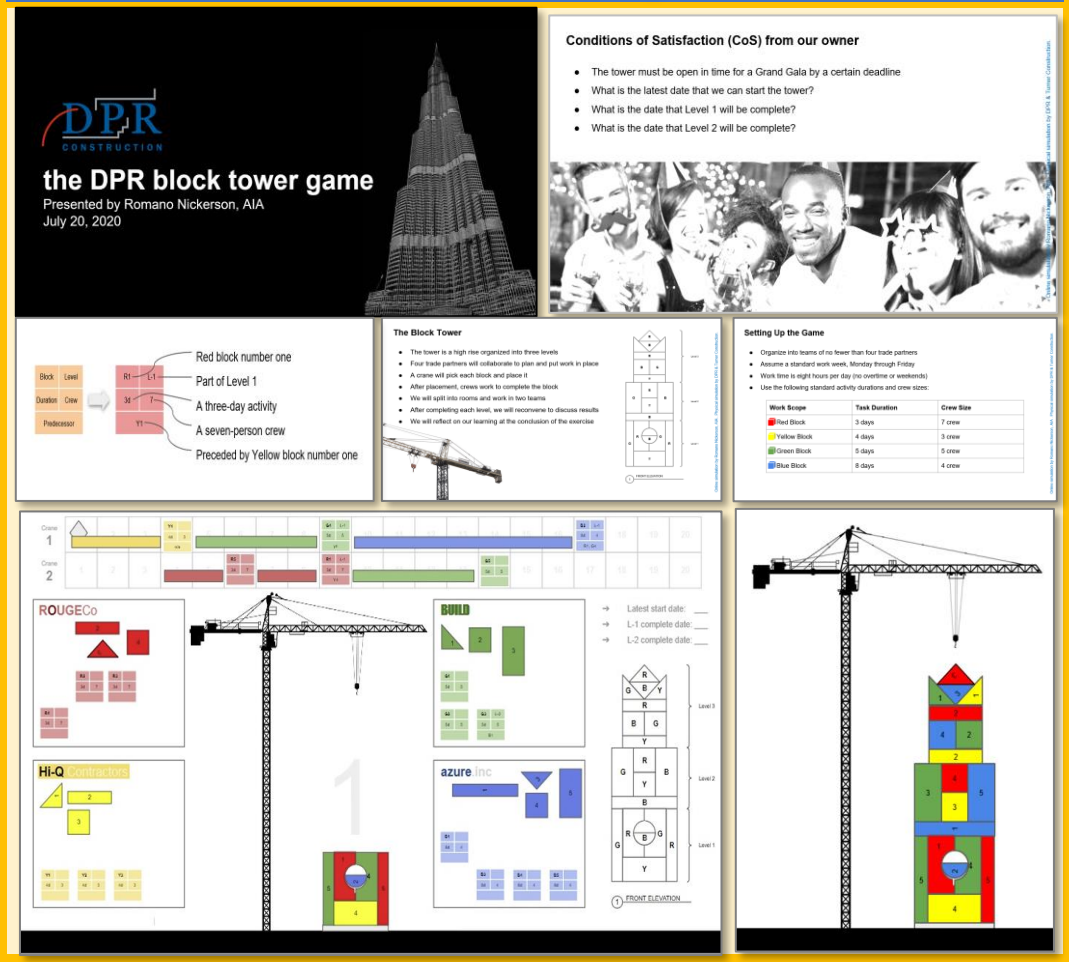


Image Credits- the ReAlignment Group of California, LLC <http://danzpage.com/>; Nieto-Morote, A. and Ruz-Vila, F. (2012) "Last Planner Control System Applied to a Chemical Plant Construction," *Journal of Construction Engineering and Management,* 138(2)

On-line version

DPR/Turner Tower Simulation



Adapted from DPR for DPR/Turner Joint Venture. Online by Romano Nickerson <rnickerson@boulderassociates.com>

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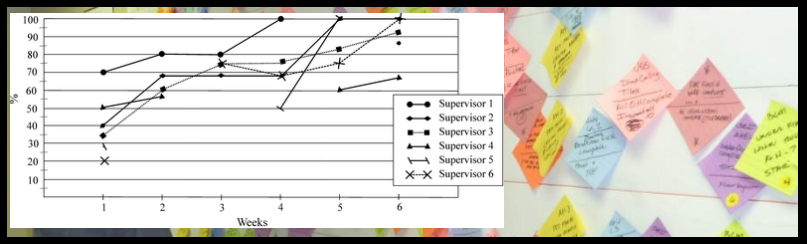

