Introduction to the Theory of Constraints

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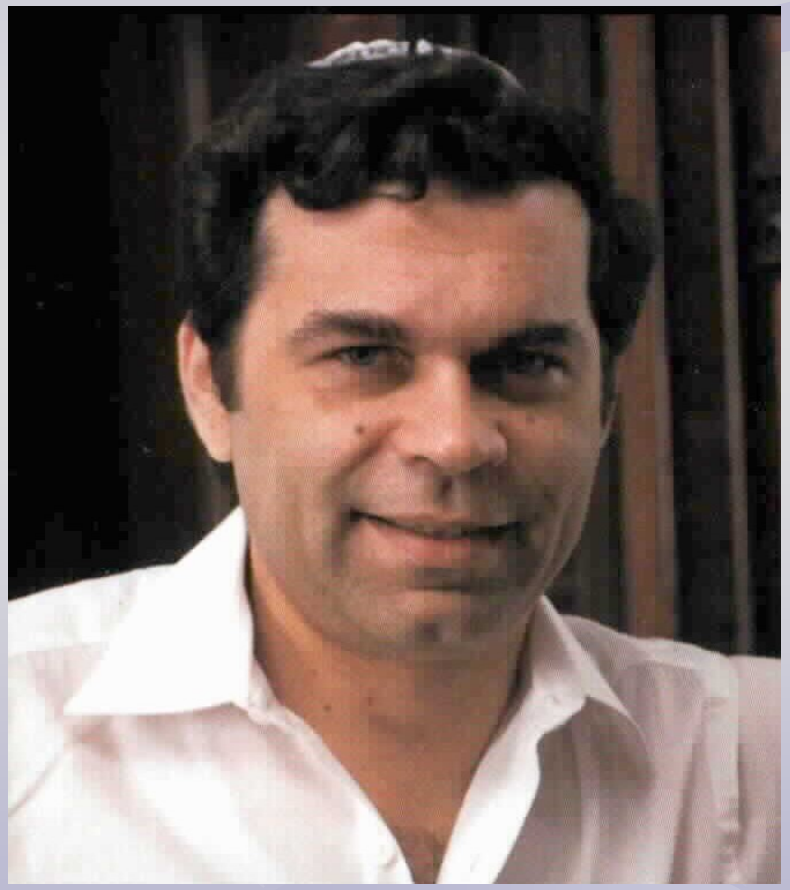
Introduction

- Theory of Constraints - TOC) was formulated approximately in 1980 in the USA. Some important roots of this theory were connected to the ideas incorporated in programs for planning and production control (Optimized Production Technology)

Introduction

- Author: Eliyahu Moshe Goldratt



The Goal by Eliyahu Goldratt

- The goal of a manufacturing company?

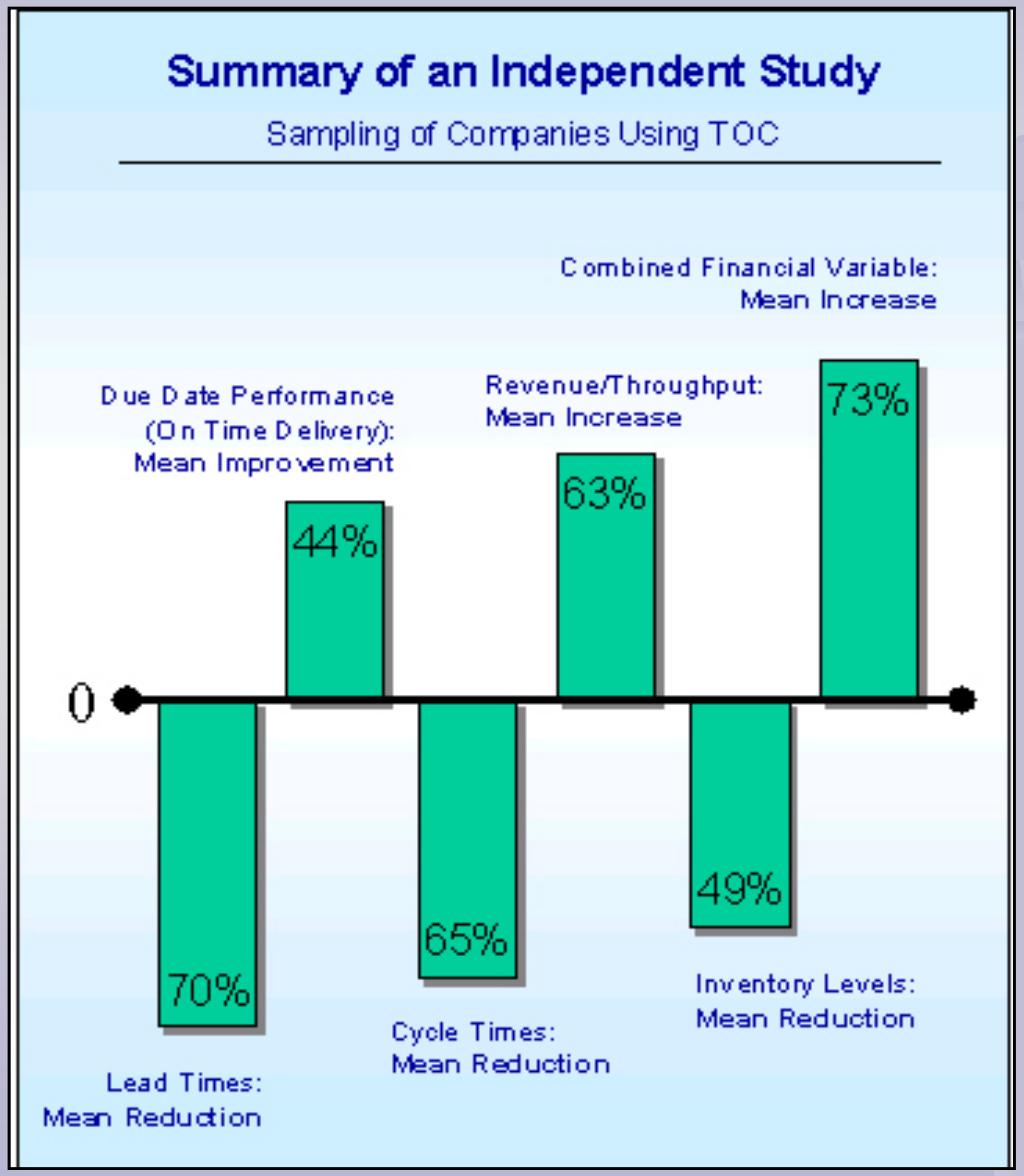
Make money !!!

Introduction -novels

TOC has became popular particularly thanks to the novels :

- The Goal - A Process of Ongoing Improvement
- It´s Not Luck
- The Race
- The Critical Chain
- The Haystack Syndrome
- Necessary But Not Sufficient
- Late night discussion
- TOC was together with TQM (Total Quality Management) and JIT (Just-In-Time) classified as one of the most important managerial methods of the last two decades of the twentieth century .

Some impacts of **TOC** implementation



Some impacts of **TOC** implementation

Ford Motor – Electronics Div.

Revenue: $3,000,000,000

Number of employees: 15,000

Implementation Date: 1991

TOC Applications: DBR

Comment: **D**rum-**B**uffer-**R**ope **(will be explained later in this course)**

Some impacts of **TOC** implementation

IMPLEMENTATION RESULTS

Inventory Decrease: Reduced 100 million dollars (50%)

On-time performance: From 89% - to 98%

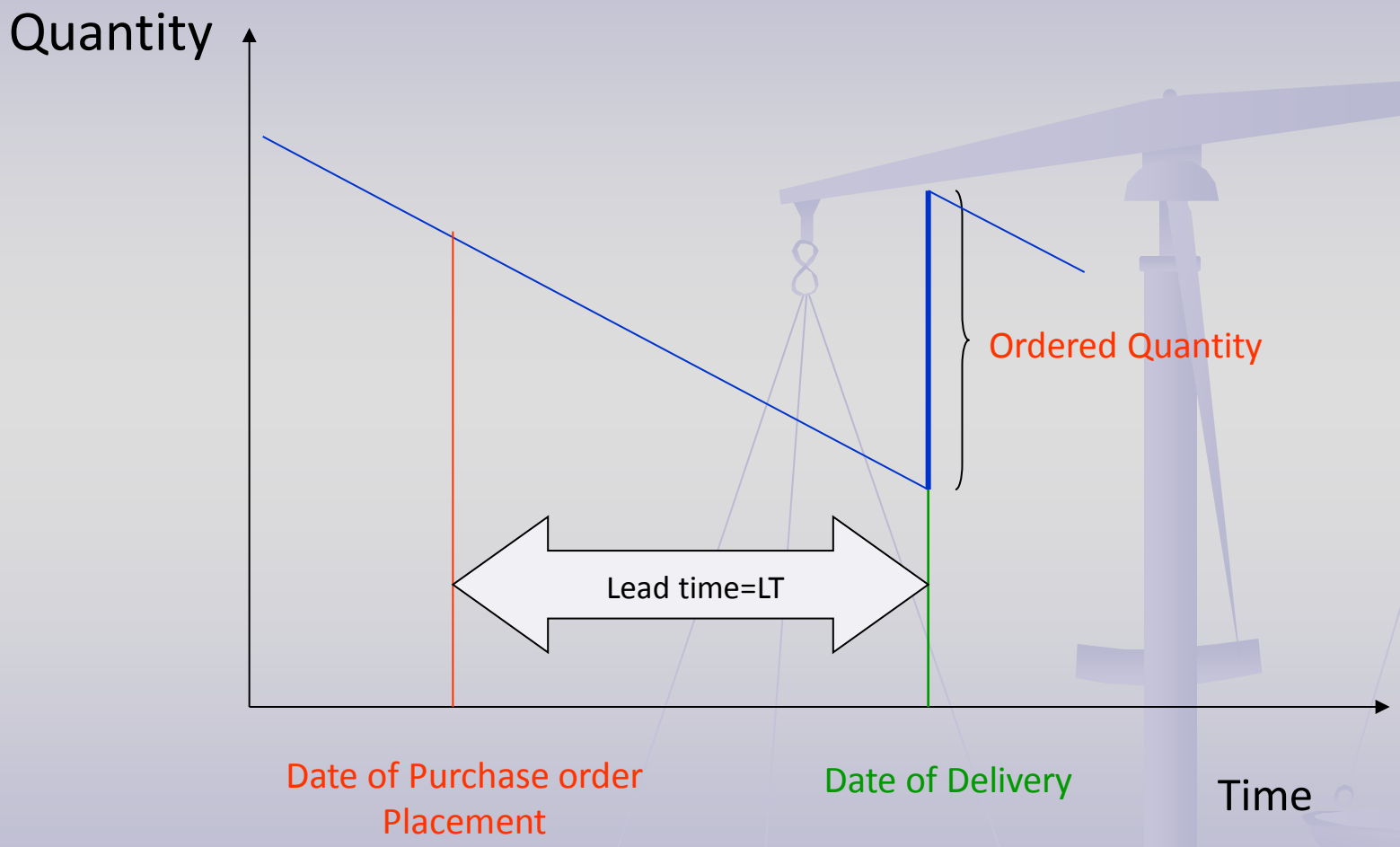
Lead times: From 6.4 days with JIT to 2.6 days

Cost efficiency: Reduced floor space by 57%

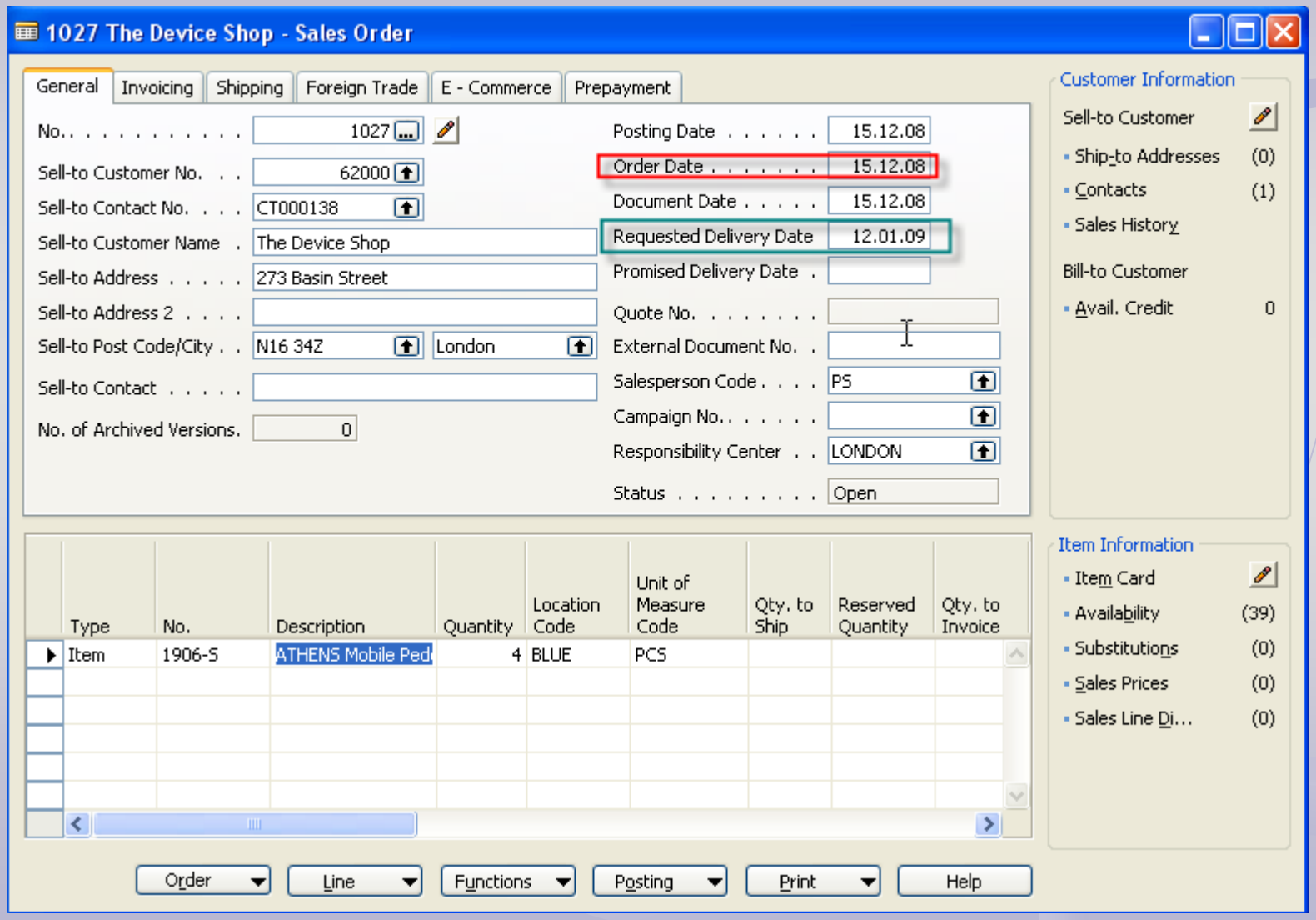
Quality: Reduced quality defects by 50%

LEAD Time explanation-purchase

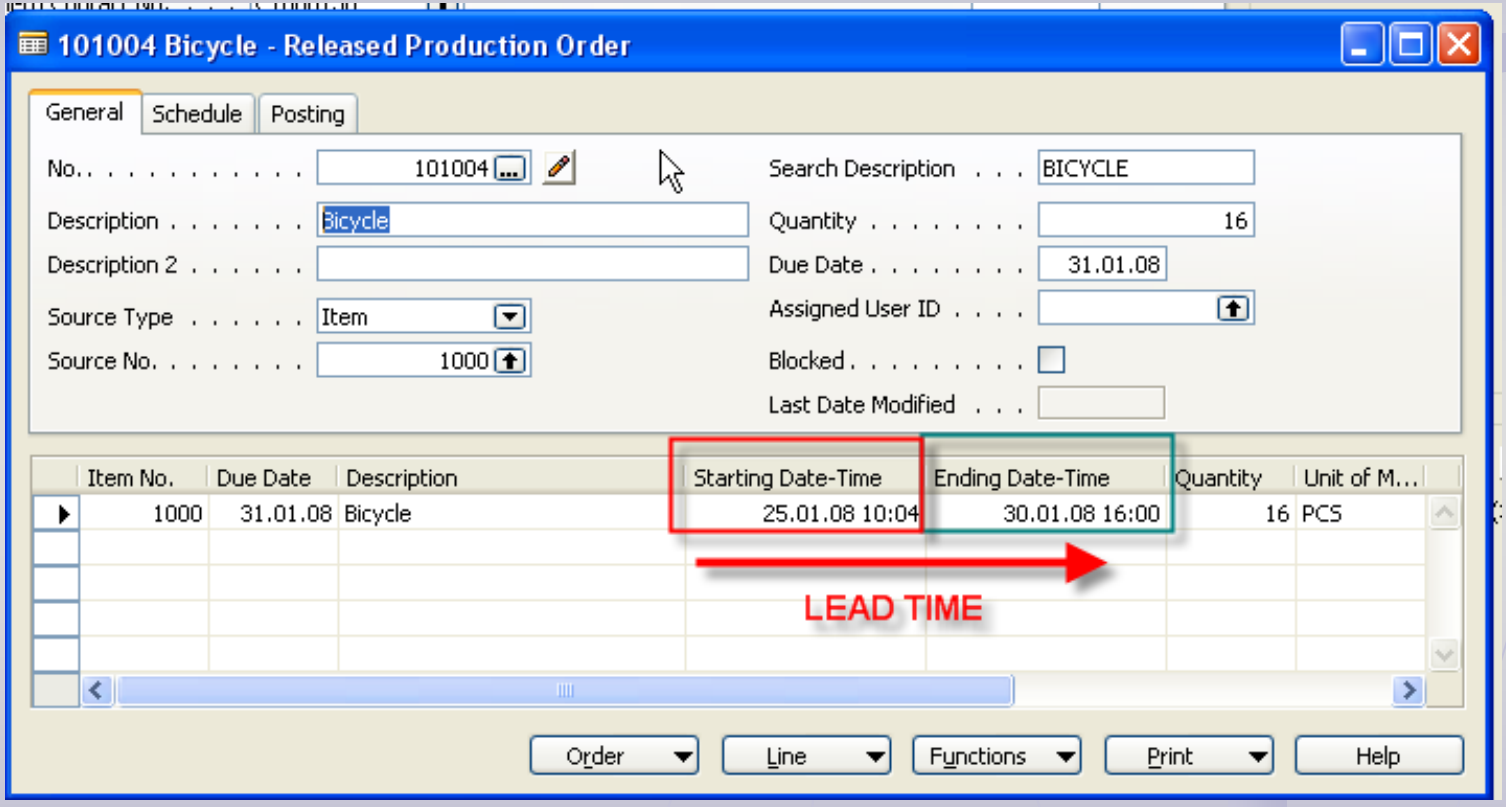
(one of many examples of LT)



