

TOC – Critical chain

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TOC concisely I (see PWP presentation about TOC)

- origin: E.M.Goldratt, Jerusalem
- cost world<->throughput world
- analogy weight of the chain – solidity of the chain
- how to find a bottleneck?
- tools of TOC – tree structures
- CRT – EC – TT – PT – FRT **meaning:**
- Current Reality Tree - Evaporating Cloud Tree– Transition Tree -
 - Prerequisite Tree – Future Reality Tree



TOC concisely I (see PWP presentation about TOC)

- **bottleneck** in the project management is a critical path
- finding (assessment) of bottleneck is not easy and often it is not explicit (uncompromising)
- everybody knows something about TOC and nobody knows **how to implement it** to the real world- and this is again another bottleneck (tendon of Achilles from the heel to the scruff)



TOC-five steps (revision)

Five steps process:

Step 0. Identify the Goal of the System/Organization

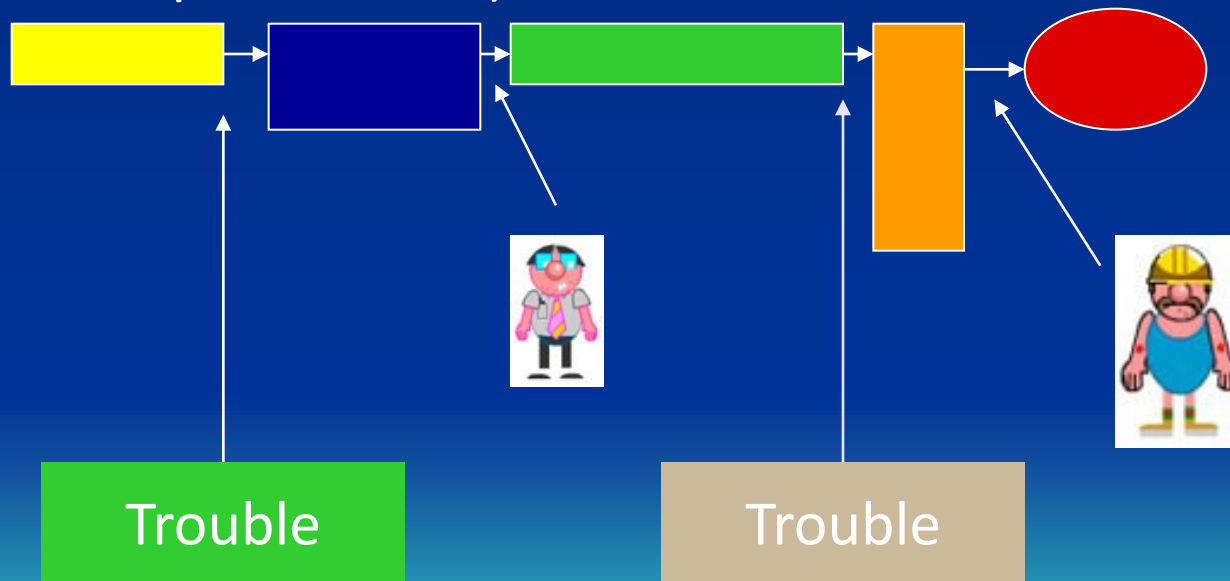
Step 0.5 Establish a way to measure progress to Goal

- **Step 1. *Identify*** the system's constraint.
- **Step 2. *Exploit*** the system's constraint.
- **Step 3. *Subordinate*** everything else to the above decision.
- **Step 4. *Elevate*** the system's constraint.
- **Step 5.** If a constraint is broken (that is, relieved or improved), go back to Step 1. But don't allow *inertia* to become a constraint.

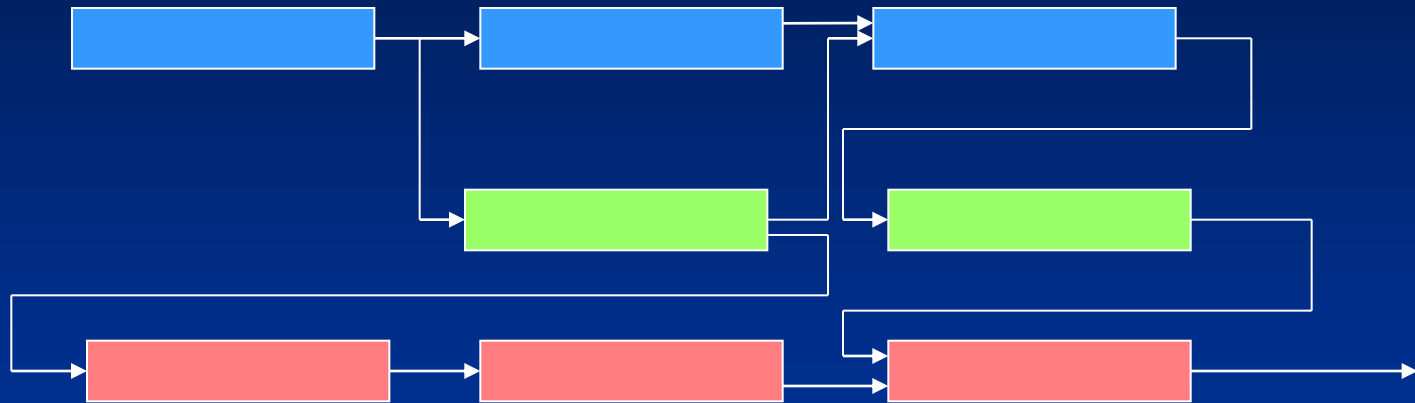


Linear image of the project

- activities – abscissas – Gantt graph
- constantly changing conditions (Parkinson law, Murphy law, Student syndrome, customer changes - „fancies“ „caprices“)



Parallel image of the project



PlannerOne Scheduler

The screenshot displays the PlannerOne Scheduler interface within a Microsoft Dynamics NAV environment. The window title is "ScreenShot_02_20140926 - Windows Prohlížeč fotografií". The application title bar reads "View - PlannerOne Production Scheduler - Microsoft Dynamics NAV". The breadcrumb navigation shows the path: "CRONUS International Ltd. > Departments > Manufacturing > PlannerOne > PlannerOne Production Scheduler".

The interface includes a navigation pane on the left with categories such as "Departments", "Financial Management", "Sales & Marketing", "Purchase", "Warehouse", "Manufacturing", "Product Design", "Capacities", "Planning", "Execution", "Costing", "PlannerOne", "Jobs", "Resource Planning", "Service", "Human Resources", and "Administration".

The main workspace features a toolbar with various icons for "Dnes", "Výbrat datum", "Předchozí období", "Následující období", "Počátek plánování", "Konec plánování", "Přejít na", "Týden", "Měsíc", "Pololetí", "Časové měřítko", "Skryj nepracovní dny", "Zvětšit operace", "Operace", "Uživatelské úpravy", "Výška řádku", "Úřky operací", "Popisky operací", "Zvětšení", "Zmenšení", "Zrušit", "Zoom", "Automatické obnovení", "Obnovení", and "Obnovit výchozí".

Below the toolbar, there are tabs for "Resource Gantt chart", "WO Gantt chart", "WO status / Item code Gantt chart", "Graf zatížení", "Pořadí zdrojů", and "10108410000 Touring Bicycle". The selected view is "Resource Gantt chart".

The Gantt chart displays a production schedule for "10108410000 Touring Bicycle" from September 11, 2014, to September 16, 2014. The chart is organized into columns for each day. The left side of the chart lists resources with their codes, names, and types:

| Kód skupiny | Kód zdroje | Název zdroje | Typ zdroje |
|-------------|------------|---------------------|------------|
| 100 | 130 | Linda Mitchel | --- |
| 200 | 210 | Packing table 1 | --- |
| 200 | 220 | Packing table 2 | --- |
| 200 | 230 | Packing Machine | --- |
| 300 | 310 | Painting Cabin | --- |
| 300 | 320 | Painting Robot | --- |
| 300 | 330 | Drying Cabin | --- |
| 300 | 340 | Painting inspection | --- |
| 400 | 410 | Drilling machine | --- |
| 400 | 420 | CNC machine | --- |
| 400 | 430 | Machine deburr | --- |
| 400 | 440 | Machine inspection | --- |
| 700 | 700 | Uncoiler_Recoller | --- |

The Gantt chart shows various operations as colored bars, including "Final assembly", "Wheel assembly", "Packing department", "Painting department", "Machine department", and "Assembly depart". Each bar is labeled with a code and a time range, such as "1011041000030 Final assembly" or "1010602000050 Machine department".

PlannerOne Resource Planner

View - PlannerOne Resource Planner - Microsoft Dynamics NAV

CRONUS International Ltd. ▶ Departments ▶ Resource Planning ▶ PlannerOne ▶ PlannerOne Resource Planner

Search (Ctrl+F3)

POWERED BY ORTEMA

Plánování | Zobrazit | Akce | Filtr

Dnes | Předchozí období | Počátek plánování | Vybrat datum | Následující období | Konec plánování | Přejít na | Týden | Den | Měsíc | Pokročilé | Časové měřítko | Skrytí nepracovní doby | Zvětšit aktivity | Aktivita barvy | Výška řádku | Štítky aktivit | Popisky aktivit | Uživateléské úpravy | Zvětšení | Zmenšení | Zrušit | Zoom | Automatické obnovení | Obnovení | Obnovit výchozí | Zobrazit

Resource Gantt chart | Job Gantt chart | Load Chart | Resource Sequence | Calendar view | Job planner

SO000013 Service Order for Planner...
SO000013 Service Order for Planner...

SO000015 Servis order for our priority... +

Přehled

- ★ Oblíbené (4)
- 🕒 Plánováno v poslední době
- Pouze částečně naplánováno (12)
- Plně naplánováno (11)
- 🚨 Překročení rozpočtu (7)
- Dokončeno (2)

★ **Oblíbené (4)**

| Task Name | Company | Days | Progress | Completion |
|------------------------------------|----------------------------|-------------|----------|--------------------|
| LONDON, 10 WP Setting up 10 Wc | Deerfield Graphics Company | 114 dny | 100 % | Dokončeno: 0 % |
| SERVICE ORDER 1 Service Order 1 | The Cannon Group PLC | 137 dny | 100 % | Dokončeno: 66,67 % |
| SO000013 Service Order for Plann | The Cannon Group PLC | před 63 dny | 100 % | Dokončeno: 51,22 % |
| SO000015 Servis order for our pric | The Cannon Group PLC | před 63 dny | 100 % | Dokončeno: 0 % |

Project and its budget

- price of the whole project
- project length (time)
- project stages and length of each activity
- assigned resources to every activity and their capacities (time per defined period)
- time reserves (buffers) and their estimation
- unfavourable influences (see Murphy's laws - <http://murphy.euweb.cz>, etc.)
- additional activities (unexpected costs)

Selected Murphy's laws

- If your attack is going well, you have walked into an ambush (trap)
- Planner is alerted about modification of the plan exactly in the moment, when the plan is finally adjusted
- To carry out **n+1** trivialities you need two times more time than time necessary to carry out **n** trivialities (law 99 %)
- **If anything can go wrong, it will**
- Any given program, when running, is obsolete
- No matter how many resources you have, it is never enough
-



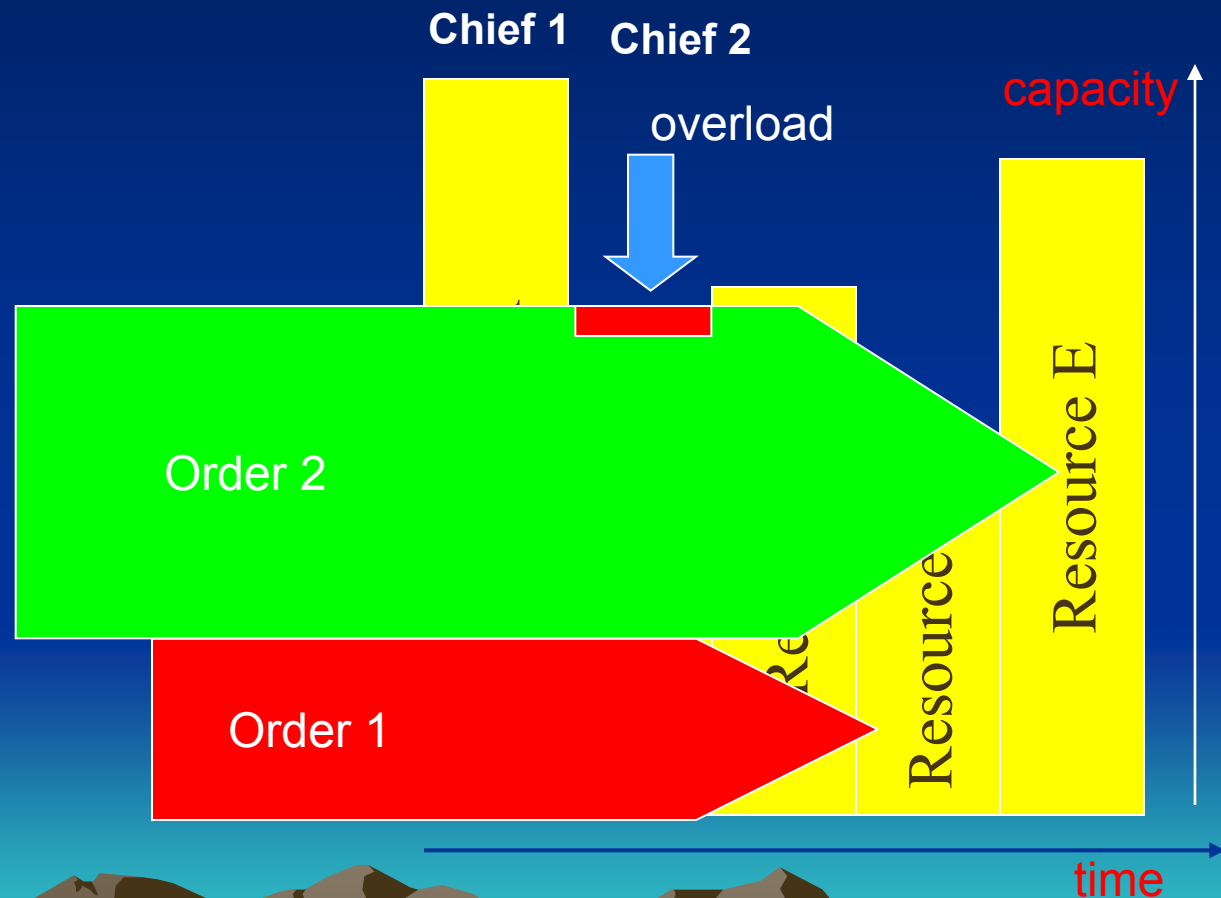
Resources and orders

Matrix structure of multi-project environment – responsibility of project managers and responsibility of department managers are **in conflict**



