



SMARTLOG 2022 Seminar on
Effective Project-based Production

Takt Planning for Low Volume Stationary Production: Construction

Professor Iris D. Tommelein
tommelein@berkeley.edu
University of California, Berkeley, USA
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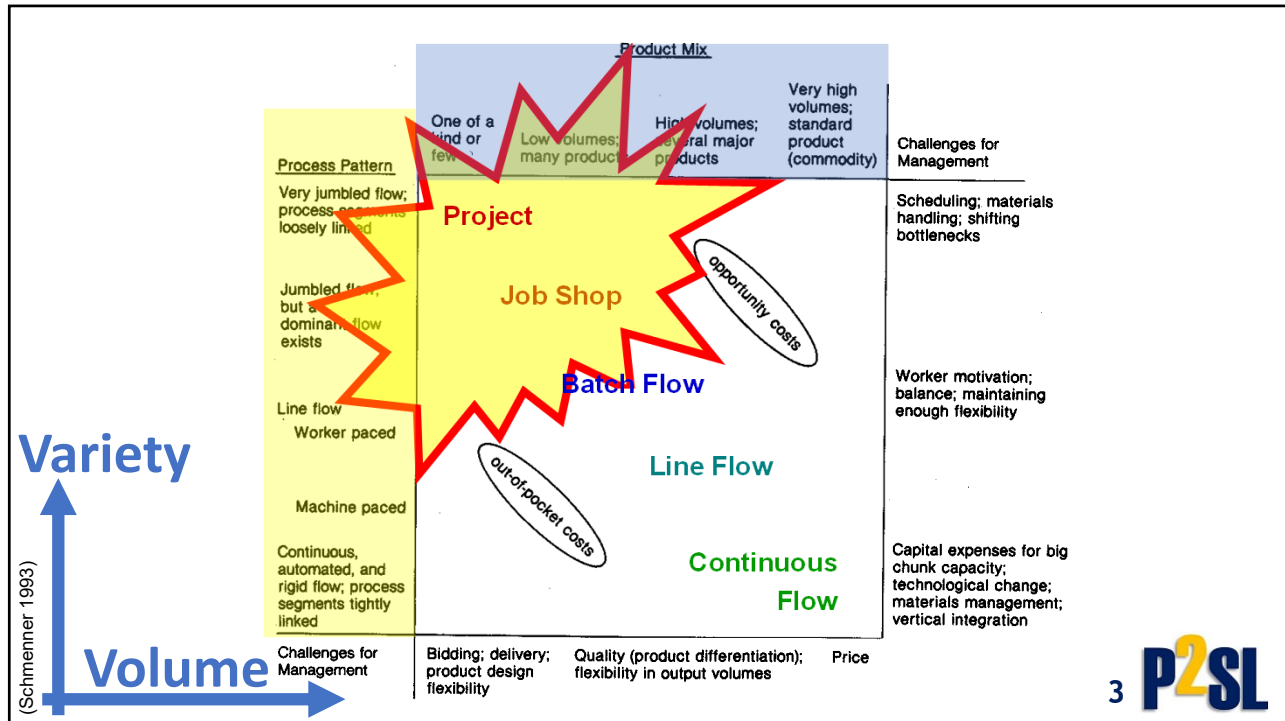
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Objectives

- Takt Planning in Project-based Production/Low Volume Stationary Production
 - Definition
 - Takt Planning in the Last Planner® System
- Assembly Line Balancing & the Work Density Method
- Workload Leveling and Zoning (WoLZo)
 - Visual Workload Leveling and Zoning (ViWoLZo)
 - WoLZo Mixed-Integer Linear Programming (MILP) Solution



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What is Takt time?

German word for *beat*, the regularity with which something gets done.

DEFINITION: *The unit of time within which a product must be produced (supply rate) in order to match the rate at which that product is needed (demand rate).*

A design parameter used in a production setting (be it manufacturing, construction,...) that we can use in *Work Structuring*.

www.netanimations.net

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Taichi Ohno House of Toyota

**Best Quality - Lowest Cost - Shortest Lead Time -
Best Safety - High Morale**
through shortening the production flow by eliminating waste

<p>Just-in-Time Right part, right amount, right time</p> <ul style="list-style-type: none"> ▪ Takt time planning ▪ Continuous flow ▪ Pull system ▪ Quick changeover ▪ Integrated logistics 	<p>People & Teamwork</p> <ul style="list-style-type: none"> ▪ Selection ▪ Common goals ▪ Ringi decision making ▪ Cross-trained <p>Continuous Improvement</p> <p style="text-align: center;">Waste Reduction</p> <ul style="list-style-type: none"> ▪ Genchi Genbutsu ▪ 5 Why's ▪ Eyes for Waste ▪ Problem Solving 	<p>Jidoka (In-station quality) Make Problems Visible</p> <ul style="list-style-type: none"> ▪ Automatic stops ▪ Andon ▪ Person-machine separation ▪ Error proofing ▪ In-station quality control ▪ Solve root cause of problems (5 Why's)
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Leveled Production (*heijunka*)

Stable and Standardized Processes

Visual Management


Toyota Way Philosophy



Figure 3-3. The Toyota Production System

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The challenge of any business: Matching capability with demand



MURA (Instability) Management

- Know your demand
- Know your true capability (capacity)
- Create flexibility to get them to match

----- TIME ----->

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Last Planner® System

When?

MASTER SCHEDULE


What?

PHASE SCHEDULE

How?