LEAD Time explanation-purchase



LEAD Time explanation-production



Some impacts of **TOC** implementation

McDonagh Furniture Ltd

Revenue: $8,000,000

Number of employees: 100

Implementation Date: 2000

TOC Applications: DBR

Some impacts of **TOC** implementation

IMPLEMENTATION RESULTS

Revenue Increase: 28% Yr 1; 17% Yr 2

On-time performance: From 70% - To 98%

Lead times decrease: 20 %

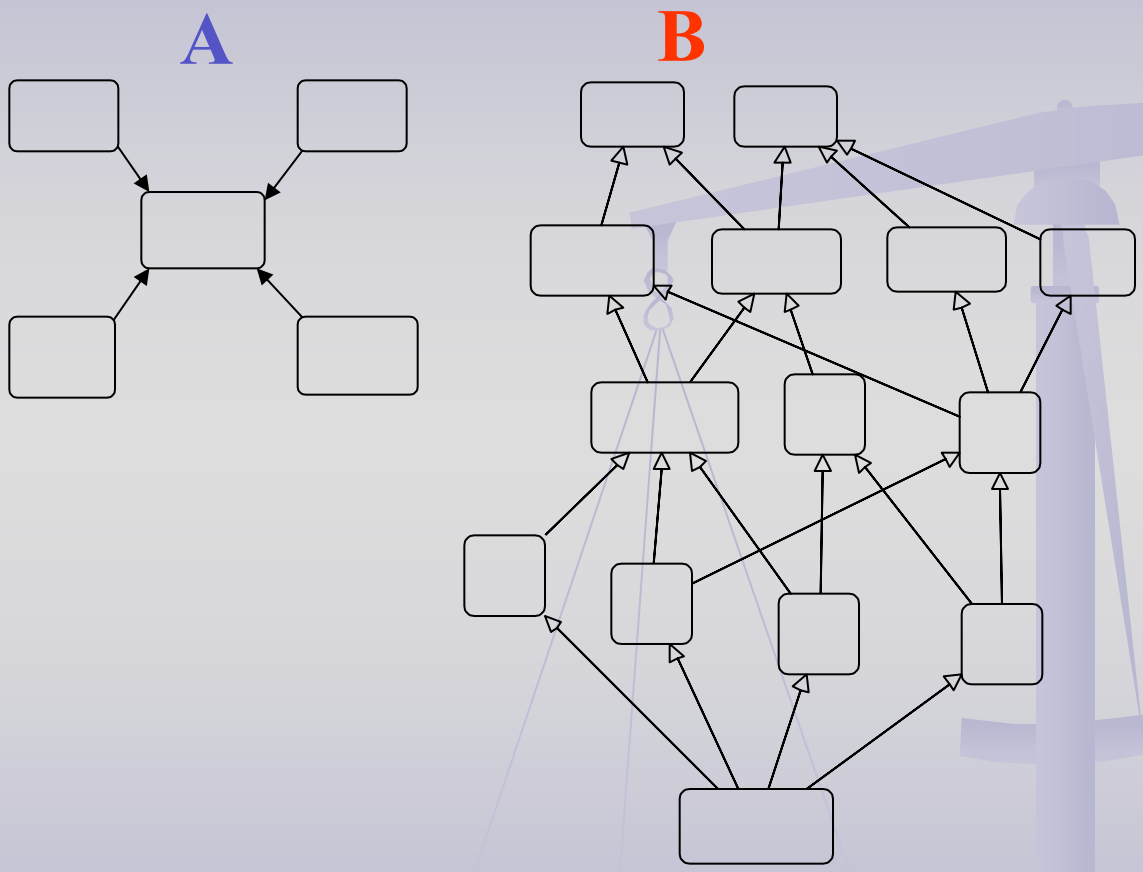
Net profit increase: over 300%

Some impacts of **TOC** implementation

Some other companies using TOC applications:

- BOEING –maintenance departments
- MOTOROLA -research
- GENERAL MOTORS
- LOCKHEAD MARTIN (F 22)
- BAE SYSTEMS
- .....

TOC



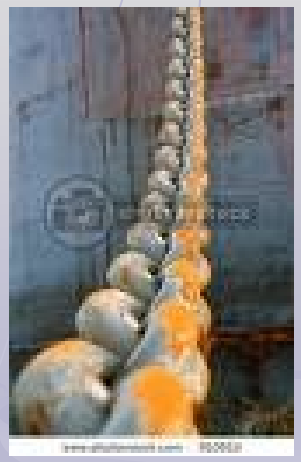
Which is harder to manage? Left or Right?

TOC

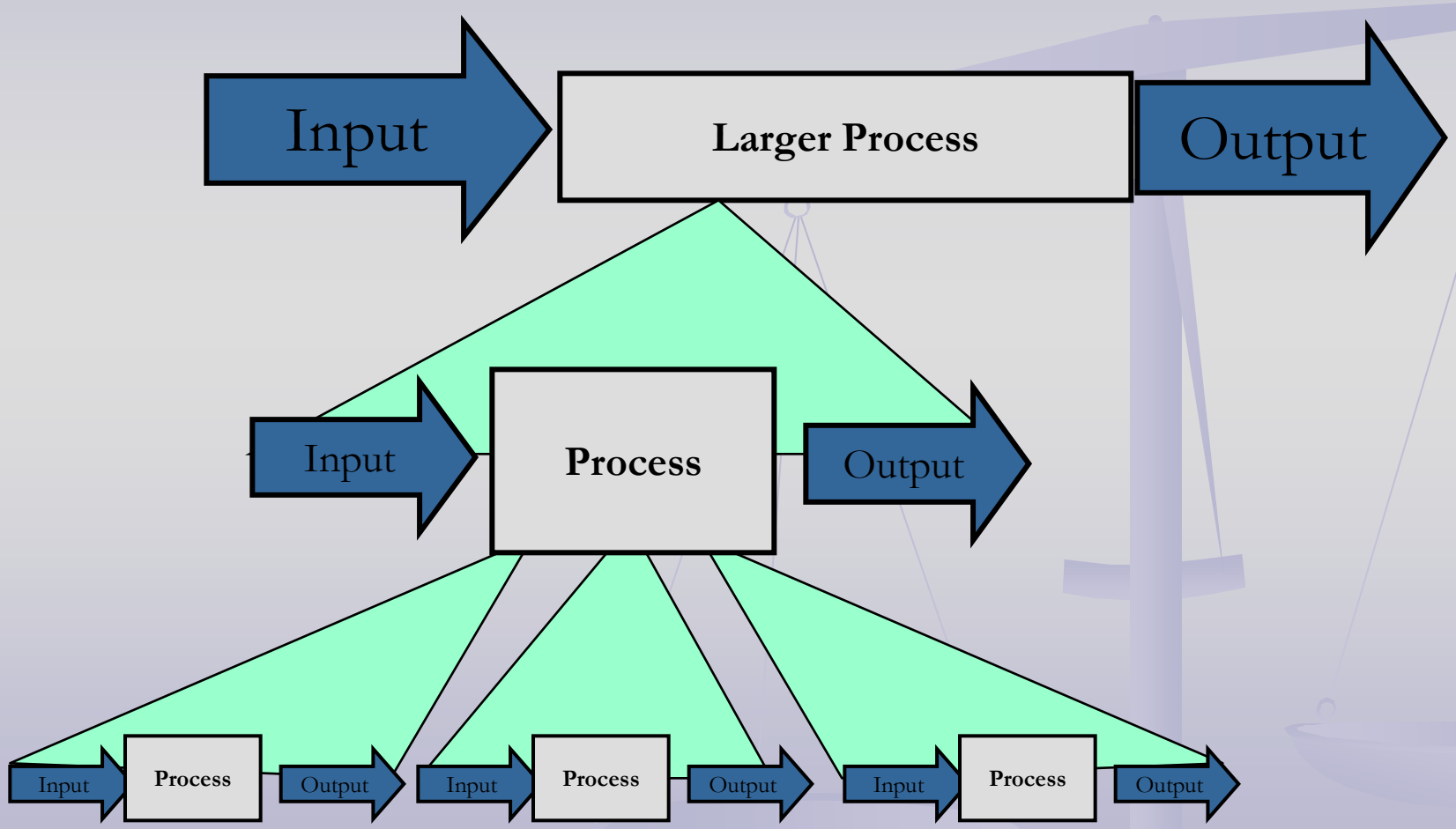
- It is based on **system approach**
- A company (enterprise) is to be understood as a chain of dependent processes – this picture below is very, very simplified

See next slide

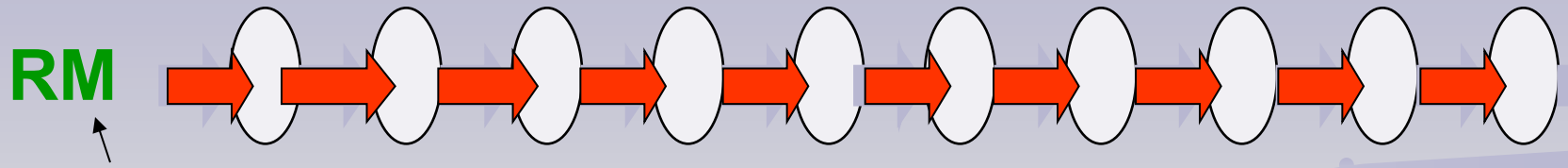
Marketing → Orders → Purchase → Production → Packaging → Shipment



Process Theory – more complex than one way chain



Process Theory – more complex than one way chain

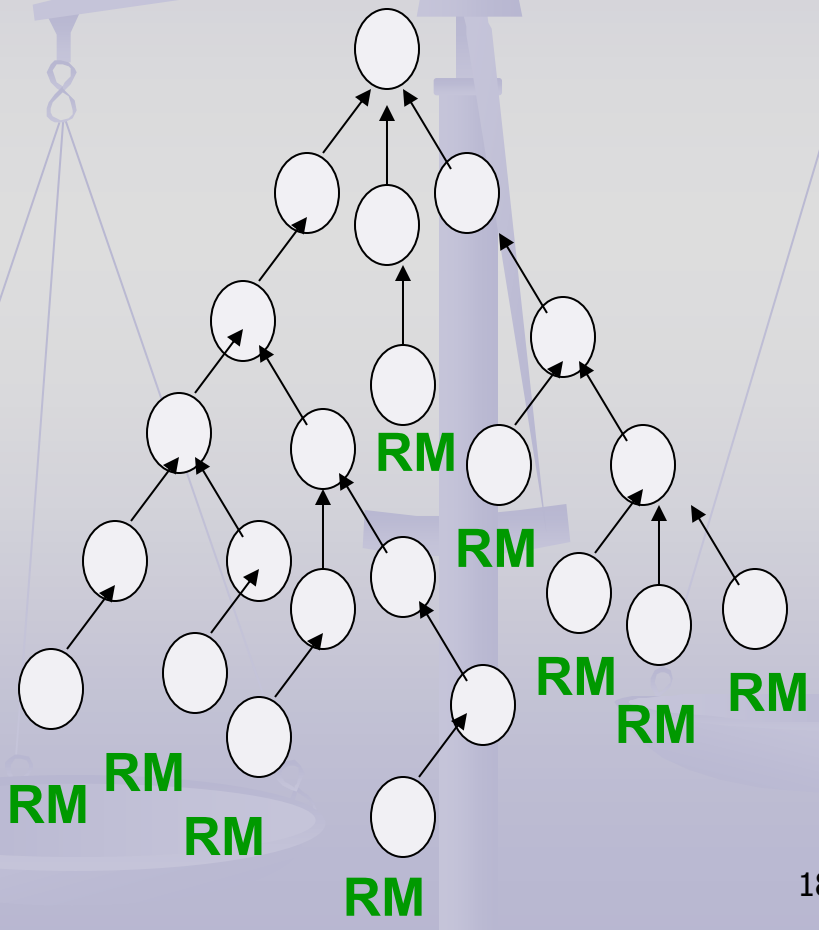


Raw Material

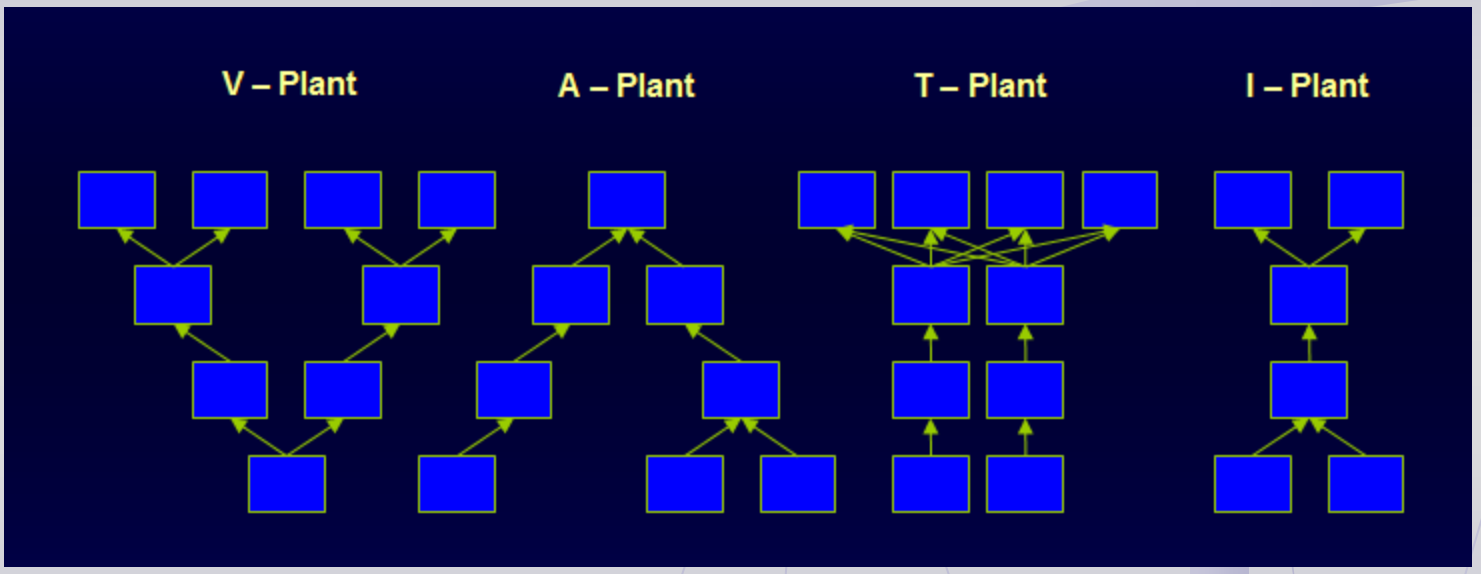
Linear or "I" system

FG ← Finished Goods

Aircraft assembly is more of an "A" Plant



Types of plants



TOC – system approach

- Organizations / Systems exist for a purpose
- That purpose is better achieved by cooperation of multiple, independent elements linked together
- Each Inter-linked event depends in some detail upon the other links.
- The system owner determines purpose

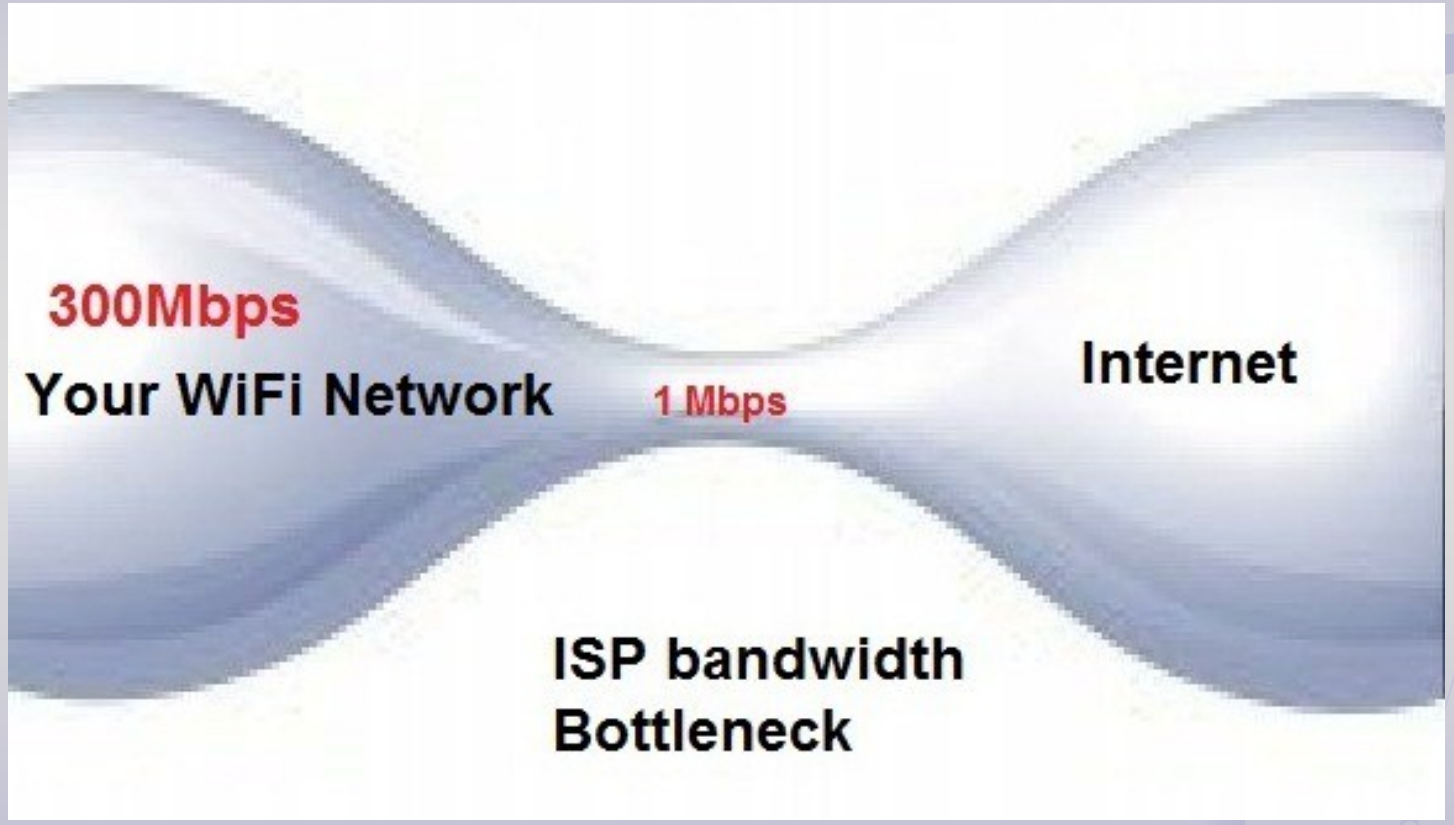
TOC (home study)

- Most real systems could be seen in such a way, that there are only a few or better **only one element** (factor), which is the **key point**, where and only there all possible managerial methods have to be focused in order to control whole system
- „Every system is based on inherent simplicity".
- This element in TOC is called **Constraint of the system =** bottleneck

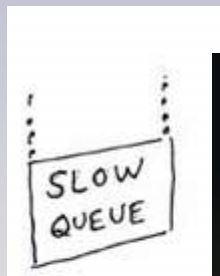
- Bottleneck: Any resource whose capacity is equal to or **less than** the demand placed upon it.