Project manager 1

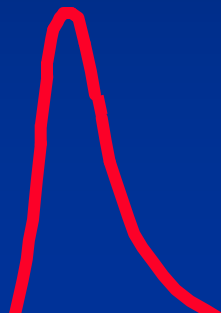
Project manager 2



Partial time of any activity in the project

Variability of the real time assigned to activity

Probability– median an element of statistical file,
which is after sorting in the middle .Median of the set (1,5,2,2,1) is 2

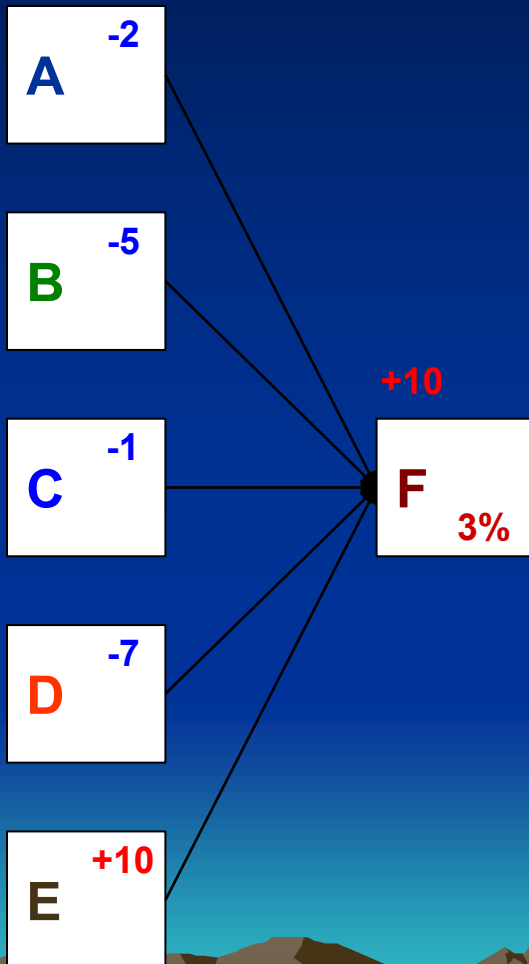


*100 „5-miniutes meeting happened.
How many times it took 5 minutes only ?*

Colleague ask for a quick rendez-vous: „Do not worry, it will take maximum 5 minutes!“.

How long it takes on average?

Project environment is very complicated because of integration linkages and their dependencies



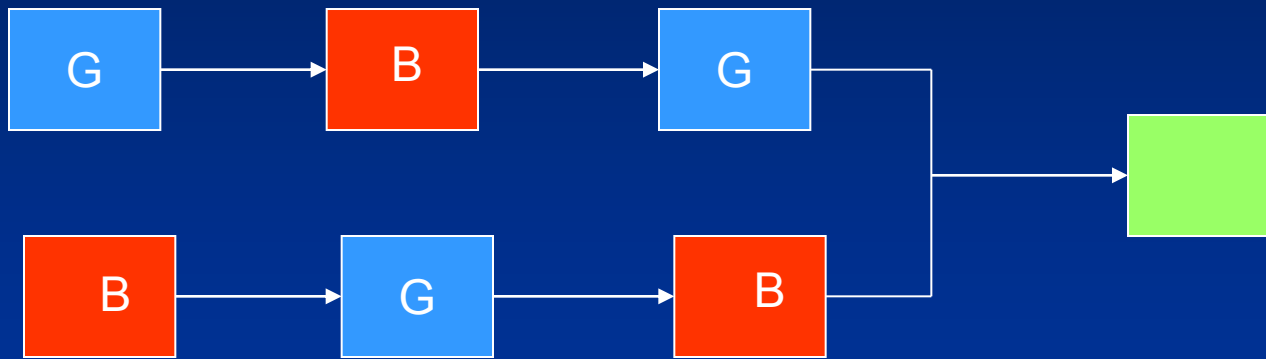
Probability of finishing tasks A to E in time is 50%. ($50 \times 50 \times \dots \times 50 = 3,125 \%$)

What is a probability, that task F will start in time ?

How the timely finishing of the tasks A,B,C and D will influence the integration point ?

- a) saving are fully wasted
- b) delay in one task will be immediately transferred to the next project task (activity) see **+10**

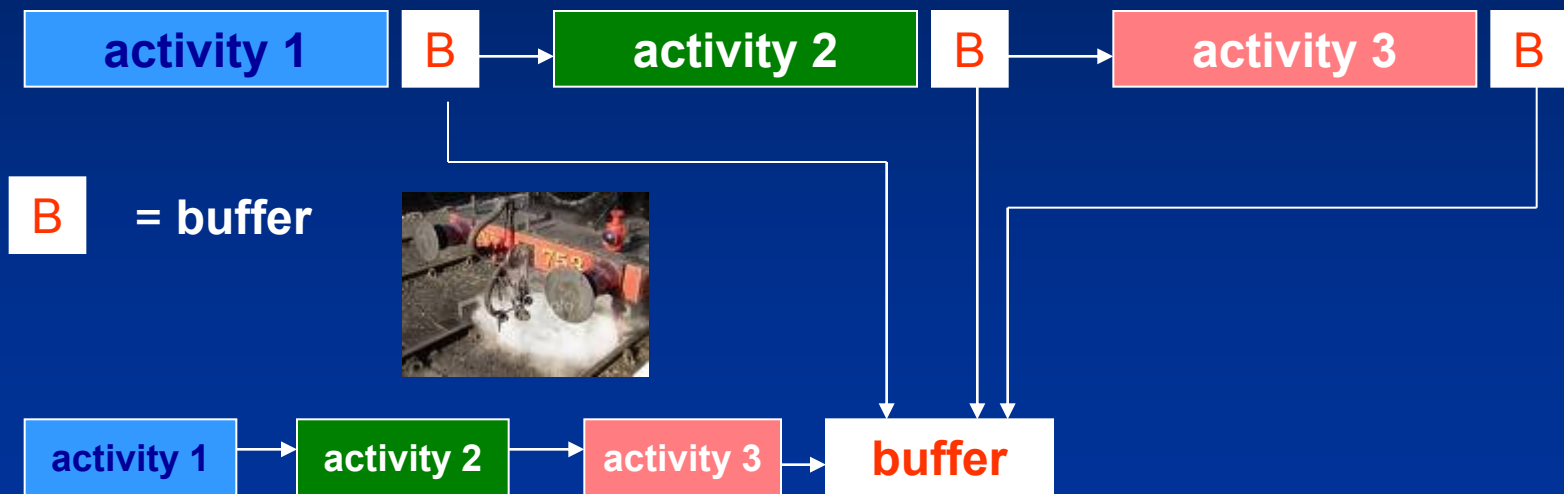
Project environment is very complicated because of integration linkages and their dependencies



In order to start **B** in the upper branch, you have to finish **G** and also **B** in the lower branch. The probability, that **B** start in time is 50 % worse, than it was shown on the previous slide.

The project must be protected against influences of breakdowns (troubles)

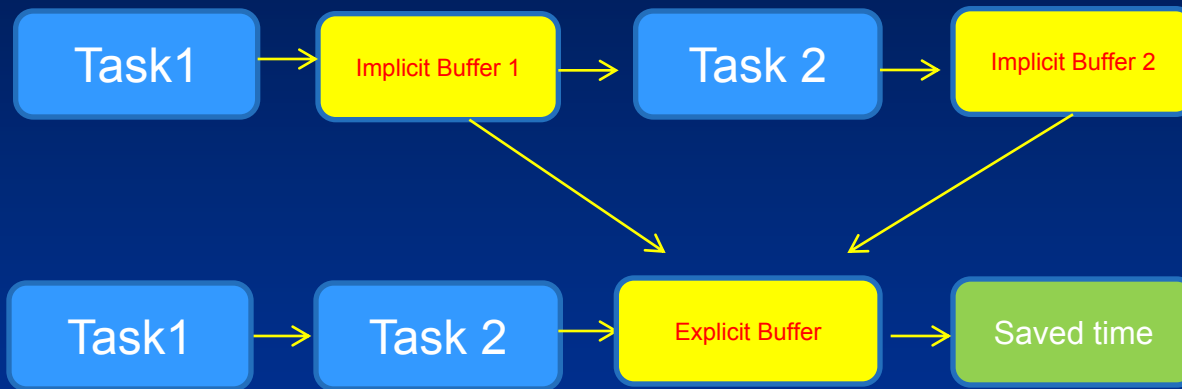
Standard estimation with protecting buffers for every activity



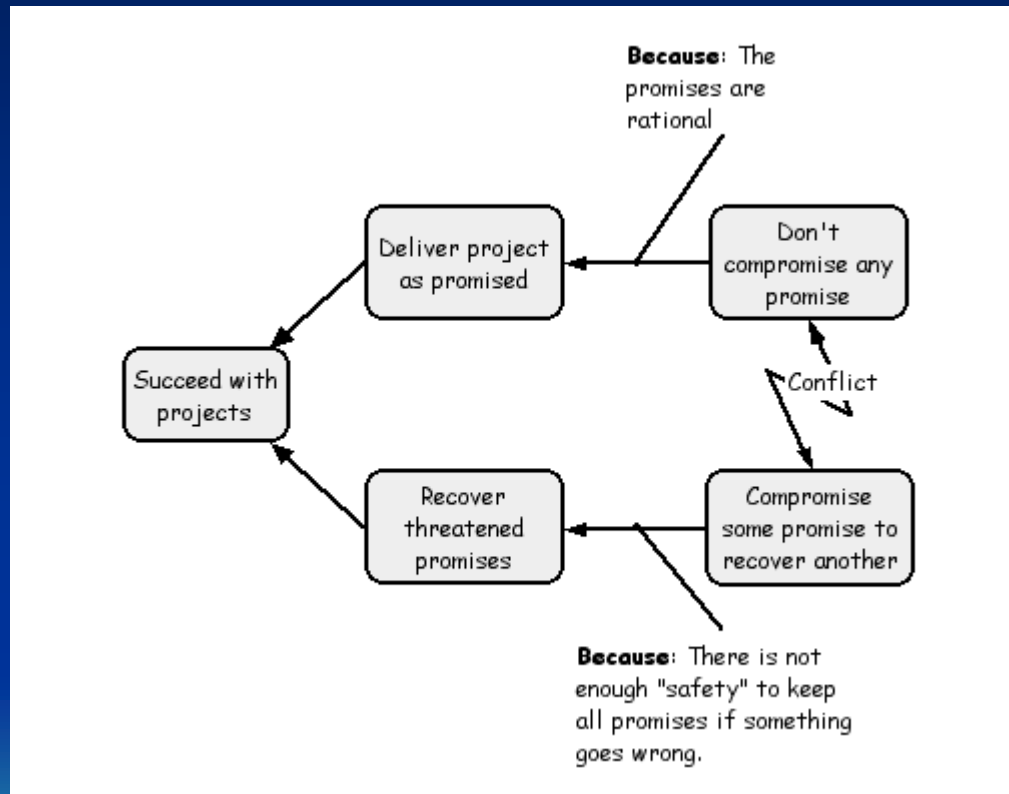
1st step : every activity is shorten to 50 % of its original time size.

2nd step : **critical path buffer** at the end of the project will have size of 50 % of the total sum of saved time created by shortening all partial activities

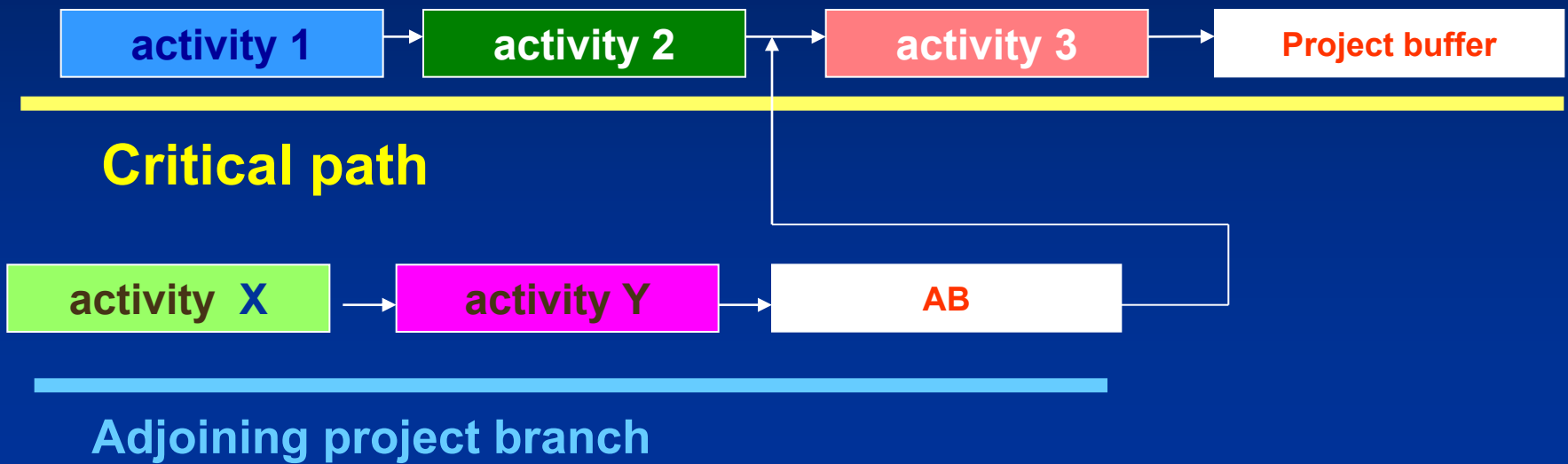
Simplified scenario CPM and CCPM



EC and project management



Critical path, adjoining branches of the project and adjoining buffers (AB)



Buffer serves as a safety tool to accumulate reasons of expected and unexpected delays