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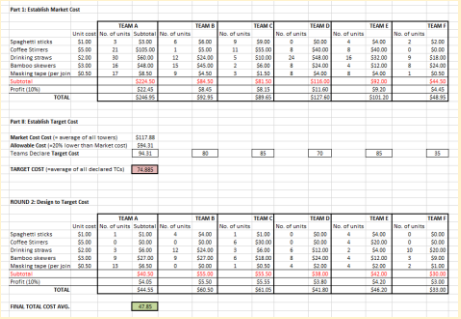
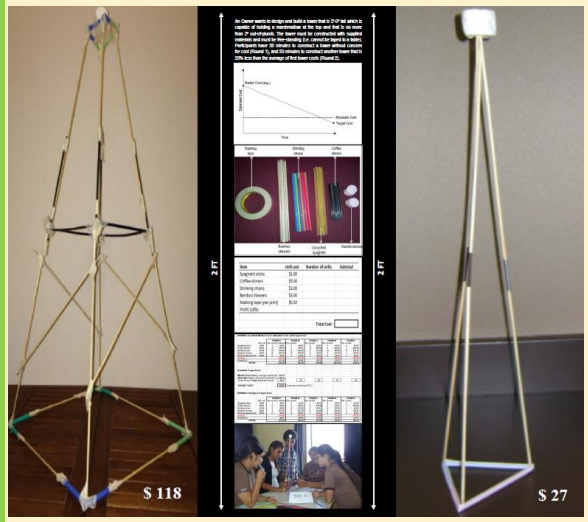
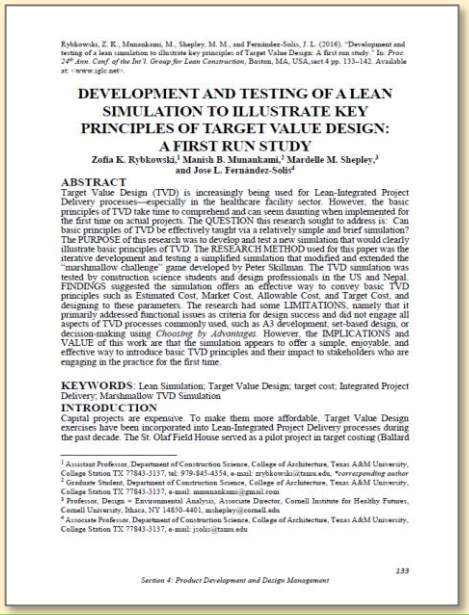
Zofia Rybkowski, PhD . Texas A&M University . zrybkowski@tamu.edu

In person simulation

Target Value Design Simulation







Rybkowski, Z. K., Munankami, M., Shepley, M. M., and Fernández-Solis, J. L. (2016). "Development and testing of a lean simulation to illustrate key principles of Target Value Design: A first run study." In: *Proc. 24th Ann. Conf. of the Int'l. Group for Lean Construction*, Boston, MA, USA, sect 4 pp. 133–142. Available at: www.iglc.net.

DEVELOPMENT AND TESTING OF A LEAN SIMULATION TO ILLUSTRATE KEY PRINCIPLES OF TARGET VALUE DESIGN: A FIRST RUN STUDY

Zofia K. Rybkowski,[1] Manish B. Munankami,[2] Mardelle M. Shepley,[3] and Jose L. Fernández-Solis[4]

ABSTRACT

Target Value Design (TVD) is increasingly being used for Lean-Integrated Project Delivery processes—especially in the healthcare facility sector. However, the basic principles of TVD take time to comprehend and can seem daunting when implemented for the first time on actual projects. The QUESTION this research sought to address is: Can basic principles of TVD be effectively taught via a relatively simple and brief simulation? The PURPOSE of this research was to develop and test a new simulation that would clearly illustrate basic principles of TVD. The RESEARCH METHOD used for this paper was the iterative development and testing a simplified simulation that modified and extended the "marshmallow challenge" game developed by Peter Skillman. The TVD simulation was tested by construction science students and design professionals in the US and Nepal. FINDINGS suggested the simulation offers an effective way to convey basic TVD principles such as Estimated Cost, Market Cost, Allowable Cost, and Target Cost, and designing to these parameters. The research had some LIMITATIONS, namely that it primarily addressed functional issues as criteria for design success and did not engage all aspects of TVD processes commonly used, such as A3 development, set-based design, or decision-making using *choosing by advantages*. However, the IMPLICATIONS and VALUE of this work are that the simulation appears to offer a simple, enjoyable, and effective way to introduce basic TVD principles and their impact to stakeholders who are engaging in the practice for the first time.

KEYWORDS: Lean Simulation; Target Value Design; target cost; Integrated Project Delivery; Marshmallow TVD Simulation

INTRODUCTION

Capital projects are expensive. To make them more affordable, Target Value Design exercises have been incorporated into Lean-Integrated Project Delivery processes during the past decade. The St. Olaf Field House served as a pilot project in target costing (Ballard