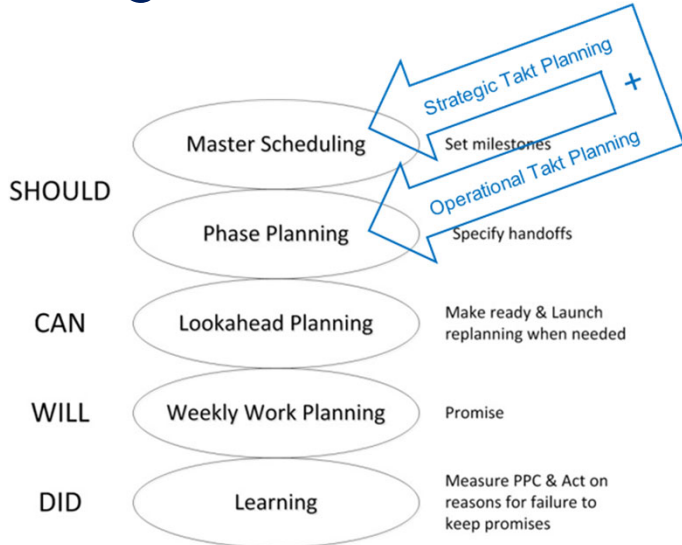
LOOKAHEAD PLAN

WEEKLY WORK PLAN



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Takt Planning in the Last Planner® System



SHOULD

CAN

WILL

DID

Master Scheduling

Phase Planning

Lookahead Planning

Weekly Work Planning

Learning


Set milestones

Specify handoffs

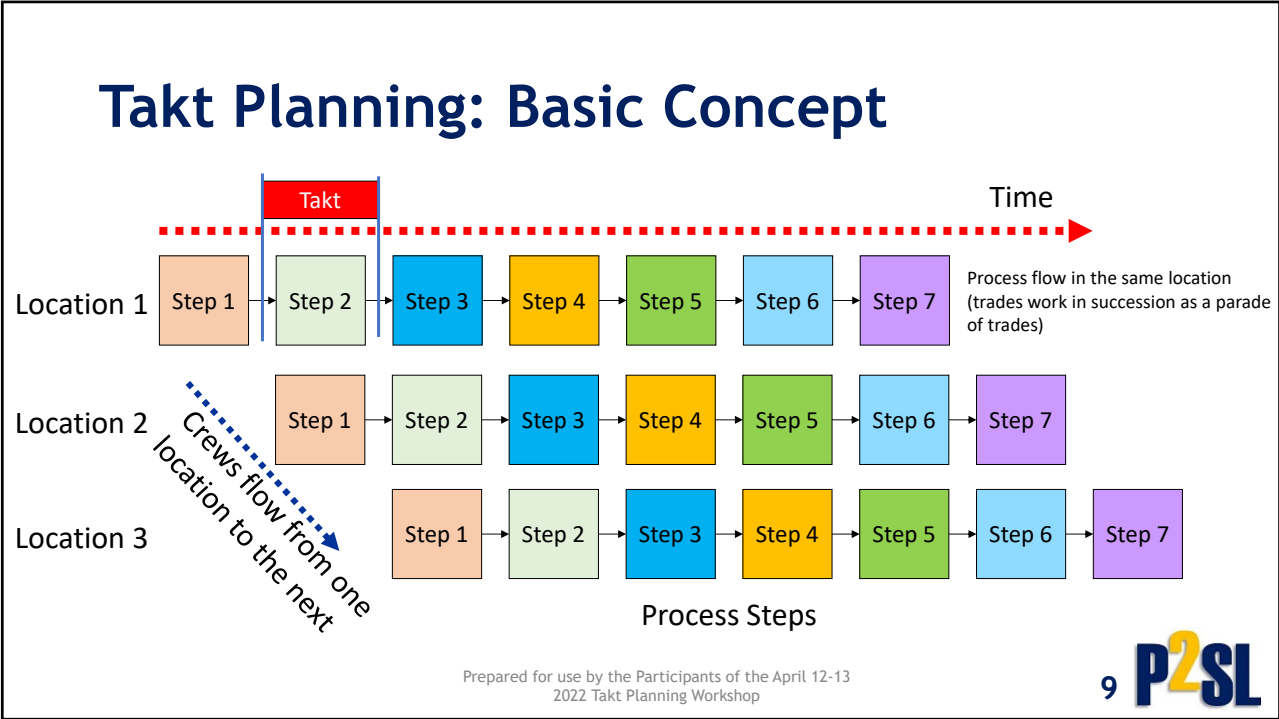
Make ready & Launch replanning when needed

Promise

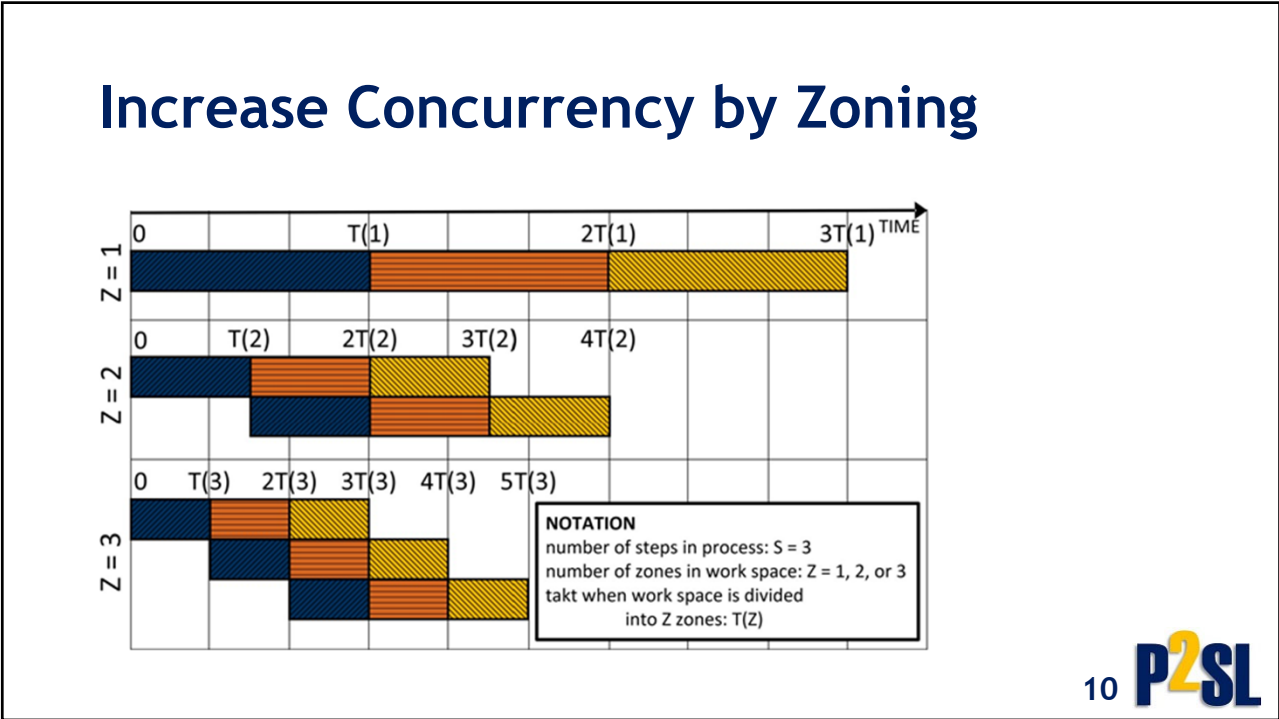
Measure PPC & Act on reasons for failure to keep promises



