Aalto University
School of Engineering

Operation Management in Construction
Lecture #2
Location-based planning systems

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Topics, Lecture #2

- Learning objectives of Lecture #2
- Location-based planning overview – two methods
- Production System cost
- Production System risk
- Buffers in LBMS and takt
- Planning examples

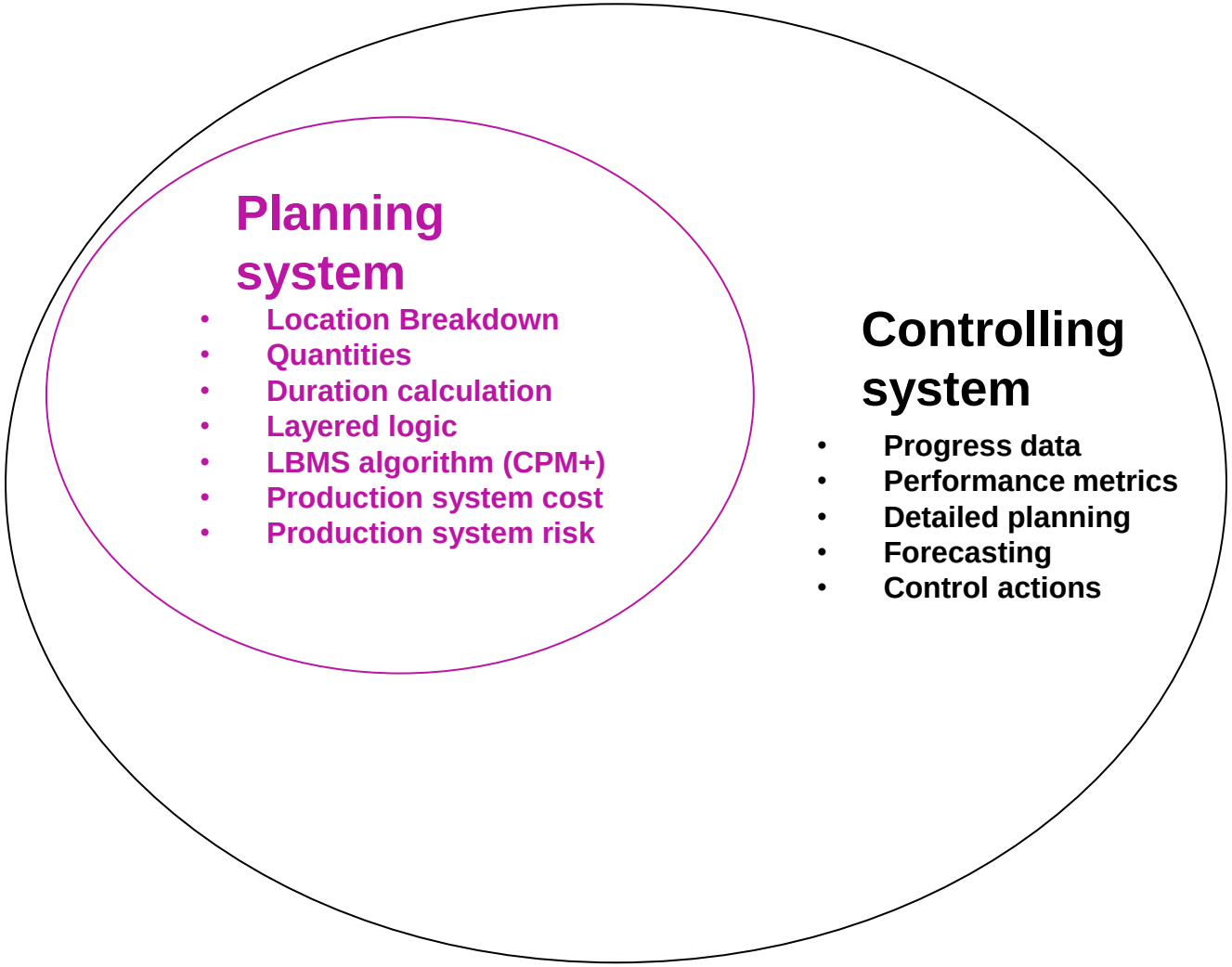
Intended learning objectives for this lecture

- ILO 2: **Students can compare and contrast** the similarities and differences of different production planning and control methods
  - *ILO emphasized for location-based planning systems*
- ILO 3**: Students can calculate** the production system cost of a schedule
  - *ILO introduced: theory of production system cost*
- ILO 4: **Students can explain** the factors related to production system risk of a schedule
  - ILO *emphasized*
- ILO 5**: Students can explain** the significance of work and labor flow and how flow can be achieved in construction
  - *ILO introduced (planning)*
- ILO 9**: Students can analyze** the quality of a location-based schedule
  - ILO introduced

Two location-based systems – with similarities and differences

Factor	Location-based management system / LBMS	Takt planning & control
Planning concepts	Locations, tasks, production rates	Takt areas, takt process, takt time
Buffers	Time buffers preferred	Capacity buffers preferred
Location / area size	Generally larger	As small as possible
Durations	Calculated and vary in locations depending on quantities	Takt time fixed
Emphasis	Operations flow	Process flow
Repeatability	Not required but beneficial	Very beneficial

LBMS technical system



LBMS location hierarchy

Project 1

Quadrant	Floor
Center	Roof
	3
	2
	1
Northwest	Roof
	3
	2
	1
Northeast	Roof
	3
	2
	1
Southwest	Roof
	3
	2
	1
Southeast	Roof
	3
	2
	1

Project 2

Building	Floor	Area
Residential	7	B A
	6	B A
	5	B A
	4	B A
	3	B A
	2	B A
	1	B A
	Basement	Garage
Office	9	B A
	8	B A
	7	C B A
	6	C B A
	5	C B A
	4	C B A
	3	C B A
	2	C B A
	1	B A

Floor	Area
Tower Roof	STR C
Level 12	STR C
Tower Roof	STR B
	STR A
Level 12	STR B
	STR A
Level 11	STR C
Level 10	STR C
Level 09	STR C
Level 08	STR C
Level 11	STR B
	STR A
Level 10	STR B
	STR A
Level 09	STR B
	STR A
Level 08	STR B
	STR A
Level 04	STR F
Level 03	STR F
Level 02	STR F
Level 01	STR F
Level 03	STR E
Level 02	STR E
Level 01	STR E
Level 04	STR D
Level 03	STR D
Level 02	STR D
Level 01	STR D
Level 07	STR C
Level 06	STR C
Level 05	STR C
Level 04	STR C
Level 07	STR B
	STR A
Level 06	STR B
	STR A
Level 05	STR B
	STR A
Level 04	STR B
	STR A
Level 03	STR C
Level 02	STR C
Level 01	STR C
Level 03	STR B
	STR A
Level 02	STR B
	STR A
Level 01	STR B
	STR A

2	3	4
[INT]	Level 4	Area C&D
		Area A&B
	Level 3	Area C&D
		Area A&B
	Level 2	Area C&D
		Area A&B
	Level 1	Area C&D
		Area A&B
	Lower Level	Area C&D
		Area A&B
[EXT]	East B@3	COURTYARD
	South@3	South
	West B@3	West B
	West A@3	West A
	North@3	North
[SUP]	Level 4	Area D
		Area C
		Area B
		Area A
	Level 3	Area D
		Area C
		Area B
		Area A
	Level 2	Area D
		Area C
		Area B
		Area A
	Level 1	
[SUB]	Lower Level	Area D
		Area C
		Area B
		Area A

Some LBS guidelines (LBMS)

- **Locations must be physical and clearly defined**

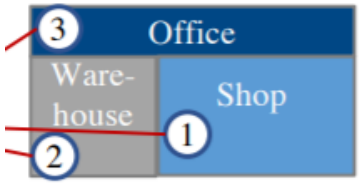
- **Top level locations**
  - Structurally independent sections (building / part of building) that can be completed as one entity
  - Separate buildings or separated by module lines / joints

- **Lowest level locations**
  - Small areas where only one **space-critical** task happens at the same time

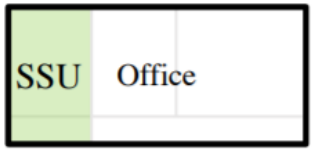
Takt areas

Binninger et al. 2017: Technical takt planning and takt control in construction

- **1. Pick one functional area**



- **2. Define takt areas for one functional area**



- **3. Preferably repeating areas, in complex cases based on work density**

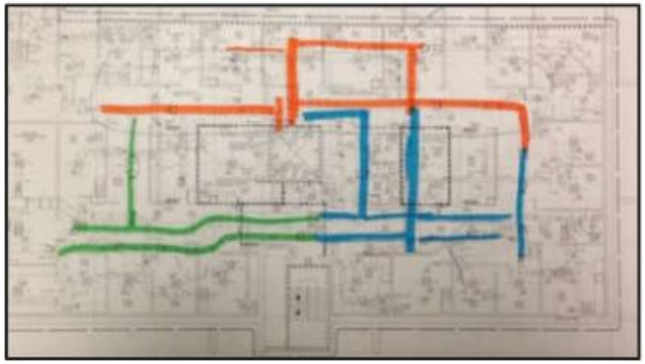
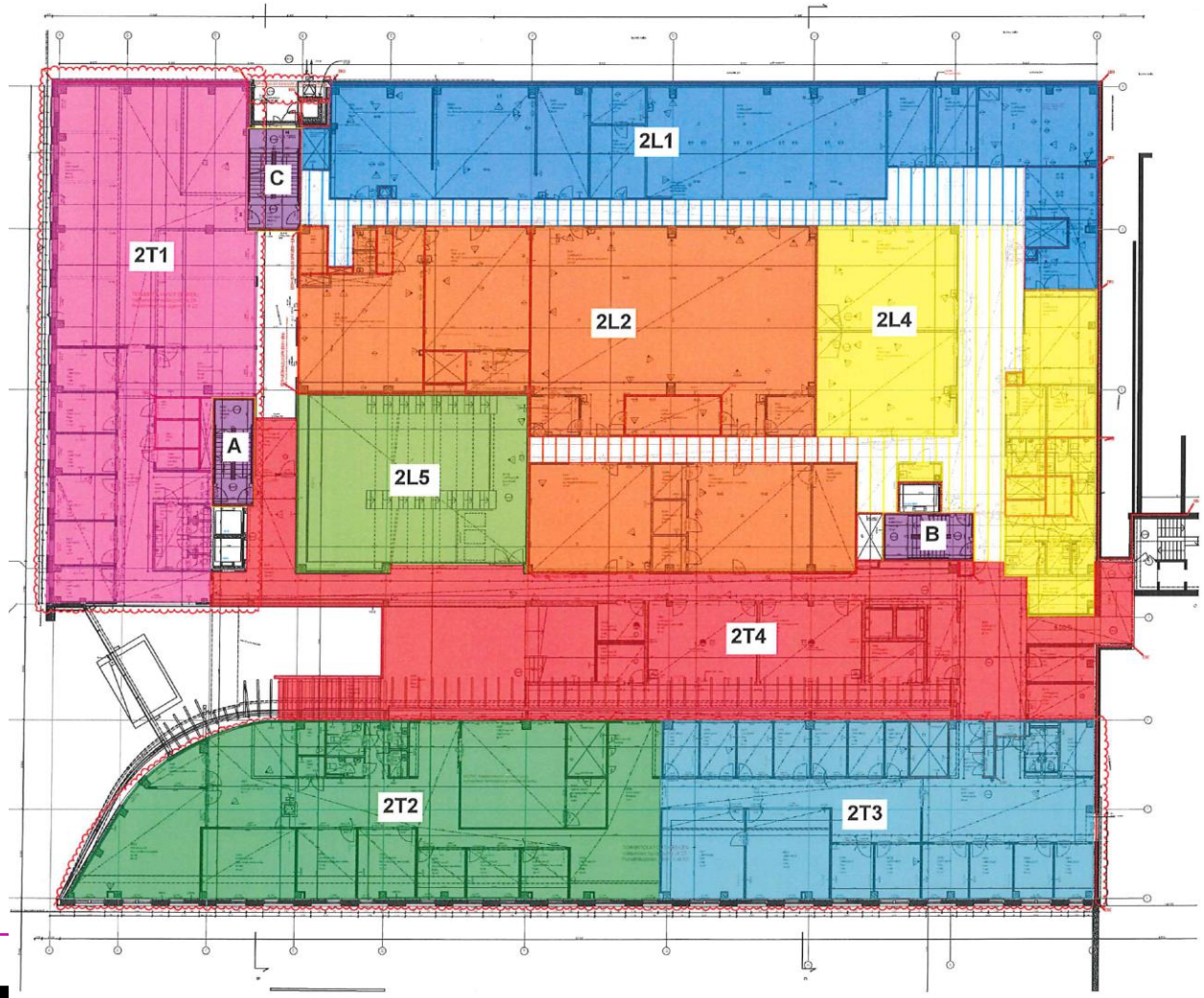


Figure 3: Input from Mechanical Trade using Work Chunks of 2-Day Takt, Sequenced Orange, Blue, then Green

Tommelein, I. D. 2017, 'Collaborative Takt Time Planning of Non-Repetitive Work' In:, *25th Annual Conference of the International Group for Lean Construction.* Heraklion, Greece, 9-12 Jul 2017. pp 745-752

Example locations (takt project)



Quantities

- **Estimated by location**
  - Manually – time consuming
  - BIM-based – enables automated updates of quantities

- **Related quantity items can form a task / takt process IF the work**
  - Can be done at the same time in one location
  - Has the same logic outside the task
  - Can be completely finished in one location before moving to the next location

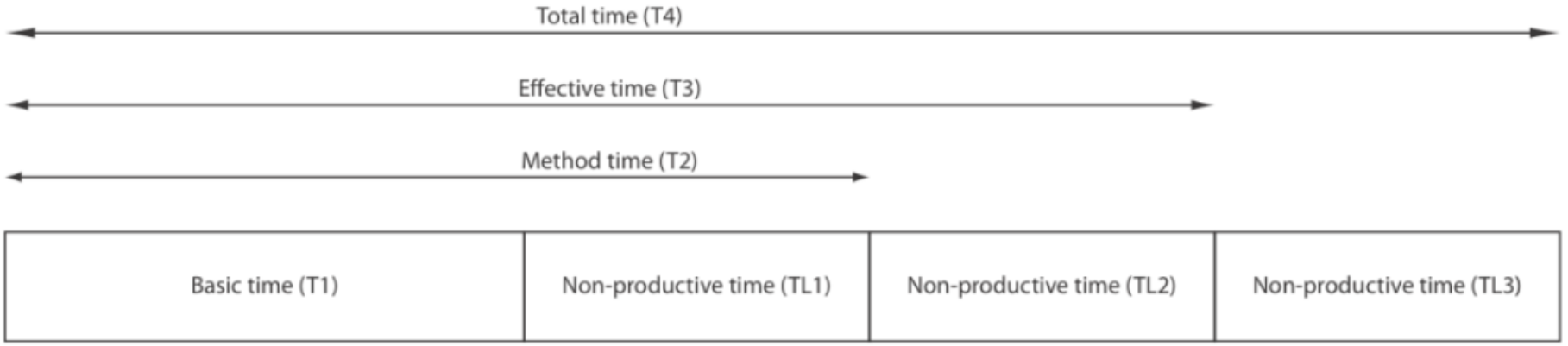
Location-based quantities

Same crew performs all items

Man-hours/unit

Code	Item	Consumption	A 1	A 2	A 3	A 4	A Roof	B 1	B 2	B 3	B 4	B Roof	Unit
	Section:		A					B					
	Floor:		1	2	3	4	Roof	1	2	3	4	Roof	
365116	Fit prefabricated balcony post units	2,25	7	7	7	7		7	7	7	7	5	NO
355125	Install room-size/square panels	1,8	8	1	1	1		10	1	1	1		NO
335107	Install precast concrete floor slabs	0,6		2	2	2	3		2	2	2	3	NO
345115	Install prefabricated staircases	1,98	1	1	1			1	1	1	1		NO
355115	Install load-bearing room-size/square panels	1,8	8	1	1	1		9	1	1	1	19	NO
335108	Install prefabricated beams	1		32	32	32	32		32	32	32	32	NO
365135	Fit prefabricated balcony roof units	0,62					5					5	NO
355145	Install thin-shell panels	1,8		17	17	17	19	17	17	17		19	NO
365125	Fit prefabricated balcony floor units	1,85		5	5	5			5	5	5		NO
325125	Top layer finishing to concrete floor slabs	1,84	14	6	6	6		14	6	6	6		NO
325115	Install precast dividing walls	1,84	10	15	15	15		16	16	16	16		NO
235150	Install precast concrete hollow core slabs	0,61	28					32					NO
	Total man-hours		**108**	**133**	**133**	**131**	**71**	**157**	**135**	**135**	**105**	**117**	

What is the right labor consumption rate?

