Project Scheduling with Microsoft Project 2016

CERN | EN ENGINEERING DEPARTMENT

Pierre Bonnal

version **1.0**

Prerequisite to Project Scheduling

- **Project scoping →** agreeing upon the **boundaries** and the **deliverable(s)** of the project ⇢ Project Roadmap  ✔
- **Project planning →** identifying the **set of activities** to carry out to perform the project ⇢ Work Breakdown Structure (WBS) ✔
- **Project *costing* →** estimating and assigning **resources** to the project activities ⇢ Budget Document + RACI matrix ✔
- **Project scheduling →** sequencing the activities, calculating dates, floats and critical path(s), levelling/smoothing resources, baselining the result ⇢ **Coordination Schedule / Gantt Chart**

Typology

2 types of **project schedules**

Master Schedule

~ Summary Schedule
Masterplan
Calendrier directeur

Strategic level
The whole project
Intuitive approach

One page/slide
Can be in the **Project Roadmap**

Coordination Schedule

~ ~~"PERT"~~, Gantt chart
Activity network
Calendrier de coordination

Tactical level
One or a few phases
Analytical approach

Several pages
Can be in the **PMP**

Project **Planning** for Complex Systems Projects

- 1 Identifying the project activities
  - 1.1 Describing the final deliverable(s) in a **PBS**
  - 1.2 Deriving the **WBS top nodes** from the PBS
  - 1.3 Preparing and populating the **WBS matrix**
  - 1.4 Generating the **list of activities** from the WBS matrix
- 2 Estimating and assigning resources
  - 2.1 Identifying the resources that are available in a **RBS**
  - 2.2 Estimating the resources that are required (**workload**)
  - 2.3 Assigning resources to activity in a **RACI matrix**

Project **Scheduling** for Complex Systems Projects

3 Sequencing and scheduling the activities

- **3.1** Estimating the **duration** for each activity
- **3.2** Deriving the **technical constraints** between activities
- **3.3** Perhaps, getting rid of **loops** → DSM (Design Structure Matrix)
- **3.4** If needed, defining **temporal constraints** and **calendars**
- **3.5** Calculating earliest/latest start/finish **dates**, **floats** and **critical path**(**s**) → PDM (Precedence Diagramming Method)
- **3.6** If needed, calculating (earliest) start/finish dates considering **resource constraints** → RCPS
- **3.7** Analysing the resulting schedule, inserting **buffers**, and freezing a **baseline** in view of following up progress

Scheduling the CanNet Project by hand

The project context (1)

- OrgaDairy is an industrial dairy that makes **yogurts**
- OrgaDairy factory houses **a lot of tanks** (homogenization, fermentation)
- The process shall be carefully monitored (**regular samplings**), the tanks shall also be carefully cleaned, rinced and controlled after each batch

the **initial situation**, i.e. problem (1)

- Until now, **this monitoring is carried out very manually**:
  many time-consuming rides between the factory lab and the many tanks
- To improve the monitoring process and to comply with evolving rules, OrgaDairy executive management decided to invest in an **enhanced sampling system** which shall be in operation in less than one year

the **project objectives** (2)

The project context (2)

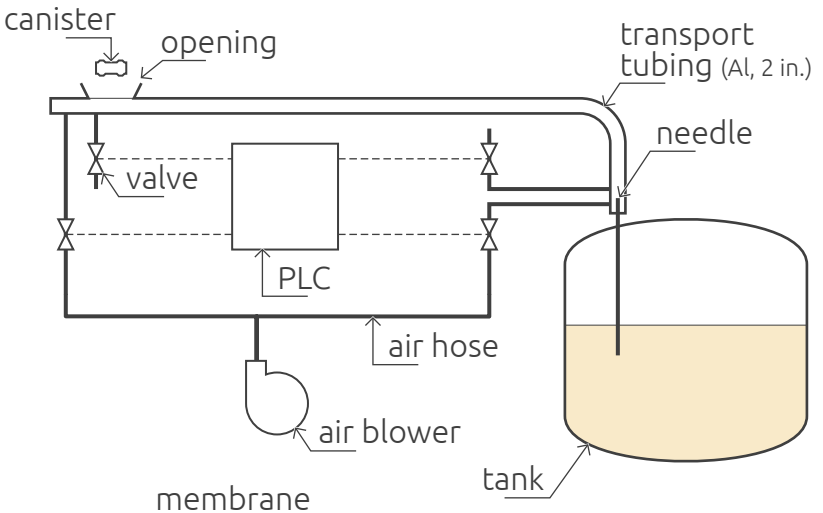
some **possible solutions** 3

- A few possible solutions were considered during the **initialize phase**
- The one that was preferred consists of installing a **pneumatic tube transport system** (PTTS) to propel **canisters** between the factory lab and the many tanks

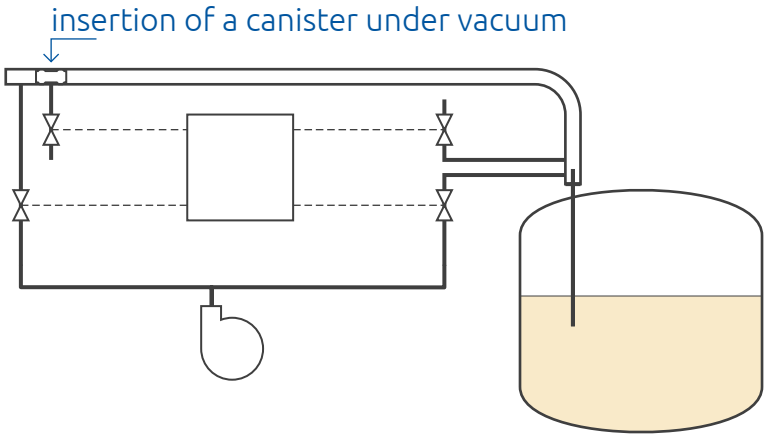
the **preferred solution** 4

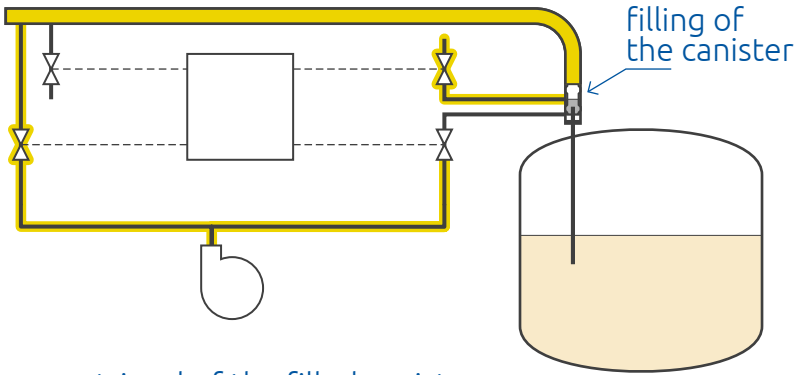
- Its feasibility was demonstrated during the **study phase** ← CDR
- The initiative is named **CanNet** (**can**ister **net**work) **Project** and **Mr. Ayrton**, senior plant engineer, was appointed project manager ← 4.2
- The project is made of **three major phases**: ← 4.3
  - A study phase (already completed)
  - A pilot project → PTTS between the factory lab and three tanks
  - A full deployment project throughout the entire factory

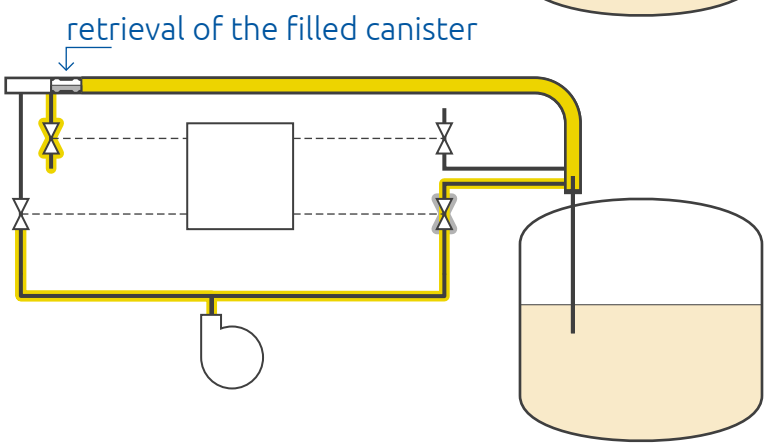
The process


canister
opening
transport
tubing (Al, 2 in.)
needle
valve
PLC
air hose
air blower
tank

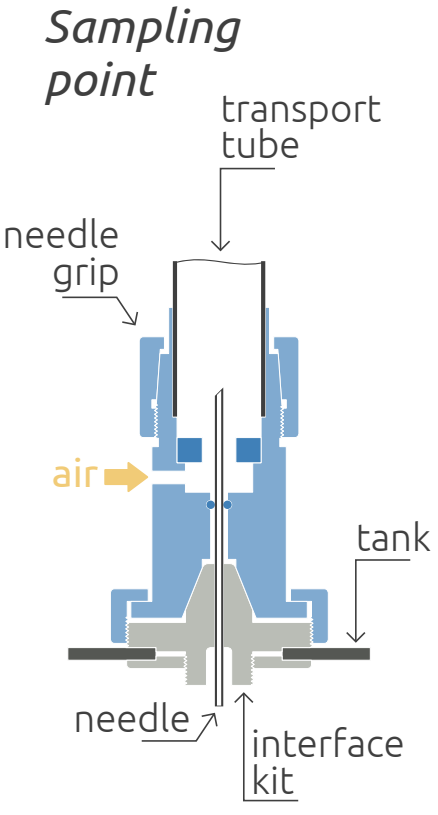

membrane

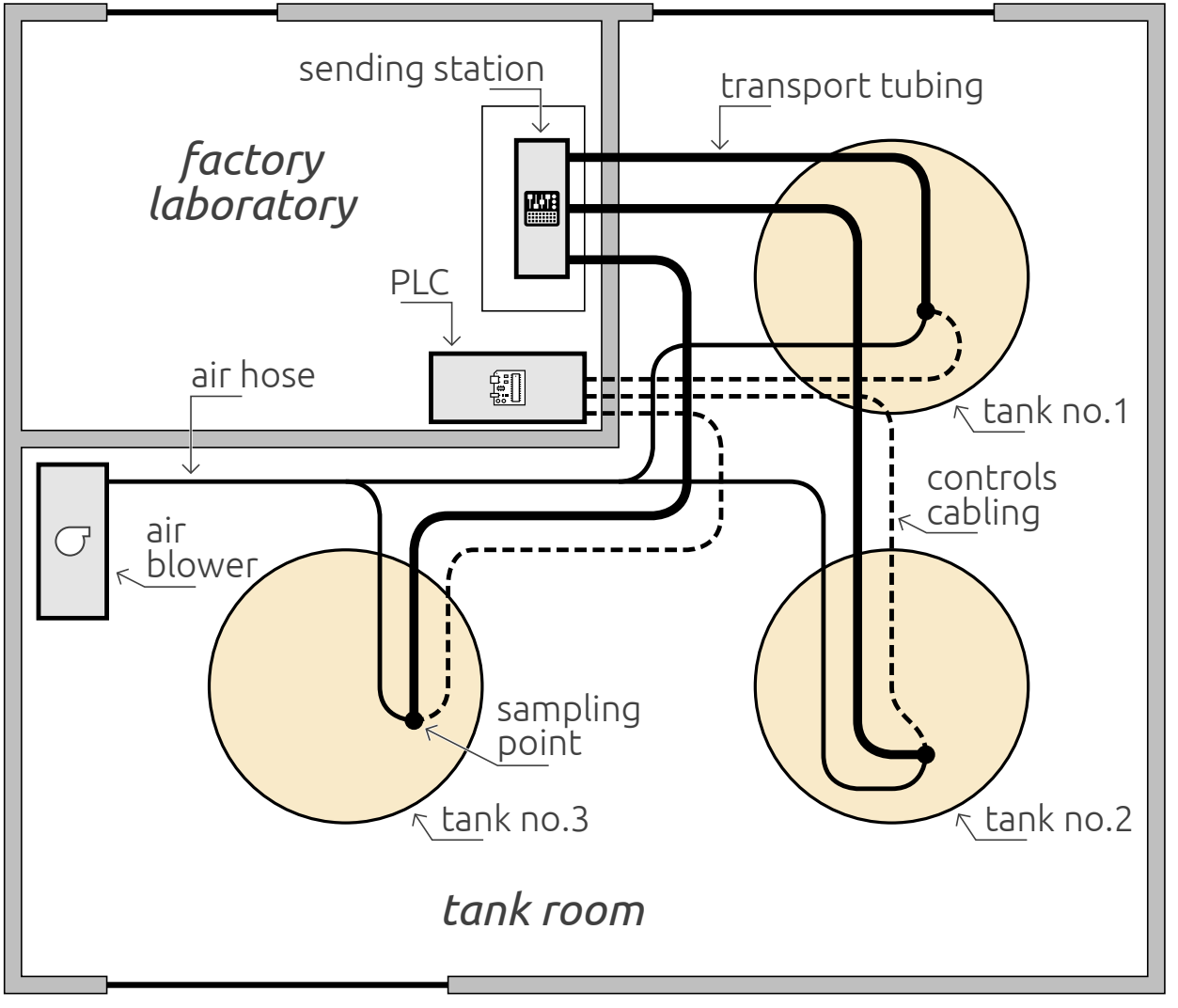

insertion of a canister under vacuum


filling of
the canister

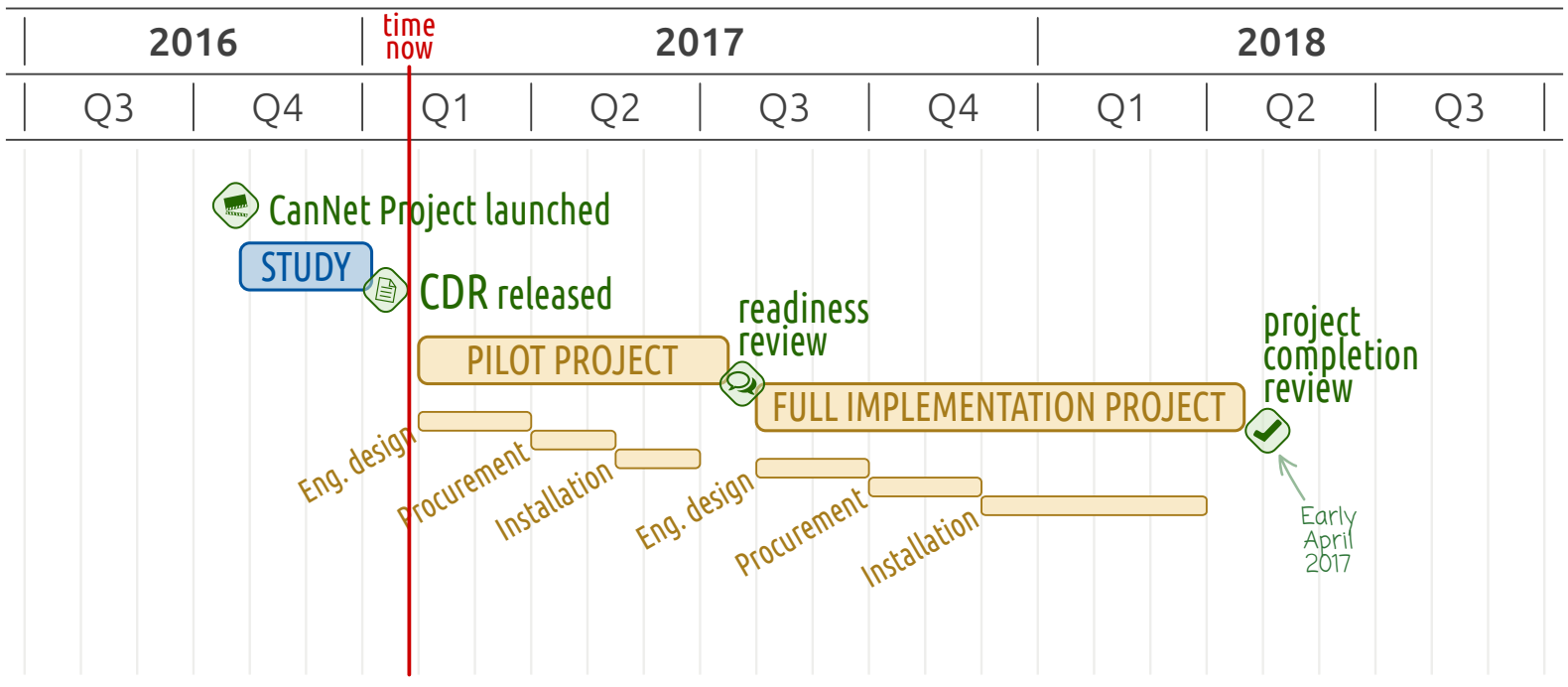

retrieval of the filled canister

The layout


Sampling point
transport tube
needle grip
air
tank
needle
interface kit


sending station
transport tubing
factory laboratory
PLC
air hose
tank no.1
controls cabling
air blower
sampling point
tank no.3
tank no.2
tank room

The project master schedule

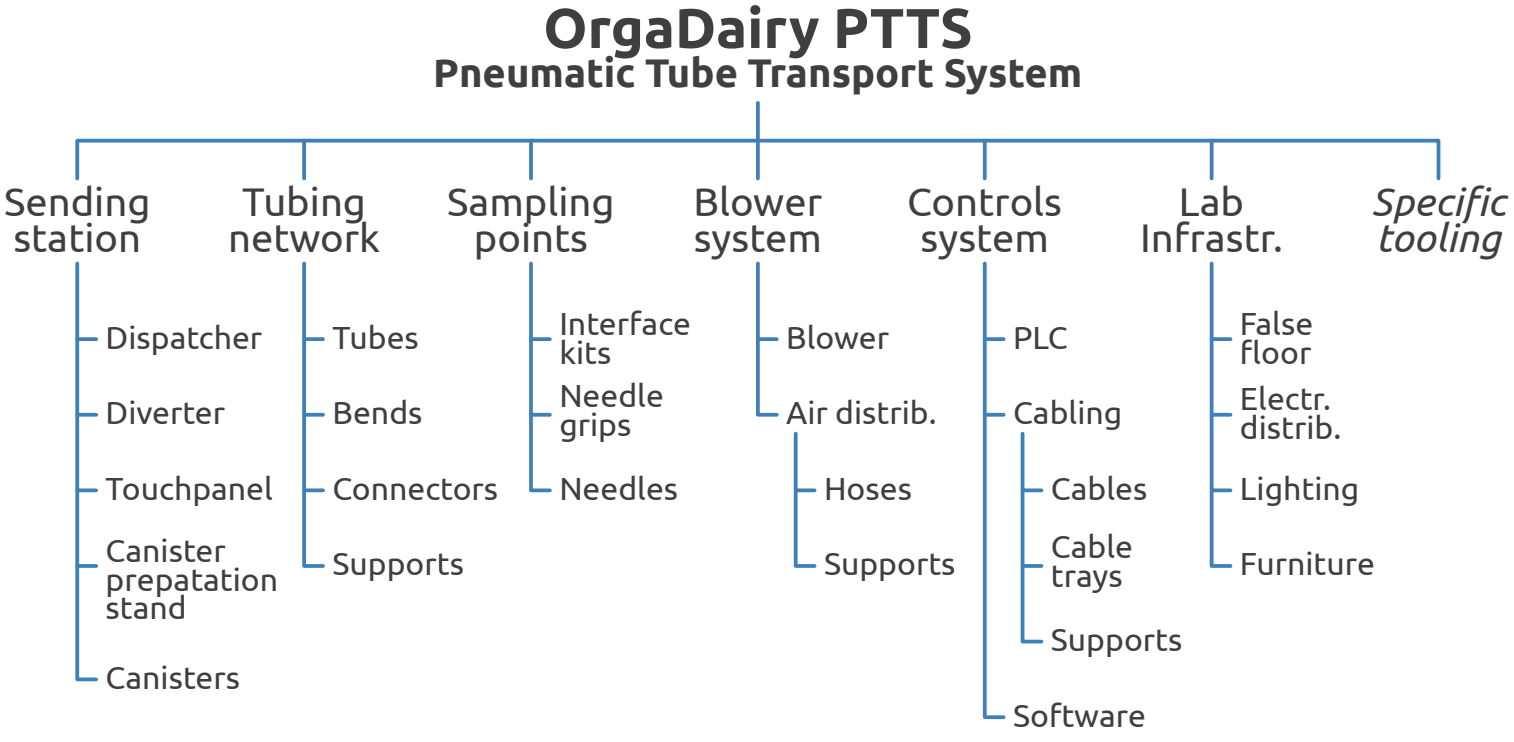


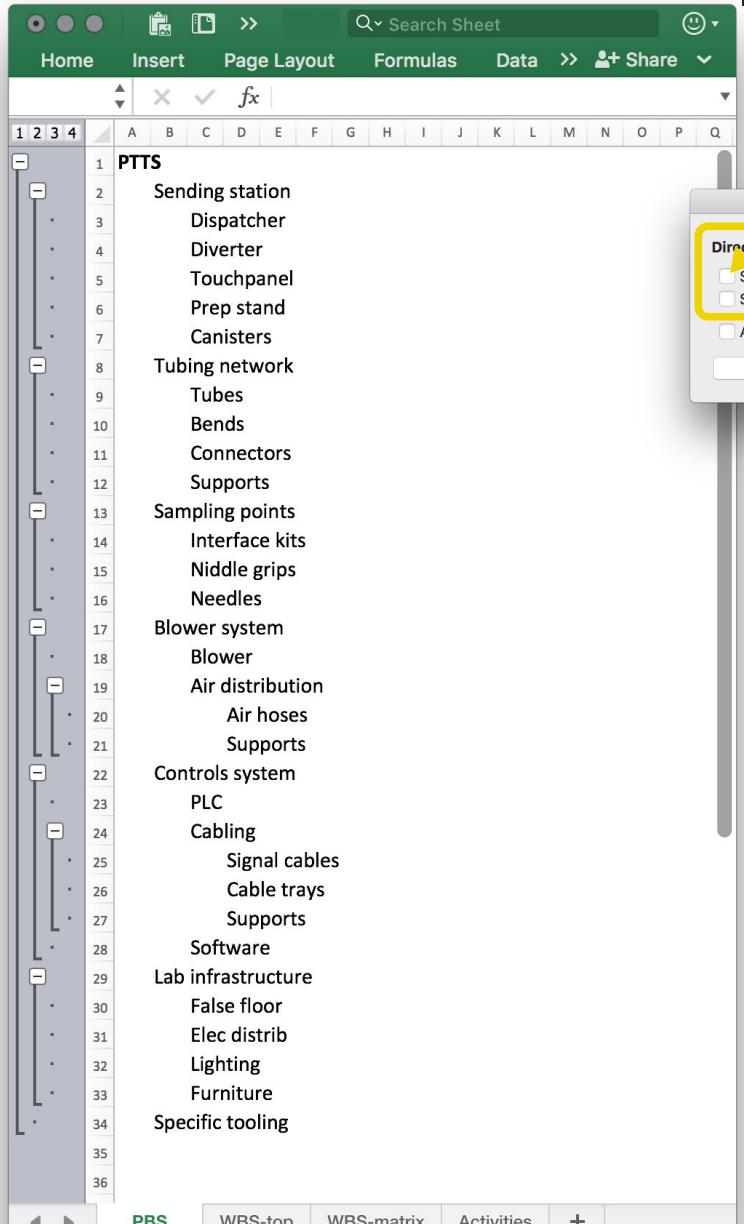
version 2.0 validated by the CanNet Project Board - dated 2017-01-13

2.1

PBS, WBS and list of activities

*Product Breakdown Structure (**PBS**)*

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Touchpanel
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Canisters
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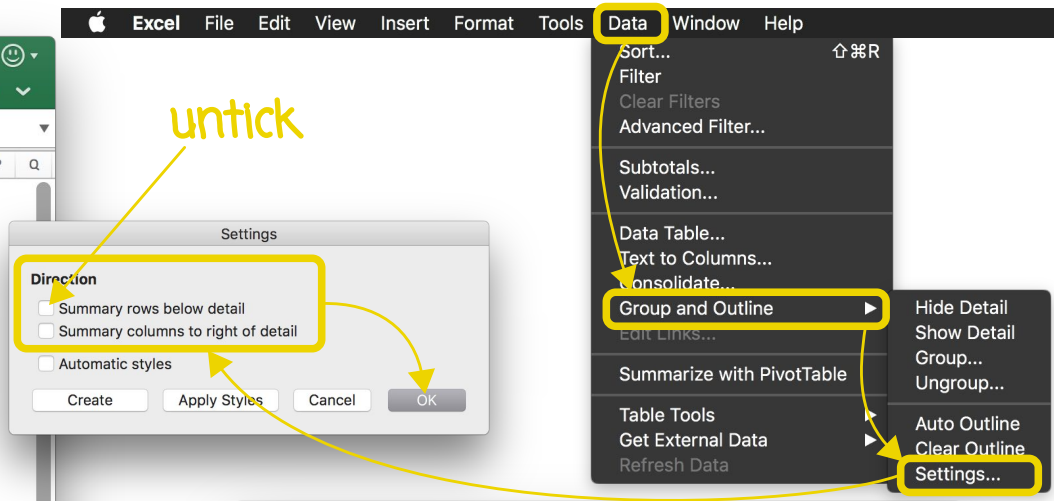
Tubes
Bends
Connectors
Supports
Sampling points
Interface kits
Niddle grips
Needles
Blower system
Blower
Air distribution
Air hoses
Supports
Controls system
PLC
Cabling
Signal cables
Cable trays
Supports
Software
Lab infrastructure
False floor
Elec distrib
Lighting
Furniture
Specific tooling
PBS
WBS-top
WBS-matrix
Activities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Advanced Filter...
Subtotals...
Validation...
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Text to Columns...
Consolidate...
Group and Outline
Edit Links...
Summarize with PivotTable
Table Tools
Get External Data
Refresh Data
Hide Detail
Show Detail
Group...
Ungroup...
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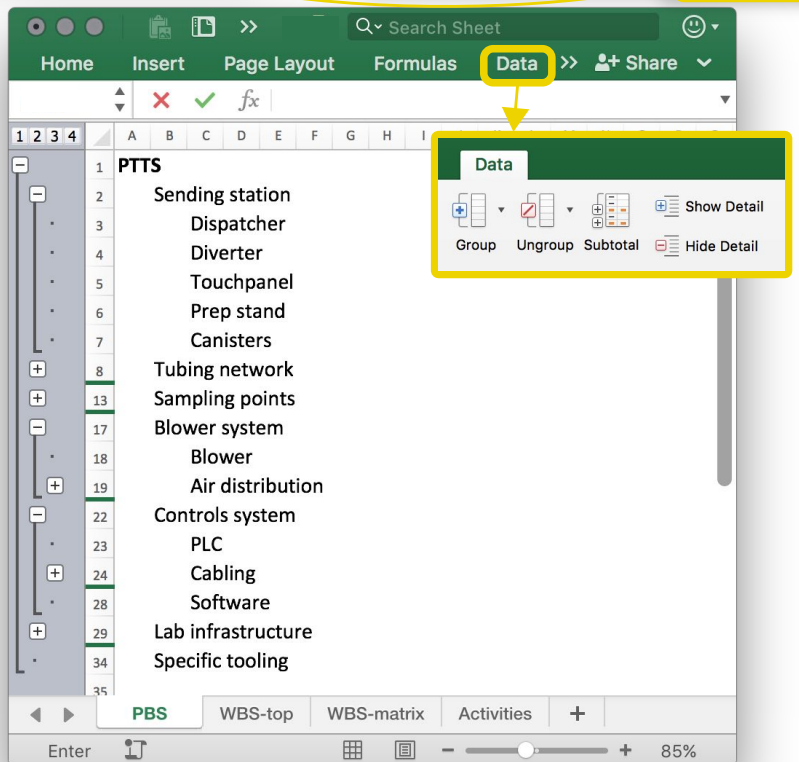
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Dispatcher
Diverter
Touchpanel
Prep stand
Canisters
Tubing network
Sampling points
Blower system
Blower
Air distribution
Controls system
PLC
Cabling
Software
Lab infrastructure
Specific tooling
PBS
WBS-top
WBS-matrix
Activities
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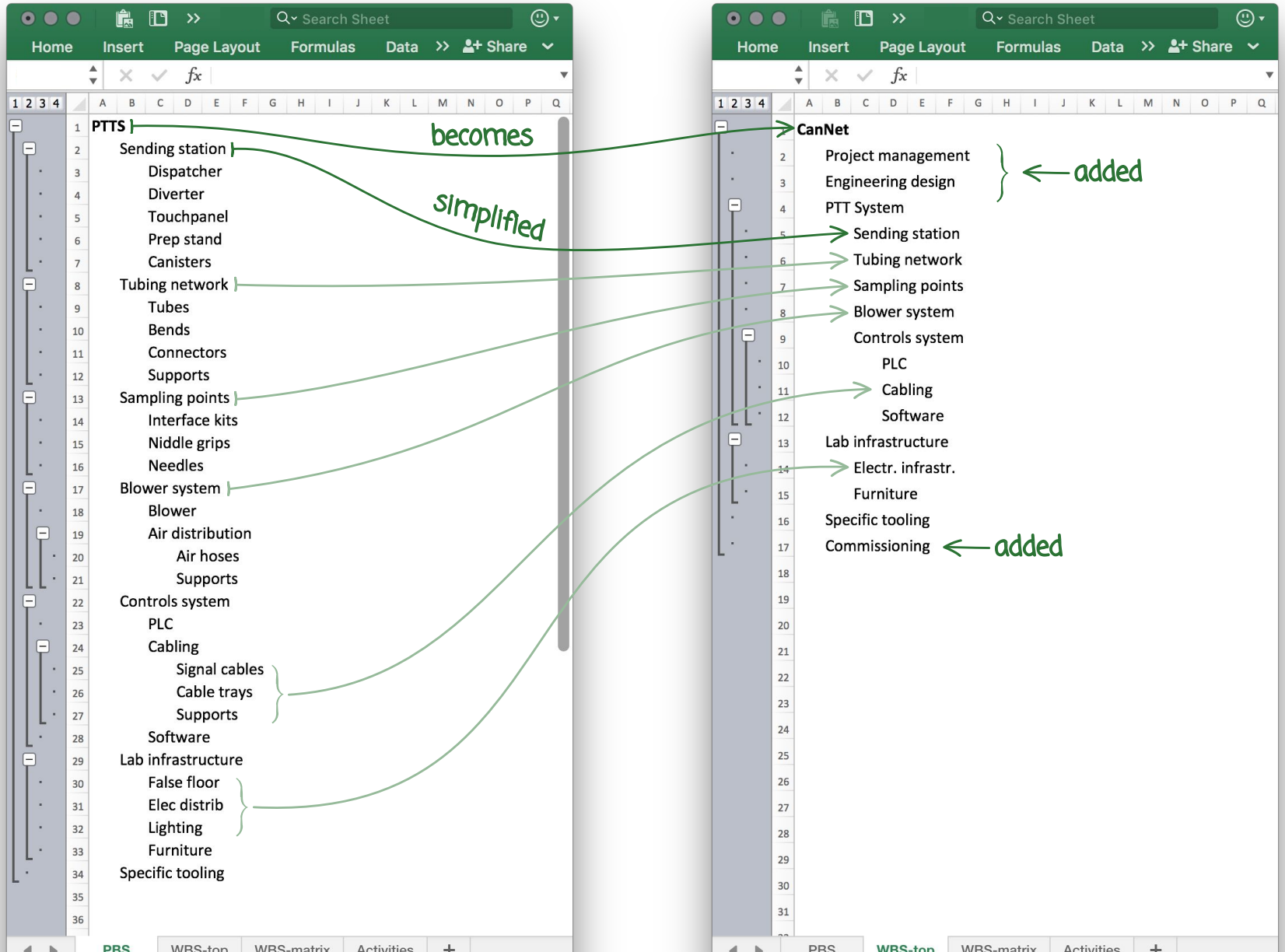
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Touchpanel
Prep stand
Canisters
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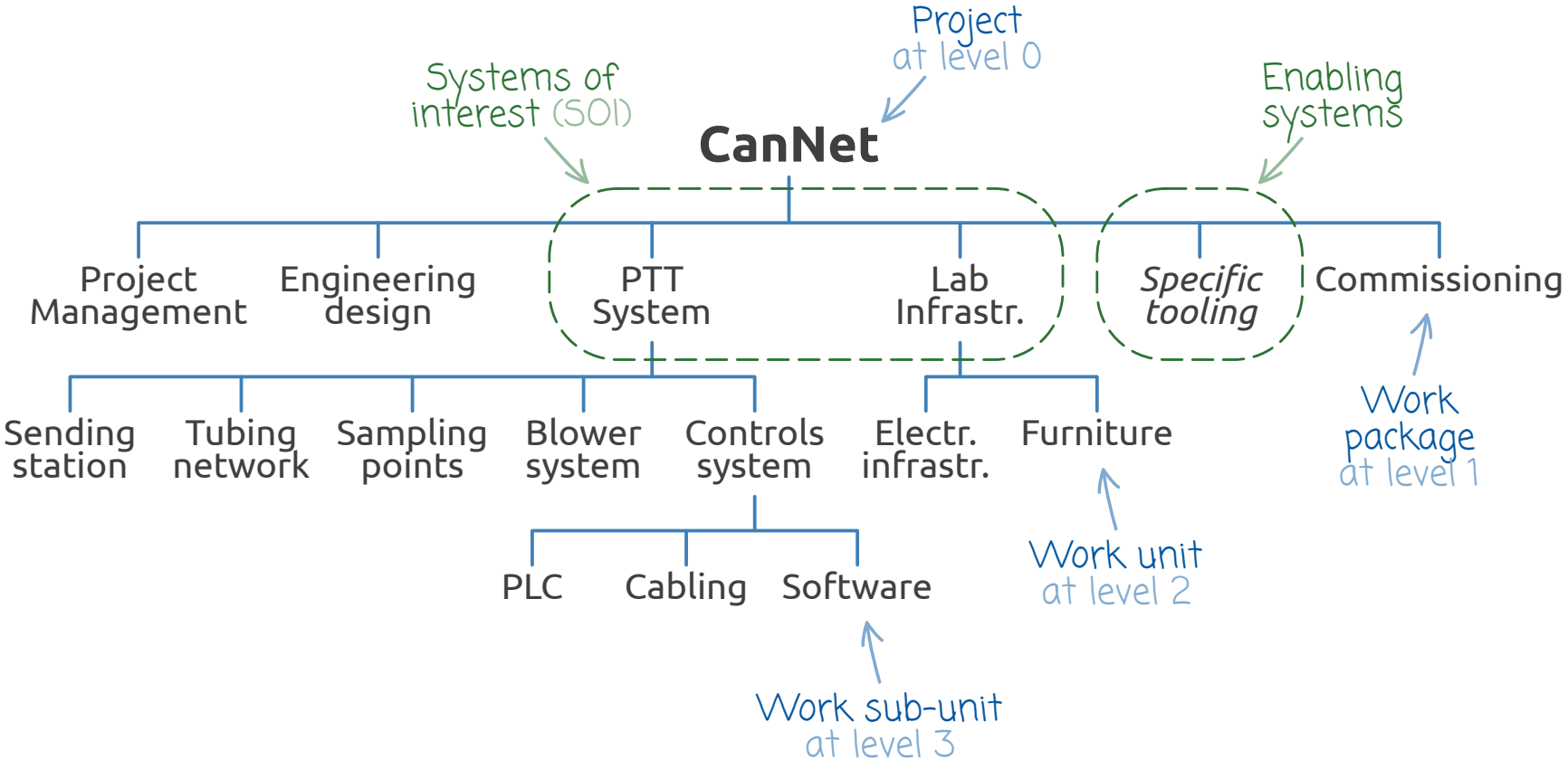
Tubes
Bends
Connectors
Supports
Sampling points
Interface kits
Niddle grips
Needles
Blower system
Blower
Air distribution
Air hoses
Supports
Controls system
PLC
Cabling
Signal cables
Cable trays
Supports
Software
Lab infrastructure
False floor
Elec distrib
Lighting
Furniture
Specific tooling
becomes
simplified
CanNet
Project management
Engineering design
PTT System
Sending station
Tubing network
Sampling points
Blower system
Controls system
PLC
Cabling
Software
Lab infrastructure
Electr. infrastr.
Furniture
Specific tooling
Commissioning
added
added
PBS
WBS-top
WBS-matrix
Activities

