R&D Project Management in the Chemical Industry

The following collection of PowerPoint® Charts is intended to further clarify and supplement the relevant specialist publications on the subject matters dealt with. This collection in no way is used for any commercial purposes, but as learning material for students.

Selected sources for in-depth studies of the respective subject matters are given in some lists of references.

The chemical-technical target components, formulas, deadlines, data, project structures and action plans shown in project examples P1-P3 are widely with a practical orientation, but yet purely fictitious. They are solely used for a clear illustration of the particular topic and for learning purposes.

The names of all persons with project functions are solely fictional. Matches with the names of other people would be purely coincidental.

Rainer Buerstinghaus

R&D Project Management
in the Chemical Industry

The Subject Matter

- Innovations: Characteristics, Measures for its Promotion, Process Variants.
- Three Examples for Innovation Projects (Chemistry and Technology):
  1. Highly Elastic Clear Coats for the OEM Automotive Sector.
  2. Nitrilase Catalyzed Synthesis of a Chiral Hydroxy-Carboxylic Acid.
  3. New Metal-Organic Frameworks for the Adsorptive Storage of Gases.
- Projects, Target Systems, Project Management in R&D.
- Appropriate Organization and Effective Structure Planning of R&D Projects.
- **Project Flow Planning, Milestones, the Stage-Gate®-Process, Network Diagrams.**
- Effective Implementation and Control of R&D Projects, Trend Analyses.
- Success Risks: Identification, Classification and Treatment.
- Recruitment and Lead of Project Staff:
  Chemists (m/f/d) – Team Players, Pacemakers and Executives in Projects.
- Project Manager (m/f/d): Tasks, Leadership Functions and Personality Profile.
- The Systematic Evaluation of Individual R&D Projects.
- R&D Strategy: The Planning of a Project Portfolio.

R&D Project Management in the Chemical Industry

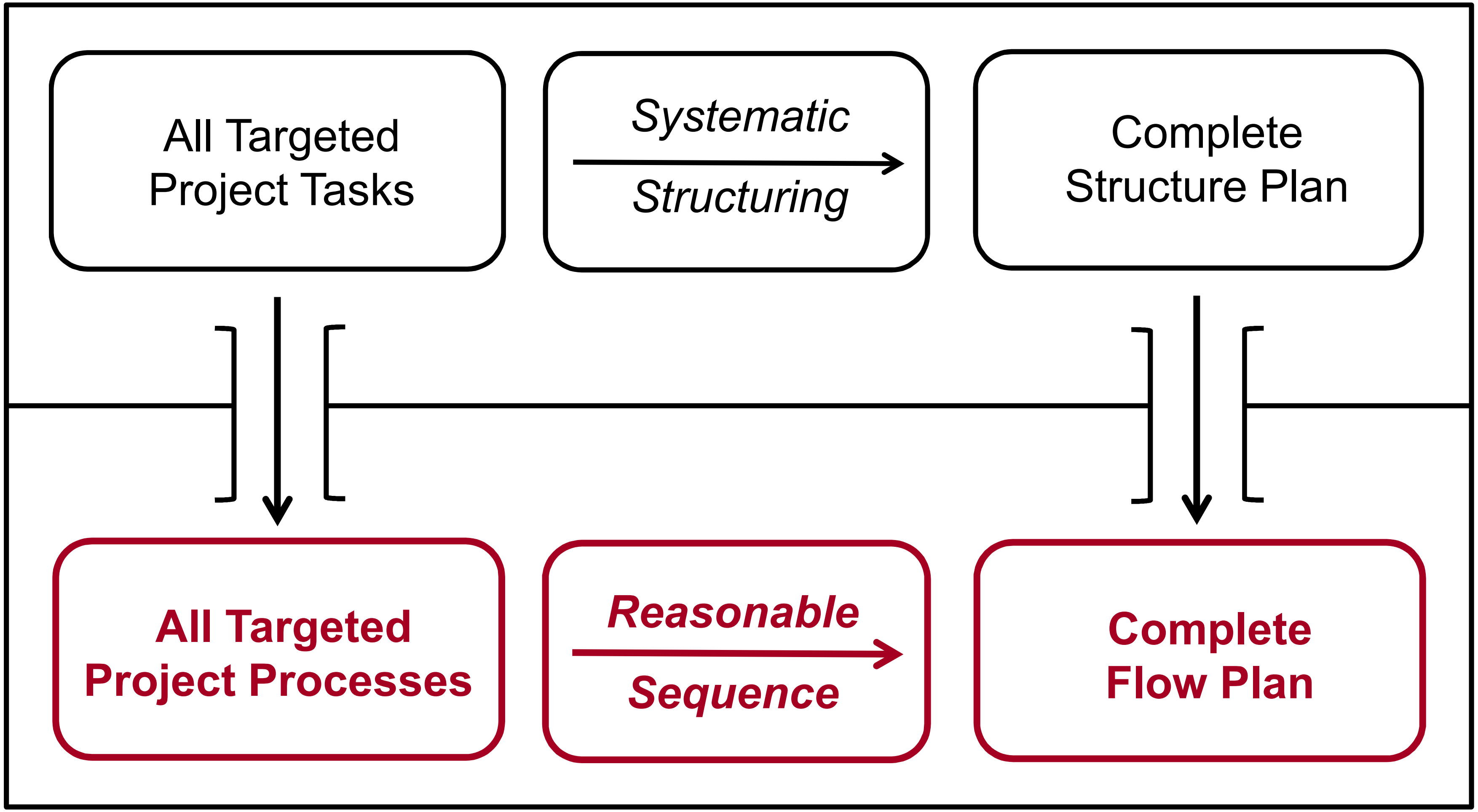
Subject Matter →

Project Flow Planning.

Rainer Buerstinghaus

Flow Planning of R&D Projects

Project Flow Planning;
The Structure Plan Serves as the Basis:



Rainer Buerstinghaus

Project Flow Plan → Characteristics, Information Content:

Flow Plan: Reasonable temporal linkage of ***all*** project processes required for the achievement of the targets.

It contains action-relevant information about *all* the operations to be performed, in particular regarding their →

→ start dates.

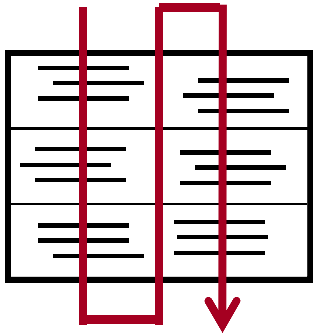
→ respective durations (therefore also final dates).

→ affiliations to defined project phases.

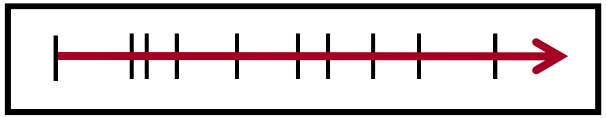
→ possibly mutual dependencies.

Flow Planning of R&D Projects

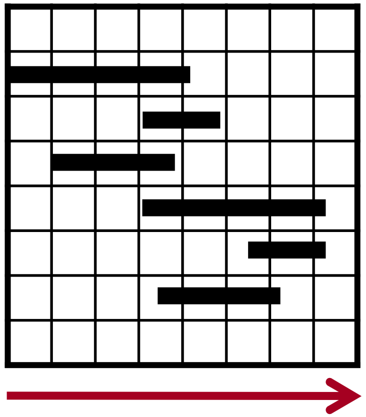
Forms of Time Planning in R&D Projects:



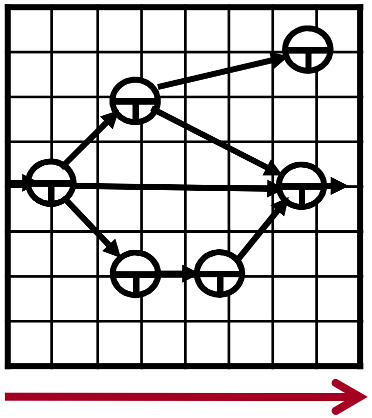
Diary



"Event Timeline"



Gantt Diagram



CPM-Network Diagram

Rainer Buerstinghaus

Project Flow Plan → Purpose of the Forward Planning:

Wisdom (Prudentia, Sapientia) is not the knowledge of what finally has to be done, but the sure knowledge of **what needs to be done in the next step**!

"Wisdom reveals itself in the ability to make the right **decision** at the right time **about the goal-oriented actions** ..."

Flow Planning of R&D Projects

Professionalism: → Mental Factors :=)

Expert-/Method-Knowledge | Social Competence | Emotional Intelligence

↓ ↓ ↓

Reasonable **Planning for Effectiveness and Efficiency**

Project Experience

"Wisdom" and "methodical-professional reliability"
for an effective project planning!

Rainer Buerstinghaus

The Different Phases within an R&D Project:

	Project Phase	*Actions*
▪	**Conception**	Identification of the opportunity fields; First laboratory studies on feasibility; Idea reviews; Patent applications; Comparison with the strategy of the GBU; Drafting a business scenario.
▪	**Planning**	Concrete target system; Structures; Processes; Required resources; Cost plan.
▪	**Project Start**	"Kick-off"; Beginning of the R&D work; Systematic laboratory experiments; First test series.
▪	**Scale-up**	Trials in the pilot plant; Standardization; QM.
▪	**Market Launch**	Technical marketing; Initial production runs; Supply of competent pilot customers.
▪	**Final Phase**	Closing decision for the production; "Debriefing".

Flow Planning of R&DProjects

Requirements for a Valid Project Order:

1. Defined Company Guidelines →
2. Defined Corporate Strategy →
3. Brilliant Idea, Patent, Project Idea →
4. Feasibility Studies, Laboratory →
5. Project Application, Steering Committee →
6. **Project Order** Project start

Important rule: No project without a project order!

Example

Project Order, Corporate Guidelines:

Corporate Guidelines, Excerpt:
"Four Strategic Guidelines" of BASF SE.

(Source: Online Report 2010)

We earn a premium on our cost of capital.

We help our customers to be more successful.

We form the best team in industry.

We ensure sustainable development.

Example

Project Order, Corporate Guidelines:

Corporate Strategy, Excerpt: "Principles as a Strategic Basis for our Success in the Market".

(Source: BASF-Online Report 2017)

We add value as one company.

We innovate to make our customers more successful.

We form the best team.

We drive sustainable solutions.

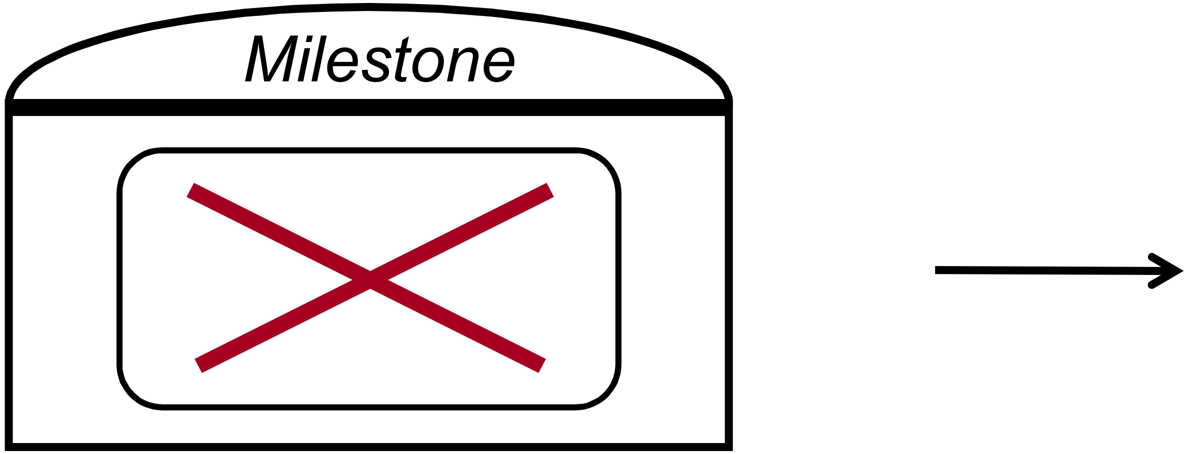
R&D Project Management in the Chemical Industry

Subject Matter →

Milestones.

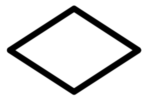
Flow Planning: Milestones

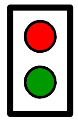
Core Elements in Every Project Flow Planning!



Verifiable (intermediate) goal with a defined **point** in time, therefore an event. Exactly this is coupled with decisions.

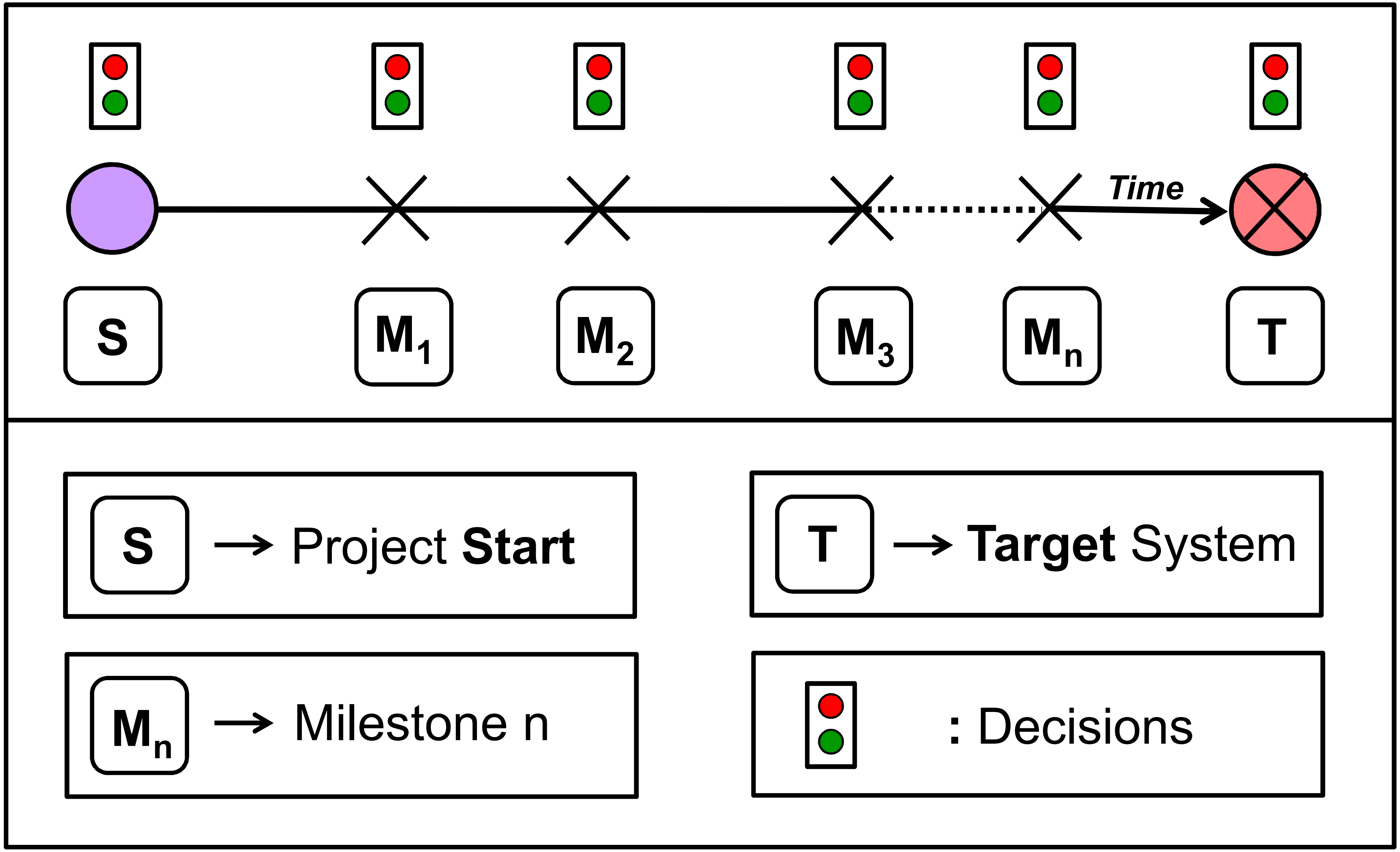
Decisions!





Flow Planning: Milestones

Core Elements in Every Project Flow Planning!



Flow Planning: Milestones

Defined Stage Goals within Project Course:

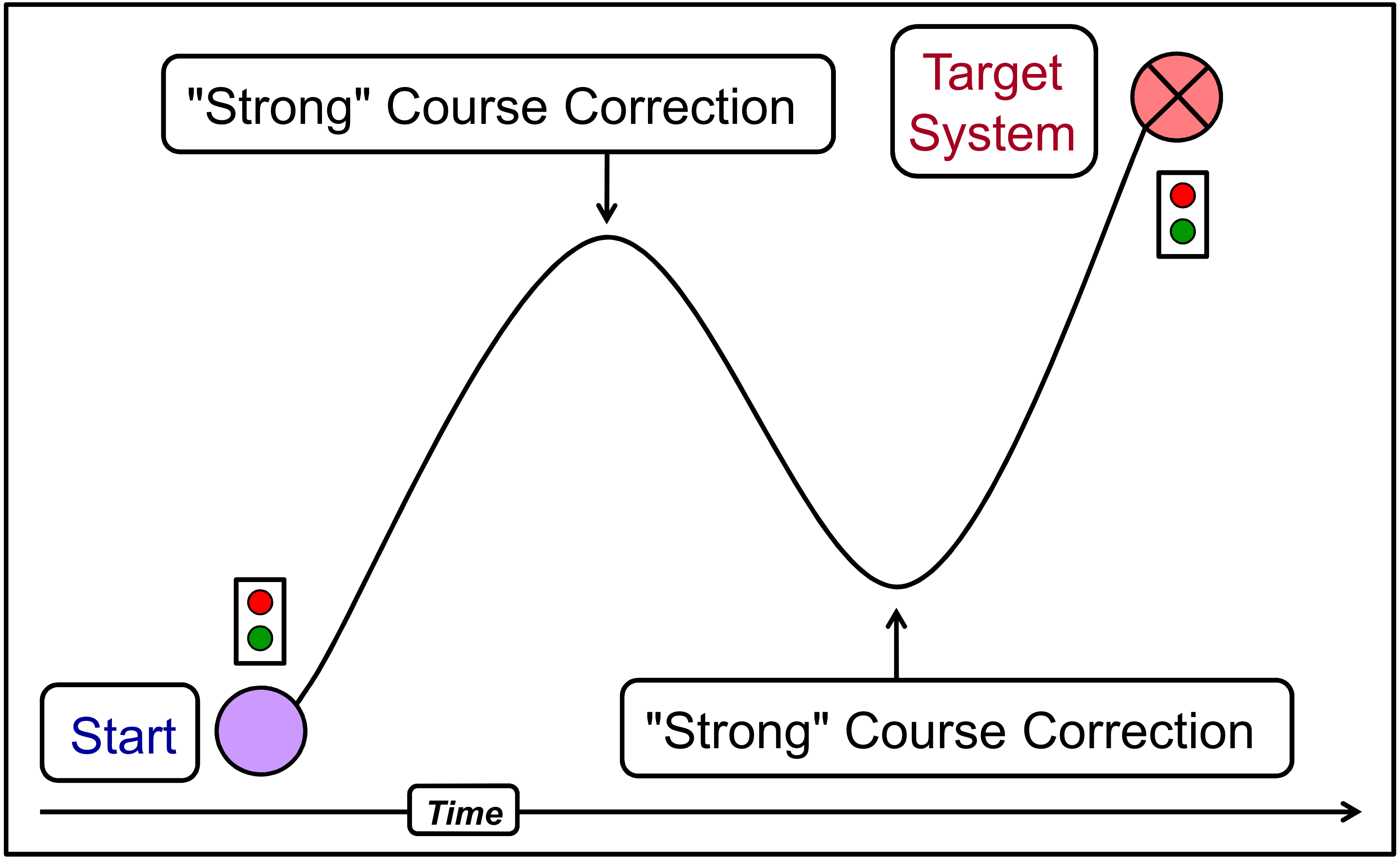
- Verifiable intermediate goal with "event character".
- Contents and date are defined, interim result.
- Forces the assessment of all previous project results.
- **Decisions on project progress are to be made!**