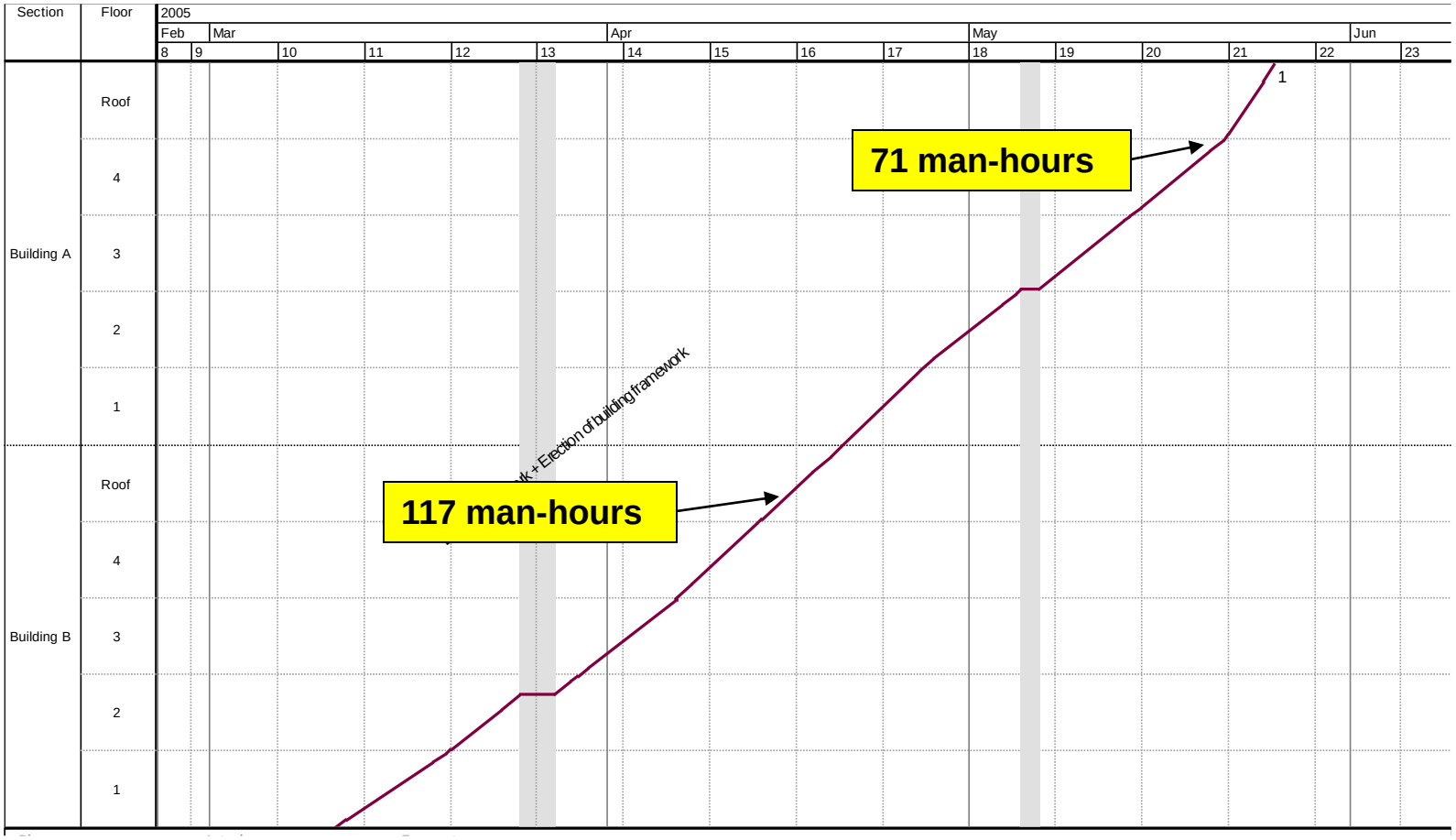


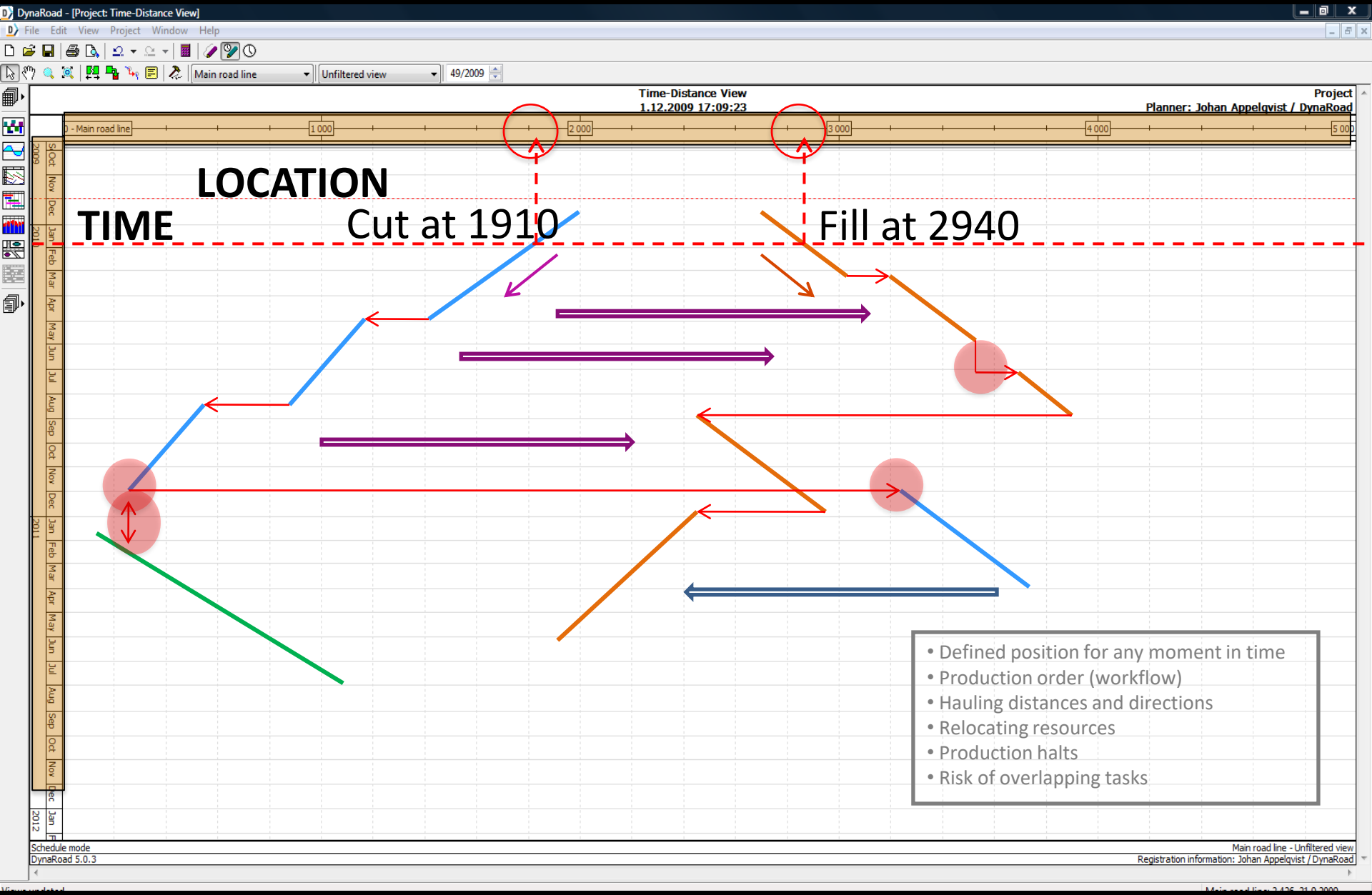
- ”Effective time” 10-20% more than Method time
  - Includes ”normal” disruptions of less than 1 hr
- Total time T4, 10-30% more than Effective time

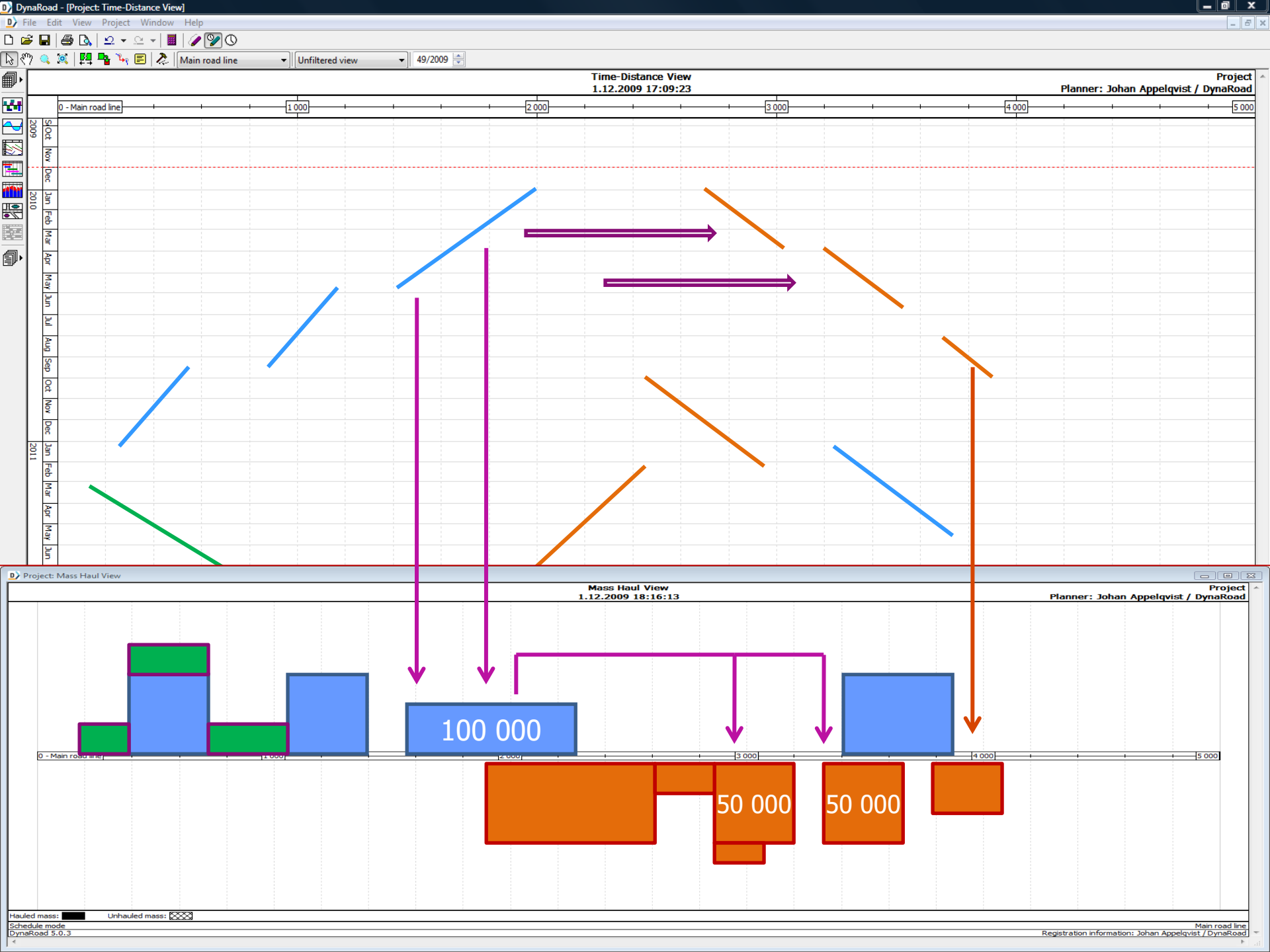
- = a lot of waste in productivity estimates!

Source: Koskenvesa, Koskela et al. (2010)

LBMS: quantities to duration



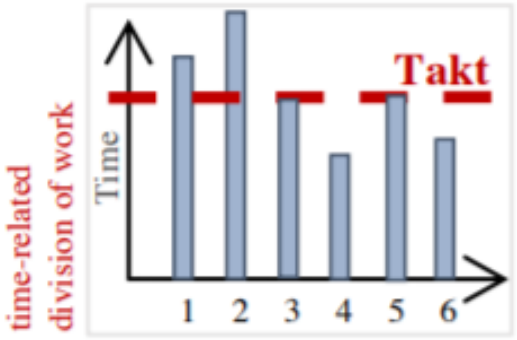

DynaRoad - [Project: Time-Distance View]
File Edit View Project Window Help
Main road line
Unfiltered view
49/2009
Time-Distance View
1.12.2009 17:09:23
Project
Planner: Johan Appelqvist / DynaRoad
1 000
2 000
3 000
4 000
5 000
LOCATION
TIME
Cut at 1910
Fill at 2940
• Defined position for any moment in time
• Production order (workflow)
• Hauling distances and directions
• Relocating resources
• Production halts
• Risk of overlapping tasks
Schedule mode
DynaRoad 5.0.3
Main road line - Unfiltered view
Registration information: Johan Appelqvist / DynaRoad


DynaRoad - [Project: Time-Distance View]
File Edit View Project Window Help
Main road line
Unfiltered view
49/2009
Time-Distance View
1.12.2009 17:09:23
Project
Planner: Johan Appelqvist / DynaRoad
0 - Main road line
1 000
2 000
3 000
4 000
5 000
2009
Oct Nov Dec
2010
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2011
Jan Feb Mar Apr May Jun
Project: Mass Haul View
Mass Haul View
1.12.2009 18:16:13
Project
Planner: Johan Appelqvist / DynaRoad
100 000
50 000
50 000
Hauled mass:
Unhauled mass:
Schedule mode
DynaRoad 5.0.3
Main road line
Registration information: Johan Appelqvist / DynaRoad

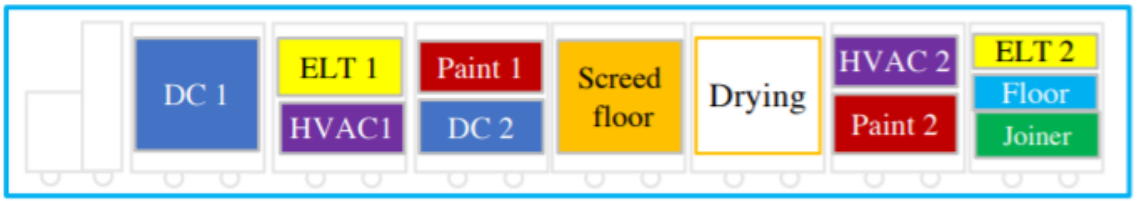
In takt: takt time fixed

- **Work densities calculated in the same way as LBMS**
- **Every process should fit the takt time**

- Takt levelling:
  - shifting variable work steps
  - variation of manpower
  - duplication of wagons
  - capacity buffer, etc.