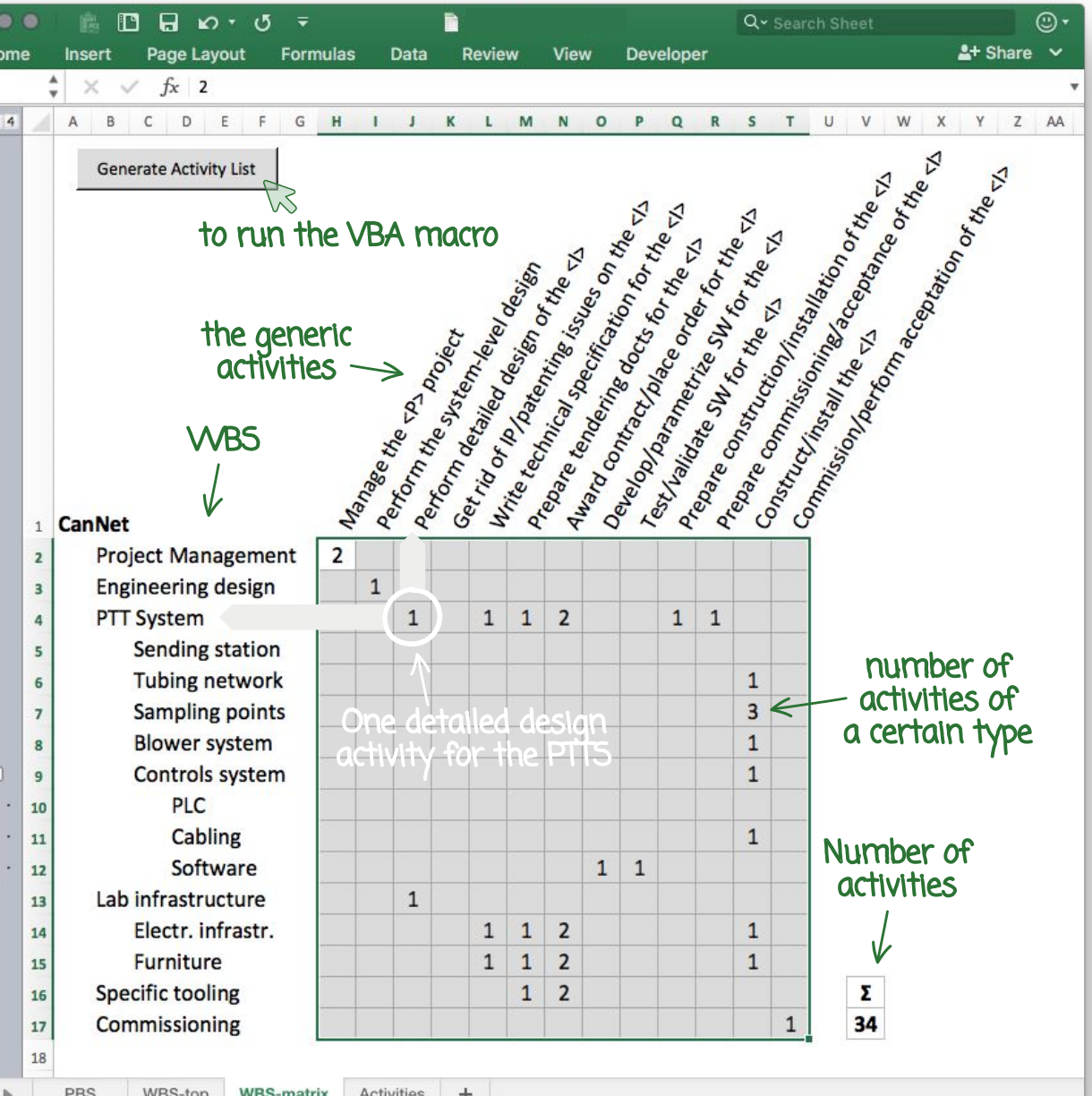
*Work Breakdown Structure (**WBS**)*



The generic activities

suited to OrgaDairy improvement projects

Manage the project
Perform the system-level design
Perform detailed design
Get rid of IP/patenting issues
Write technical specification
Prepare tendering docts
Award contract/place order
Develop/parametrize software
Test/validate software
Prepare construction/installation
Prepare commissioning/acceptance
Construct/install
Commission/perform acceptation



To run the macro:

1. Put a '>' in col. A (e.g. cell A20)
2. Select cells for which activities will be generated (e.g. H2:T17)
3. Click the button

Activity ≈ Work Unit ≈ Work Package

An activity is an elementary action that:

- consumes **time**
- consumes **resources**
- has a **start** and a **finish** dates
- is assignable to **one person**
- produces **deliverable**(**s**)
- is **measurable** (to assess its progress)

Activity ≠ Deliverable

To avoid confusion, clever professional practices and several textbooks suggest to label activities as follow:

Action verb (infinitive tense) + Substantive

How many activities on a schedule?

What should be the size of a project's **Activity Portfolio**?

- No definitive answer!
- That depends of the size and complexity of the project
- But more than **300 or 400 activities*** is known to be difficult to handle
- **100 activities*** sounds reasonable for a project spanning over one year

* Activities + remaining planned activities

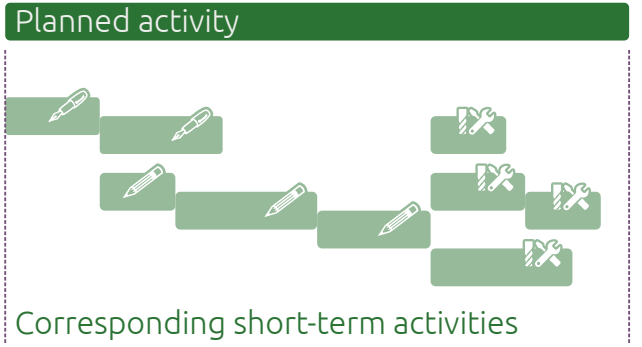
Activity vs. **Planned Activity**

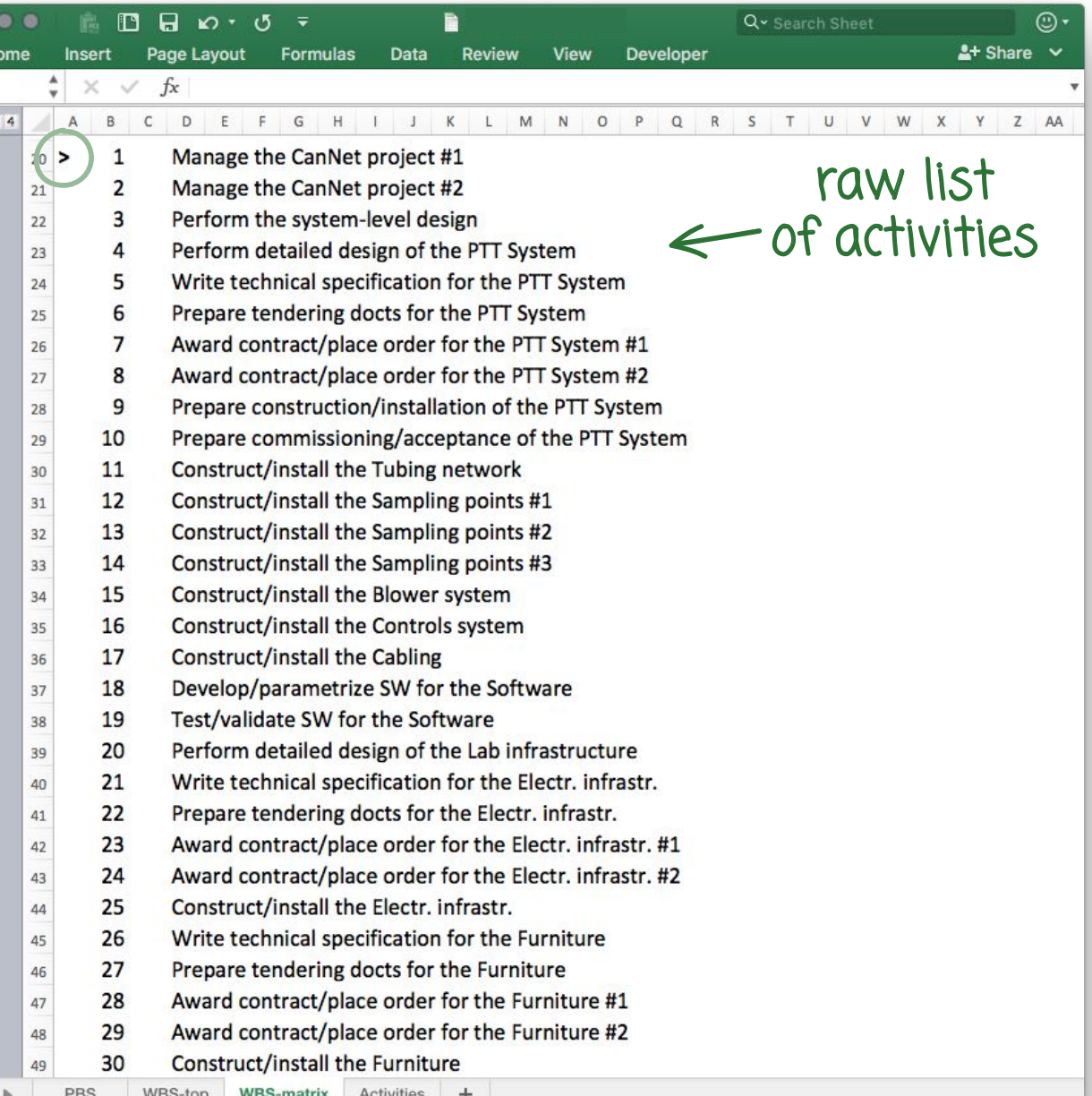
The ANSI **#748** project management standard for reporting distinguishes two types of activities:

- **Activities** (work units) ⇢ short/medium term
- **Planned activities** (planned units) ⇢ longer term

Planned activities are defined more roughly that short/medium term activities

As the project progresses, planned activities arrive on a shorter term and are split up in short/medium term activities





>	1	Manage the CanNet project #1
	2	Manage the CanNet project #2
	3	Perform the system-level design
	4	Perform detailed design of the PTT System
	5	Write technical specification for the PTT System
	6	Prepare tendering docts for the PTT System
	7	Award contract/place order for the PTT System #1
	8	Award contract/place order for the PTT System #2
	9	Prepare construction/installation of the PTT System
	10	Prepare commissioning/acceptance of the PTT System
	11	Construct/install the Tubing network
	12	Construct/install the Sampling points #1
	13	Construct/install the Sampling points #2
	14	Construct/install the Sampling points #3
	15	Construct/install the Blower system
	16	Construct/install the Controls system
	17	Construct/install the Cabling
	18	Develop/parametrize SW for the Software
	19	Test/validate SW for the Software
	20	Perform detailed design of the Lab infrastructure
	21	Write technical specification for the Electr. infrastr.
	22	Prepare tendering docts for the Electr. infrastr.
	23	Award contract/place order for the Electr. infrastr. #1
	24	Award contract/place order for the Electr. infrastr. #2
	25	Construct/install the Electr. infrastr.
	26	Write technical specification for the Furniture
	27	Prepare tendering docts for the Furniture
	28	Award contract/place order for the Furniture #1
	29	Award contract/place order for the Furniture #2
	30	Construct/install the Furniture

To run the macro:

1. Put a '>' in col. A (e.g. cell A20)
2. Select cells for which activities will be generated (e.g. H2:T17)
3. Click the button

Activities listed as from row marked '>' downward

4. Adjust the labels*
5. Copy-paste the list into the project scheduling software

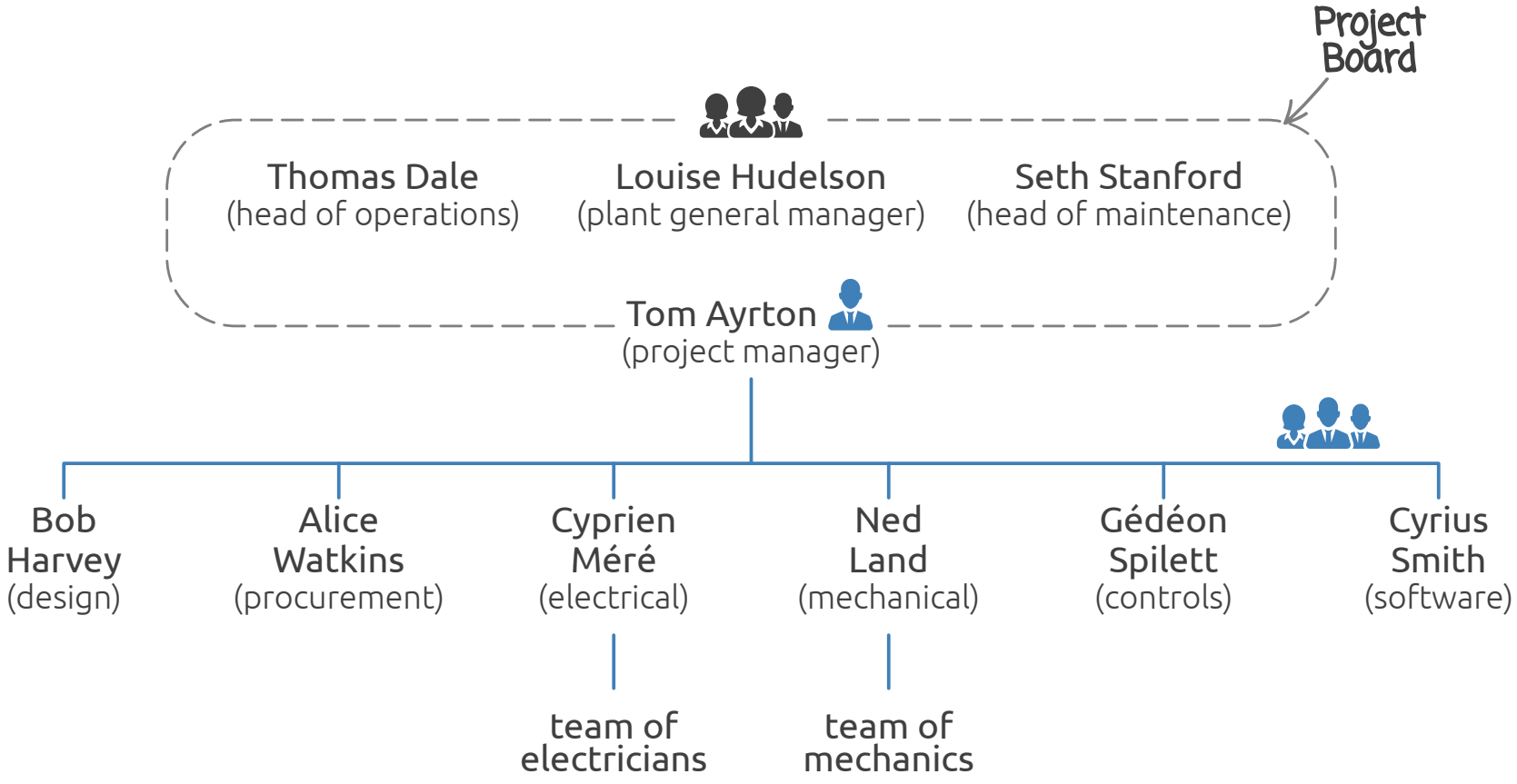
*List of activities (**LoA**) with ajusted labels*

Manage the CanNet project
Set the project management framework
Perform detailed design of the PTT system
Write technical specification for the PTT system
Prepare tendering docts for the PTT system
Send invitations to tender for the PTT system
Open tenders and place order for the PTT system
Perform the installation design
Prepare installation of the PTT system
Prepare commissioning of the PTT system
Install the tank #1 sampling point assembly
Install the tank #2 sampling point assembly
Install the tank #3 sampling point assembly
Lay down the tubing network
Install the blower and lay down the air hoses
Pull and connect controls cabling
Install the PLC and sending station in the lab
Parametrize software for the PTT system
Test and validate software for the PTT system
Perform detailed design of the lab arrangement
Write technical specification for the electr. infrastr.
Prepare tendering docts for the electr. infrastr.
Send invitations to tender for the electr. infrastr.
Open tenders and place order for the electr. infrastr.
Install the electr. infrastr. In the lab
Write technical specification for the lab's furniture
Prepare tendering docts for the lab's furniture
Send invitations to tender for the lab's furniture
Open tenders and place order for the lab's furniture
Arrange the furniture in the lab
Prepare tendering docts for the specific tooling
Send invitations to tender for the specific tooling
Open tenders and place order for the specific tooling
Debug and commission the pilot PTT system

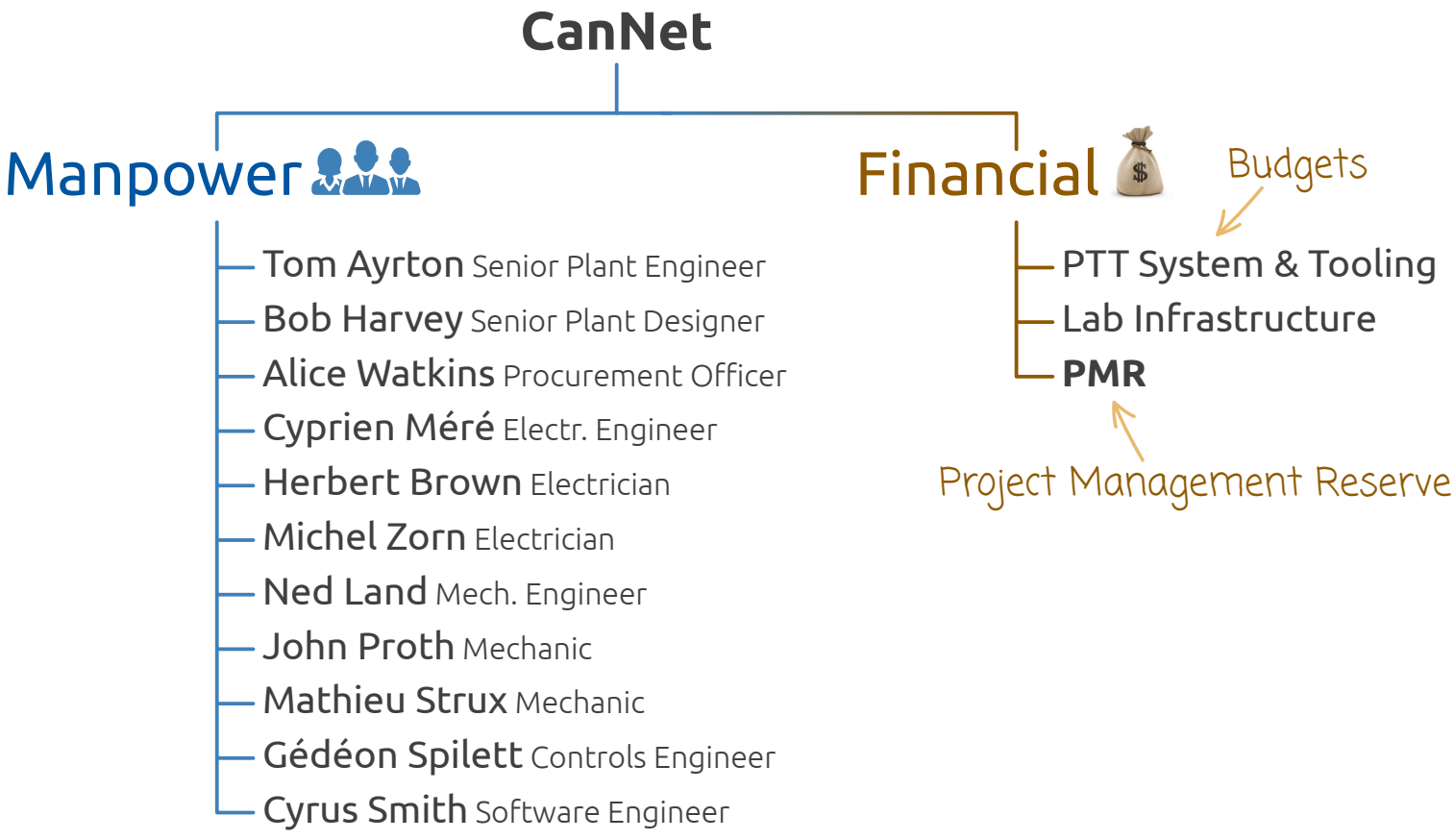
2.2

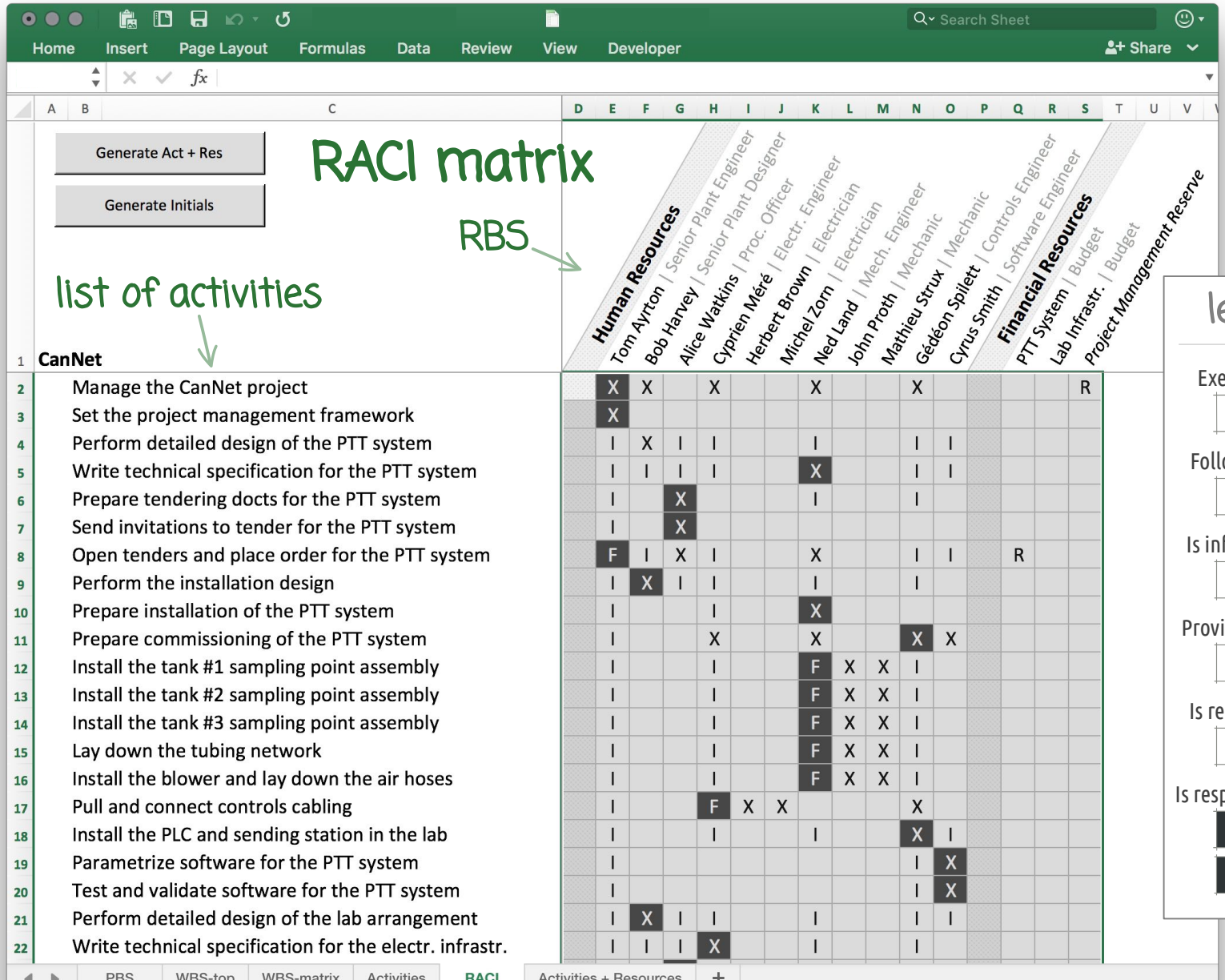
OBS, RBS and RACI matrix

*Organisational Breakdown Structure (**OBS**)*



*Resource Breakdown Structure (**RBS**)*




Home Insert Page Layout Formulas Data Review View Developer
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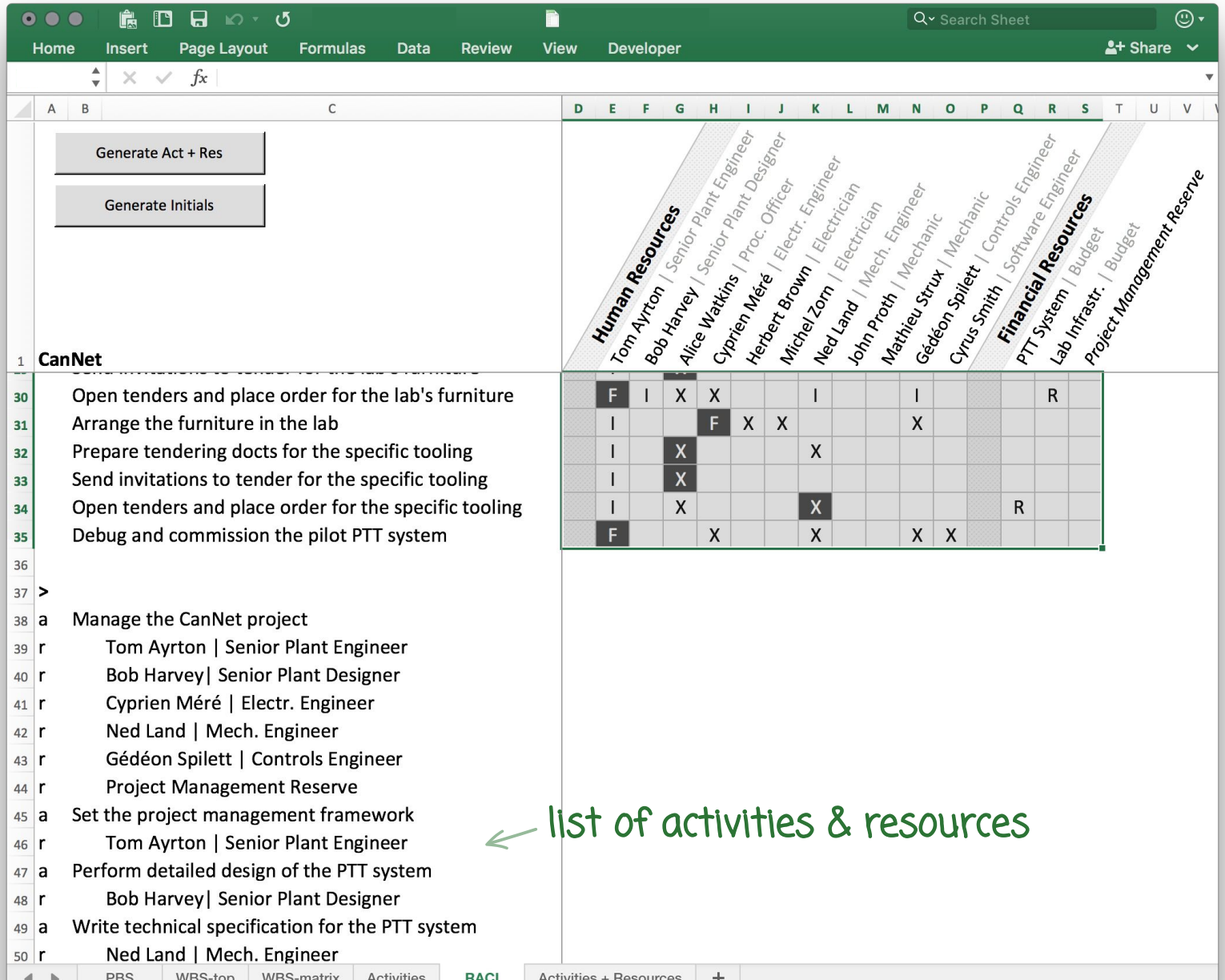
RACI matrix
RBS
list of activities
Human Resources
Financial Resources
Tom Ayrton | Senior Plant Engineer
Bob Harvey | Senior Plant Designer
Alice Watkins | Proc. Officer
Cyprien Méré | Electr. Engineer
Herbert Brown | Electrician
Michel Zorn | Electrician
Ned Land | Mech. Engineer
John Proth | Mechanic
Mathieu Strux | Mechanic
Gédéon Spilett | Controls Engineer
Cyrus Smith | Software Engineer
PTT System | Budget
Lab Infrastr. | Budget
Project Management Reserve
CanNet
Manage the CanNet project
Set the project management framework
Perform detailed design of the PTT system
Write technical specification for the PTT system
Prepare tendering docts for the PTT system
Send invitations to tender for the PTT system
Open tenders and place order for the PTT system
Perform the installation design
Prepare installation of the PTT system
Prepare commissioning of the PTT system
Install the tank #1 sampling point assembly
Install the tank #2 sampling point assembly
Install the tank #3 sampling point assembly
Lay down the tubing network
Install the blower and lay down the air hoses
Pull and connect controls cabling
Install the PLC and sending station in the lab
Parametrize software for the PTT system
Test and validate software for the PTT system
Perform detailed design of the lab arrangement
Write technical specification for the electr. infrastr.
PBS WBS-top WBS-matrix Activities RACI Activities + Resources
legend
Executes
X
Follows up
F
Is informed
I
Provide help
H
Is required
R
Is responsible
X
F



list of activities & resources

2.3

Duration Estimates

Activity

An activity is an elementary action that:

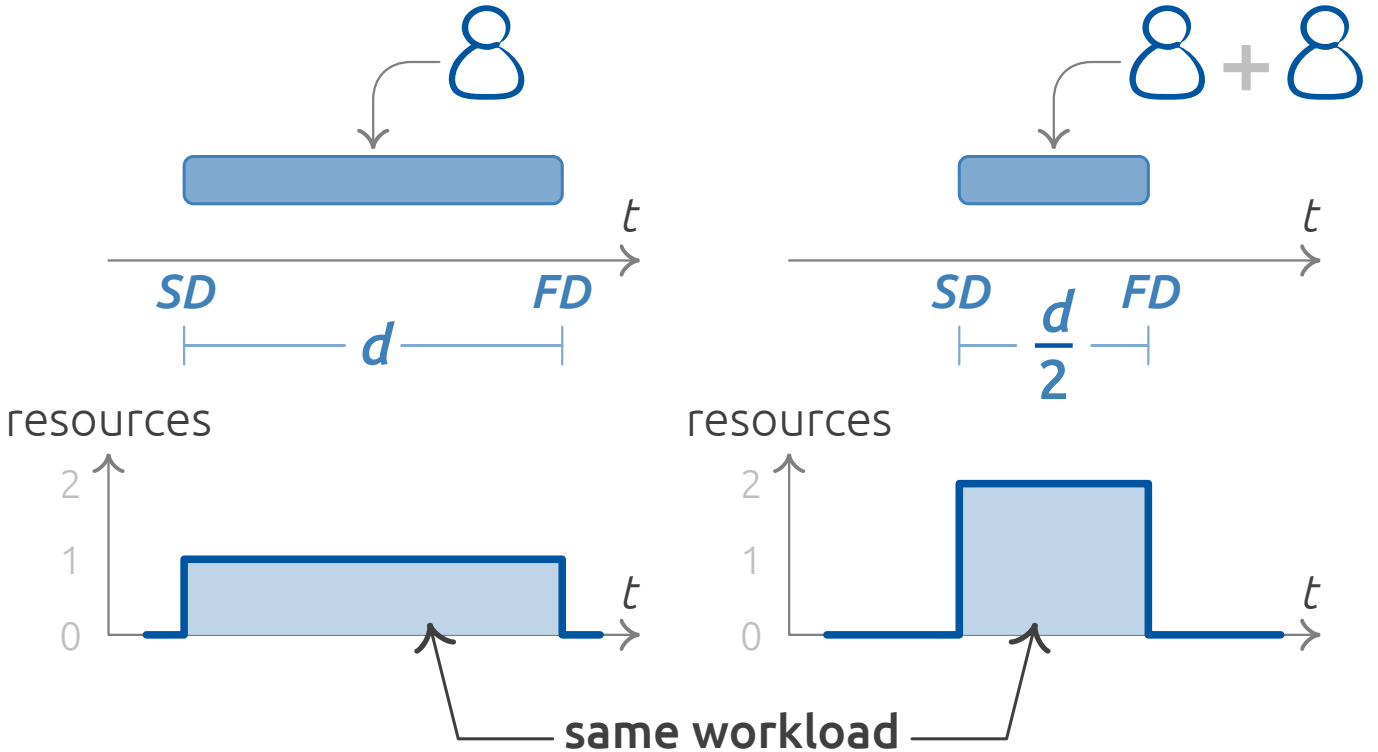
- consumes **time** *yes, but within certain limits!*

What is then the maximum duration for an activity?

- No definitive answer!
- No more than **5%** to **10%** of the project duration
- No more than **13 weeks** (long lead projects)
- Some so-called **Level-of-Effort** activities are allowed **one** such or up to **1%** of the activities ANSI **#748**

Estimating Activity Duration

Workload Histogram



Units for **duration**:
- hour [hr]
- day [d]
- week [wk]
- month [m]

Units for **workload**:
- person·day [p·d]
- person·week [p·wk]
- person·month [p·m]
- person·year [p·yr]
- working hours [whr]

Estimating Activity Duration

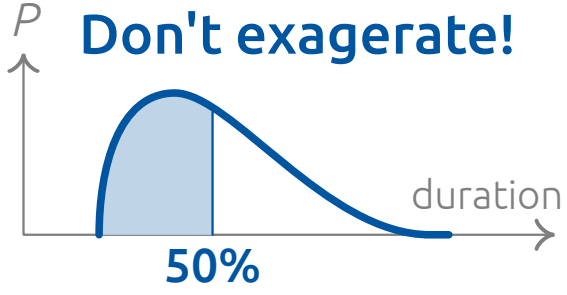
Sources of Estimates

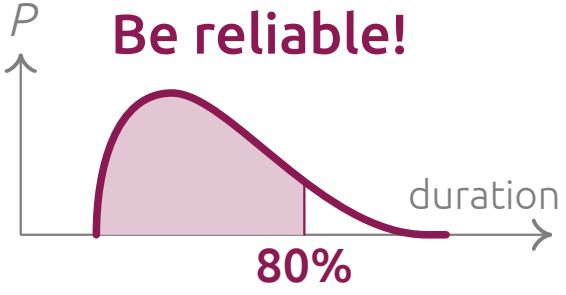
global knowledge

- professional knowledge database
- knowledge database of the company

knowledge of project members

- Project Manager
- Project Participant





*List of activities (**LoA**) + duration estimates* [weeks]

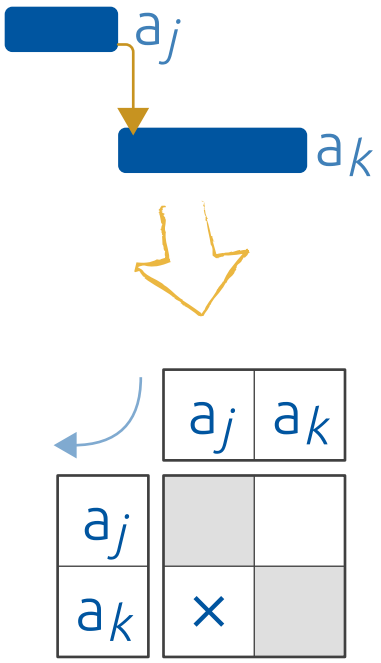
PM	Manage the CanNet project	**LoE**
PMF	Set the project management framework	**1**
DDP	Perform detailed design of the PTT system	**5**
TSP	Write technical specification for the PTT system	**2**
TDP	Prepare tendering docts for the PTT system	**1**
ITP	Send invitations to tender for the PTT system	**0**+ε*
POP	Open tenders and place order for the PTT system	**1**
IDP	Perform the installation design	**1.5**
IPP	Prepare installation of the PTT system	**2**
CPP	Prepare commissioning of the PTT system	**2**
Tk1	Install the tank #1 sampling point assembly	**0.5**
Tk2	Install the tank #2 sampling point assembly	**0.5**
Tk3	Install the tank #3 sampling point assembly	**0.5**
Tub	Lay down the tubing network	**2**
Blw	Install the blower and lay down the air hoses	**1**
Ctrl	Pull and connect controls cabling	**1**
Lab	Install the PLC and sending station in the lab	**2**
PSW	Parametrize software for the PTT system	**4**
TSW	Test and validate software for the PTT system	**2**
DDL	Perform detailed design of the lab arrangement	**2**
TSE	Write technical specification for the electr. infrastr.	**1**
TDE	Prepare tendering docts for the electr. infrastr.	**1**
ITE	Send invitations to tender for the electr. infrastr.	**0**+ε*
POE	Open tenders and place order for the electr. infrastr.	**0.5**
Elec	Install the electr. infrastr. In the lab	**2**
TSF	Write technical specification for the lab's furniture	**0.5**
TDF	Prepare tendering docts for the lab's furniture	**0.5**
ITF	Send invitations to tender for the lab's furniture	**0**+ε*
POF	Open tenders and place order for the lab's furniture	**0.5**
Furn	Arrange the furniture in the lab	**1**
TDT	Prepare tendering docts for the specific tooling	**0.5**
ITT	Send invitations to tender for the specific tooling	**0**+ε*
POT	Open tenders and place order for the specific tooling	**0.5**
Com	Debug and commission the pilot PTT system	**1**

* ca. one hour, but once converted in weeks, dur = 0+ε = 0 wk

2.4

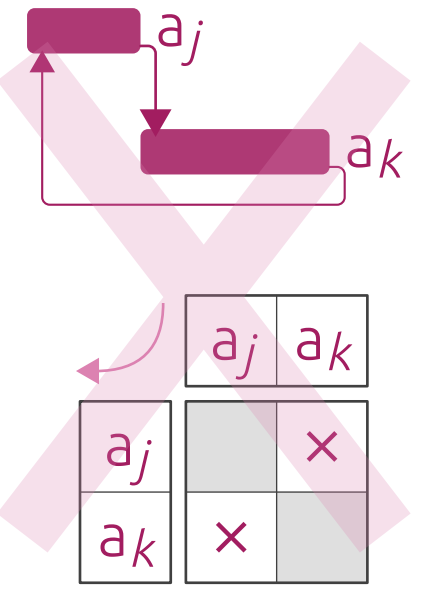
Technical Constraints + Loops

Technical Constraints

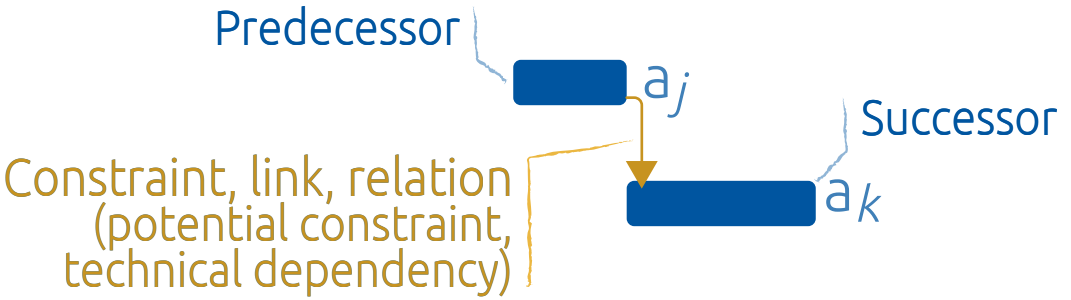


Precedence Matrix

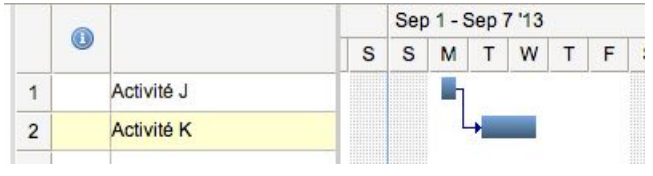
ATTENTION
The activity net shall be free of loops!



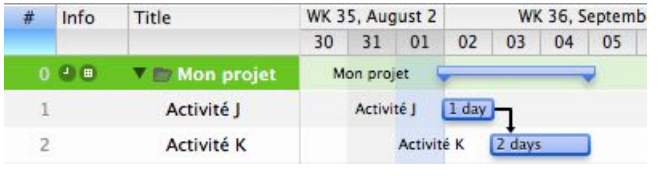
Technical Constraints → Finish–Start



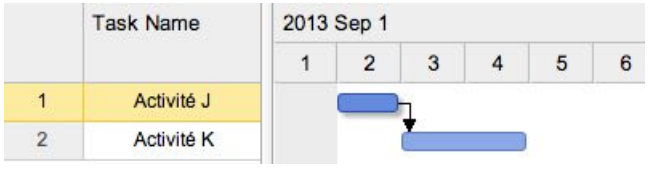
Finish–start constraint in **Gantter.com**



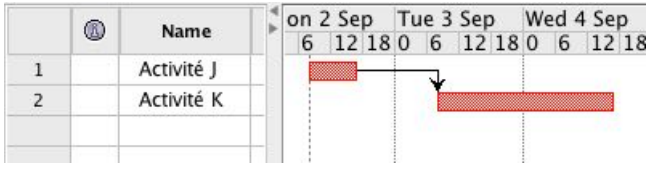
Finish–start constraint in **Merlin**



Finish–start constraint in **Gantic.com**

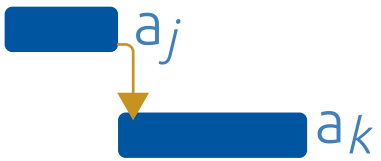


Finish–start constraint in **OpenProj**



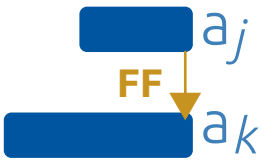
Technical Constraints

finish-start

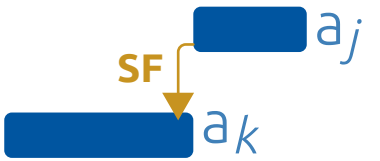


start-start

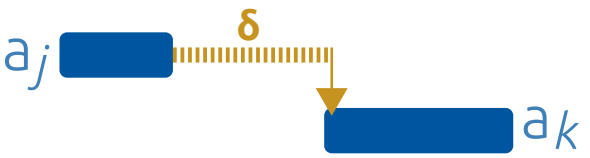
finish–finish



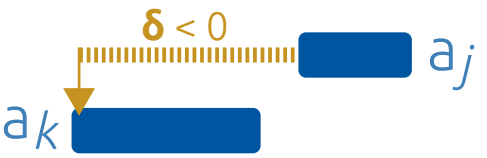
start–finish



positive lag



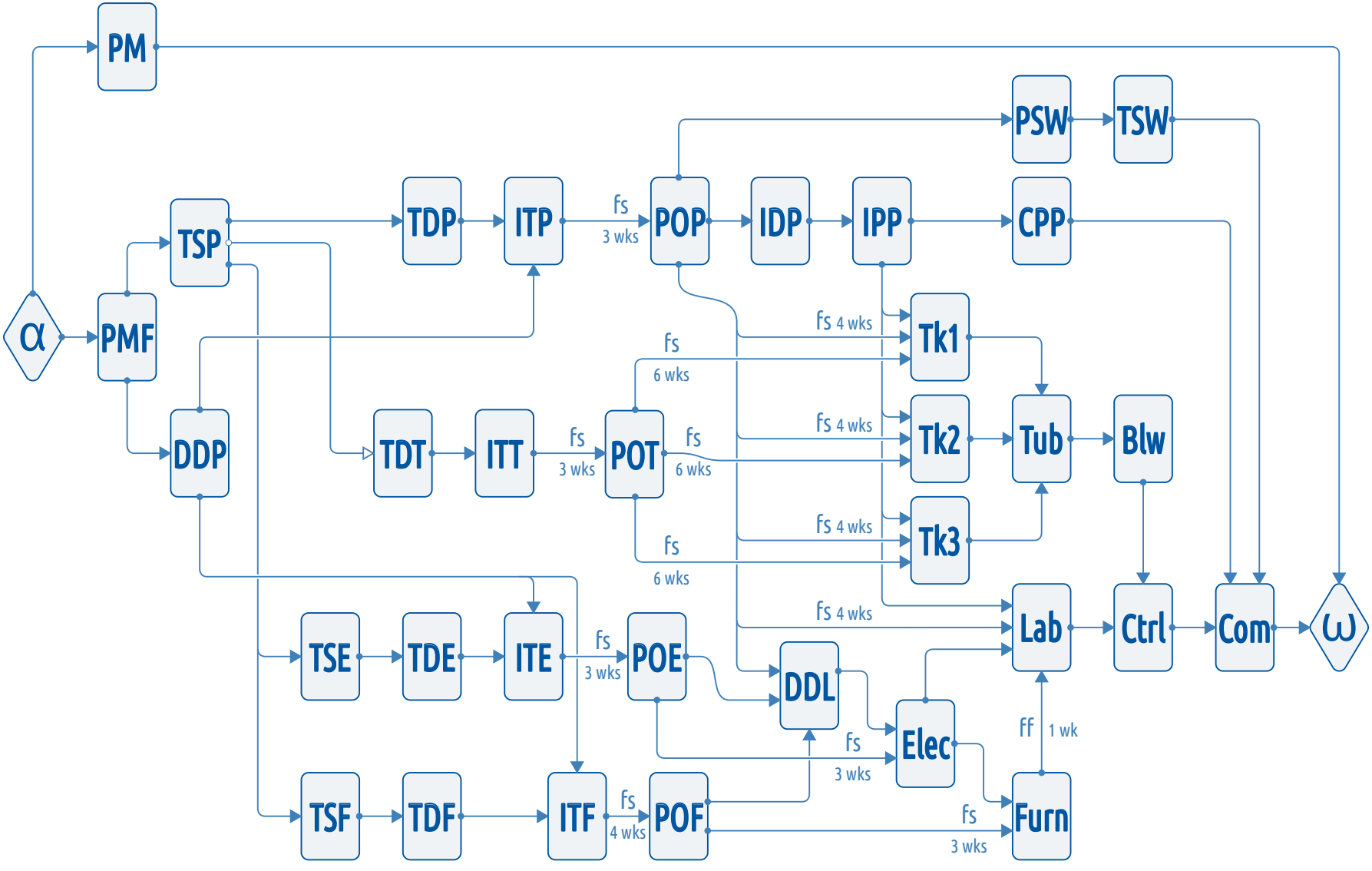
negative lag



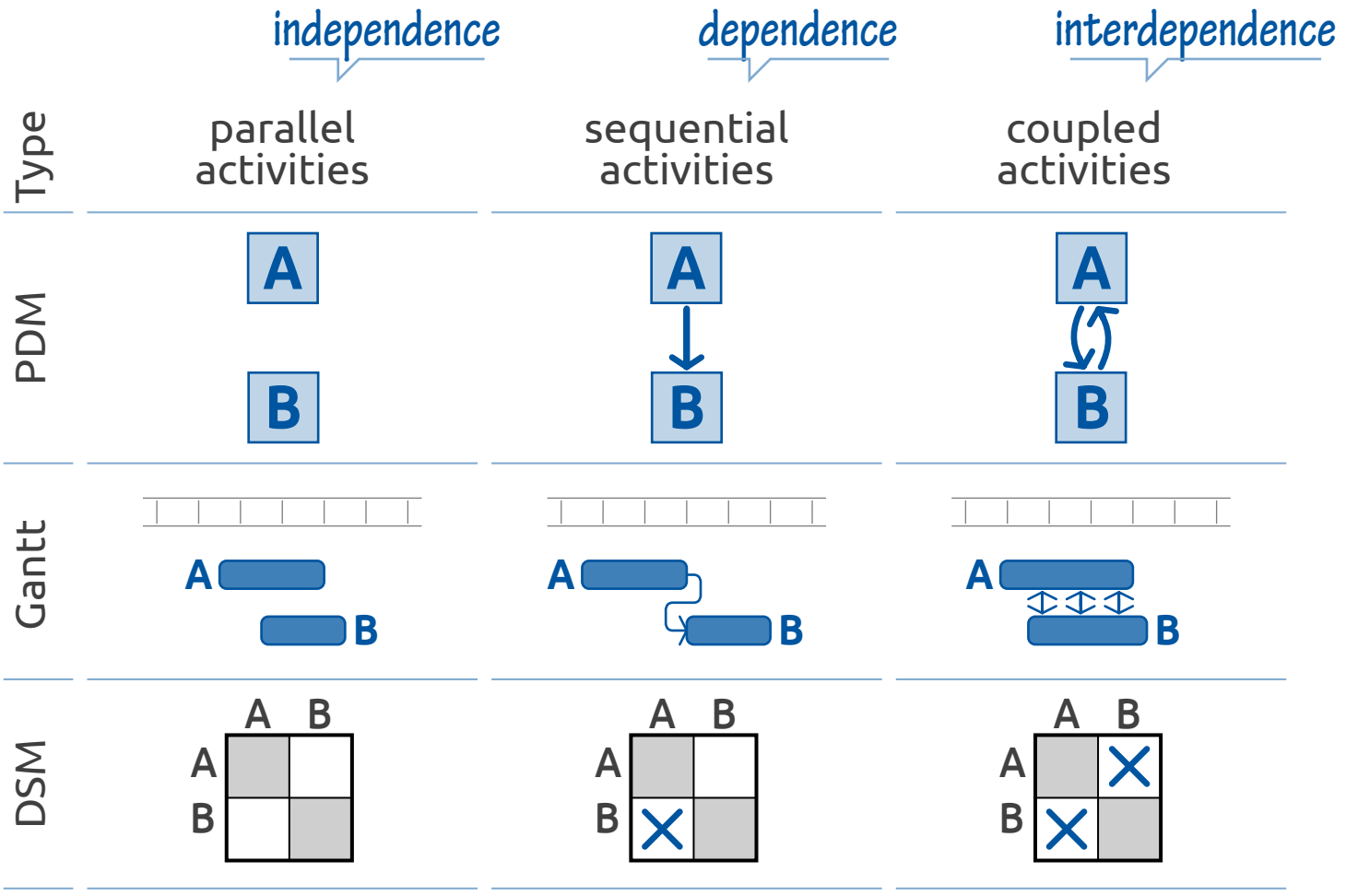
*List of activities (**LoA**) + duration estimates* [weeks] *+ predecessors*

α ← project start node		
PM	α	LoE
PMF	α	1
DDP	sPMF	5
TSP	PMF	2
TDP	TSP	1
ITP	DDP, TDP	0
POP	ITP fs+3 wks	1
IDP	POP	1.5
IPP	IDP	2
CPP	IPP	2
Tk1	POP fs+4 wks, IPP, POT fs+6 wks	0.5
Tk2	POP fs+4 wks, IPP, POT fs+6 wks	0.5
Tk3	POP fs+4 wks, IPP, POT fs+6 wks	0.5
Tub	Tk1, Tk2, Tk3	2
Blw	Tub	1
Ctrl	Blw, Lab	1
Lab	POP fs+4 wks, IPP, Elec, Furn ff+1 wk	2
PSW	POP	4
TSW	PSW	2
DDL	POP, POE, POF	2
TSE	TSP	1
TDE	TSE	1
ITE	DDP, TDE	0
POE	ITE fs+3 wks	0.5
Elec	DDL, POE fs+3 wks	2
TSF	TSP	0.5
TDF	TSF	0.5
ITF	DDP, TDF	0
POF	ITF fs+4 wks	0.5
Furn	Elec, POF fs+3 wks	1
TDT	TSP	0.5
ITT	TDP	0
POT	ITT fs+3 wks	0.5
Com	Ctrl, TSW, CPP	1
ω	PM, Com	

ω ← project finish node


PM
PSW
TSW
TSP
TDP
ITP
fs
3 wks
POP
IDP
IPP
CPP
α
PMF
fs 4 wks
Tk1
fs
6 wks
DDP
TDT
ITT
fs
3 wks
POT
fs
6 wks
fs 4 wks
Tk2
Tub
Blw
fs 4 wks
Tk3
fs
6 wks
fs 4 wks
Lab
Ctrl
Com
ω
TSE
TDE
ITE
fs
3 wks
POE
DDL
Elec
ff
1 wk
fs
3 wks
TSF
TDF
ITF
fs
4 wks
POF
fs
3 wks
Furn

Design Structure Matrix



2.5

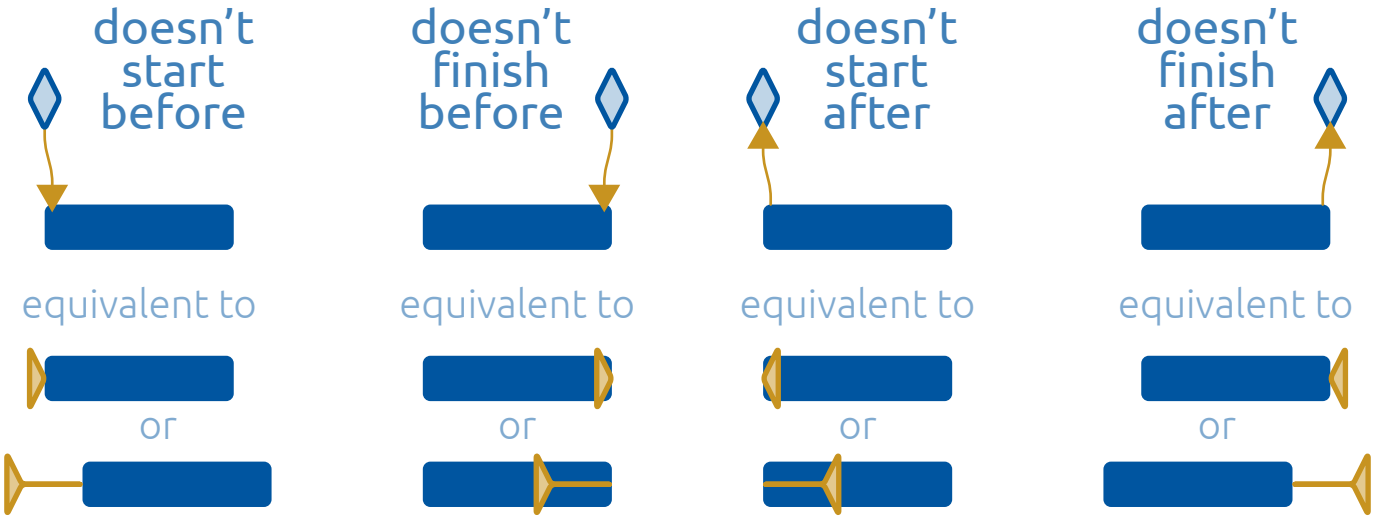
also referred to as
Time Constraints

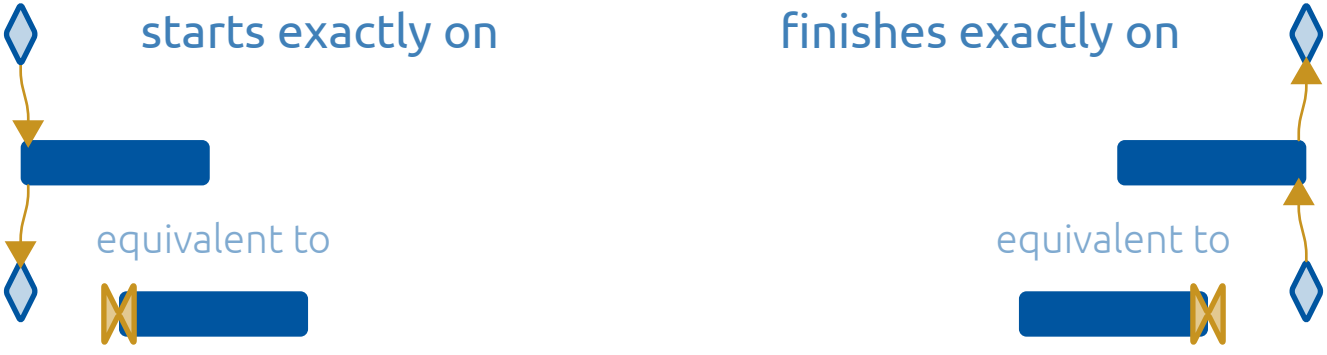
Temporal Constraints + Calendars

3.4

PDM Scheduling

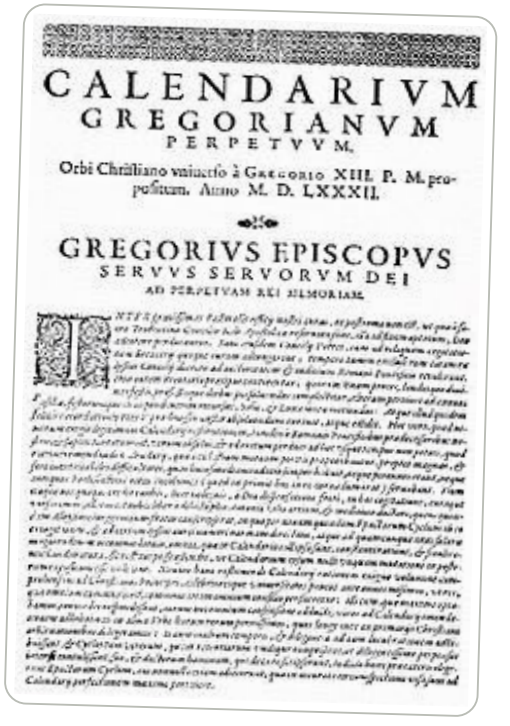
Six possible temporal constraints





Calendars

The Gregorian Calendar
and the calendar handling issue


CALENDARIVM
GREGORIANVM
PERPETVVM.
Orbi Christiano vniuerso à Gregorio XIII. P. M. propositum. Anno M. D. LXXXII.
GREGORIVS EPISCOPVS
SERVVS SERVORVM DEI
AD PERPETUAM REI MEMORIAM.

- one year = 12 months, 365 or 366 days,
  ca. 52 weeks

  every 4.09 years
  in average
- one month = from 28 to 31 days,
  slightly more than four weeks
- one week = seven days, but five working days
- one day = 24 hours, but 7 or 8 working hours
- one hour = 60 minutes and one minute = 60 seconds

ISO 8601:2004 *Representation of dates and times* ⇢ `YYYY-MM-DDTHH:MM:SS`

2.6

Precedence Diagramming Method

PDM Scheduling

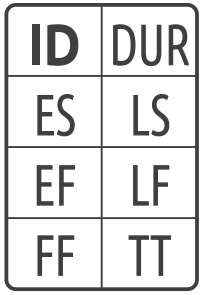
3.5

PDM Scheduling

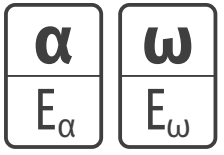
- A given **set of activities**: $A = \{ a_1, a_2, \ldots, a_n \}$
- For each activity, a **duration** is estimated: $a_i \rightarrow DUR_i$
- Some activities are interdependent by means of **technical constraints**
- **Earliest start** (ES_i) and **earliest finish** (EF_i) dates
- **Latest start** (LS_i) and **latest finish** (LF_i) dates
- **Total float** (TF_i), **free floats** (FF_i) and **critical path**(**s**)
- While minimizing the project duration

PDM Scheduling

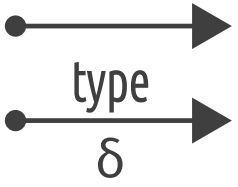
"a PDM convention"



ID	Activity ID
DUR_{ID}	Estimated duration
ES_{ID}	Earliest start date
EF_{ID}	Earliest finish date
LS_{ID}	Latest start date
LF_{ID}	Latest finish date
FF_{ID}	Free float (slack)
TT_{ID}	Total float (slack)



α, ω	Project start and finish nodes
E_α	Project fixed start date ← given!
E_ω (L_ω)	Project earliest finish date



Technical constraint: default type = finish–start

Technical constraint: type (**fs**, **ff**, **ss**, **sf**) and lag δ

PDM Scheduling

Calculations in three steps

1. Calculation of the **earliest dates** by propagation (**forward pass**) from left to right
2. Calculation of the **latest dates** by propagation (**backward pass**) from right to left
3. Calculation of the **total floats** and **free floats**

The CPM algorithm

$\mathbf{E}_{\alpha} \leftarrow$ Project start date

Order $\{ \boldsymbol{a}_j \}$ so that $\boldsymbol{a}_i \prec \boldsymbol{a}_k \; \forall \; \boldsymbol{i} < \boldsymbol{k}$

For $\boldsymbol{j} = 1$ to $| \{ \boldsymbol{a}_j \} |$ repeat:

$$\mathbf{ES}_j \leftarrow \begin{cases} \mathbf{E}_{\alpha} \text{ if } \Gamma_j^{-1} = \emptyset \\ \max_{\boldsymbol{k} \in \Gamma_j^{-1}} \{ \mathbf{ES}_k + \mathbf{DUR}_k \} \text{ otherwise} \end{cases}$$

$\mathbf{L}_{\omega} \leftarrow \mathbf{E}_{\omega}$

For $\boldsymbol{j} = | \{ \boldsymbol{a}_j \} |$ to 1 repeat:

$$\mathbf{LF}_j \leftarrow \begin{cases} \mathbf{L}_{\omega} \text{ if } \Gamma_j = \emptyset \\ \min_{\boldsymbol{k} \in \Gamma_j} \{ \mathbf{LF}_k - \mathbf{DUR}_k \} \text{ otherwise} \end{cases}$$

$\mathbf{TF}_j \leftarrow \mathbf{LF}_j - \mathbf{EF}_j$

$\mathbf{FF}_j \leftarrow \min_{\boldsymbol{k} \in \Gamma_j} \{ \mathbf{ES}_k \} - \mathbf{EF}_j$

PDM Scheduling

The real PDM algorithm!