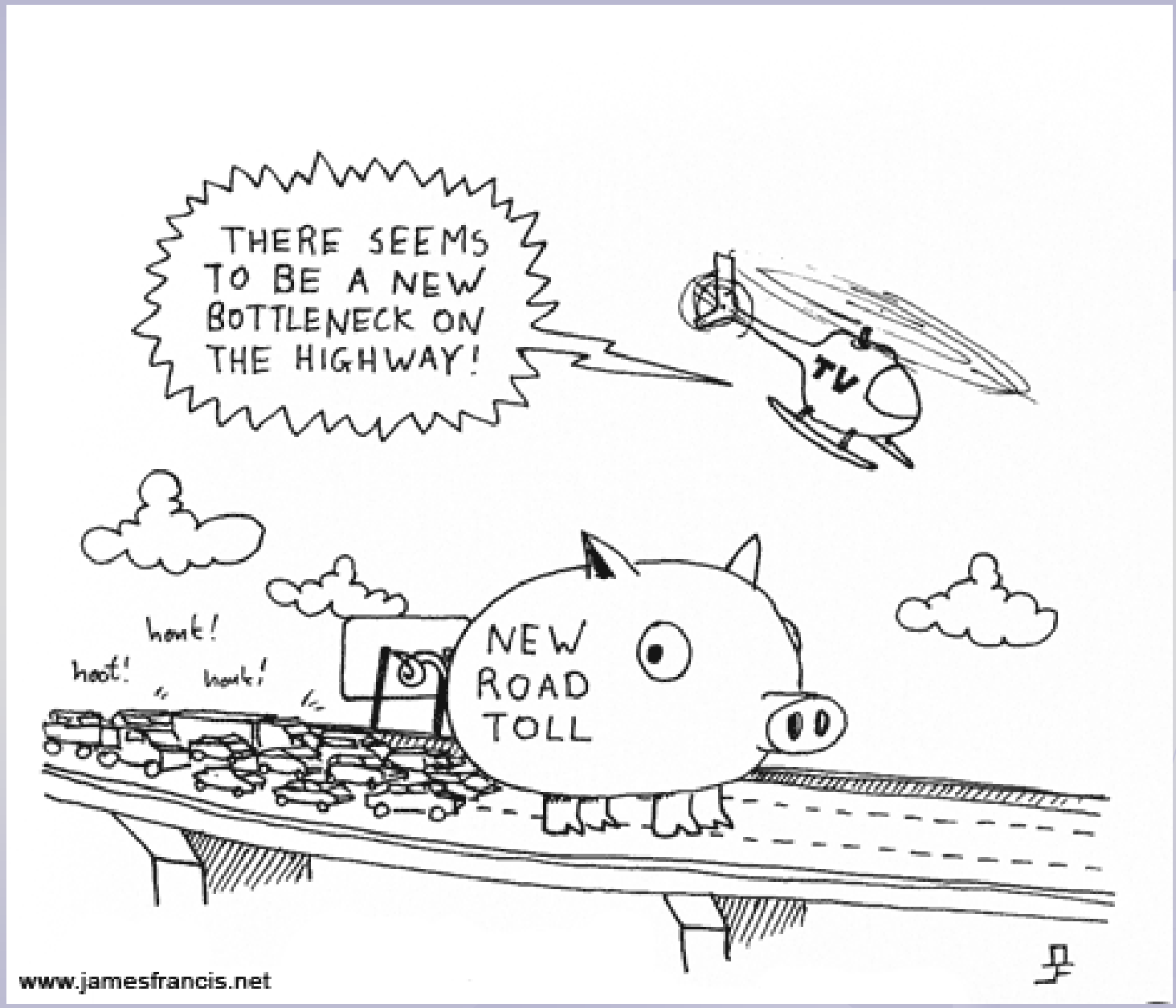
Inherent : základní, podstatná. neodmyslitelná….- only for Czech students

Bottleneck –1st example



Bottlenecks –2nd adn 3rd examples




THERE SEEMS TO BE A NEW BOTTLENECK ON THE HIGHWAY!
TV
NEW ROAD TOLL
honk!
haot!
honk!
www.jamesfrancis.net

Scout Troop – Initial Condition

Scout Troop - Problem

Scout Troop - Solution

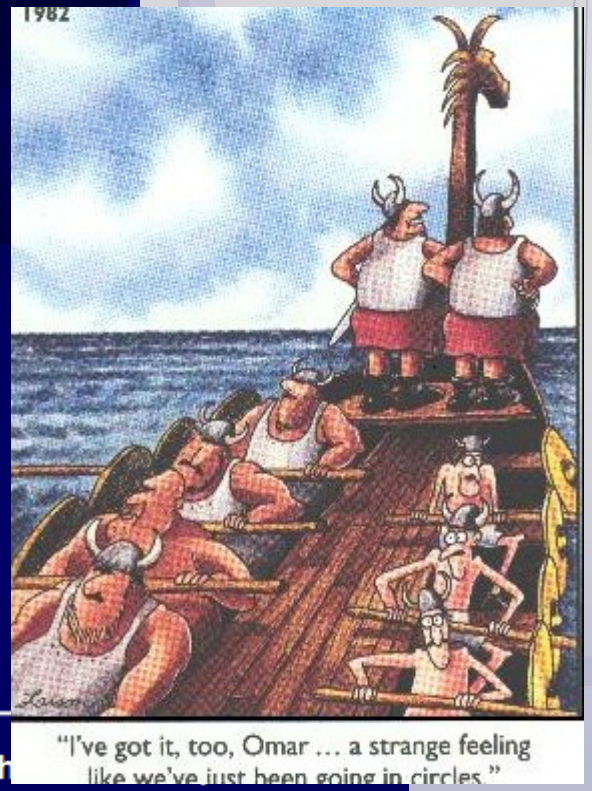
Army Solution

Mass Production Solution

Just-In-Time Solution

Drum-Buffer-Rope Solution

Time Synch

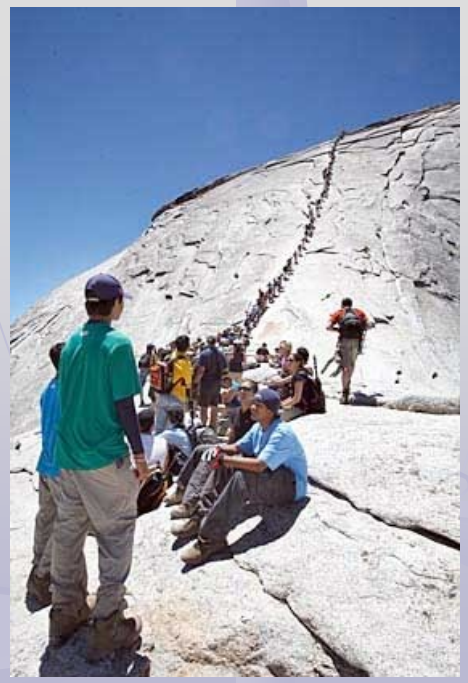


Resource :www.dbrmfg.co.nz

TOC- bottleneck I

- Different link capabilities, normal variation

  and changing workload make it impossible to balance everything.
- One element of the system is more limited than another.



TOC- bottleneck II

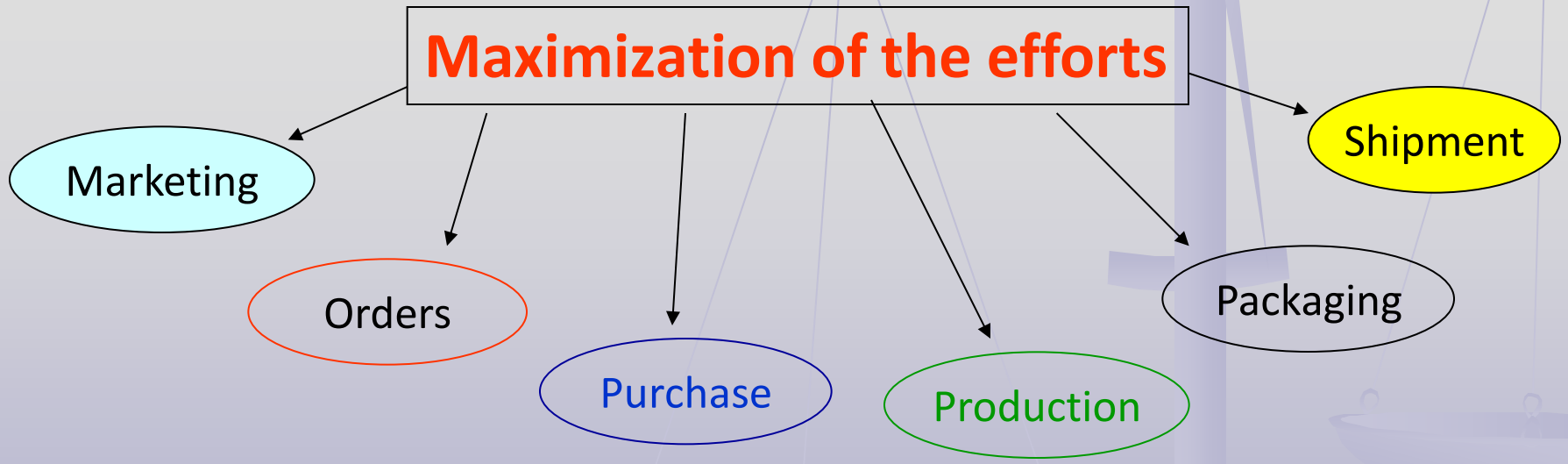
- When the whole system is dependent upon the cooperation of all elements, **the weakest link determines the strength of the chain.**
- An exactly balanced chain (system) is stronger than a non-homogeneous chain, but when close to the breaking point, all links must be managed

TOC

- Why constraint ?
- Constraint prevents to reach the goal (make money now and in the future)
- **The TOC goal** : „Make money now and in the future“
- Every system has at least one such a constraint.
  The system without such a bottlenecks would reach the predefined business plans in infinite volumes.

TOC :  of the costs

- Traditional approach – world of where the aim of any endeavour is to optimize locally every segment of the chain, meaning balancing **the capacity** of every element and **not the flow** through the chain



TOC :  of the throughput

- Use of : „common sense“
- The consistent focus of the bottleneck- – global optimization

Maximization of the efforts

Marketing → Orders → Purchase → Production → Packaging → Shipment

TOC

TOC

World of costs:

- **main metric** – the weight of the chain (every decrease of the weight of any components will result in better efficiency (performance)
- **Total improvement** = sum of local improvements

World of throughput:

- **main metric** –the compactness of the chain
- Only improvement of bottleneck will improve performance of the whole chain
- **Total improvement** = improvement of the bottleneck

Life show

- http://www.tocca.com.au/

TOC

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**.**

http://www.leadingagile.com/2014/01/theory-constraints-brooks-law/

Adding manpower to a late software project makes it later ! **HOME STUDY**

Brooks´law !!!

TOC

- „Cost Accounting is enemy number one of productivity“. *
- Impact on the behaviour of the people and they habits of finding and improvements of local elements having reason in optimising of these particles.
- New metrics were introduced – already presented

* Eric Noreen, Debra Smith and James t. Mackey

Definition (TOC metric) - summary

- Throughput (T): The rate at which the system generates **money** through sales.
  - Note that the money is generated through sales and not production because if you produce something and don't sell it, you have not really had throughput. (You've just put it into inventory).
- Inventory (I): All the **money** that the system has invested in purchasing things, which it intends to sell.
- Operational Expense (OE): All the **money** the system spends in order to turn Inventory into Throughput. See classification of OE later in this show

TOC metrics more in detail (T)

- **throughput** is the rate at which a system achieves its goal. Often this is monetary revenue and is in contrast to **output**, which is inventory that may be sold or stored in a warehouse. In this case **throughput** is measured by revenue received (or not) at the point of sale—exactly the right

TOC metrics more in detail (OE)

- **Operating expenses includes e.g. :**
- accounting expenses
- license fees
- maintenance and repairs, such as snow removal, trash removal, janitorial service, pest control, and lawn care
- advertising
- office expenses
- supplies
- attorney fees and legal fees
- utilities, such as telephone

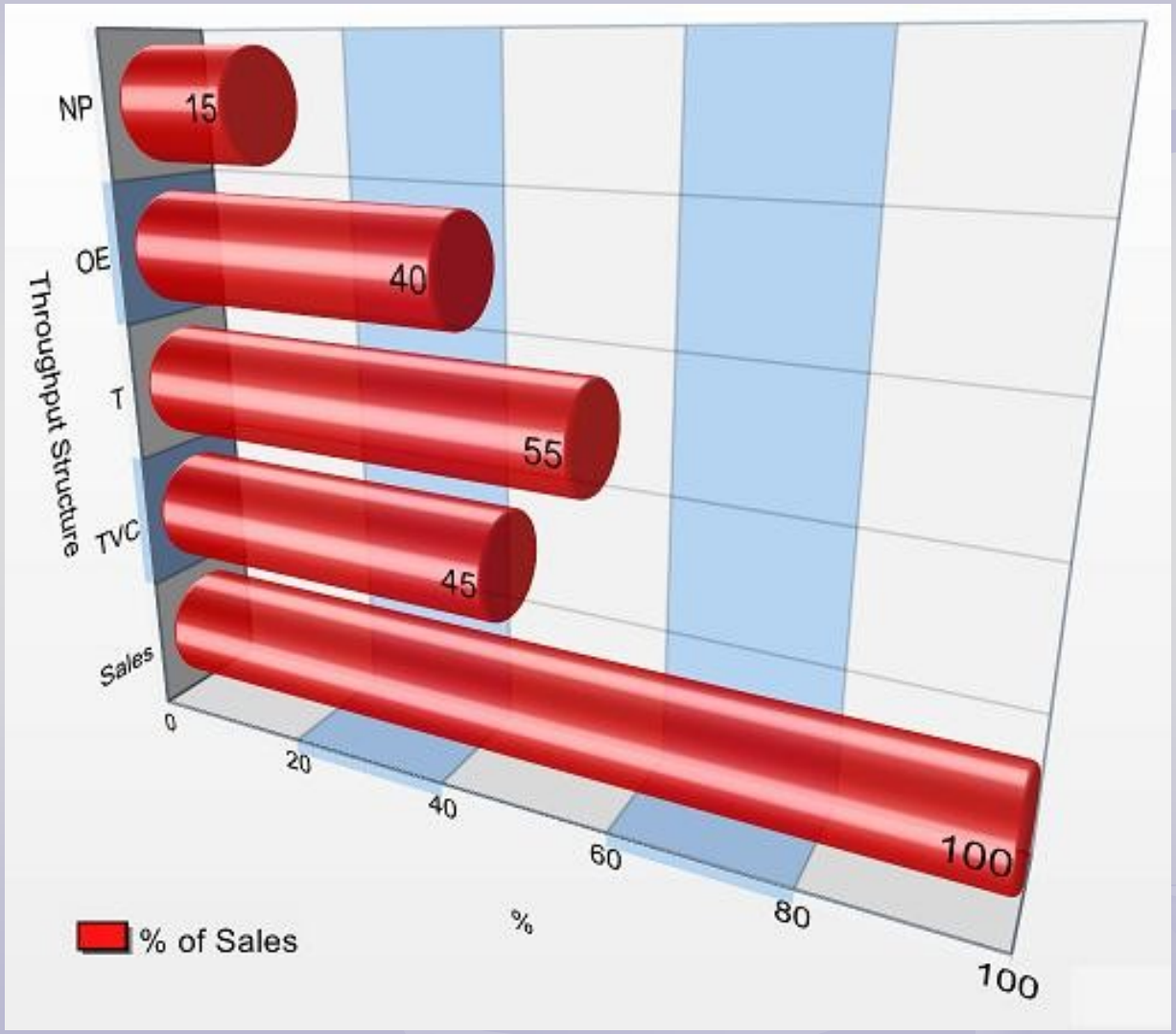
Measuring the goal (TOC metric)

- Net profit (NP=T-OE) : (T, I and OE was already explained in this course) -> T=Net Sales – TVC =S-TVC, where TVC=Total Variable Costs
- Cash
- Return on Investment (ROI=NP/I)

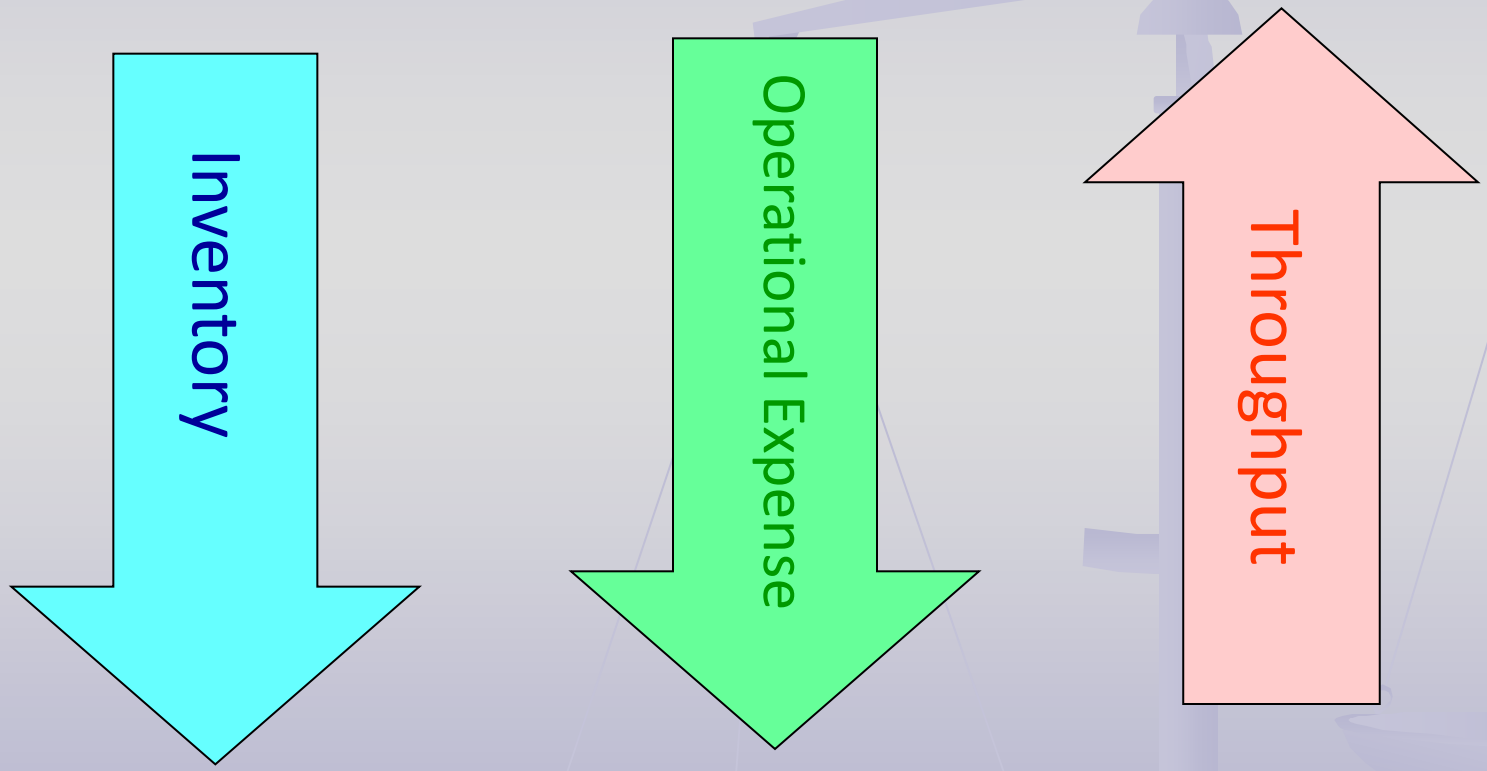
For a manufacturing enterprise, the goal can also be measured by:

- Throughput =T
- Inventory = Investment =I
- Operating Expenses =OE

Metrics and their relationships

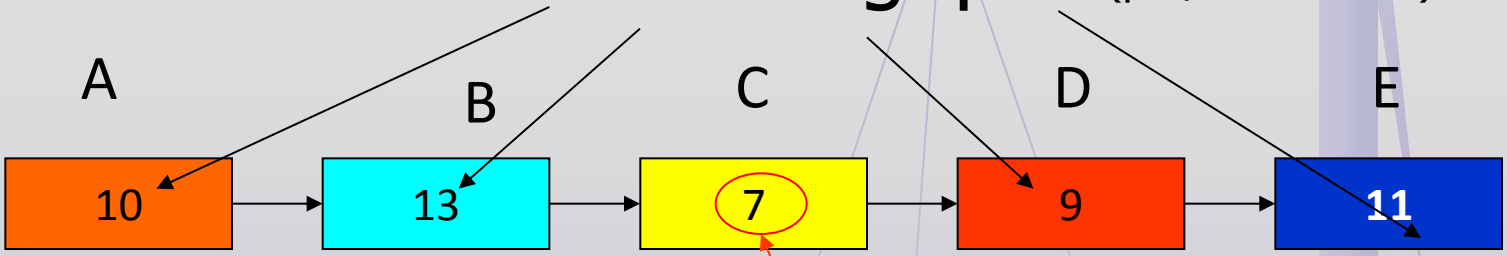


TOC –required trends



T,I,OE,NP and ROI example (home study)

- NP=**T**-OE = (S-TVC) – OE ; where **TVC**=Total Variable Costs and **S**=Unit Price
- ROI=(T-OE)/I=NP/I, where NP=Net Profit
- where T=total throughput (pcs/unit of time)

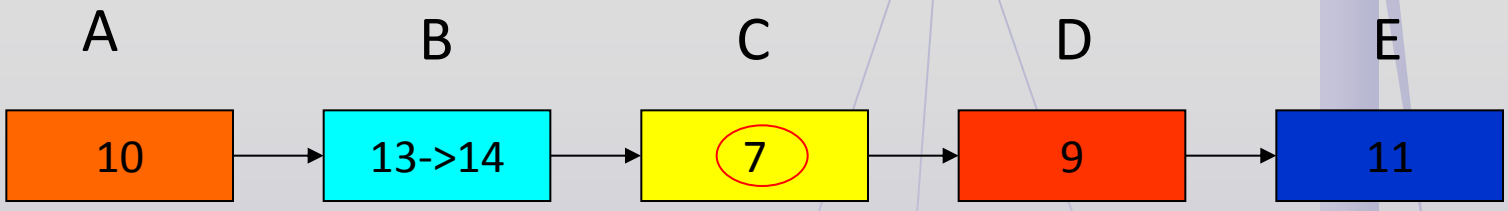


1. Only one product !!! In our example TVS=0
2. Unit Price (Selling price) = **100 USD = S**
3. Raw material /one product =**35** USD =**OE**
4. **NP**/product=(T-OE)=**100**-**35**=**65**
5. 176 hours/month (constraint of the company)
6. T=176 * 7 = **1232** parts/month
7. Monthly **NP** =**1232** * **65** USD = **80 080** USD

CCR=Capacity Constraint Resource= =weakest link of the chain= bottleneck

T,I,OE,NP and ROI example (home study)

- 1st suggestion is to optimize B from 13->14 parts per hour
- T will not increase ->**You cannot produce more than 7 !!!!**
- Investment to optimize B=5000 USD with depreciation 10 %
- OE(month) =(5000 USD * 0,1)/12= 41,67 -> 42 USD (when rounded)

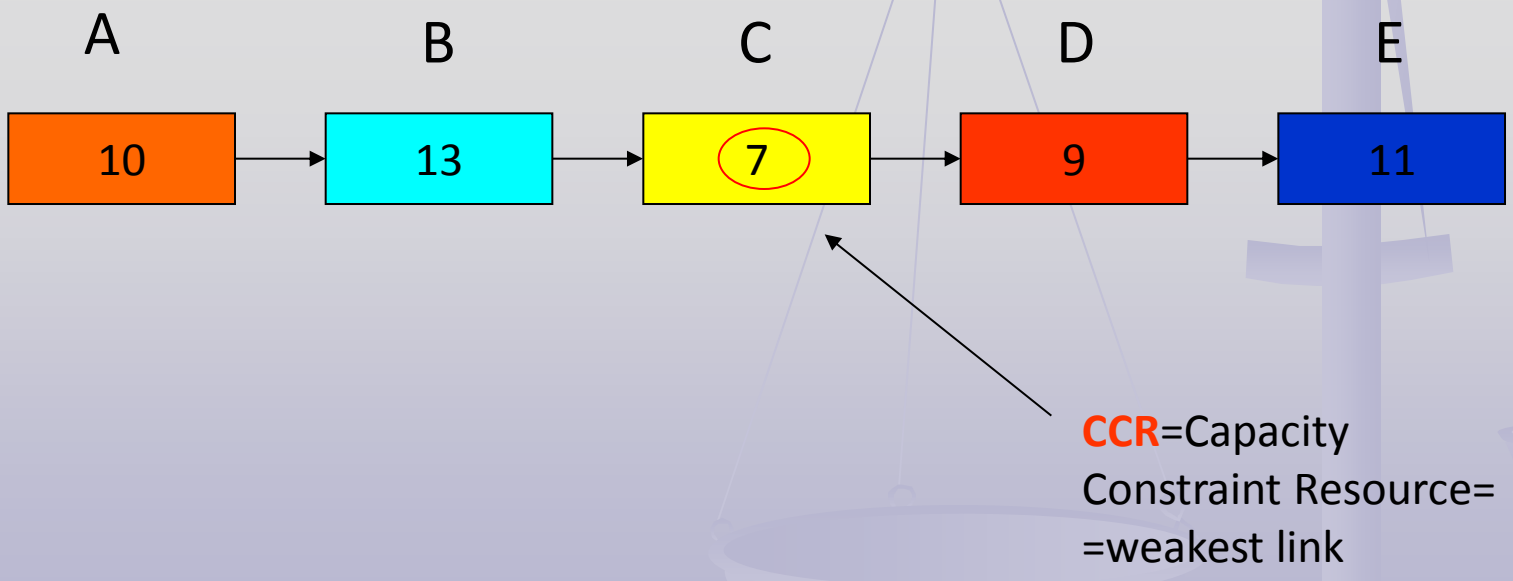


1. Only one product
2. Unit Price (Selling price) = **100 USD**
3. Raw material /one product =**35** USD =**OE**
4. **NP**/product=**100**-(**35+42**)=**23**
5. 176 hours/month (constraint of the company)
6. T=176 * 7 = **1232** parts/month
7. Monthly **NP** =**1232** * **23** USD = **28 336** USD

CCR=Capacity Constraint Resource=weakest link

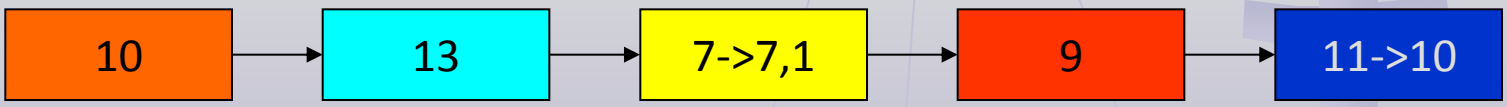
T,I,OE,NP and ROI example (home study)

- T = **throughput** will not increase
- NP (Net Profit) will decrease based on increased OE (**41,67 USD /month**)
- Based on NP decrease ROI is negative
- **Bad suggestion !!!!!!**



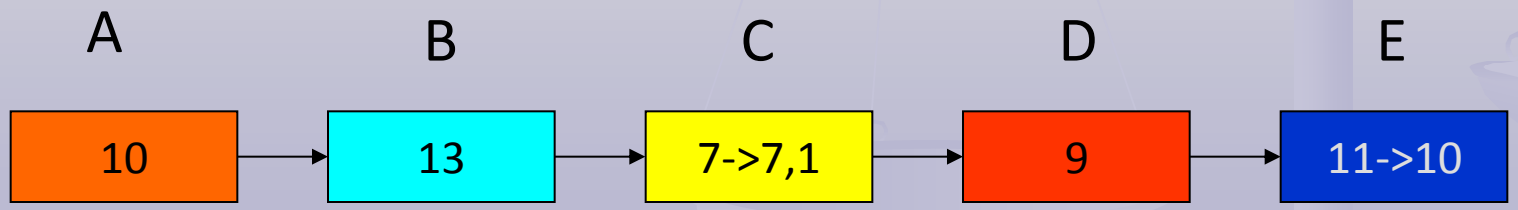
T,I,OE,NP and ROI example (home study)

- 2nd suggestion is to optimize C from 7->7,1 parts/hour
- part of the 2nd suggestion is an extra load of E so it goes from 11->10
- Necessary investment is 5000 USD (remains the same)
- Increase of the T=production/month = 0,1*176=17,6 parts
- Increase of the company NP= 17,6***23** USD= **404** USD/month
- A B C D E



T,I,OE,NP and ROI example (home study)

- Necessary investment is **5000** USD = I =Inventory= Investment
- Increase of the T= production/month = 0,1*176=17,6 parts
- Increase of the company/month NP= 17,6***23** USD= **404** USD
- OE/month =(5000 * 0,1)/12= 41,67 -> **42** USD
- OE will be increased by **42** USD/month
- Annual increase of the NP = **404***12=4848 USD
- ROI=NP/I = (28336*12+4848)/**5000** = 69 % !!!
- **T** does not measure local efficiencies, except at the constraint- see next slide



Throughput

1. T=176 * 7,1 = **1250** parts/month (rounded)
2. Monthly **NP** =**1250** * **23** USD = **28 750** USD
3. Originally :
    1. T=176 * 7 = **1232** parts/month (rounded)
    2. Monthly **NP** =**1232** * **23** USD = **28 336** USD

Implementation of TOC is complicated **switchover process**

- it represents challenging adventure, where the invested efforts are often not predictable
- it requires cooperation, coordination and use of well informed and trained teams on both sides.
- you will certainly overcame natural resistance against changes and persuade distressed and indolent people
- no one is willing to change anything

Implementation of TOC is complicated switchover process

- try to find somebody who could accept changes !!!
- you must persuade these guys, that the suggesting changes are in fact their idea and without their creativity TOC would be only toothless beast !
- but how to achieve it ??

Implementation of TOC is complicated switchover process

- **Socratic teaching** – proving the logic by use of **dialog**
- **Buy-in approach** – initiator of the changes must have interpersonal and communication talents in order to persuade the targets and squeeze from the people their best ideas.

Socratic teaching

Implementation of TOC is complicated switchover process

We have to find out the answers to these questions:

1. What to change?
2. To what to change to ?
3. How to make the change happen?

Implementation of TOC is complicated switchover process

What to change?

- Objectives : **Situation assessment, description of "current reality," and identification of the core problem or conflict and assumptions that sustain it. Diagnosis and systemic root cause analysis.**

- **But at any time you will meet enemies – the ones who hate any changes**

  You have a lot of people wishing to do the same, a lot o people doing exactly the opposite and immense quantity of people which would like to do nothing !

- Layers of resistance: **Lack of agreement on the problem**

RESISTANCE

Implementation of TOC is complicated switchover process

To what to change?

- Objectives : **Verbalization of vision/solution, description of strategy to attain the desired state, and avoidance of undesirable side effects. Prescription, decision-making, and solution development.**

- Layers of resistance:
  - **Lack of agreement on a possible direction for a solution**
  - **Lack of agreement that the solution will truly address the problem**
  - **Concern that the solution will lead to new undesirable side effects ("Yes, but…")**
  - **Or you will get even worse reaction („NO, because…")**

Thinking Process Tools

- offer the answers to three TOC questions about changes
- help to **clear away** every layers of resistance
- visualisation of the thinking process
- verbalization of the thinking process
- use of **casual logic** (cause ->effect)
- use of **sufficiency logic** - **„IF - AND - THEN“**
- use of necessity logic - **„IN ORDER TO - THEN - BECAUSE“**

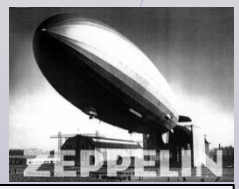
Basics

Cause A → Assumption → Effect B

Battery is empty → The engine do not start

The engine do not start because battery is flat (empty)

I drink a lot of bier → My belly looks like Zeppelin

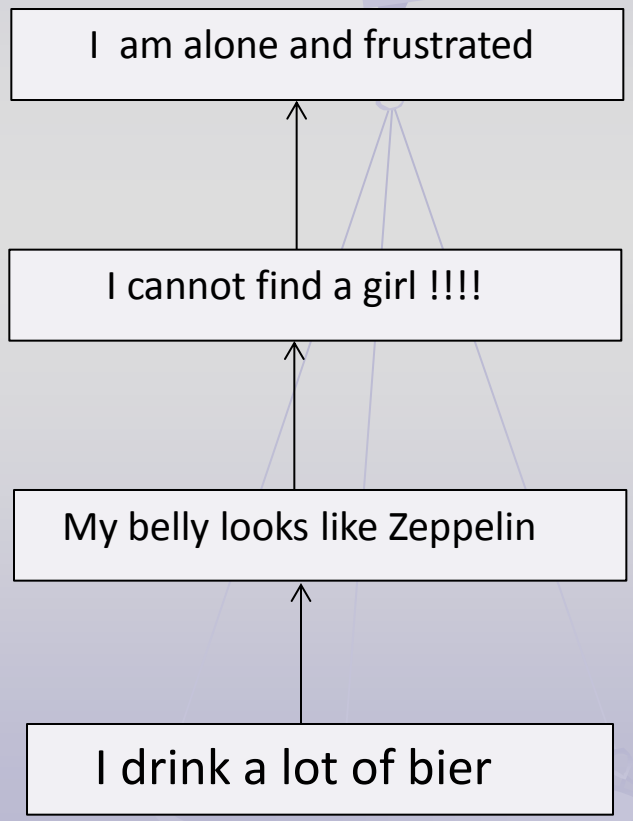


The bier is an energy drink

My belly looks like Zeppelin → I cannot find a girl !!!!

The girls like slim athletes

Cause-effect simple sturcture



Thinking Process Tools

Necessity logic

IN ORDER TO - THEN - BECAUSE

In order to survive and to be strong as **Hercules** I must eat fatback

I will survive and I will date girls every day

I am eating fatback every day

Thinking Process Tools

Sufficiency logic

IF - AND - THEN

I have in my room a lot of light

AND

I have one good bulb in my castle hall

The chandelier is connected to the electric network

Switch is on

We have to solve the crucial question: what is a core problem (what should be changed)

A tool for solving such a task : **Current Reality Tree**

- Why to change something and what is something (core problem=constraint, bottleneck)
- Summary of all Undesirable Effects (UDE) and their layout based on **casual logic** - **sufficiency logic**
- **Core Problem** – common cause of all UDE

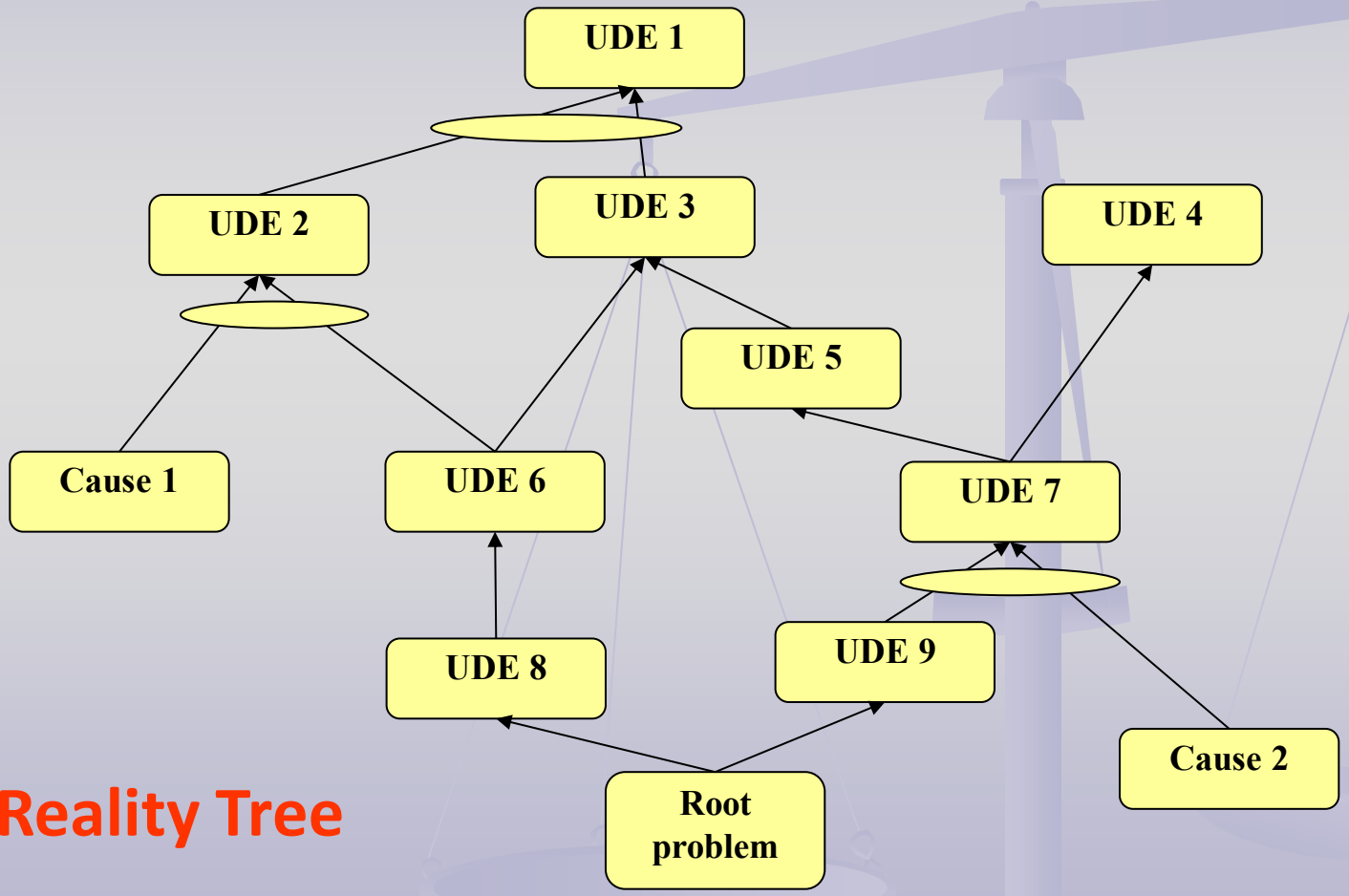
UDE examples

- **From the book "It's Not Luck", some examples of the UDEs are:**
- Production and distribution do not improve fast/significantly enough
- Engineering is unable to deliver new products fast and reliably enough.
- Companies don't come up with sufficient innovative ideas in marketing.
- In more and more cases the price the market is willing to pay doesn't leave enough margin.
- There is unprecedented pressure to take actions that will increase sales
- Competition is fiercer than ever.
- In advanced material industries there is a need to launch new products at an unprecedented rate.
- In advanced material industries the constant introduction of new products confuses and spoils the market.
- Sales people are overloaded.
- There is increasing pressure to reduce prices.