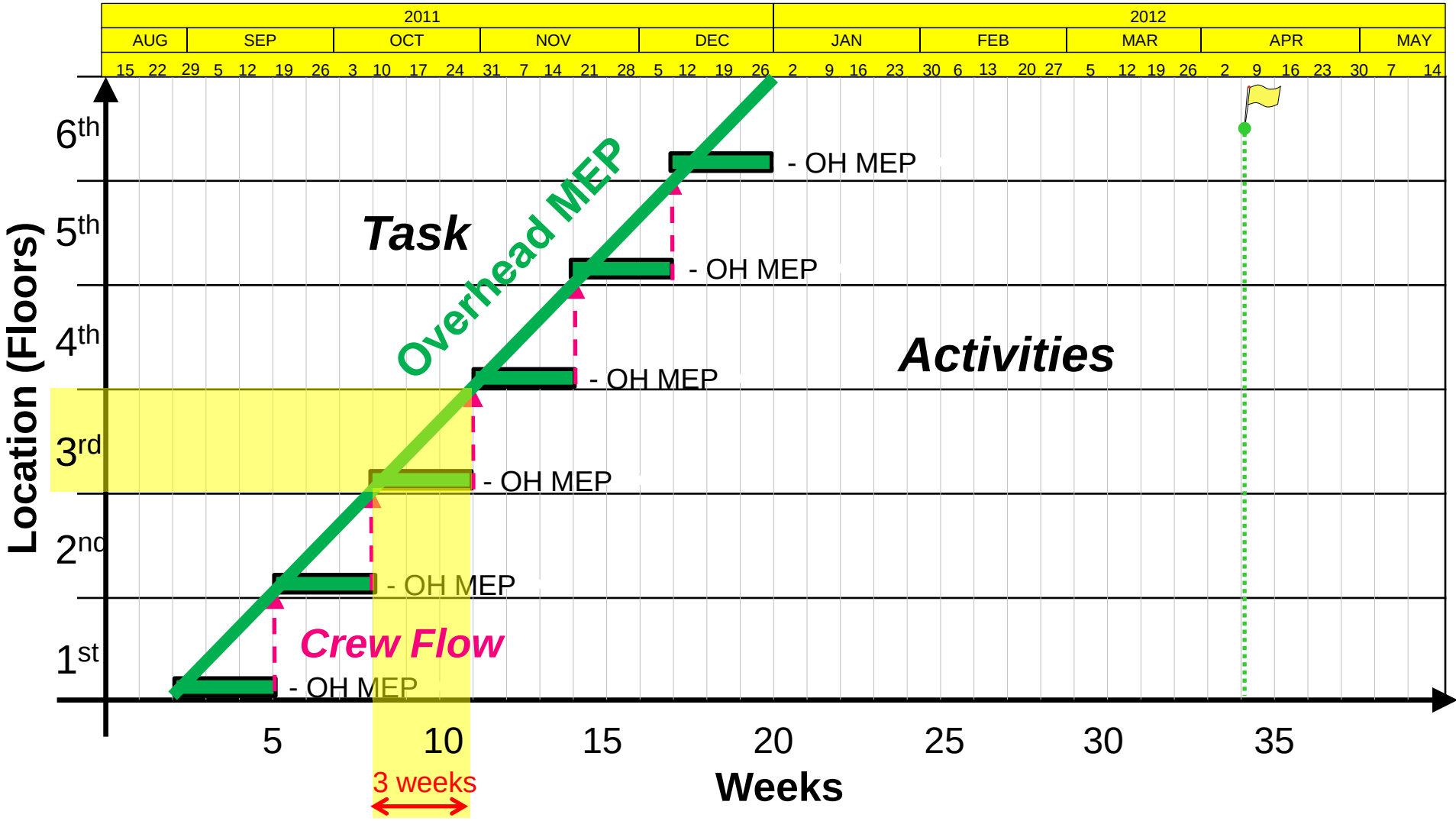
- Takt: Combine the work packages best for determined takt time & area (in LBMS only tasks of the same subcontractors combined)



LBMS schedule optimization

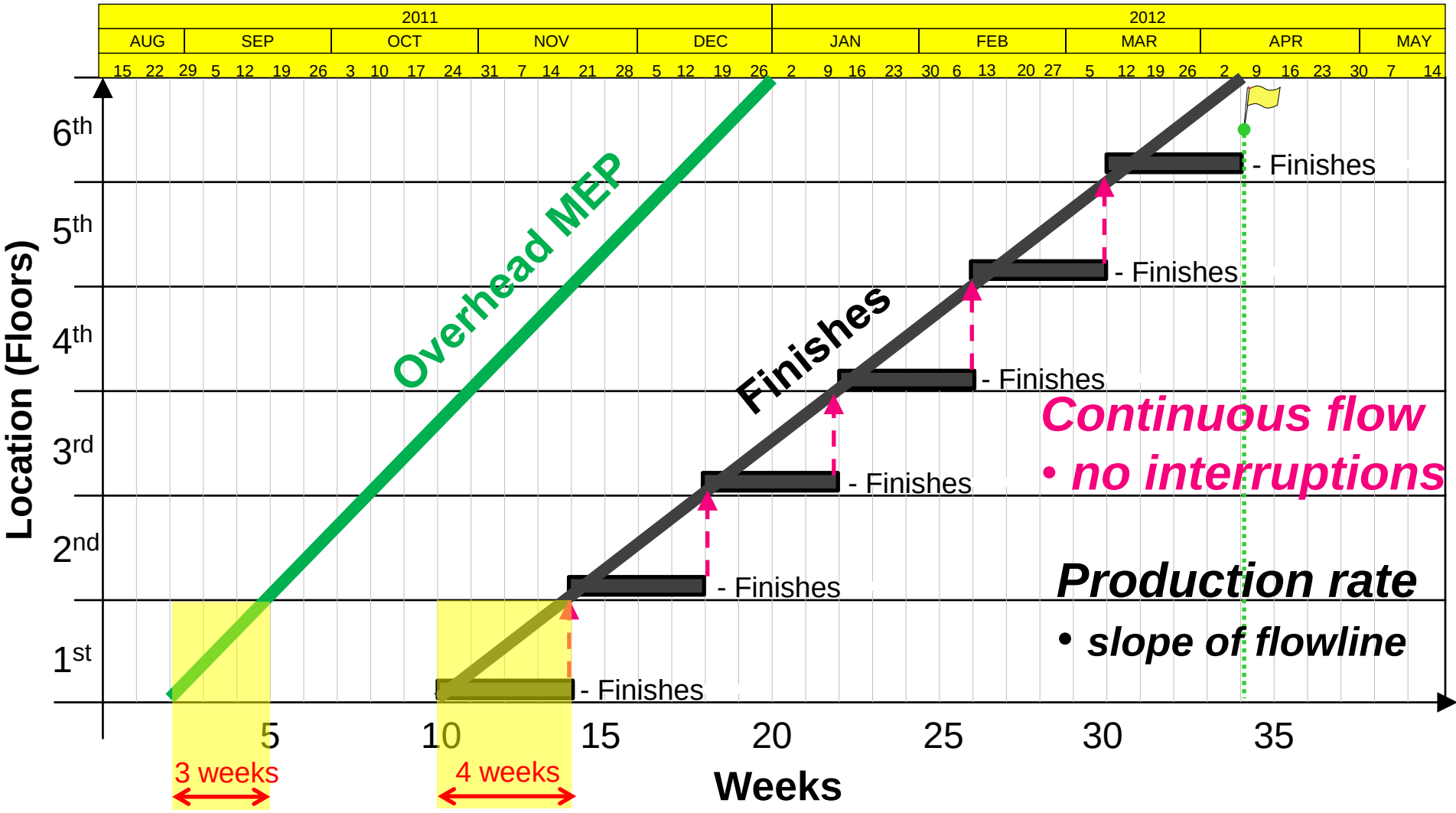
- **Aligning the schedule to achieve parallel flowlines**
  - Changing manpower
  - Moving work steps from a task to another task
- **Selecting whether tasks should be continuous or discontinuous**