$\mathbf{E}_{\alpha} \leftarrow$ Project start date

Order $\{ \boldsymbol{a}_j \}$ so that $\boldsymbol{a}_i \prec \boldsymbol{a}_k \; \forall \; \boldsymbol{i} < \boldsymbol{k}$

For $\boldsymbol{j} = 1$ to $| \{ \boldsymbol{a}_j \} |$ repeat:

$$\mathbf{ES}_j \leftarrow \begin{cases} \mathbf{E}_{\alpha} \text{ if } \Gamma_j^{-1} = \emptyset \\ \max_{\boldsymbol{k} \in \Gamma_j^{-1}} \{ \; \text{✹} \; \} \text{ otherwise} \end{cases}$$

$\mathbf{ES}_k + \mathbf{DUR}_k + \mathbf{LAG}_{kj}$ if $\sigma_{kj} =$ "FS"

$\mathbf{ES}_k + \mathbf{LAG}_{kj}$ if $\sigma_{kj} =$ "SS"

$\mathbf{ES}_k - \mathbf{DUR}_j + \mathbf{LAG}_{kj}$ if $\sigma_{kj} =$ "SF"

$\mathbf{ES}_k + \mathbf{DUR}_k - \mathbf{DUR}_j + \mathbf{LAG}_{kj}$ if $\sigma_{kj} =$ "FF"

$\mathbf{L}_{\omega} \leftarrow \mathbf{E}_{\omega}$

For $\boldsymbol{j} =$ $| \{ \boldsymbol{a}_j \} |$ to 1 repeat:

$$\mathbf{LF}_j \leftarrow \begin{cases} \mathbf{L}_{\omega} \text{ if } \Gamma_j = \emptyset \\ \min_{\boldsymbol{k} \in \Gamma_j} \{ \; \text{✹} \; \} \text{ otherwise} \end{cases}$$

$\mathbf{LF}_k - \mathbf{DUR}_k - \mathbf{LAG}_{kj}$ if $\sigma_{jk} =$ "FS"

$\mathbf{LF}_k - \mathbf{DUR}_k + \mathbf{DUR}_j - \mathbf{LAG}_{kj}$ if $\sigma_{jk} =$ "SS"

$\mathbf{LF}_k + \mathbf{DUR}_j - \mathbf{LAG}_{kj}$ if $\sigma_{jk} =$ "SF"

$\mathbf{LF}_k - \mathbf{LAG}_{kj}$ if $\sigma_{jk} =$ "FF"

$\mathbf{TF}_j \leftarrow \mathbf{LF}_j - \mathbf{EF}_j$

$\mathbf{FF}_j \leftarrow \min_{\boldsymbol{k} \in \Gamma_j} \{ \mathbf{ES}_k \} - \mathbf{EF}_j$

PDM Scheduling

Floats and Critical Path(s)

- So called **total floats**, **free floats** and **critical paths** are obtained from PDM calculations

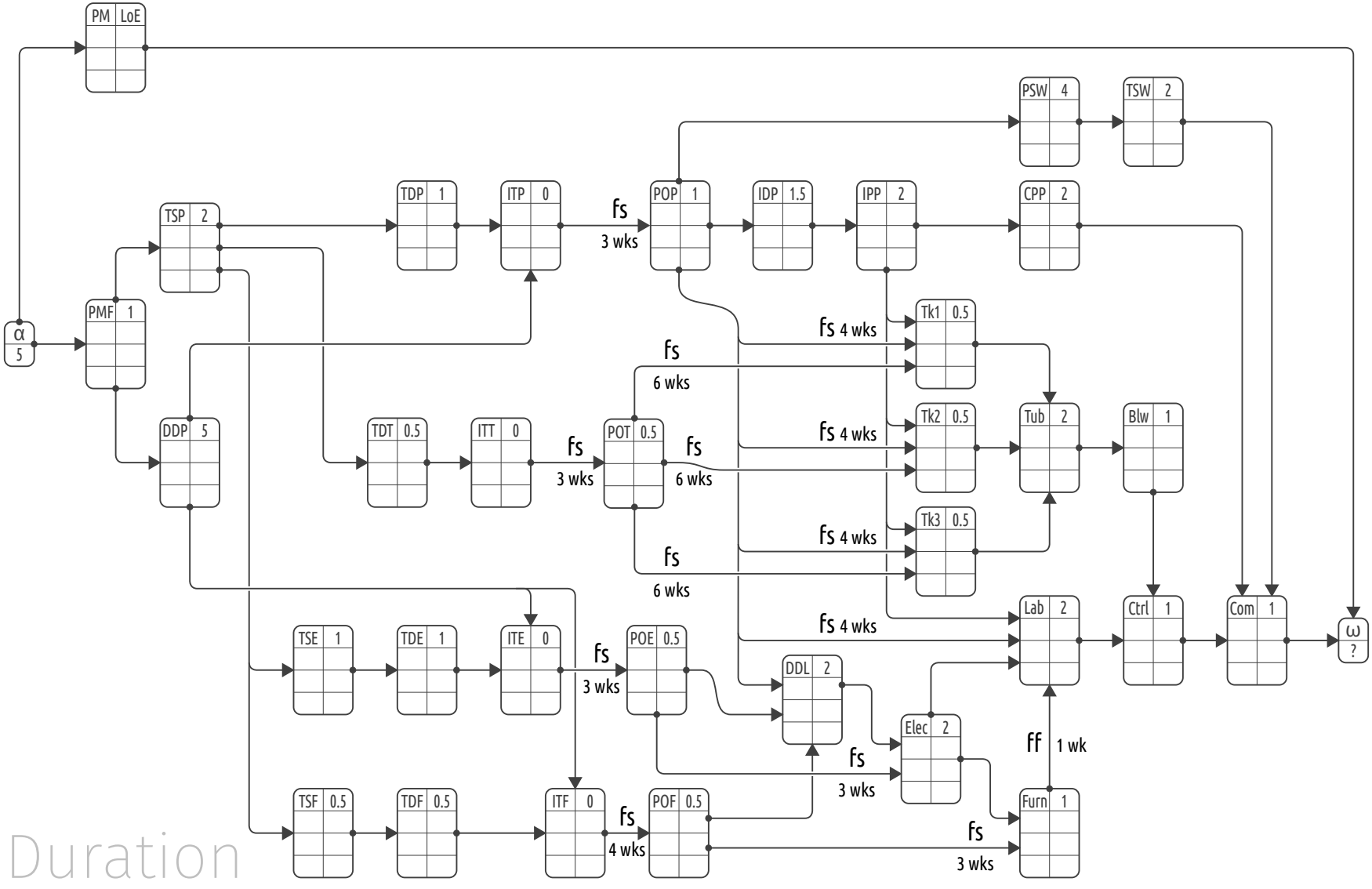
- Free slack in Microsoft Project
- **Free float** = the amount of time that an activity can be delayed from its earliest start date without causing a delay to **the earliest dates of subsequent activities**

- Total slack in Microsoft Project
- **Total float** = the amount of time that an activity can be delayed from its early start date without causing a delay to **the project finish date**

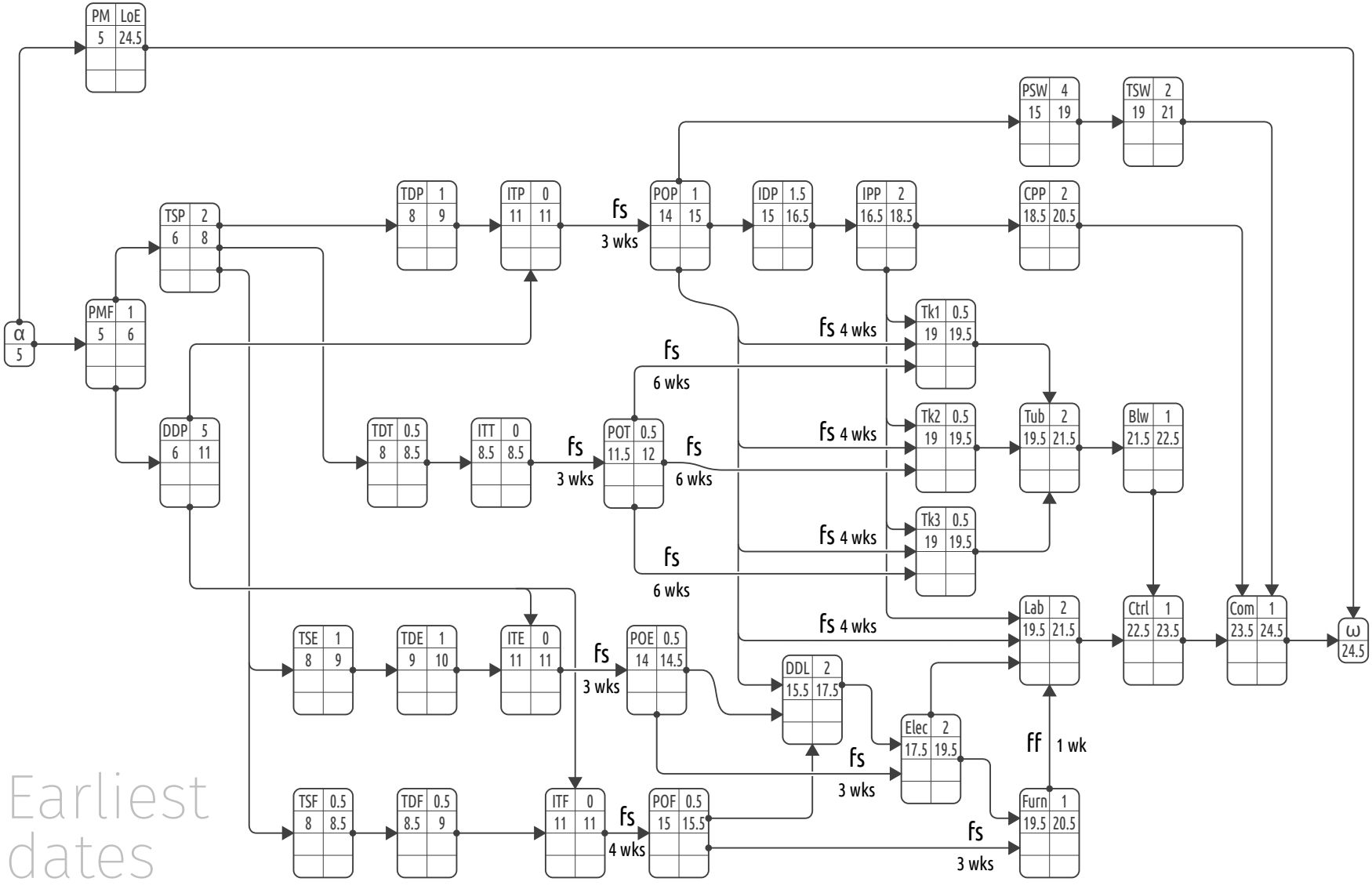
- If $TF_{ID} = 0$ then necessarily $FF_{ID} = 0$!

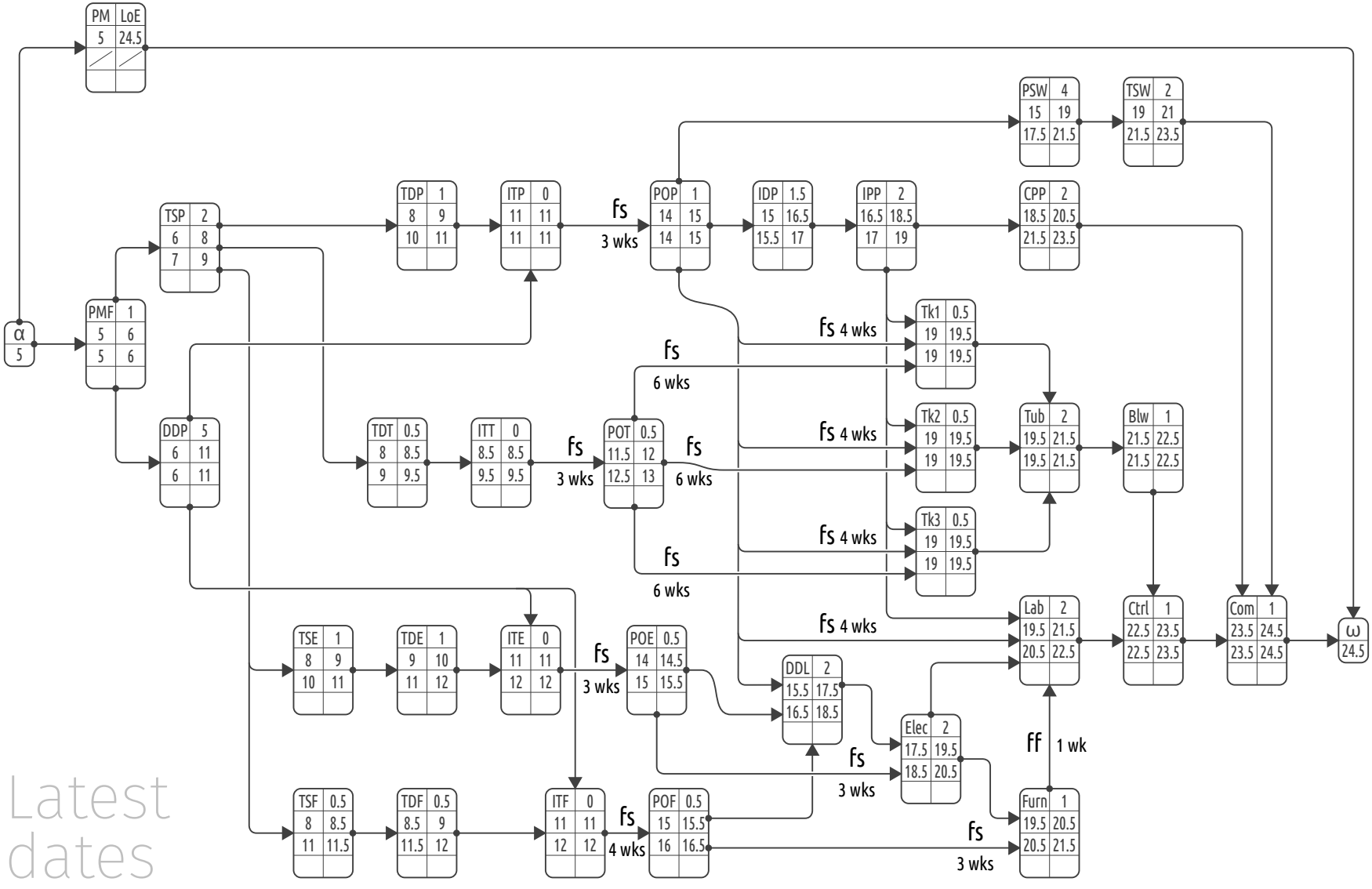
- **Critical path** = the sequence of activities which add up to the **longest overall duration**, i.e. which makes the project duration

- **Critical activity** = an activity that belongs to a critical path ($TF_{ID} = 0$)

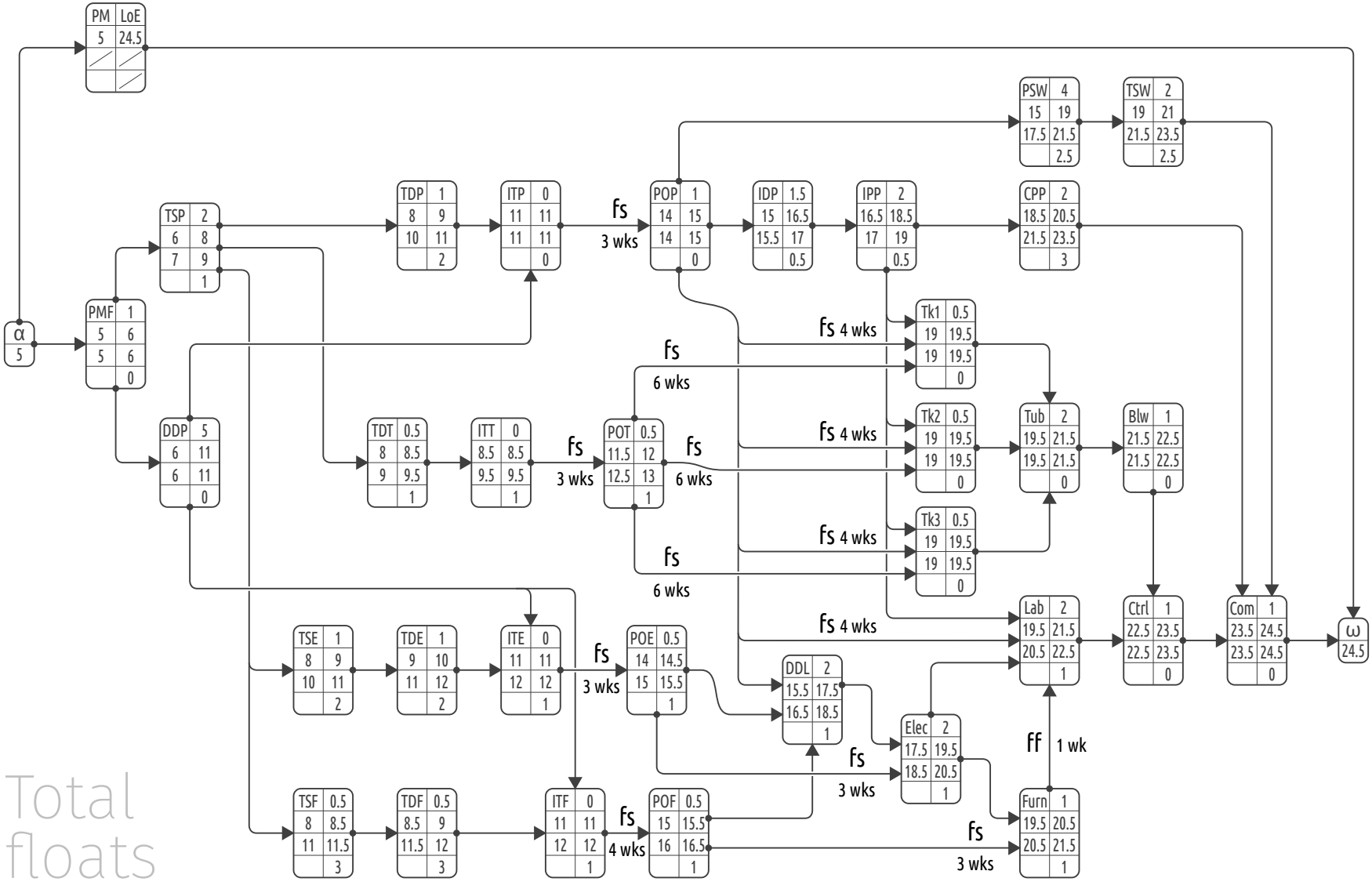

PM LoE
α 5
PMF 1
TSP 2
DDP 5
TDP 1
ITP 0
TDT 0.5
ITT 0
TSE 1
TDE 1
ITE 0
TSF 0.5
TDF 0.5
ITF 0
fs 3 wks
POP 1
POT 0.5
POE 0.5
POF 0.5
fs 6 wks
fs 4 wks
IDP 1.5
IPP 2
PSW 4
TSW 2
CPP 2
Tk1 0.5
Tk2 0.5
Tk3 0.5
Tub 2
Blw 1
Lab 2
Ctrl 1
Com 1
ω ?
DDL 2
Elec 2
Furn 1
ff 1 wk

Duration

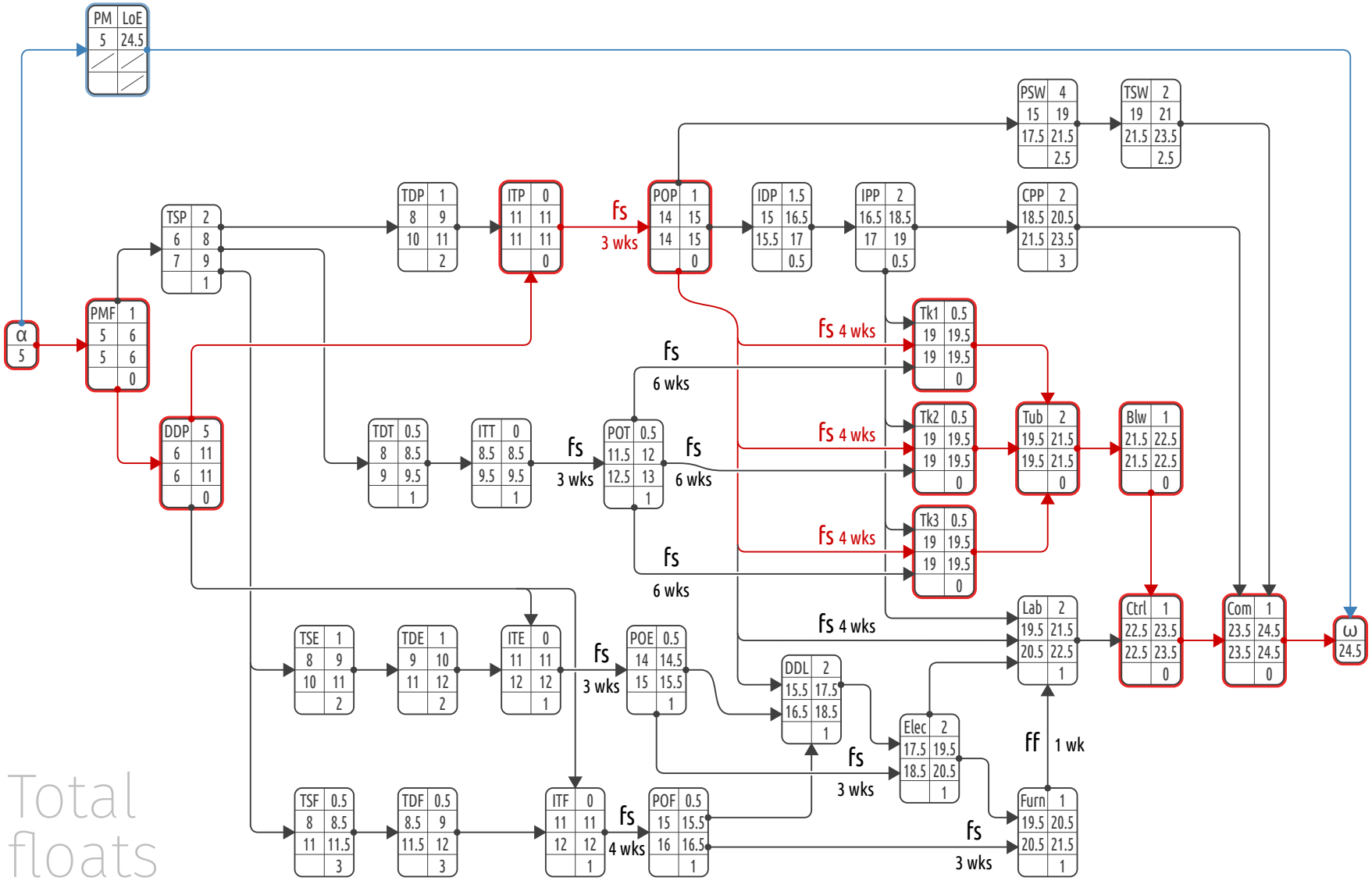

PM 5 LoE 24.5
α 5
PMF 5 1 6
TSP 6 2 8
DDP 6 5 11
TDP 8 1 9
ITP 11 0 11
TDT 8 0.5 8.5
ITT 8.5 0 8.5
TSE 8 1 9
TDE 9 1 10
ITE 11 0 11
TSF 8 0.5 8.5
TDF 8.5 0.5 9
ITF 11 0 11
POP 14 1 15
POT 11.5 0.5 12
POE 14 0.5 14.5
POF 15 0.5 15.5
IDP 15 1.5 16.5
IPP 16.5 2 18.5
PSW 15 4 19
TSW 19 2 21
CPP 18.5 2 20.5
Tk1 19 0.5 19.5
Tk2 19 0.5 19.5
Tk3 19 0.5 19.5
Tub 19.5 2 21.5
Blw 21.5 1 22.5
DDL 15.5 2 17.5
Elec 17.5 2 19.5
Lab 19.5 2 21.5
Ctrl 22.5 1 23.5
Furn 19.5 1 20.5
Com 23.5 1 24.5
ω 24.5
fs 3 wks
fs 6 wks
fs 4 wks
ff 1 wk
Earliest dates