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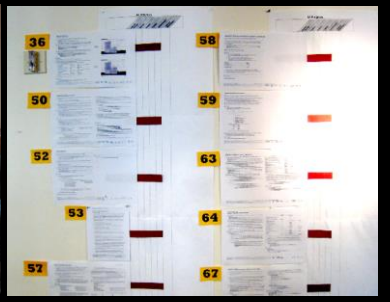
[2] Graduate Student, Department of Construction Science, College of Architecture, Texas A&M University, College Station TX 77843-3137, e-mail: munankami@gmail.com
[3] Professor, Design + Environmental Analysis, Associate Director, Cornell Institute for Healthy Futures, Cornell University, Ithaca, NY 14850-4401, mshepley@cornell.edu
[4] Associate Professor, Department of Construction Science, College of Architecture, Texas A&M University, College Station TX 77843-3137, e-mail: jolis@tamu.edu

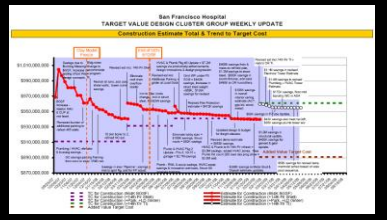
Research: Rybkowski, Z. K., Munankami, M., Shepley, M. M. and Fernández-Solis, J. L. (2016). "Development and testing of a lean simulation to illustrate key principles of Target Value Design: A first run study," *Proc. 24th Annual Conf. of the Int. Group for Lean Construction*, Boston, MA USA. <https://www.youtube.com/watch?v=Xg9rWE3qj2M&t=8s>

Example application in Industry:

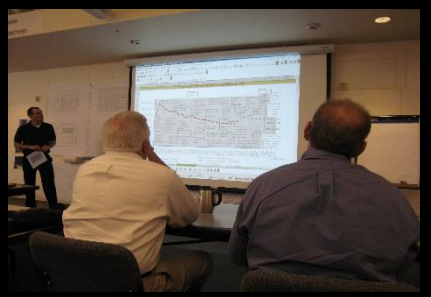
Target Value Design: Cathedral Hill Hospital, SF CA



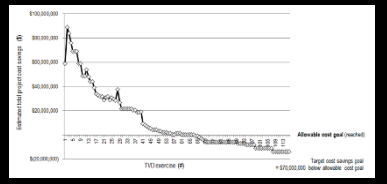
A3s from TVD Exercises, Cathedral Hill Hospital, San Francisco, CA (Rybkowski 2009)



Cost savings from TVD Exercises with scope changes, Cathedral Hill Hospital, San Francisco, CA (Rybkowski 2009)



Cluster group for Assembly Cost estimating, Cathedral Hill Hospital, San Francisco, CA (Rybkowski 2009)



Total cost savings from TVD Exercises, Cathedral Hill Hospital, San Francisco, CA (Rybkowski 2009)

Source: Rybkowski, Z. K. (2009). "The Application of Root Cause Analysis and Target Value Design to Evidence-Based Design in the Capital Planning of Healthcare Facilities." PhD Dissertation, Civil and Envir. Engrg, University of California, Berkeley.

Zofia Rybkowski, PhD . Texas A&M University . zrybkowski@tamu.edu

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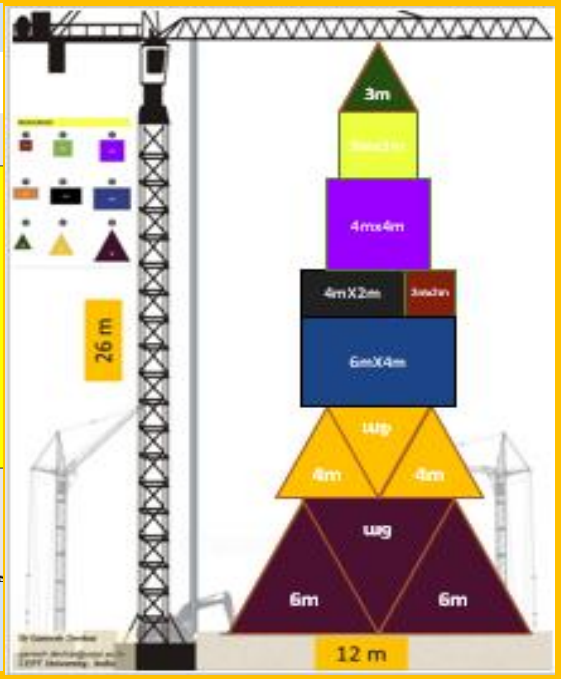

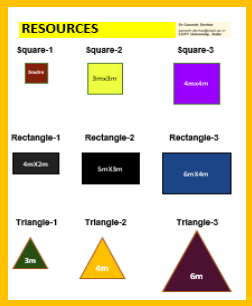

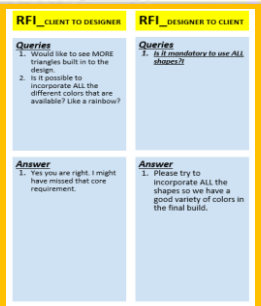

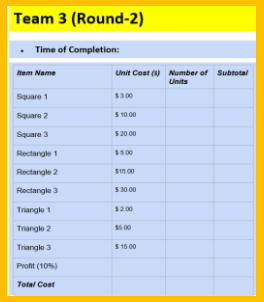

Research source: Jacob, G., Sharma, N., Rybkowski, Z. K., and Devkar, G. (2021). "Target Value Design: Development and Testing of a Virtual Simulation." Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC29), Alarcon, L.F. and González, V.A. (eds.), Lima, Peru, pp. 320–329.