Flowline Diagram – Overhead MEP

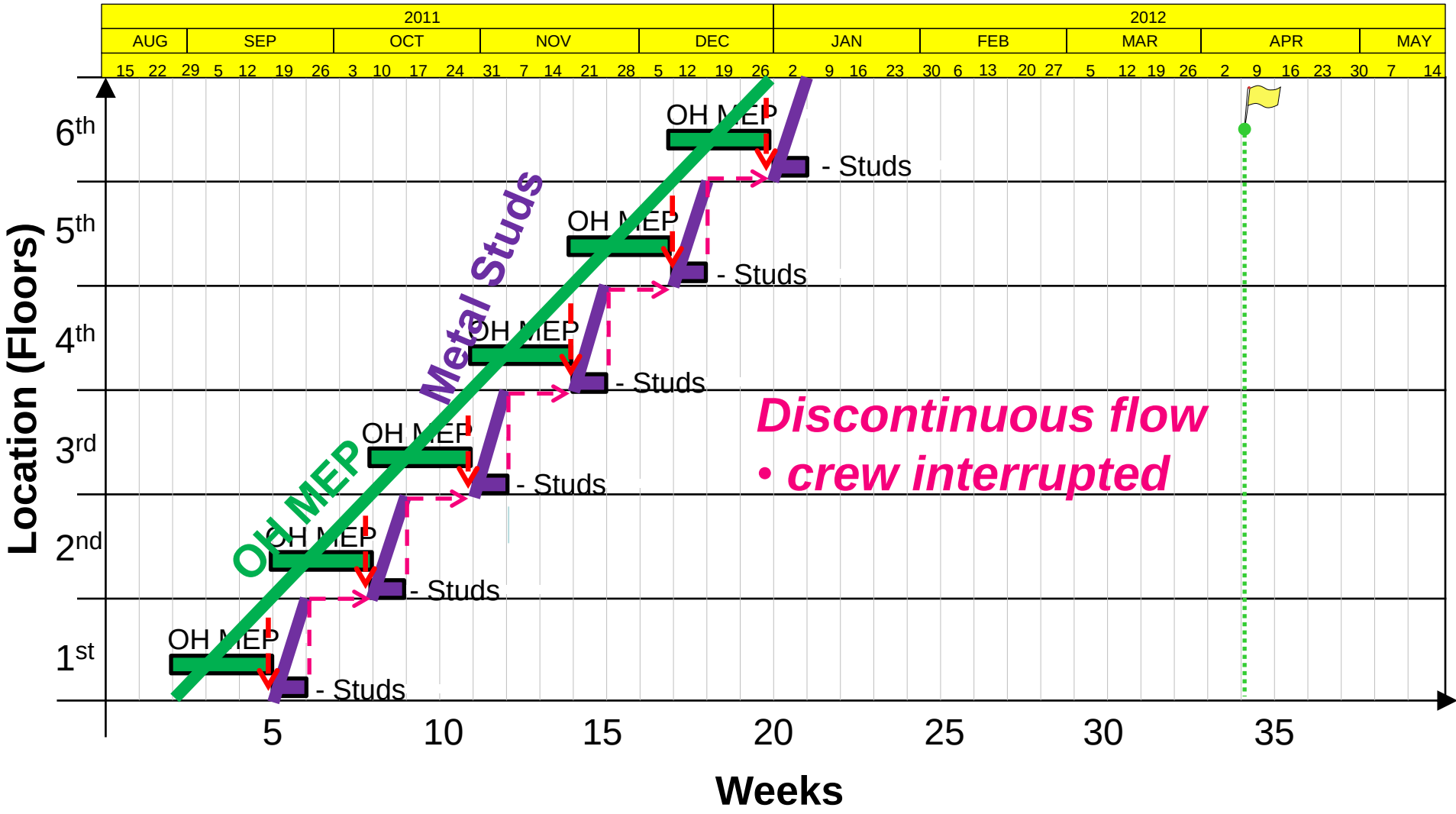


Flowline: graphical representation of movement of crews over time

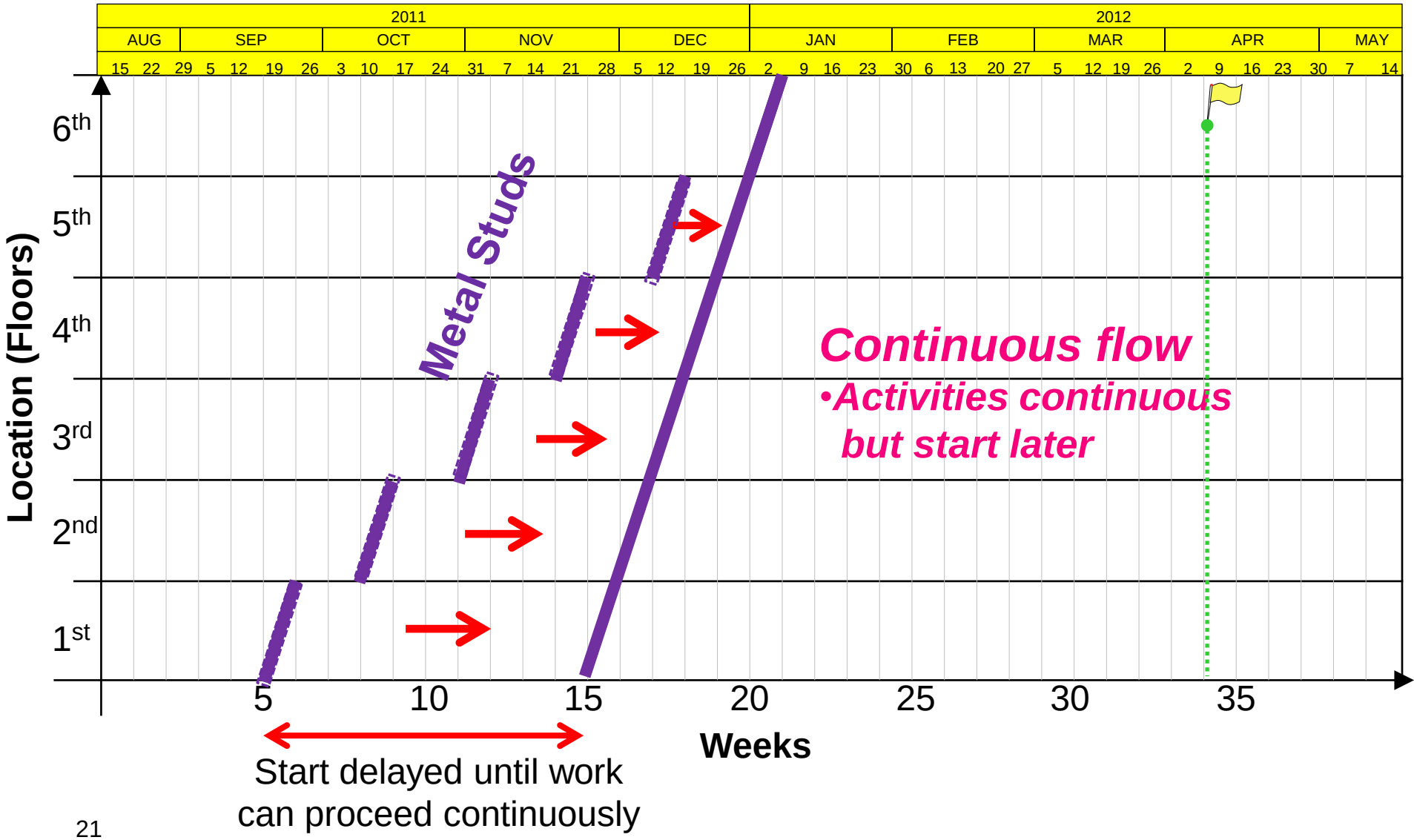
Flowline Diagram



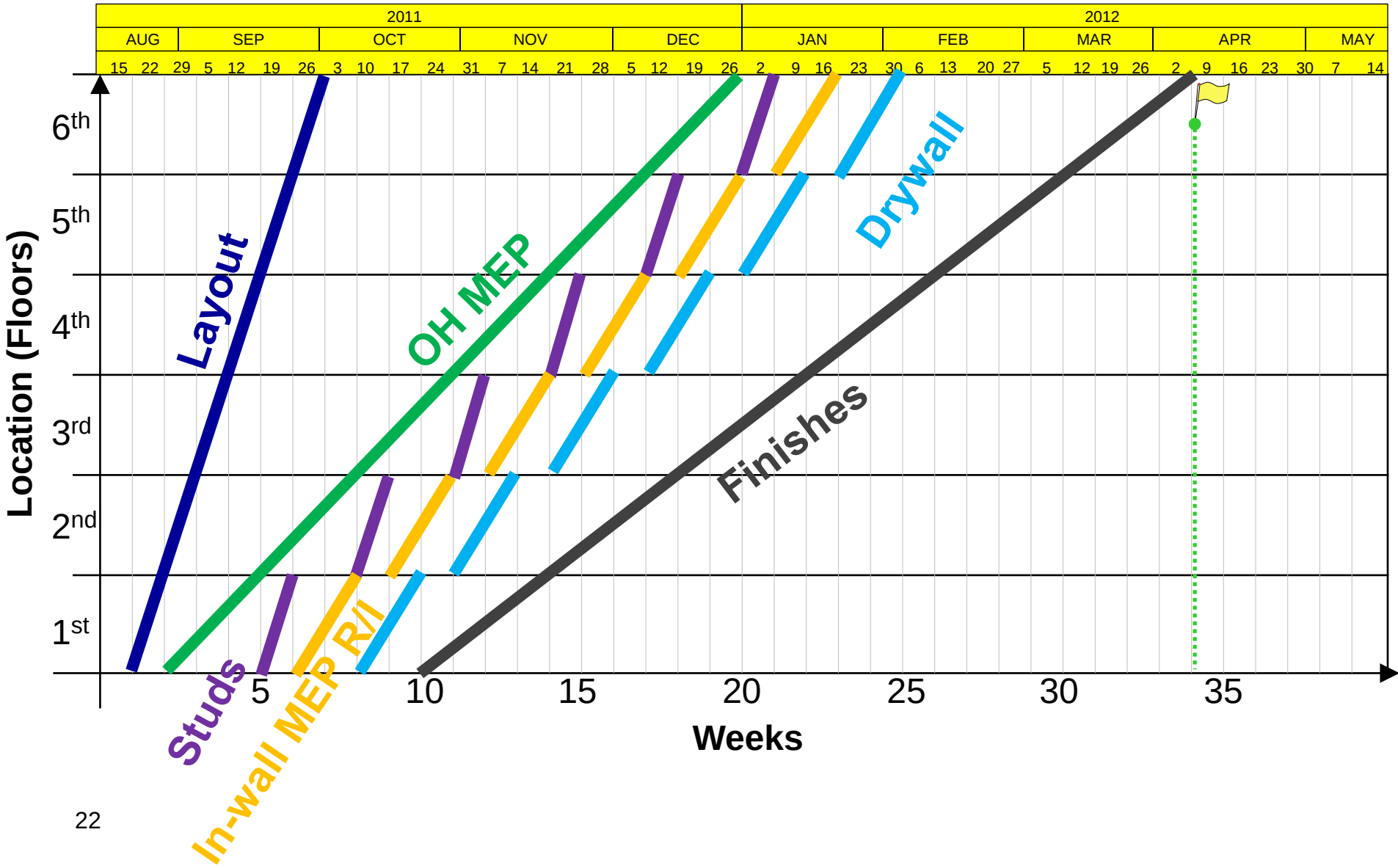
Flowline Diagram



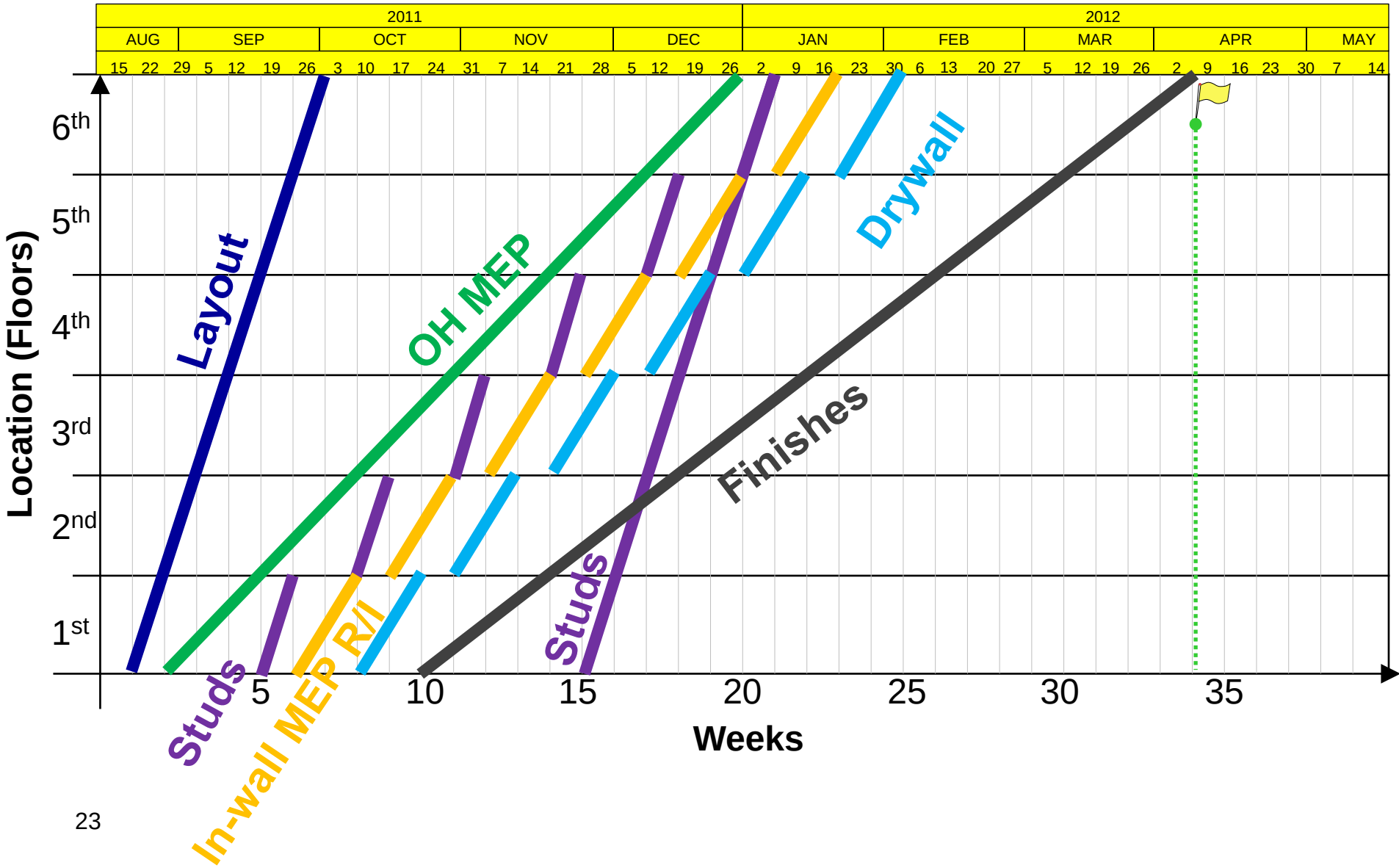
Flowline Diagram – Continuous Flow



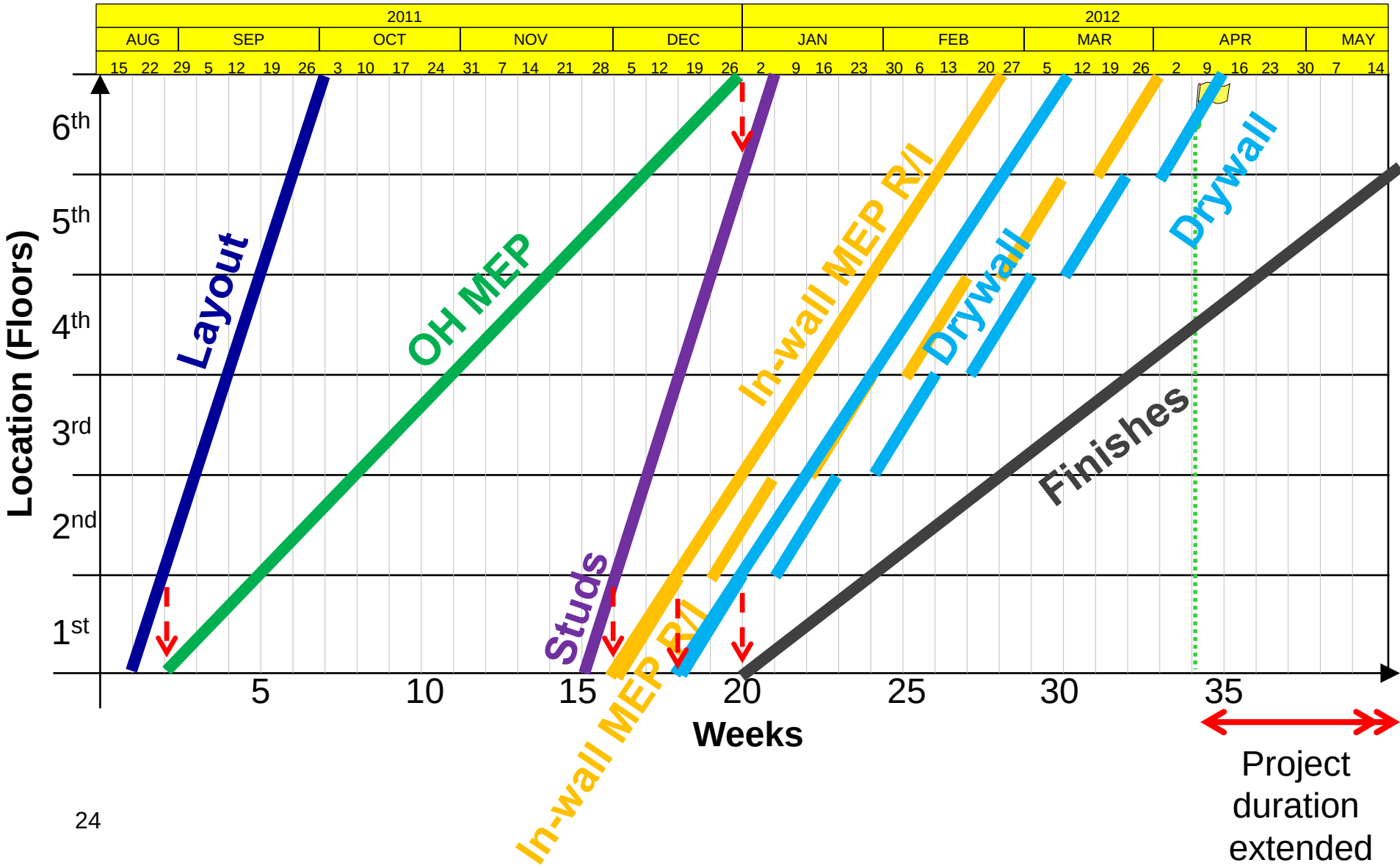
Flowline Diagram – Continuous Flow



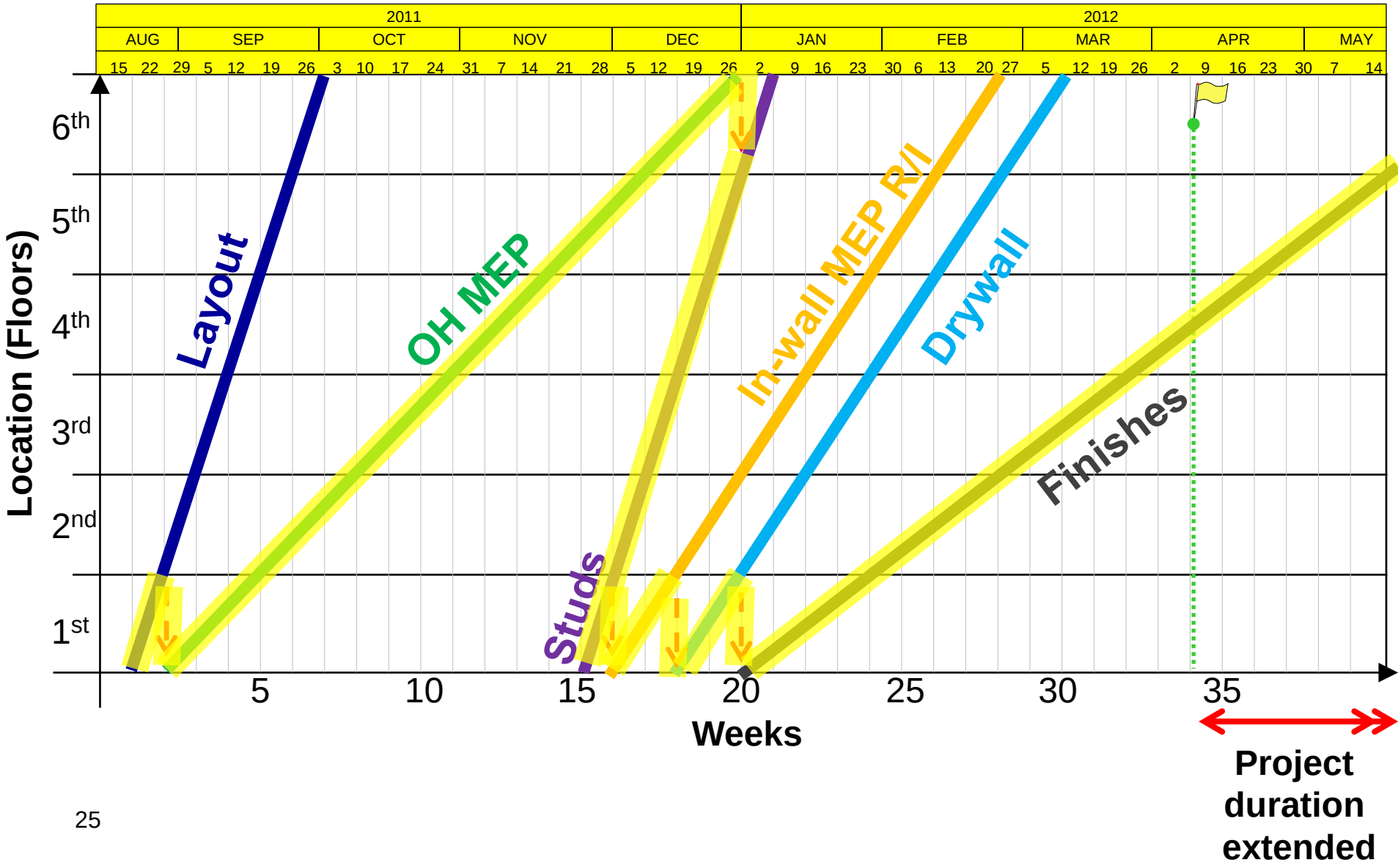
Flowline Diagram – Continuous Flow



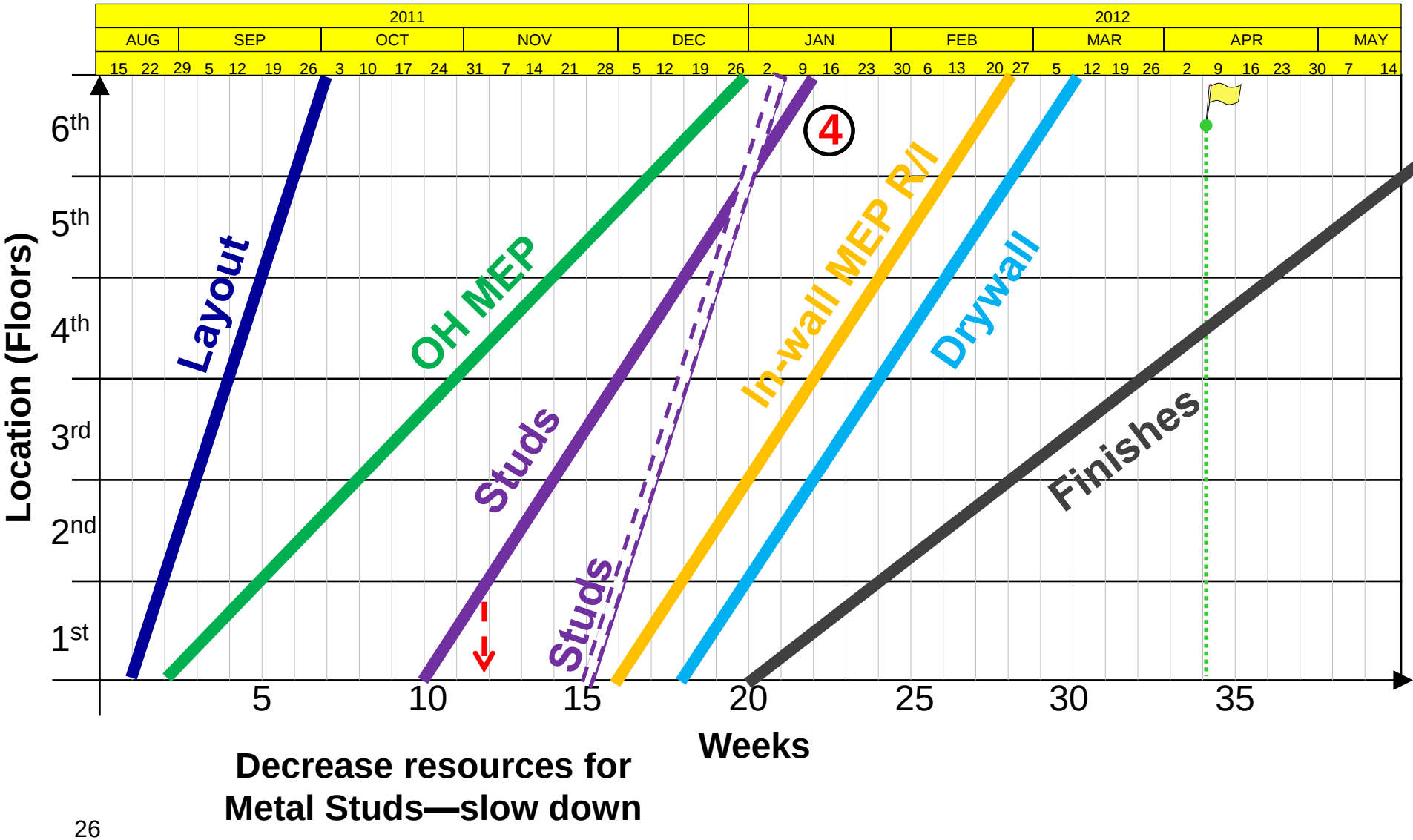
Flowline Diagram – Continuous Flow



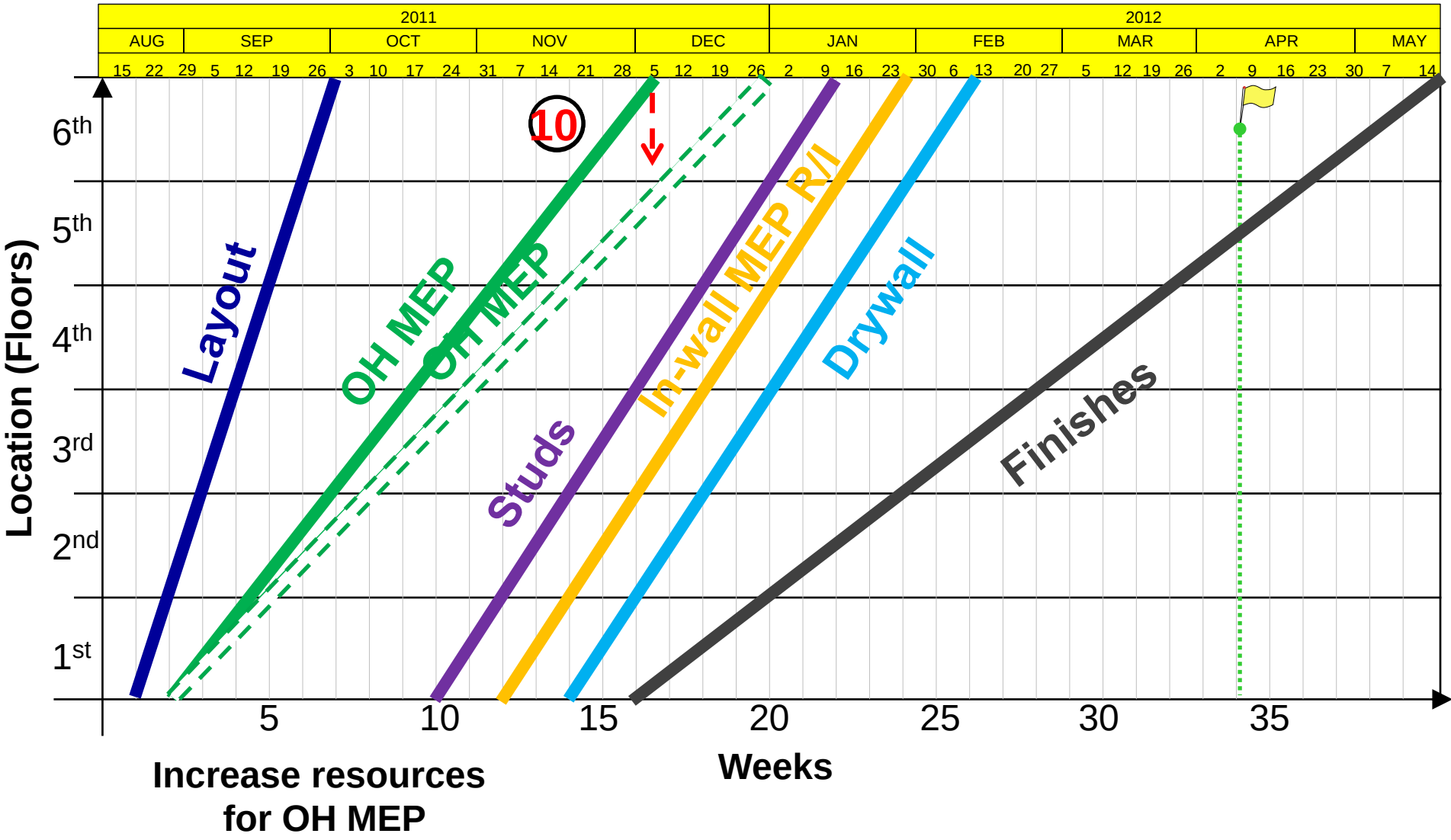
Flowline Diagram – Continuous Flow



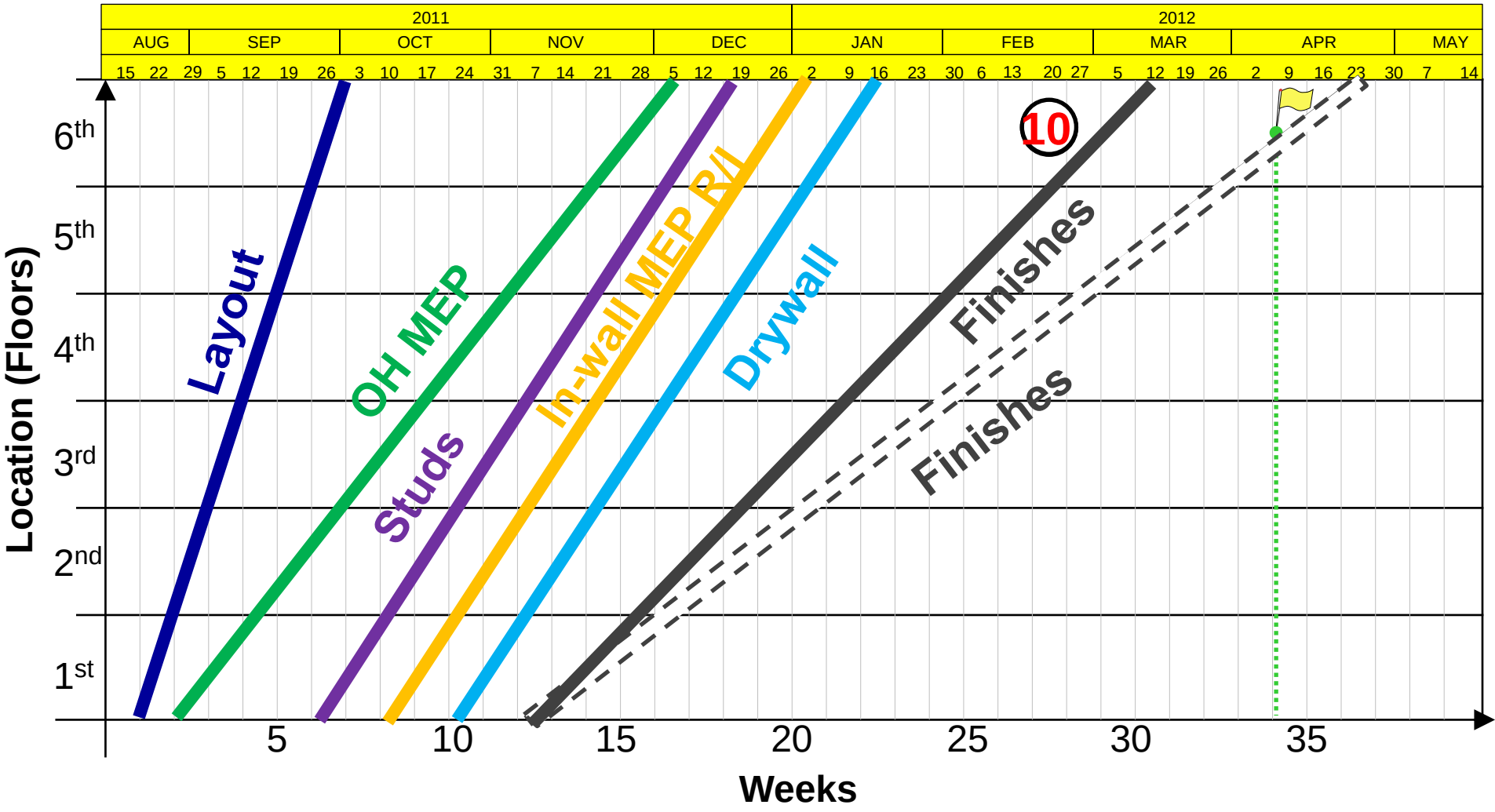
Flowline Diagram – Optimization



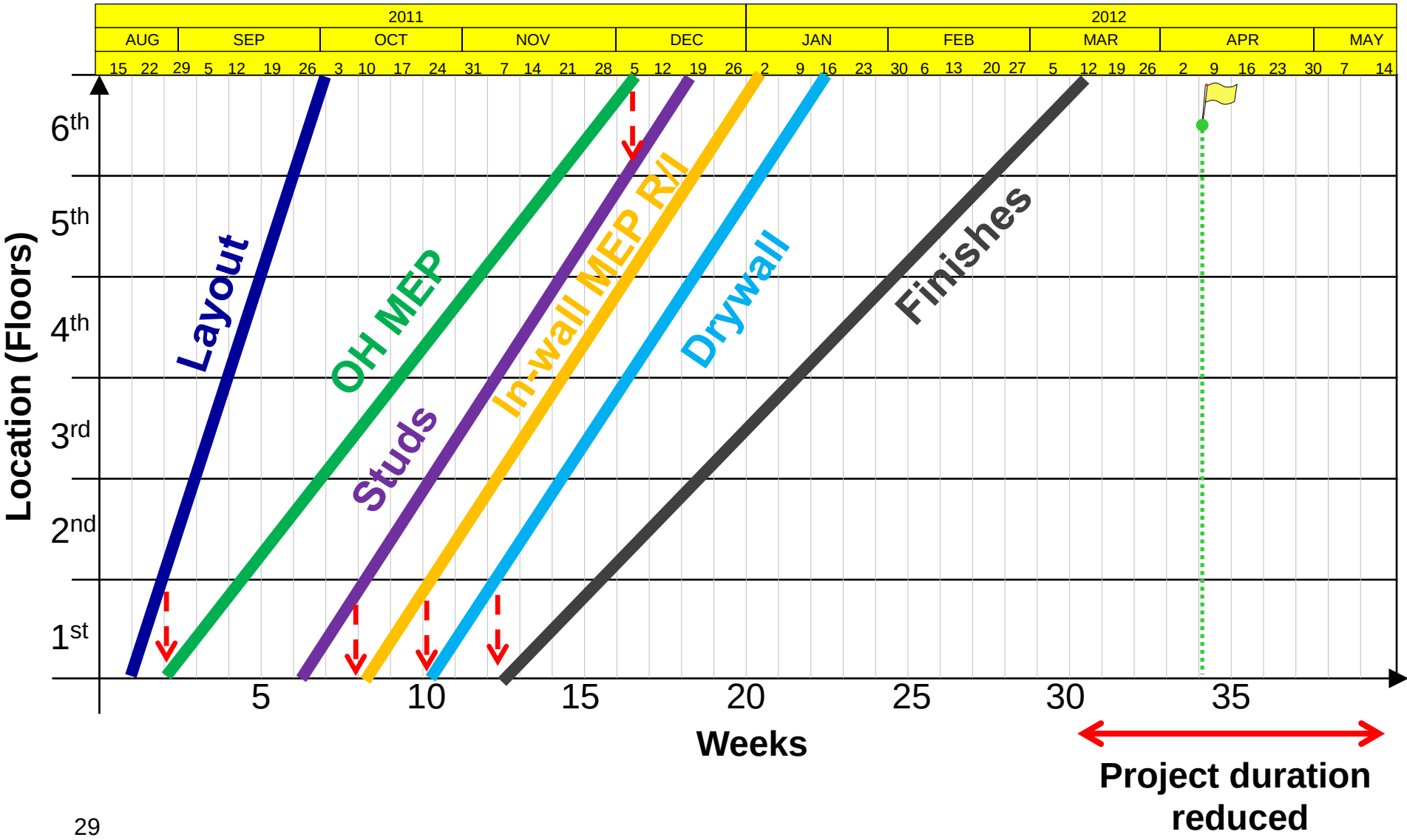
Flowline Diagram – Optimization



Flowline Diagram – Optimization



Flowline Diagram – Optimization



Takt optimization

Takt dimensions can be related through a formula (Nezval et al. 1960, Binninger et al. 2018)

$$(\textbf{Number of takt areas} + \textbf{Number of wagons} - \textbf{1}) * \textbf{takt time} = \textbf{Lead time}$$

Smaller takt and more takt areas

+ Reduce lead time