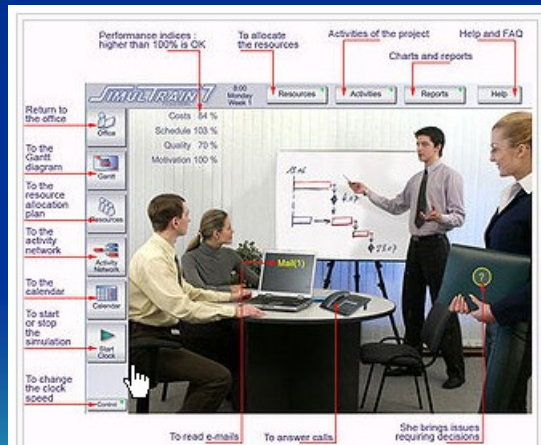
Critical Path (CP)

- Critical path is defined as **the longest way** (meaning time) from the starting point of the project graph to the ending point.
- Every project has at least one critical path
The rules of CP:
 - Every delayed task on CP will essentially delay the whole project
 - Truncation of duration of any task on CP will shorten whole project

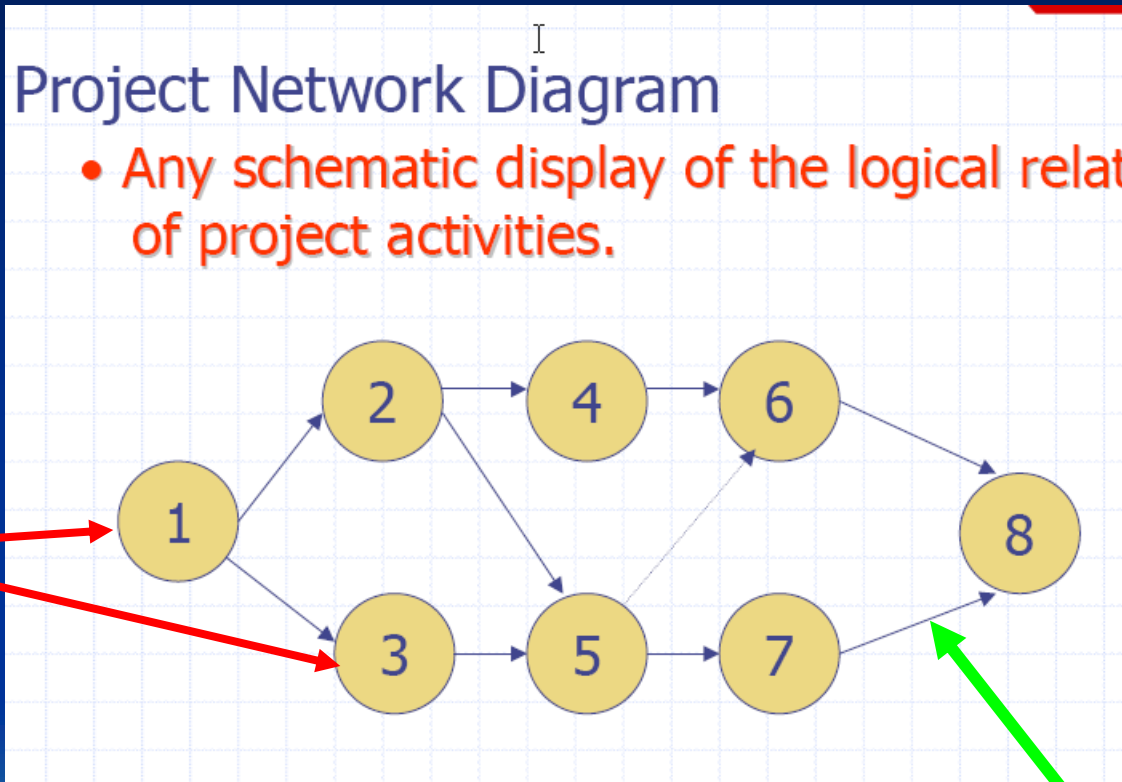


Critical Path (CP)

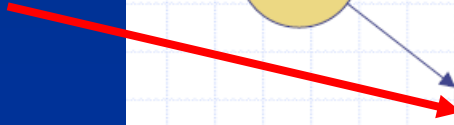
- **Critical Path Method**, abbreviated **CPM**, or **Critical Path Analysis**, is a mathematically based algorithm for scheduling a set of project activities. It is an important tool for effective project management.



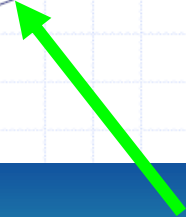
Critical Path (CP)



Milestones

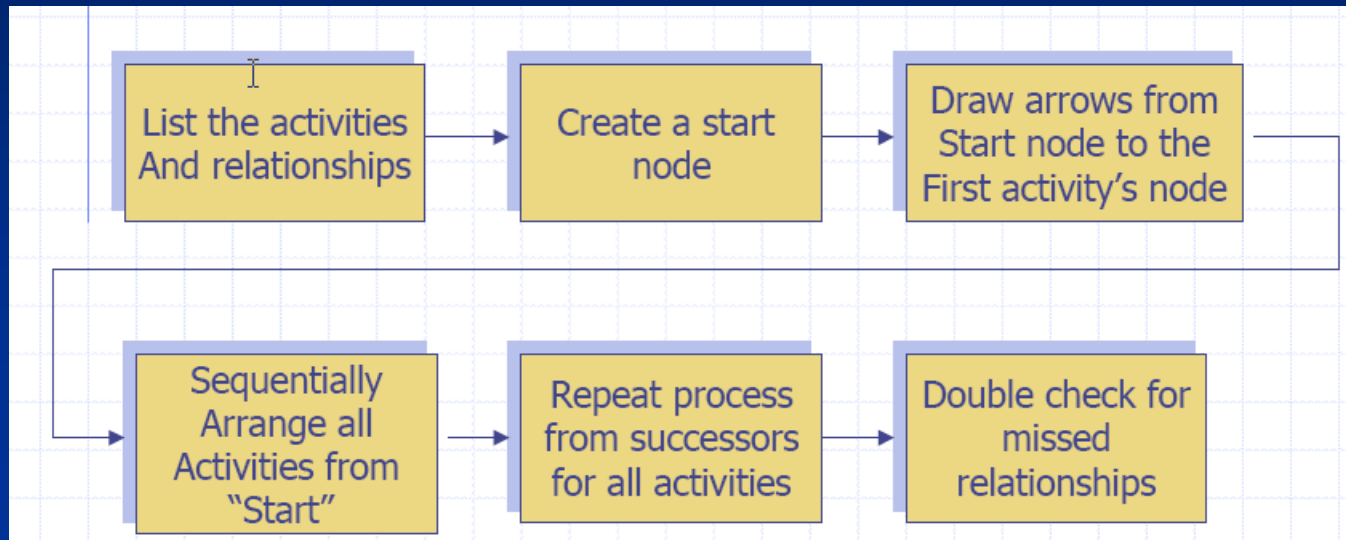


Activity



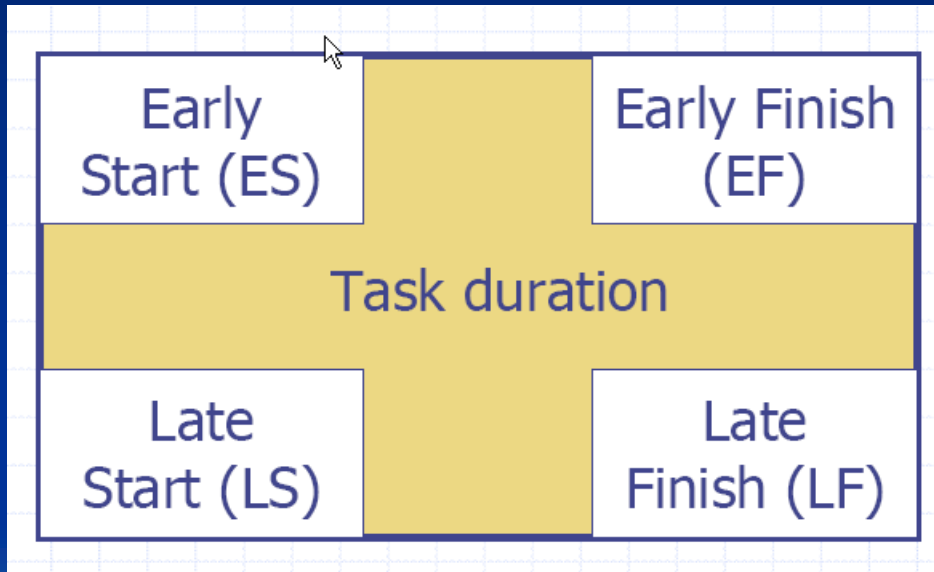
Critical Path (CP)

Building a diagram 1



Critical Path (CP)

Building a diagram 2



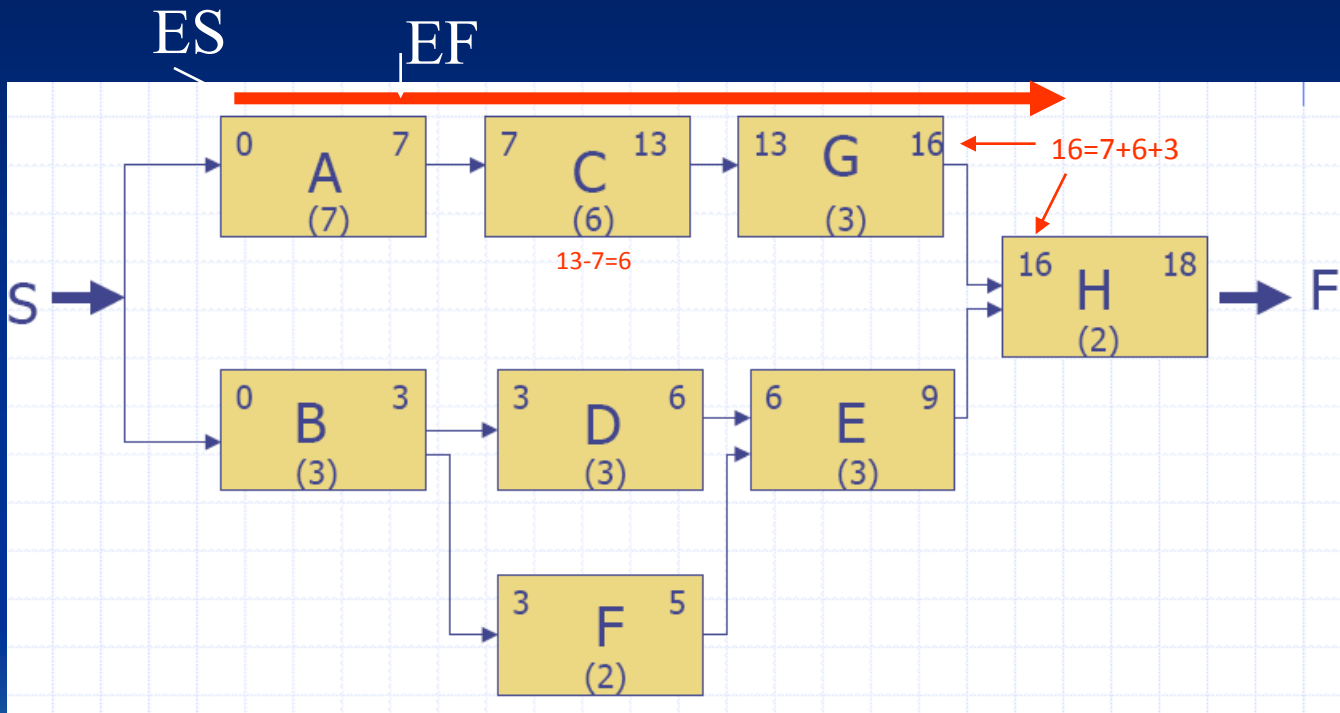
Critical Path (CP)

Building a diagram 3

| <i>Task ID</i> | <i>Duration</i> | <i>Dependency</i> |
|----------------|-----------------|-------------------|
| A | 7 | |
| B | 3 | |
| C | 6 | A |
| D | 3 | B |
| E | 3 | D,F |
| F | 2 | B |
| G | 3 | C |
| H | 2 | E,G |

Critical Path (CP)

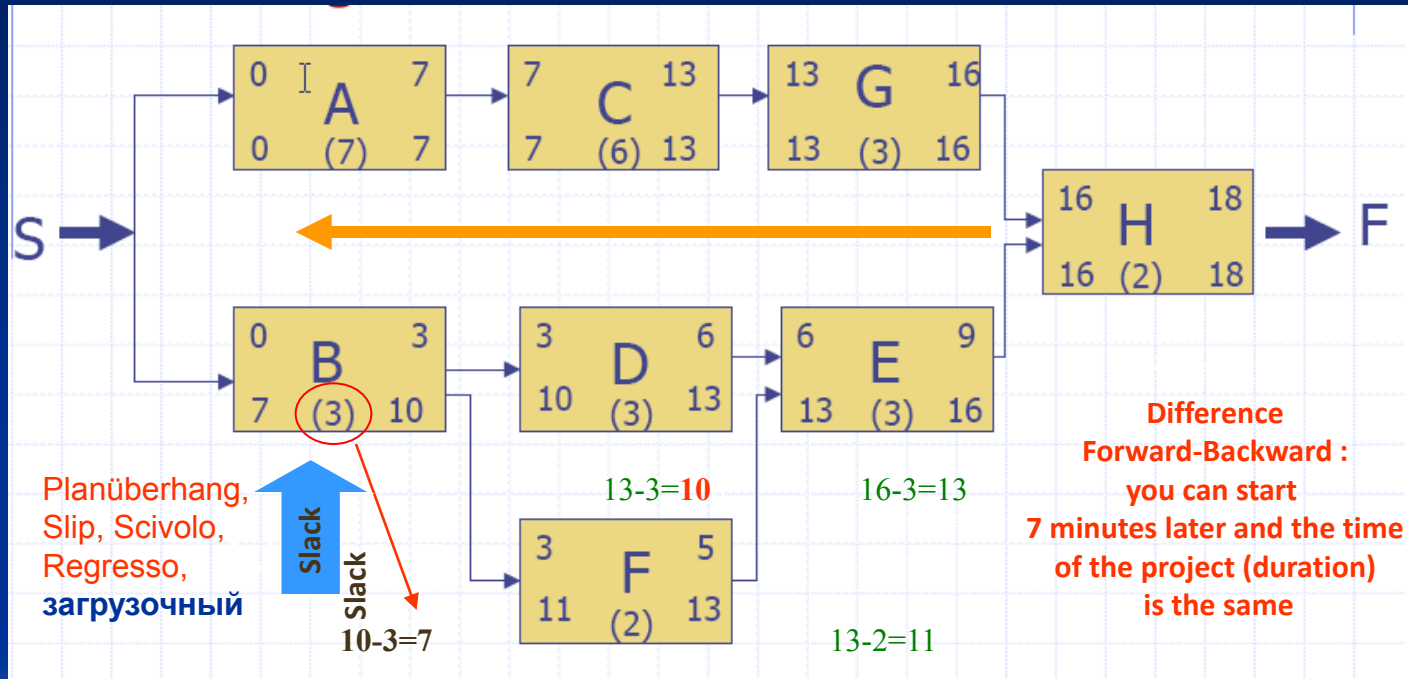
Building a diagram 4 – calculating the **FORWARD PASS**