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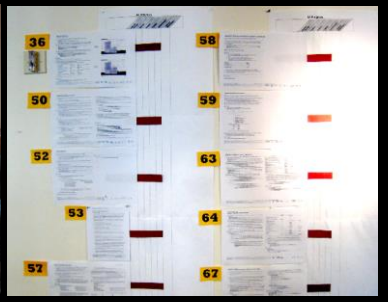

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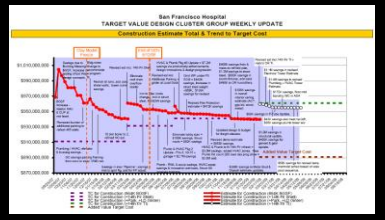

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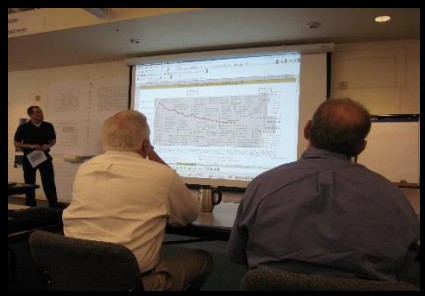

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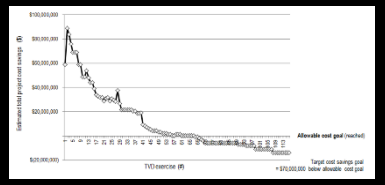

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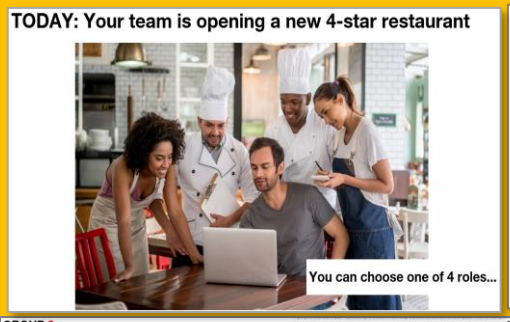
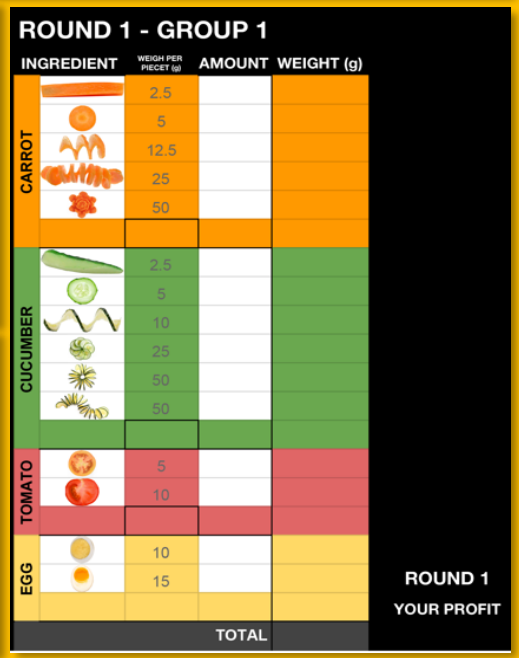
Target Value Design Simulation





Ng, M. S. and Hall D. H. (2021). "Teaching Target Value Design for digital fabrication in an online game: overview and case study." *Proc. 29th Annual Conference of the International Group for Lean Construction* (IGLC29), Alarcon, L.F. and González, V.A. (eds.), Lima, Peru, pp. 249–258.

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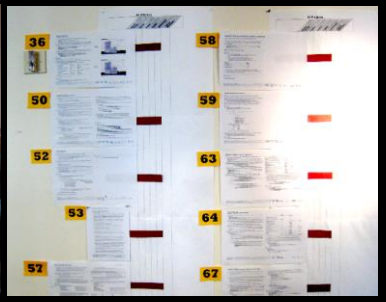

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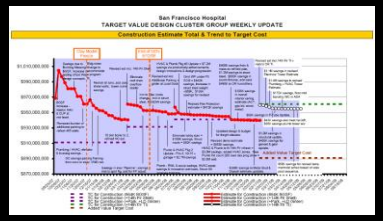

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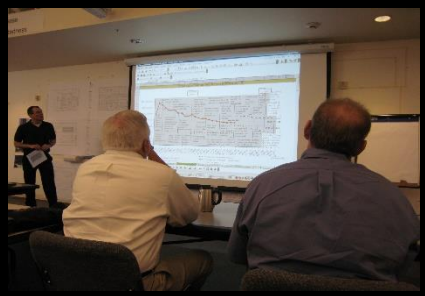

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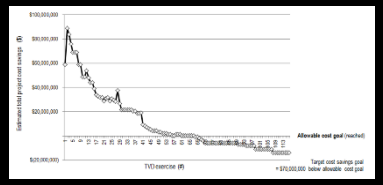