+ Enables better control and transparency as the trades has to work closer together

- More things to control
- Becomes chaotic if external variance is high

Takt optimization – example of cycle times

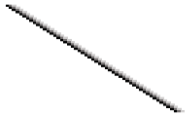
(Number of takt areas + Number of wagons − 1) ∗ takt time = Lead time

Normal 5day schedule: (5 + 10 -1)* 5 days = **14 weeks**

2 day takt: (12,5 + 10 -1)* 2 days = **8,6 weeks (-39%)**
(takt time reduced by 60%)

1 day takt: (25 + 10 -1)* 1 day = **6,8 weeks (-51%)**
(takt time reduced by 50%)

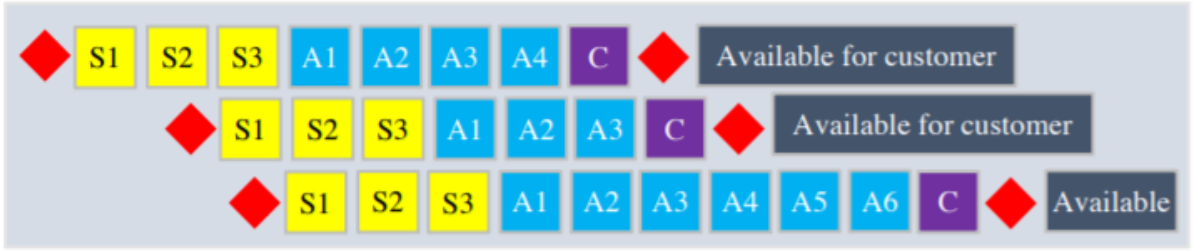
4hr takt: (50 + 10 -1)* 4 hours = **5,9 weeks (-58%)**
(takt time reduced by 50%)



Takt – finalizing the schedule

- **Optimization done already when deciding takt areas, takt time and leveling**
- **Final steps easy:**
- Repeat the same process for all functional areas

- Finish the schedule by adding areas outside of takt, define backlog areas
- Fit the schedule to meet the fundamental flow and milestones (e.g. by iterating takt time and location size)



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Video 2

Production system cost

Production system costs are functions of the schedule