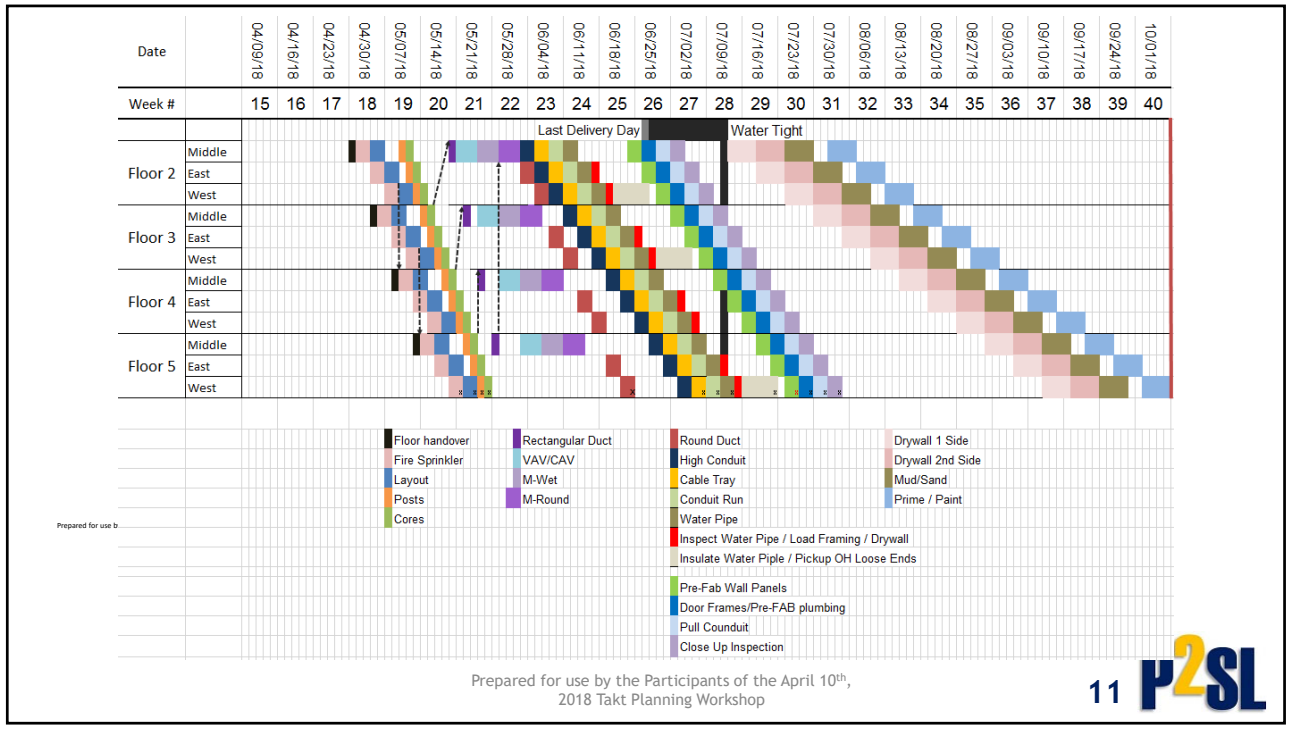
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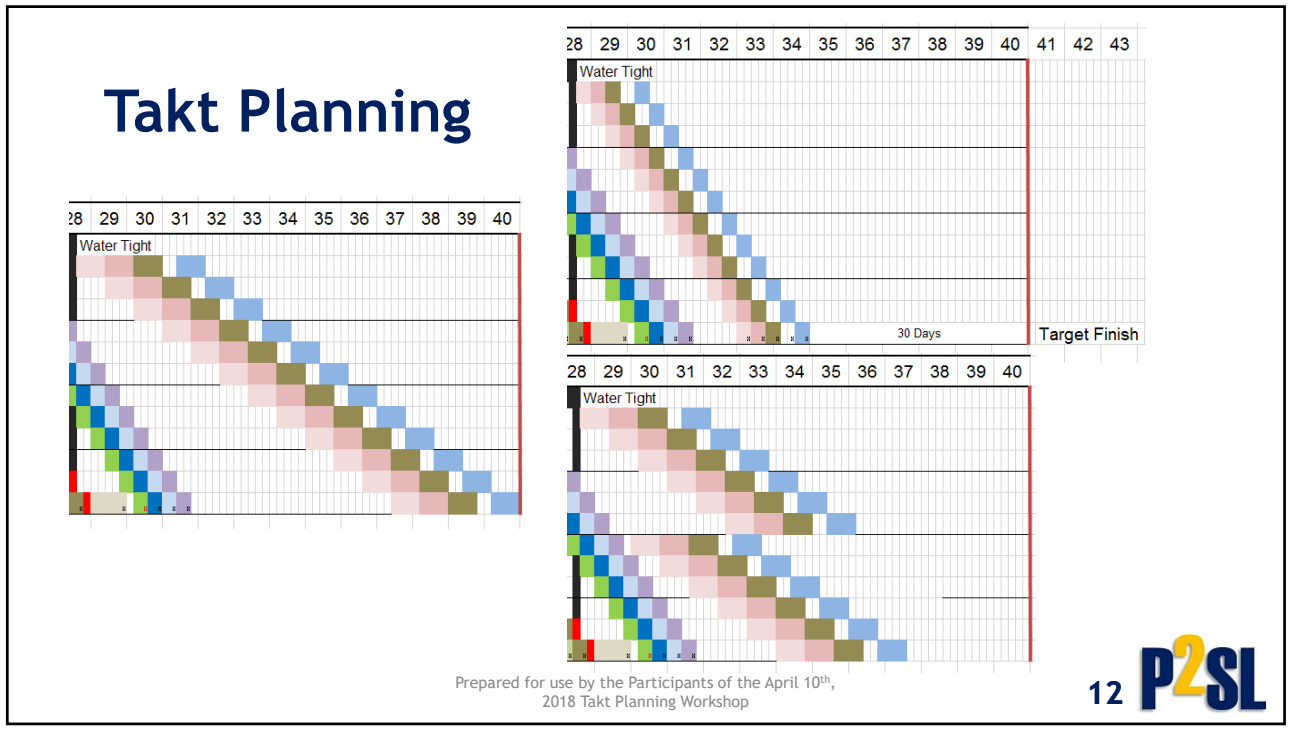
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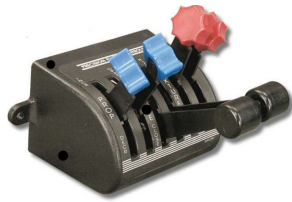