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On-line version

Target Value Design Simulation

Developers: "David Jeong"<djeong@tamu.edu>, Jinsil Hwaryoung Seo, Peter Mainardi, Soo Wan Chun, Suryeon Kim, and Zofia Rybkowski, Texas A&M University

Example application in Industry:

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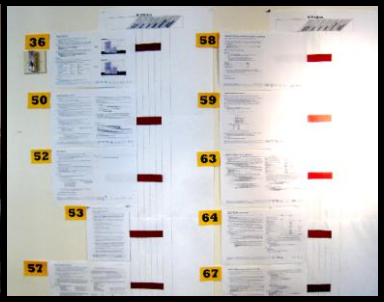

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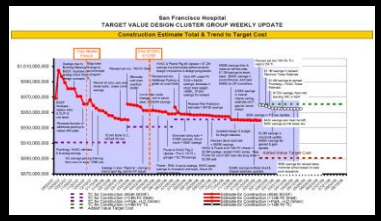

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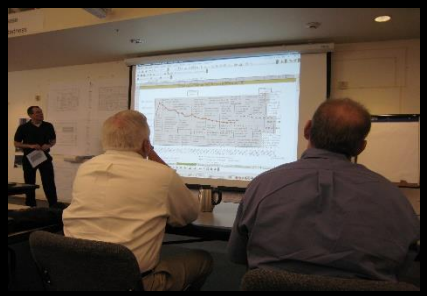

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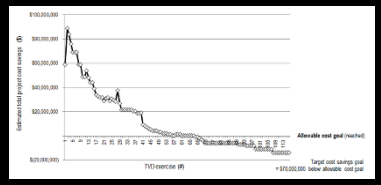