CRT Example- UDE´s are onlay specified

1. We lose customers
2. Customers are not happy
3. Many meeting (in order to get information for decision making)
4. Often we do not have meeting room available (so no meeting can be organized)
5. Information delay
6. Decision making delay
7. Work delay
8. Due date performance is not good
9. Revenue is going down (due to customer rush)
10. Shortage of information sharing

We have to solve the crucial question: what is a core problem (what should be changed)

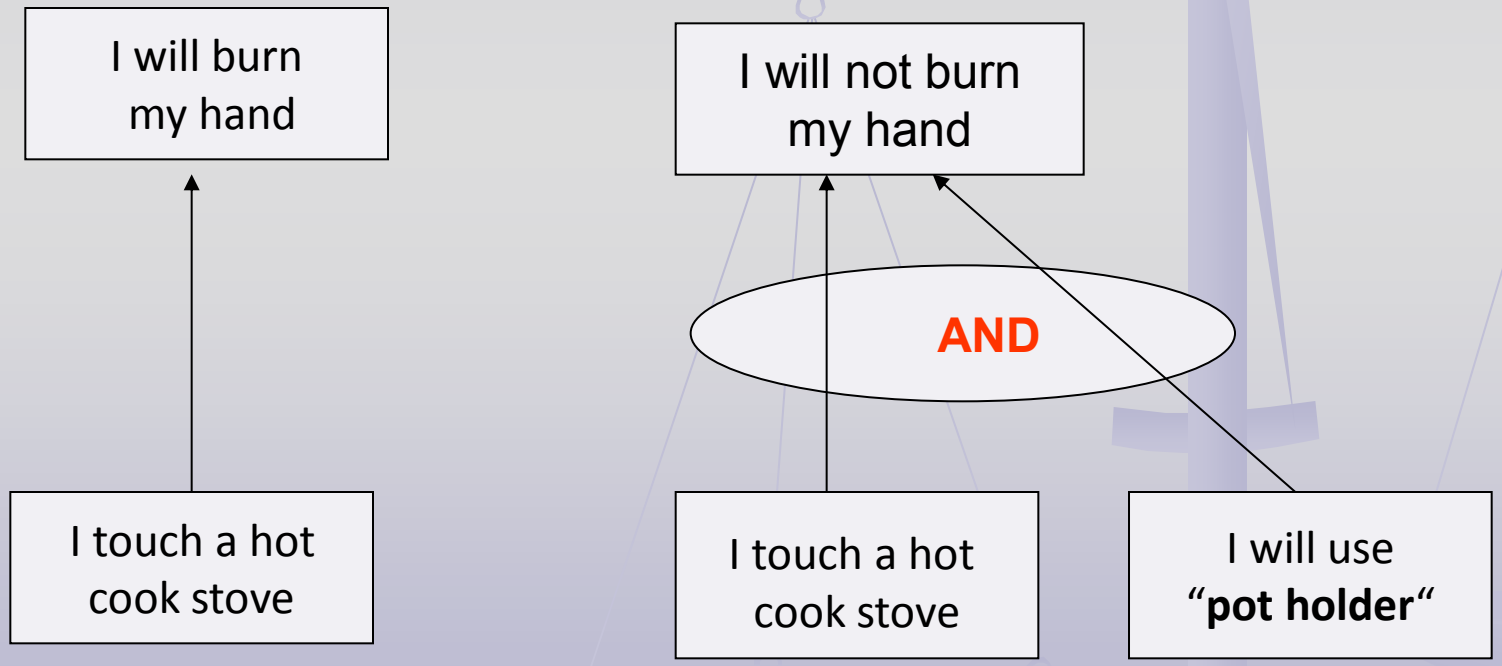


Current Reality Tree

We have to solve the crucial question: what is a core problem (what should be changed)

Causality:

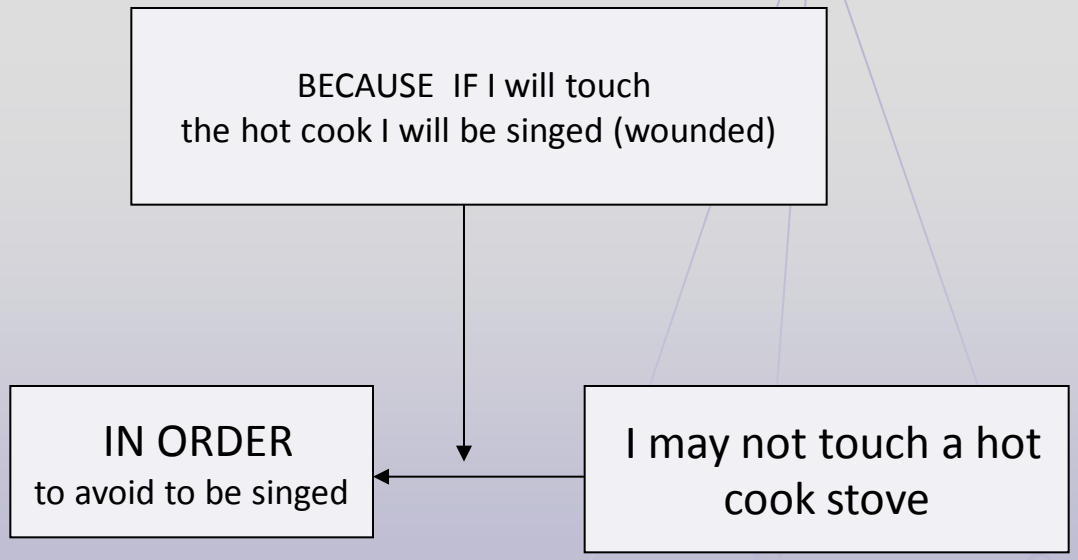
IF a lot of snow AND snowboarding in restricted area THEN avalanche



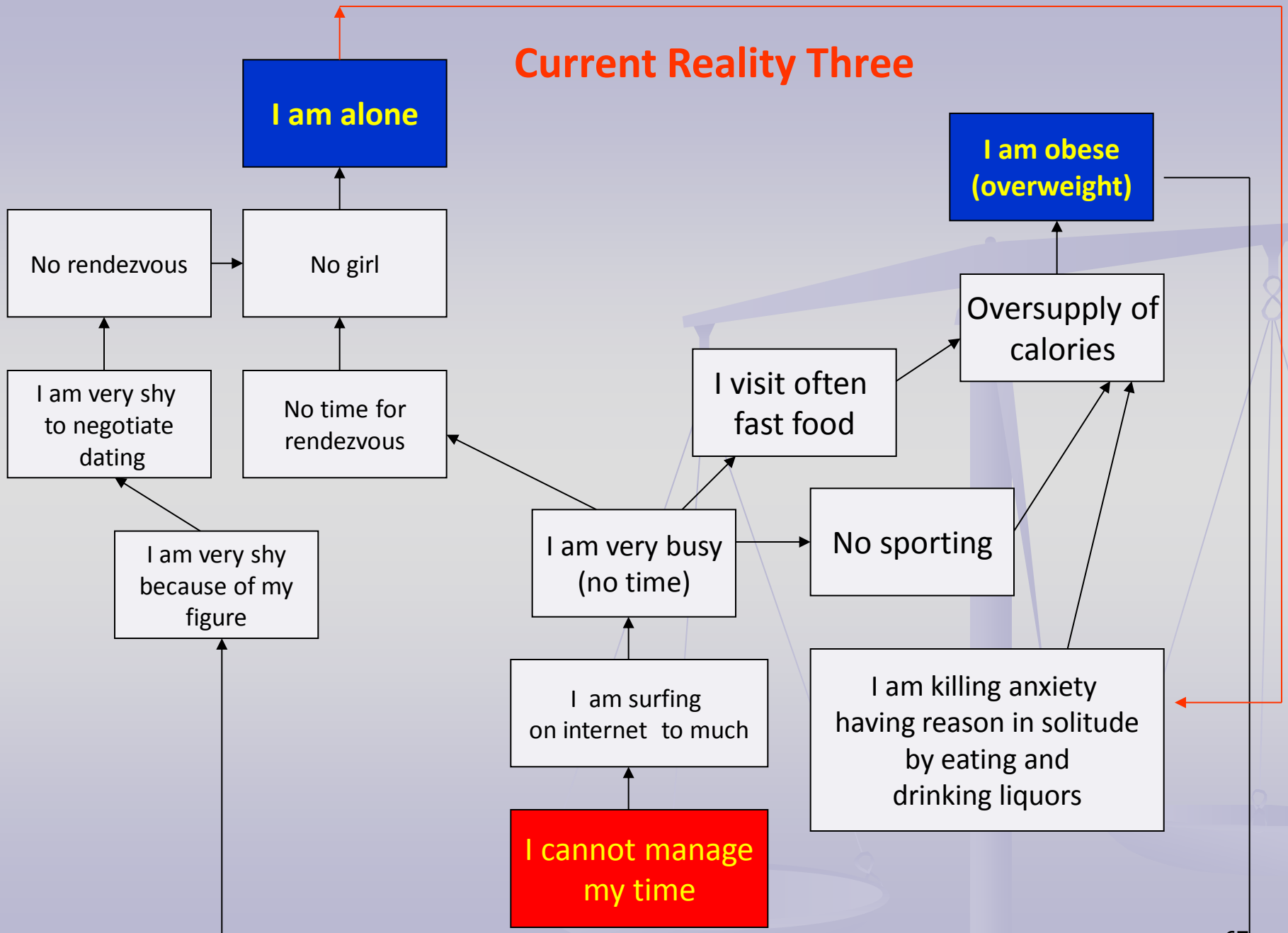
We have to solve the crucial question: what is a core problem (what should be changed)

Necessity logic:

IN ORDER to avoid something I HAVE TO do this



Current Reality Three

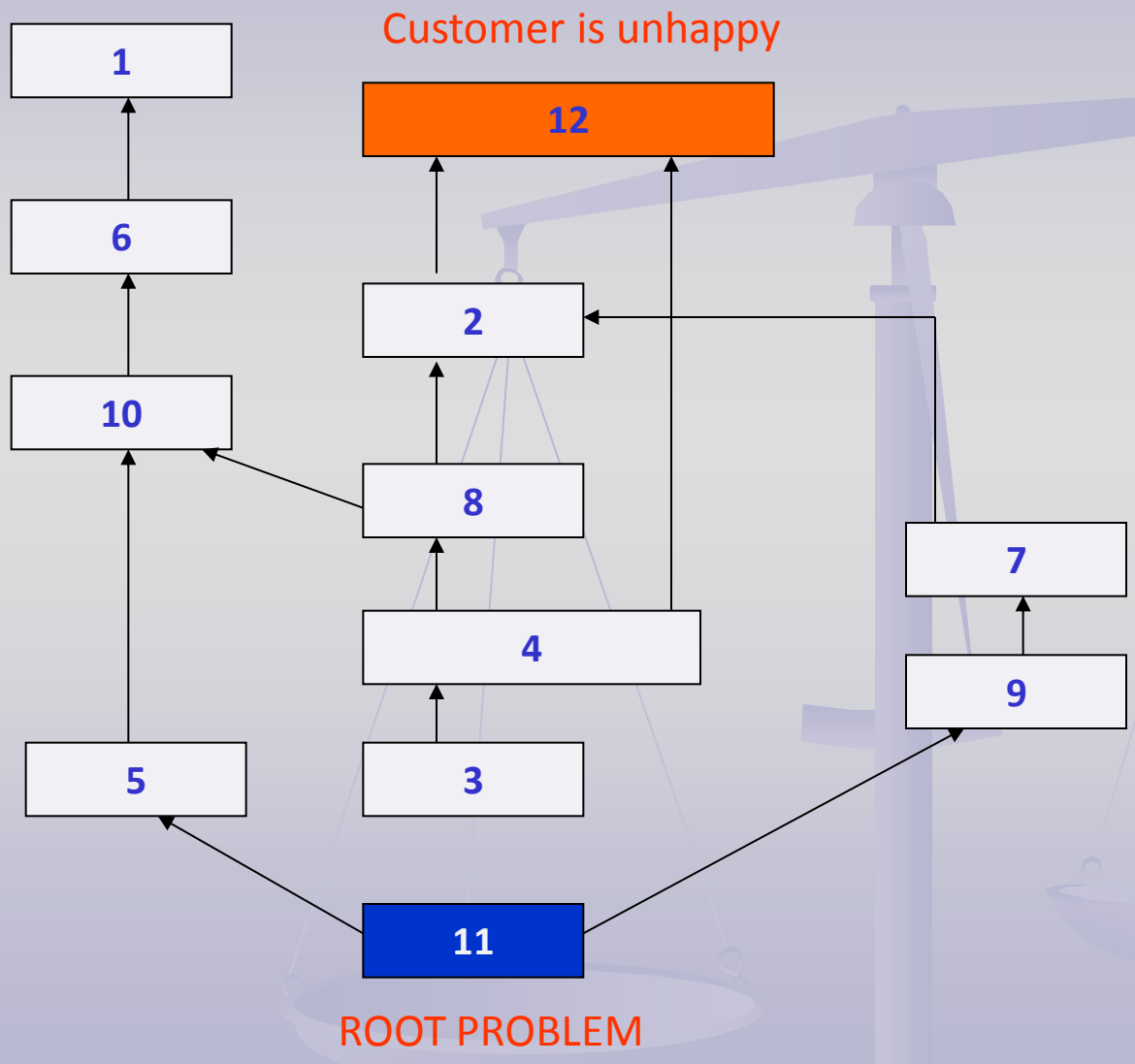


Current reality three (home study)

List of UDE´s :

- **UDE1 :** lack of financial consultants (FC)
- **UDE2 :** late hand-over of required services during implementation and support
- **UDE3 :** a modern design of ERP is not easily understood by rigid customer´s accountants
- **UDE4 :** the customer´s accountants tend to use old fashioned methods and processes which are difficult to manage by using a modern ERP
- **UDE5 :** rigid remuneration does not allow to pay more FC than the others
- **UDE6 :** high level of fluctuation and job-hopping
- **UDE7 :** overburdened FC as a consequence of bad multitasking (will be explained later in Critical Chain PWP)
- UDE8 : FC are fed up by permanent repetitive explanation to the customer´s accountants who do no want to understand
- UDE9 : bad multitasking
- UDE10 : FC are unhappy because of a salary, which is much more lower then their expectations
- UDE11 : The management sticks to Cost world and tends to decrease costs by minimising payroll and having all resources as a CCR (Critical Constraint Resources)
- UDE12 : Customer is unhappy

Current reality three (home study)



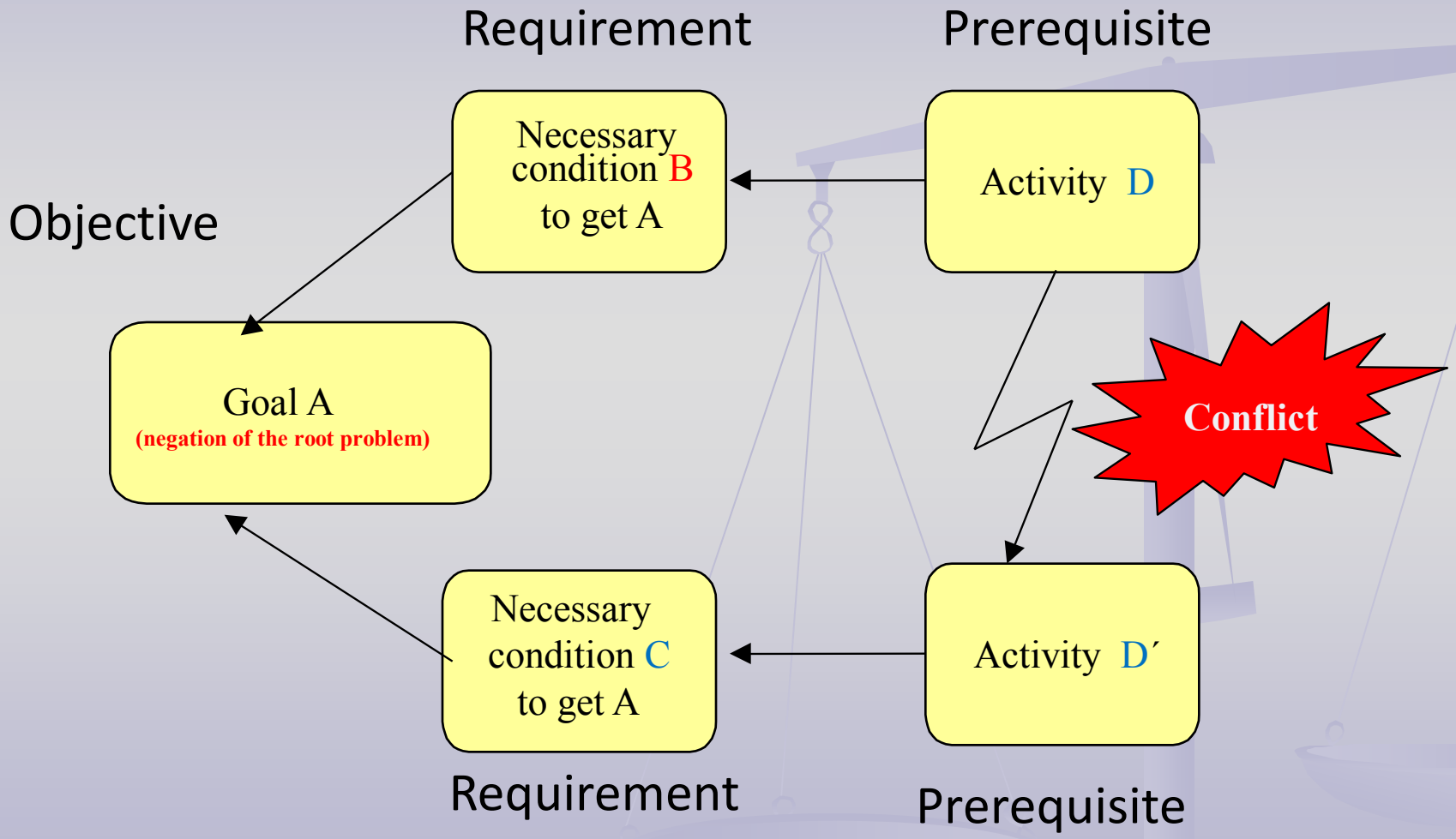
We have to solve another crucial question: the direction of solving a core problem

What is the main reason (injection) supporting the change !

Evaporating Cloud Tree

- the change without any compromise - basic and starting impulse for the change
- use of „**necessity logic**“ – common goal, necessary condition to reach this goals, what have to be done and where is a conflict
- „**well thought out from the scratch**“ of the problem, disclosure (findings)and verbal definition of hidden assumptions
- Win-Win solution of the whole conflict = **injection !!!**

We have to solve another crucial question: the direction of solving a core problem



Evaporating Cloud Tree (a conflict tree, a conflict resolution diagram)

How to read this Evaporation tree

In order to have objective A, we must have requirement B..