Early Starts and Early finishes dates are calculated by means of **Forward Pass**

Critical Path (CP)

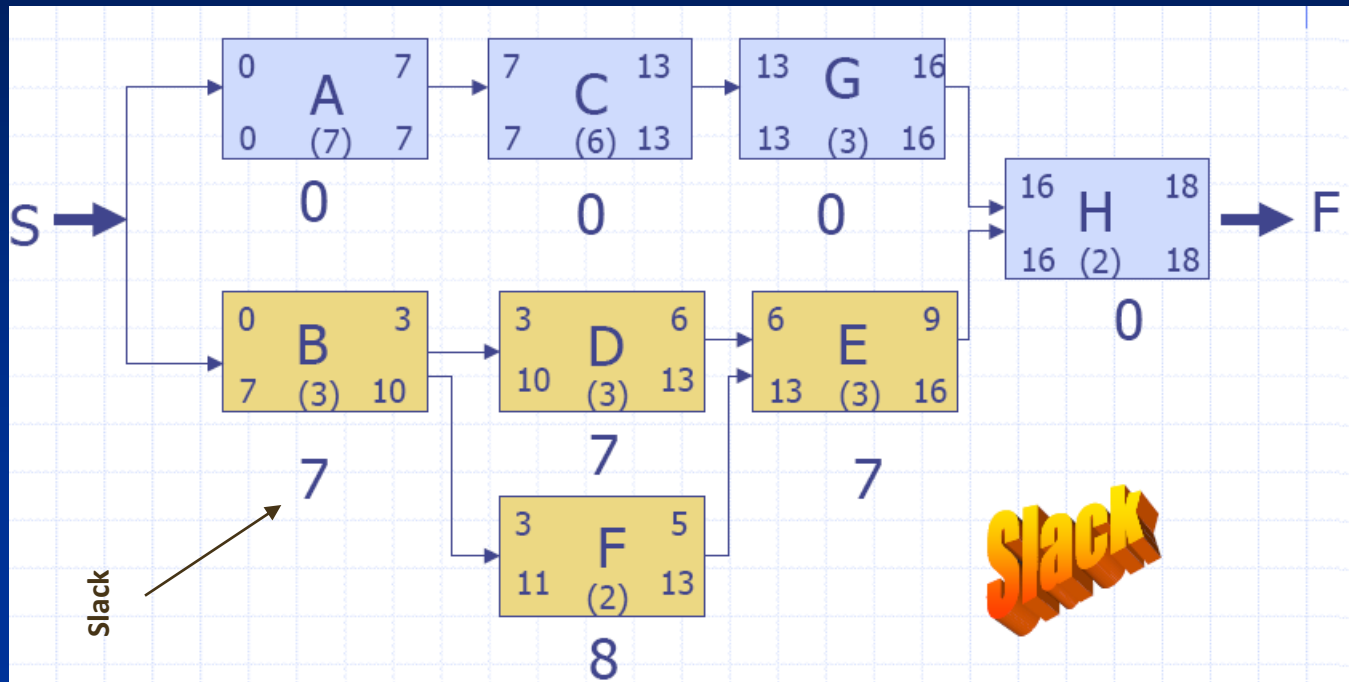
Building a diagram 5 – calculating the **BACKWARD PASS**



Late Starts and Late Finishes dates are calculated by means of Backward Pass

Critical Path (CP)

Building a diagram 6 – calculating the **FLOAT(SLACK)/CP**



Free Float: Amount of time a single task **can be delayed** **without** delaying the early start of any successor task = $LS-ES$ or $LF-EF$

Critical Path (CP)

CPM is helpful in :

- Project Planning and control.
- Time-cost trade-offs.
- Cost-benefit analysis.
- Reducing risk.



Critical Path (CP)

Limitation of CPM :

- Does not consider resource capacities.
- Less efficient use of buffer time.
- Less focus on non critical tasks that can cause risk.
- Based on only deterministic task duration.
- Critical Path can change during execution.



Multi-project Management

| | w1 | w2 | w3 | w4 | w5 | w6 | w7 | w8 | w9 | w10 | w11 | w12 | w13 | w14 | DAP |
|-----------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|
| Project 1 | ■ | | | ■ | ■ | | | ■ | ■ | | | ■ | | | 12 |
| Project 2 | | ■ | ↗ | | ■ | ■ | | ↗ | ■ | ■ | ↗ | | ■ | | 12 |
| Project 3 | | | ■ | | | ■ | ■ | | | ■ | ■ | | | ■ | 12 |
| | | | | | | | | | | | | | | | 36 |

Bad multitasking causes, that one project will be significantly longer and no other project will be shorter



| | w1 | w2 | w3 | w4 | w5 | w6 | w7 | w8 | w9 | w10 | w11 | w12 | | | DAP |
|-----------|----|----|----|----|----|----|----|----|----|-----|-----|-----|--|--|-----|
| Project 1 | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | 6 |
| Project 2 | | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | 6 |
| Project 3 | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | 6 |
| | | | | | | | | | | | | | | | 18 |

Multitasking characterization

- people always **overestimate the length of their tasks**
- **salesman offers impracticable terms (dates)**
- The fight for reserves (capacities) causes, that all saved time is fully wasted (Student s syndrome)
- **Reserves (if any) are used badly !!!!!**
- Bad use of reserves causes lack of transparent assignment
- Non transparent priorities are parents of bad multitasking
- **Bad multitasking causes longer duration of all activities (tasks) and thus all the projects**



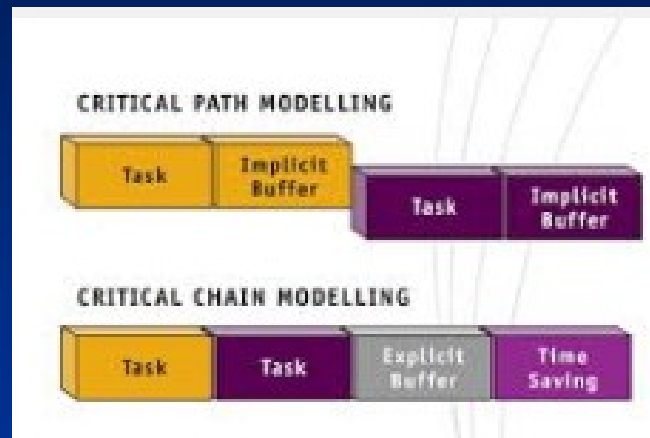
CP definition (more in detail)

Critical path is defined as the longest way (meaning time) from the starting point of the project graph to the ending point

Critical path represents technological dependencies and given times of every task on Critical path inclusive of necessary condition for fulfilment of foregoing tasks (activities) framed by integration points.



Critical chain



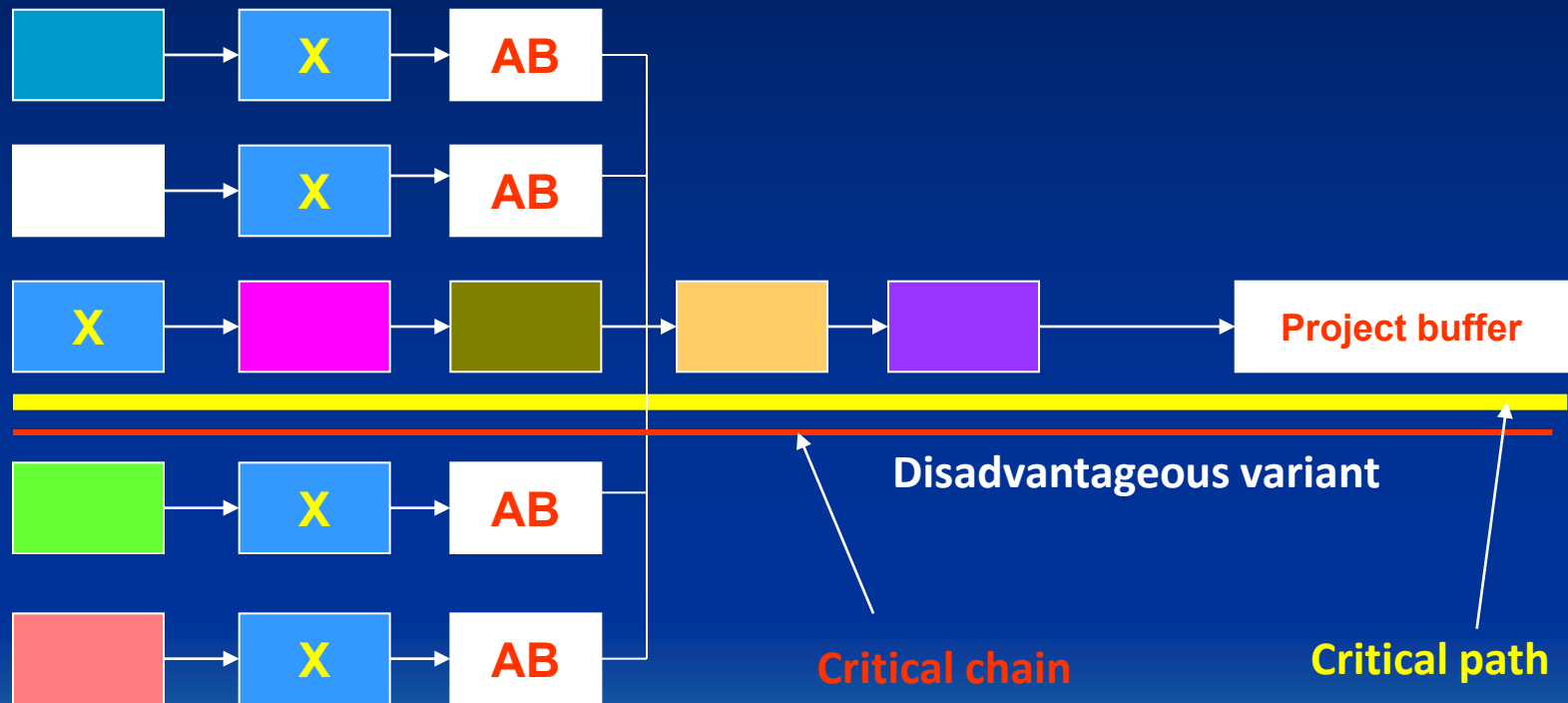
Critical chain definition

In TOC the **Critical chain** is defined as the longest way (meaning time) from the starting point of the project graph (Gantt) to the ending point which takes into account **technological dependencies** as well as time of the tasks and moreover, **capacities of assigned resources**.

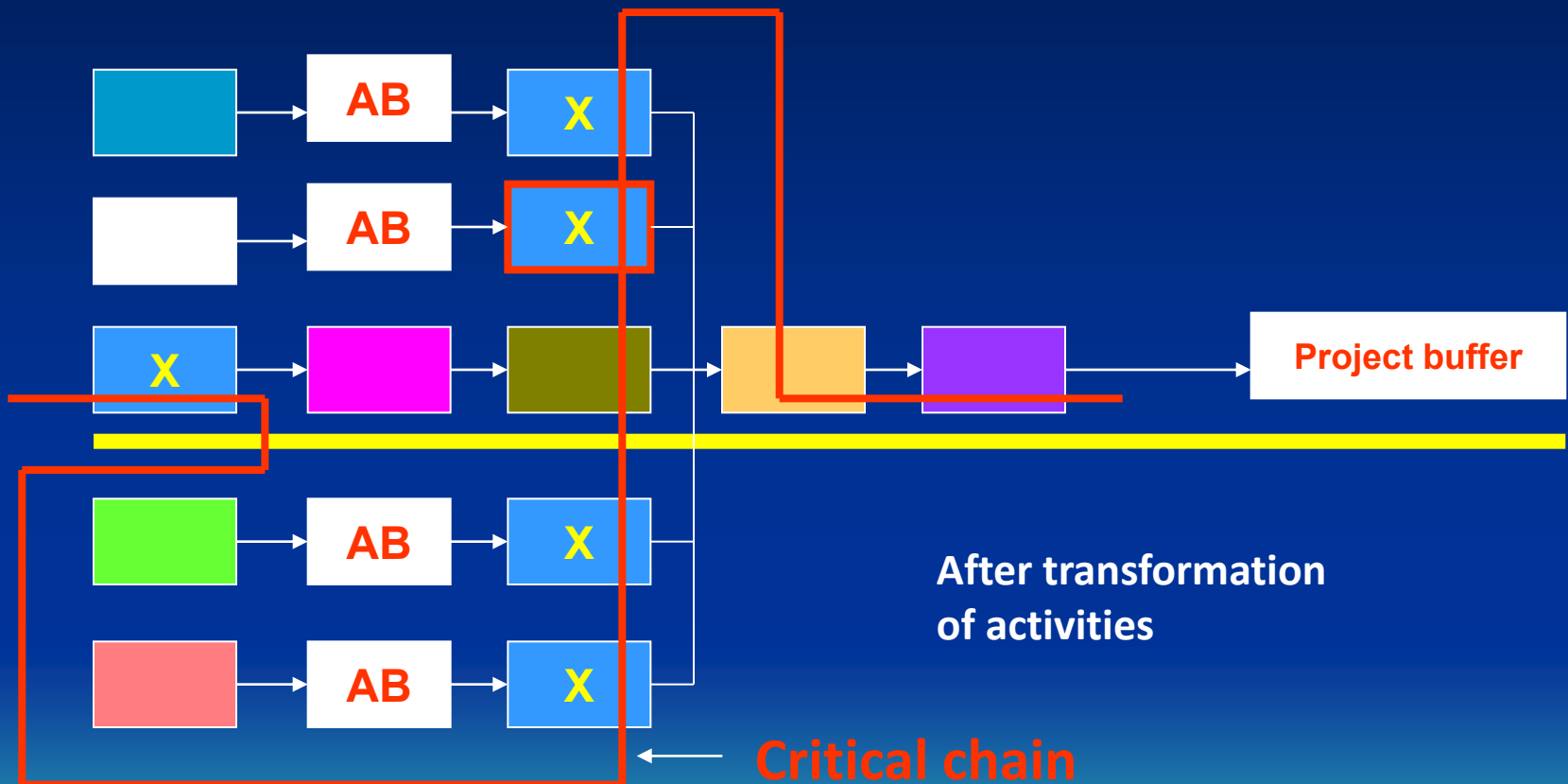
With infinite capacities of resources you can consider Critical path=**Critical chain**