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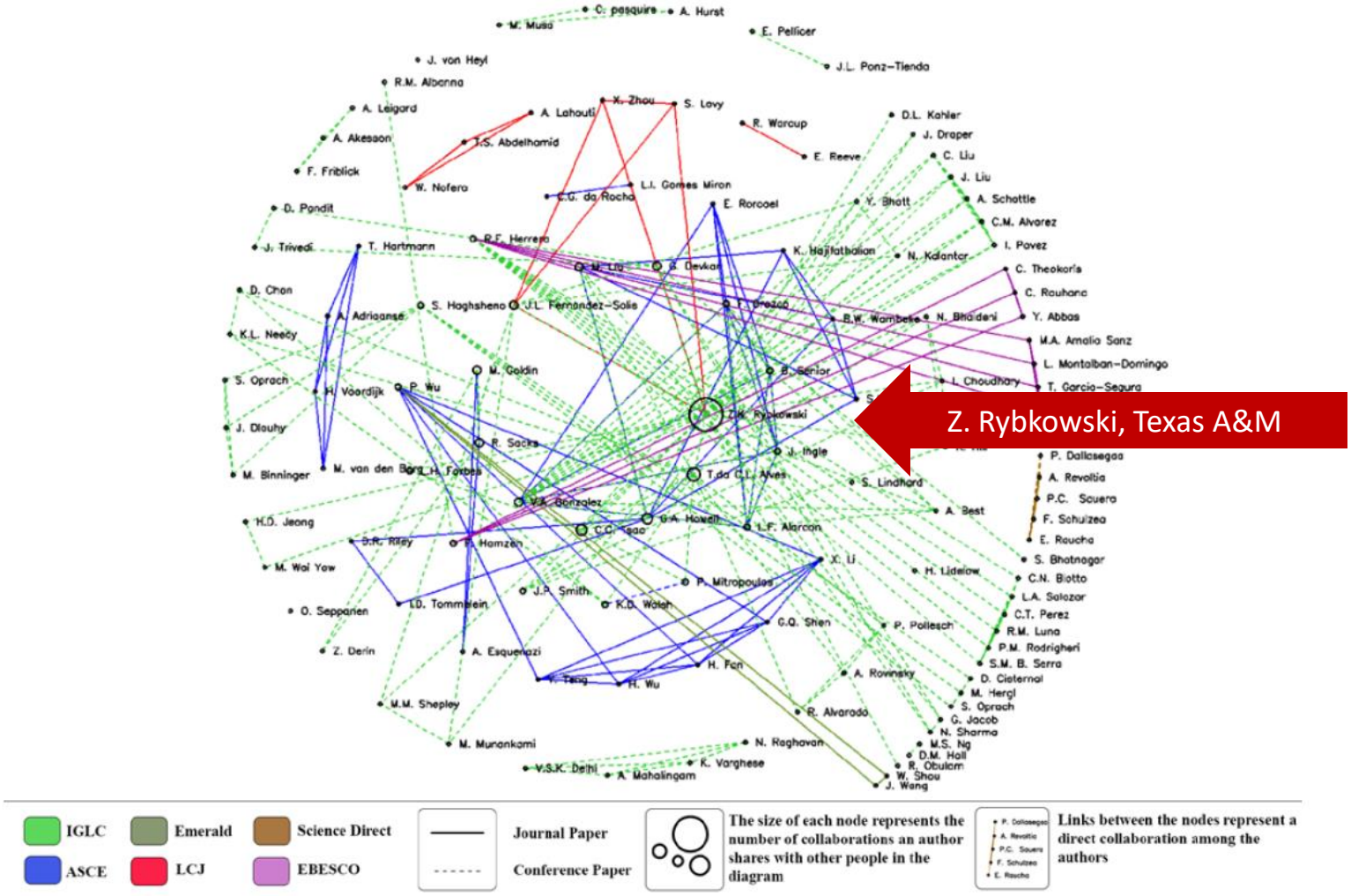
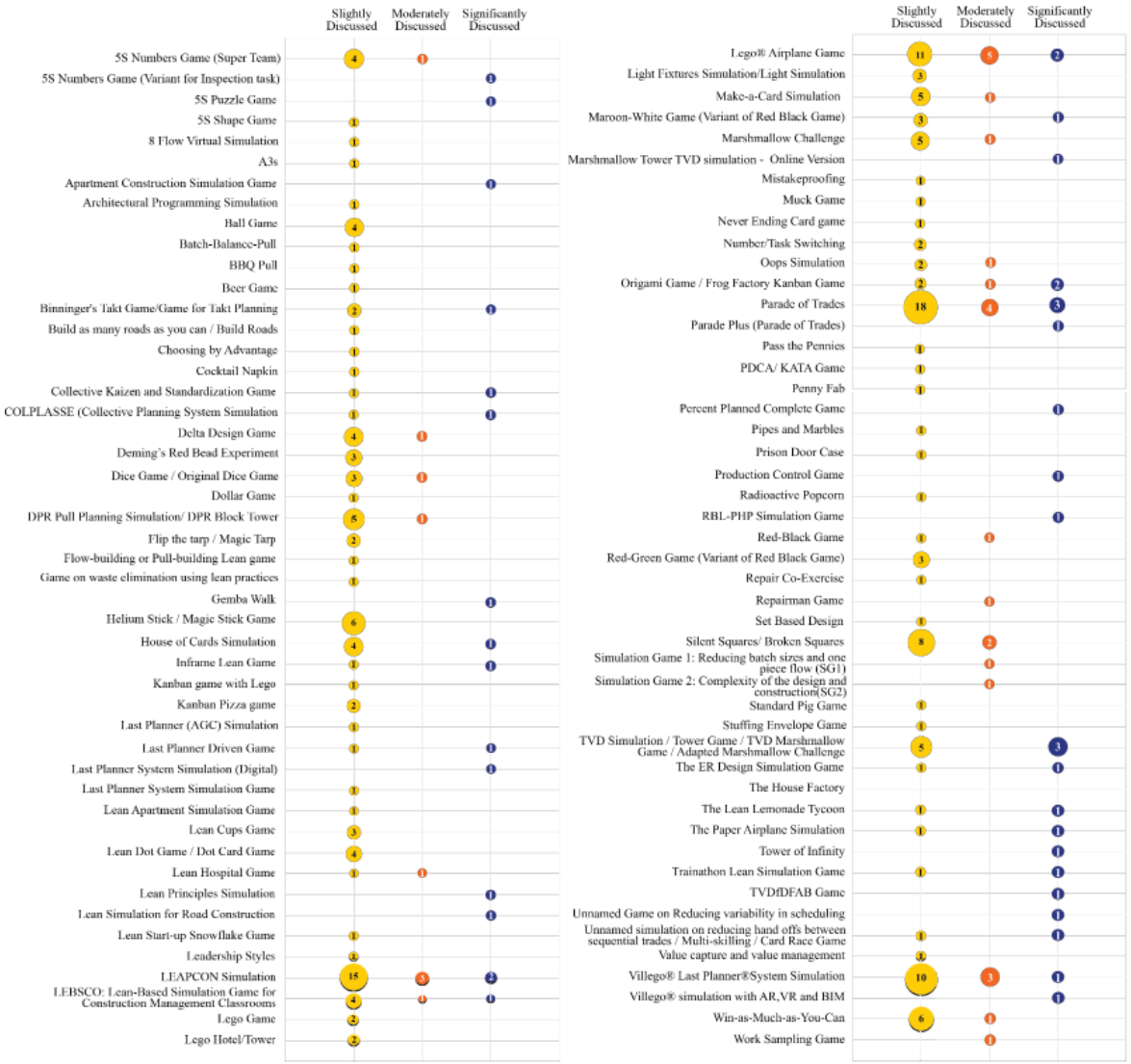
Shameless self-promotion…



Z. Rybkowski, Texas A&M

Social Network Analysis (SNA) map showing unique authors and their levels of collaboration across different databases.

Bhatnagar, S., Jacob, G., Devkar, G., Rybkowski, Z. K., Arefazar, Y., and Obulam, R. (2022). "A systematic review of lean simulation games in the construction industry," *Architectural Engineering and Design Management*.