- Direct labor costs
- Overhead costs

Measures the efficiency of the plan

- Better schedule – lower overall production system costs

Motivator for trade contractors to follow the plan

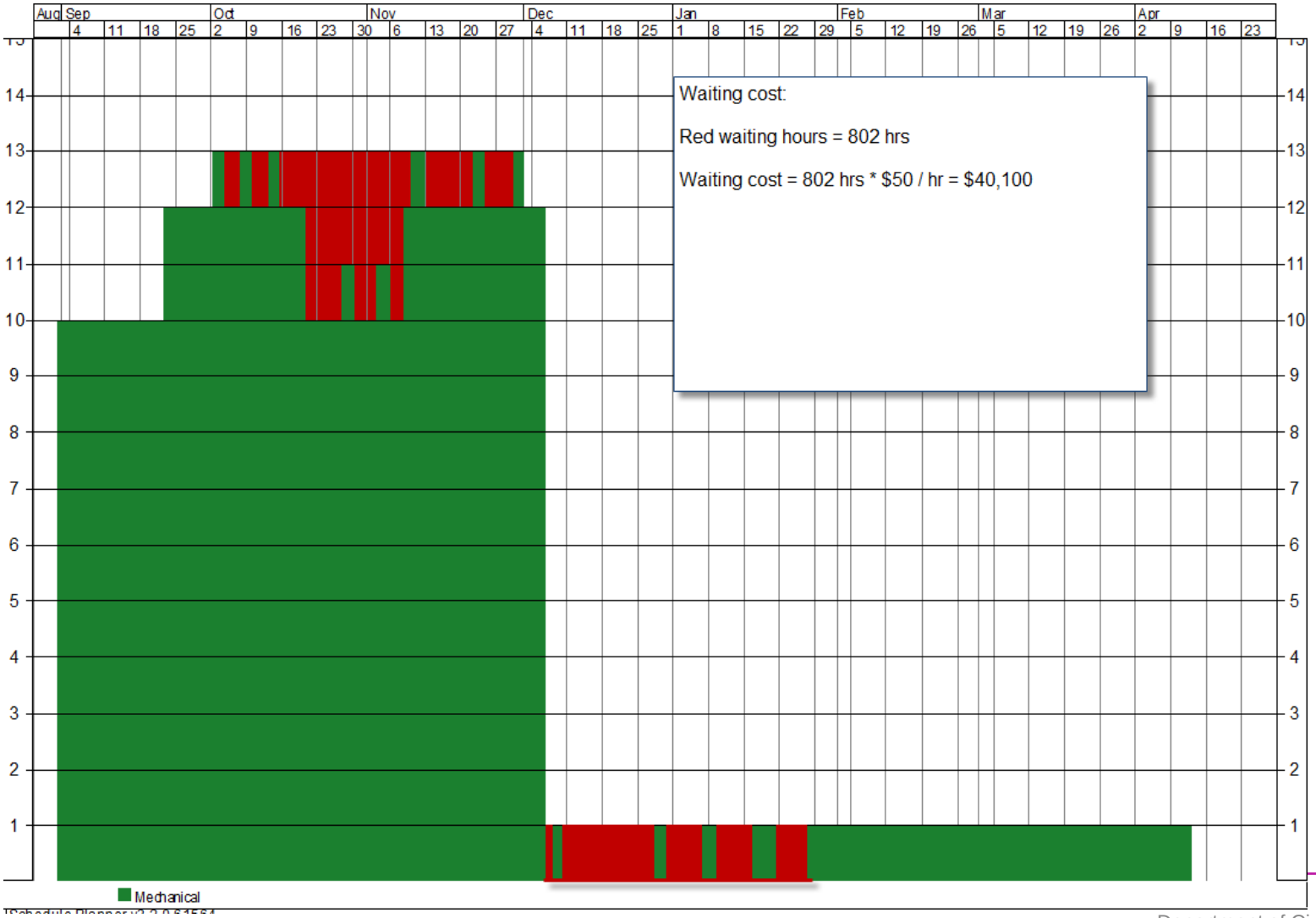
- Trade contractors pay for direct labor costs and any improvement in production system cost affects their bottom line

Production system cost is a measure of operations flow – emphasized in LBMS

Production system cost components

- **Working time**
- **Mobilization / demobilization**
- **Waiting time**
- **Moving around**
- **Logistics**
- **Overhead**

Production system cost example



Takt – paradox in production system cost

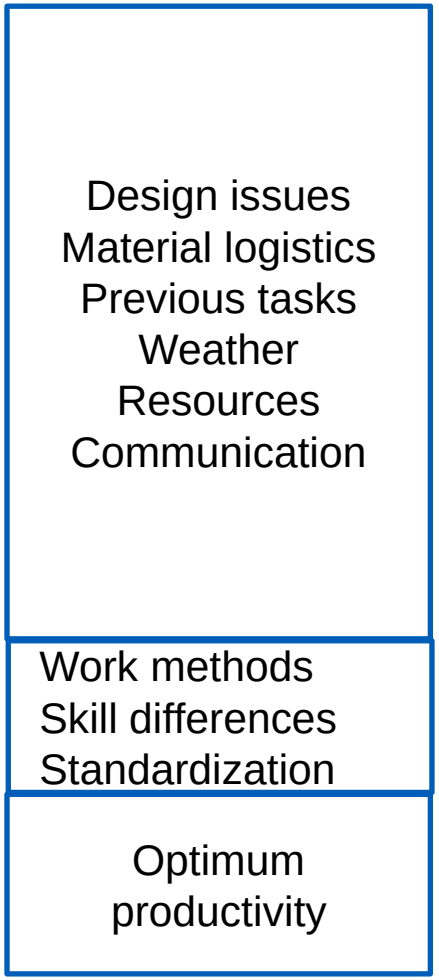
- **Although capacity buffers are used in takt, their labor costs have not increased!**

- **In theory, we would expect an increase because the workers have no work during capacity buffer – i.e. if everything goes according to plan, workers of a five day takt would leave on Thursday (20% capacity buffer)**

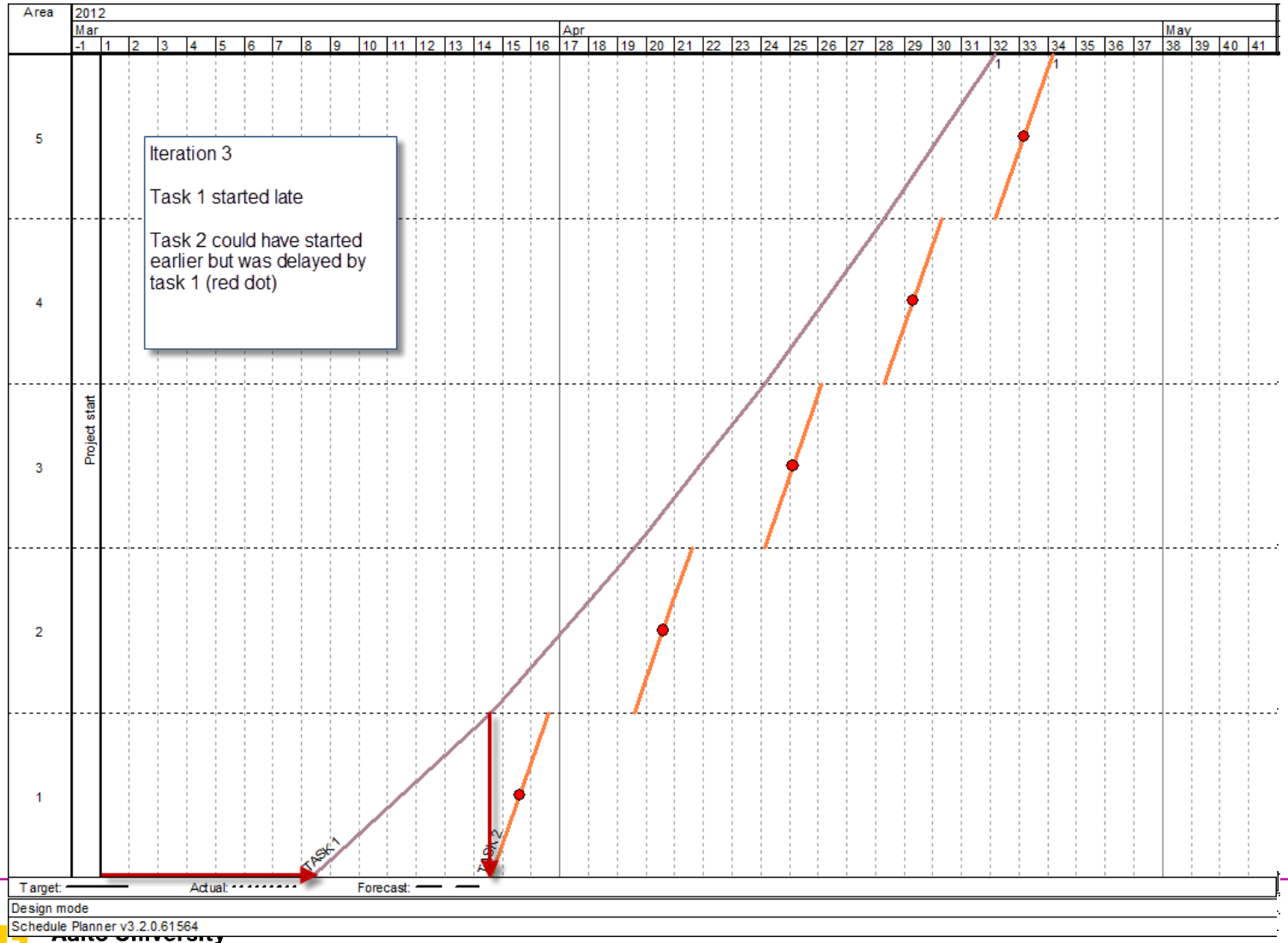
- **Possible explanations:**
  - Contractors are flexibly adjusting workforce
  - Less waste in the process (Lecture #5)