◇	◇	◇

- Continuation of the project as scheduled?
- Project delay, realization of improvements?
- Accelerated continuation of the project; Extra effort?
- Realization of the next planned actions?
- If necessary: Changes in the target system?
- **If necessary: Project Stop?**

Flow Planning: Milestones

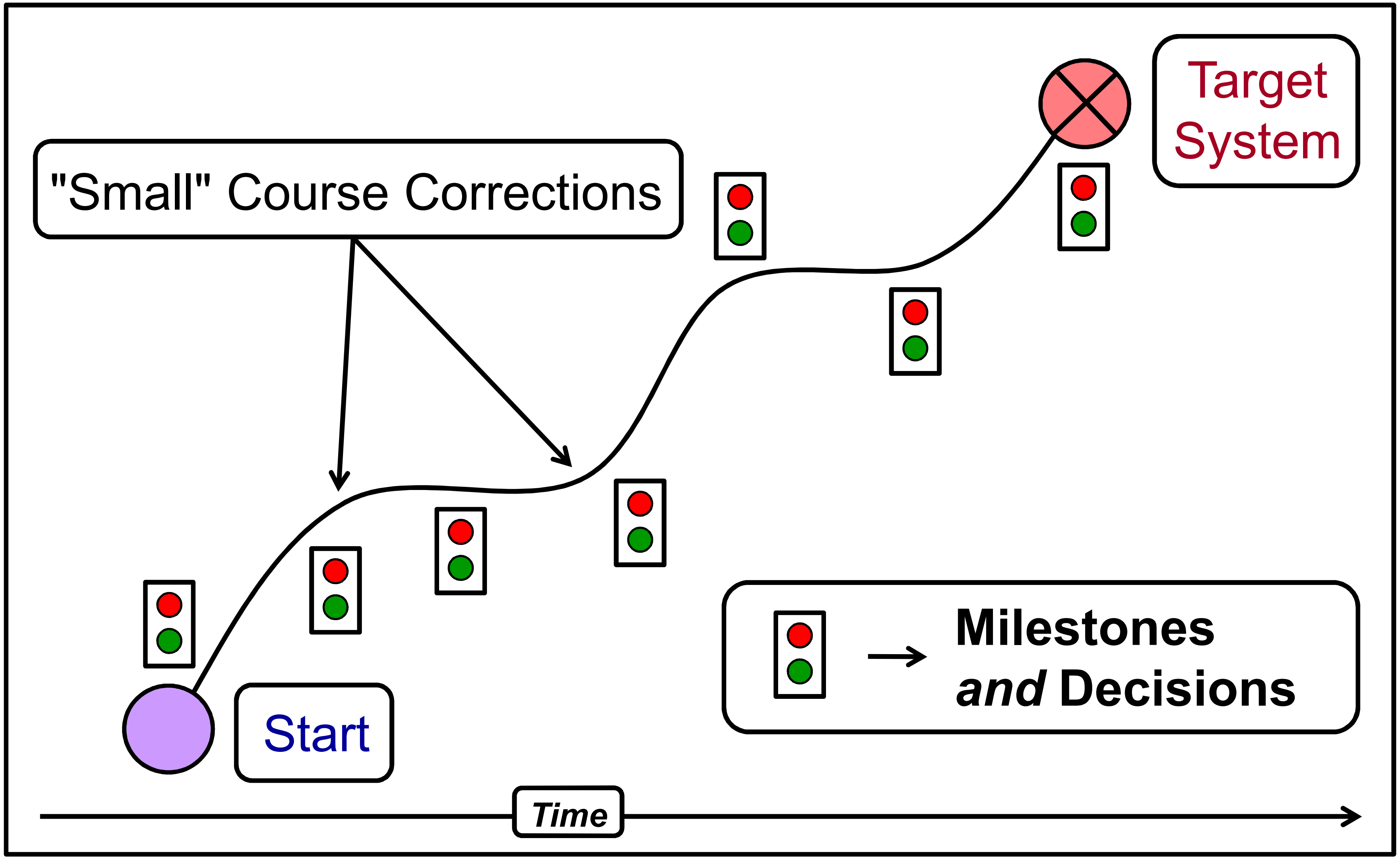
Course of a R&D Project Without Interim Milestones:



Rainer Bürstinghaus

Flow Planning: Milestones

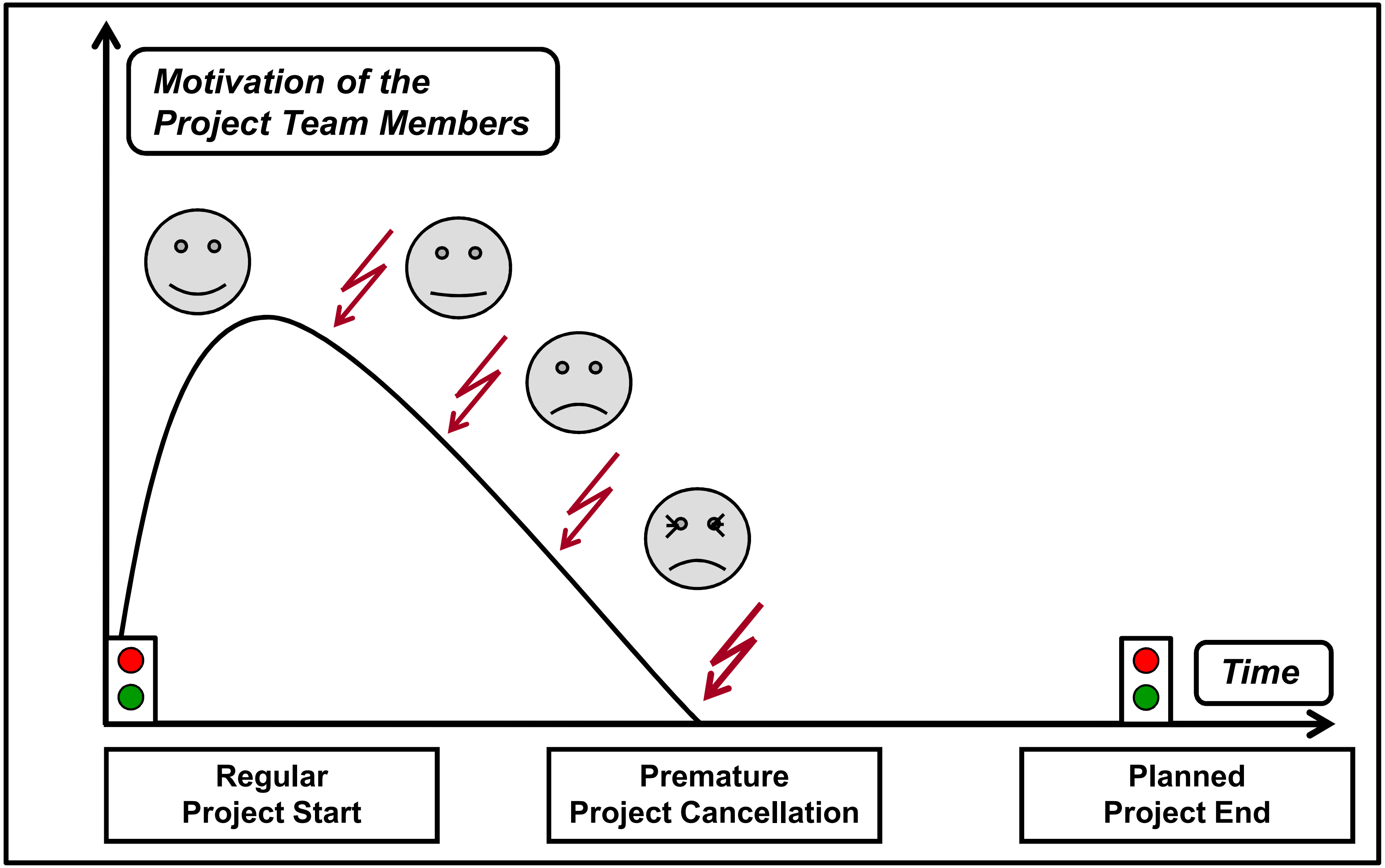
Course of a R&D Project with Several Milestones:



Rainer Bürstinghaus

Flow Planning: Milestones

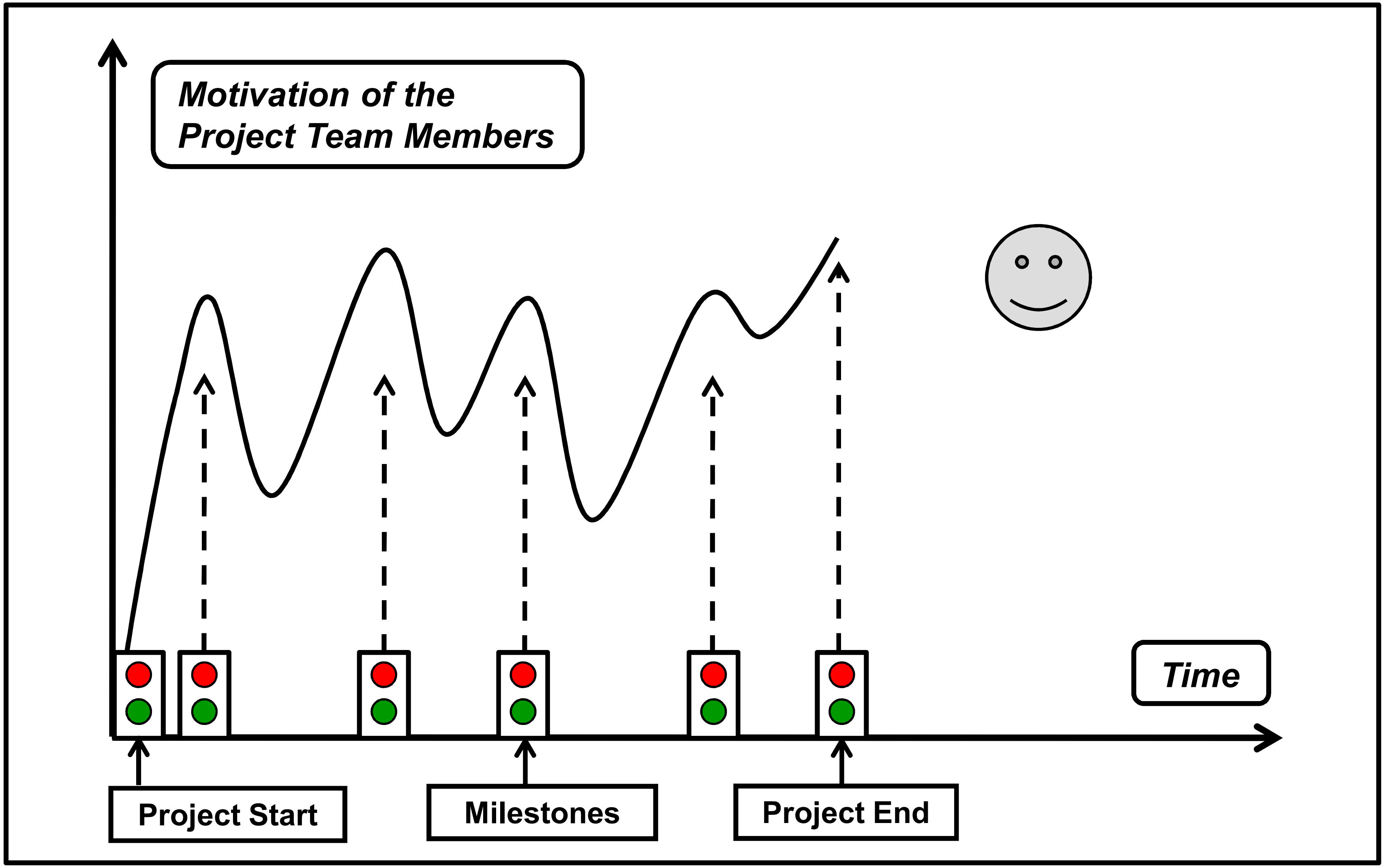
Milestones as "Motivators" in One R&D-Project:



Rainer Buerstinghaus

Flow Planning: Milestones

Milestones as "Motivators" in One R&D-Project:



Rainer Buerstinghaus

Example P2

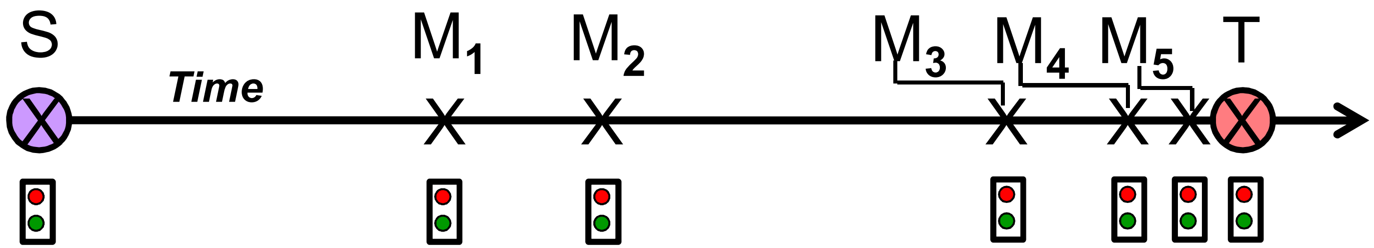
Milestone Planning
(From the Start of the Laboratory Phase):

Project	**"Nitrilase-Catalyzed Synthesis of a Chiral α-Hydroxycarboxylic Acid".**

Rainer Buerstinghaus

Flow Planning, Milestones (From Start of the Lab Phase):

Project "Nitrilase-Catalyzed Carboxylic Acid-Synthesis…"



Year	2019	2020	2021	2022	2023

S : **Start of the laboratory work** 01.10.2019

M_1 : Completed vector design for the most active nitrilase gene 31.12.2020

M_2 : Optimized parameters for the reaction in the lab-bioreactor 30.06.2021

M_3 : Completed scale-up with a stable microbial culture 30.09.2022

M_4 : Reproducible initial run in the 6000l bioreactor of production 28.02.2023

M_5 : Successful market launch for at least three customers 31.05.2023

T : Valid production decision; Target System √ ; **Project End** 31.07.2023

Rainer Buerstinghaus

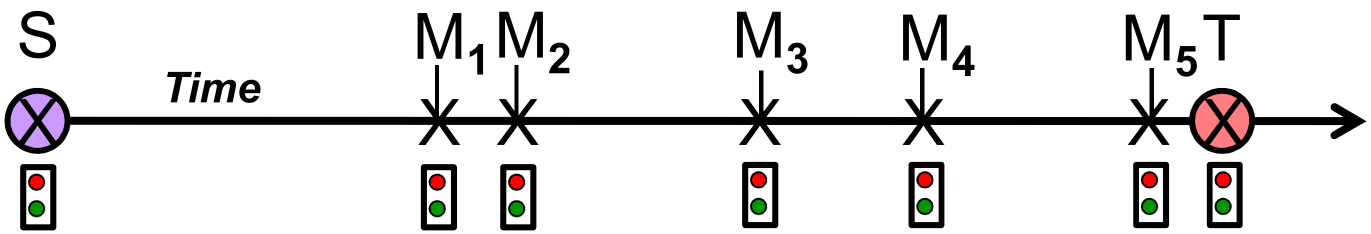
Example P3

Milestone Planning
(From the Start of the Laboratory Phase):

Subproject	**"New Metal Organic Frameworks for the Adsorptive Storage of Hydrogen Gas".**

Flow Planning, Milestones (From Start of the Lab Phase):

Subproject "New Metal-Organic Frameworks…"



Year	2019	2020	2021	2022	2023

S : **Start of the laboratory work** 01.10.2019

M_1 : Completed lab syntheses of the new TM and PM MOFs 31.12.2020

M_2 : Complete measurements of their specific H_2-adsorption 31.03.2021

M_3 : Completed scale-up of the most suitable MOF 31.12.2021

M_4 : Reproducible production run on the 2t-scale 30.06.2022

M_5 : Successful market launch with at least three customers 31.03.2023

T : Valid production decision; Target system √ ; **Project End** 30.06.2023

Rainer Buerstinghaus

R&D Project Management in the Chemical Industry

Subject Matter →

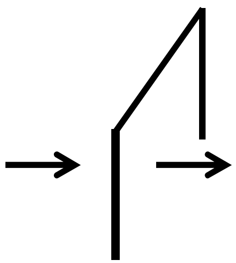
The Stage-Gate®-Process.

The Stage-Gate®-Process: Effective Planning and Control

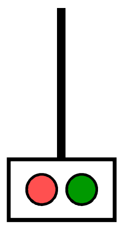
For the Project Course of Strategic Importance!

Stage-Gates® as defined milestones, each with comprehensive return assessments; Method of R. G. Cooper / E. Kleinschmidt.

- Future expenses until project completion **(€)**.
- Assessment of general technical progress.
- Probability of technical success **(%)**.
- Expected future income / savings **(€)**.
- Assessment of the long-term market development.
- Probability of economic success **(%)**.
- **Stop** / **Go** Decision.