Analysis of simulation games with levels of discussion

Top games played:

- **Last Planner**: Villego®/LEAPCON/DPR -Turner block tower
- **Impact of Variability**: Parade of Trades ("Dice Game")
- **Pull & one-piece flow:** Make-a-Card (Lego® Airplane Game)
- **Collaboration:** Silent Squares, Helium stick
- **Target Value Design**: Marshmallow Tower TVD Game

Bhatnagar, S., Jacob, G., Devkar, G., Rybkowski, Z. K., Arefazar, Y., and Obulam, R. (2022). "A systematic review of lean simulation games in the construction industry," *Architectural Engineering and Design Management.*

Participation in APLSO by country

(115 total participants, 38 universities in 17 countries)

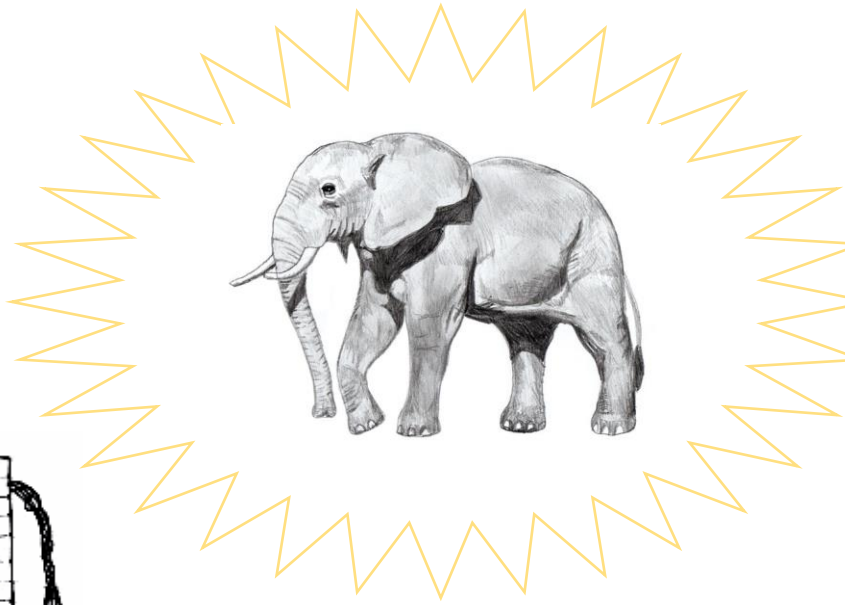
Location of Registered, Unique Participants

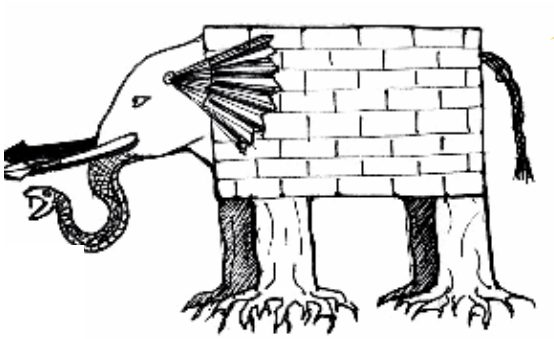
Unique Registered Participants by Country and Type of Occupation

Country	R/U	C	Total	Country	R/U	C	Total
USA	43	19	62	Finland	2		2
Canada	5	4	9	Lebanon	2		2
UK	7	2	9	Switzerland	2		2
India	6	3	9	Denmark		1	1
New Zealand	3	3	6	France	1		1
Brazil	4		4	Germany		1	1
Australia	2		2	Italy	0	1	1
Chile	2		2	Norway	1		1
				Qatar		1	1
R/U:	Research Institute/ University				**80**	**35**	**115**
C:	Company/ Consultancy				70%	30%	100%

Source: Rybkowski, Z. K., Alves, T. d. C. L., and Liu, M. (2021). "The emergence and growth of the on-line serious games and participatory simulation group APLSO," *Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC29), Alarcon, L.F. and González, V.A. (eds.)*, Lima, Peru, pp. 269–278)

Moving toward a fuller understanding of the whole elephant





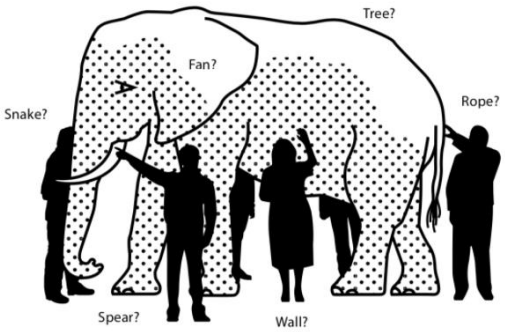


Image sources: <https://fs.blog/elephant/>
<http://housechurchministriesforjesus.com/newsletters/perspectives-blind-men-and-the-elephant/>
<http://www.yedraw.com/how-to-draw-elephant.html#.YDw412hKiUk>

Let's play the Spaghetti Kitchen Game!