Multi-project management and critical resources (CCR) used in more than one project branch



Multi-project management and critical resources (CCR) used in more than one project branch



Project management based on remaining time in buffers – **Buffer Management**

- Buffers are used for timely warning and that is to say predicting and avoiding future problems related to project deadlines (milestones)
- It is also used as a guideline for corrective actions

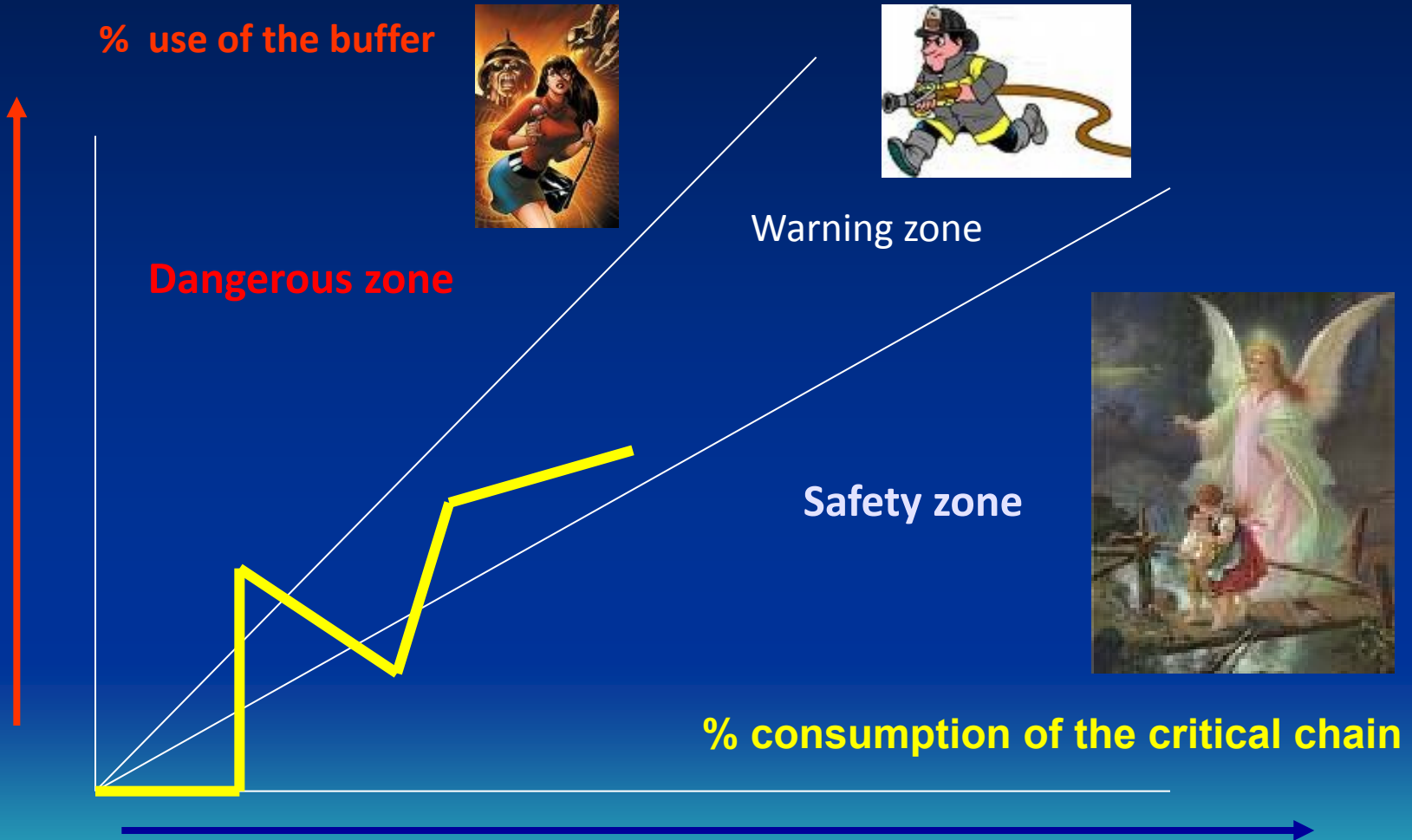


Basic metrics showing the project status

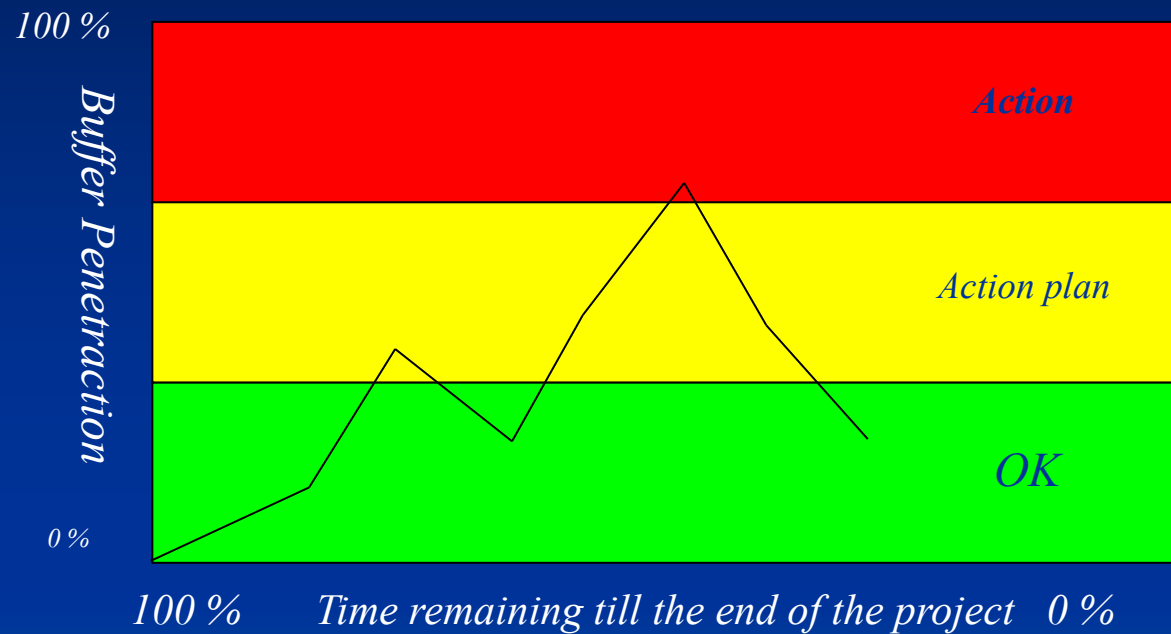
- The partial size of Critical chain (CC) fulfilled in days (in %)
- How much of buffer size was used to fulfil above mentioned partial size of CC ?
- Trend of project (buffer consumption graph- [see next slide](#))
- Consumption of the financial buffer
- Priorities – bigger buffer penetration- bigger priority
- Adjoining branches have always lower priorities
- It is not allowed to create bad multitasking



Trends of the project



Trend of the project advancement – (another angle of view)

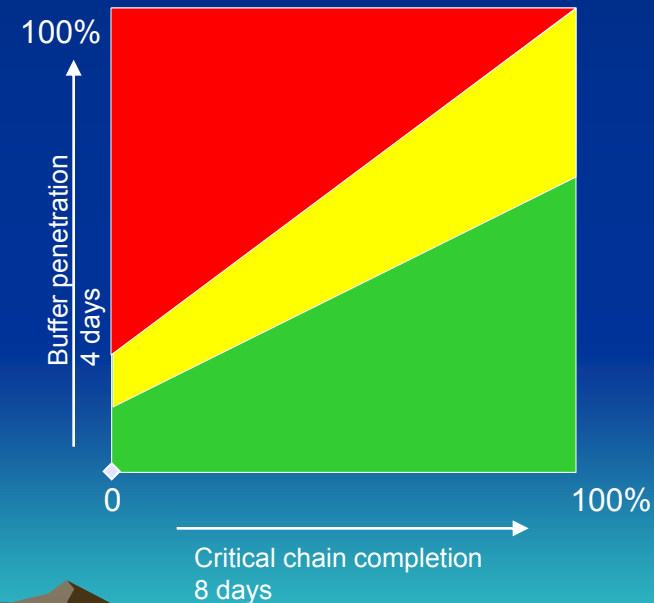


Resource: DP R.Jurka (2006); taken from LEACH, L., P. (2004), s. 12.

Planning - principles

We are working with plan , which takes into account different times of tasks :

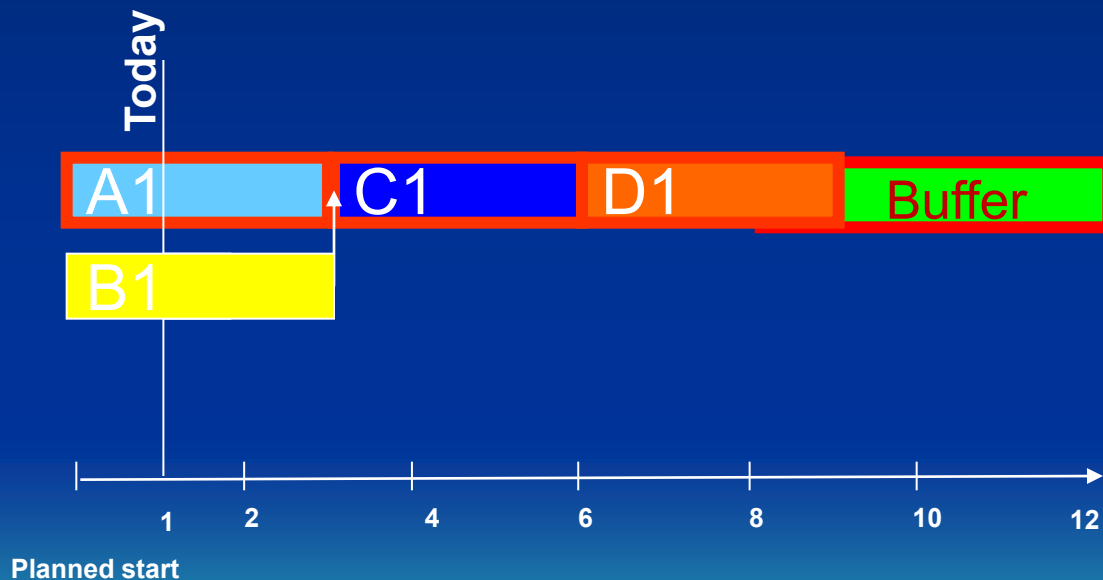
- start of the tasks are changed based on termination of preceding tasks
- you have to react in project in such a way , that handover is done as a baton pass during races



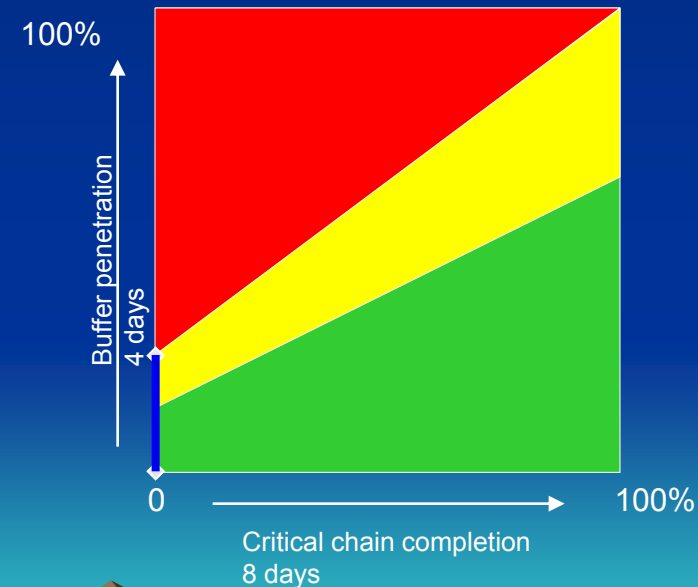
Plan with sharp deadlines with buffers 50% ($2+3+3=8$ $8+4=12$)

Planning - principles

A1 did not start yet, because this A1 resource is still working on another order (task), which may be part of another project
B1 already started and for completion will need another two days

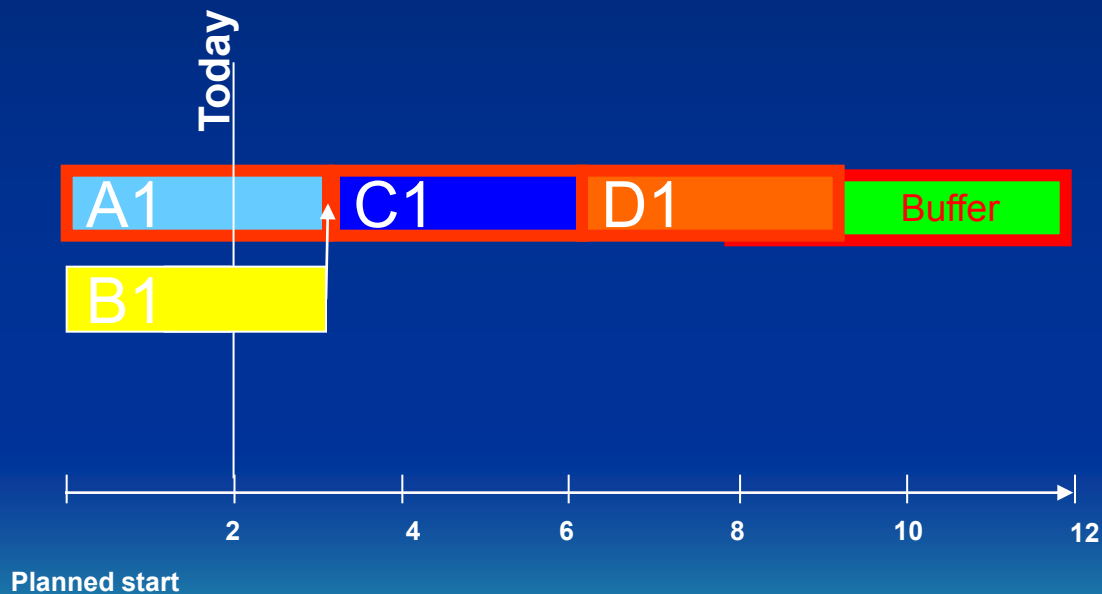


Plan with sharp deadlines with buffers 50% ($2+3+3=8$ $8+4=12$)