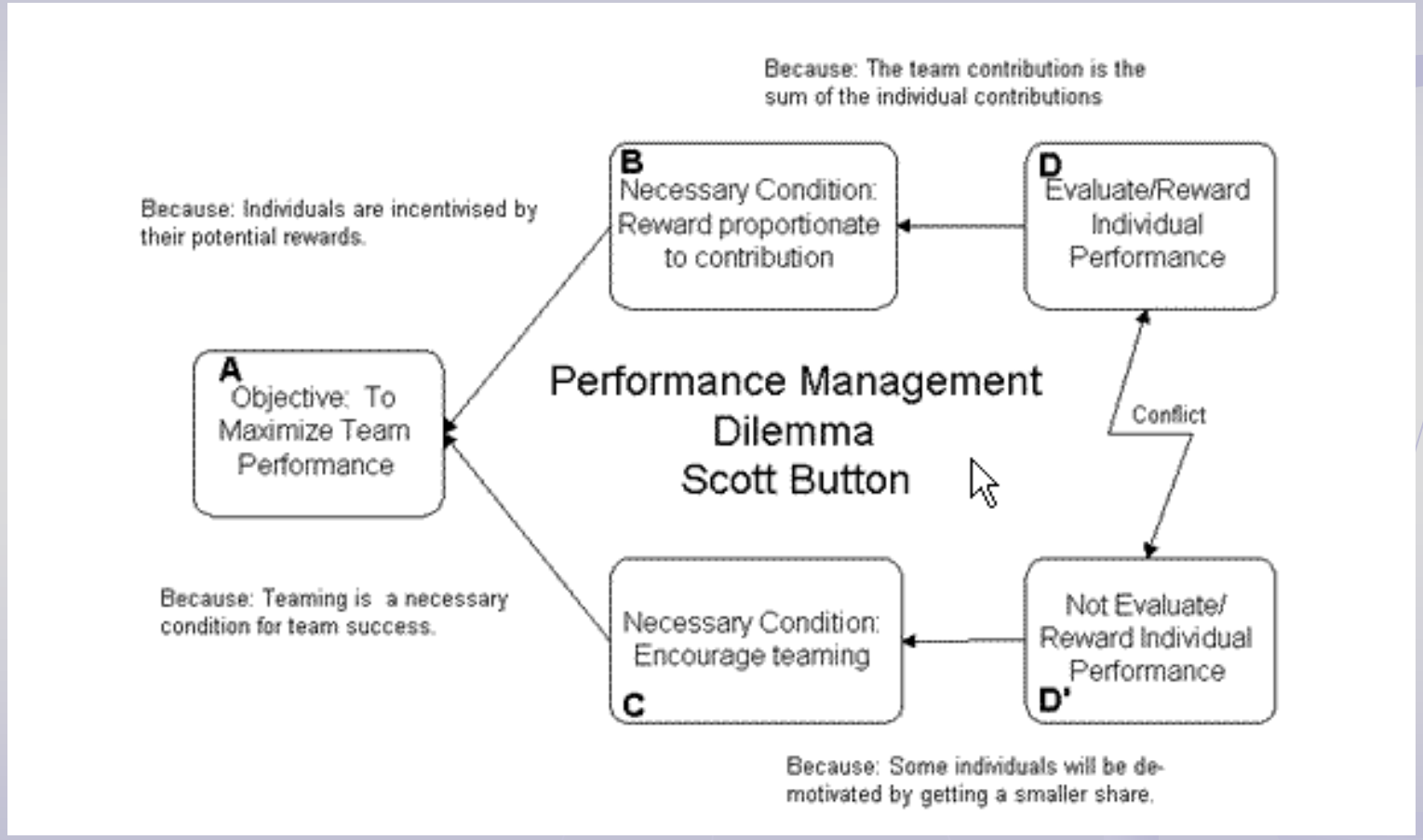
In order to have requirement B, we must have prerequisite D...

In order to have objective A, we must have requirement C...

In order to have requirement C, we must have prerequisite D'...

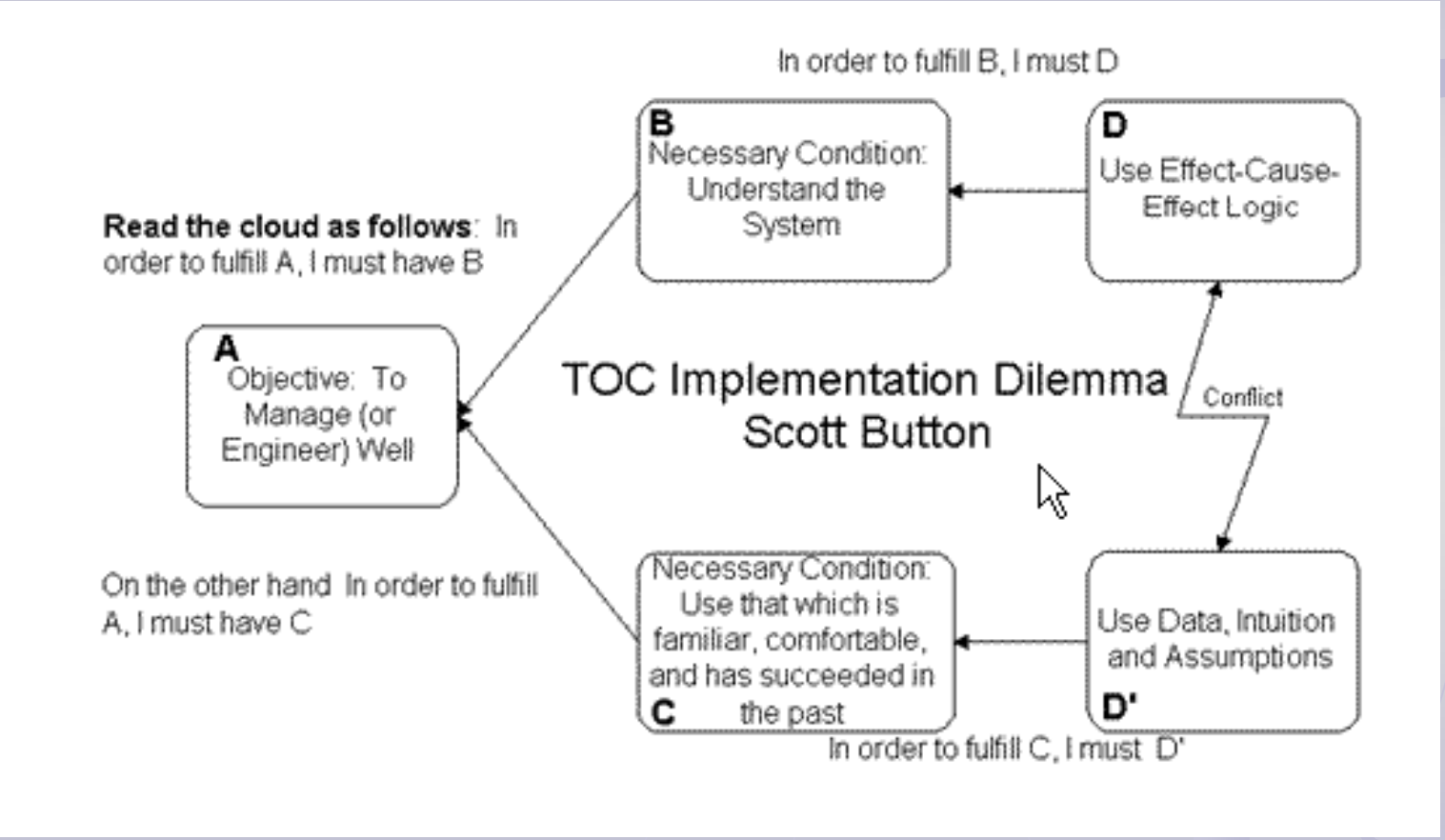
But prerequisites D and D' are in conflict... Like fire and water

Evaporation cloud tree- example 1



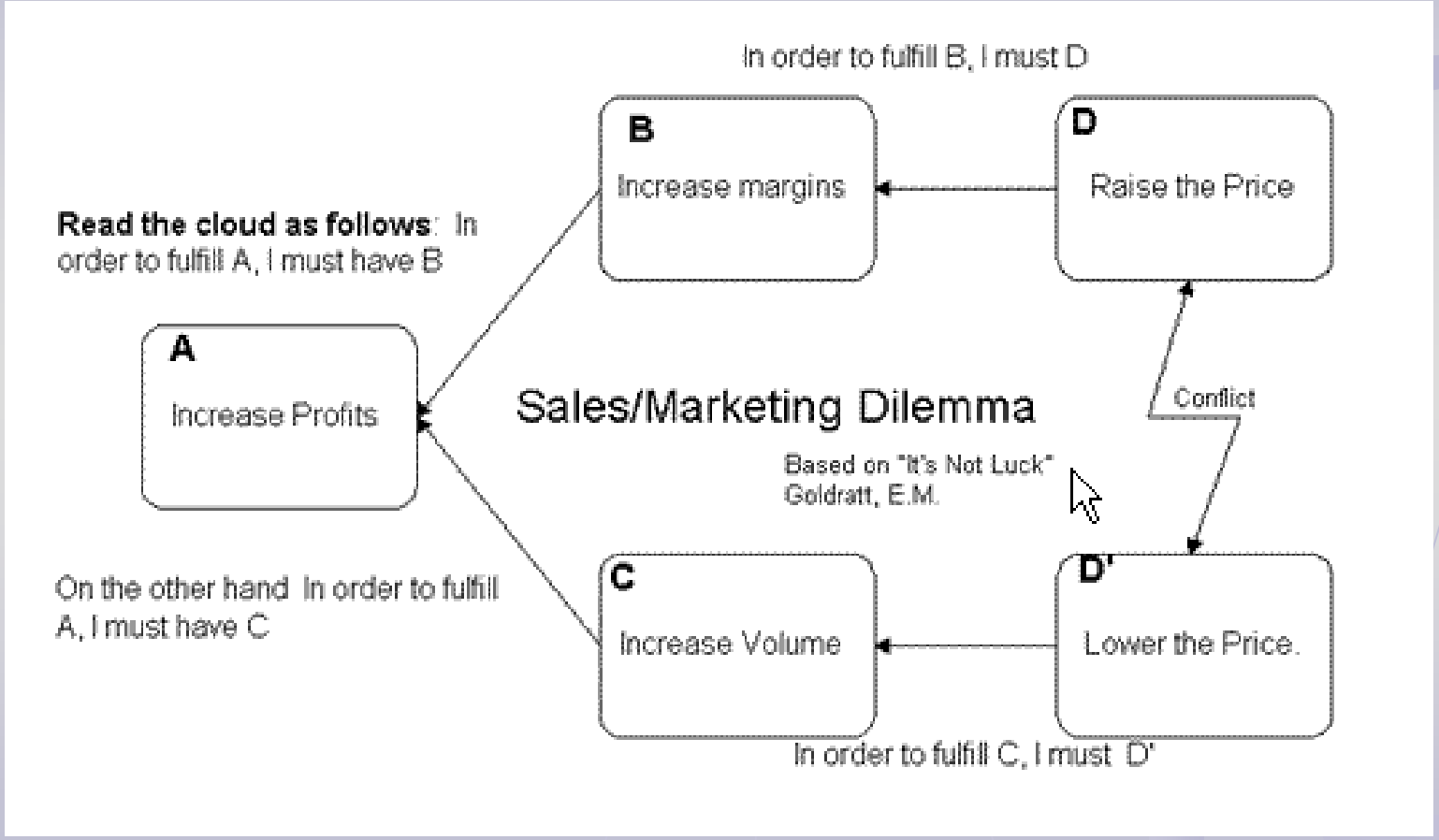
Performance Management

Evaporation cloud tree- example 2



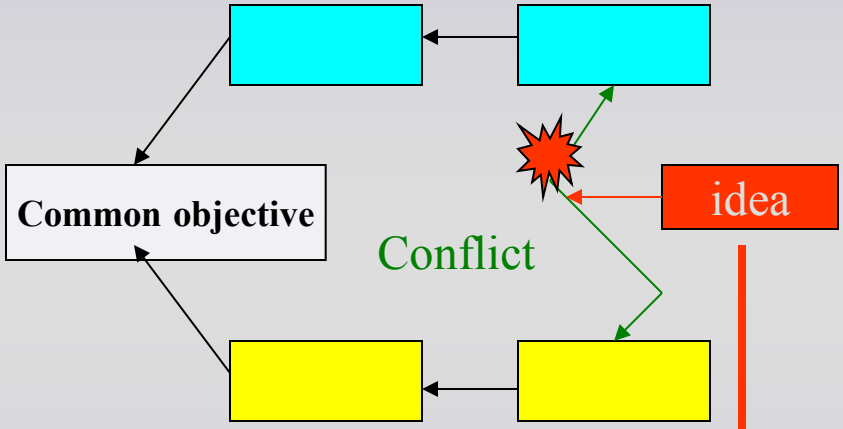
Implementation of TOC

Evaporation cloud tree- example 3

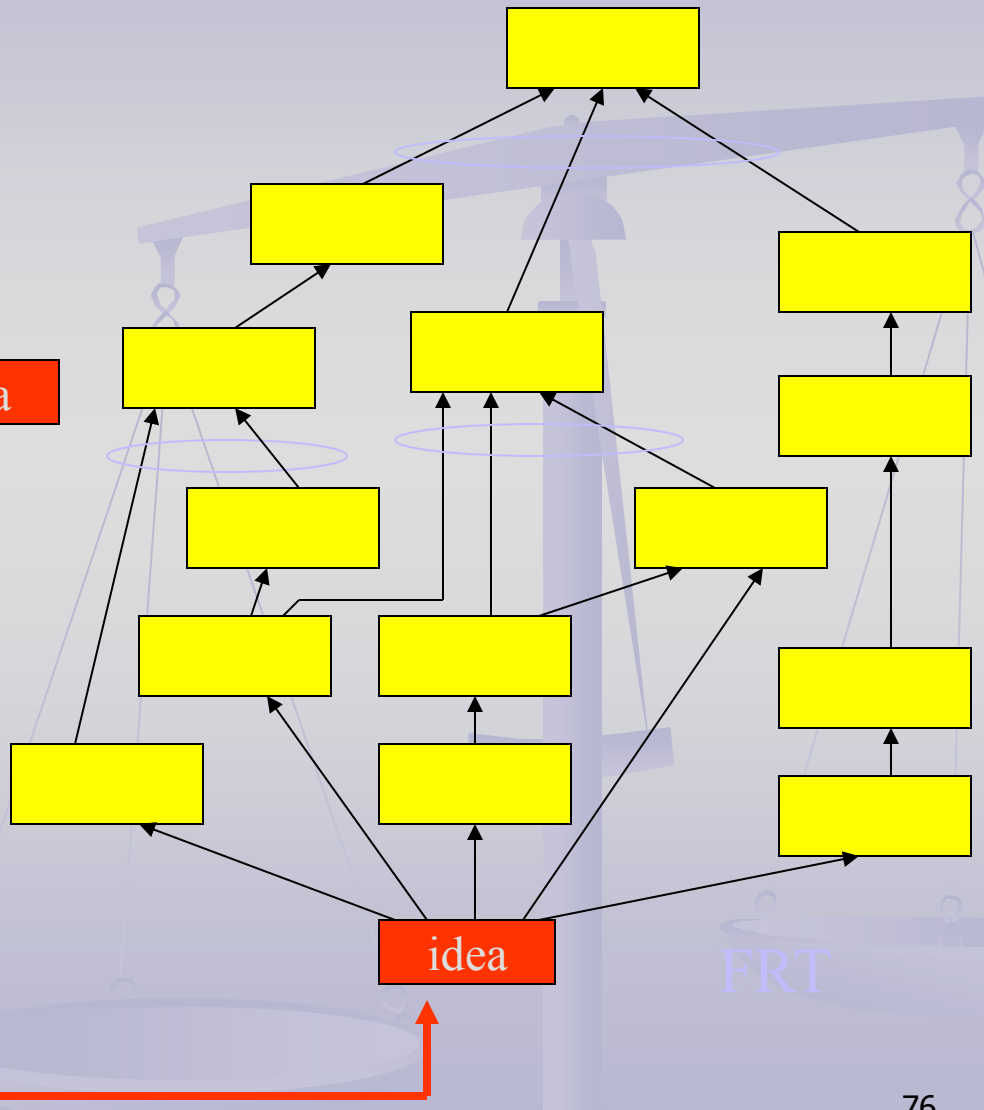


Sales and prices

Transition Evaporation Cloud Tree ➡ Future Reality Tree (FRT)

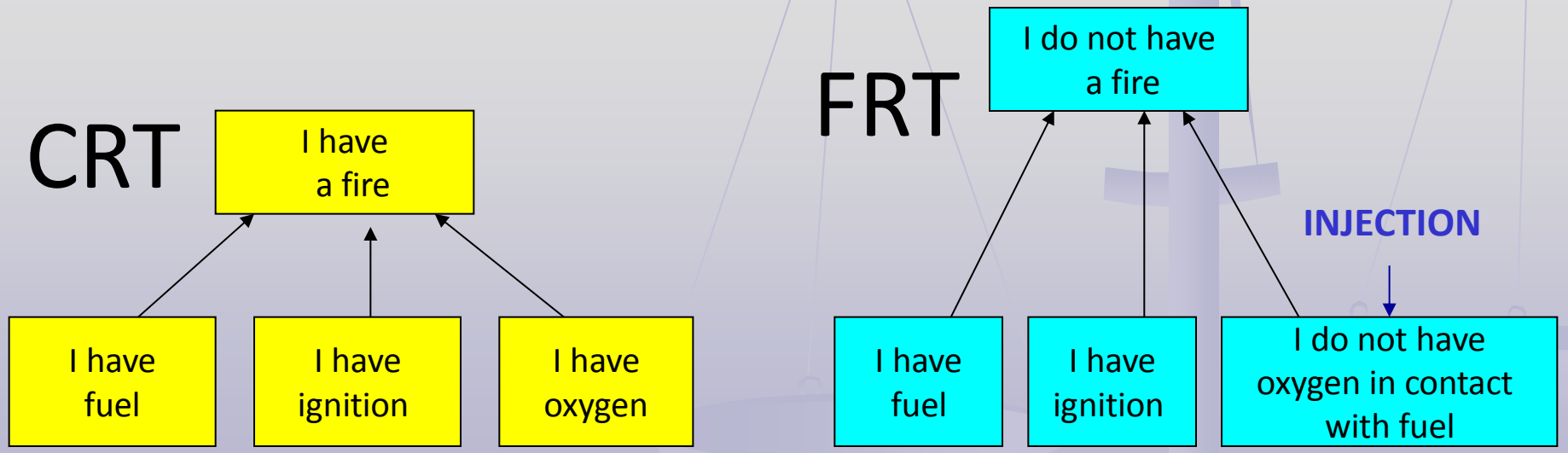


Evaporation Cloud Tree



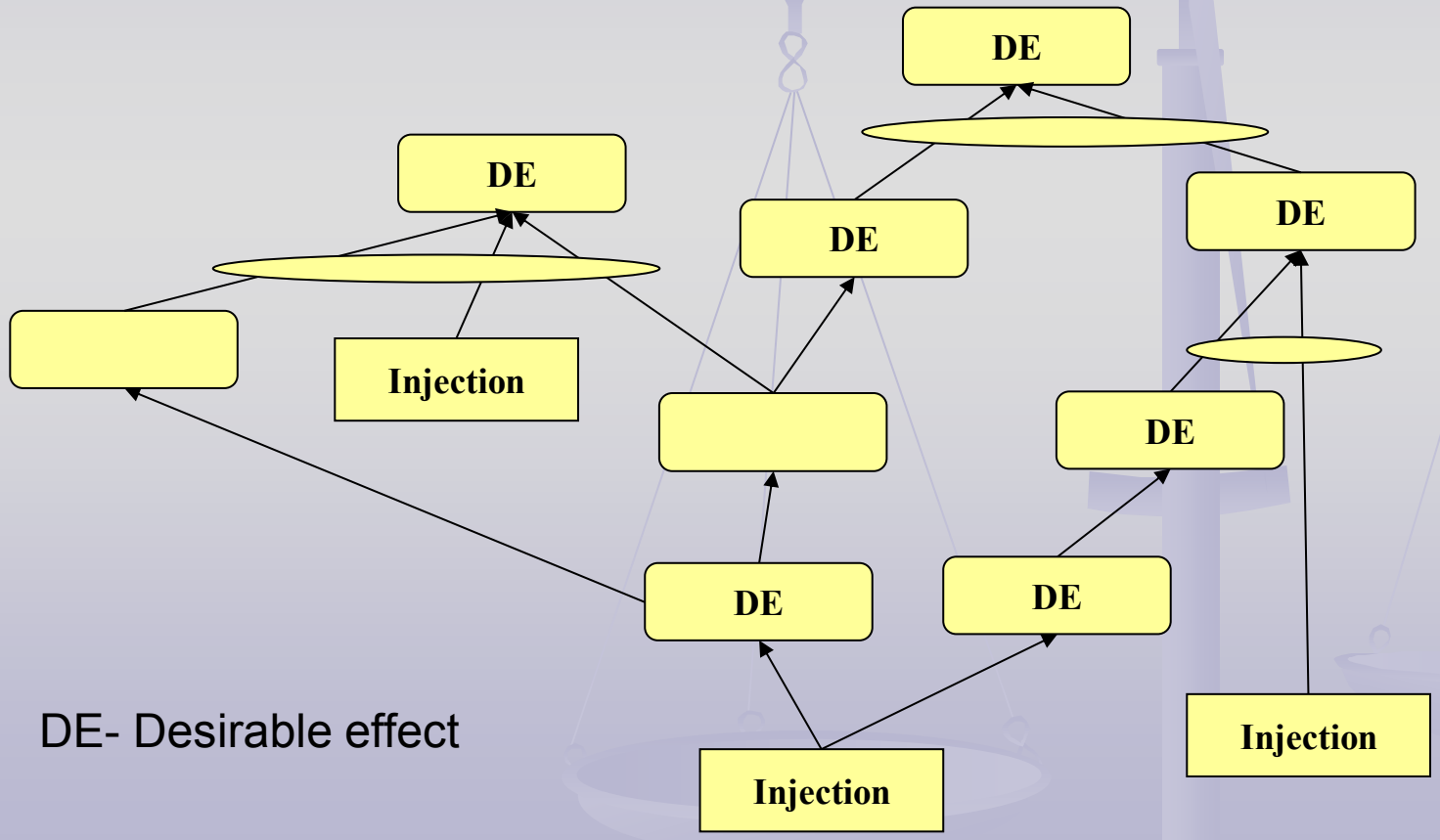
Future Reality Tree (FRT)