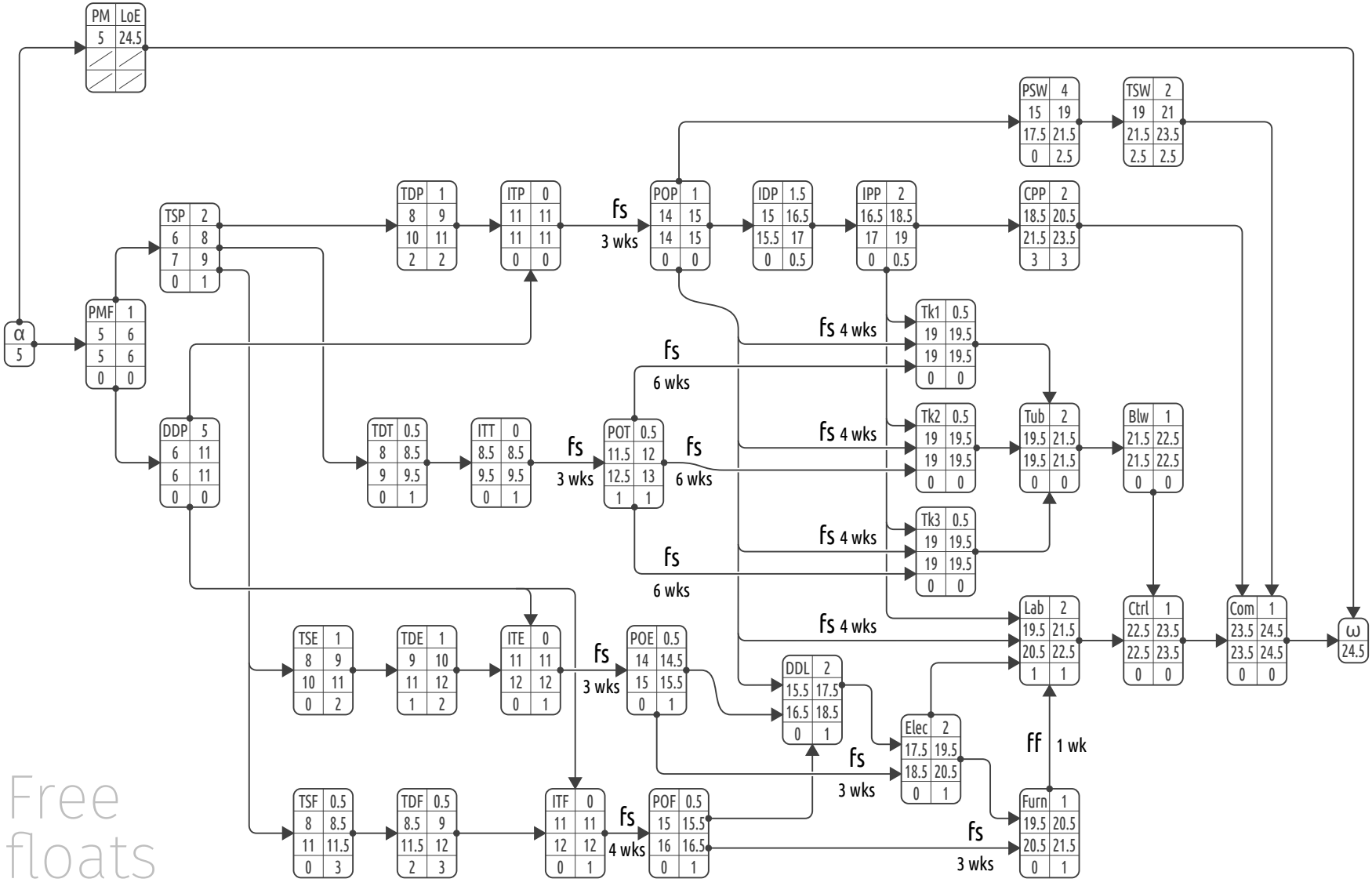
Latest dates



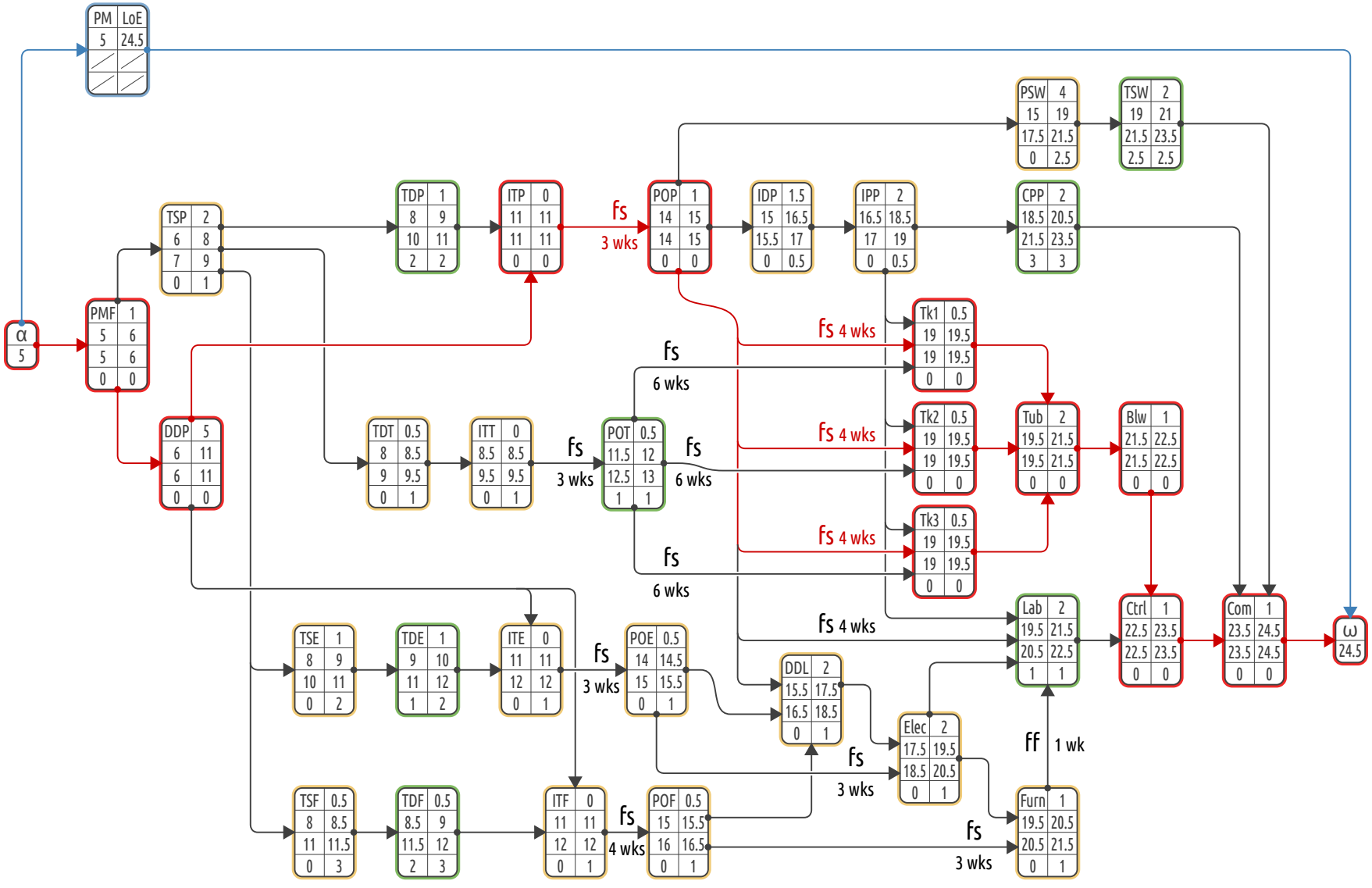
Total floats

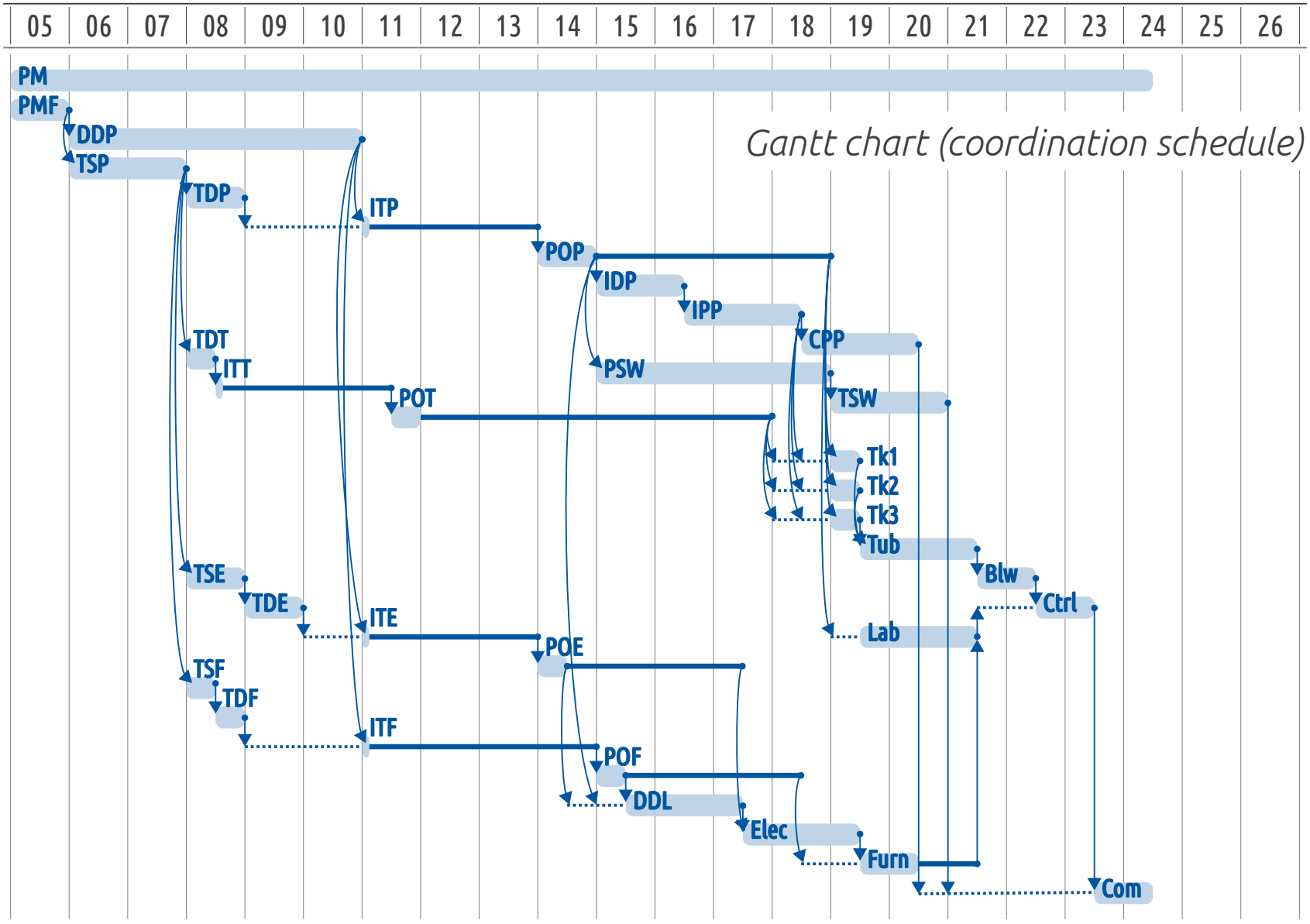


Total floats

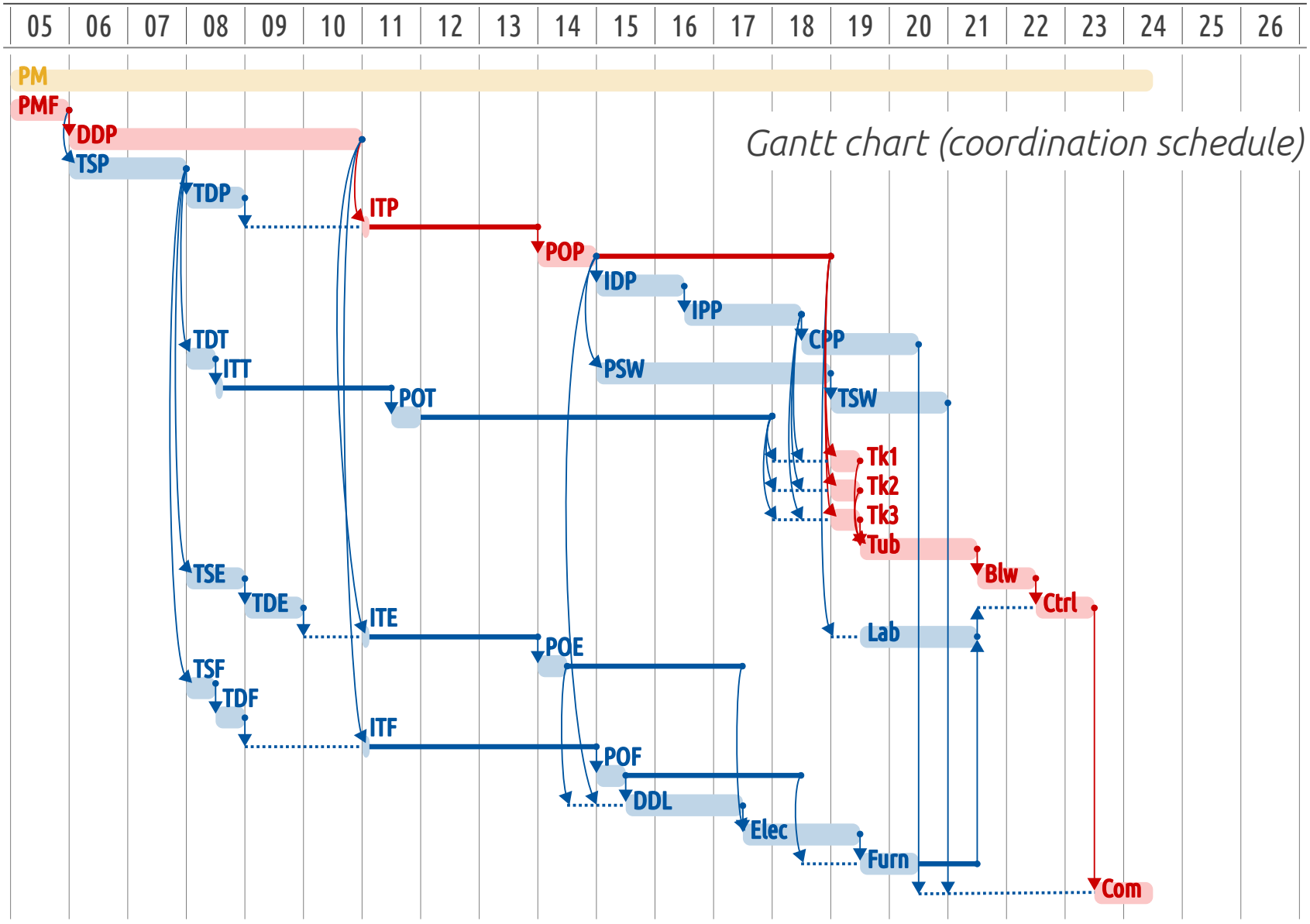

PM LoE 5 24.5
α 5
PMF 1 5 6 5 6 0 0
TSP 2 6 8 7 9 0 1
DDP 5 6 11 6 11 0 0
TDP 1 8 9 10 11 2 2
ITP 0 11 11 11 11 0 0
TDT 0.5 8 8.5 9 9.5 0 1
ITT 0 8.5 8.5 9.5 9.5 0 1
TSE 1 8 9 10 11 0 2
TDE 1 9 10 11 12 1 2
ITE 0 11 11 12 12 0 1
TSF 0.5 8 8.5 11 11.5 0 3
TDF 0.5 8.5 9 11.5 12 2 3
ITF 0 11 11 12 12 0 1
POP 1 14 15 14 15 0 0
POT 0.5 11.5 12 12.5 13 1 1
POE 0.5 14 14.5 15 15.5 0 1
POF 0.5 15 15.5 16 16.5 0 1
IDP 1.5 15 16.5 15.5 17 0 0.5
IPP 2 16.5 18.5 17 19 0 0.5
PSW 4 15 19 17.5 21.5 0 2.5
TSW 2 19 21 21.5 23.5 2.5 2.5
CPP 2 18.5 20.5 21.5 23.5 3 3
Tk1 0.5 19 19.5 19 19.5 0 0
Tk2 0.5 19 19.5 19 19.5 0 0
Tk3 0.5 19 19.5 19 19.5 0 0
Tub 2 19.5 21.5 19.5 21.5 0 0
Blw 1 21.5 22.5 21.5 22.5 0 0
DDL 2 15.5 17.5 16.5 18.5 0 1
Elec 2 17.5 19.5 18.5 20.5 0 1
Lab 2 19.5 21.5 20.5 22.5 1 1
Ctrl 1 22.5 23.5 22.5 23.5 0 0
Com 1 23.5 24.5 23.5 24.5 0 0
Furn 1 19.5 20.5 20.5 21.5 0 1
ω 24.5
fs 3 wks
fs 6 wks
fs 4 wks
ff 1 wk
fs 4 wks

Free floats


PM LoE 5 24.5
α 5
PMF 1 5 6 5 6 0 0
TSP 2 6 8 7 9 0 1
DDP 5 6 11 6 11 0 0
TDP 1 8 9 10 11 2 2
ITP 0 11 11 11 11 0 0
fs 3 wks
POP 1 14 15 14 15 0 0
IDP 1.5 15 16.5 15.5 17 0 0.5
IPP 2 16.5 18.5 17 19 0 0.5
PSW 4 15 19 17.5 21.5 0 2.5
TSW 2 19 21 21.5 23.5 2.5 2.5
CPP 2 18.5 20.5 21.5 23.5 3 3
fs 4 wks
Tk1 0.5 19 19.5 19 19.5 0 0
fs 6 wks
TDT 0.5 8 8.5 9 9.5 0 1
ITT 0 8.5 8.5 9.5 9.5 0 1
fs 3 wks
POT 0.5 11.5 12 12.5 13 1 1
fs 6 wks
Tk2 0.5 19 19.5 19 19.5 0 0
Tub 2 19.5 21.5 19.5 21.5 0 0
Blw 1 21.5 22.5 21.5 22.5 0 0
fs 4 wks
Tk3 0.5 19 19.5 19 19.5 0 0
fs 6 wks
TSE 1 8 9 10 11 0 2
TDE 1 9 10 11 12 1 2
ITE 0 11 11 12 12 0 1
fs 3 wks
POE 0.5 14 14.5 15 15.5 0 1
fs 4 wks
Lab 2 19.5 21.5 20.5 22.5 1 1
Ctrl 1 22.5 23.5 22.5 23.5 0 0
Com 1 23.5 24.5 23.5 24.5 0 0
ω 24.5
DDL 2 15.5 17.5 16.5 18.5 0 1
fs 3 wks
Elec 2 17.5 19.5 18.5 20.5 0 1
ff 1 wk
TSF 0.5 8 8.5 11 11.5 0 3
TDF 0.5 8.5 9 11.5 12 2 3
ITF 0 11 11 12 12 0 1
fs 4 wks
POF 0.5 15 15.5 16 16.5 0 1
fs 3 wks
Furn 1 19.5 20.5 20.5 21.5 0 1



Gantt chart (coordination schedule)

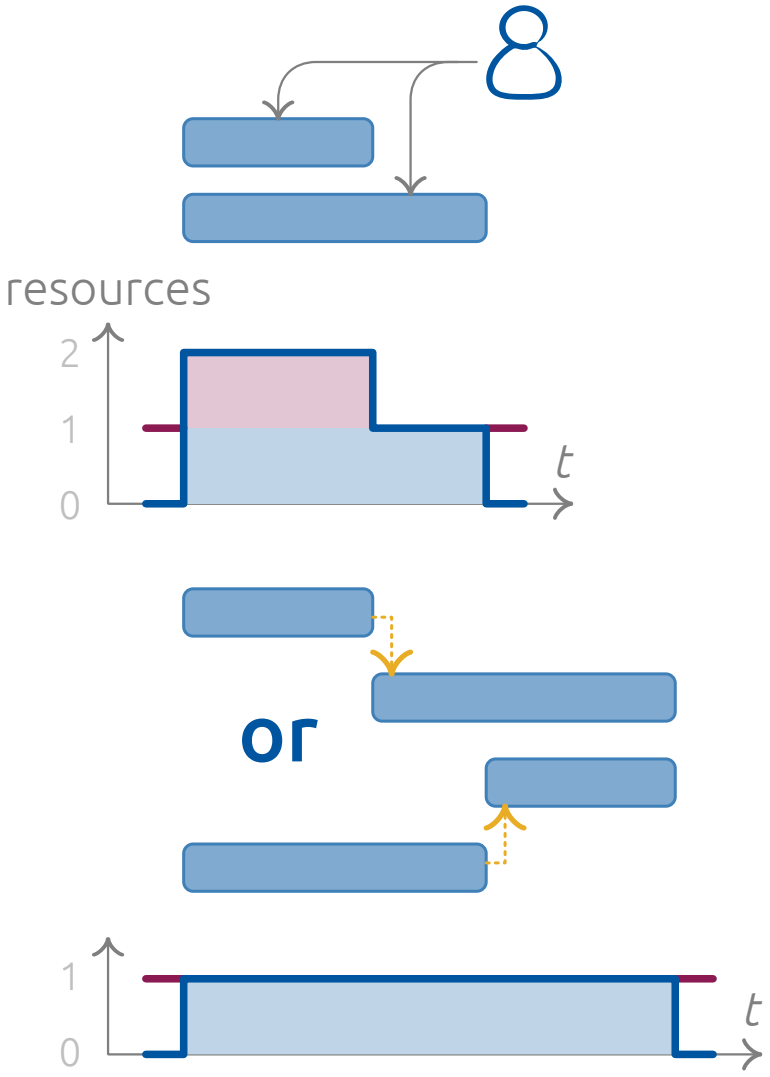


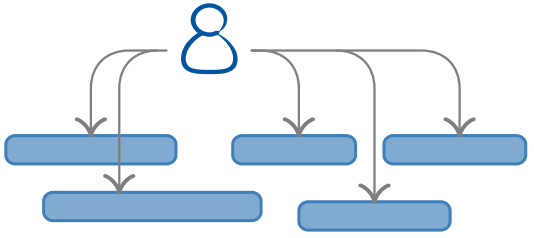
Gantt chart (coordination schedule)

2.7

Resource-Constrained Project Scheduling

Resource-Constrained Scheduling



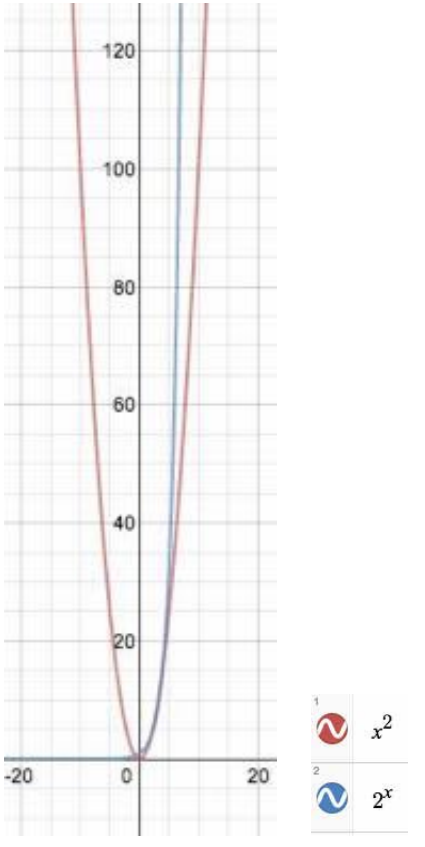


2 activities **1** resource → **2** combinations
3 activities **1** resource → **6** combinations
4 activities **1** resource → **24** combinations
5 activities **1** resource → **120** combinations
720 combinations
5040 combinations
40320 combinations
362880 combinations
3628800 combinations

Resource-Constrained Scheduling

In algorithmics, there are two types of problems:

- Those which complexity grows **polynomially** with the quantity of data to handle ⇢ $O(q) \sim q^c$
- Those which complexity grows **exponentially** with the quantity of data to handle ⇢ $O(q) \sim c^q$



- PDM algorithm ⇢ **polynomial** growth algorithm
- Exact solution for the RC-PSP ⇢ **exponential** growth algorithm
- Sufficiently good solution for the RC-PSP ⇢ **optimization heuristics**
  E.g. → priority-rule-based optimization algorithms

2.8

Resulting **Schedule Analysis**

3.7

Schedule Analysis

Three aspects to look at
prior to freeze the coord. schedule baseline

Conformity

Does the coord. schedule conform good PDM-based coord. schedule construction?

Achievability

Is the schedule really feasible? sufficient activity duration, appropriate resource assignment, schedule risk analysis, etc.

Adequacy

Does the coord. schedule fit the master schedule? What is the global float?

Schedule Analysis | Conformity

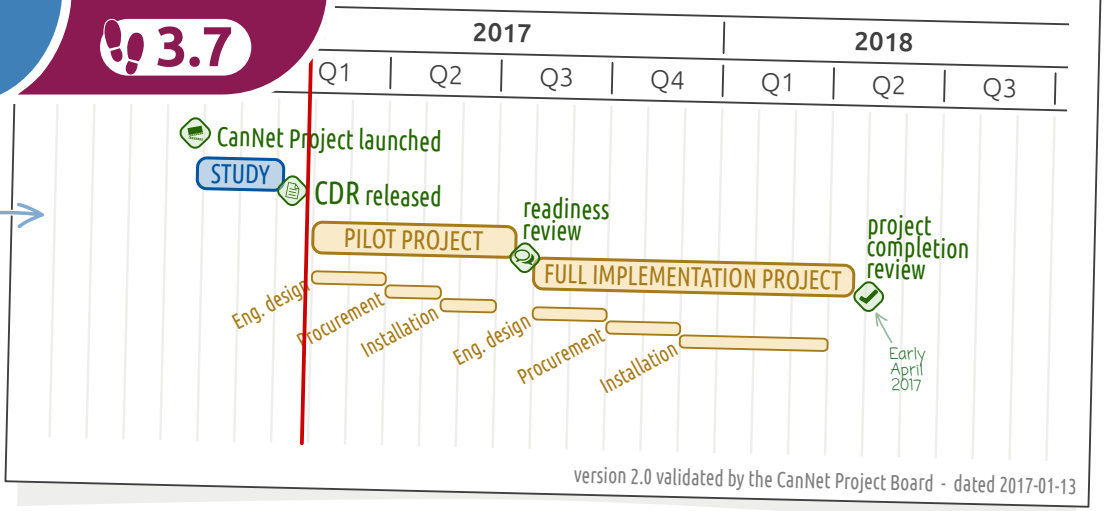
- Size ⇢ # activities < 400
- Task labelling ⇢ action verbs + substantives
- Activity duration < 10% of project duration
- Activity typology ⇢ # LoE activities < min(1 ; 1% of # activities)
- PDM logic
  - # activities with no predecessor = 0
  - # activities with no successor = 0
  - # FS constraints / # constraints > 80%

Schedule Analysis | Achievability

- General agreement w.r.t. activity duration
- General agreement w.r.t. activity sequencing
- Schedule criticity ⇢ # critical activities $< 0.3 \times$ # activities

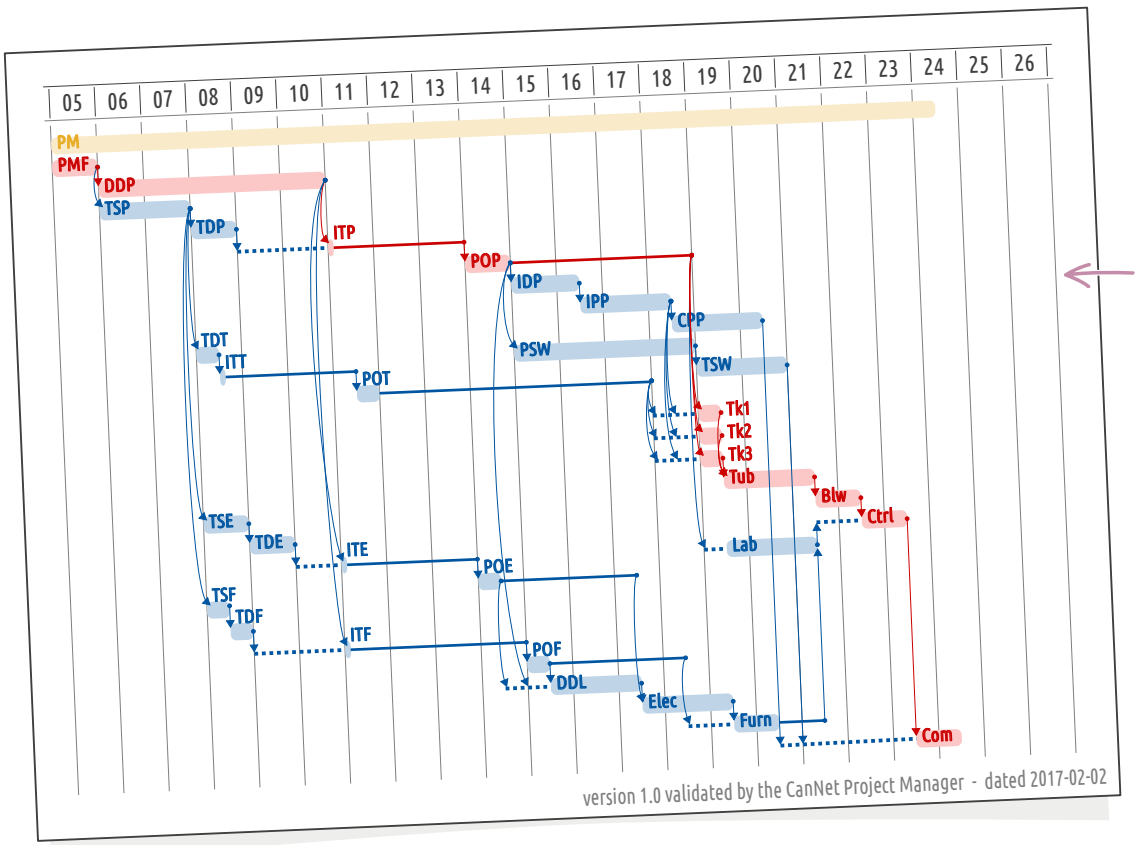
Project Master Schedule

Pilot Project makespan:
from end January (Monday of week 05)
to mid-July (Friday of week 28)

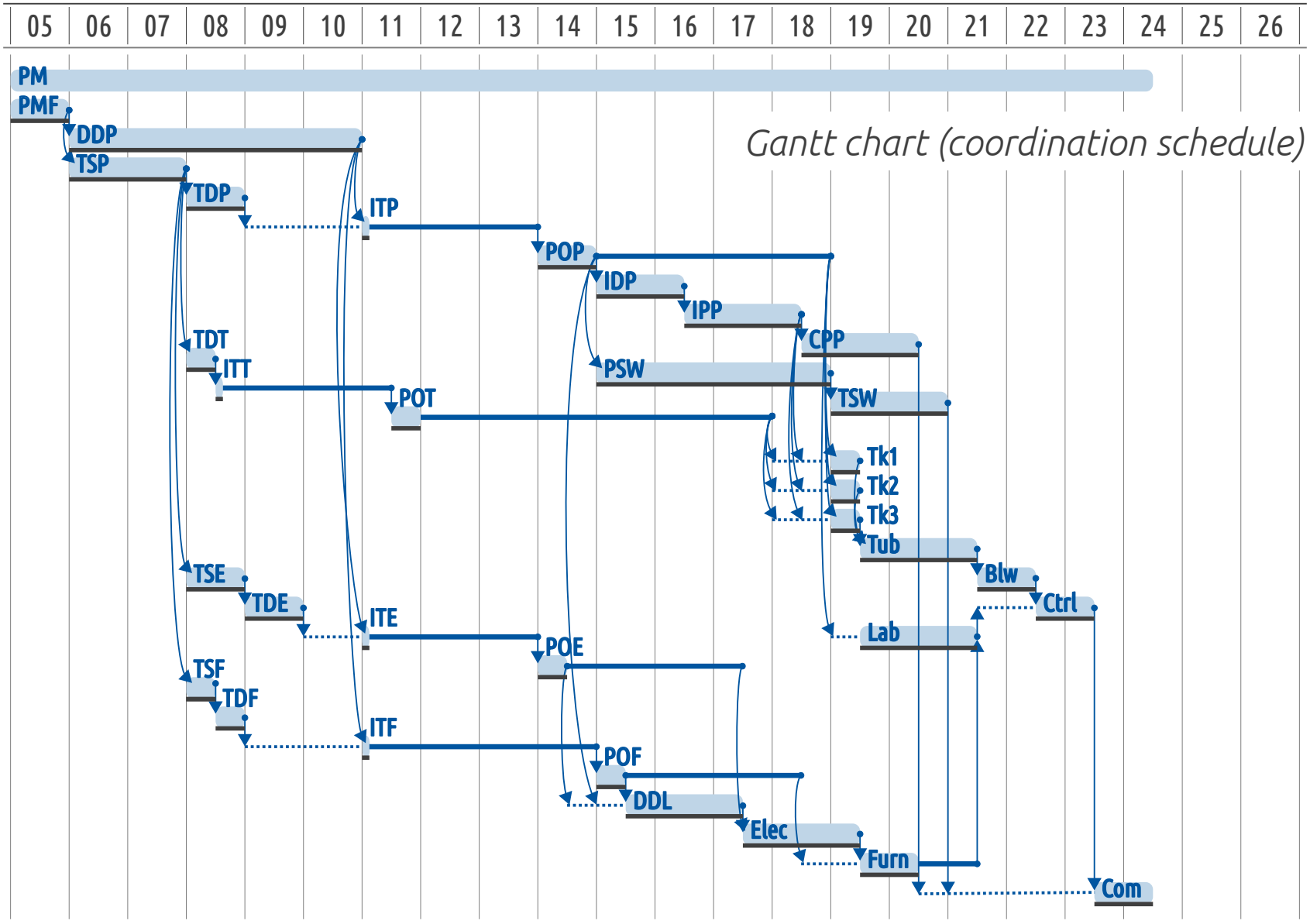


Coordination Schedule

Pilot Project makespan:
from early week 05
to mid week 24



Float = 29 - 24.5
= 4.5 wks



Gantt chart (coordination schedule)