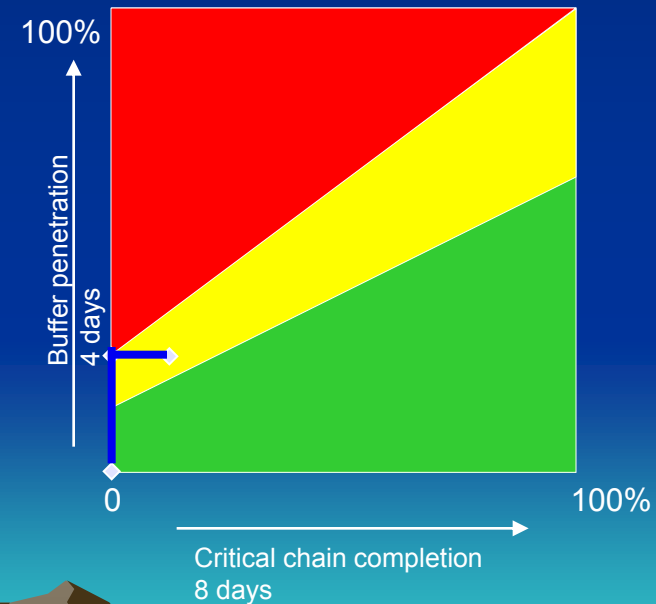


Plan 2nd day after start

A1 started and will be finished (completed) tomorrow.
B1 will be finished (completed) tomorrow

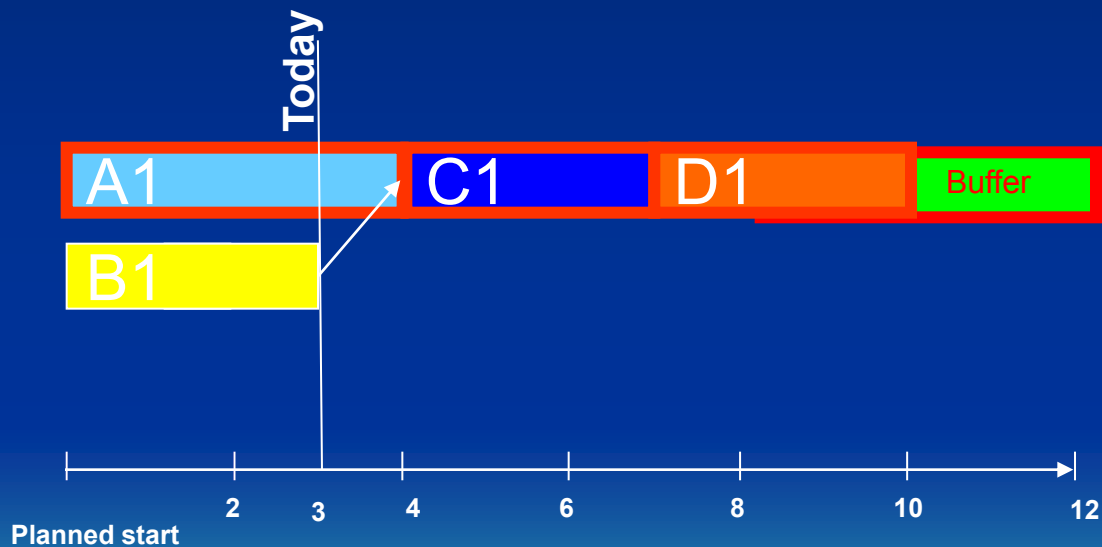


Plan with sharp deadlines with buffers 50% ($2+3+3=8$ $8+4=12$)

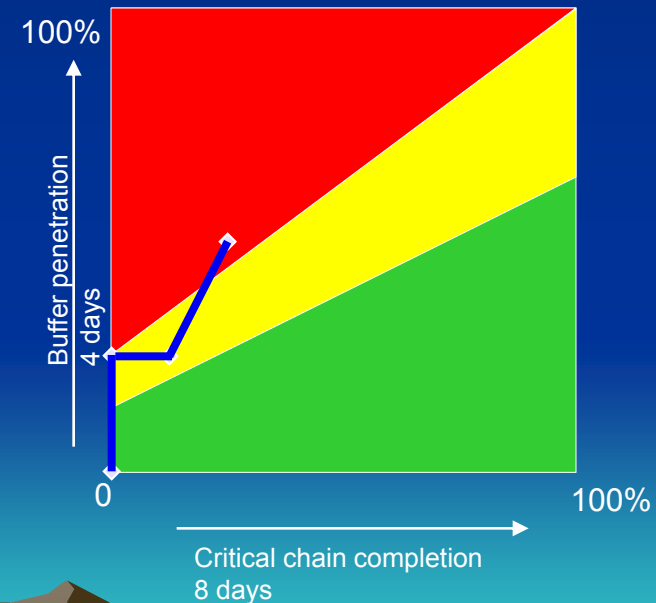


Plan 3rd day after start

A1 despite all efforts resource A1 needs another day to complete.
B1 has completed his work with 2 days delay



Plan with sharp deadlines with buffers 50% ($2+3+3=8$ $8+4=12$)



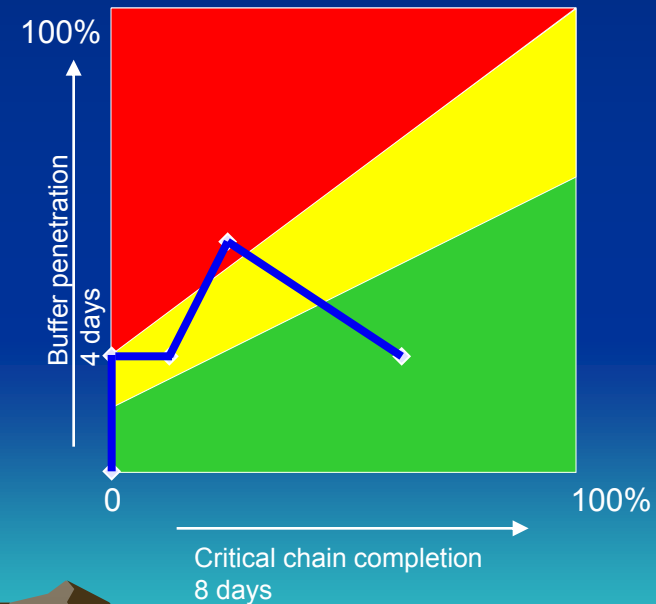
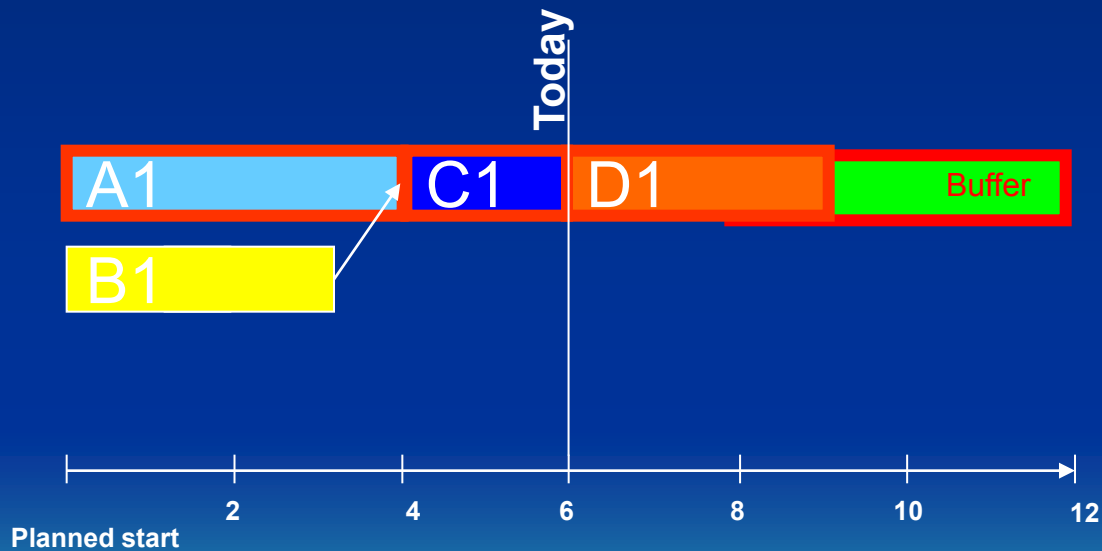
Plan 6 day after start

A1 completed his task with 2 days delay

B1 completed his task with 2 days delay

C1 completed his task 1 day earlier than expected (planned)

D1 will start to work tomorrow



Plan with sharp deadlines with buffers 50% ($2+3+3=8$ $8+4=12$)

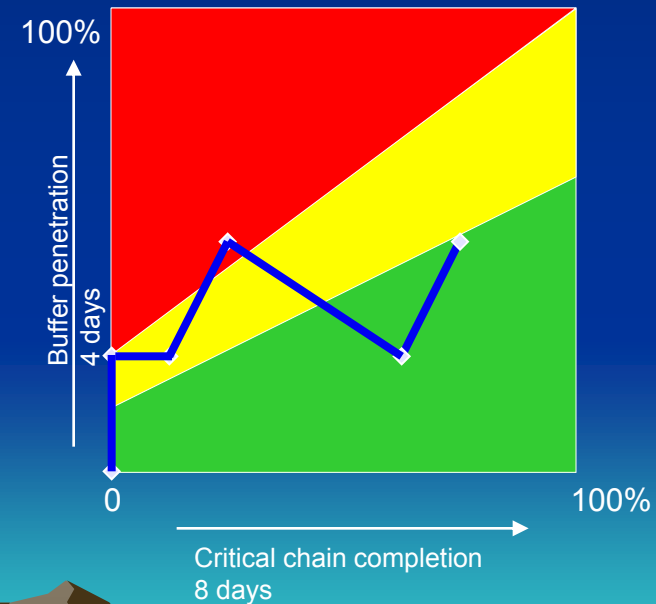
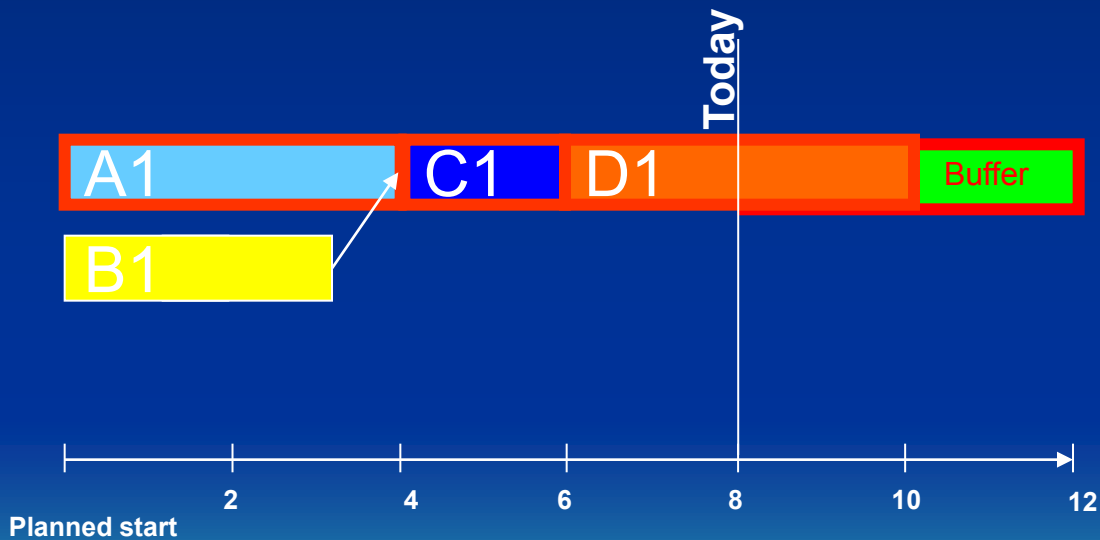
Plan 8 day after start

A1 completed his task with 2 days delay

B1 completed his task with 2 days delay

C1 completed his task 1 day earlier than expected (planned)

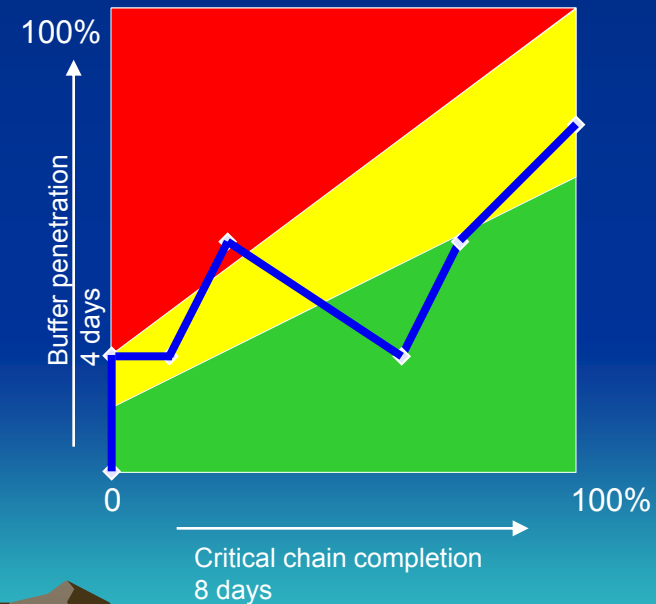
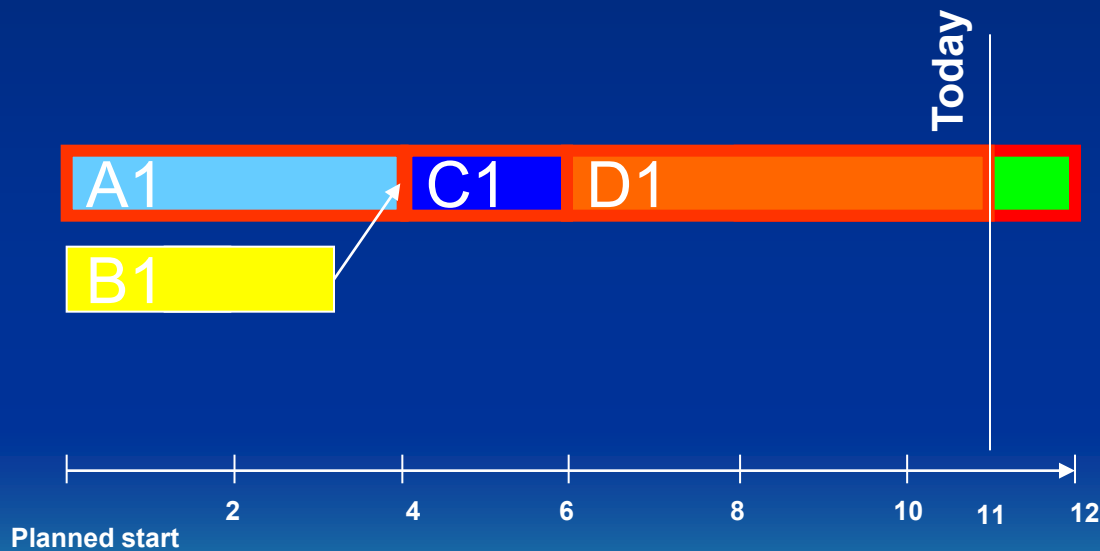
D1 needs one day more to complete



Plan with sharp deadlines with buffers 50% ($2+3+3=8$ $8+4=12$)

Plan 11 day after start

- A1 completed his task with 2 days delay
- B1 completed his task with 2 days delay
- C1 completed his task 1 day earlier than expected (planned)
- D1 completed his task with 2 days delay



Plan with sharp deadlines with buffers 50% ($2+3+3=8$ $8+4=12$)

Clear way to setup and control priorities.