- The FRT **is similar** to the CRT in structure, but with new proposed actions, policies, and behaviour injected into it in order to create a new vision of the future reality of the system.
- The power of the logical "**if-then**" construction is that if any one of the lower-level causes are removed or mitigated, everything that is above it is subject to change.
- If any one of the three „IFs“ are removed or modified, the „THEN“ may be removed from consideration as a problem



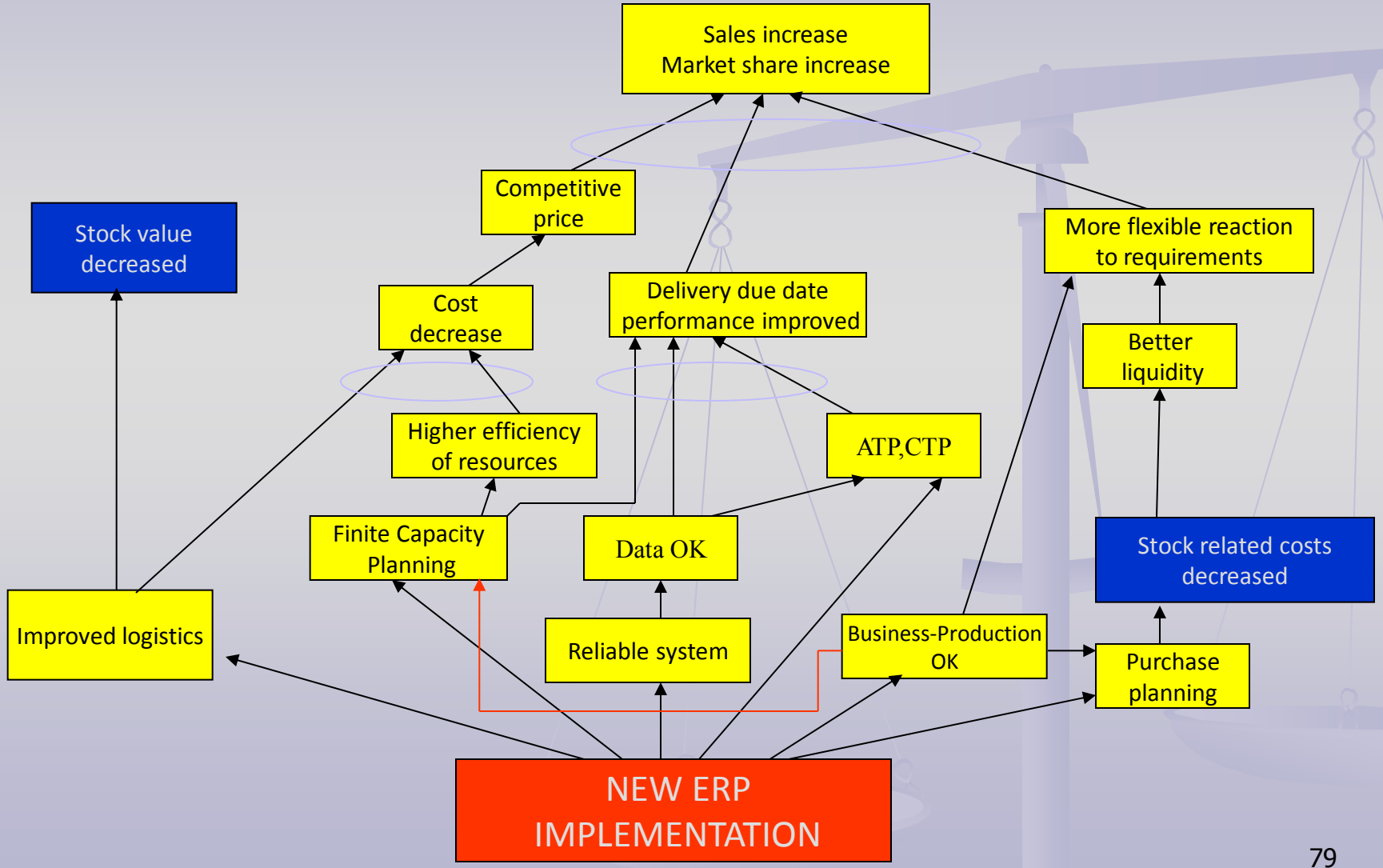
Future Reality Tree (FRT)

- The objective of the FRT is to communicate a vision of how to change the undesirable effects found in the CRT to desirable effects.



DE- Desirable effect

Future Reality Tree (FRT)



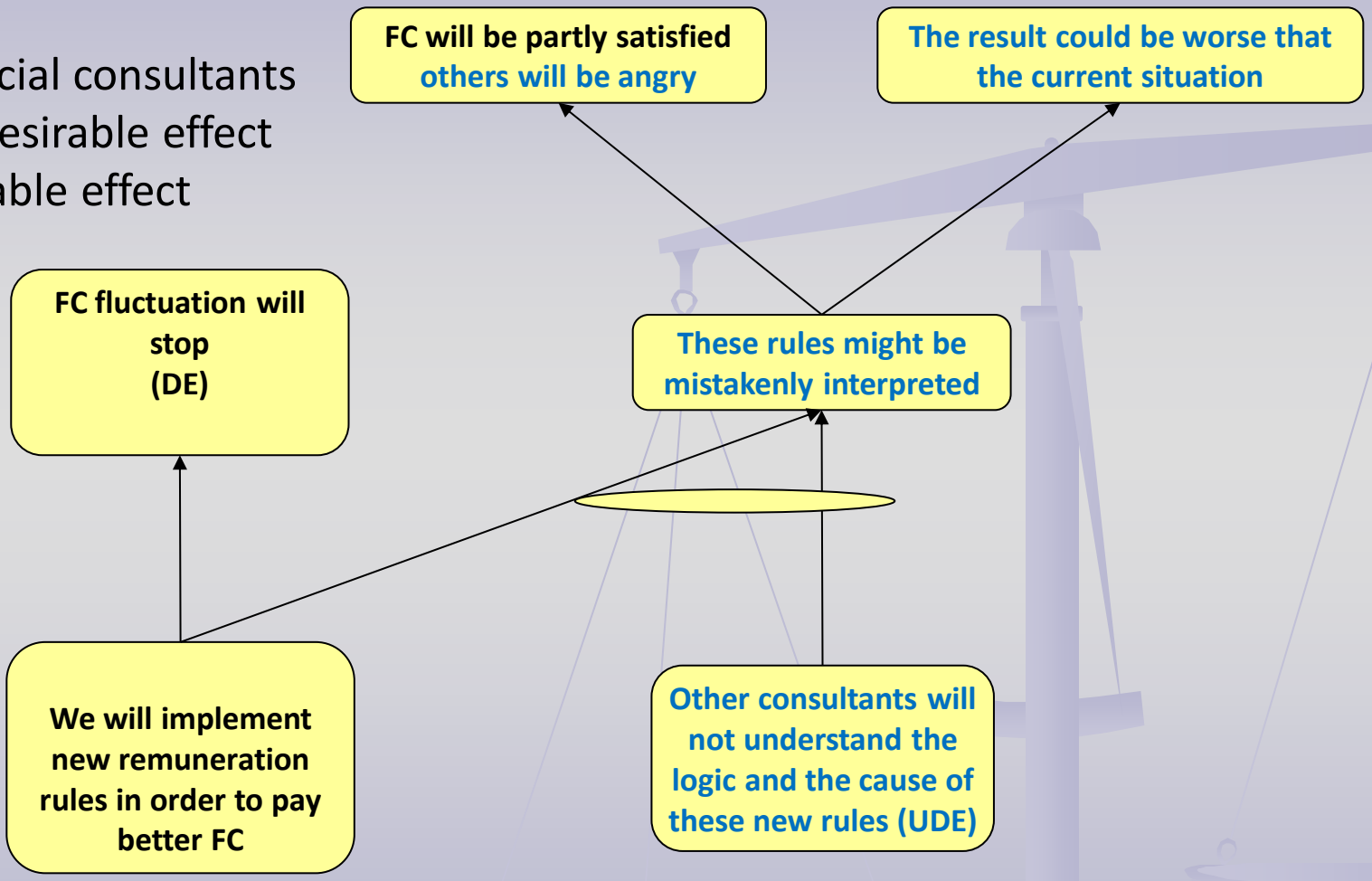
YES, this could be managed BUT……

Negative Branch Reservations (NBR):

- use of **sufficiency logic** – by taking into consideration **objections** of other involved persons
- these objections were related to possible **undesirable impacts** of the injection (solution) implementation
- **NBR** is often a part of the **FRT** (**F**uture **R**eality **T**ree)
- Evaporation Cloud Tree, FRT and **NBR** enable to answer the second question : **To What To change ?**

YES, this could be managed BUT……

FC= financial consultants
UDE=undesirable effect
DE=desirable effect



Negative Branch Reservations

We cannot implement it, because . . . . .

(Prerequisite Tree):

- use of **necessity logic** – identification of **obstacles**
- use of the human ability to invent any reason

WHY IT IS NOT FEASIBLE

- setup of the necessary intermediate objectives
- setup of the schedule for change process

We cannot implement it, because . . . . .

(Prerequisite Tree):

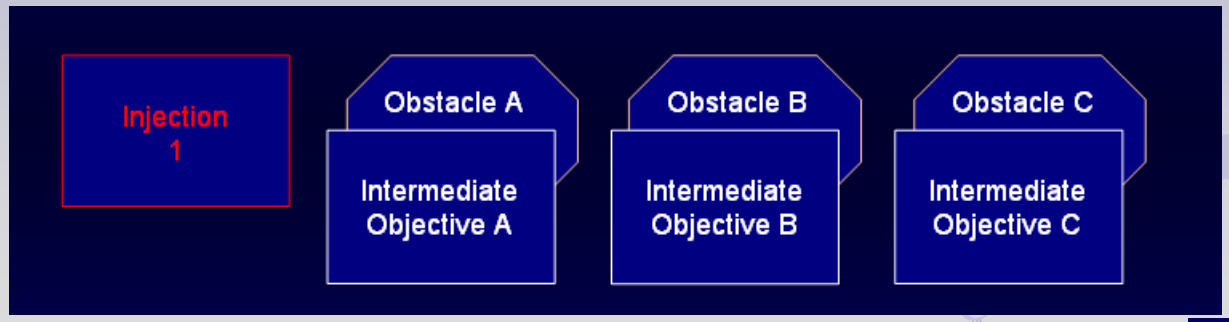
- The pre-requisite tree ought to be considered **the most important tree** in the **Thinking Process** suite.
- It is the tree that allows us to overcome the **obstacles** that stop us from implementing our plan.
- It is also the tree that in fact becomes the **implementation plan** ***(it is very, very close to project management practice !!!!)***
- And it is the tree to which timelines, responsibilities, and accountabilities can be assigned to.

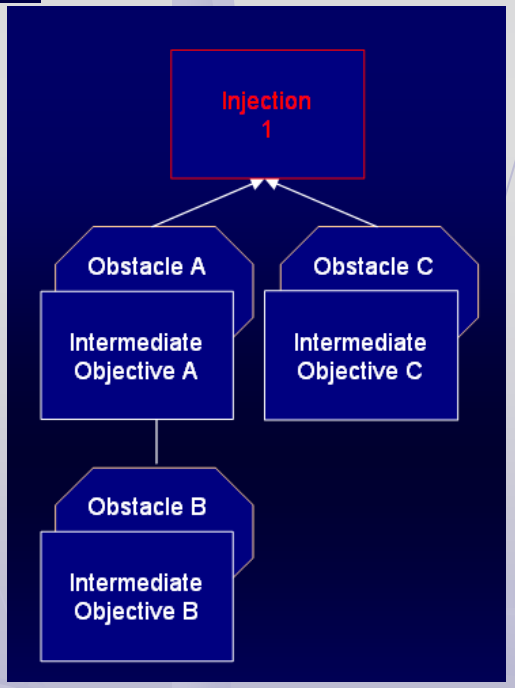
- The pre-requisite tree occupies the position of “plan” amongst the Thinking Process tools.

HOME study ONLY !!!!

Prerequisite tree - construction

So our first step will look like this

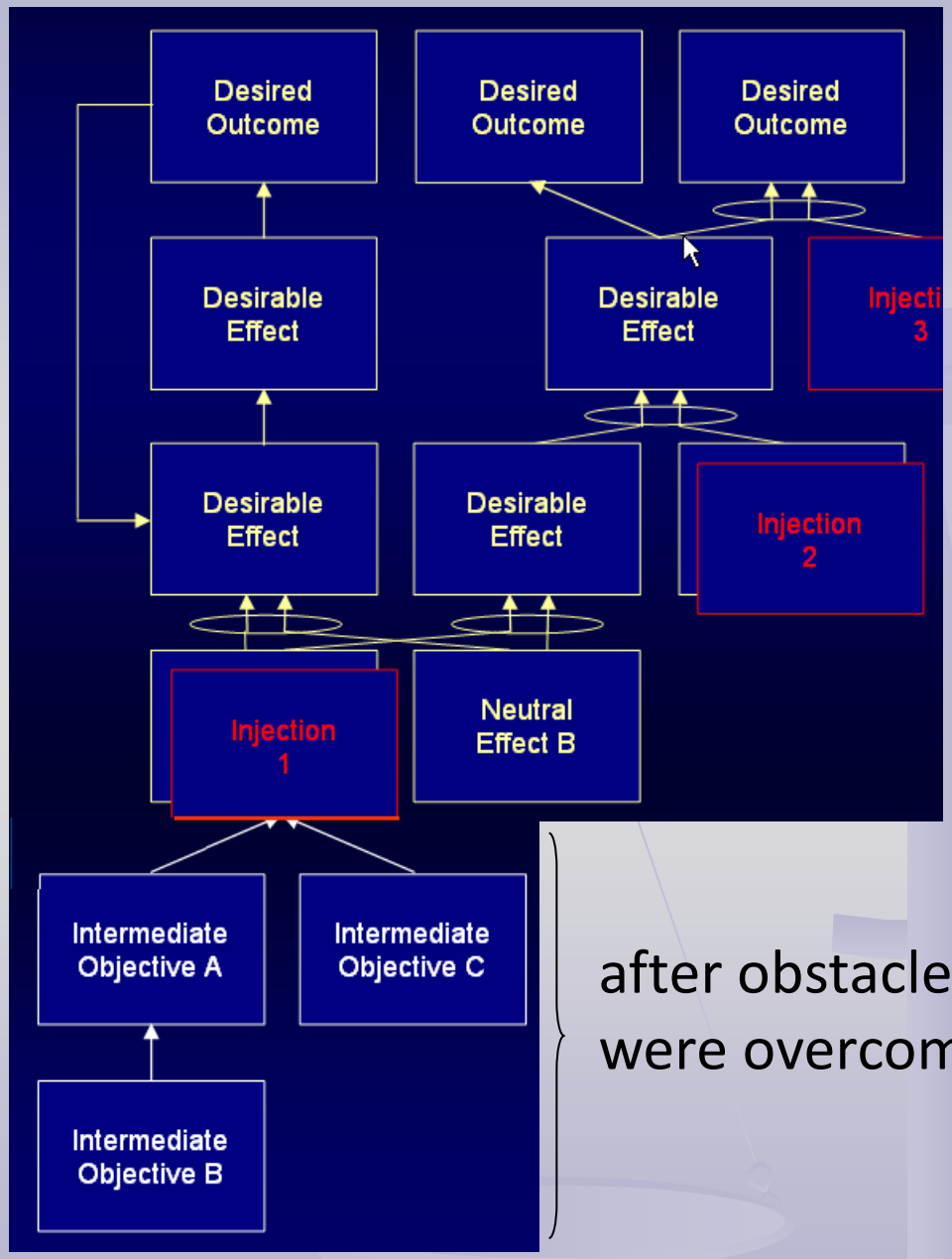




Objectives	Obstacles	Actions
Better reports	Not SW tool	Buy it
Improve liquidity	High Safety Stock	Optimization of ROP
Smart organization	Not Workflow Tool	Buy it or modify ERP

ROP=Reorder Point –see logistics theory

HOME study ONLY !!!!



after obstacles were overcome

HOME study ONLY !!!!