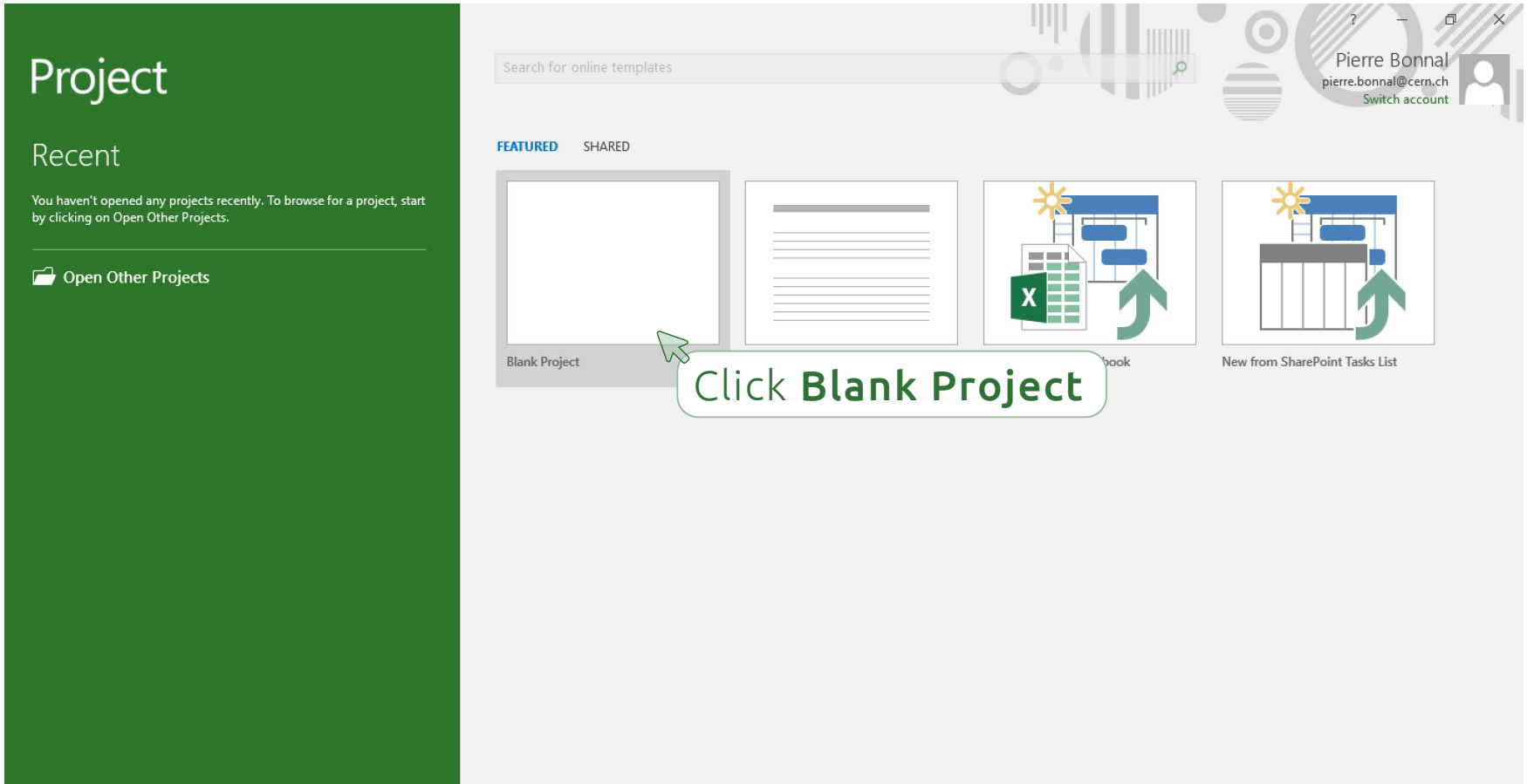
3

Scheduling the CanNet Project with Microsoft Project

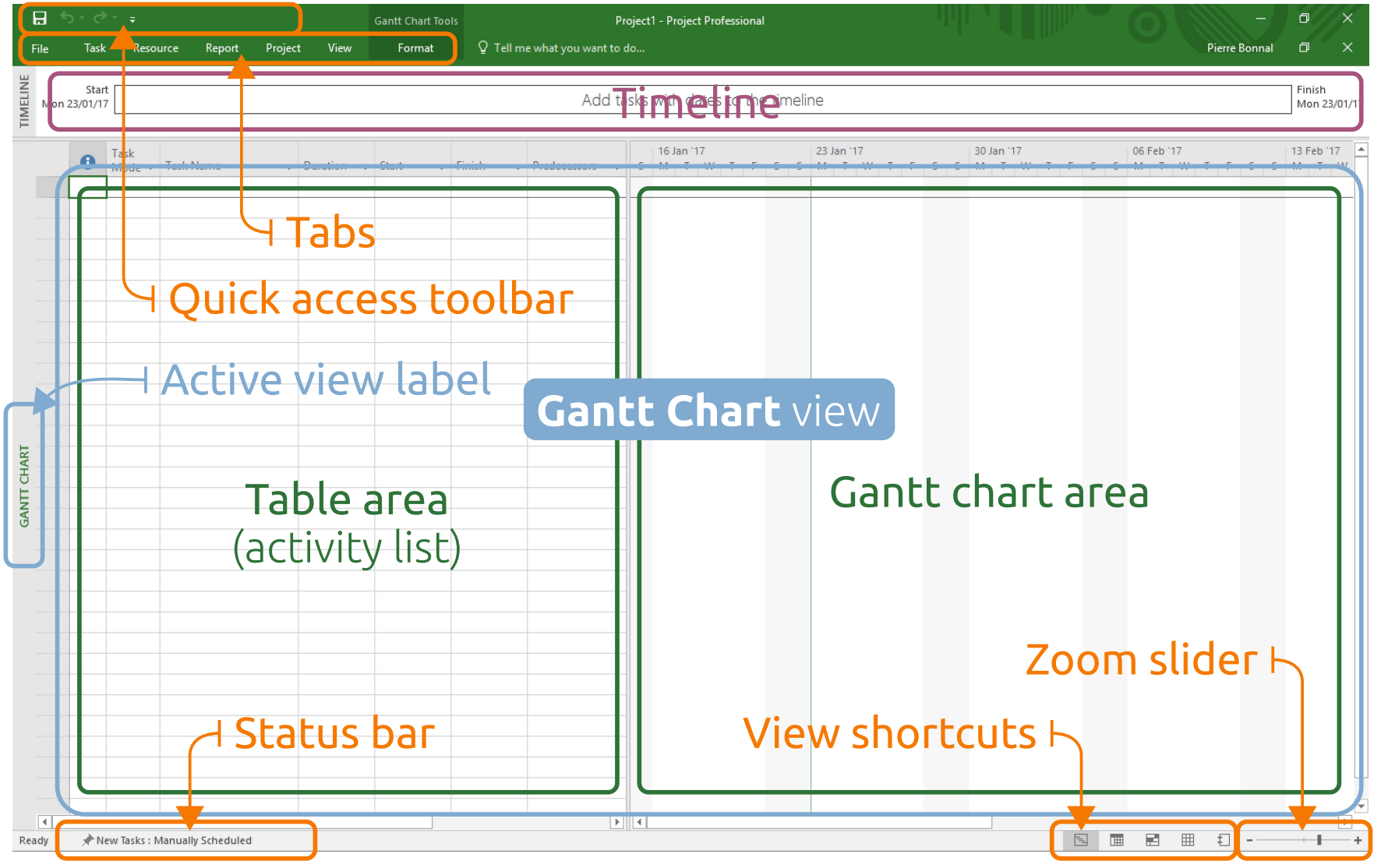
Launching the software

Windows 10 ▸ Start Menu ▸ Microsoft Office ▸ Microsoft Project

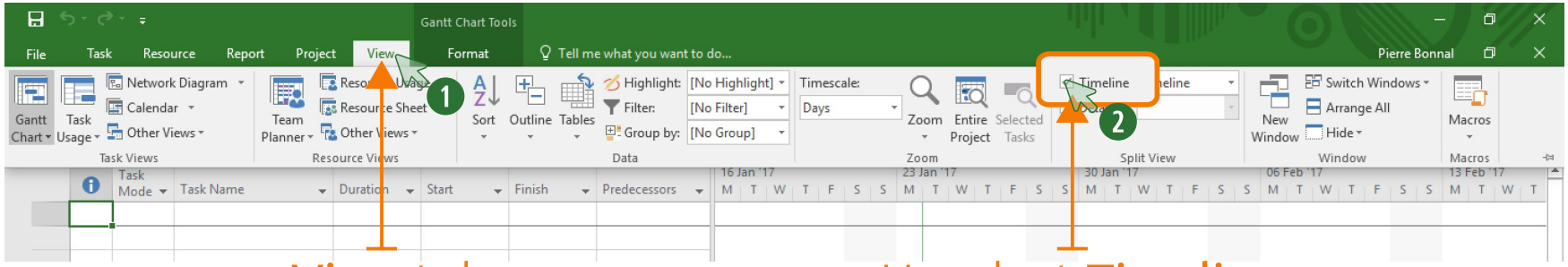
Mac OS X ▸ Launchpad ▸ Windows 10 Applications ▸ Microsoft Project