Setup of priorities of partial tasks based on assigned reserves.

Do as good as you can, but only where it is needed



Project Quick, resources **A-E** and activities **X,Y,Z,V**, and **W**

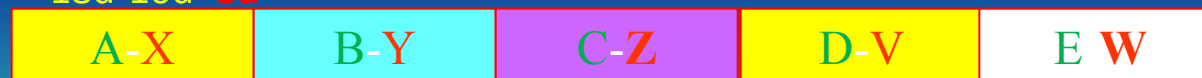
| Resource and activity | Median of the required time |
|-----------------------|-----------------------------|
| A-X | 10 days |

Activity=Task

A (John) X (ERP Training)

You can say, that 50 % of any activities finish earlier, and other **50 %** will be delayed, meaning, that **10 days** represents **50 %** of the estimated time for chosen activity

Project managers decided, that activity ends if **90 %** of estimated time will be consumed. It means, that they add a time buffer of **8 days** (for the safety reasons). $10d = 50\%$, $20d = 100\%$, $2d = 10\%$, $20d - 2d = 18d$ ($90\% = 100\% - 10\%$), $18d - 10d = 8d$



5 x 10 days = 50 days

Time distribution



Five activities (tasks) and applied modifications

- If we consider for every activity time buffer 8 days we will get :

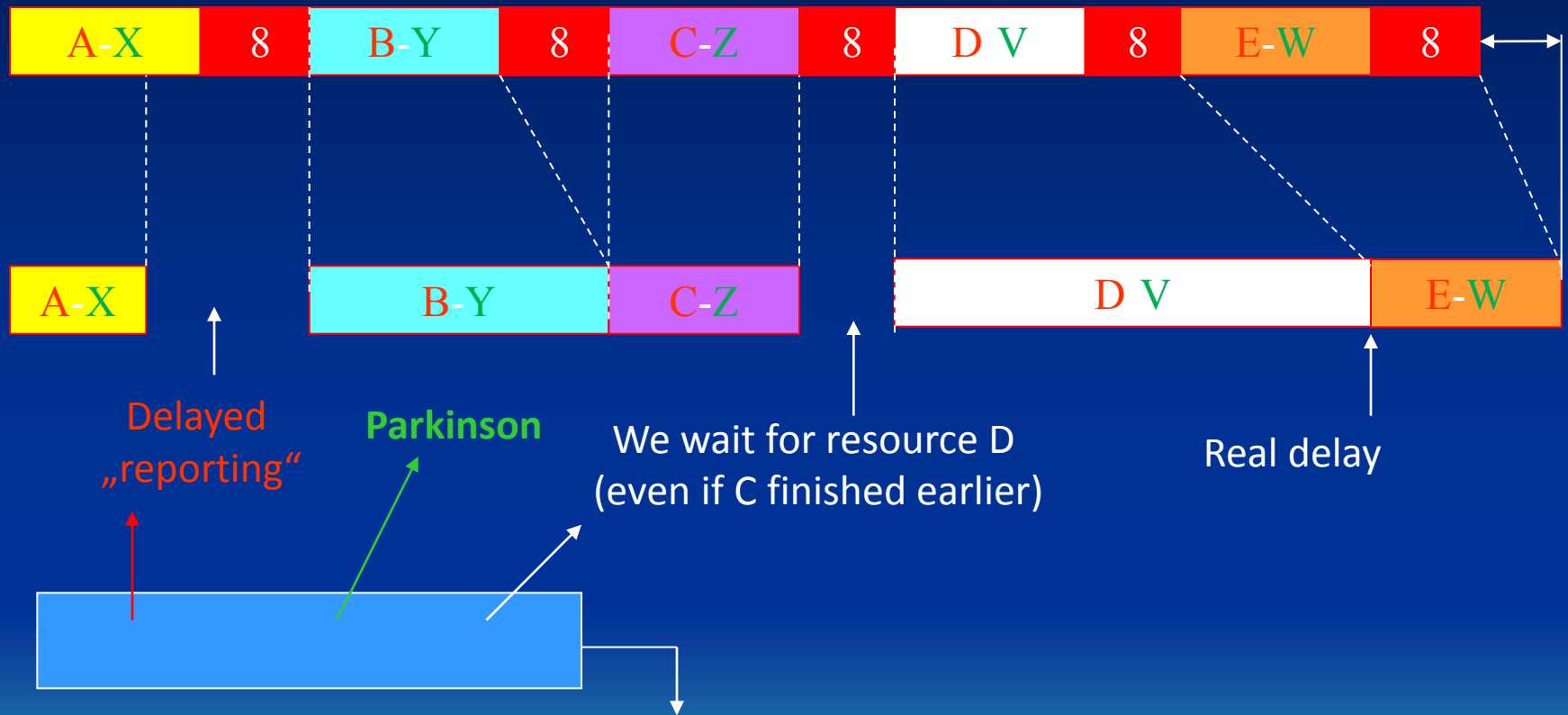


5 x 10 days = 50 days



5 x 18 days = 90 days

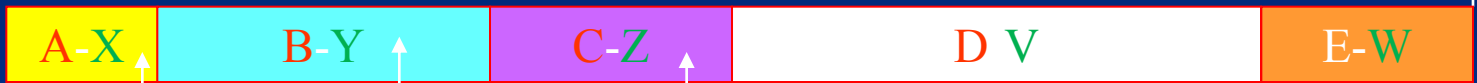
Five activities and modifications (added buffers) and four types of troubles



No one trouble causes project delay taking into consideration planned delivery date (agreed date of the project).

Dissipation of acquired time reserves was caused by company strategy saying strictly stick to the planned project schedule (example of rigid management)

Five activities after modification (buffers united to one and placed to the end of the project)



Parkinson

Little bit longer than 20 days median but shorter than 18 days

Earlier end of activity A

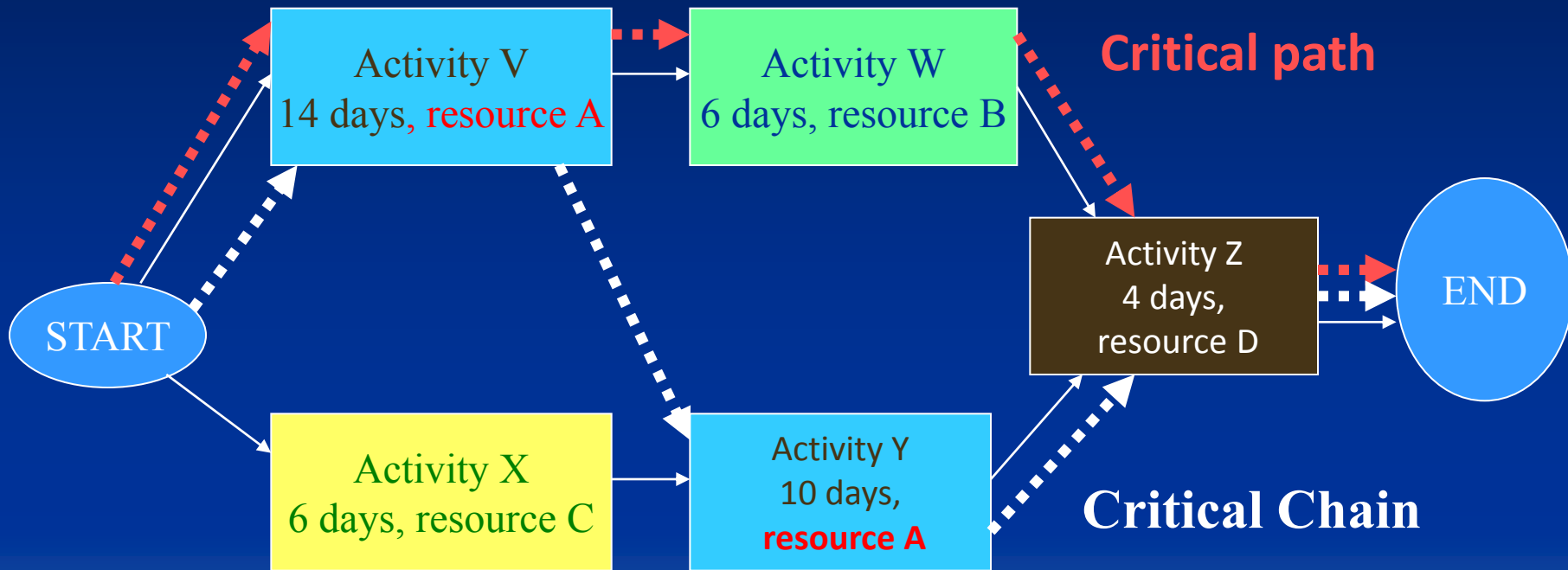


= CPB=current project buffer = 40 days



= new buffer = 50 % out of CPB, which makes CPB/2

Critical path- Critical chain



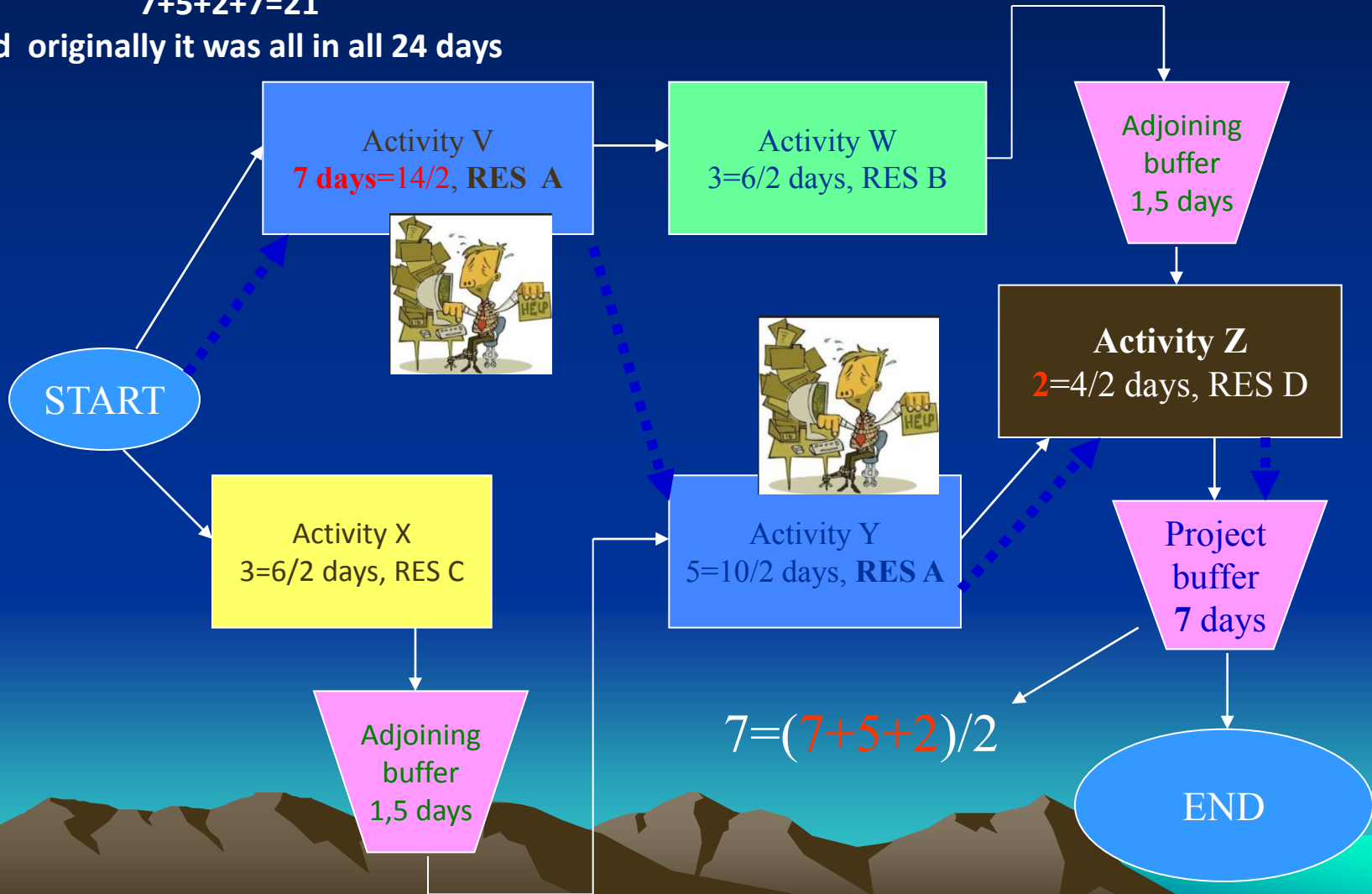
Project is considered as successful if is finished in expected time and financial budget is not exceeded