Gate

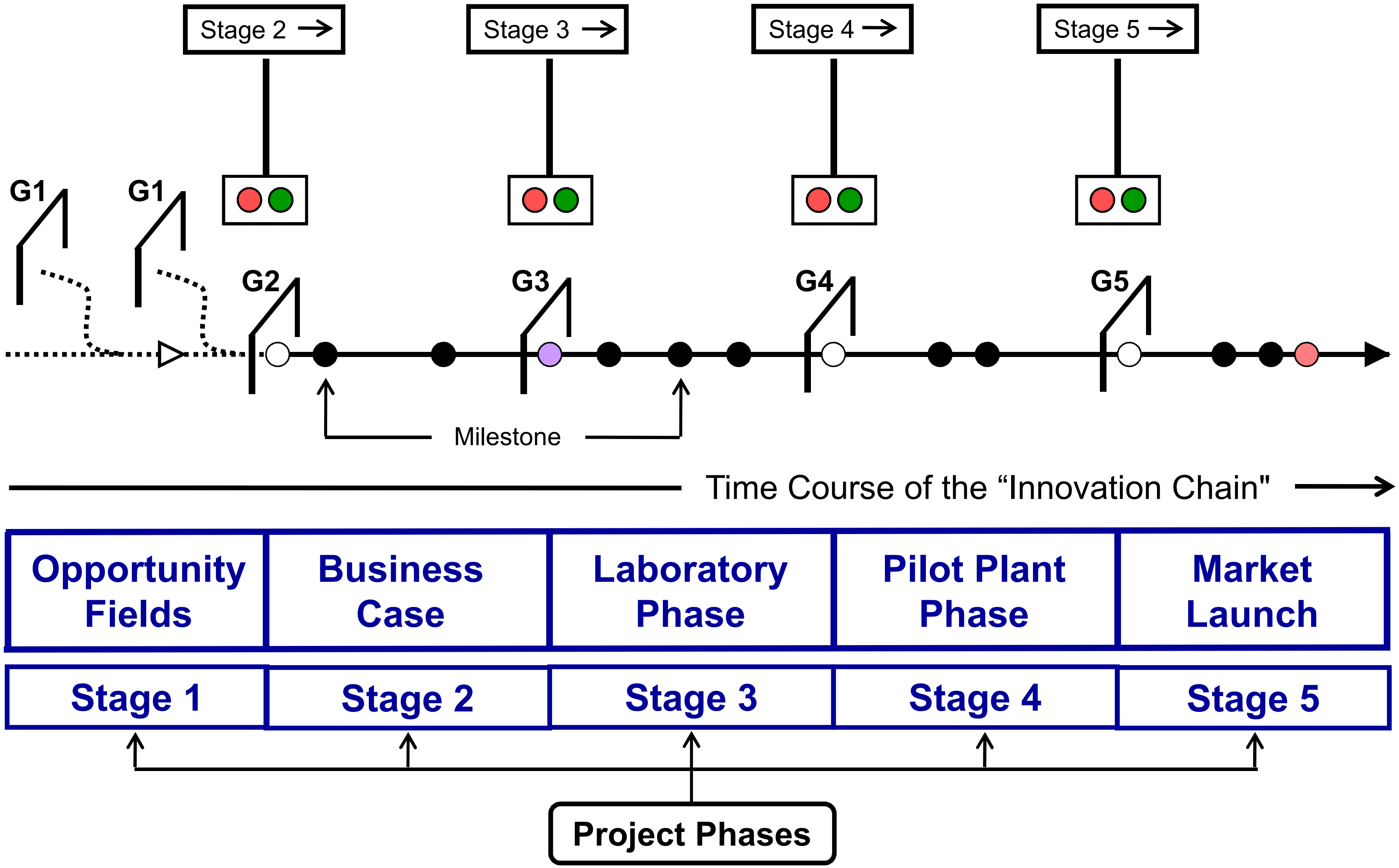


Stop/Go

Rainer Buerstinghaus

The Stage-Gate®-Process: Effective Planning and Control

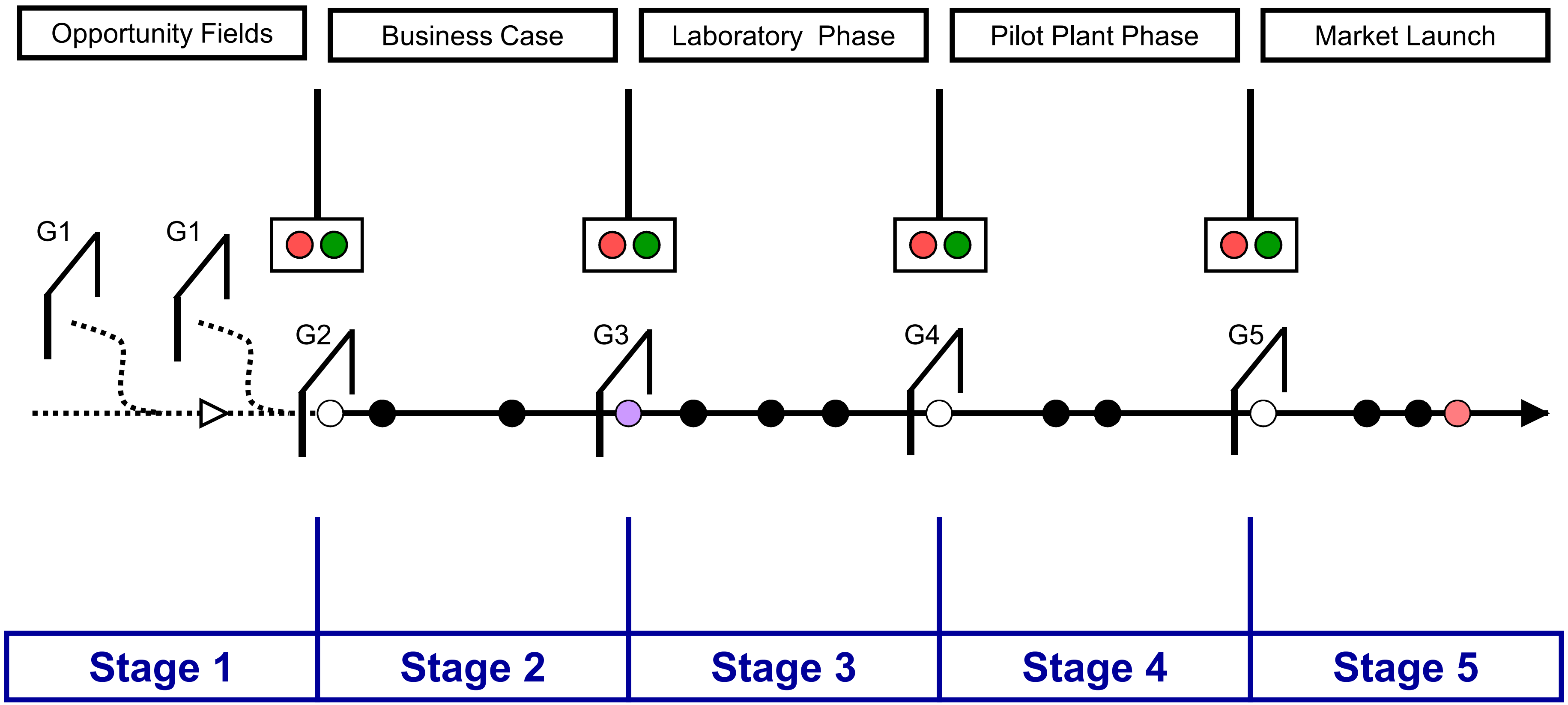
Gates G1-G5 after the Method of R. G. Cooper/ E. Kleinschmidt:



Rainer Buerstinghaus

The Stage-Gate®-Process: Effective Planning and Control

Gates G1-G5 after the Method of R. G. Cooper/ E. Kleinschmidt:



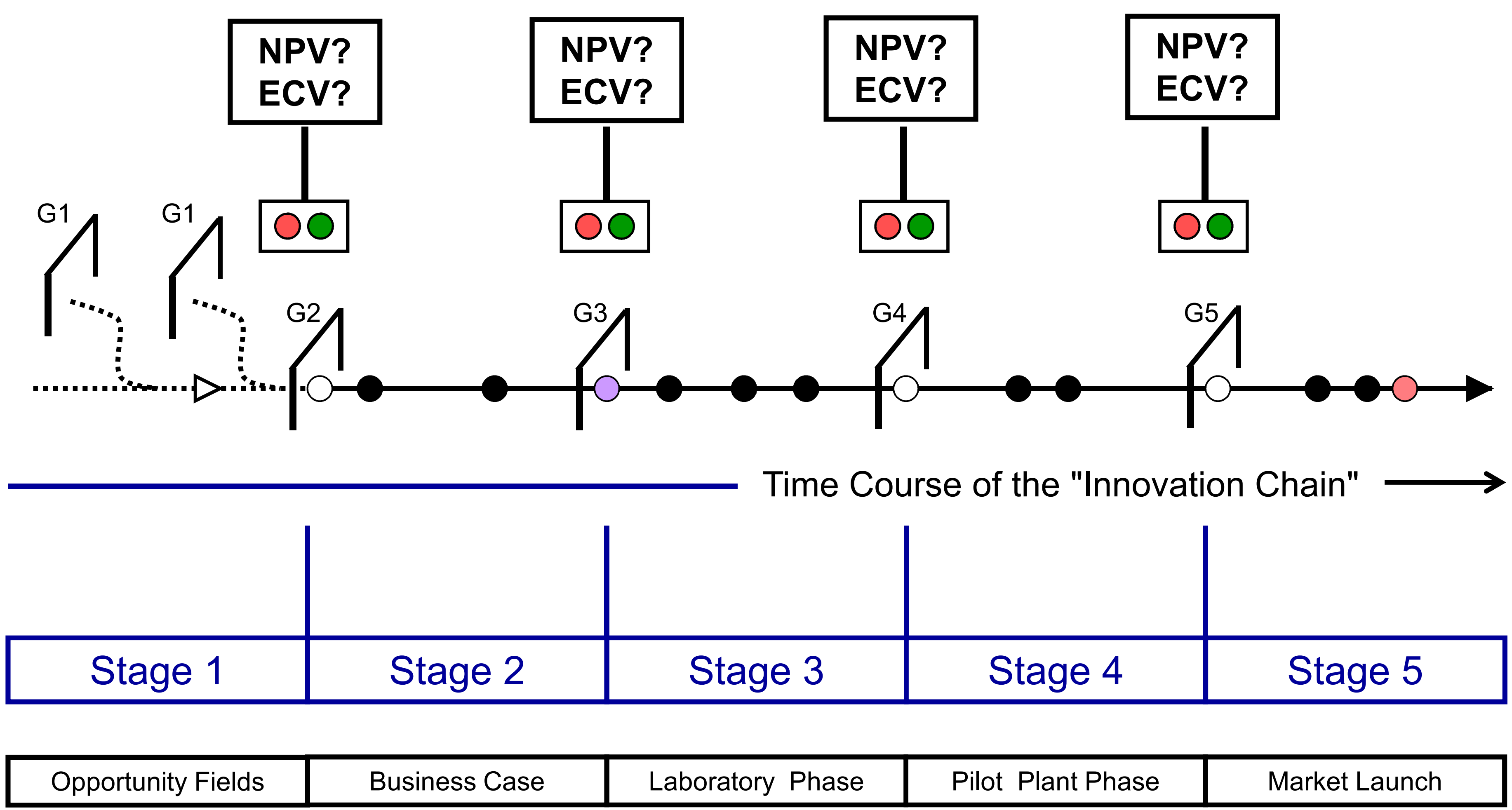
Open, creative opportunity checks: Research trends. Technology trends. Market needs.	**Project plan/Project evaluation:** Economic efficiency. Innovation strategy. Business model.	**Lab experiments:** Optimization of the product properties. Optimization of the synthesis method.	**Pilot Plant/Scale-up:** Process Engineering; Raw materials supply; QM; Preparation of all safety data.	**Production start:** First production run. Filling / Storage. Transport / Safety / Delivery / Controlling.

Rainer Buerstinghaus

The Stage-Gate®-Process: Effective Planning and Control

Return-Checks at the Gates G2-G5:

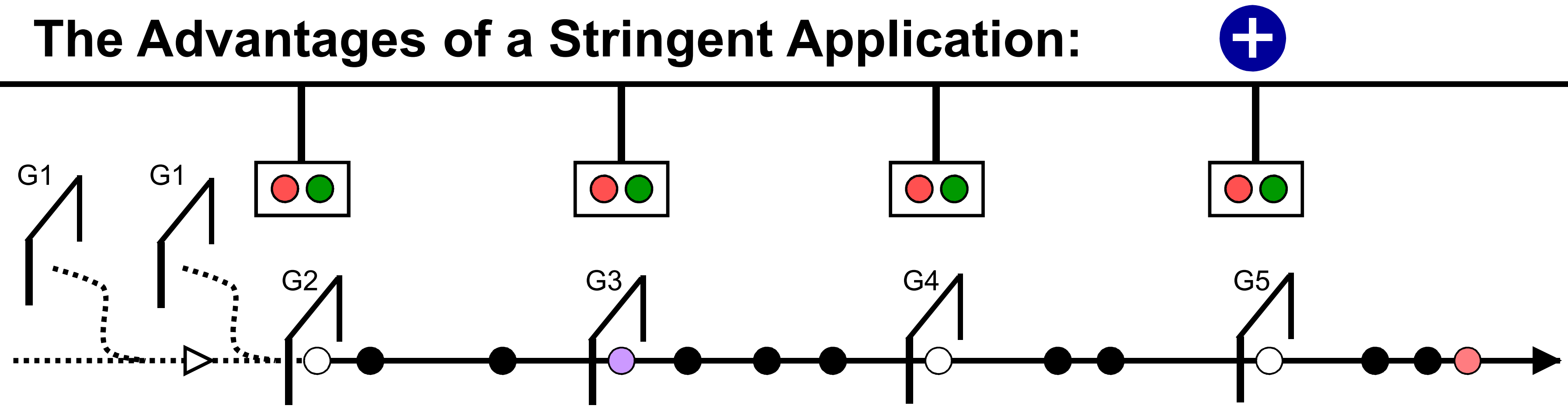
NPV: Net Present Value; ECV: Expected Commercial Value.



Rainer Buerstinghaus

The Stage-Gate®-Process: Effective Planning and Control

The Advantages of a Stringent Application:

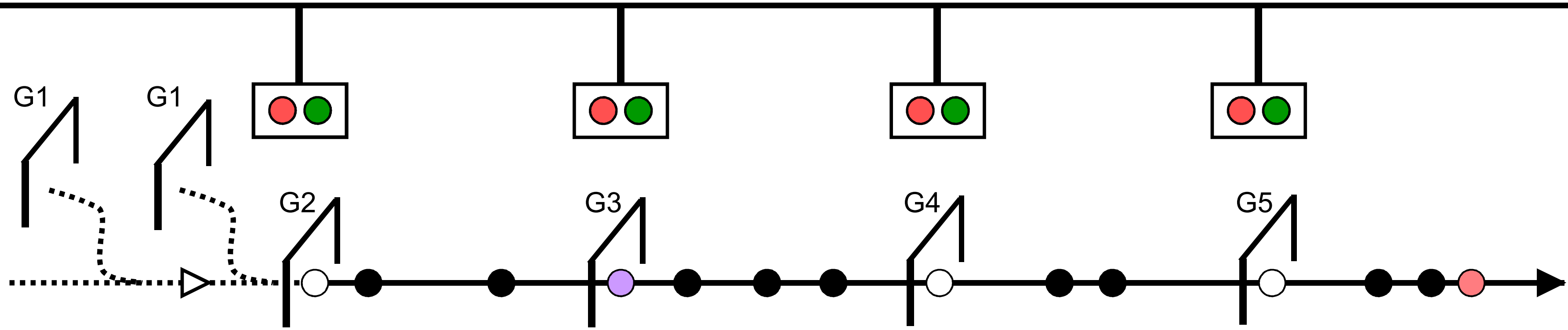


- **Rapid project progress** through regular decisions by "Gatekeeper" (or "Steering Committee").
- Clearly defined **success criteria** at each gate (NPV, ECV).
- Clear and valid **Go/Stop decisions** under strategic, chemical-technical, economic and company-political aspects at fixed, predetermined times.

Rainer Buerstinghaus

The Stage-Gate®-Process: Effective Planning and Control

The Advantages of a Stringent Application: +



- Immediate **availability of decision-relevant data** and facts for the entire project team.
- Transparent and comprehensible decisions for all.
- Budget compliance and effective budget control thanks to "decision compulsion" (Need for approval!) at each gate.

- If necessary, **rapid and effective project termination** to **avoid** further open or even "hidden" **costs**.

Phase Plan (Stages) for the R&D Project "Nitrilase-Catalyzed Synthesis of a Chiral α-Hydroxy-Carboxylic Acid".

Example P2

Stage 1 ⟶ Opportunity Fields:

- Identification, comparison and evaluation of the potential ways to obtain enantiomerically pure (R) -2-hydroxy-3-methoxy-3-methyl-butanoic acid by chemical, enzymatic or microbiological methods.
- Determination of the state of scientific knowledge (New publications, dissertations) on the catalytic effects of different nitrilases.
- Determination of the state of the art (Patent and published patent applications, new publications on biotransformations with nitrilase-active microbes).
- First laboratory experiments on microbial enrichment cultures with 2-hydroxy-3-methoxy-3-methyl-butyronitrile as substrate.
- First metagenome preparations from diverse biotopes and screening of nitrilase-encoding DNA regions, laboratory syntheses and testing of nitrilase primers.
- Preparation of first recombinant plasmids, introduction into model-like host cells, laboratory tests for nitrilase activity on the substrate (Laser fluorimetry). First patent applications.
- Exploratory talks with potential clients of ChiPros.
- Rough estimation of the future market size and market growth.
- Brief scetch of the stimulative effects for their own and potential customer companies on their respective business strategies.

Phase Plan (Stages) for the R&D Project "Nitrilase-Catalyzed Synthesis of a Chiral α-Hydroxy-Carboxylic Acid".

Example P2

Stage 2 ⟶ Business Case:

- Rough estimation of the probability of success, the phased R&D costs, foreseeable investment costs, sales, net sales, contribution margin I, contribution margin II as a function of time, storage costs and distribution costs.
- First estimation of the NPV and the ECV at project start.
- Preliminary positioning of the R&D-project in the market-technology-portfolio.
- Brief description of the project contribution to the realization of the GBU-strategy for chiral intermediates.
- Identification of the target markets, as well as the potential locations of production and distribution.
- Creating an R&D project plan with the chemical-biotechnological, economic and temporal objectives, the appropriate project organization, the project structure, the required technical and human resources, the milestone schedule, reporting/controlling (type and frequency).
- Designation of the project manager (m/f/d), the core team and the gatekeepers from the operative business.
- Detailed planning of the laboratory phase and the screening phase.

Phase Plan (Stages) for the R&D Project "Nitrilase-Catalyzed Synthesis of a Chiral α-Hydroxy-Carboxylic Acid".

Example P2

Stage 3 ⟶ Laboratory Phase:

- Planning and implementation of the amplification for biologically diverse, nitrilase-encoding DNA-fragments. Incorporation of DNA sequences into kanamycin-resistant plasmids. Expression and testing of the nitrilase activity on the substrate.
- Optimization of nitrilase-encoding DNA-fragments using newly synthesized, point-mutated primers.
- Vector design: synthesis of diverse plasmids to optimize the vector for the nitrilase gene.
- Introduction of suitable vectors into various host organisms (Escherichia coli, Bacillus subtilis, Saccharomyces cerevisiae, Pichia pastoris, ...)
- Inoculation of appropriate nutrient media and growth of the most suitable microorganisms for biotransformation on a 10 liter scale.
- Optimization of the yield of (R) -2-hydroxy-3-methoxy-3-methyl-butanoic acid on a laboratory scale: wide variation of nutrient medium, pH, T, oxygen supply.
- Filing of related key patents in major industrialized countries.
- Detailed planning of the pilot phase, including occupational safety concept.
- Further improvement of the key figures for the technical and economic success estimated in Stage 2.

Phase Plan (Stages) for the R&D Project "Nitrilase-Catalyzed Synthesis of a Chiral α-Hydroxy-Carboxylic Acid".

Example P2

Stage 4 → Pilot Plant Phase:

- Procurement, equipment or conversion of the bioreactors for the scale-up process, selection of suitable (pipe) systems for substrate addition and product removal.
- Selection of suitable sensors and online probes, as well as installation of the necessary measuring and control technology.
- Elaboration of the product data required for REACH approval.
- Identification of future cyanohydrin suppliers together with technical purchasing.
- Planning and implementation of a quality management system, especially with regard to product purity (% content, ee, suitable measuring methods, calibrated measuring instruments).
- Optimization of the stability for the genetically modified microorganisms.
- First customer samples, distribution of product data sheets.
- Detailed planning of the market launch phase, specification of the appropriate "marketing mix“.
- Further ascertainment of the key figures estimated in stage 3 for technical and economic success.