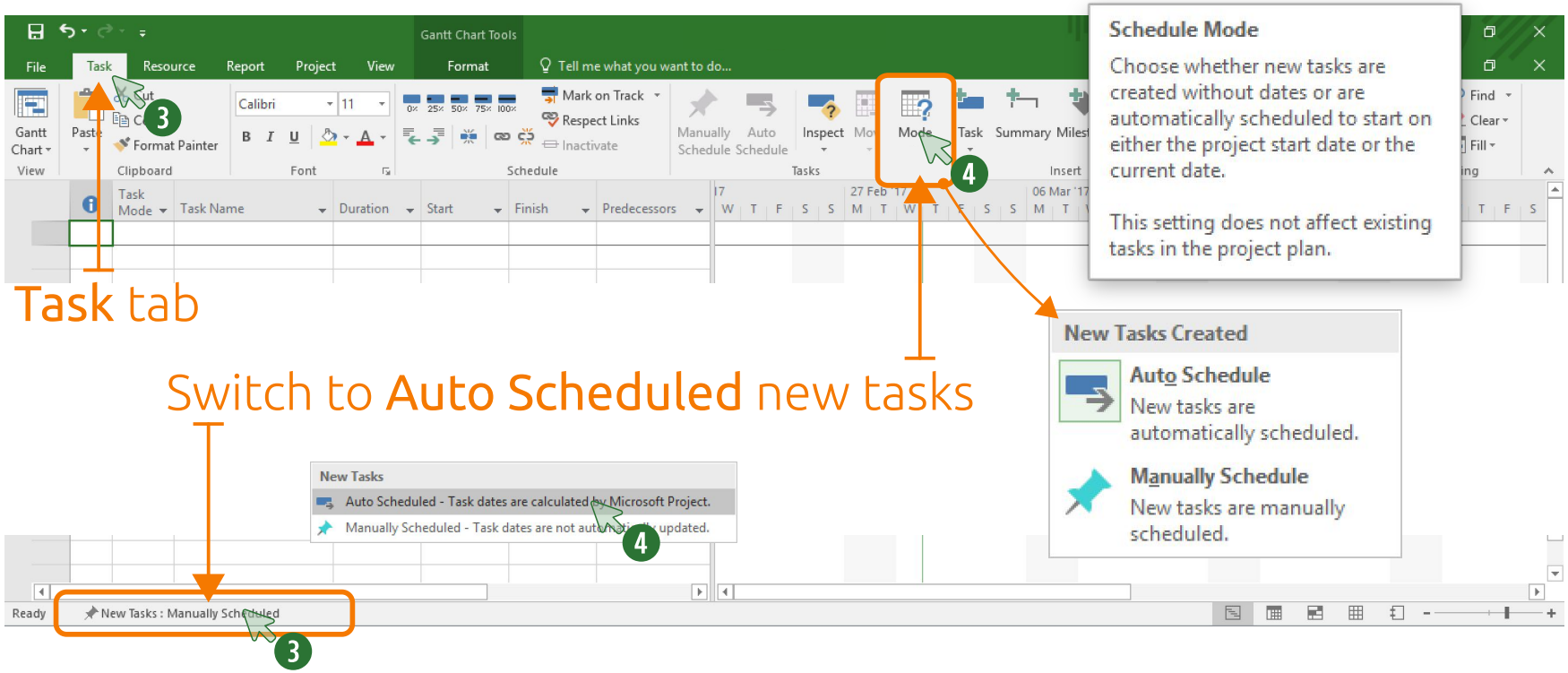


Getting familiar with Microsoft Project's interface



Setting up a *proper scheduling configuration*

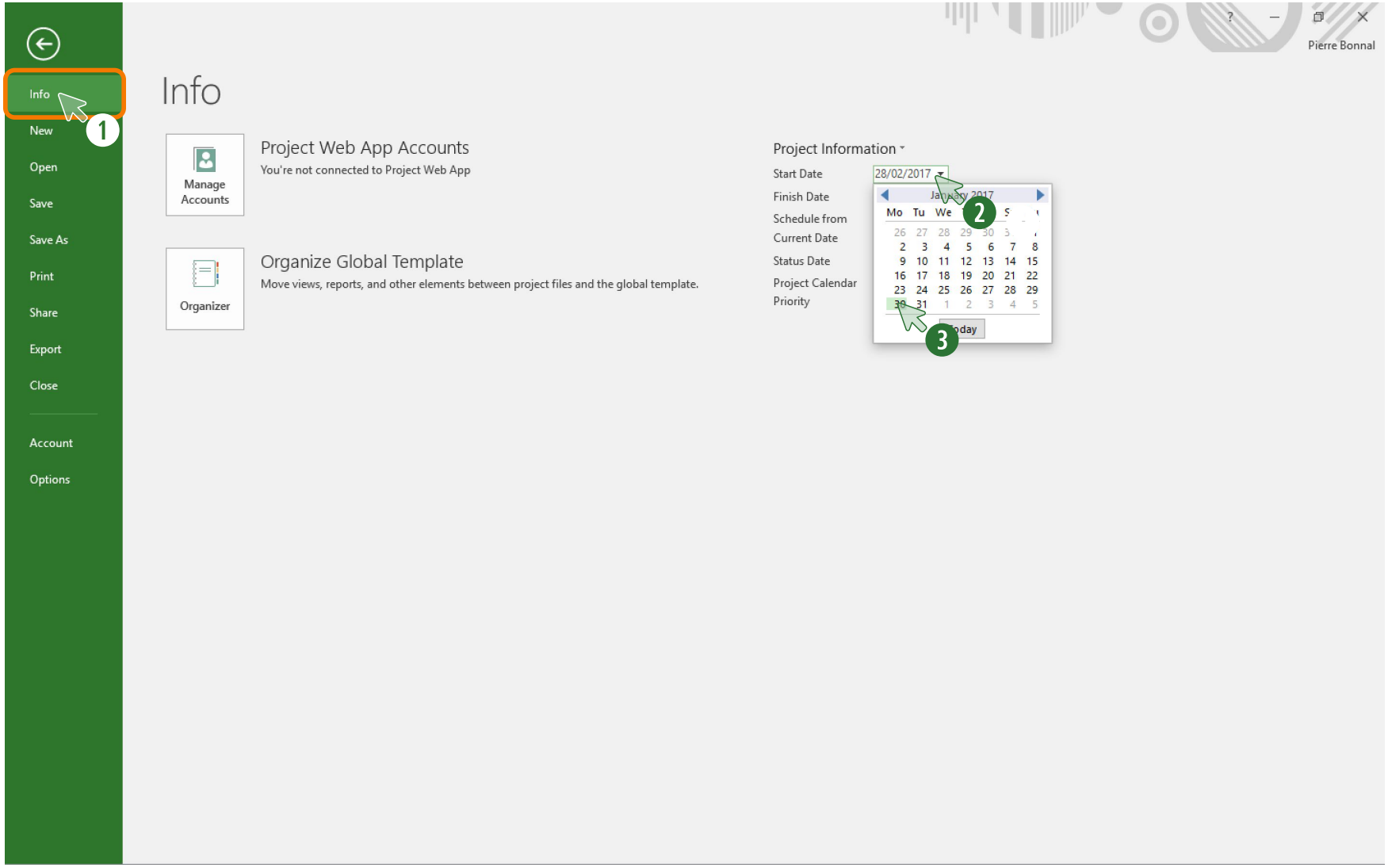




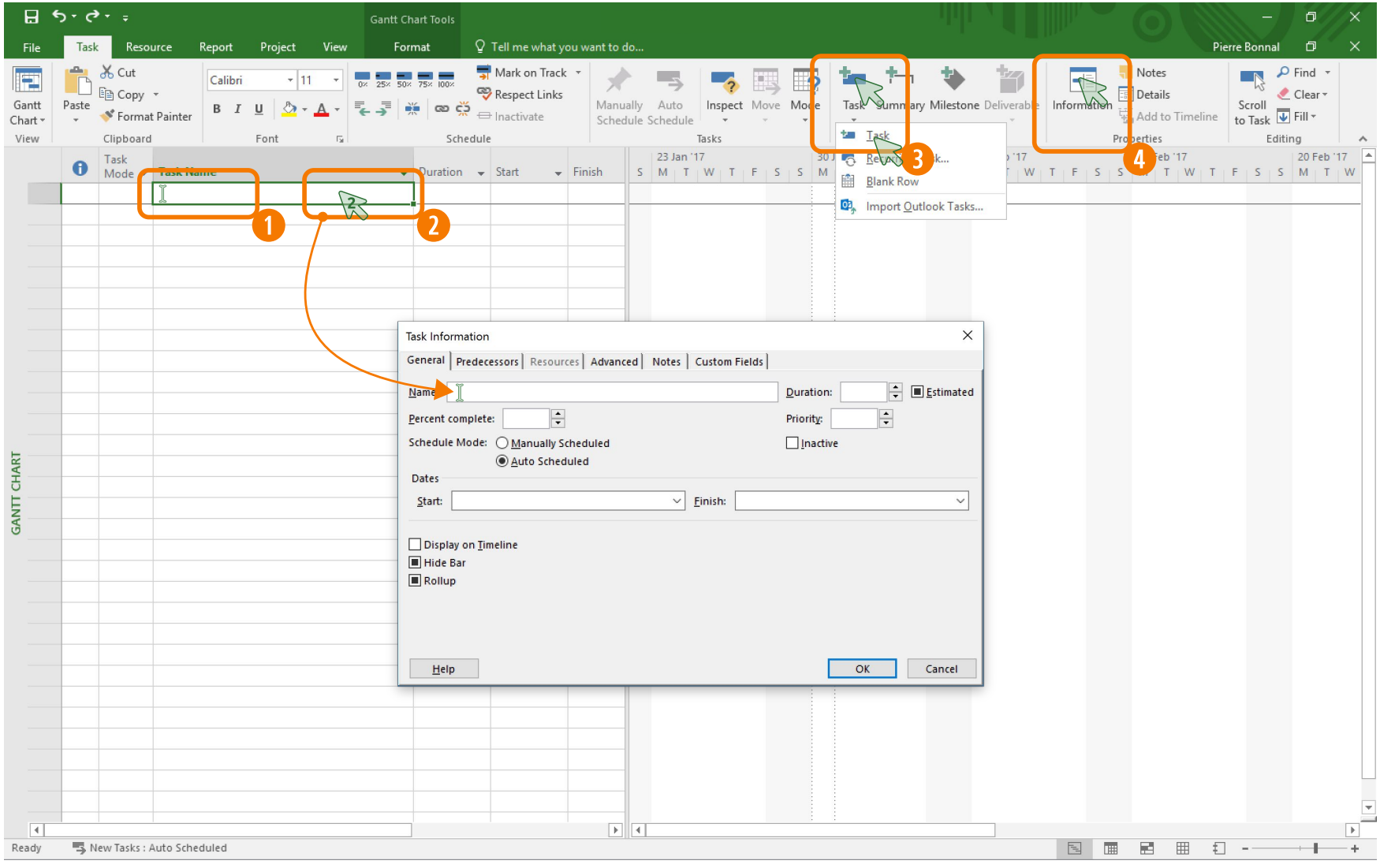
Setting the project start date

The project start date is a temporal constraint

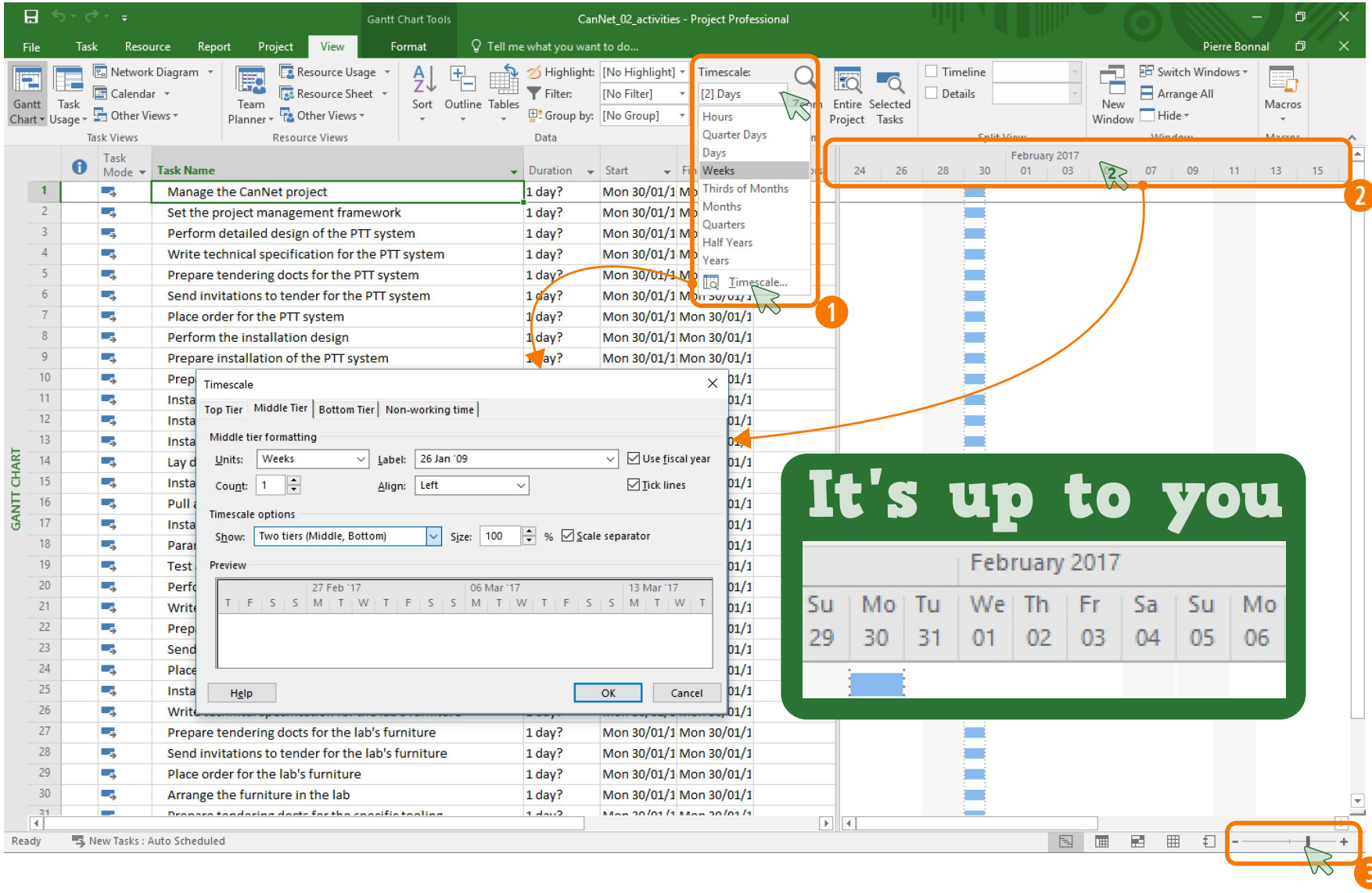
3.4



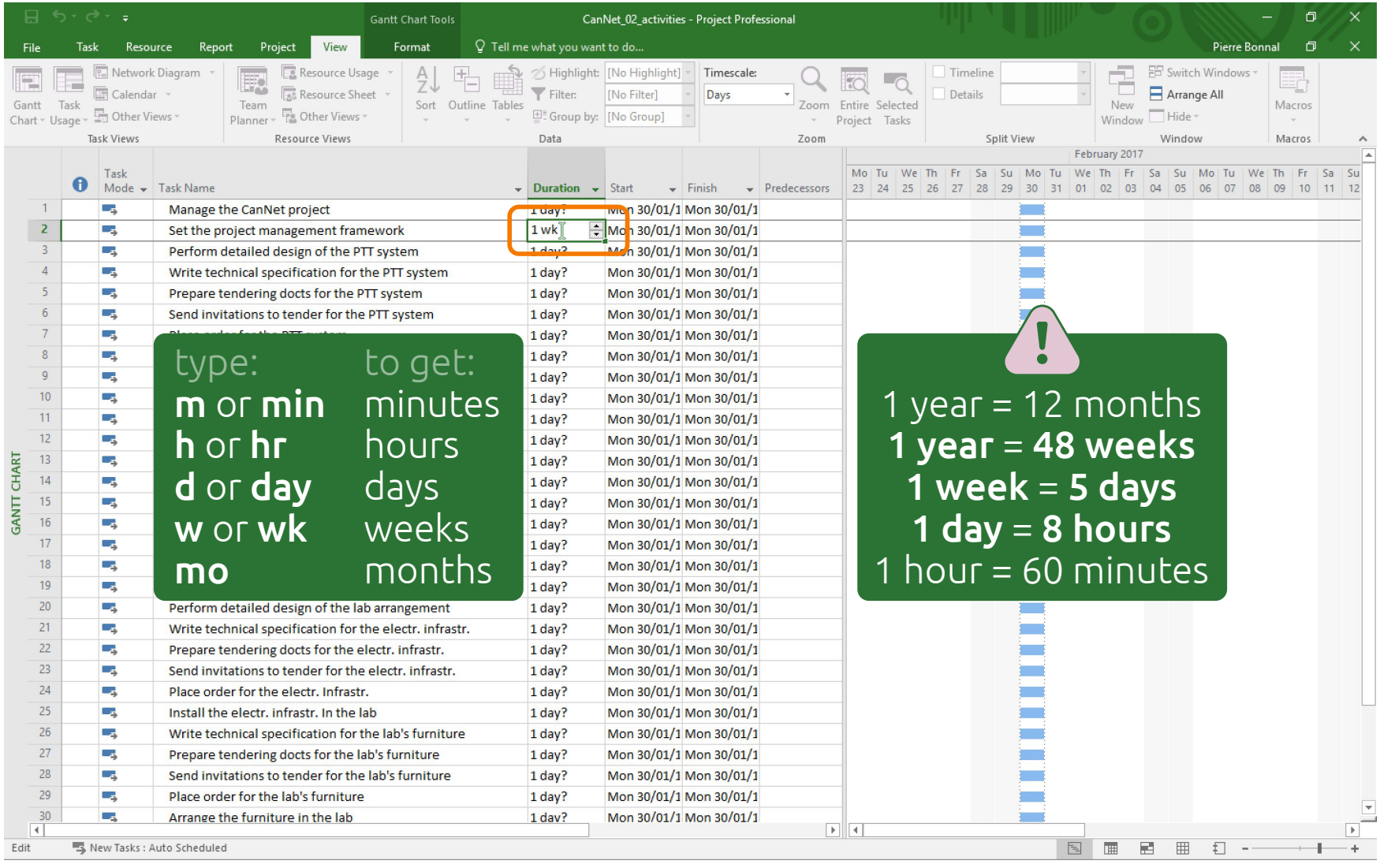
Entering and editing activity labels



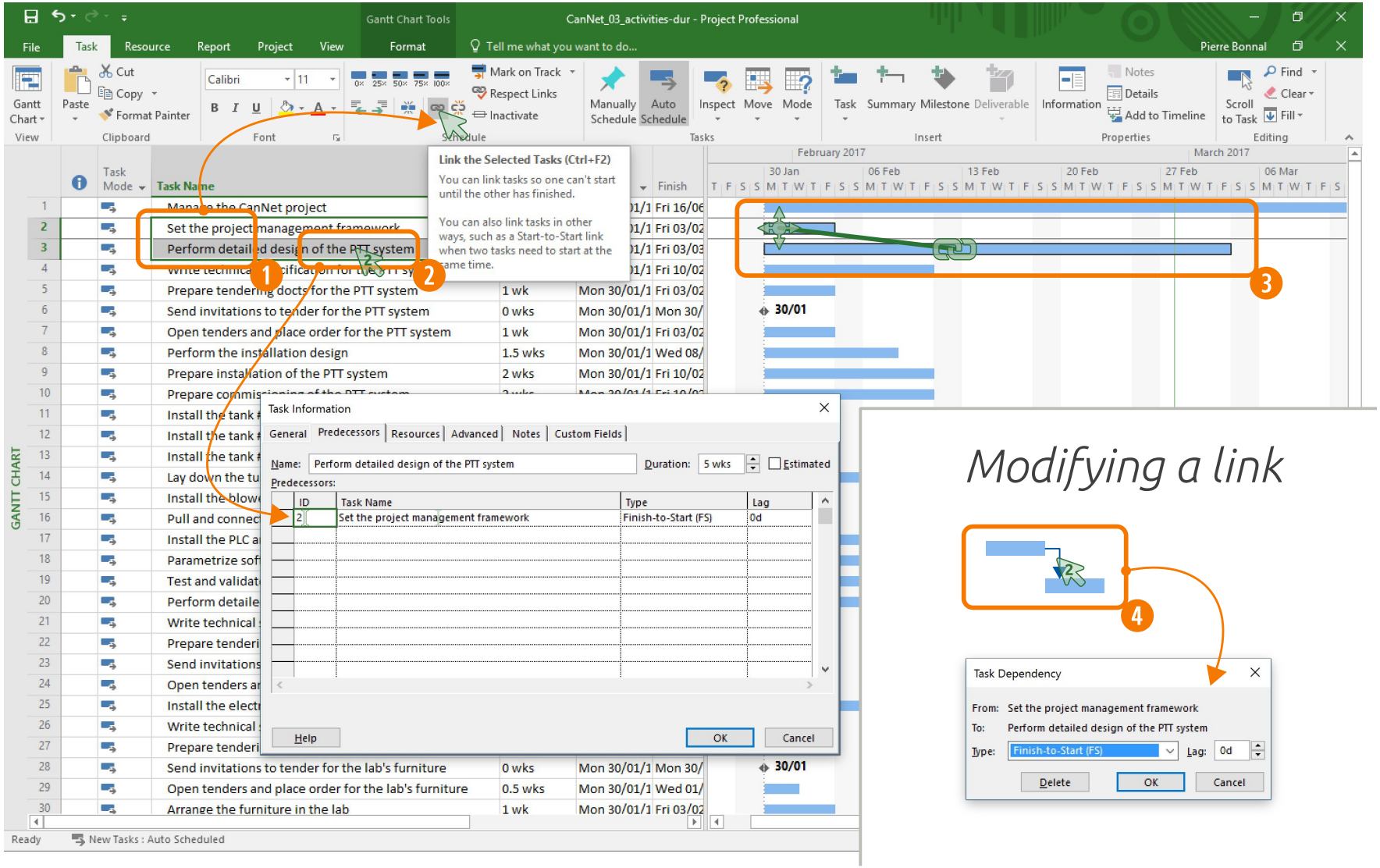
Adapting the Gantt view timescale



Entering and updating activity duration

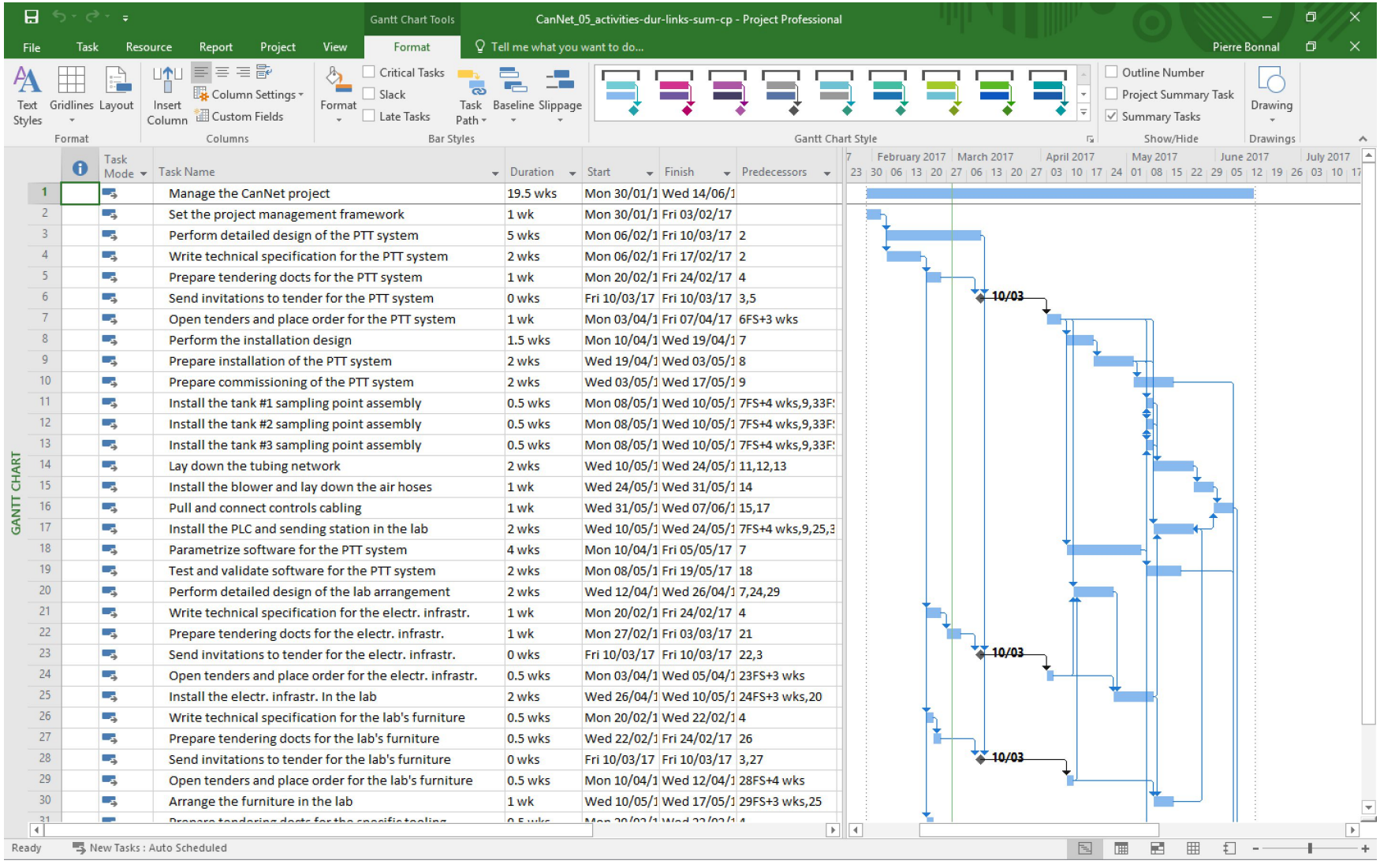


Defining technical constraints

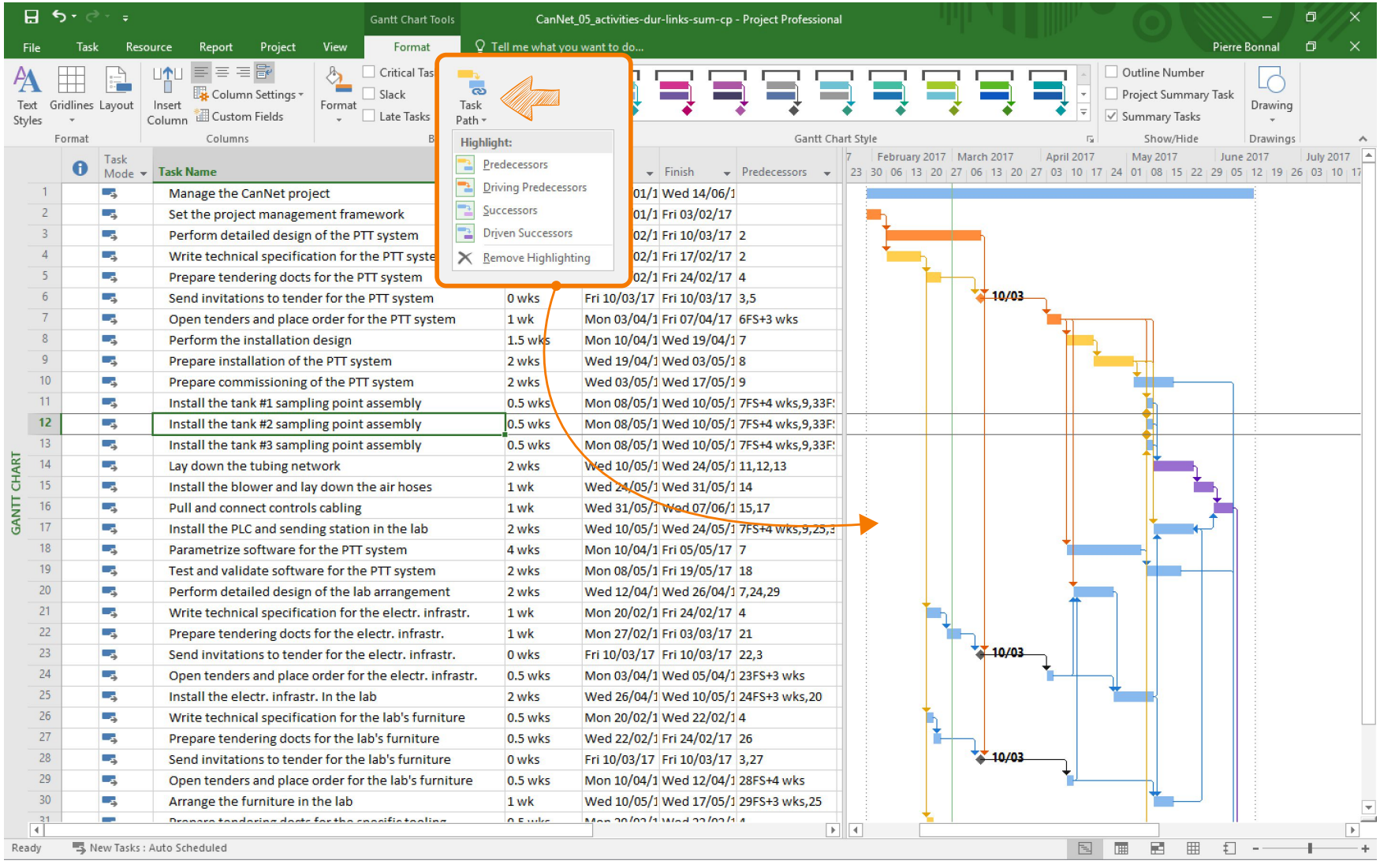


Modifying a link

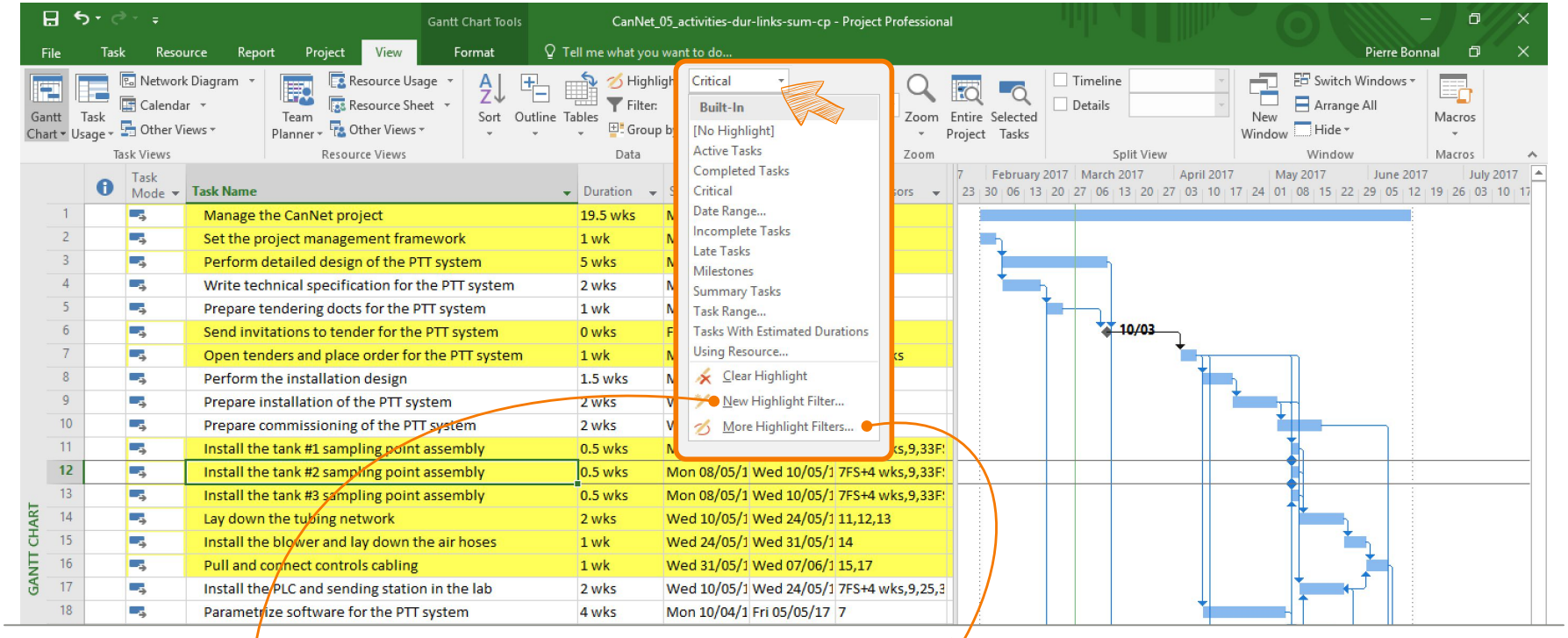
Analysing the resulting schedule (before RCPS)

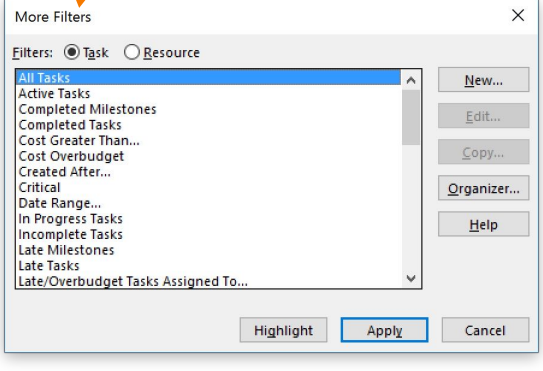


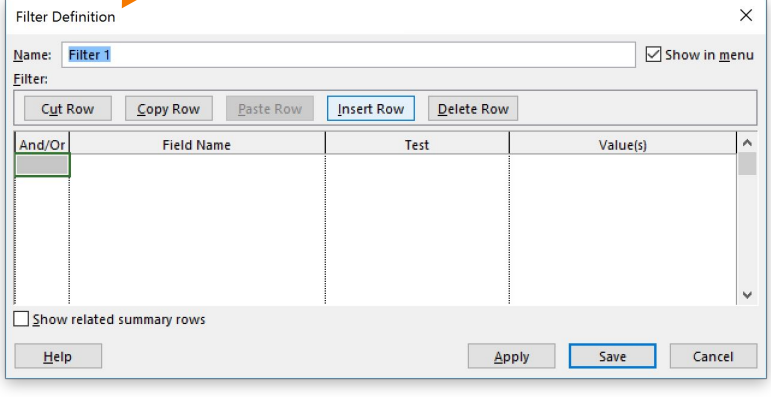
Analysing the resulting schedule (before RCPS)



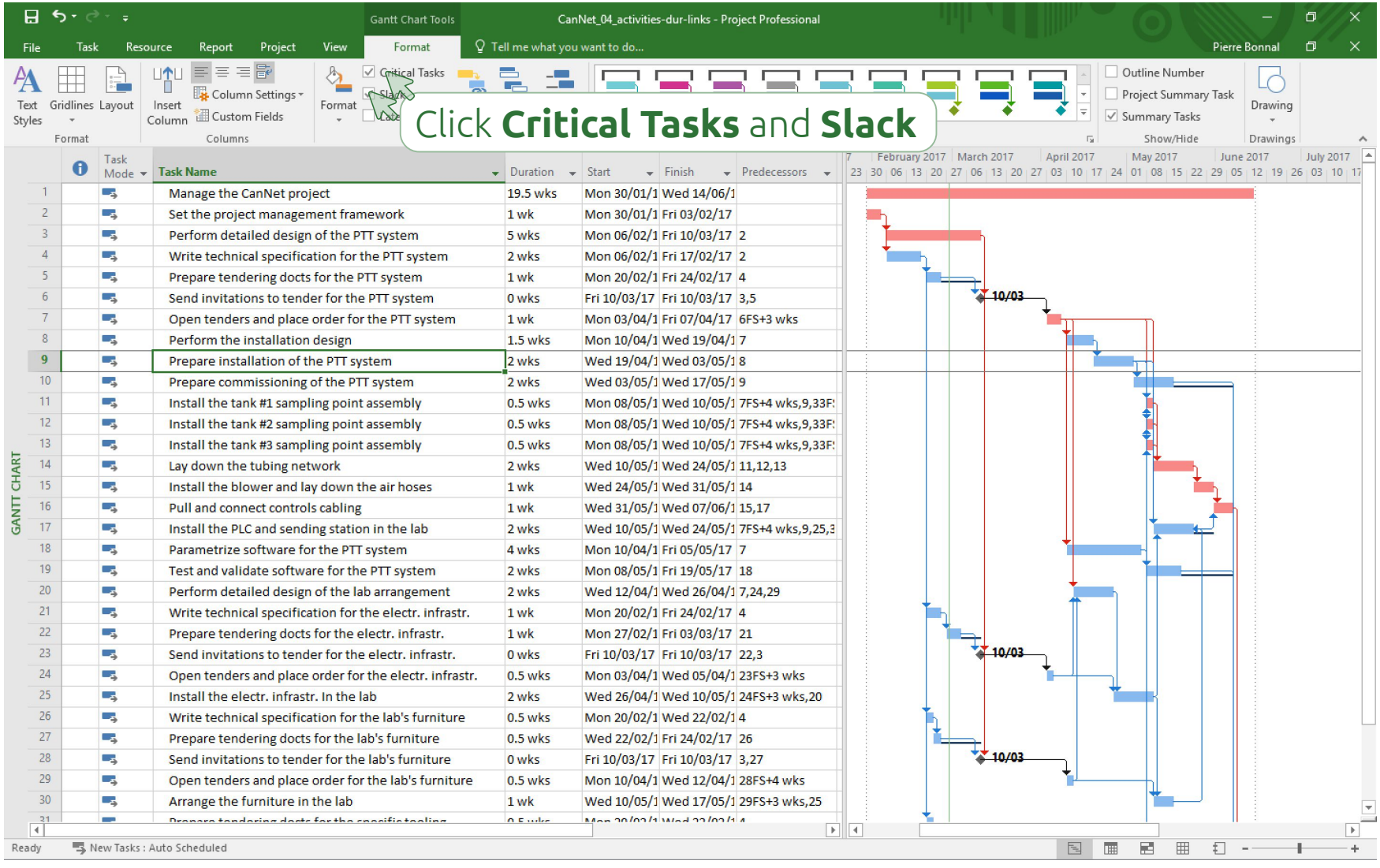
Analysing the resulting schedule (before RCPS)



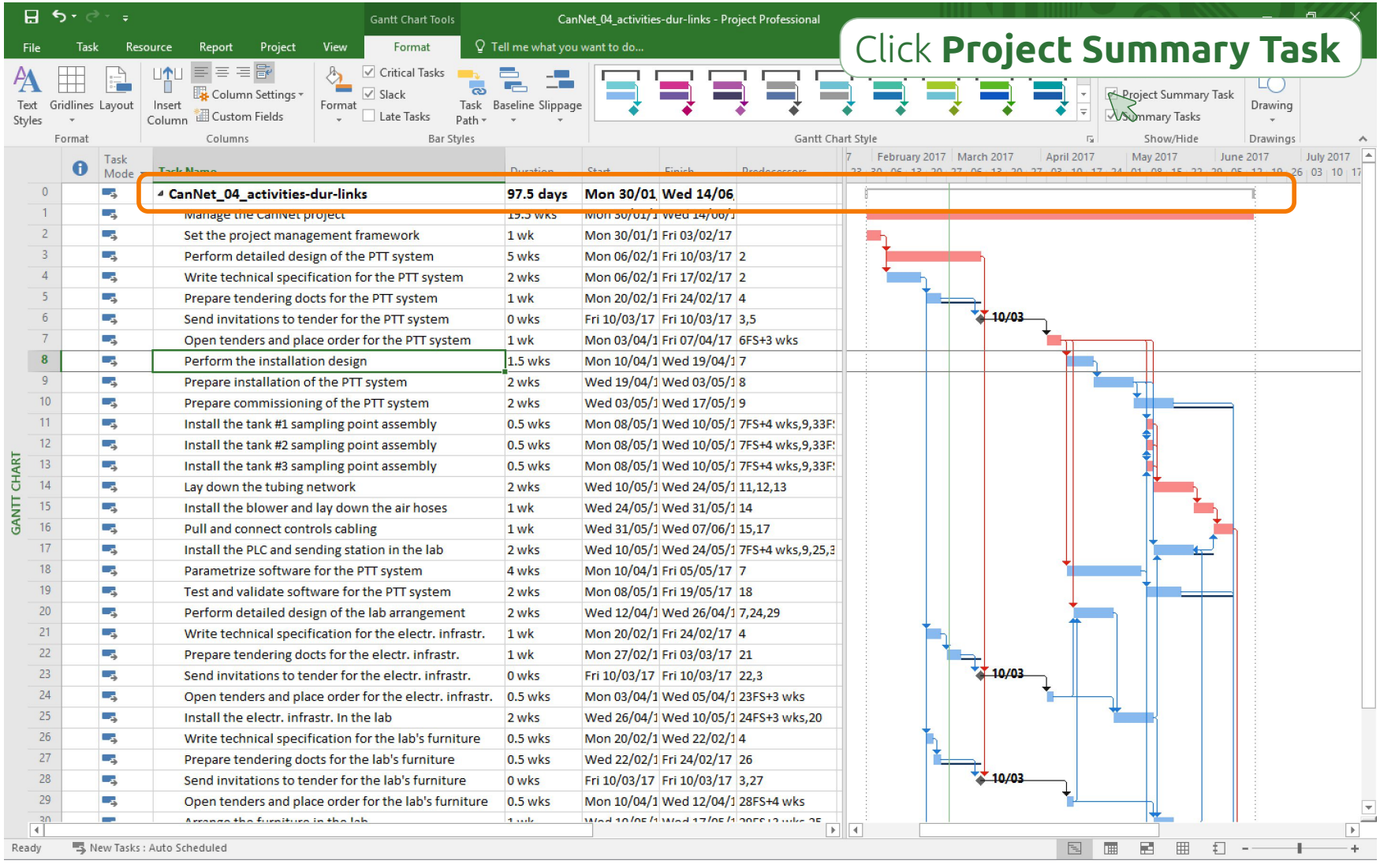




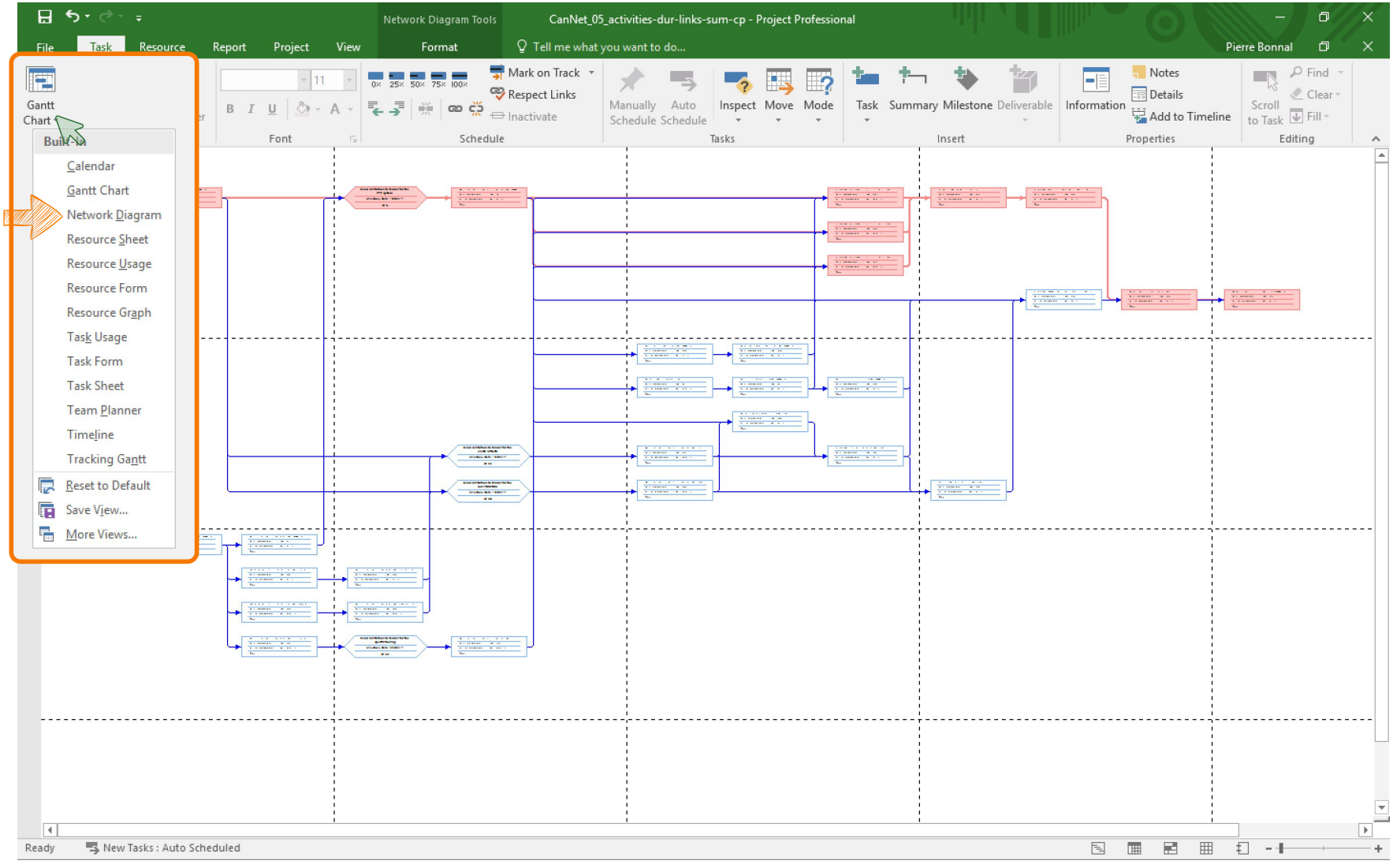
Analysing the resulting schedule (before RCPS)



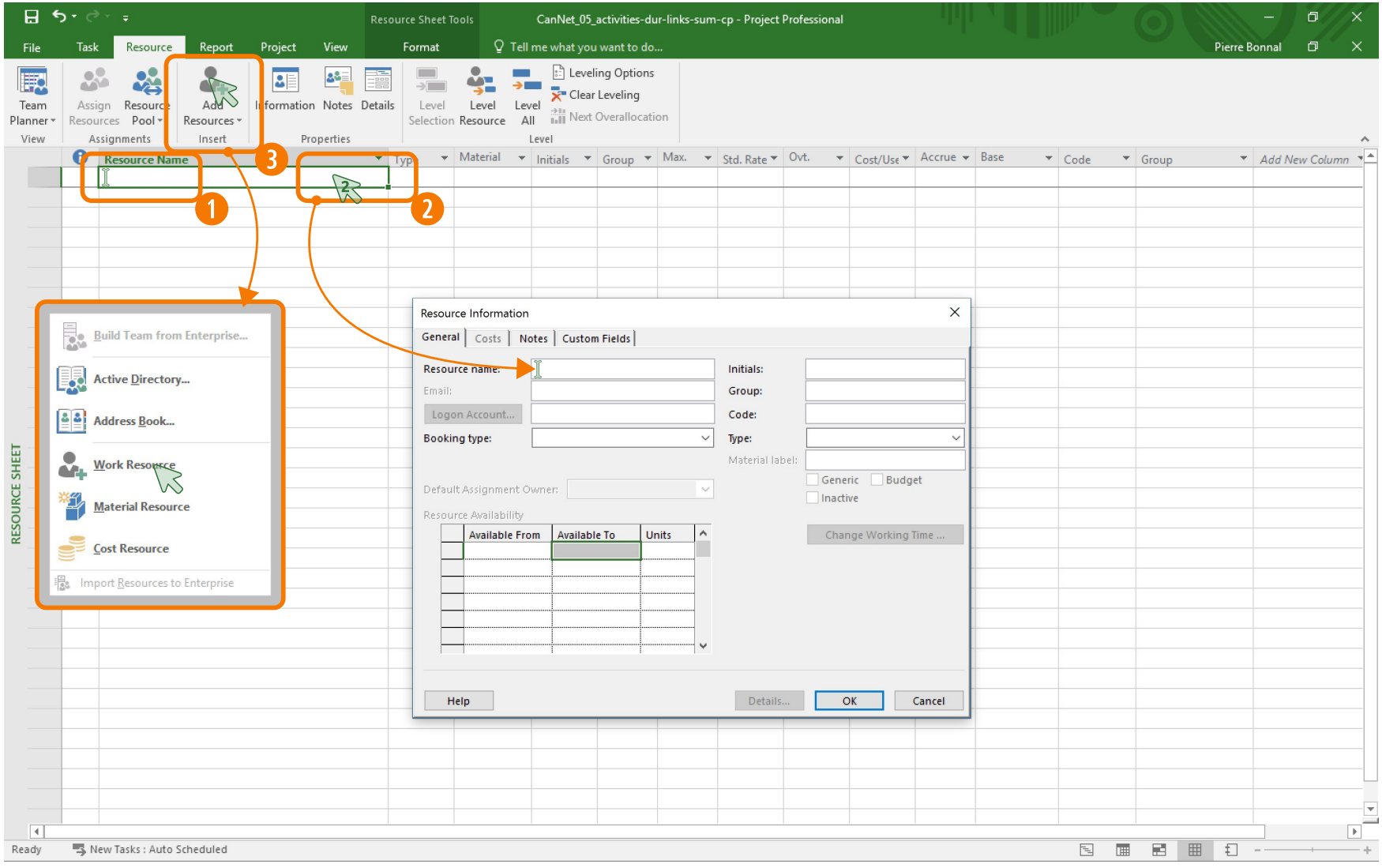
Analysing the resulting schedule (before RCPS)



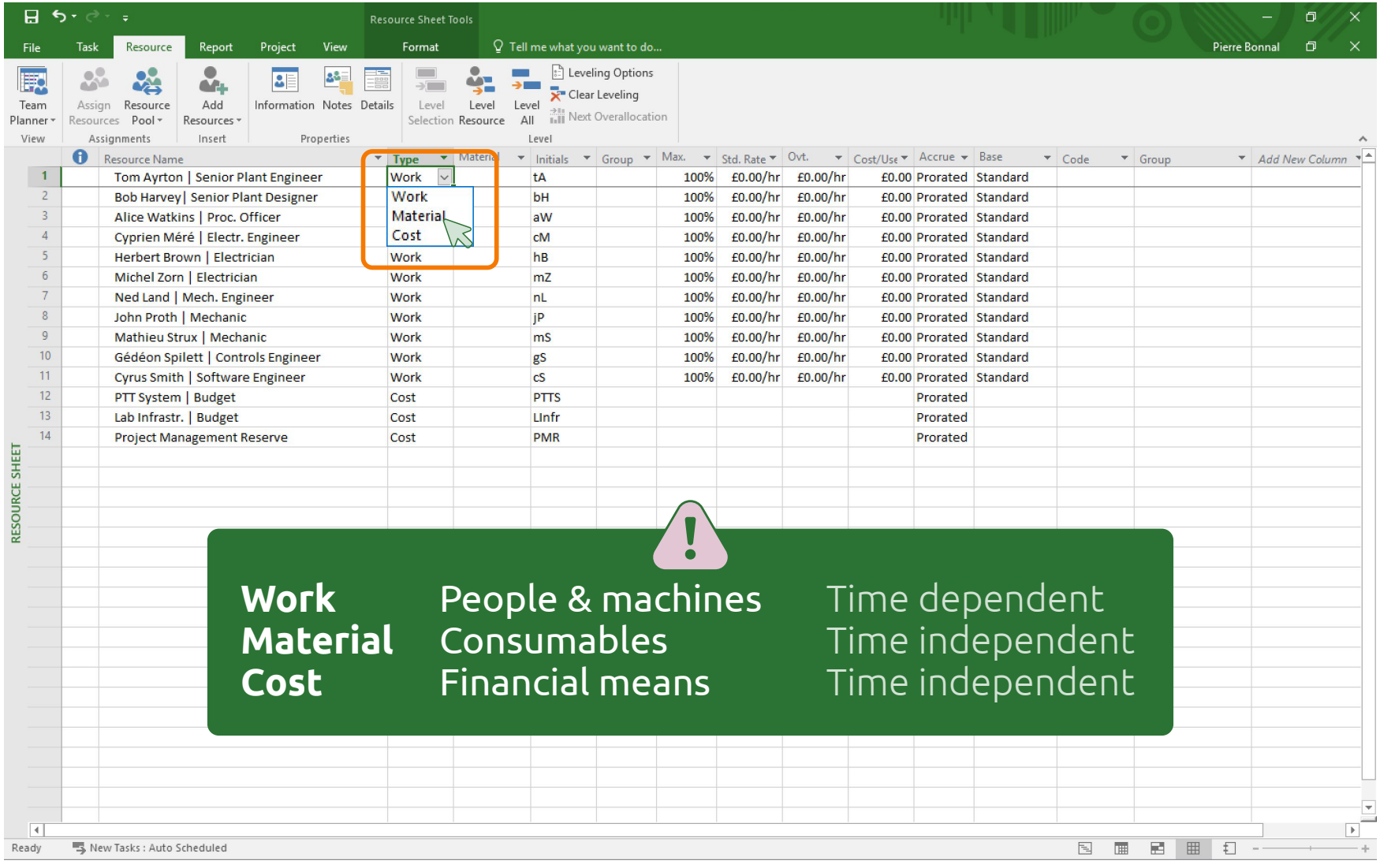
Analysing the resulting schedule (before RCPS)



Entering and editing resources

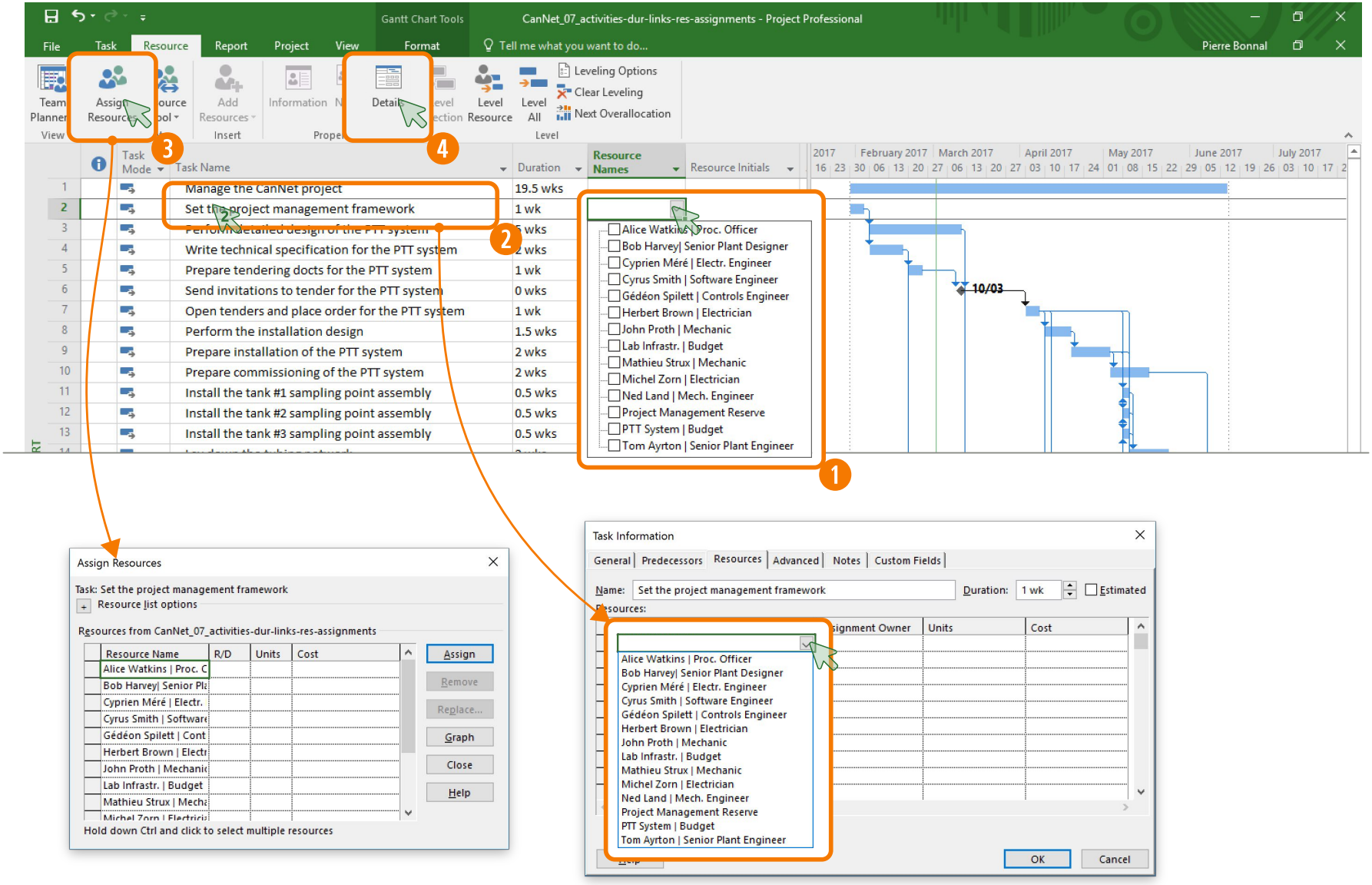


Entering and editing resources

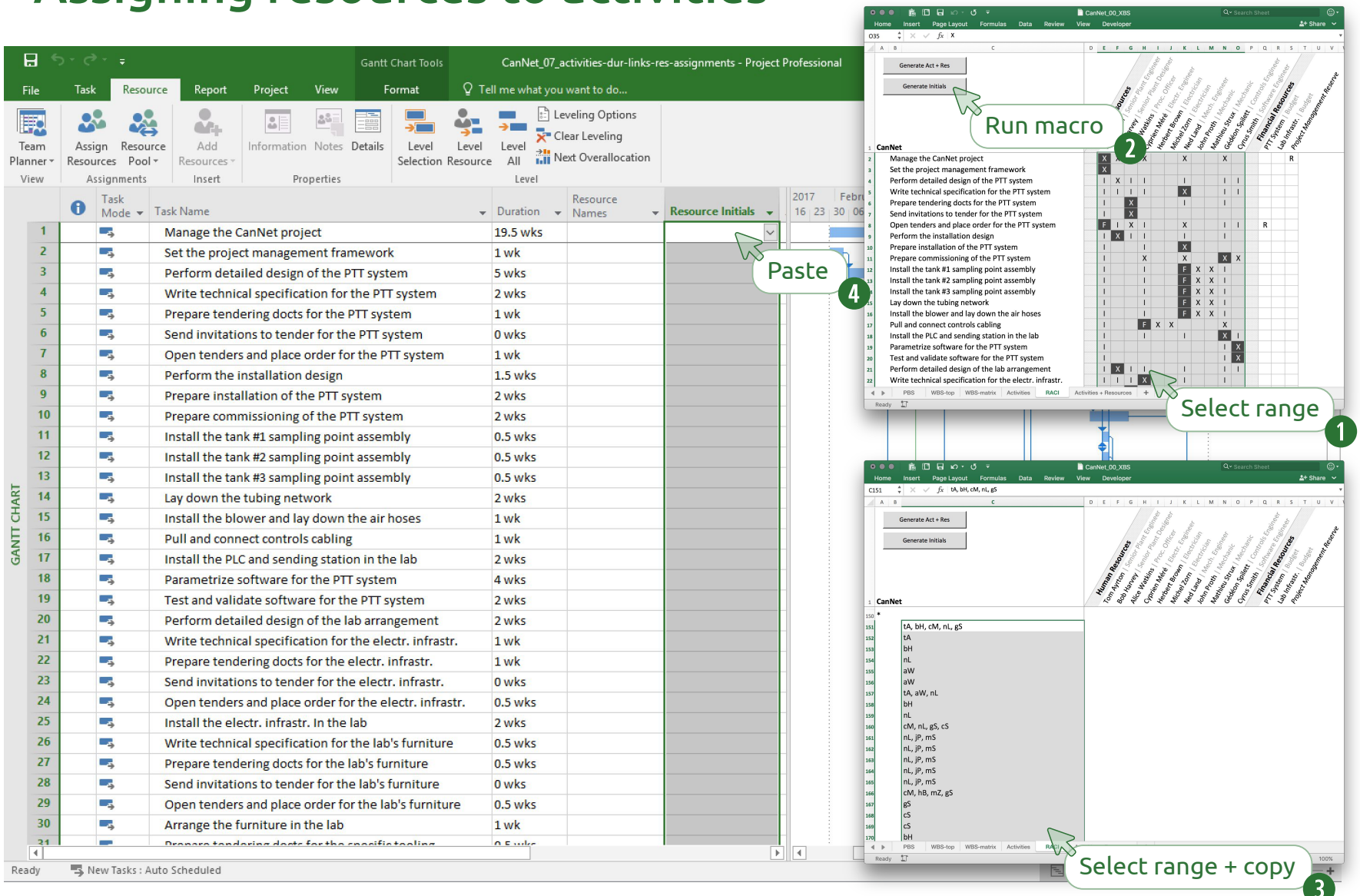


Work	People & machines	Time dependent
Material	Consumables	Time independent
Cost	Financial means	Time independent