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https://flypic.com/shop/throttle-quadrants/multi-engine-propthrottlemixture-old-baron-style/ visited 24 SEP 2017

Production System Parameters

1. Product and components characteristics
2. Worker and crew trade skills
3. Alternative breakdowns of the scope and sequence of work
4. Alternative means and methods available to each trade
5. Number of trade resources that can be assigned



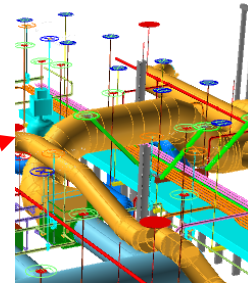
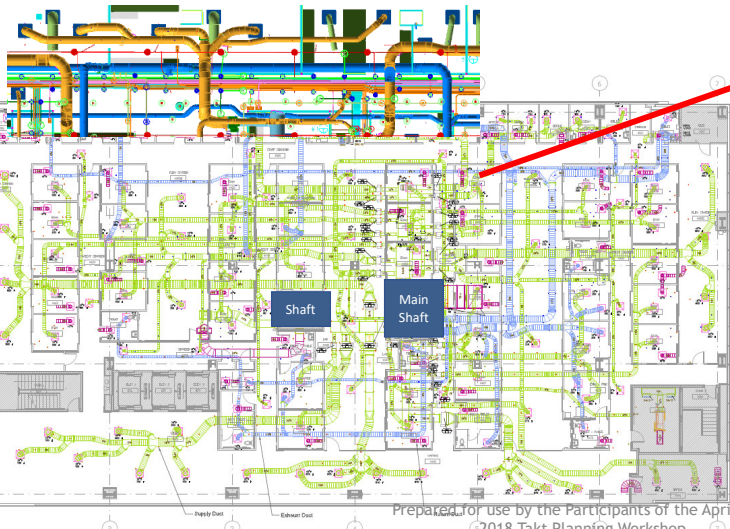
“throttles” to find repetition in non-repetitive work

Prepared for use by the Participants of the April 10th, 2018 Takt Planning Workshop



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Application in Construction Trade: Mechanical Dry



When ducts cross corridors they are the highest system after sprinkler pipe

You prefer to start from shafts and move out.

Rectangular duct is the largest duct and is generally at high elevation.

Prepared for use by the Participants of the April 10th, 2018 Takt Planning Workshop



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Trade: Electrical Cable Tray

Prepared for use by the Participants of the April 10th,
2018 Takt Planning Workshop

15 PZSL

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Work Density Data Collection

Collect Work Density Data #1
QUANTITY TAKE-OFF
*** PRODUCTION RATE**

Prepared for use by the Participants of the April 10th,
2018 Takt Planning Workshop

Collect Work Density Data #2
COLOR-UPS
Frandsen and Tommelein (2014)

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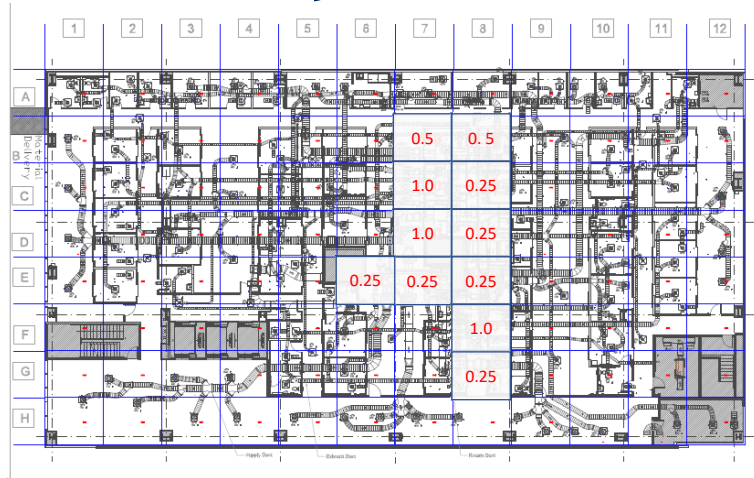
Collecting Data: Work Density

Example:

A crew of 3 can install 40 m/day
you measure 20 m in a grid cell,
so that

Work Density = 20 m / 40 m/day = 0.5 days

Example (Overhead Wet Mechanical):
Total Duration on the Floor = 5.5 Days



Prepared for use by the Participants of the April 12-13,
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19 **P2SL**

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Work density [unit of time/unit of area]

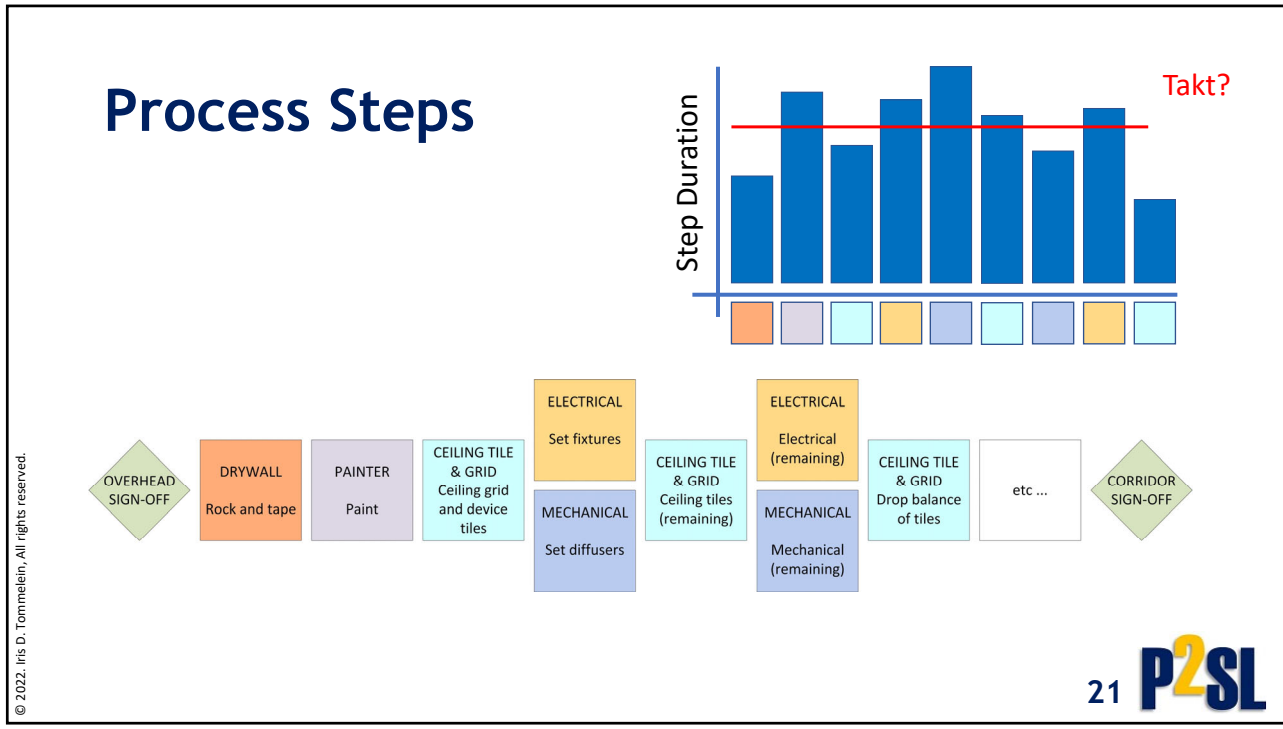
Given a certain work area, work density describes how much time trade will require to do their work in that area based on

1. *product design*
2. *scope of their work*
3. *... for a given task in the schedule (depending on work already in place and work that will follow)*
4. *means and methods trade will use*
5. *while accounting for crew capabilities and size.*

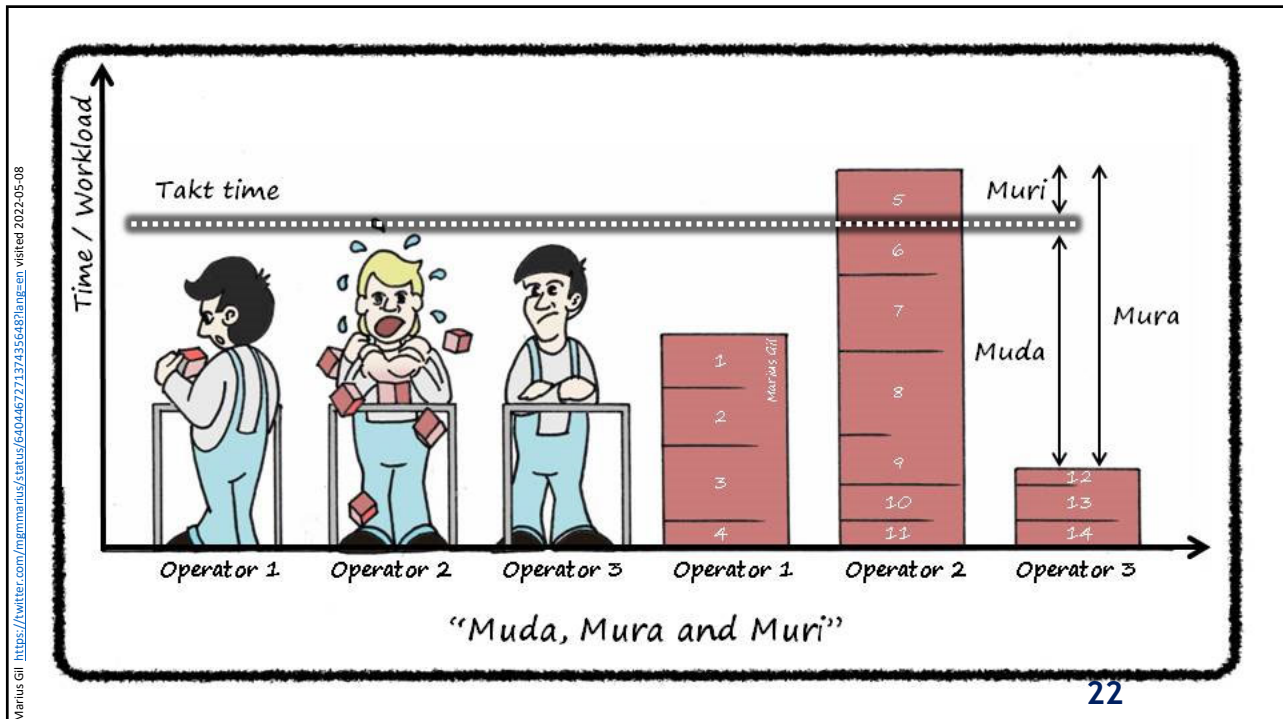
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20 **P2SL**