Phase Plan (Stages) for the R&D Project "Nitrilase-Catalyzed Synthesis of a Chiral α-Hydroxy-Carboxylic Acid".

Example P2

Stage 5 → Market Launch:

- Test and selection of the bioreactor operation mode: batch mode, fed-batch mode, continuous chemostat mode, etc.
- Testing of a suitable reactor type for the desired biotransformation (stirred tank, fixed bed, airlift, loop, membrane bioreactor, etc.).
- Optimization of bioreactor operating parameters: selection of the best nutrient mix, the most suitable stirring rate, the optimum air/oxygen supply, the correct pH, and the selection of an effective antifoaming agent.
- Implementation of the first production run or a continuous initial production for pilot customers, establishment of strict controlling for biotransformation, filling, storage, transport / logistics for timely customer deliveries and for the monthly profitability analysis.
- Implementation of a production decision procedure and a structured, documented "debriefing" of the R&D project.
- Continuous delivery to other key customers in the target markets.

Rainer Buerstinghaus

Phase Plan (Stages) for the Subproject "New Metal-Organic Frameworks for the Adsorptive Storage of H_2−Gas".

Example P3

Stage 1 ⟶ Opportunity Fields:

- Identification, testing and comparison (technical and economic advantages/ disadvantages) of future possibilities for physical or chemical hydrogen storage (E.g. metal hydrides, complex hydrides, fullerenes, nanotubes, MOFs, cryo- / pressure storage).
- Determination of the state of science (New publications on H_2 chemistry).
- Determination of the state of the art (Publications, patent applications).
- Exploratory talks with first-class university institutes or research working groups (MPI/Fraunhofer) about meaningful cooperation.
- First laboratory experiments (Synthesis, measurement of gas storage capacity).
- First patent applications (Substances, syntheses)
- Exploratory talks with potential customers about the possibilities for adsorption storage under pressure.
- Rough estimation of future market size and market growth.
- Brief outline of the impact effects from the project results: On the own company and on potential customer companies, regarding their business strategies.

Phase Plan (Stages) for the Subproject "New Metal-Organic Frameworks for the Adsorptive Storage of H_2−Gas".

Example P3

Stage 2 → Business Case:

- Rough estimation of the probability of success, of the phased R&D costs, foreseeable investment costs, sales, net sales, contribution margin I, contribution margin II as a function of time, storage and distribution costs.
- First estimation of NPV and ECV at project start.
- First positioning of the R&D project in the market-technology-portfolio.
- Brief description of the project contribution to the realization of the GBU strategy.
- Description of the regional target markets, as well as the potential production and distribution locations.
- Creating an R&D project plan with the chemical-technical, economic and temporal objectives, the project organization, the project structure, the required technical and human resources, the milestone schedule, reporting / controlling (Type and frequency).
- Name of the project manager (m/f/d), the core team and the gatekeepers from the operative business.
- Detailed planning of the laboratory phase.

Phase Plan (Stages) for the Subproject "New Metal-Organic Frameworks for the Adsorptive Storage of H_2–Gas".

Example P3

Stage 3 → Laboratory Phase:

- Planning and realization of the MOFs to be synthesized with variation of the connectors (Metal ions) and linkers (Oligo-carboxylic acids).
  Possibly, preparation / application of a suitable statistical trial design.
- Testing the H_2 -adsorption capacity of all new MOFs as a function of P and T.
- Registrations of further key patents (Substance- and process-protection).
- Determination of the MOF structure with the highest technical and economic chance of success.
- Initiation of the required toxicological and regulatory examinations (REACH).
- Exploration of synthesis alternatives and determining appropriate process chemistry.
- Detailed planning of the pilot phase.
- Possibly, initiation and "kick-off" for the required additional investment projects.
- Further improvement of the key figures estimated in Stage 2 for technical and commercial success potential.

Phase Plan (Stages) for the Subproject "New Metal-Organic Frameworks for the Adsorptive Storage of H_2−Gas".

Example P3

Stage 4 ⟶ Pilot Plant Phase:

- Procurement, equipment or conversion of test reactors, pipelines, suitable fittings, the necessary procedural devices (Heating, cooling, mixing, filtration, extraction method), the measurement and control technology, the appropriate machinery, the conveyor technology, the storage facilities.
- Together with technical purchasing: Identification of future raw material suppliers.
- Planning and implementation of a quality management system, especially with regard to product purity (Suitable measuring methods, calibrated measuring instruments) and on-time customer delivery, first customer samples, elaborated product data sheets.
- Detailed planning of the market launch phase, specification of the most appropriate "marketing mix“.
- Further concretization of the key indicators for technical and economic successes estimated in Stage 3.

Phase Plan (Stages) for the Subproject "New Metal-Organic Frameworks for the Adsorptive Storage of H_2−Gas".

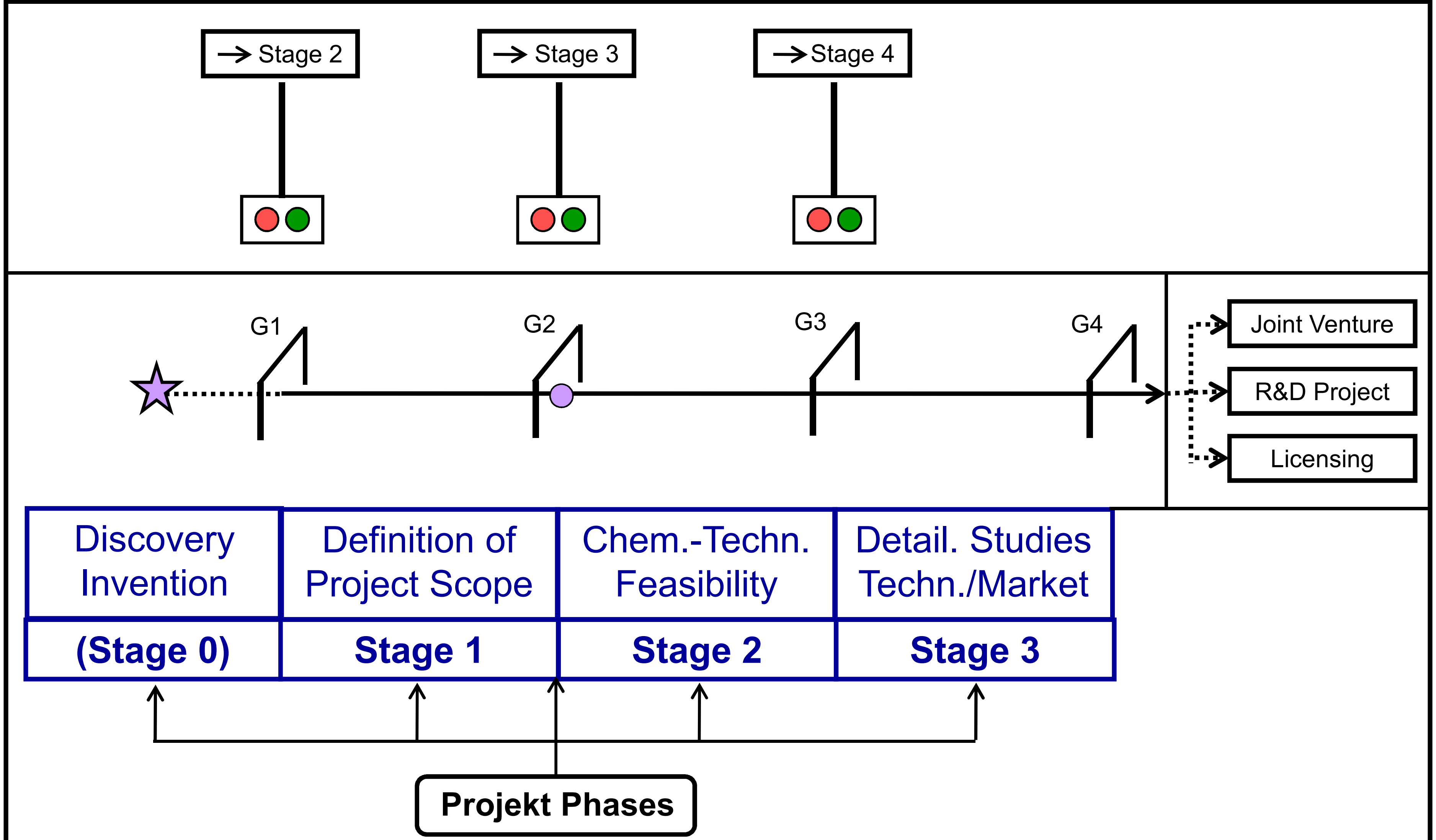
Example P3

Stage 5 ⟶ Market Launch:

- Preparation and realization of a first production run for the pilot customer / project partner.
- Elaboration of documents / brochures for the new product with information about its chemical-technical characteristics, as well as necessary environmental protection and safety measures.
- Realization of a procedure for the official, internally approved "production decision“.
- Establishment of a reliable controlling for production, filling, storage, transport/logistics for on-time delivery to customers.
- Start of monthly, product-specific profitability analyzes.
- Establishment of a structured, complete "debriefing document" for the R&D project.
- Continuous delivery to other key customers in the target markets.

The Stage-Gate®-Process: Effective Planning and Control

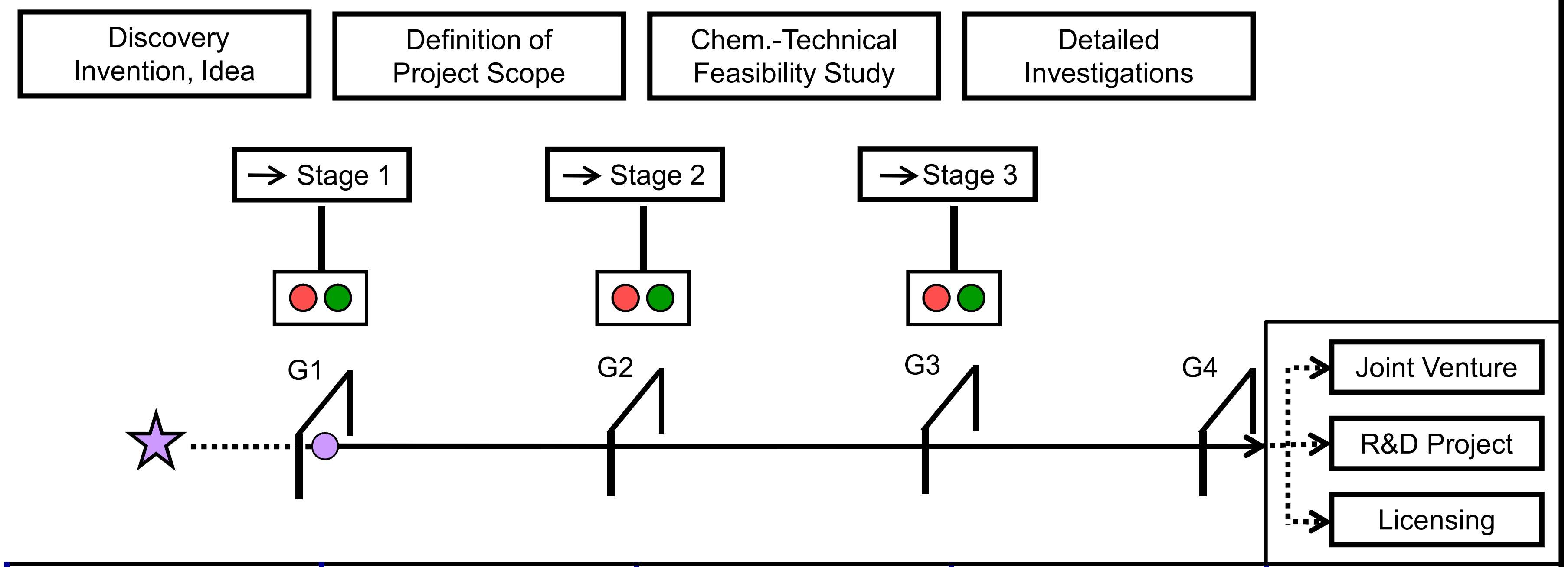
Planning and Realization of "Pure" *Research* Projects:



Rainer Buerstinghaus

The Stage-Gate®-Process: Effective Planning and Control

Planning and Realization of "Pure" *Research* Projects:



("Stage 0")	Stage 1	Stage 2	Stage 3
First assessment of discoveries or ideas: Research trends, Technology trends, Market needs.	Start of the project. Definition of the scope for the project. First planning in advance. Duration: ~ 3 weeks.	Initial experiments under ideal conditions; Preliminary laboratory series of tests. Duration: 3-4 months.	Implementation of a comprehensive experimental program. Business model? Duration: If nec:. Years.

Rainer Buerstinghaus

Gate-Scorecard® According to the R. G. Cooper-Method for the Systematic Check of Individual R&D Projects:

Check / Score	0	10
Congruence with the business strategy	No influence on the business strategy.	Existence of the business depends on the project.
Strategic leverage effect, patent situation, synergies	No copy protection / syn-ergies not foreseeable.	Excellent patent situation / Internal widely applicable.
Probability of technical success	Numerous hurdles on the realization path.	According to the state of the art certainly feasible.
Probability of commercial success	Shrinking market. Only speculative assumptions.	Growth market Strong customer demand.
Contribution to added value Break-even-point	< 1 Million € In more than 7 years.	> 250 Million € In less than one year.

The Stage-Gate®-Process: Effective Planning and Control

Possible Errors and Disruptive Factors within the Practice of the Stage-Gate®-Process:

01.	→	**Stagnant Information Flows** The project team does not receive the really important information.
02.	→	**Escape from Responsibility** Gatekeepers shy away from early terminating a project.
03.	→	**Slow Decision-Making** Gatekeepers have too little decision-making authority.
04.	→	**Misalignment of Priorities** The project team focuses too much on the gate sessions and too little on the result oriented *flow* of important processes (!).

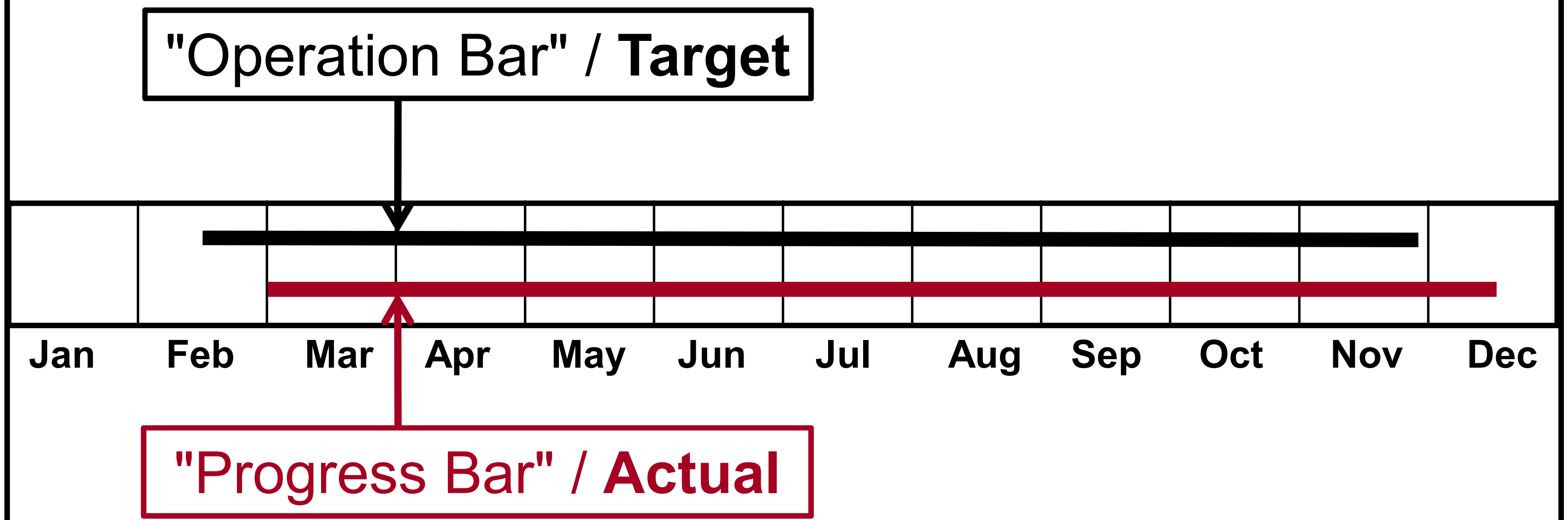
The "Gate-Trap" No. 04 is particularly relevant in practice!

Rainer Buerstinghaus

Flow Planning: Gantt-Charts as "Project Activity Calendars"

Gantt Bar Charts, Illustration in a Month Scale:

Henry L. Gantt 20.05.1861 - 23.11.1919	1910: „Scientific Management": Bar Charts	Teacher, mechani-cal engineer and ship designer

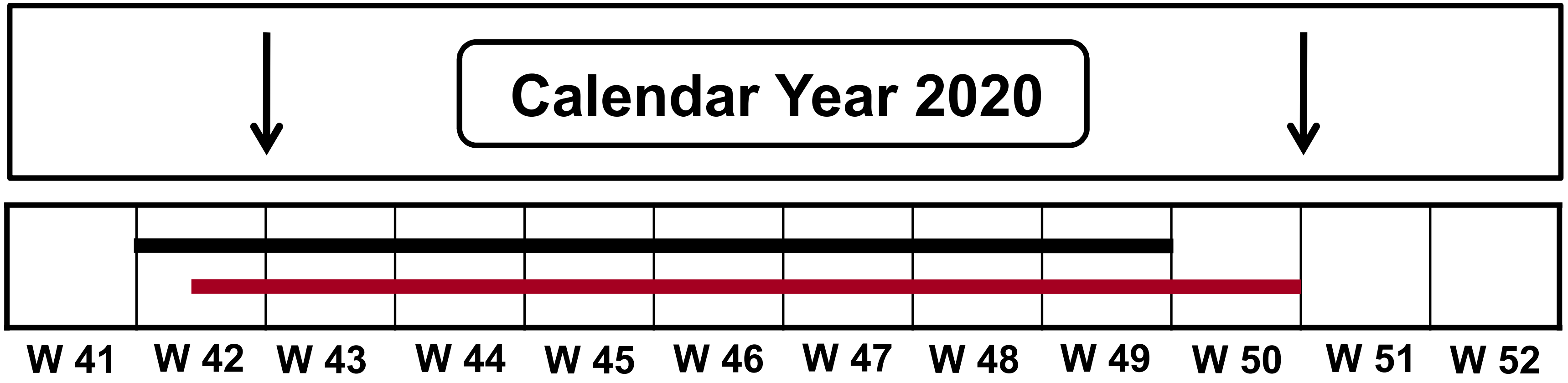


Rainer Buerstinghaus

Flow Planning: Gantt-Charts as "Project Activity Calendars"

Bar Chart (Gantt), (Target / Actual):

Example P2



Project: "Nitrilase-Catalyzed Synthesis of a chiral α-Hydroxy-Carboxylic Acid."

Amplification of 30 different nitrilase-encoding DNA-segments from laboratory prepared metagenomes using PCR-technique.