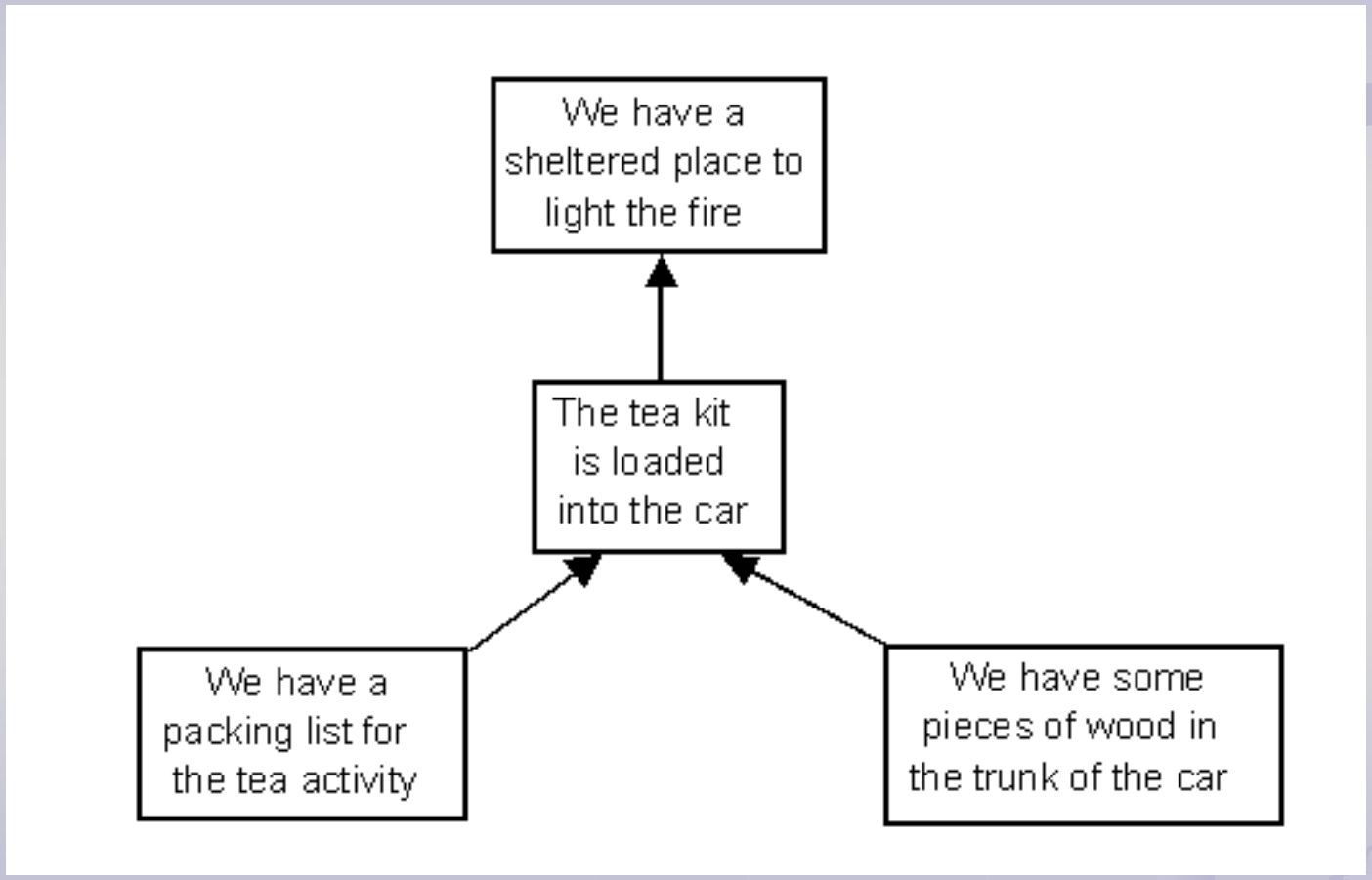
Prerequisite tree - example

- Tea Mission (we want to have a nice cup of tea in the wilderness)
- **Obs-1 :** We do not have material to burn
  Obs-2 : Collection of such material is not allowed in the wilderness.
  Obs-3 : There could be a strong wind
  Obs-4 : We do not have matches
  Obs-5 : We do not have cups
  Obs-6 : We don't have a container to boil the water
- **IO-1 :** We have some pieces of wood in the trunk of the car.
  IO-3 : We have a sheltered place to light the fire
  IO-4.1 : We have a packing list for the tea activity
  IO-4.2 : The tea kit is loaded into the car

IO= intermediate (partial) objective
Obs= obstacle

HOME study ONLY !!!!

Prerequisite tree - example



HOME study ONLY !!!!

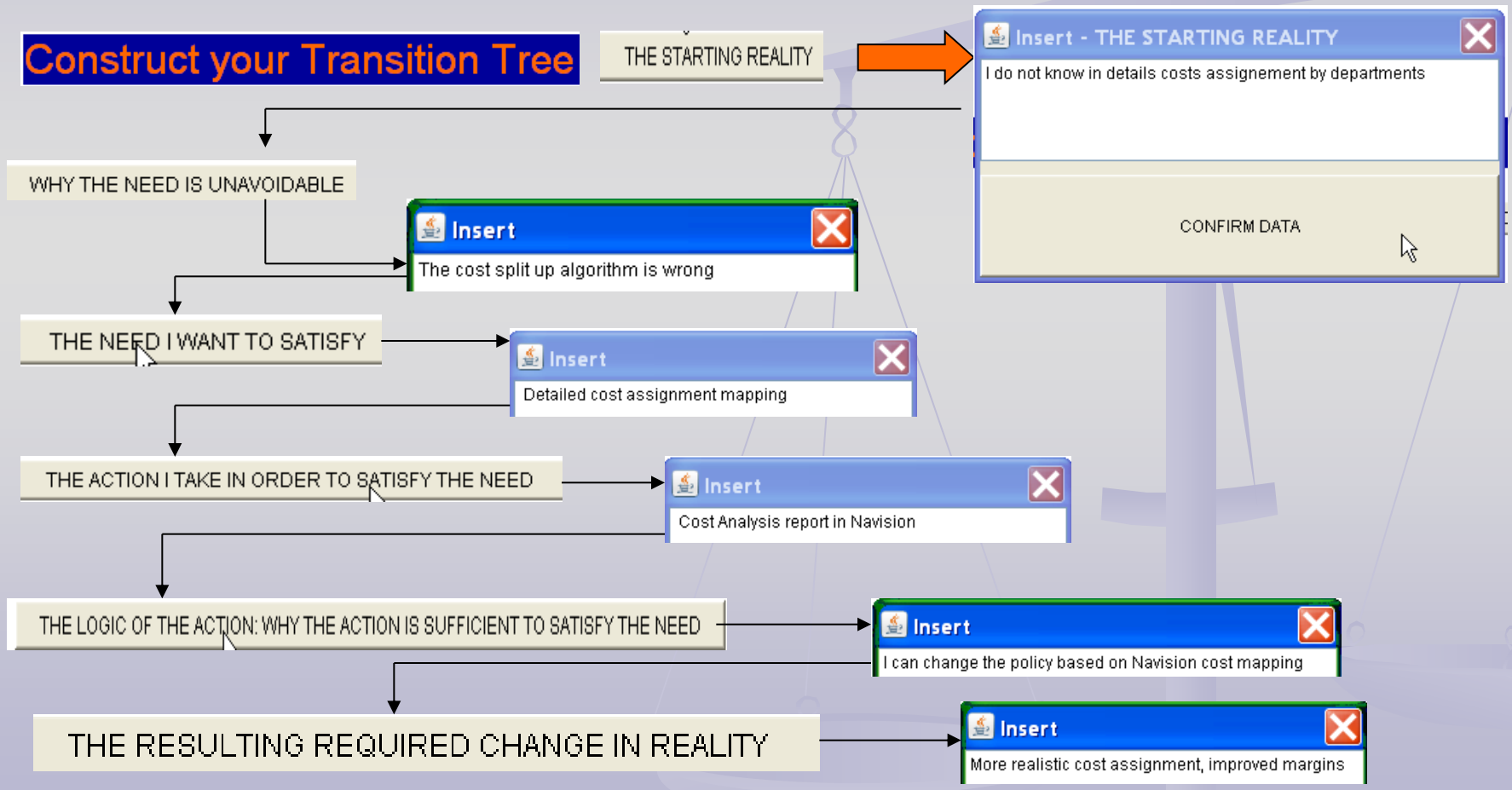
We cannot implement it, because . . . . .

(Transition Tree):

- detailed schedule of change implementation process
- what actions have to be taken in order to reach intermediate objectives using sufficiency logic (IF-THEN-ELSE)

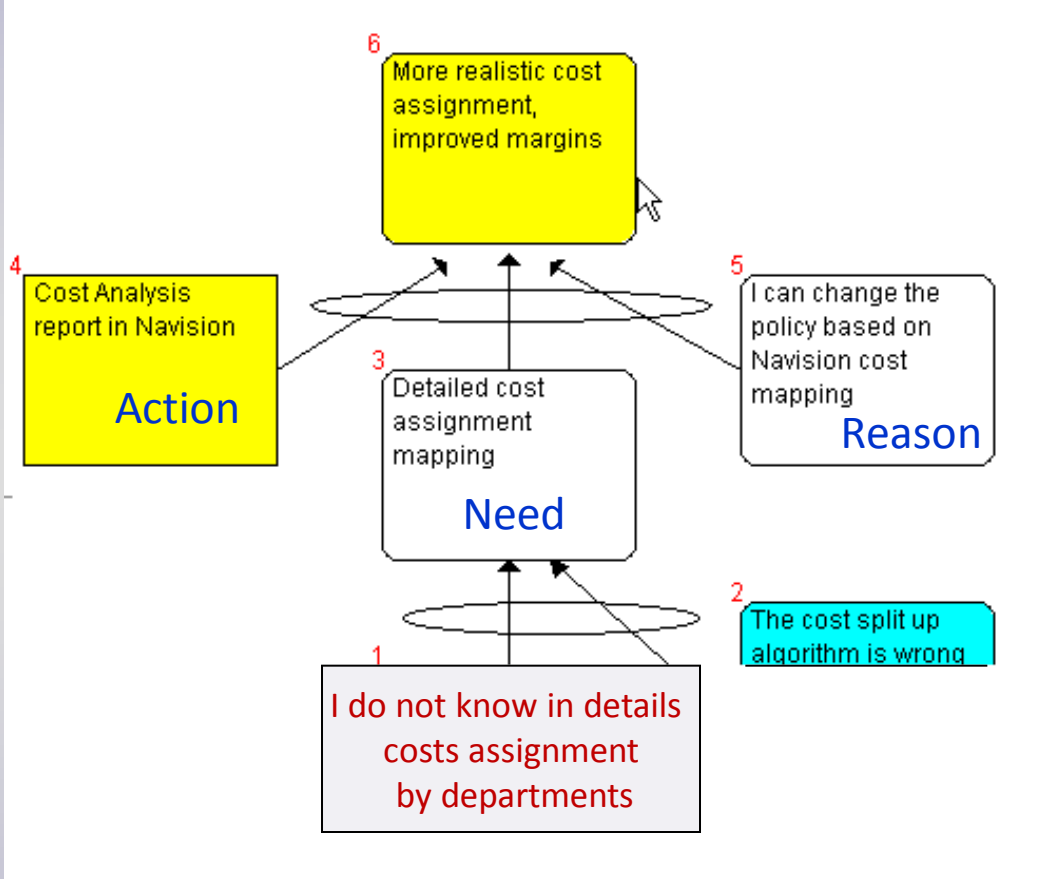
We cannot implement it, because…..HOME study ONLY !!!!

(Transition Tree) http://www.thedecalogue.com/Tools/trt/TREE.html:

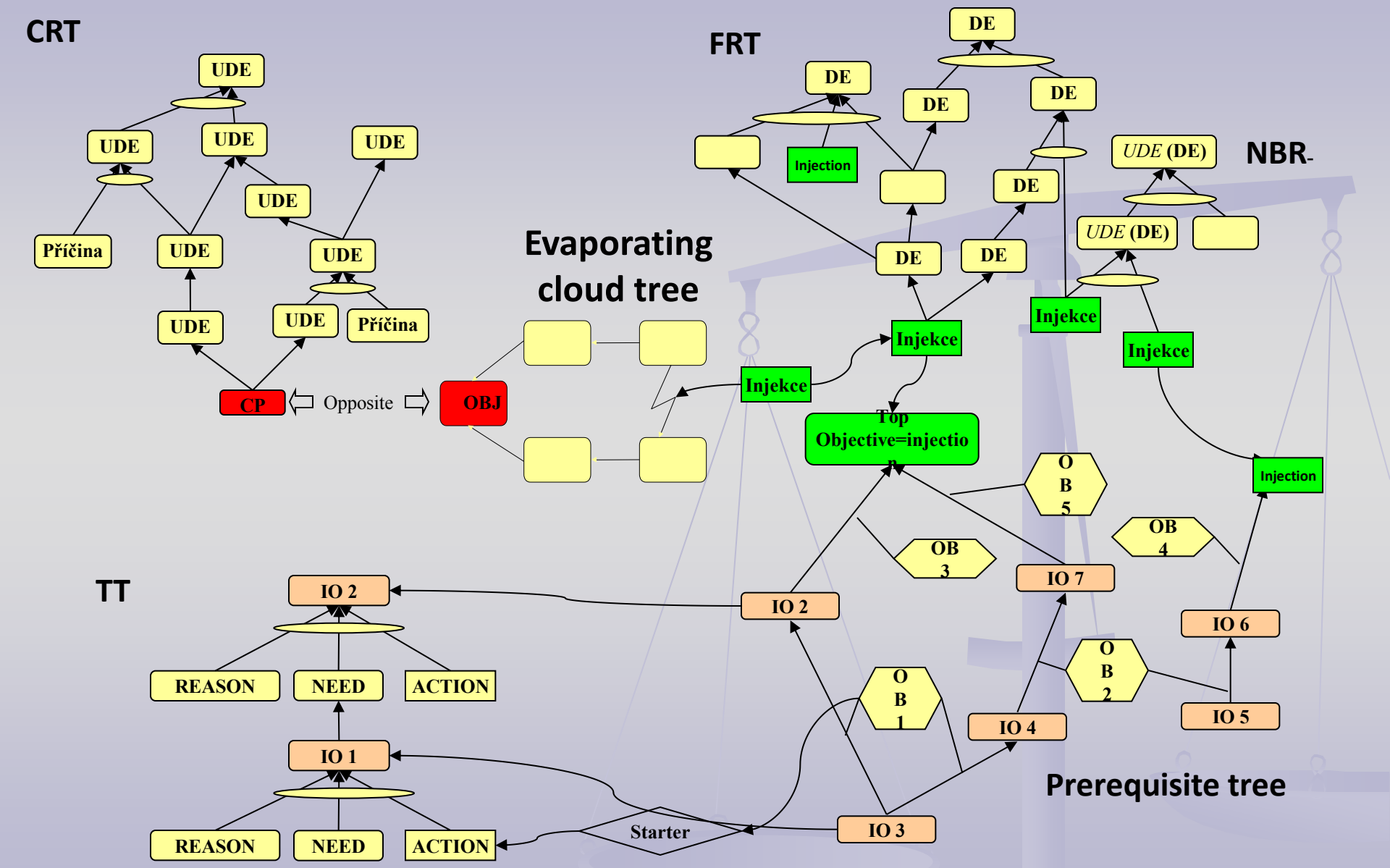


HOME study ONLY !!!!

We cannot implement it, because…..



Thinking Process Tools Relationships



Additional metrics of TOC (appendix 1)

- **Inventory dollar days (IDD)**
- A measure of the effectiveness of a supply chain – i.e., did it do things that it shouldn't have done and as a result is the supply chain holding inventory of products the customer doesn't want? IDD accounts for two things: 1. the time from when a unit is placed in stock until it is actually needed by a customer; and, 2. the monetary value of the inventory being held. IDD is calculated by multiplying the monetary value of each inventory unit on hand by the number of days since that inventory entered the responsibility of that link. The system should strive for the minimum IDDs necessary to reliability maintain zero throughput dollar days.
- NOTE: The resulting unit of measure is "dollar-days". It is neither monetary nor time based. Attempts to compare dollar-days to other monetary measures are invalid. IDDs can be compared only to other IDD levels.

Not for MPH-AOMA adn BHP_EPS1

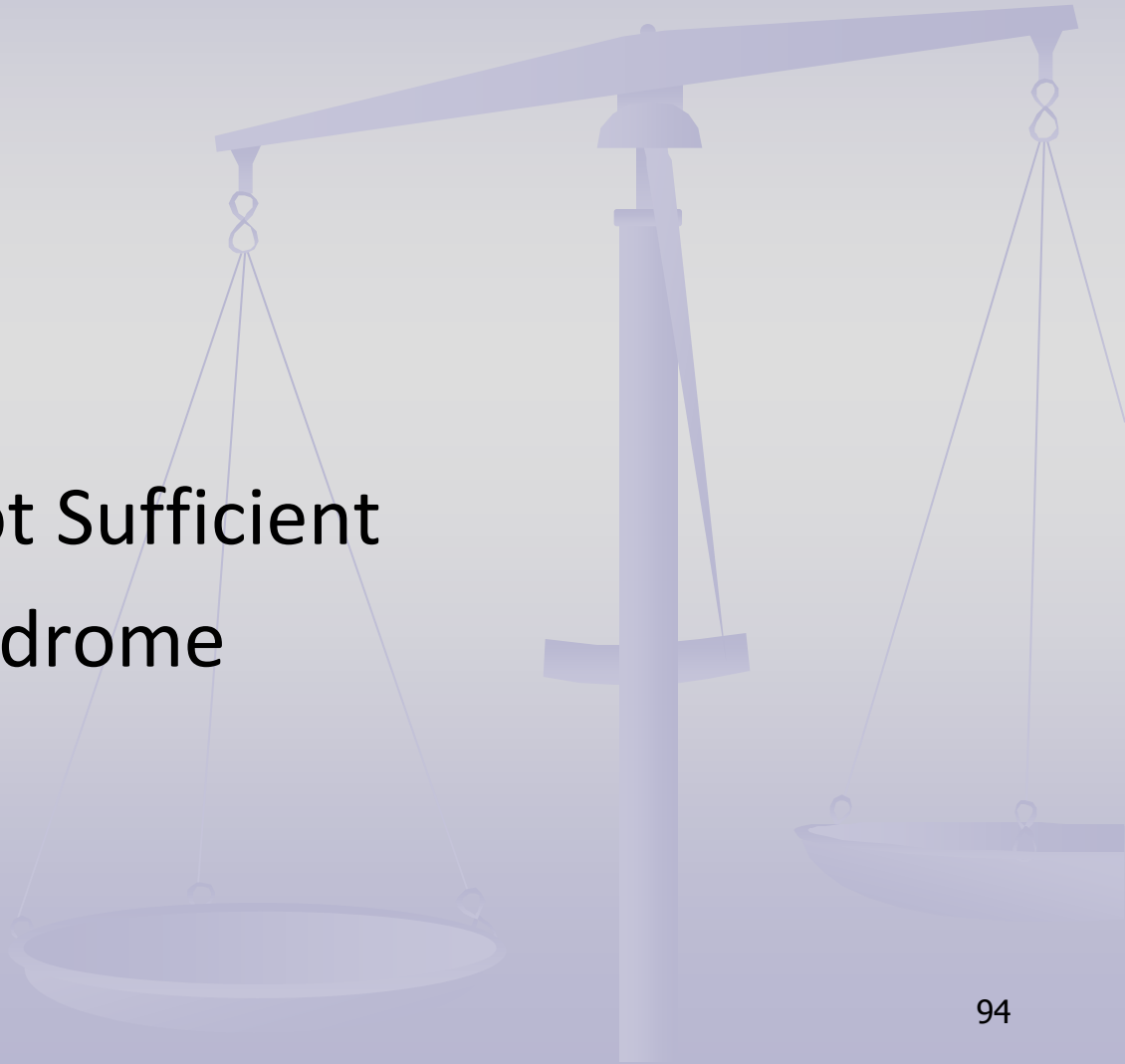
Additional metrics of TOC (appendix 2)

- **Throughput dollar days (TDD)**
- A measure of the reliability of a supply chain. TDD considers two things: 1. the monetary value of the things a link is committed to deliver but does not; and, 2. the number of days by which the link misses its commitment to deliver. TDD is the summation of the commitments not delivered on time during the chosen time period. The TDD value of individual missed commitments is calculated by multiplying the dollar value of the end product times the number of days the commitment is/was overdue. The system should strive for zero throughput dollar-days.
- NOTE: The unit of measure "dollar-days" is neither monetary nor time based. Attempts to compare dollar-days to other monetary measures are invalid. TDD levels can be compared only to other TDD levels.

Literature

<u>Goldratt, E., M.:</u>

- The Goal
- The Race
- The Critical Chain
- Necessary But Not Sufficient
- The Haystack Syndrome
- It is Not Luck



Internet

- www.goldratt.cz
- www.goldratt.com
- www.toc-goldratt.com
- www.focusedperformance.com
- www.tocc.com
- www.tocca.com.au
- http://www.dbrmfg.co.nz/ - **A guide to implement the Theory of constraints**
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- .....