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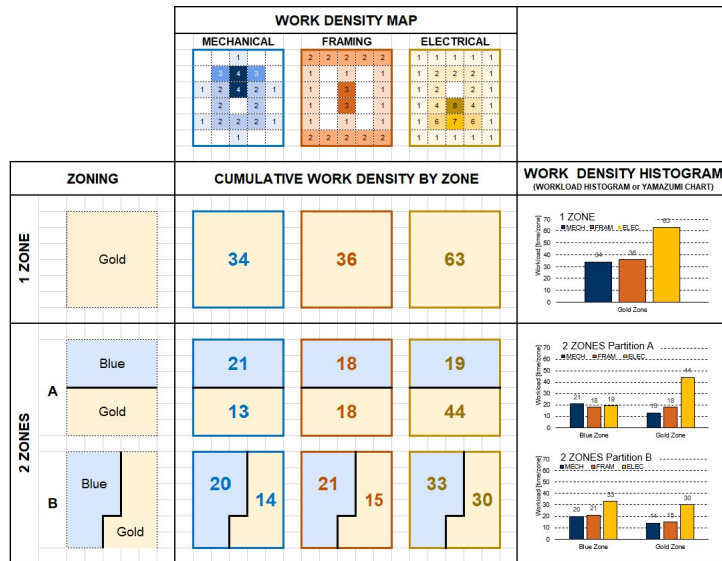
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Workload Leveling and Zoning

The problem is to determine the zoning that minimizes the work density peak (the maximum work density or workload) across trades and across zones.



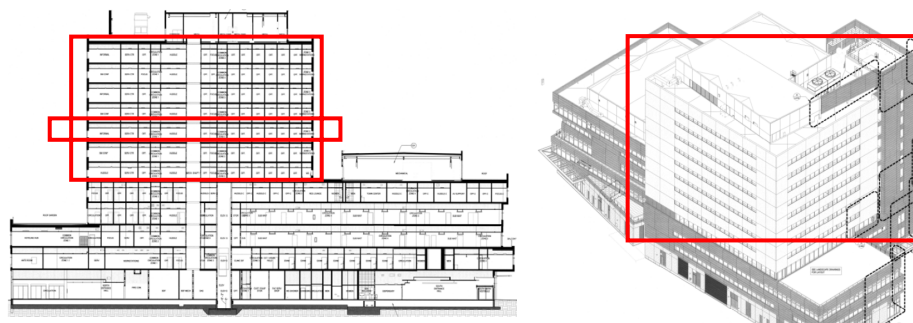
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Visual Management Tool for Workload Leveling and Zoning - ViWoLZo

Vishesh V. Singh, Iris D. Tommelein, and Lian Bardaweel
 Funded by National Science Foundation (NSF) Grant Number CMMI-1563511

Case: Mixed-use building located in San Francisco (repetitive floors 6 to 12)



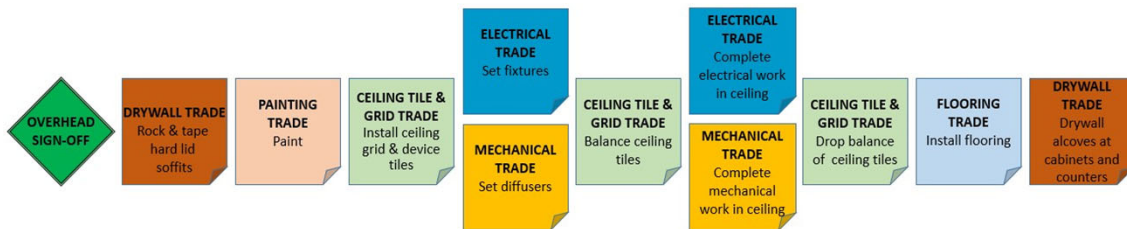
24 **P2SL**

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Visual Management Tool for Workload Leveling and Zoning - ViWoLZo

Takt Planning Steps:

1. Identify work spaces by type of work, e.g., corridor, open area, office, bathroom.
2. Define sequence of steps to complete the work in each space.



Vidheesh V. Singh, Iris D. Tommelein, and Jian Bardawel (2020). Funded by National Science Foundation (NSF) Grant Number CMMI-1563511



ViWoLZo Inputs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.27	0
B	0	0	0	0	0	5.29	0	2.39	2.92	0	0	0	0	0	6.09	0
C	0	0	0	0	0	5.38	0	0.84	1.10	0	0	0	0	0	0.02	0
D	0	0	0	0	0	0	0	1.50	1.96	0	0	0	0	0	6.49	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	3.44	1.76	0.42	0.89	0	0.58	0.87	0.81	0.92	0.47	1.73	0	3.85	2.57	1.26	
G	1.09	0.60	0.13	0.29	0	0.22	0.33	0.30	0.35	0.18	0.45	0	1.44	0.96	0.47	
H	5.20	2.76	0.58	1.20	0	1.10	1.33	1.33	0	0	2.48	0	5.47	3.67	1.78	
I	0.36	0.38	0	0	0	0	0	0	0	0	0.45	0	0	0	0	
J	1.71	0	0	0	0	0	0	0	0	0	1.08	0	0	0	0	
K	1.36	0.78	0.16	0.36	0	0	0	0	0	0.14	0.14	0.65	0	0	0	
L	4.56	2.93	0.60	1.27	0	1.12	1.34	1.10	1.40	1.10	2.54	0	0	0	0	
M	1.60	0	0	0	0	0.39	0.50	0.39	0.49	0.38	0.92	0	0	0	0	
N	1.31	0	0	0	0	0	0.35	0.28	0.49	0.36	0.80	0	0	0	0	
O	0	0	0	0	0	0	0.45	0.37	0.62	0.49	1.00	0	0	0	0	
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Q	0	0	0	0	0	0.73	0.73	0.61	0.73							
R	0	0	0	0	0	0.39	0.38	0.37	0.46							
S	0	0	0	0	0	1.92	1.89	1.69	2.22							