Start: 08. October 2020; End: 07. December 2020 → (Target-Dates)

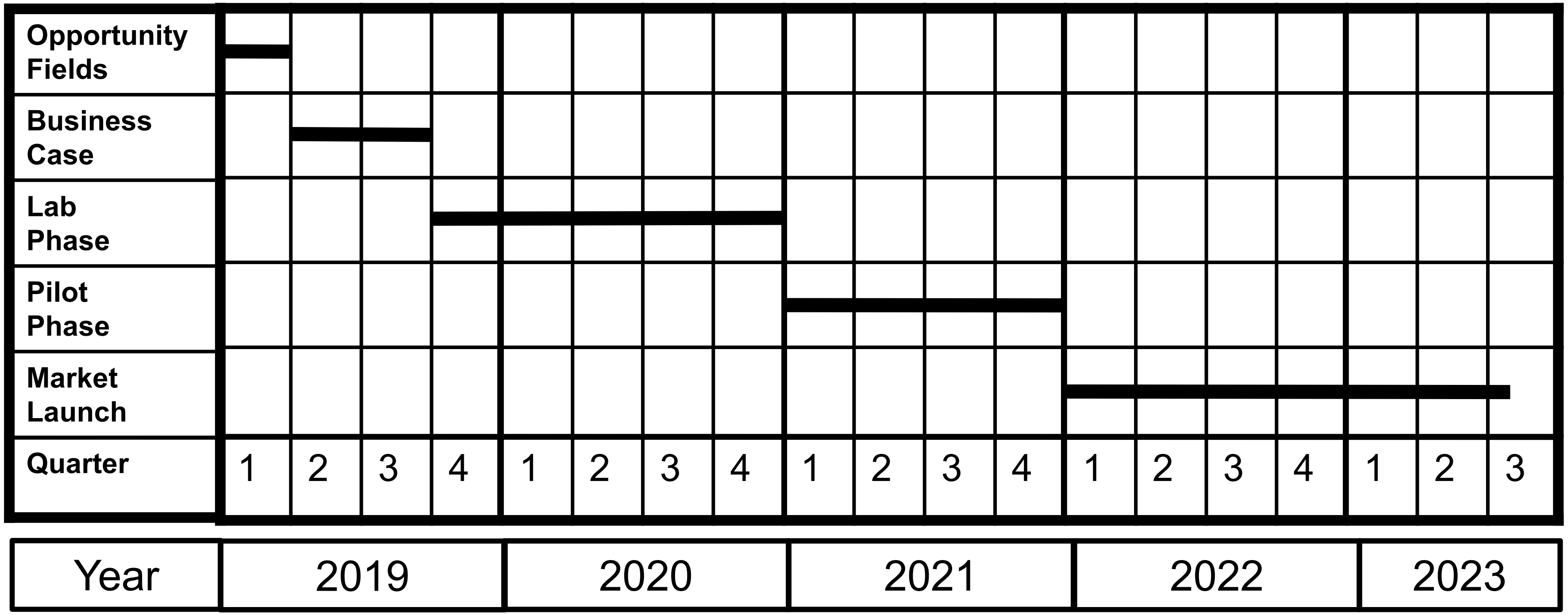
Start: 11. October 2020; End: 14. December 2020 → (Actual-Dates)

Flow Planning: Gantt-Charts as "Project Activity Calendars"

Phase Plan (Stages) in Gantt-View :

Example P2

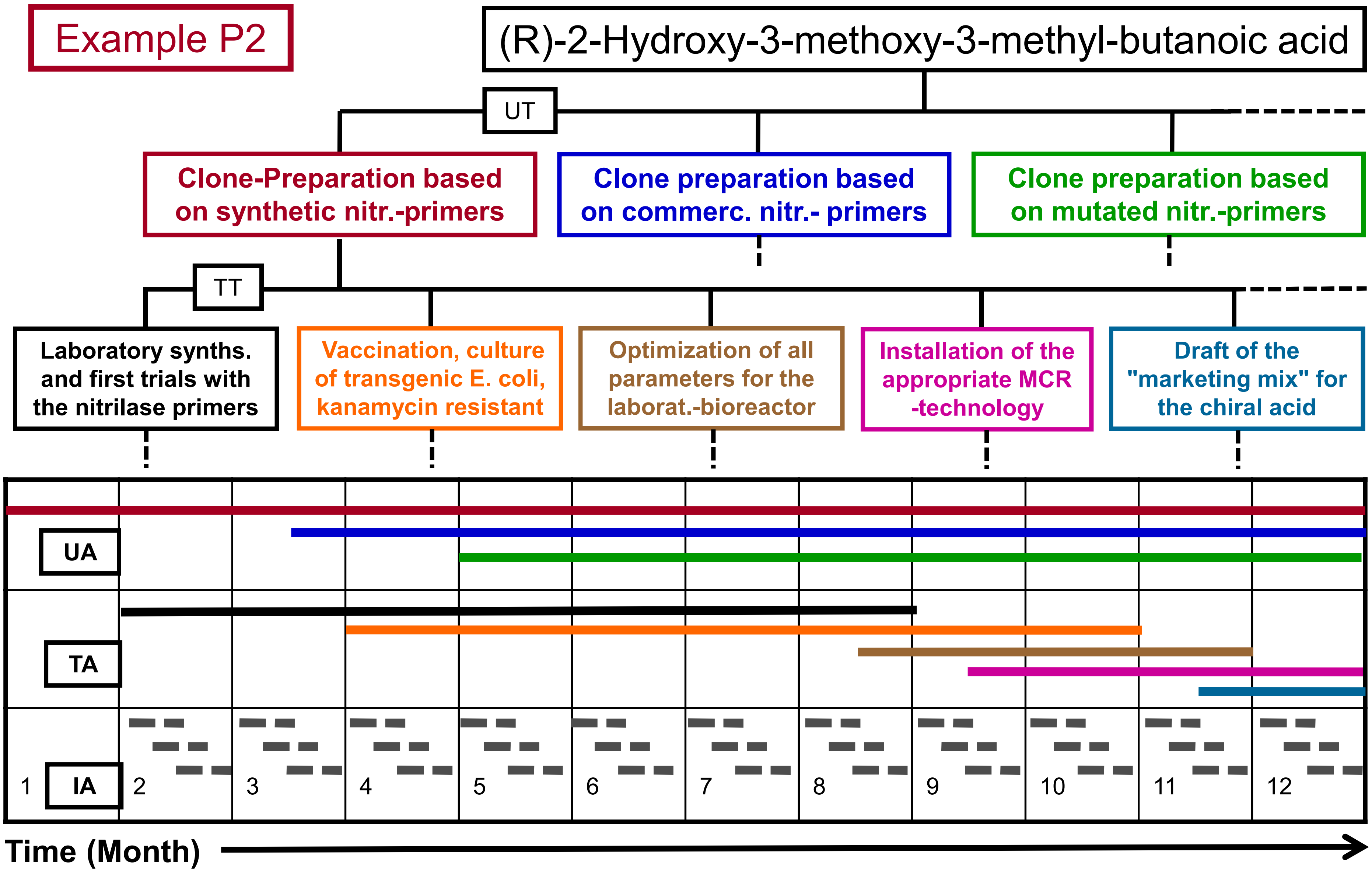
"Nitrilase-Catalyzed Synthesis of a Chiral α-Hydroxy-Caboxylic Acid."



Rainer Buerstinghaus

From Structure Plan to the Corresponding Flow Plan

R&D Project "Nitrilase-catalyzed Synthesis of a chiral α–Hydroxy-…"

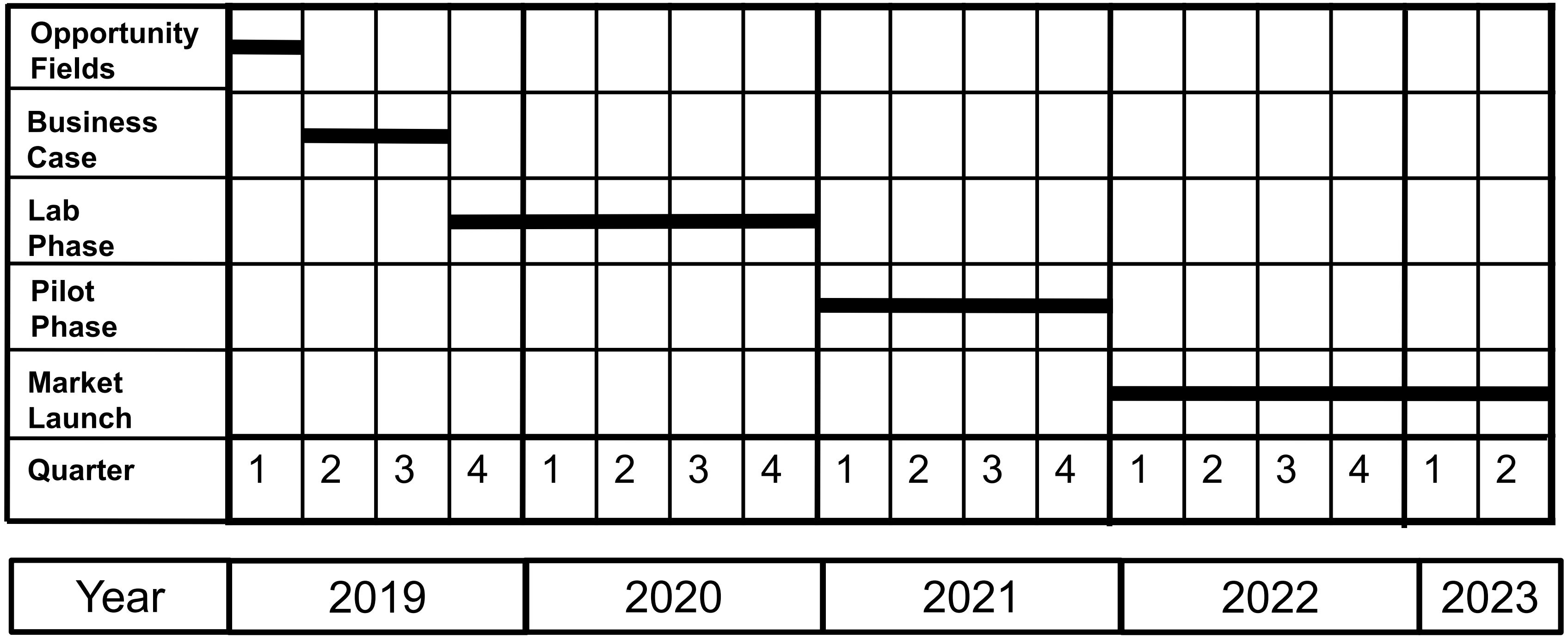


Rainer Buerstinghaus

Flow Planning: Gantt-Charts as "Project Activity Calendars"

Phase Plan (Stages) in Gantt-View: Example P3

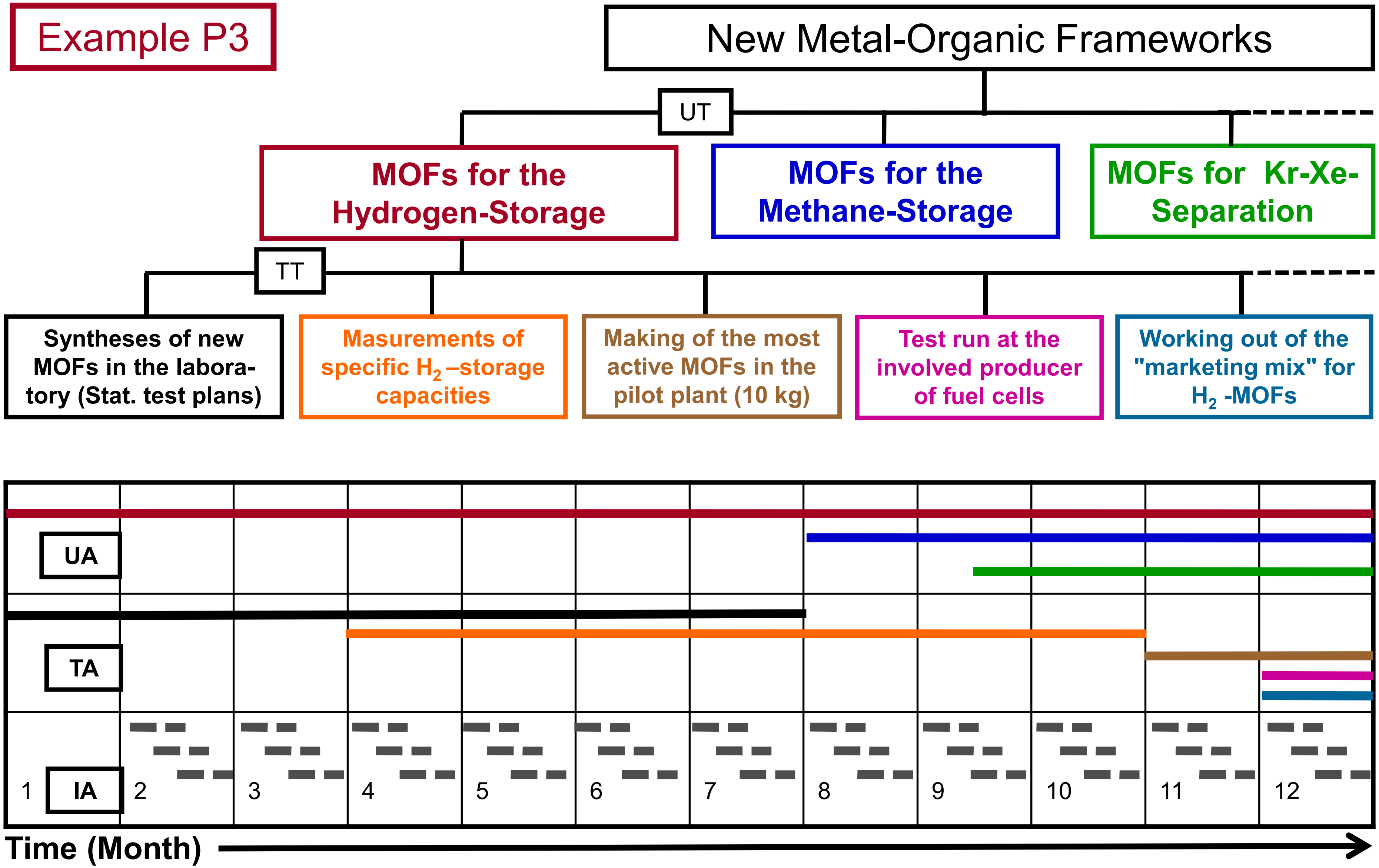
Project: "New Metal-Organic Frameworks for the Adsorptive Storage of Gases."



Rainer Buerstinghaus

From Structure Plan to the Corresponding Flow Plan:

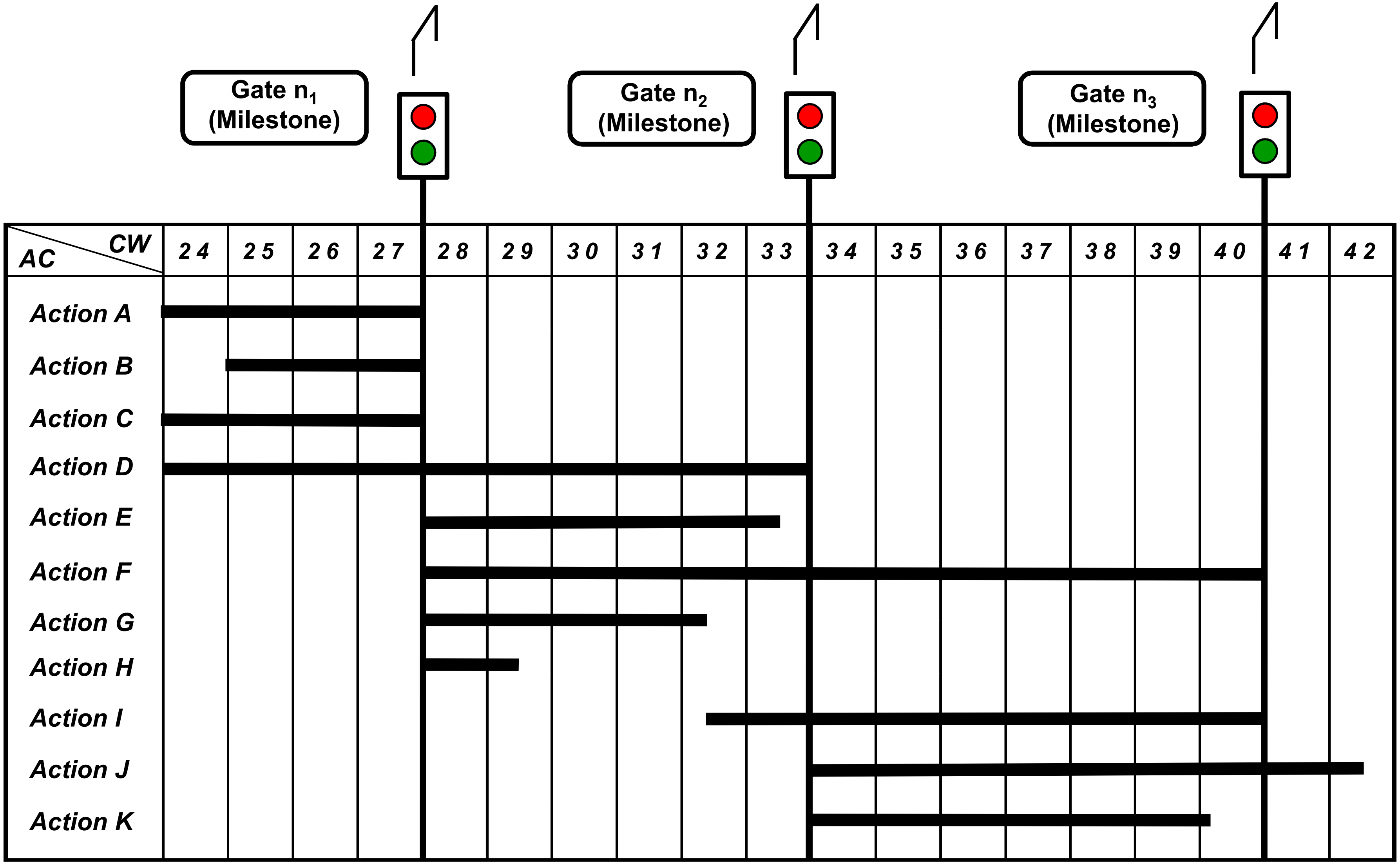
R&D-Project "New Metal-Organic Frameworks…"



Rainer Buerstinghaus

The StageGate® - (or PhaseGate® -) Process

Bar Chart with Stage-Gates® (as Milestones):



Rainer Buerstinghaus

Flow Planning: Gantt-Charts, "Project Activity Calendars"

Pros and Cons for this Method of Visualization:

+

Advantages:

- Simplicity and good representability (bars, PPTX).
- Rough scheduling and fine scheduling are easy to illustrate, high information density.
- Clarity within project control: Target actual comparison "at a glance".

–

Disadvantages:

- The dependencies between the individual activities are not recognizable.
- The predictive power for a future project progress is low.