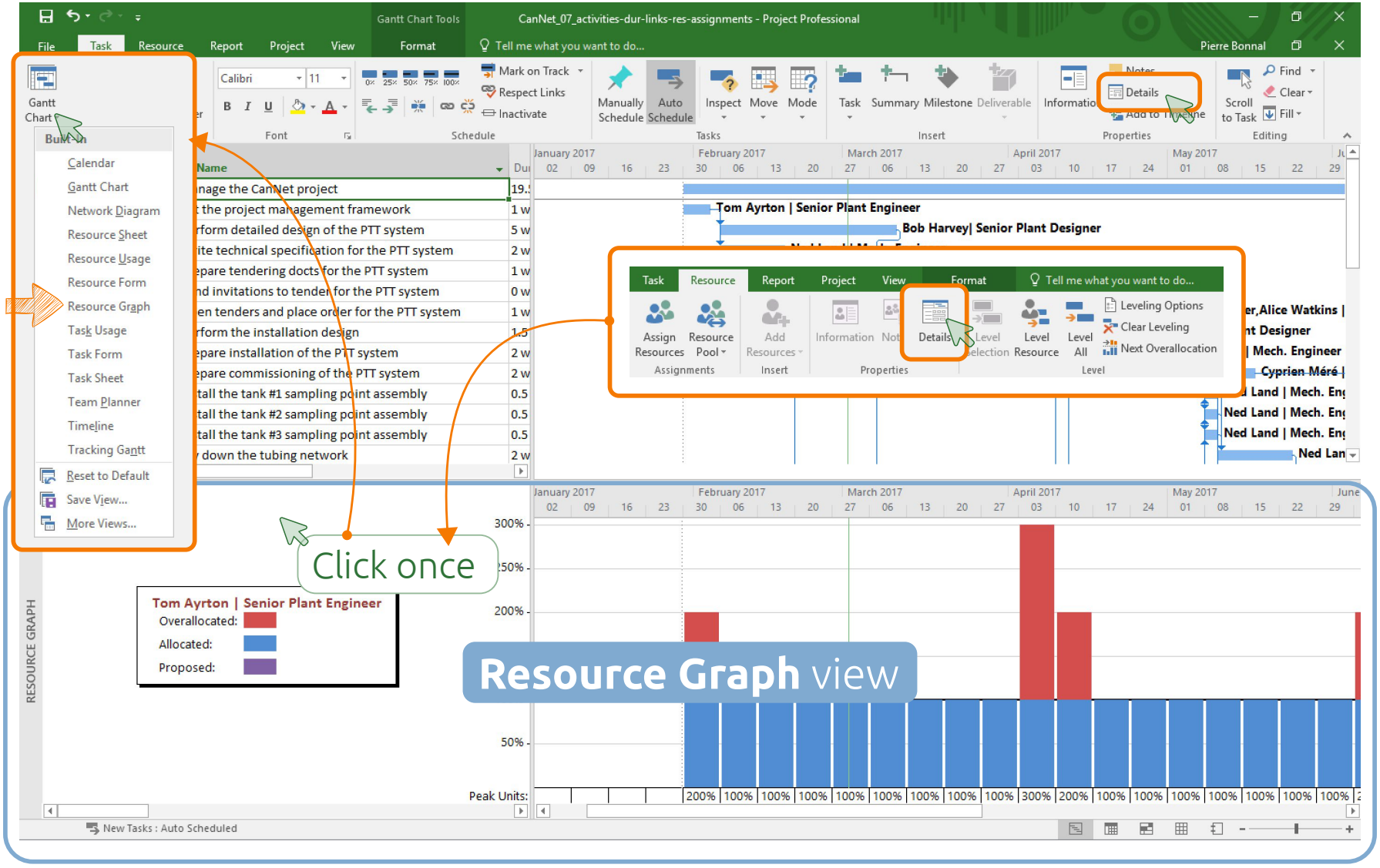
Assigning resources to activities



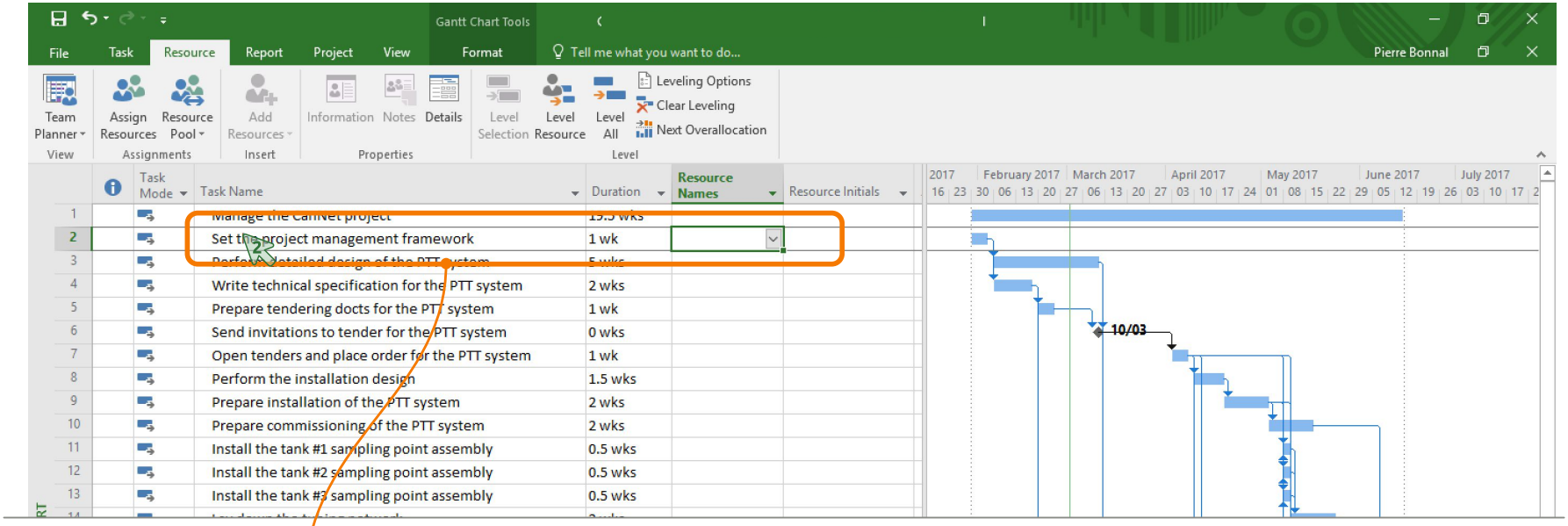
Assigning resources to activities

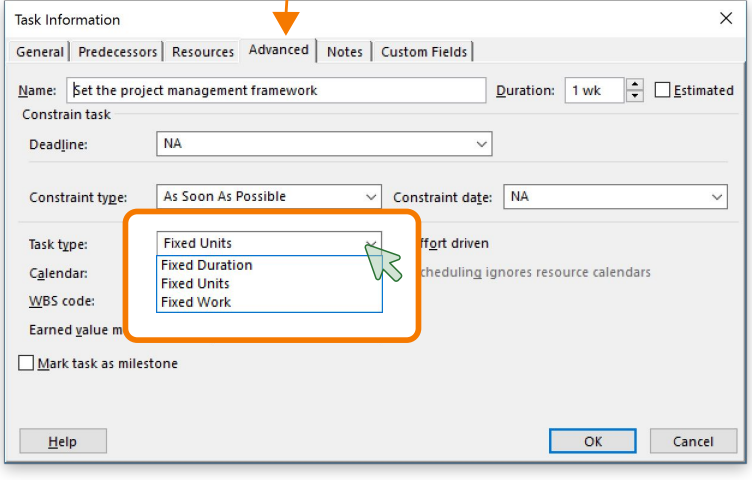


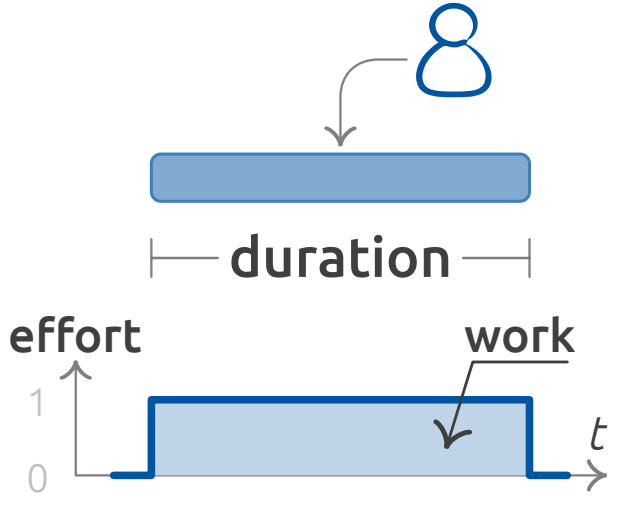
Assigning resources to activities



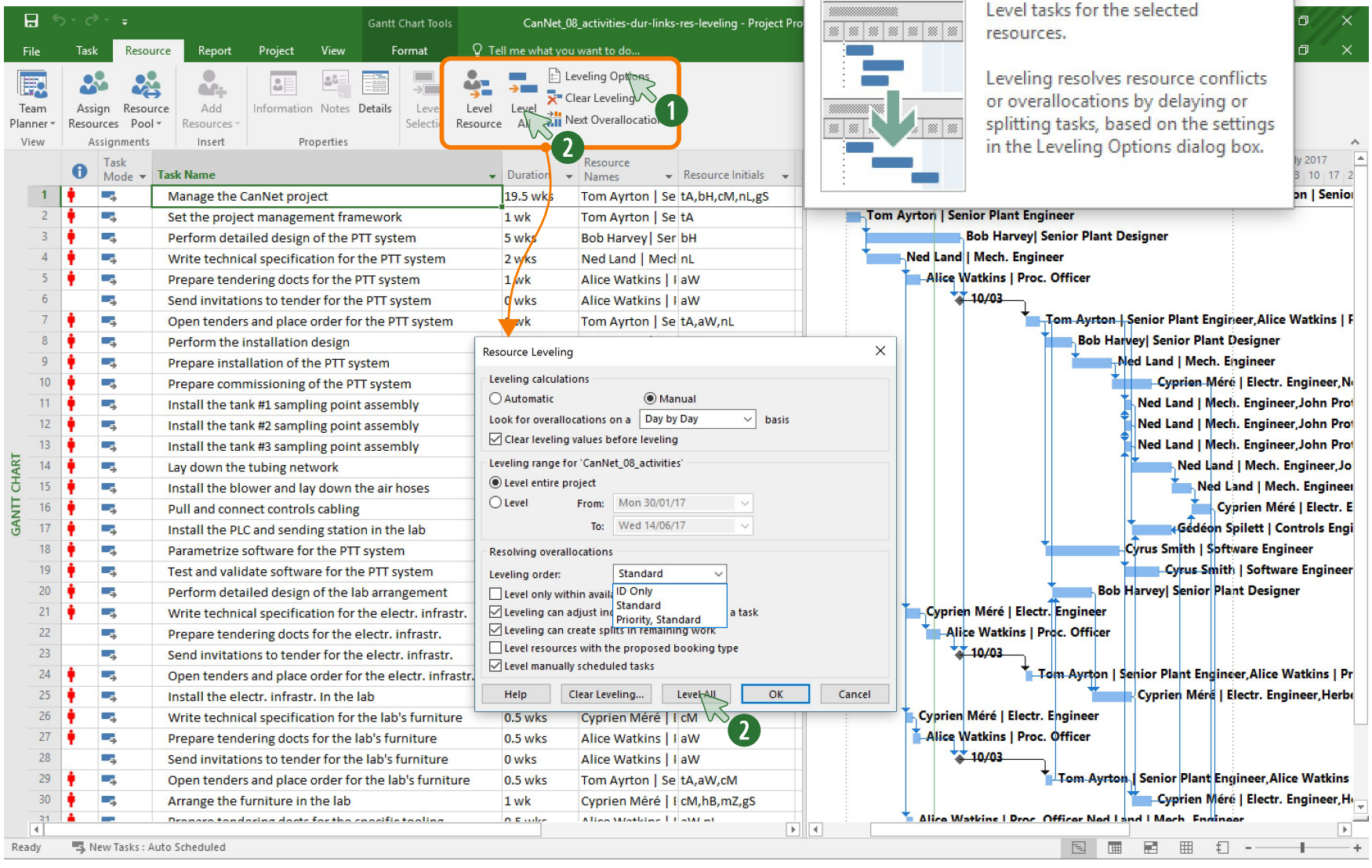
Before leveling



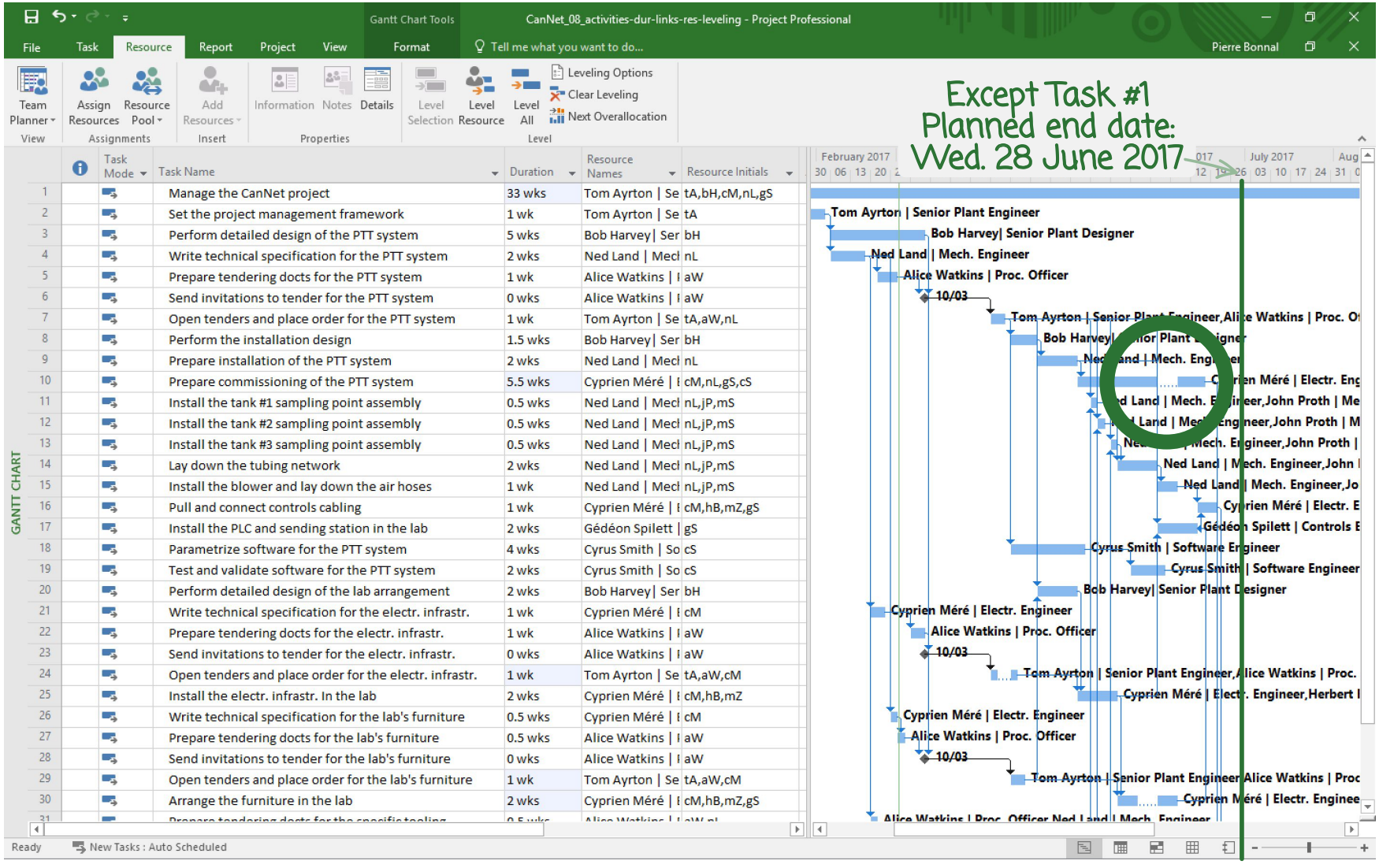




Leveling

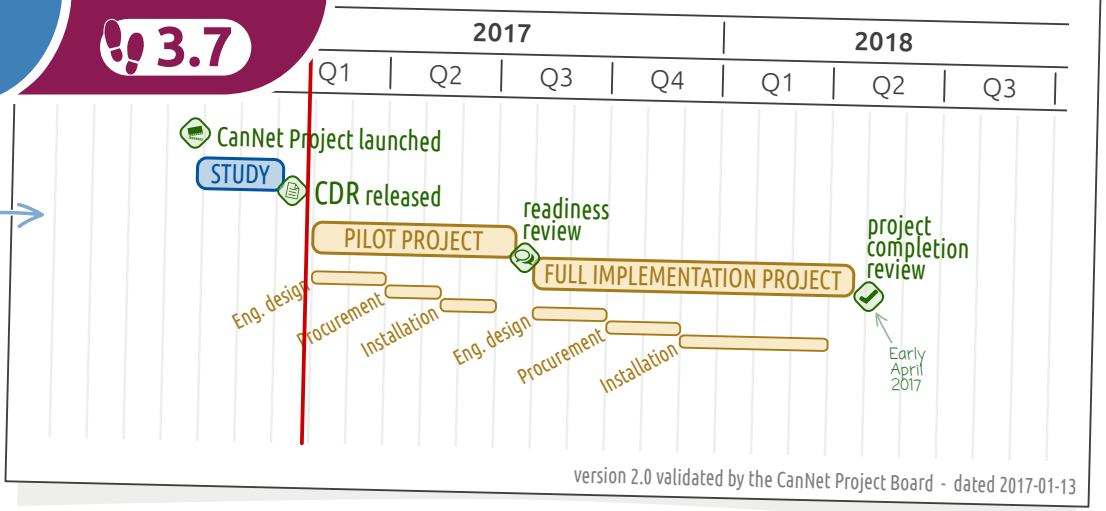

Level Resource
Level tasks for the selected resources.
Leveling resolves resource conflicts or overallocations by delaying or splitting tasks, based on the settings in the Leveling Options dialog box.
Gantt Chart Tools
CanNet_08_activities-dur-links-res-leveling - Project Pro
File
Task
Resource
Report
Project
View
Format
Tell me what you want to do...
Team Planner
Assign Resources
Resource Pool
Add Resources
Information
Notes
Details
Level Resource
Level All
Leveling Options...
Clear Leveling...
Next Overallocation
1
2
Task Mode
Task Name
Duration
Resource Names
Resource Initials
1 Manage the CanNet project 19.5 wks Tom Ayrton | Se tA,bH,cM,nL,gS
2 Set the project management framework 1 wk Tom Ayrton | Se tA
3 Perform detailed design of the PTT system 5 wks Bob Harvey| Ser bH
4 Write technical specification for the PTT system 2 wks Ned Land | Mecl nL
5 Prepare tendering docts for the PTT system 1 wk Alice Watkins | I aW
6 Send invitations to tender for the PTT system 0 wks Alice Watkins | I aW
7 Open tenders and place order for the PTT system wk Tom Ayrton | Se tA,aW,nL
8 Perform the installation design
9 Prepare installation of the PTT system
10 Prepare commissioning of the PTT system
11 Install the tank #1 sampling point assembly
12 Install the tank #2 sampling point assembly
13 Install the tank #3 sampling point assembly
14 Lay down the tubing network
15 Install the blower and lay down the air hoses
16 Pull and connect controls cabling
17 Install the PLC and sending station in the lab
18 Parametrize software for the PTT system
19 Test and validate software for the PTT system
20 Perform detailed design of the lab arrangement
21 Write technical specification for the electr. infrastr.
22 Prepare tendering docts for the electr. infrastr.
23 Send invitations to tender for the electr. infrastr.
24 Open tenders and place order for the electr. infrastr.
25 Install the electr. infrastr. In the lab
26 Write technical specification for the lab's furniture 0.5 wks Cyprien Méré | I cM
27 Prepare tendering docts for the lab's furniture 0.5 wks Alice Watkins | I aW
28 Send invitations to tender for the lab's furniture 0 wks Alice Watkins | I aW
29 Open tenders and place order for the lab's furniture 0.5 wks Tom Ayrton | Se tA,aW,cM
30 Arrange the furniture in the lab 1 wk Cyprien Méré | I cM,hB,mZ,gS
GANTT CHART
Resource Leveling
Leveling calculations
Automatic
Manual
Look for overallocations on a Day by Day basis
Clear leveling values before leveling
Leveling range for 'CanNet_08_activities'
Level entire project
Level From: Mon 30/01/17
To: Wed 14/06/17
Resolving overallocations
Leveling order: Standard
ID Only
Standard
Priority, Standard
Level only within avail
Leveling can adjust in a task
Leveling can create splits in remaining work
Level resources with the proposed booking type
Level manually scheduled tasks
Help
Clear Leveling...
Level All
OK
Cancel
Tom Ayrton | Senior Plant Engineer
Bob Harvey| Senior Plant Designer
Ned Land | Mech. Engineer
Alice Watkins | Proc. Officer
10/03
Cyprien Méré | Electr. Engineer
Gédéon Spilett | Controls Engi
Cyrus Smith | Software Engineer
Ready
New Tasks : Auto Scheduled

Schedule analysis



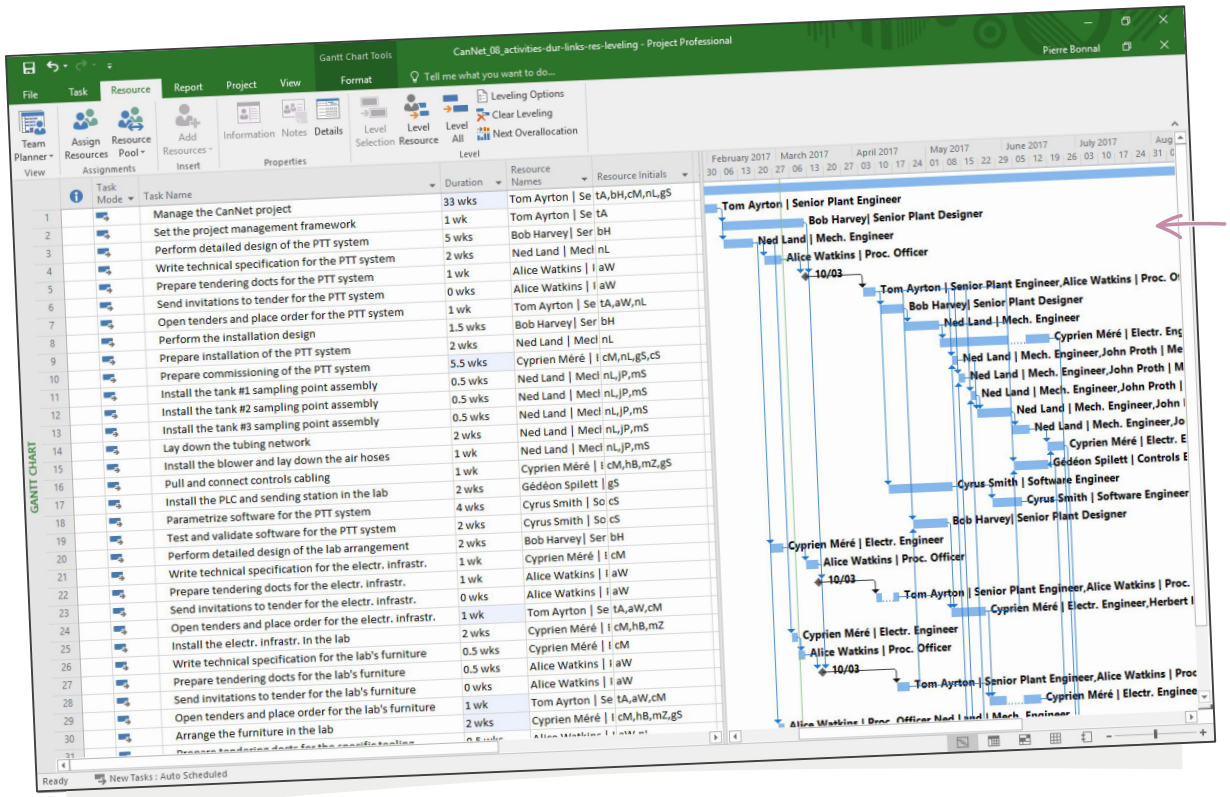
Project Master Schedule

Pilot Project makespan:
from end January (Monday of week 05)
to mid-July (Friday of week 28)



version 2.0 validated by the CanNet Project Board - dated 2017-01-13

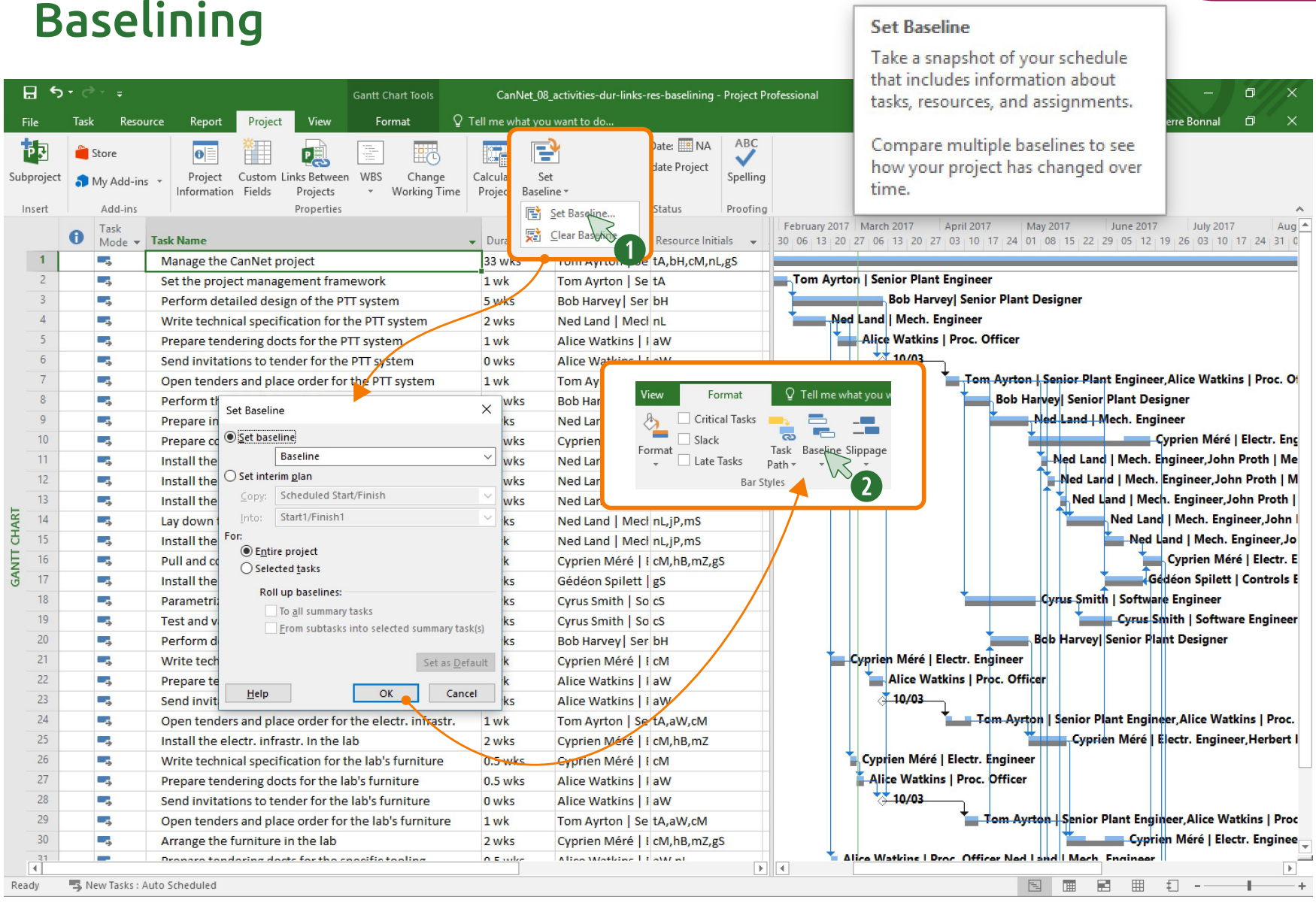
Coordination Schedule



Float = 29 - 26.5
= 2.5 wks

Pilot Project makespan:
from early week 05
to mid week 26

Baselining


Set Baseline
Take a snapshot of your schedule that includes information about tasks, resources, and assignments.
Compare multiple baselines to see how your project has changed over time.
CanNet_08_activities-dur-links-res-baselining - Project Professional
Gantt Chart Tools
File
Task
Resource
Report
Project
View
Format
Tell me what you want to do...
Subproject
Store
My Add-ins
Project Information
Custom Fields
Links Between Projects
WBS
Change Working Time
Set Baseline
Set Baseline...
Clear Baseline
Spelling
Insert
Add-ins
Properties
Status
Proofing
Task Mode
Task Name
Resource Initials
GANTT CHART
Manage the CanNet project
Set the project management framework
Perform detailed design of the PTT system
Write technical specification for the PTT system
Prepare tendering docts for the PTT system
Send invitations to tender for the PTT system
Open tenders and place order for the PTT system
Open tenders and place order for the electr. infrastr.
Install the electr. infrastr. In the lab
Write technical specification for the lab's furniture
Prepare tendering docts for the lab's furniture
Send invitations to tender for the lab's furniture
Open tenders and place order for the lab's furniture
Arrange the furniture in the lab
Set Baseline
Set baseline
Baseline
Set interim plan
Copy:
Scheduled Start/Finish
Into:
Start1/Finish1
For:
Entire project
Selected tasks
Roll up baselines:
To all summary tasks
From subtasks into selected summary task(s)
Set as Default
Help
OK
Cancel
View
Format
Critical Tasks
Slack
Late Tasks
Task Path
Baseline
Slippage
Bar Styles
1
2
Ready
New Tasks : Auto Scheduled

4

Setting up an effective **Microsoft Project** working configuration

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