Critical chain with buffers

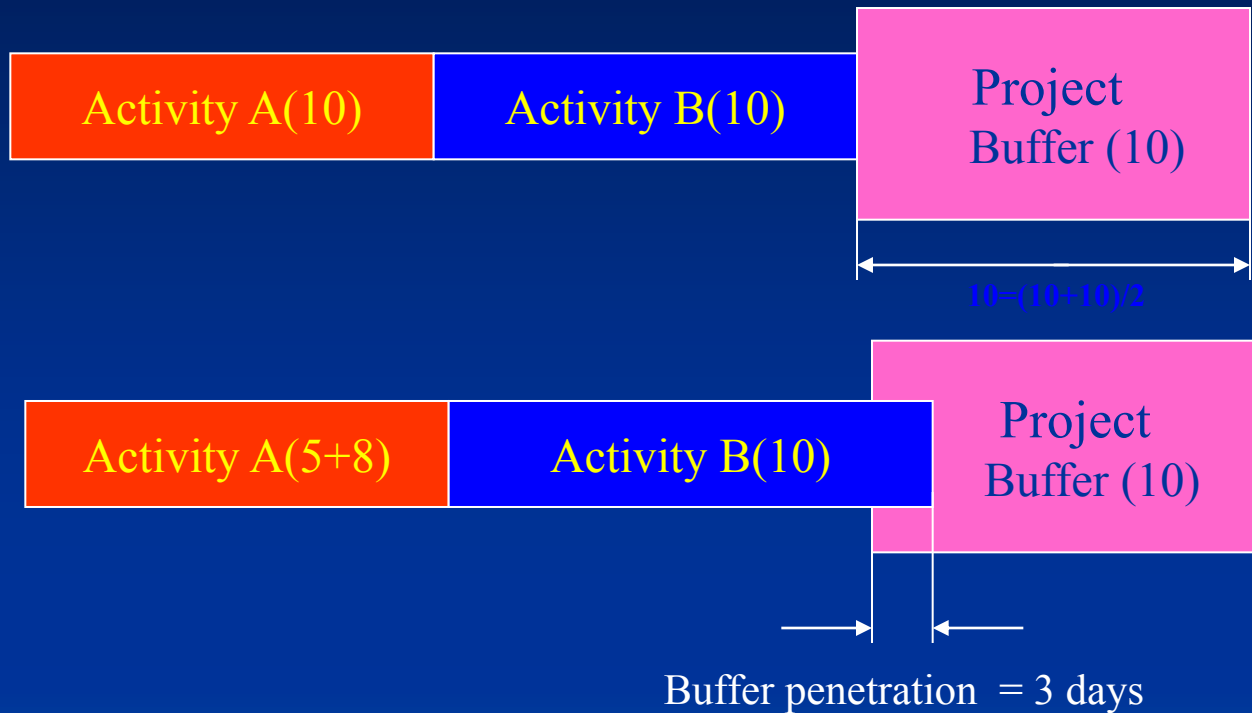
Length of the Critical Chain:

$$7+5+2+7=21$$

and originally it was all in all 24 days




Buffer consumption

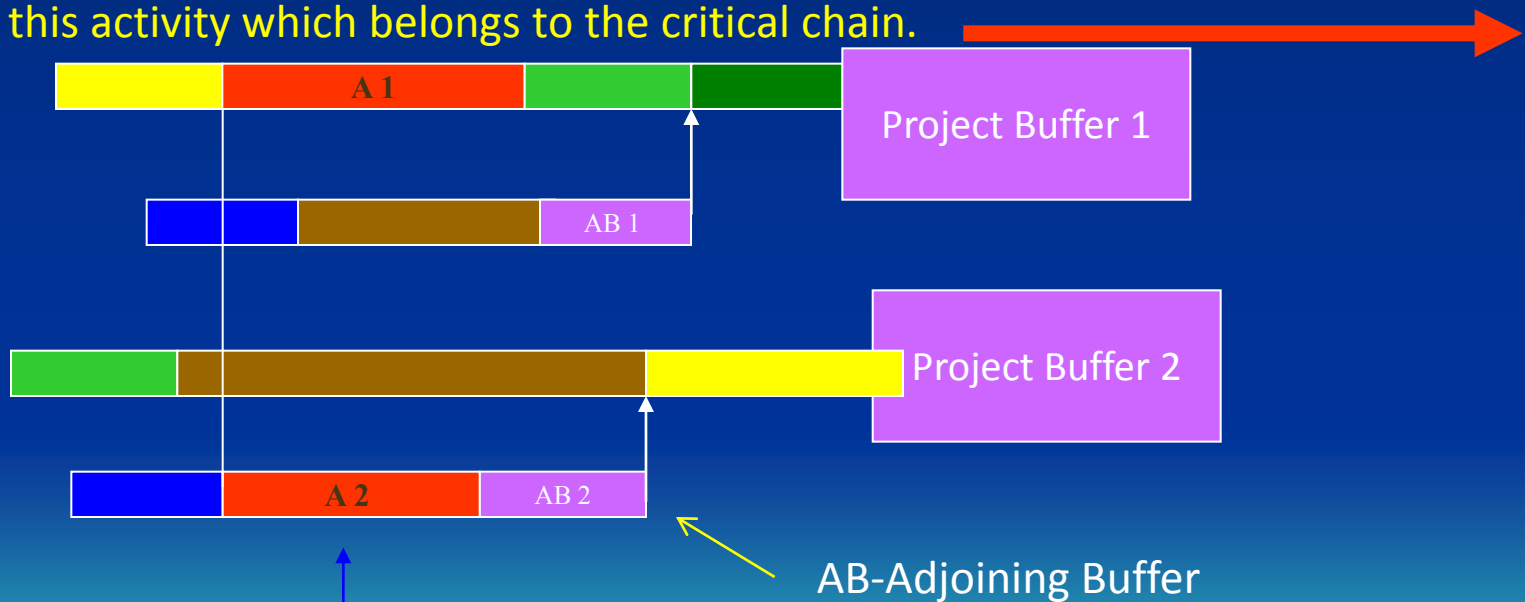


Rate of penetration is used to assign priorities to the partial activities



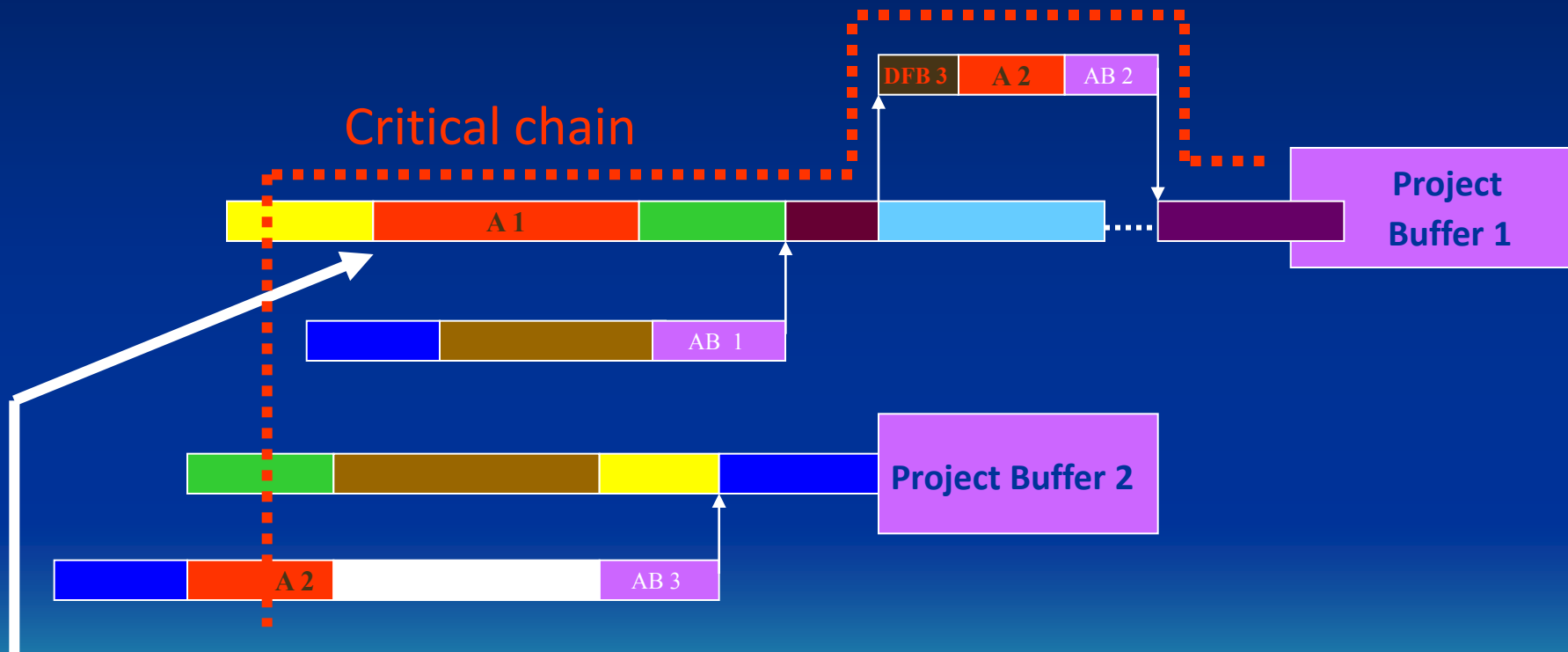
Priorities assigned to resources

- If one resource have to be assigned to two activities starting in the same moment so the first activity which will start is the one belonging to the project with bigger project buffer penetration
- If none of all project buffers were penetrated with previous activities, so the first starts this activity which belongs to the critical chain. 




A2 starts first because PB 2 is partially consumed (penetrated)

Priorities assigned to resources



This activity starts first because it is a part of the Critical chain and Project Buffer 1 is penetrated

Main benefits of the Critical Chain (CC) usage

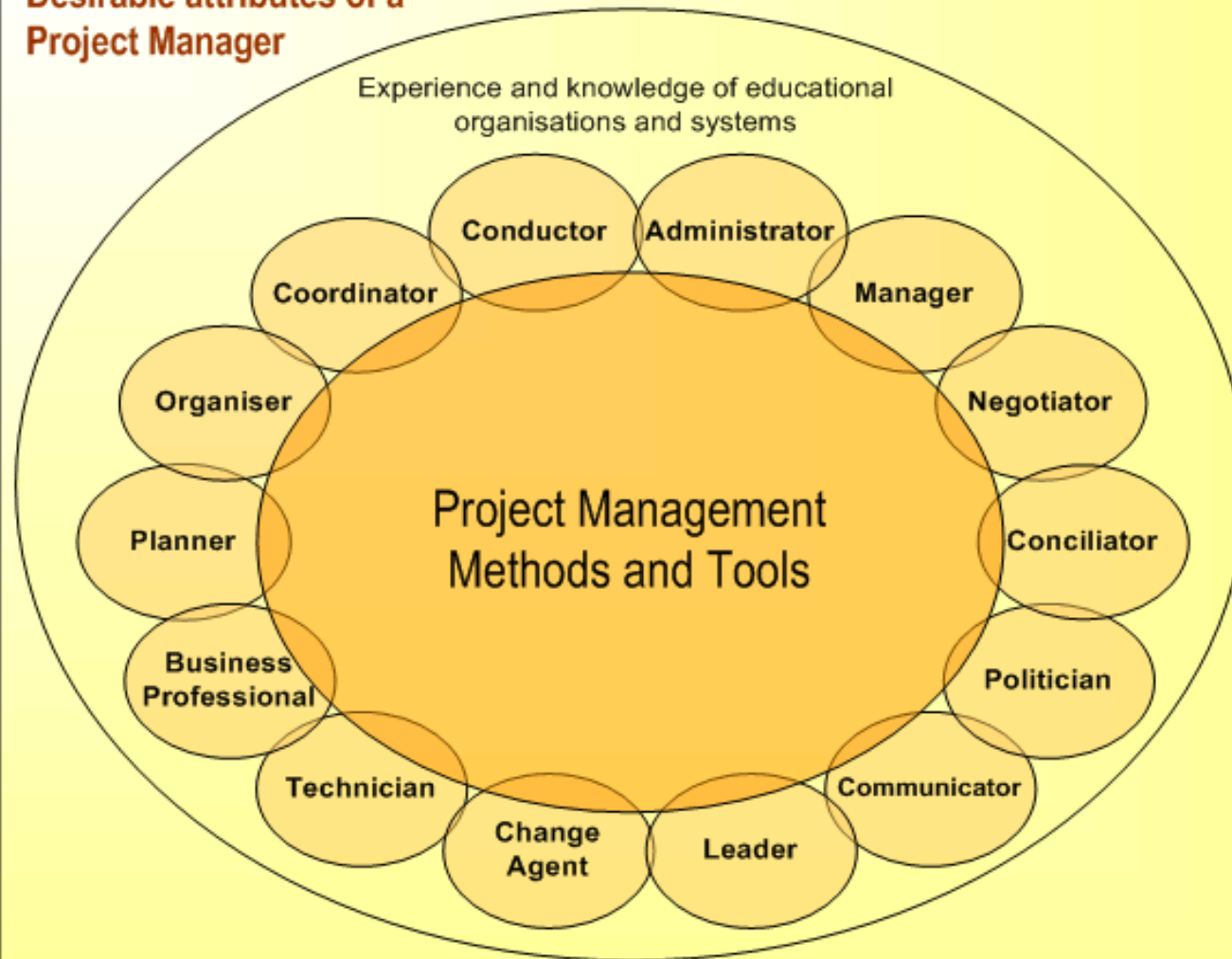
- Every single project ends significantly earlier, than projects where other project management methods than CC were applied
 - Total time needed to end more project than one is markedly shorter
 - Promised delivery times are fulfilled with higher rate of credibility
 - You will have more free capacity of all used resources
- 

Main benefits of the Critical Chain (CC) usage

- Better initial estimation about project timing and thus more accurate planning
- During starting of the projects you did not meet any problem taking into consideration drum resource
- Decrease of unfavourable effects such as Student syndrome, Murphy attacks and impacts of Parkinson's laws by redeployment and integration of all buffers to one and only one project buffer at the end of the project
- Utilization of benefits caused by earlier ended activities
- Use of reporting system which provides you with valuable information of buffer penetration, the extent of time reserves and thus better helping system for assigning priorities



Desirable attributes of a Project Manager



Thanks for Your Attention