A work density map

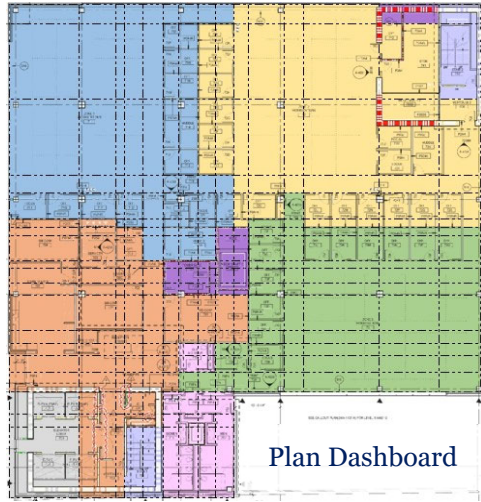
	1	2	3	5	6	7	8	9	10	11	12	13	14	15
A	x	x	x	x	x	x	x	x	x	x	x	x		
B	x	x	x	x	x					x	x	x		
C	x	x	x	x						x	x	x		x
D	x	x	x	x	x	x	x	x	x	x	x	x	x	x
E					x						x	x	x	x
F						x					x	x	x	x
G							x				x	x	x	x
H								x			x	x	x	x
I									x					
J														
K														
L														
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O														
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Work space definition

Vidheesh V. Singh, Iris D. Tommelein, and Jian Bardawel (2020). Funded by National Science Foundation (NSF) Grant Number CMMI-1563511



ViWoLZo Dashboard



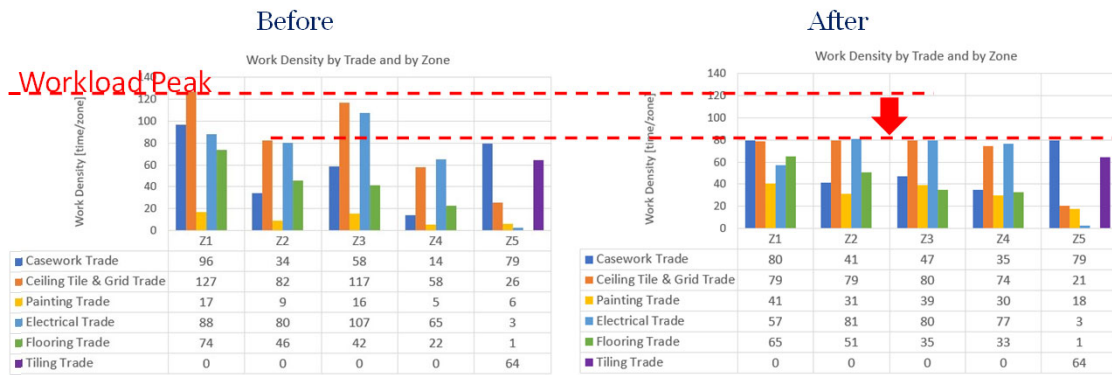
4	4	4	4	4	4	4	4	4	2	2	2	2	8	6
4	4	4	4	4	4	4	4	2	2	2	2	2	2	6
4	4	4	4	4	4	4	4	2	2	2	2	2	2	2
4	4	4	4	4	4	4	4	2	2	2	2	2	2	2
4	4	4	4	4	4	4	4	2	2	3	2	2	2	2
1	1	1	1	4	4	4	4	8	8	3	3	3	3	3
1	1	1	1	1	8	8	8	8	3	3	3	3	3	3
1	1	1	1	1	8	8	8	8	3	3	3	3	3	3
1	1	1	1	1	1	1	1	3	3	3	3	3	3	3
1	1	1	1	1	1	1	1	3	3	3	3	3	3	3
1	1	1	1	1	5	5	3	3	3	3	3	3	3	3
1	1	1	1	1	5	5	3	3	3	3	3	3	3	3
1	1	1	1	1	3	3	3	3	3	3	3	3	3	3
7	1	1	1	1	5	5	5	5						
7	1	1	1	1	5	5	5	5						
7	1	1	6	6	5	5	5	5						

Zoning Input



Vidhesh V. Singh, Iris D. Tommelein, and Ian Bardawell (2020). Funded by National Science Foundation (NSF) Grant Number CMMI-1563511

ViWoLZo Dashboard and Metrics

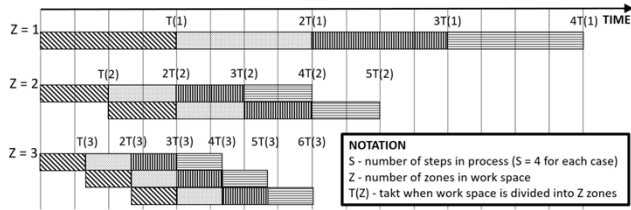


Metrics: Process Duration D
 % Underloading
 Evenness of Workloads by Trade across Zones
 and more...