Production system risk

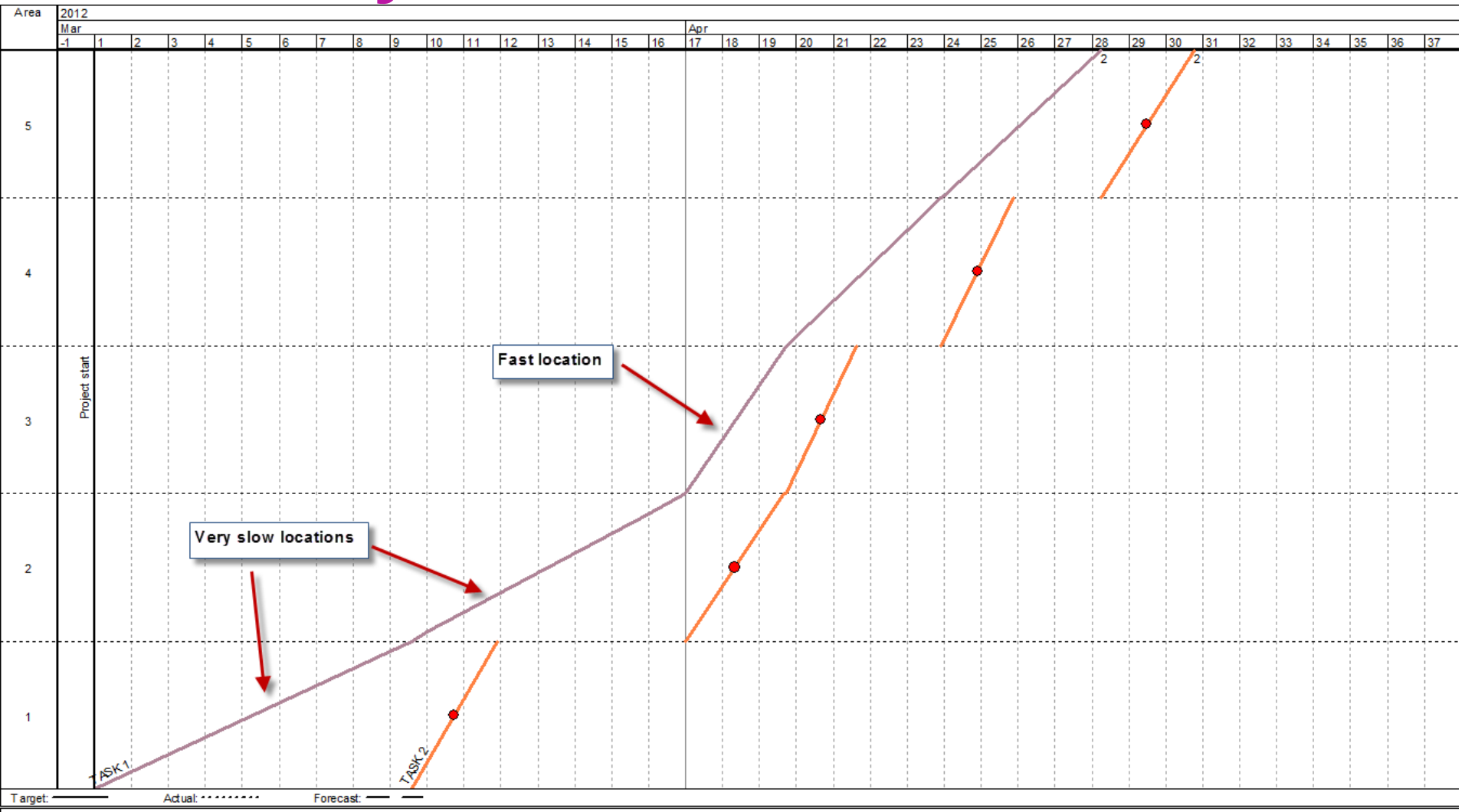
- **Construction has high variability**
  - Most of the variability is coming from external issues (70%)
  - Worker skills / work methods explain a small amount of variability (30%)
- **Variability can be analyzed with risk analysis. LBMS divides variability to:**
  - Variability in start dates
  - Variability in durations
  - Variability in productivity
  - Variability in resource availability
  - Variability caused by return delays



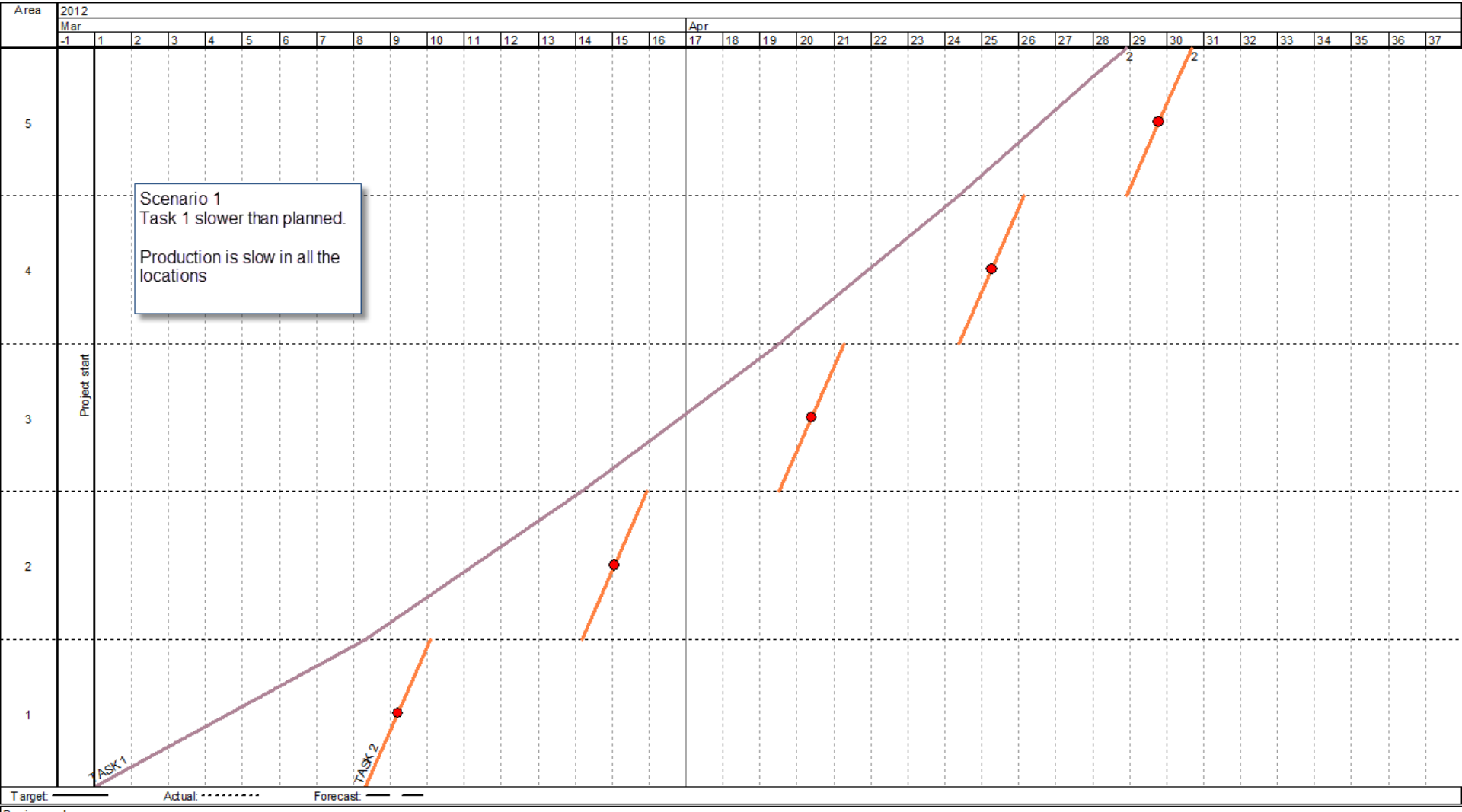
Variability in start dates



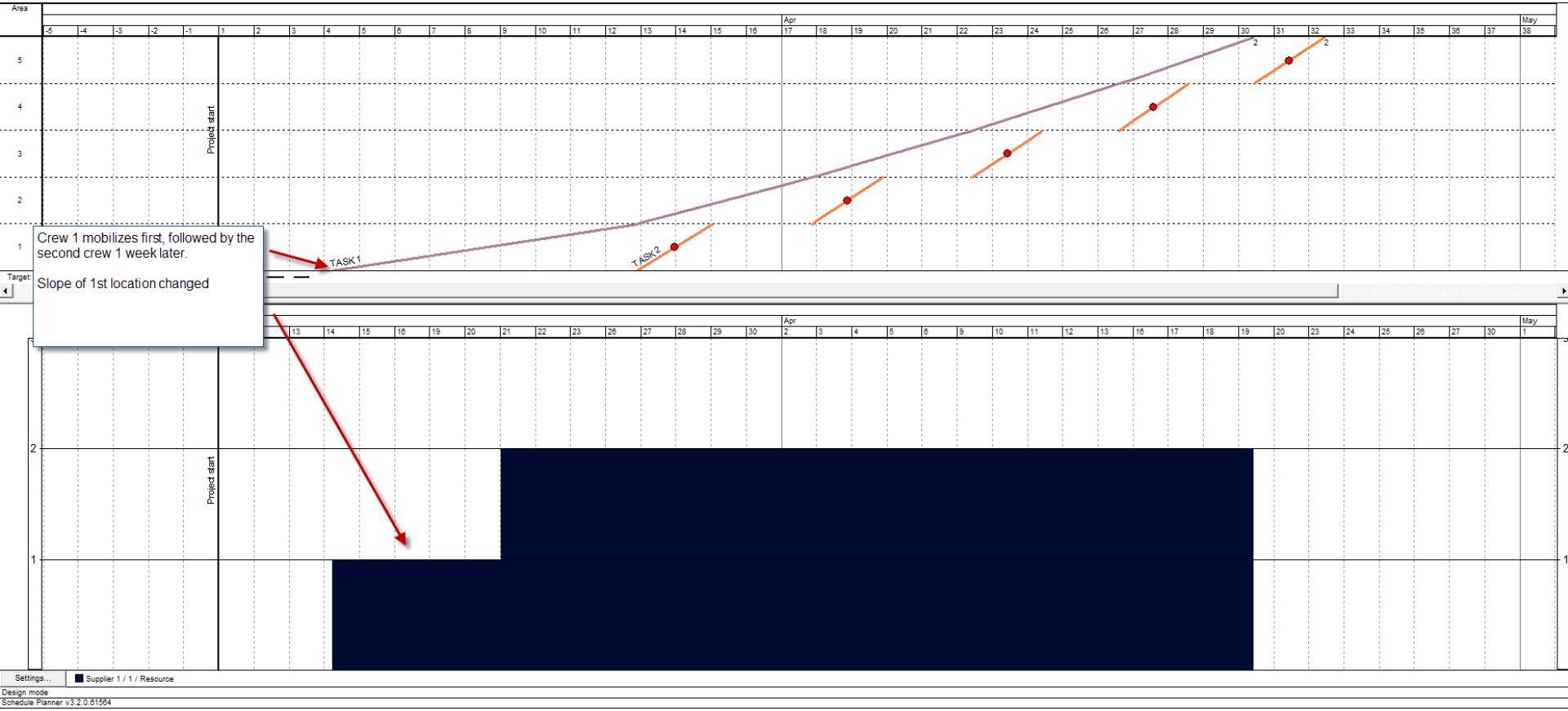
Variability in durations



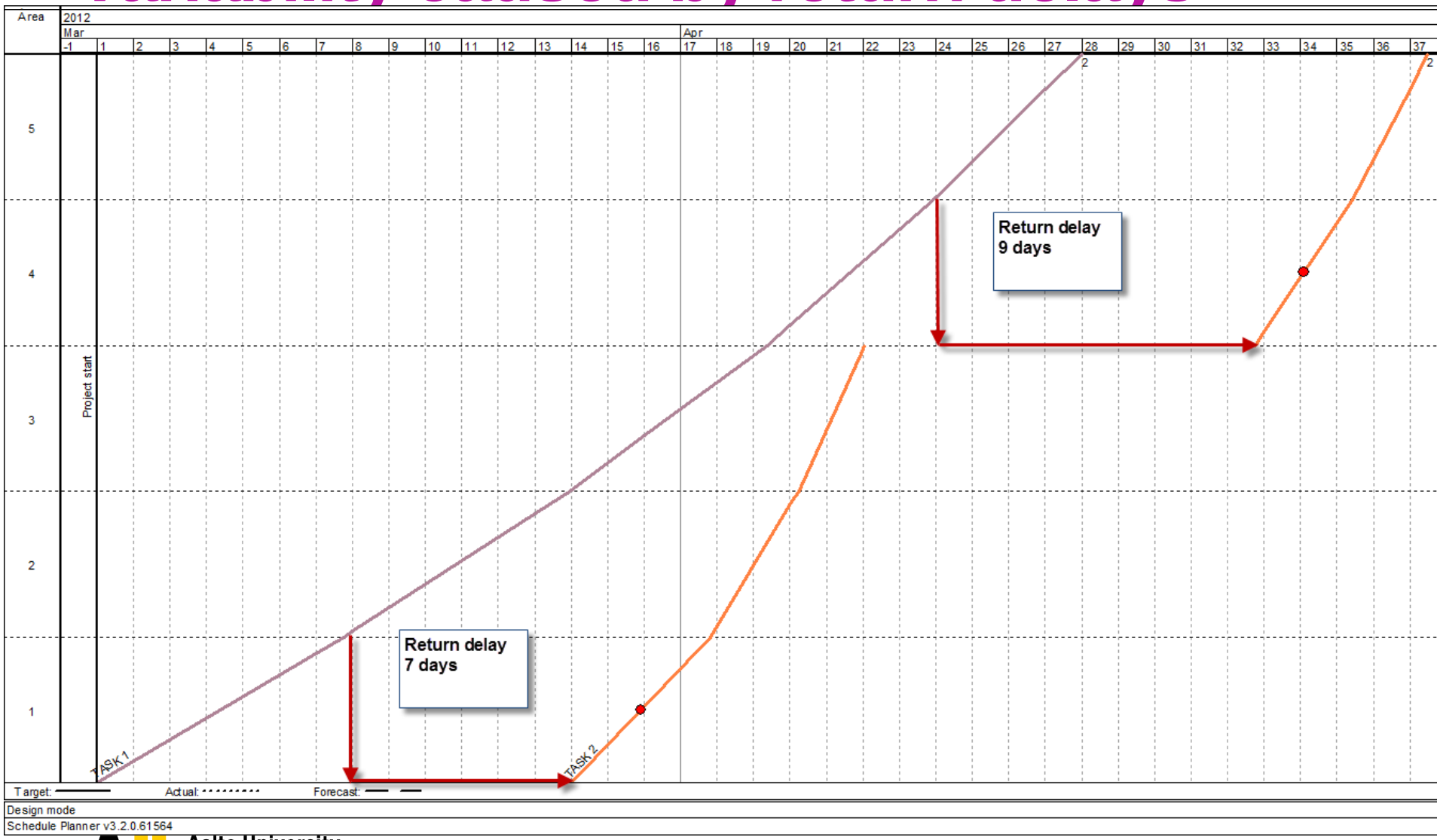
Variability in productivity



Variability of resource availability



Variability caused by return delays



Buffers to protect against risk – capacity buffer

- **If variability / risks cannot be removed, buffers are needed**

- **CAPACITY BUFFER is one way of buffering**
  - Plan with fewer resources than are available for the project