Example P1

Phase Planning
(Documented here in the "Project Data Sheets"):

Project	**"Highly Elastic Clear Coats for the OEM Automotive Sector".**

[…GmbH 1]	R&D Project Data Sheets

OPERATIVE R&D-PROJECT

PROJECT CODE	PROJECT TITLE
A 021 **Example P1**	**Highly Elastic Clear Coats for the OEM Automotive Sector.**

PROJECT MANAGER: Christoph Aberg

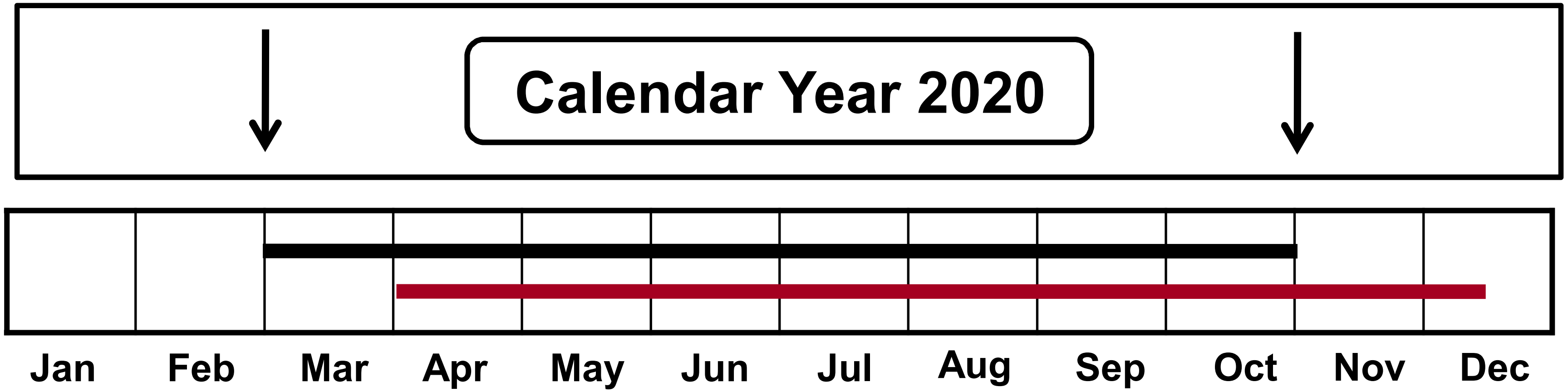
Endorsement Environment/Safety	

Signature	**Research**	**Develop-ment**	**Produc-tion**	**Marketing /Sales**	**Project Manager**
Company	[..GmbH1]	FHG WÜ	[..GmbH1]	[..GmbH1]	[..GmbH1]
Org. Code	SCF	A 4	SCP	SCS	SCE
Date	22.07.19	28.07.19	22.07.19	23.07.19	22..07.19
Signature					

Flow Planning: Gantt-Charts as "Project Activity Calendars"

Bar Chart (Gantt) (Target / Actual):

Example P3



Subproject "New Metal-Organic Frameworks for the Adsorptive Storage of Hydrogen Gas."

Measurements of the storage capacity of H_2 at 77K for the new MOFs, based on pyromellitic anhydride.

Start: 01. March 2020; End: 31. October 2020 **(⟶ Target-Dates)**

Start: 01. April 2020; End: 15. December 2020 **(⟶ Actual-Dates)**

[…GmbH 1] Operative R&D Project, **Technical Profile**

PROJECT CODE	PROJECT TITLE
A 021	**Highly Elastic Clear Coats for the OEM Automotive Sector.**

0 Technical Problems that must be solved:

Development of a highly scratch resistant clear coat for OEM with film properties in an first step comparable to those of solvent baseed clear coats and in an second step comparable to those of 2C waterborne clear coats.

0 Possible methods/approaches for solving the problems:

Development of an Si-ORMOCER-based clear coat.
Development of a clear coat , basing on a highly branched crosslinker.
Development of an UV-curing system.

	worst				RANGE					best		
Characteristics											**Unit of measure target value**	**Priority**
AMTEC Scratch				🔴					🟢		**> 95% Gloss Retention**	**A**
Acid Resistance							🟢 🔴				**Equivalent to 2-Copmonent Clearcoat**	**B**
Environmental Ech						🟢 🔴					**Equivalent to 2-Component Clearcoat**	**B**
Yellowing						🟢 🔴					**Standard-Level**	**B**
Popping Limit ESTA					🟢	🔴					**Minimum 50 µm, > 60 µm**	**A**
Circular Line Stability						🟢 🔴					**Equivalent to Standard Material**	**A**
Weather Durability							🔴	🟢			**> 3 Years Florida**	**A**

🟢 **Target Material** 🔴 **State of the Art**

Rainer Buerstinghaus

[…GmbH 1] | Operative R&D Project, **Technical Data**

PROJECT CODE	PROJECT TITLE
A 021	**Highly Elastic Clear Coats for the OEM Automotive Sector.**

0 Technical Specification:

Simulation of car wash: Polyethylene brush, diameter: 1000 mm, width: 400mm, speed of brush rotation: 120 rpm, 10 wash cycles. Water flow rate 2,2 l/min. Concentration of quartz powder 1,5 g/l: Gloss retention of the clear coats after AMTEC-Test: > 95%.

König pendulum damping device (ISO 1522) : 6°/3°-Damping: 120 oscillations.

Specular gloss (ASTM), 20° geometry: >97%.

Nanoindentation test (AFM) 95% elastic reecovery.

Erichsen-Test (DIN-ISO 1520): 3,5 mm.

QUV-Test: 2000h UVcon-A and UVcon B.

Environmental etch, Jacksonville/U.S.A., 16 weeks exposure (May-September) <5 (0-10 (best)).

Adhesion on base coats, crosscut test (DIN-ISO 2409: 0.

0 Patent Situation::

WO/06/56565 (10.03.2015) PCT (Patent Cooperation Treaty). Applicant: PPG.

US-Pat. 6,935,027 (06.12.2018): Applicant: DuPont.

EP 0 888 444 B2 (17.06.2016) : Applicant: […GmbH1].

EP 1 002 843 B2 (01.02.2018) Applicant: DuPont.

[…GmbH 1] Operative R&D Project, **Market Data I**

PROJECT CODE	PROJECT TITLE
A 021	**Highly Elastic Clear Coats for the OEM Automotive Sector.**

0 Specific Application within the target market:

This new product group is an innovation to solve customers problems with scratches on an coating surface. Advantages with regard to polishability are expected.

0 Market location and target customers:

European Union and Eastern Europe. The target customer is [Automotive…AG1] in the frame of a strategic research cooperation. Referring to the high need for action the worldwide introduction with other customers will follow as soon as possible (2022).

0 Competitive situation, competitive products:

AKZO, Dupont (Herberts), PPG and [Coatings…AG3] are developing comparable coating systems in order to increase their own market share. Market leader in clear coats is [Coatings…AG3] with a worldwide market share of 38%. […GmbH1] strives to achieve a market share of 25%.

0 Impact on business strategy:

The offering of a new generation of scratch resistant clearcoats will increase the […GmbH1]-market position in the clear coat market from 14% (2019) to 25% (2024).

0 Investment requirements:

Build up of a 3 FTE- customer advisory service team.

[…GmbH 1] Operative R&D Project, **Market Data II**

PROJECT CODE	PROJECT TITLE
A 021	**Highly Elastic Clear Coats for the OEM Automotive Sector.**

Year	2019	2020	2021	2022	2023
Volume (t)	**0**	**0**	**20**	**1230**	**2800**
Sales (T €)	**0**	**0**	**170**	**10455**	**23800**
CM I (T €)	**0**	**0**	**85**	**5228**	**11900**
Earnings (T €)	**0**	**0**	**17**	**1046**	**2380**

Start of Project: 01.08.2019

Project to be completed: 31.07.2022

Approximate total R&D FTE: 33 NE (≙ 33 x 240.000 €) + 54 TE (≙ 54 x 160.000 €).

Approximate total R&D Costs: 19.800.000 € (Including 3.200.000 € Physical Resources).

[…GmbH 1] Operative R&D Project, **Human Resources**

PROJECT CODE	PROJECT TITLE
A 021	**Highly Elastic Clear Coats for the OEM Automotive Sector.**

Unit concerned Orga-Code	2019	2020	2021	2022
SCF	3 NE + 4 TE	4 NE + 9 TE	3 NE + 8 TE	-
SCE	2 NE + 3 TE	6 NE + 8 TE	5 NE + 7 TE	1 NE + 2 TE
SCP	-	1 TE	2 NE + 2 TE	2 NE + 3 TE
SCS	-	1 NE	1 NE + 1 TE	3 NE + 6 TE
Total	5 NE + 7 TE	11 NE + 18 TE	11 NE + 18 TE	6 NE + 11 TE

Cost Rates (Staff)

NE: 1 FTE = 240.000 € /Year

TE: 1 FTE = 160.000 €/Year

Department Codes

SCF Research/Analytics
SCE Development/Appl.Techn.
SCP Pilot Plant/Production
SCS Marketing/Sales

FTE: Full Time Equivalent; NE: Non-Tariff Employee; TE: Tariff Employee

[…GmbH 1] | Operative R&D Project, **Human Resources**

PROJECT CODE	PROJECT TITLE
A 021	**Highly Elastic Clear Coats for the OEM Automotive Sector.**

Name Department Code	**Date Signature**	**Successor (if neccessary)**
Aberg, SCF	10.05.2019	
Embler, SCF	14.05.2019	
Deiters, SCF	18.05.2019	
Liekermann, SCE	30.04.2019	
Multers, FHG	28.04.2019	
Kortenbäumer, SCE	07.05.2019 Kortenbäumer	
Hagemann, SCP	07.05.2019	
Hogenfels, SCE	02.05.2019	
Wichert, SCS	17.05.2019	
Muddekämper, SCP	11.05.2019	

[…GmbH 1] Operative R&D Project, **PROJECT PHASES**

PROJECT CODE	PROJECT TITLE
A 021	**Highly Elastic Clear Coats for the OEM Automotive Sector.**

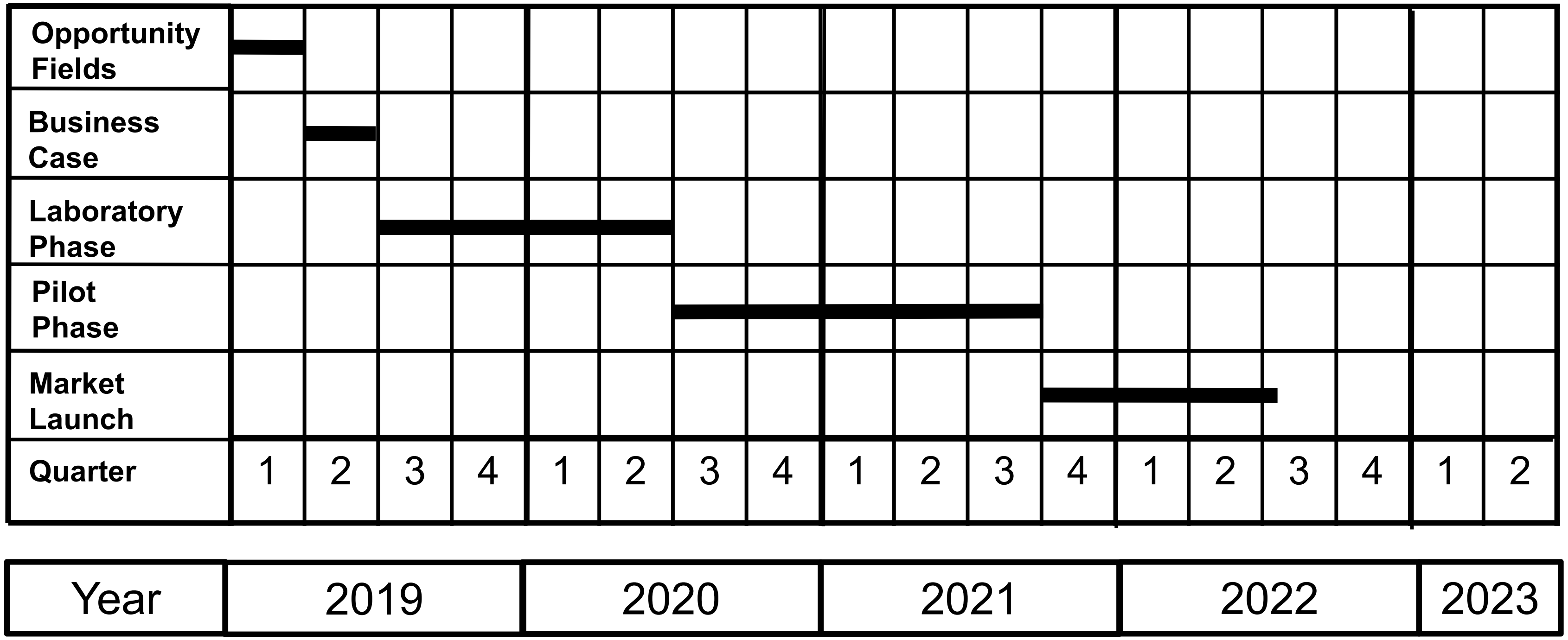
Project Phase	Milestones	Time of Realization	Person responsible
Business Case /Kick off	Patent Application. Project Plan. Valid Market Data. Congruence with the Companies Strategy.	II / 2019	Dr. Aberg
Laboratory Phase	Completion of all Syntheses and all Testings.	II / 2020	Fr. Dr. Deiters
Pilot Phase	Successful Scale-up to 500kg. Solid QM-Concept. Sure Supplying with Rawmaterials. Basic REACH−Data.	III / 2021	Ms. Hagemann
Market Launch	Continuous Production in Specification. Constant Supplying of all Key-Customers.	III / 2022	Mr. Mudde-kämper

Flow Planning: Gantt-Charts as "Project Activity Calendars"

Phase Plan (Stages) in Gantt-View:

Example P1

Project "Highly Elastic Clear Coats…"

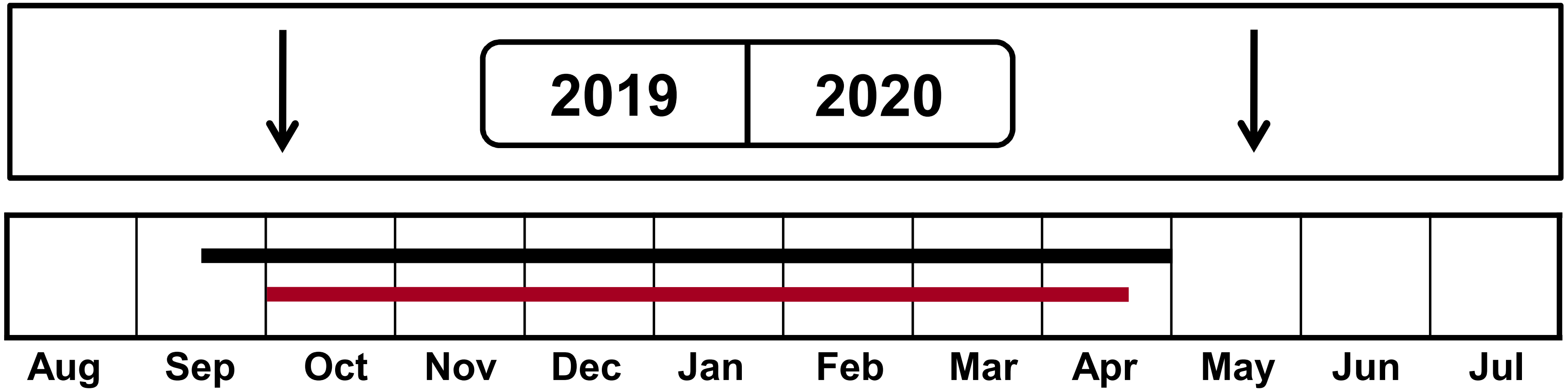


Rainer Buerstinghaus

Flow Planning: Gantt-Charts as "Project Activity Calendars"

Bar Chart (Gantt), (Target / Actual):

Example P1



***Project:* "Highly Elastic Clear Coats for the OEM Automotive Sector."**

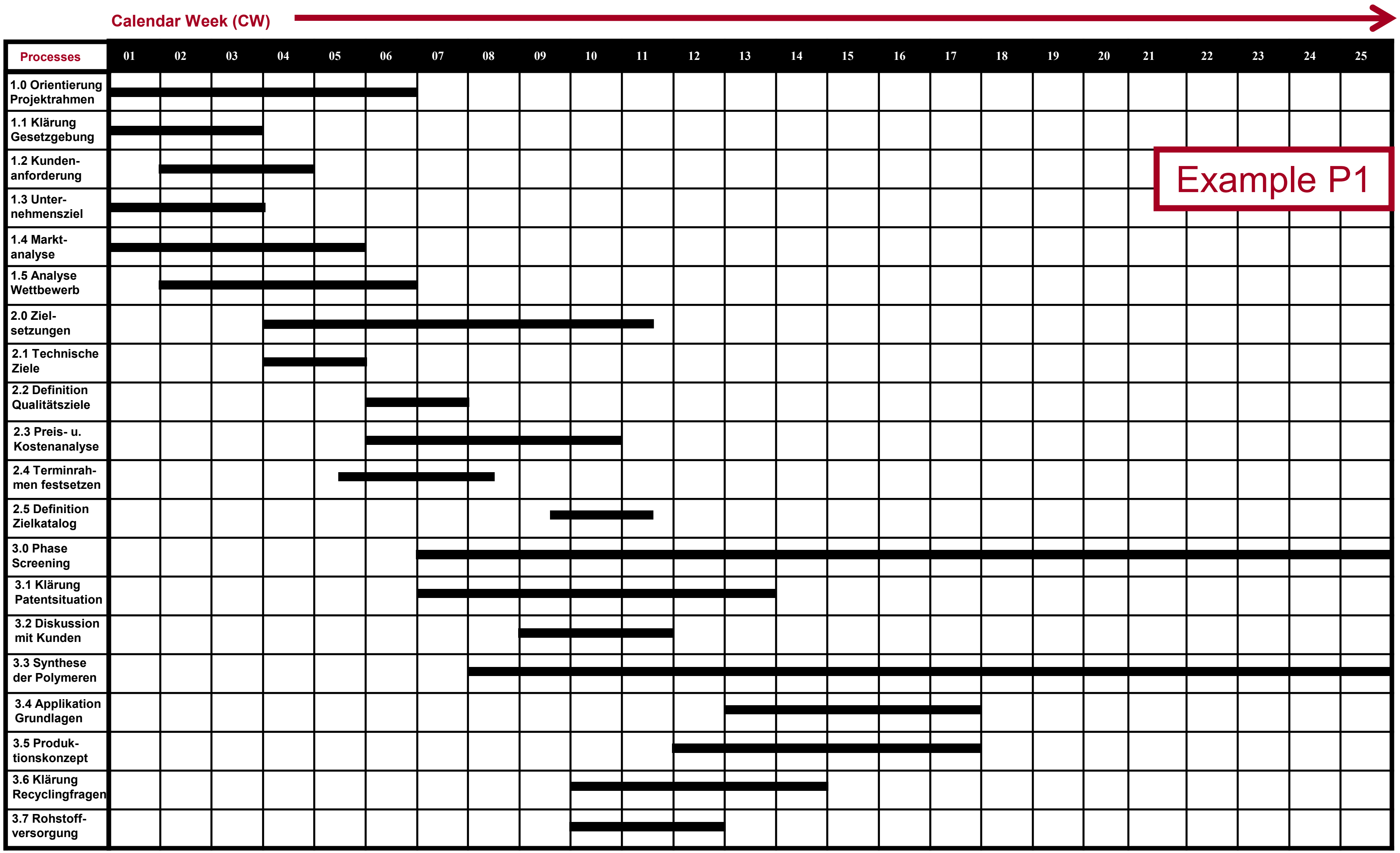
Laboratory syntheses of new "Highly Branched Crosslinkers" according to the prepared statistical test plan.