Vidhesh V. Singh, Iris D. Tommelein, and Ian Bardawell (2020). Funded by National Science Foundation (NSF) Grant Number CMMI-1563511

Duration D of Taked Process

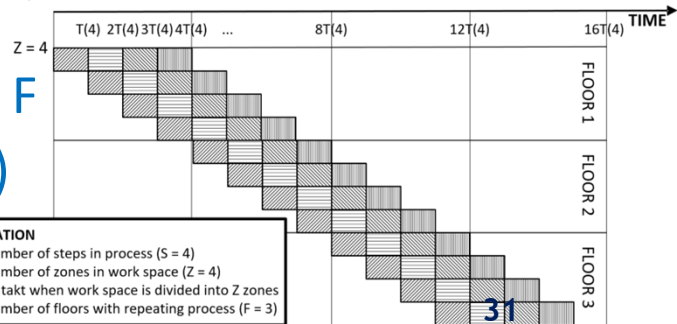


$$D = (S + Z - 1) \times T(Z)$$

NOTATION
 S - number of steps in process (S = 4 for each case)
 Z - number of zones in work space
 T(Z) - takt when work space is divided into Z zones

... with repeating Floors F

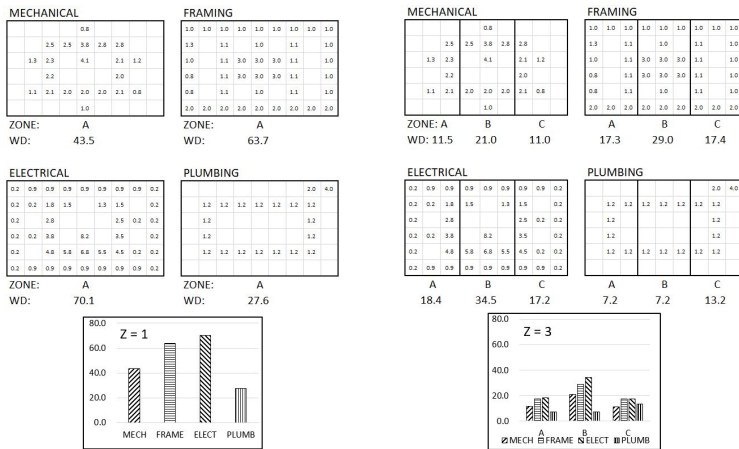
$$D = (S + (F \times Z) - 1) \times T(Z)$$



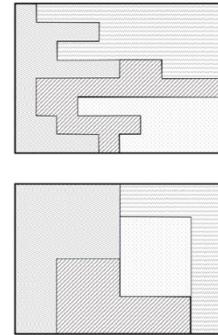
NOTATION
 S - number of steps in process (S = 4)
 Z - number of zones in work space (Z = 4)
 T(Z) - takt when work space is divided into Z zones
 F - number of floors with repeating process (F = 3)

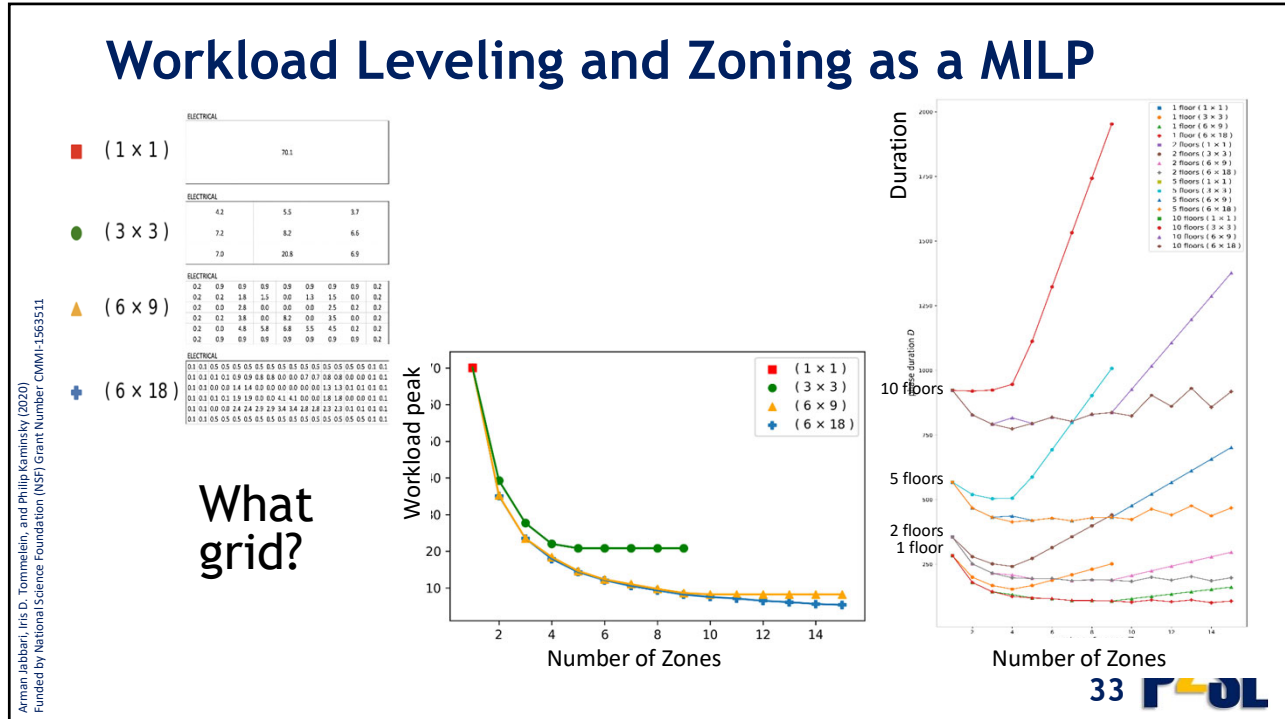
Workload Leveling and Zoning as a MILP

Arman Jabbari, Iris D. Tommelein, and Philip Kaminsky
 Funded by National Science Foundation (NSF) Grant Number CMMI-1563511



How to draw zone boundaries?





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Recap Objectives

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Questions?

tommelein@berkeley.edu

p2sl.berkeley.edu

P2SL