8 Wastes: D.O.W.N.T.I.M.E.

Defects
Overproduction
Waiting
Non-Utilized Talent
Transportation
Inventory
Motion
Excess

Donarumo, J. and Zandy, K. (2019). *The Lean Builders: A Builder's Guide to Applying Lean Tools in the Field*, Lulu Publishing Services.

A Spaghetti Kitchen, A Value Stream Mapping Exercise

Created by:

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Spring 2022

Inspired by : Toast Kaizen: An Introduction to Continuous Improvement & Lean Principles (GBMP 2009)

Google Zofia Rybkowski and go to my website→Research→Simulation Research→Value Stream Mapping Simulation

https://drive.google.com/drive/u/1/folders/1OsOUPYBnFgTztgSlxxD-iA9_5iIZoG3C

How many ways did you find to reduce waste?

Gantt Charts

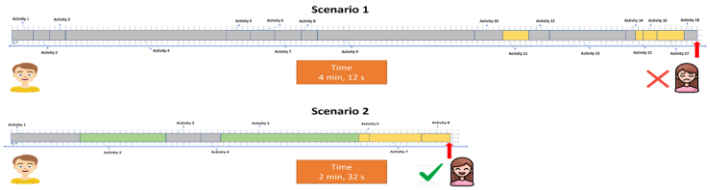
SCENARIO 1

	Activity	Duration (seconds)
-	Preparing a pasta (Total)	4min, 12 s
1	Take the pot from the cabinet	8
2	Fill the pot with water	6
3	Put the pot on the stove top	6
4	Wait for the water to boil	63
5	Take the spaghetti from the pantry and pour it in the water	9
6	Take the pan from the cabinet and put it on the stove top	9
7	Take out the meatballs from the fridge and put three of them in the pan	10
8	Put the remaining meatballs in the fridge	6
9	Wait for Spaghetti to be cooked	58
10	Take out the sieve from the cabinet and put it in the sink	10
11	Drain the spaghetti	10
12	Take the tomato-Chili sauce from the pantry and pour it over the meatballs	8
13	Wait for the meatballs to be cooked	28
14	Grab a plate from the cabinet	4
15	Put the spaghetti on the plate	3
16	Pour the meatballs over the spaghetti	5
17	Take the spaghetti to his wife	12
18	Throw the spaghetti to the trash bin	5

SCENARIO 2

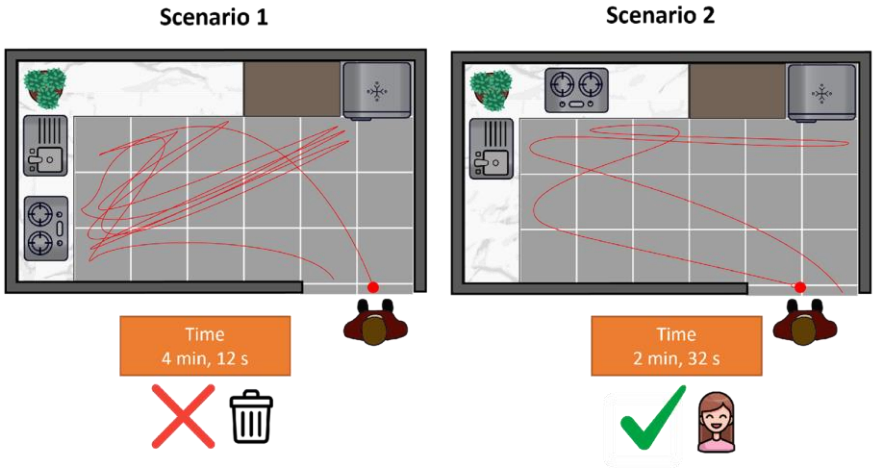
	Activity	Duration (seconds)
-	Preparing a pasta (Total)	2min 32s
1	Fill the kettle and leave it to boil	24
2	Wait for kettle to boil the water	30
	○ Take out the pan from the cabinet and place on stove	8
	○ Take out the meatballs from the fridge and put in the pan	10
	○ Put the remaining meatballs in the fridge	4
	○ Take out the pot and put it on the stove	6
3	Fill the pot with boiling water	12
4	Take out the spaghetti from the pantry and pour it into the boiling water	7
5	Wait for the spaghetti to be cooked	58
	○ Take out the sieve from the cabinet and put it in the sink	8
	○ Take out the tomato sauce and pour it over the meatballs	12
	○ Clean the kitchen	38
6	Drain the spaghetti	4
7	Grab a plate and put spaghetti and meatballs on it	17
8	Take the spaghetti to his wife	10

Timelines



40% time savings!

Spaghetti Diagrams



Arefazar, Y.*and Rybkowski, Z. K. (2022). "Developing & Testing A Value Stream Map Simulation: Helping the Construction Industry Learn to See," *Proceedings of the 30th Annual Conference of the International Group for Lean Construction (IGLC30)*, 12 pp.

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