Start: 16. September 2019; End: 30. April 2020 (→ Target Dates)

Start: 01. October 2019; End: 20. April 2020 (→ Actual Dates)

Rainer Buerstinghaus

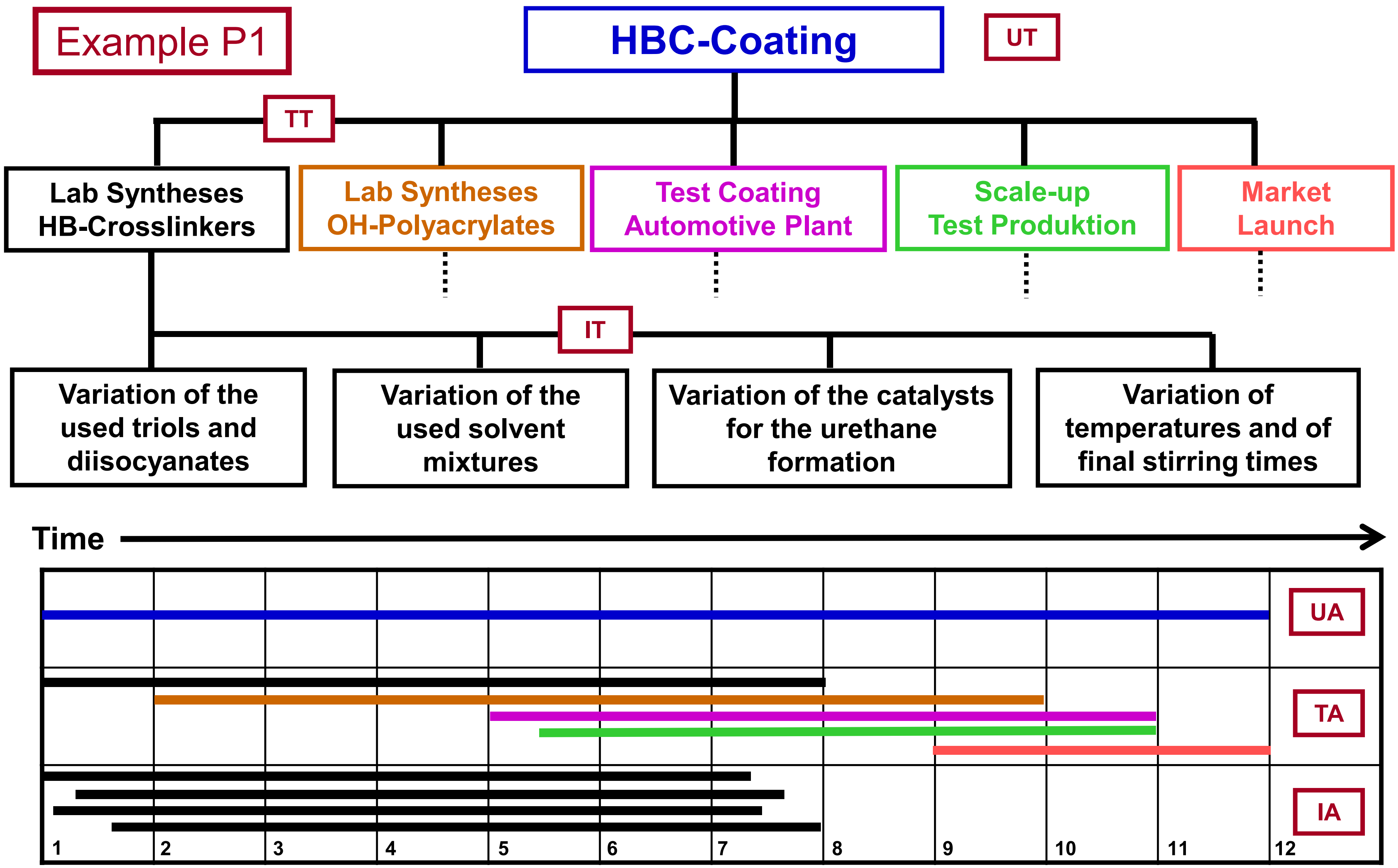
Gantt Chart (Excerpt from a Flow Plan) for the R&D Project "Highly Elastic Clear Coats for the OEM Automotive Sector."



Rainer Buerstinghaus

From Structure Plan to the Corresponding Flow Plan:

R&D Project "Highly Elastic Clear Coats…"



Rainer Buerstinghaus

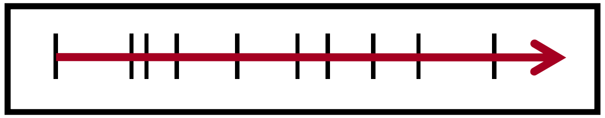
R&D Project Management in the Chemical Industry

Subject Matter →

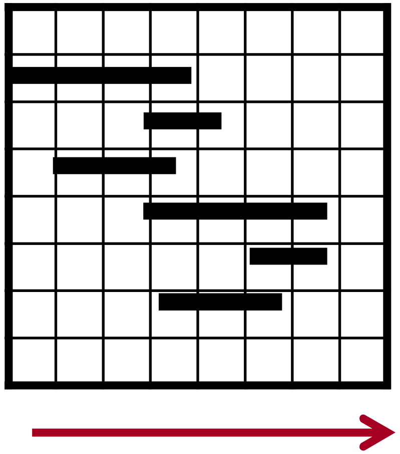
Network Diagrams.

Network Diagrams

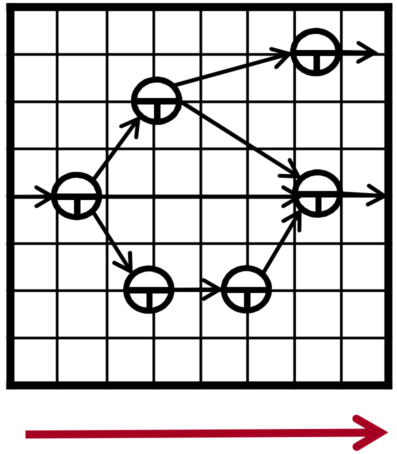
Forms of Time Planning in (R&D) Projects:



"Event Timeline"



Gantt-Chart



CPM-Network

7 0068093 6550274

Barcode

Quick Response Codes®

("One-dimensional“ Coding)

("Two-dimensional“ Coding)

Rainer Buerstinghaus

Network Diagrams

Network Diagram → **Definition, Characteristics:**

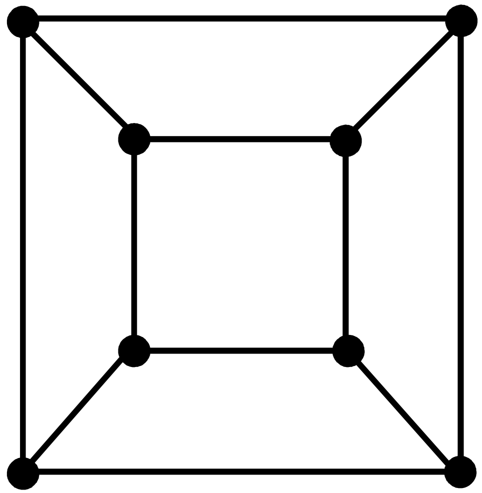
The network diagram is the graphic representation of project activities, their **temporal processes *and* their interdependencies**.

The network technique is derived from **graph theory** (mathematics). The method is used to analyze, plan, monitor and control complex (R&D-)project activities.

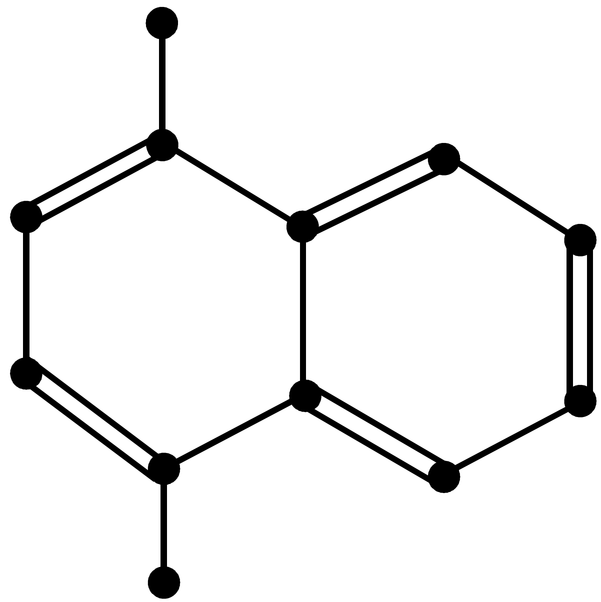
The **basic elements** of a (R&D) project network diagram are labeled and valued **vertices and directed edges** ⟶ **(arrows).**

Network Diagrams

Graph, Examples of Simple, Non-Directed Graphs:



Edge model of a cube in a "Point Projection" :
08 Vertices, 12 Edges



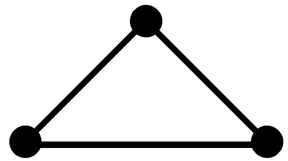
1,4-Dimethyl-naphthalene, short formula (structure):
12 Vertices, 18 Edges

Rainer Buerstinghaus

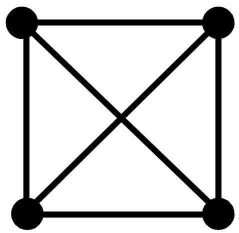
Network Diagrams. **Complete Graph within a Net (… "Simplex" within a Net,… (K_n),… or "Clique"):**

(K_1) $\begin{pmatrix} 1 \\ 2 \end{pmatrix} = 0$

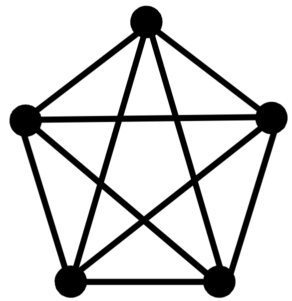
(K_2) $\begin{pmatrix} 2 \\ 2 \end{pmatrix} = 1$



(K_3) $\begin{pmatrix} 3 \\ 2 \end{pmatrix} = 3$



(K_4) $\begin{pmatrix} 4 \\ 2 \end{pmatrix} = 6$



(K_5) $\begin{pmatrix} 5 \\ 2 \end{pmatrix} = 10$

$$n \text{ Vertices} \longrightarrow \frac{n\,(n-1)}{2} \text{ Edges} \longrightarrow (K_n)$$

Rainer Buerstinghaus

Network Diagrams. **Complete Graph within a Net (… "Simplex" within a Net,… (K_n),… or "Clique"):**

	1	2	3	4	5	…	n
1	0	1	1	1	1	1	1
2	1	0	1	1	1	1	1
3	1	1	0	1	1	1	1
4	1	1	1	0	1	1	1
5	1	1	1	1	0	1	1
…	1	1	1	1	1	0	1
n	1	1	1	1	1	1	0

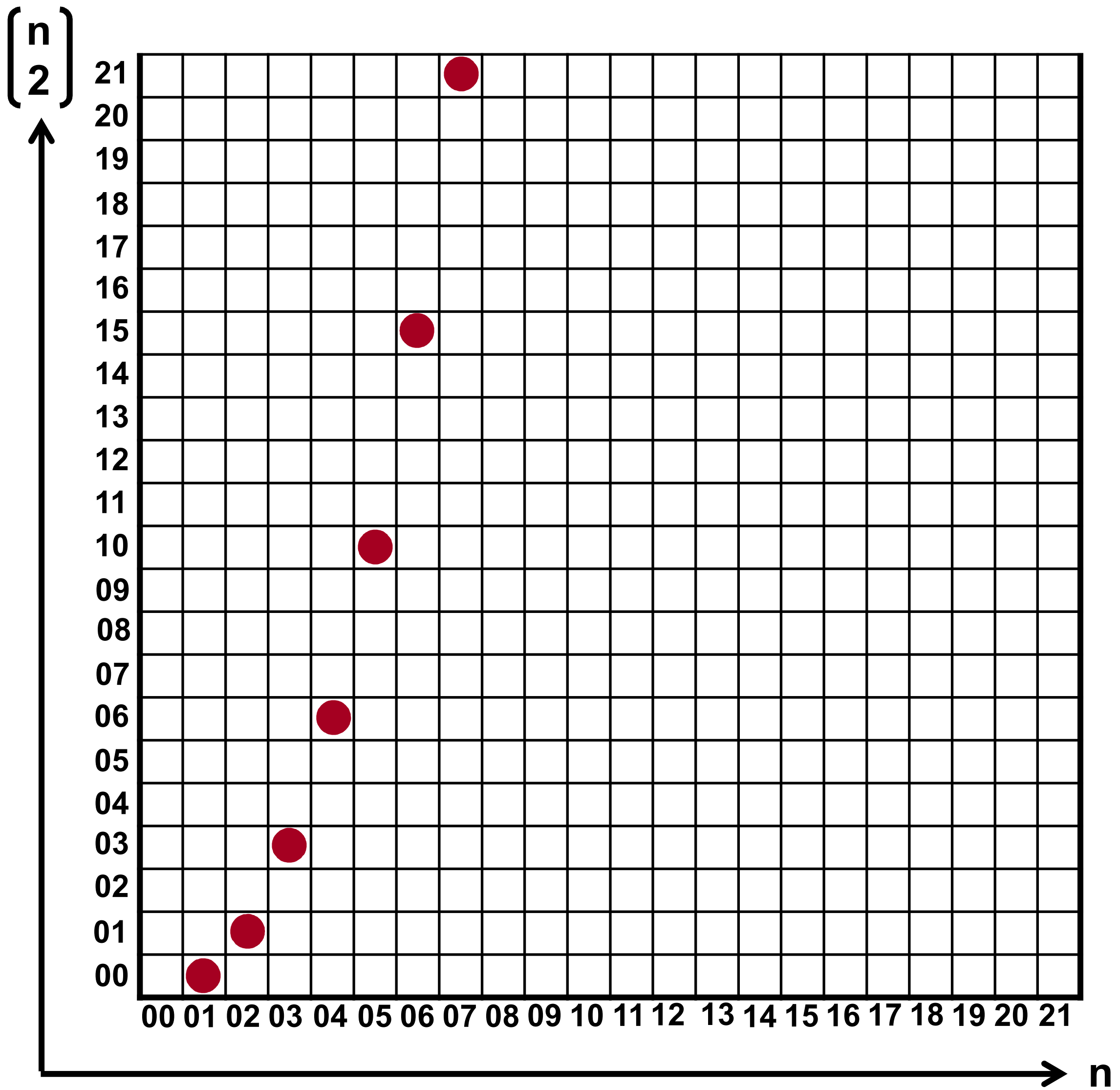
"Adjacency matrix" (“Neighborhood matrix") of a complete graph with n vertices.

It describes which vertices (n) are connected by an edge (1) or not (0).

$$n \text{ Vertices} \longrightarrow \frac{n\,(\,n-1)}{2} \text{ Edges} \longrightarrow (K_{\mathbf{n}})$$

Rainer Bürstinghaus

Complete Graph: **Exponential Growth of $\binom{n}{2}$ as f(n):**



Number of Vertices n	Number of Edges k
00	00
01	00
02	01
03	03
04	06
05	10
06	15
07	21
08	28
09	36
10	45
11	55
12	66

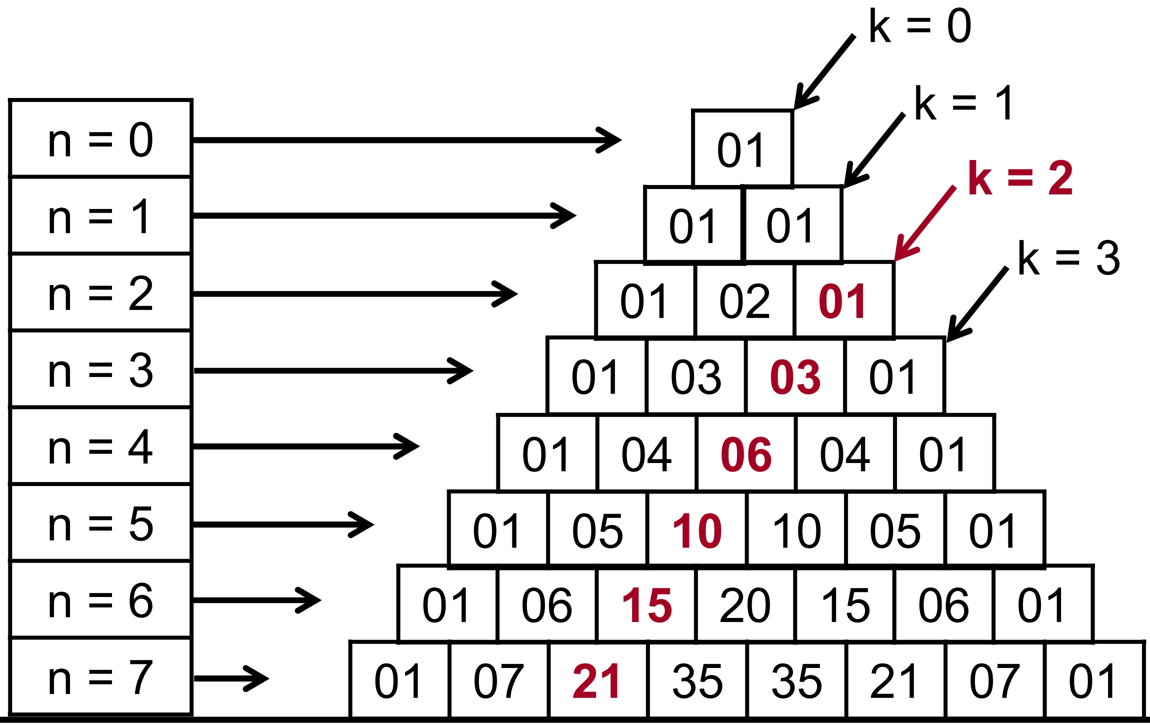
$\left(n \in \mathbb{N} \right)$

Rainer Buerstinghaus

Combinatorics, Vertex Pairs (k = 2) in the Simplex K_n :