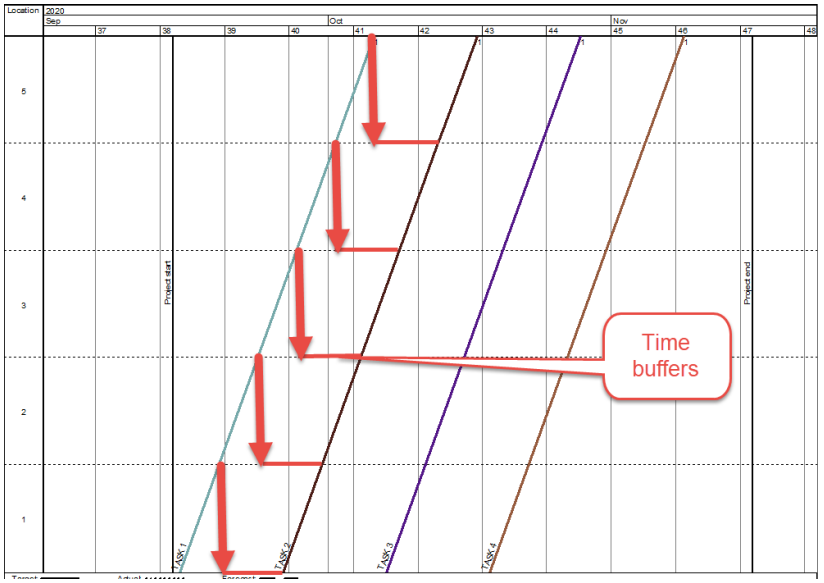
  OR
  - Plan with lower production rate

- **”Buffer resources” can work on non-critical tasks**

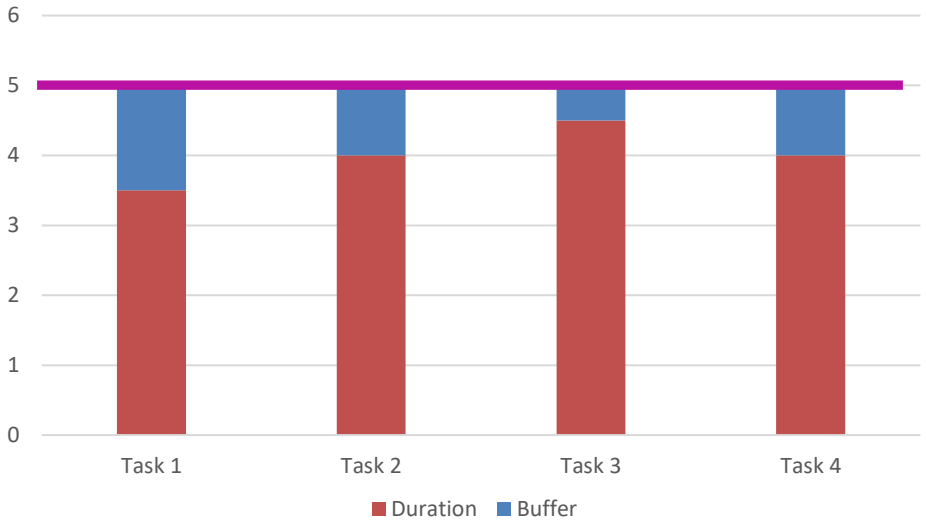
- **Potential problem: setting goals low may result in low production (Parkinson’s law)**

Different types of buffers

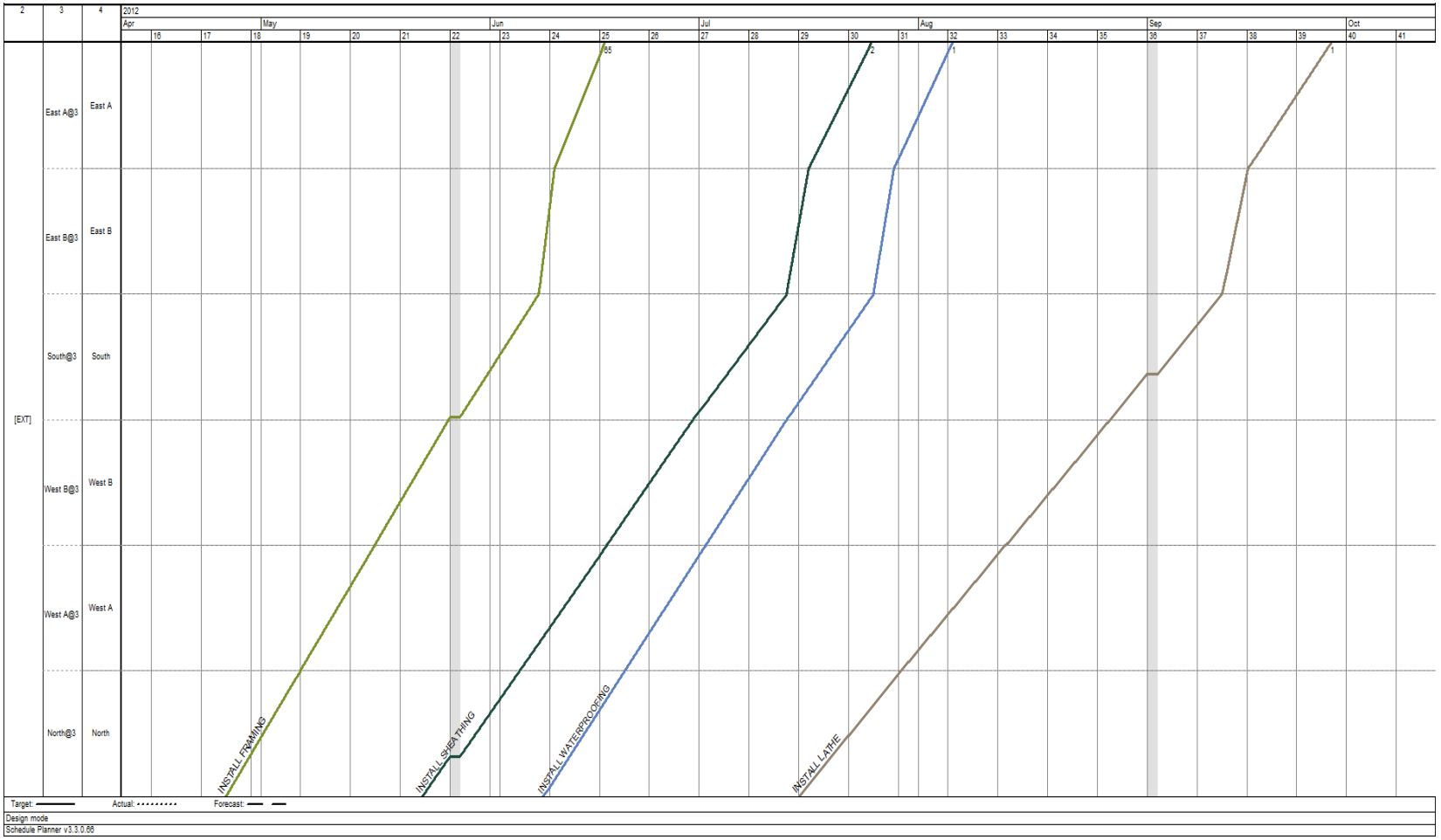
- **LBMS – primarily time buffer**



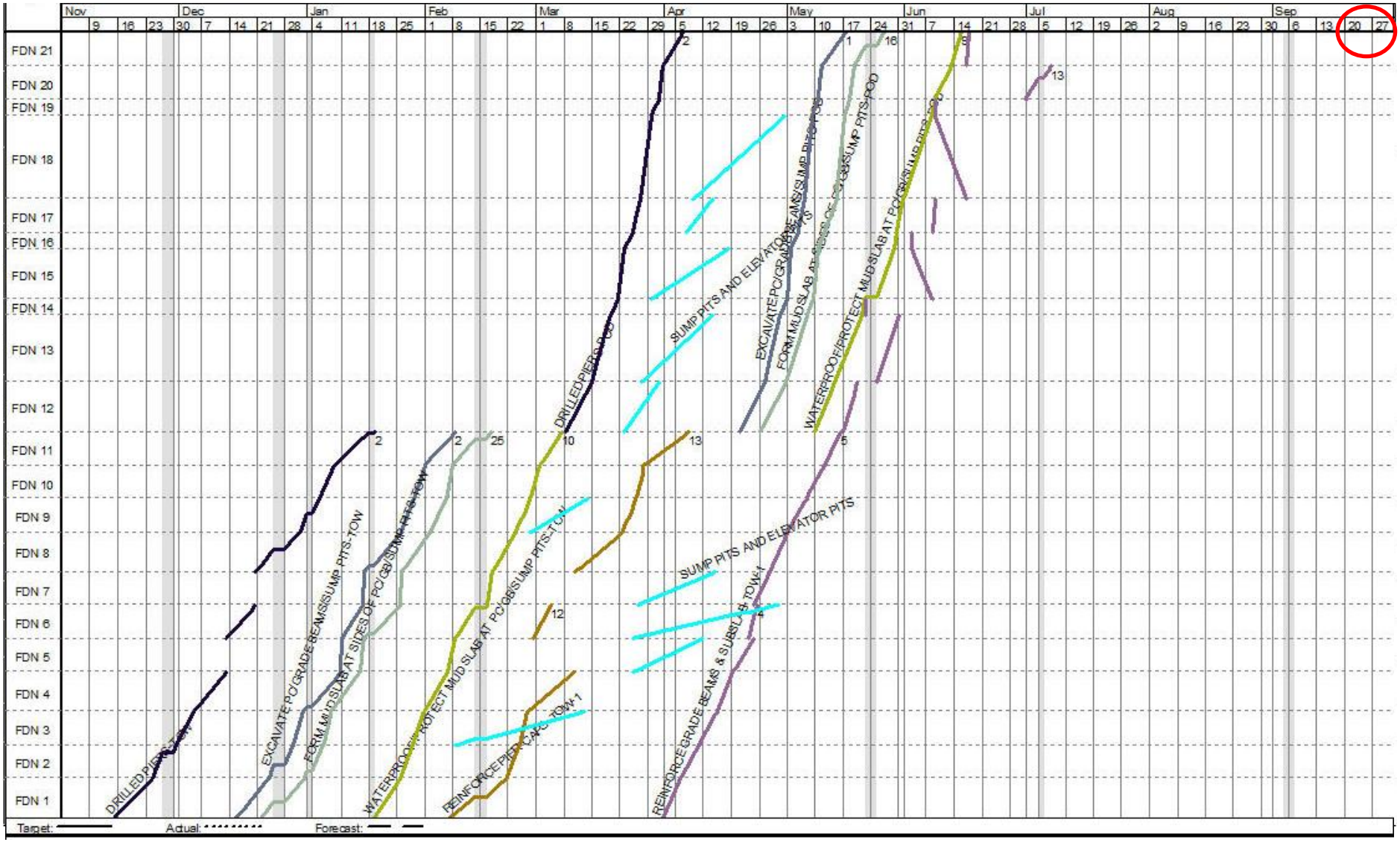
- **Takt – primarily capacity buffer and workable backlogs**



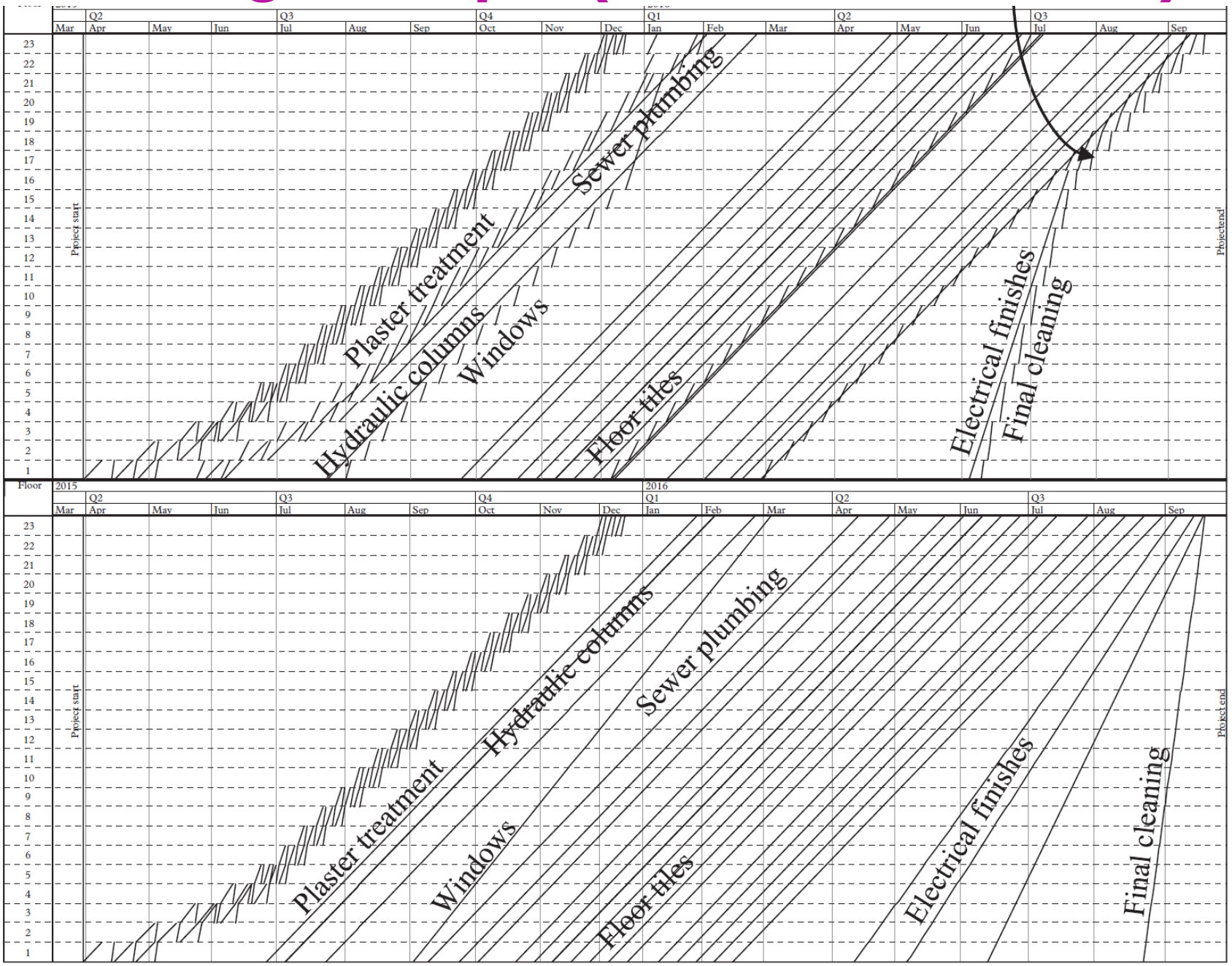
Planning example #1



Model-based Scheduling – 20 % duration compression



Planning example (Olivieri et al. 2018)



Thank you
Questions & Comments