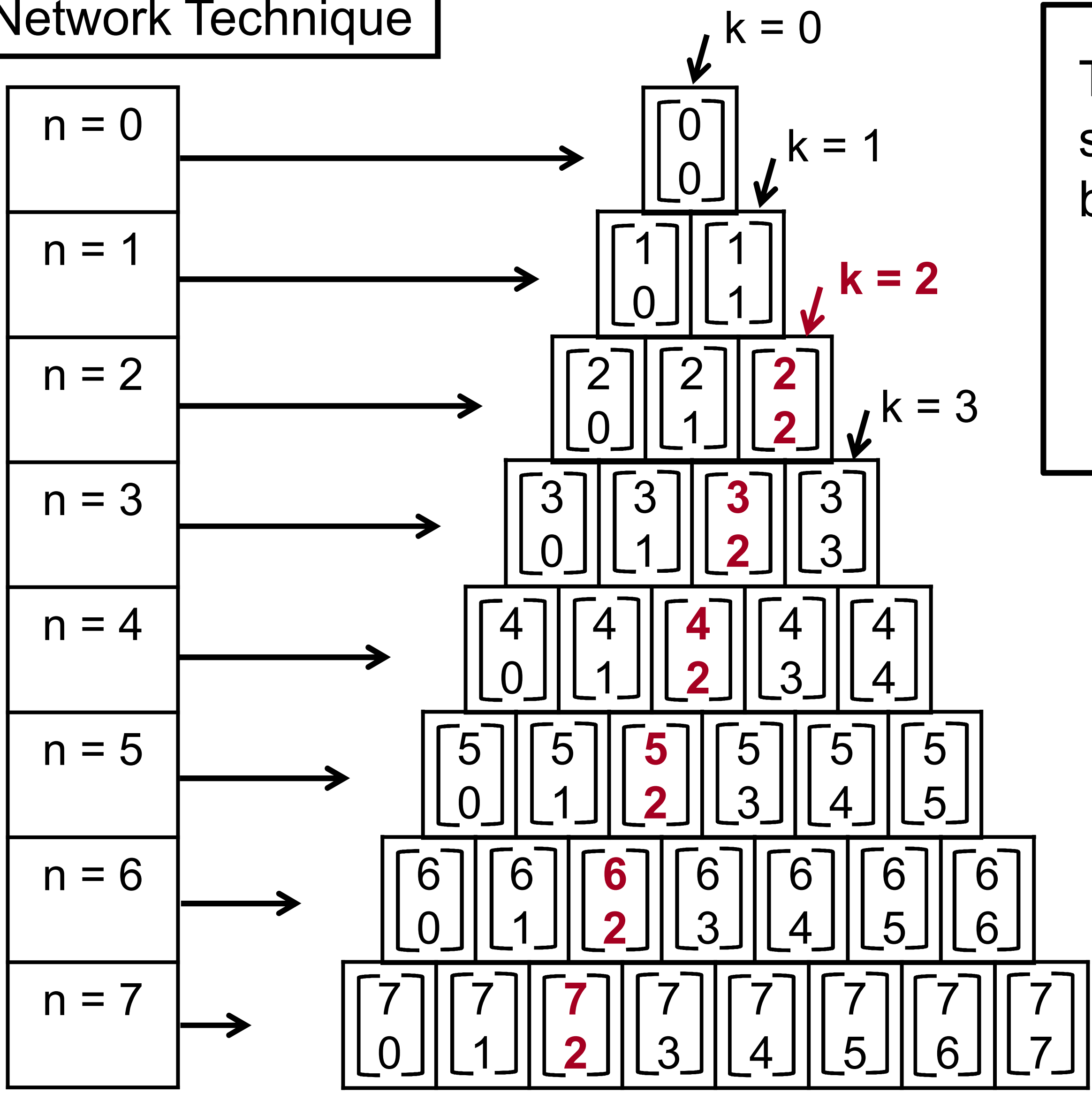
The binomial coefficient n over k can be found in the n-th row at the k-th place in the Pascal Triangle (n and k are counted from zero!).

$\begin{bmatrix} n \\ k \end{bmatrix} \longrightarrow$ "n over k": Number of all possible combinations of k elements from the total of n elements.



Combinatorics: Vertex Pairs (k = 2) in Simplex K_n :

Network Technique



The same triangle shown in the binomial symbols:

$$\begin{bmatrix}n\\k\end{bmatrix}$$

Network Diagrams, **Combinatorics → Binomial Coefficient:**

The binomial coefficient is component of a mathematical function that solves a basic task of combinatorics: It indicates, how many different ways one can select defined objects from a set of different objects (Without giving back, without respecting the order). The binomial coefficient is therefore the number of subsets of k elements consisting of n elements.

$$(x + y)^n = \begin{bmatrix} n \\ 0 \end{bmatrix} x^n + \begin{bmatrix} n \\ 1 \end{bmatrix} x^{n-1} y + \dots + \begin{bmatrix} n \\ n-1 \end{bmatrix} xy^{n-1} + \begin{bmatrix} n \\ n \end{bmatrix} y^n =$$

$$\sum_{k=0}^{n} \begin{bmatrix} n \\ k \end{bmatrix} x^{n-k} y^k$$

For integer n and k, there exists an efficient algorithm that uses the product formula of the binomial coefficient:

$$\begin{bmatrix} n \\ k \end{bmatrix} = \prod_{i=1}^{k} \frac{n - k + i}{i}$$

Rainer Buerstinghaus

Combinatorics, Number of Edges in a K_n – Simplex:

Given:

A simplex with n vertices.
The number of all edges is equal to the number of existing "vertex pairs" (k = 2).

The related algorithm: $\longrightarrow$

$$\begin{bmatrix} n \\ k \end{bmatrix} = \prod_{i=1}^{k} \frac{n-k+i}{i}$$

With k = 2, it follows:

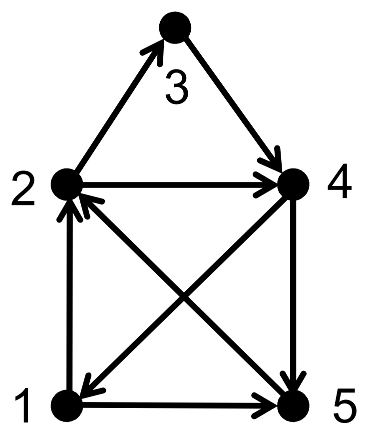
$$\begin{bmatrix} n \\ 2 \end{bmatrix} = \prod_{i=1}^{2} \frac{n-2+i}{i}$$

$$= \left[\frac{n-2+1}{1}\right] \cdot \left[\frac{n-2+2}{2}\right] = \left[\frac{n-1}{1}\right] \cdot \left[\frac{n}{2}\right] = \boxed{\frac{n\,(n-1)}{2}}$$

Network Diagrams, Connected Graphs.

Network: Connected graph.
Two vertices (nodes) are always connected by at least one edge (line).

Unicursal, that is, one-time-passable networks:
All **edges** of the network are passed through exactly once. → **Eulerian Path**.

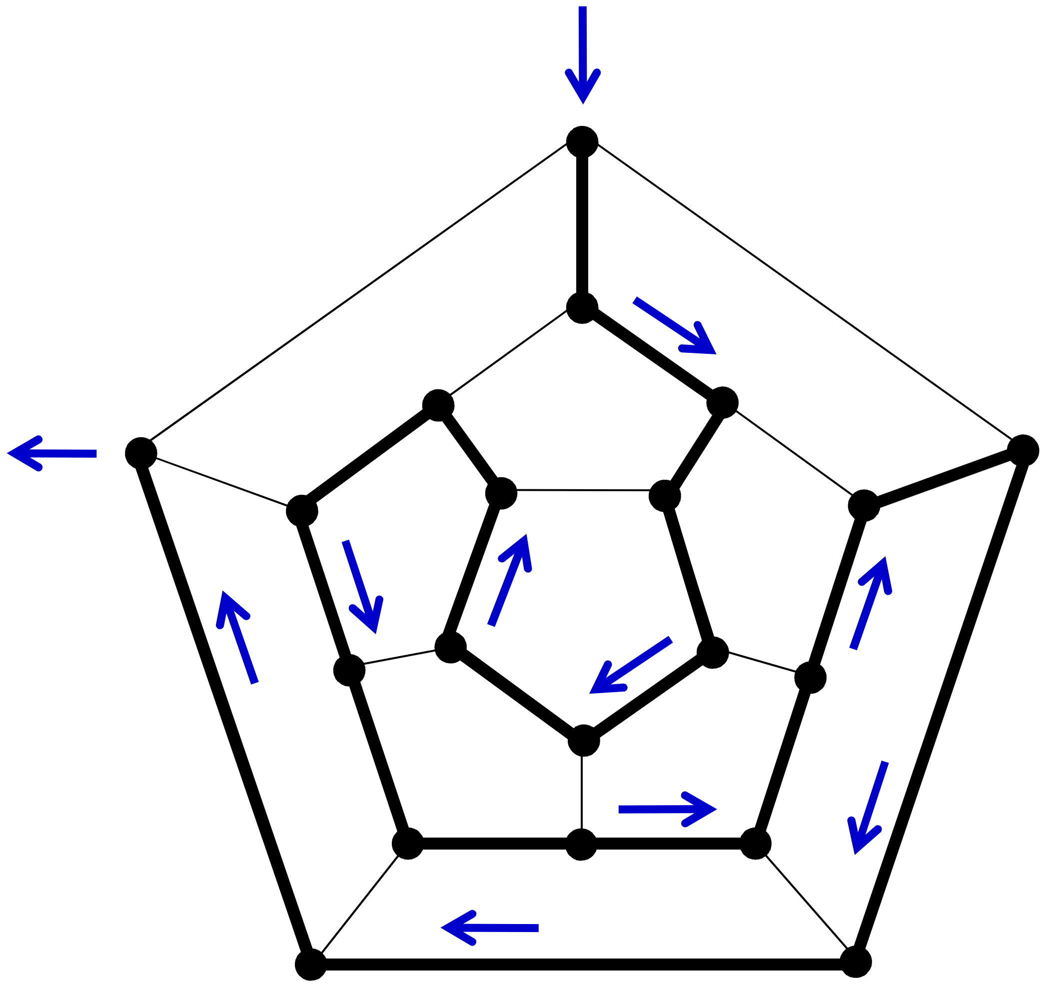


Example, Graph:
5 Vertices, 8 Edges.

A possible Eulerian Path:
1,2,3,4,5,2,4,1,5.

Network Diagrams, Connected Graphs

Connected Graph, Two vertices are always connected by at least one edge (line):

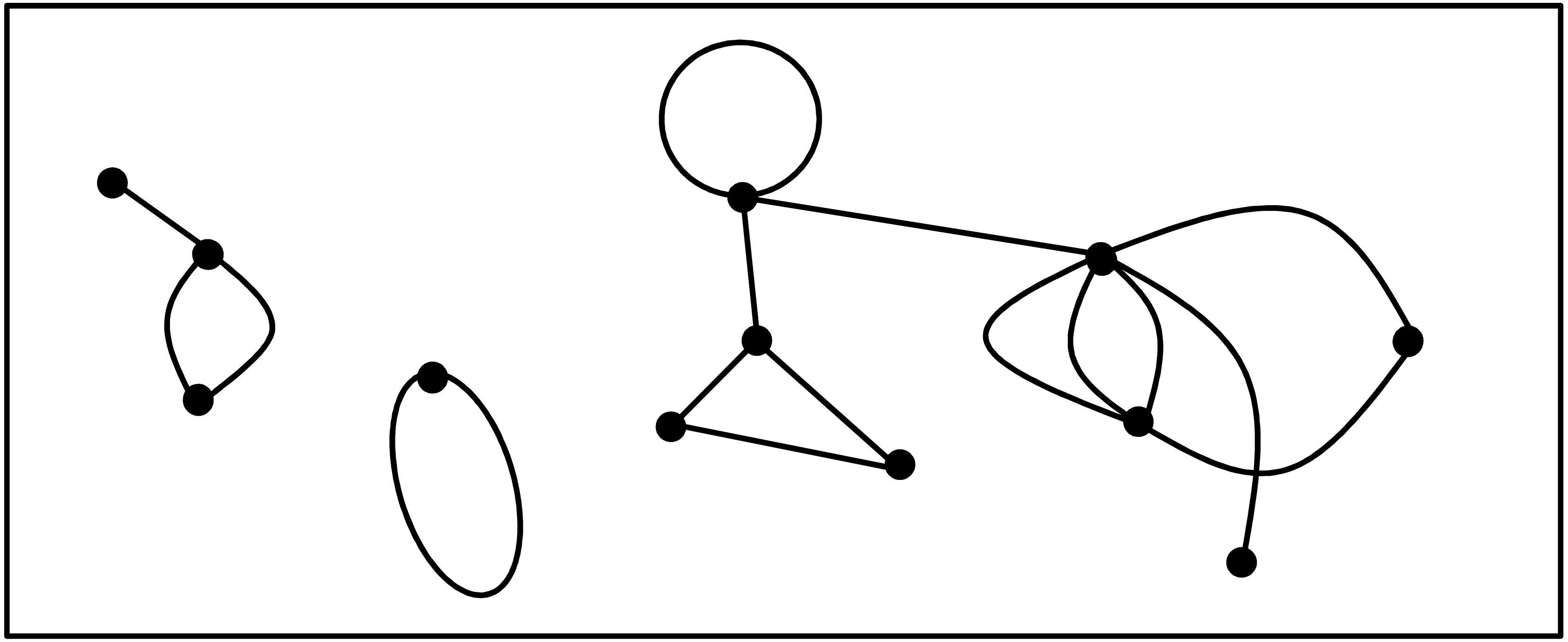


Example for a connected graph: (Dodecahedron-Net) 20 Vertices, 25 Edges.

→**"Hamiltonian Path"**: All **vertices** of a network are passed through exactly once.

Network Diagrams ⟶ **Graph** (Ancient Greek: γράφειν).

Mathematical **Definition**: Non-empty set of points and a set of lines, each connecting two points or one point to itself. The points are called **vertices** (nodes) and the lines are called **edges:**

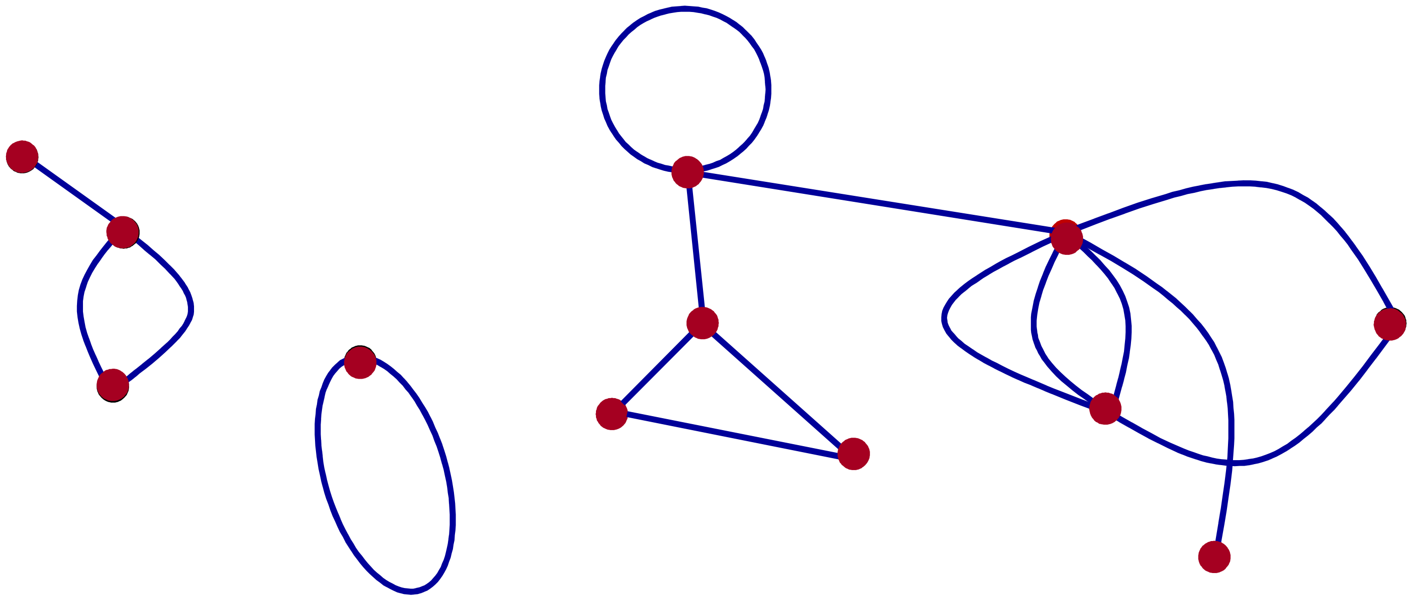


Example: Graph with **12 Vertices** and **16 Edges.**

Rainer Buerstinghaus

Network Diagrams $\longrightarrow$ **Graph** (Ancient Greek: γράφειν).

Mathematical **Definition**: Non-empty set of points and a set of lines, each connecting two points or one point to itself. The points are called **vertices** (nodes) and the lines are called **edges**.

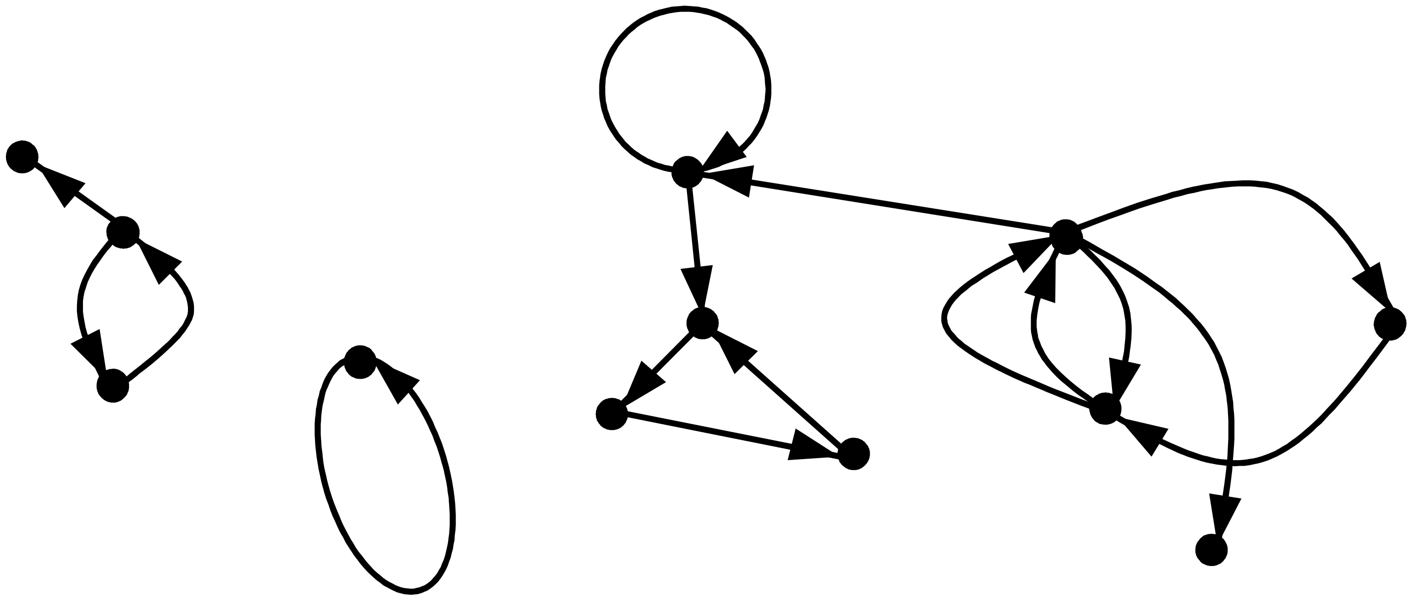


Example: Graph with **12 Vertices** and **16 Edges**.

Rainer Buerstinghaus

Network Diagrams ⟶ **Graph** (Ancient Greek: γράφειν).

Mathematical **Definition**: Non-empty set of points and a set of lines, each connecting two points or one point to itself. The points are called **vertices** (nodes) and the lines are called **edges**.



Example: **Directed Graph**: ⟶ 12 Vertices and 16 Paths.

Rainer Buerstinghaus

Network Diagrams, Network Technique

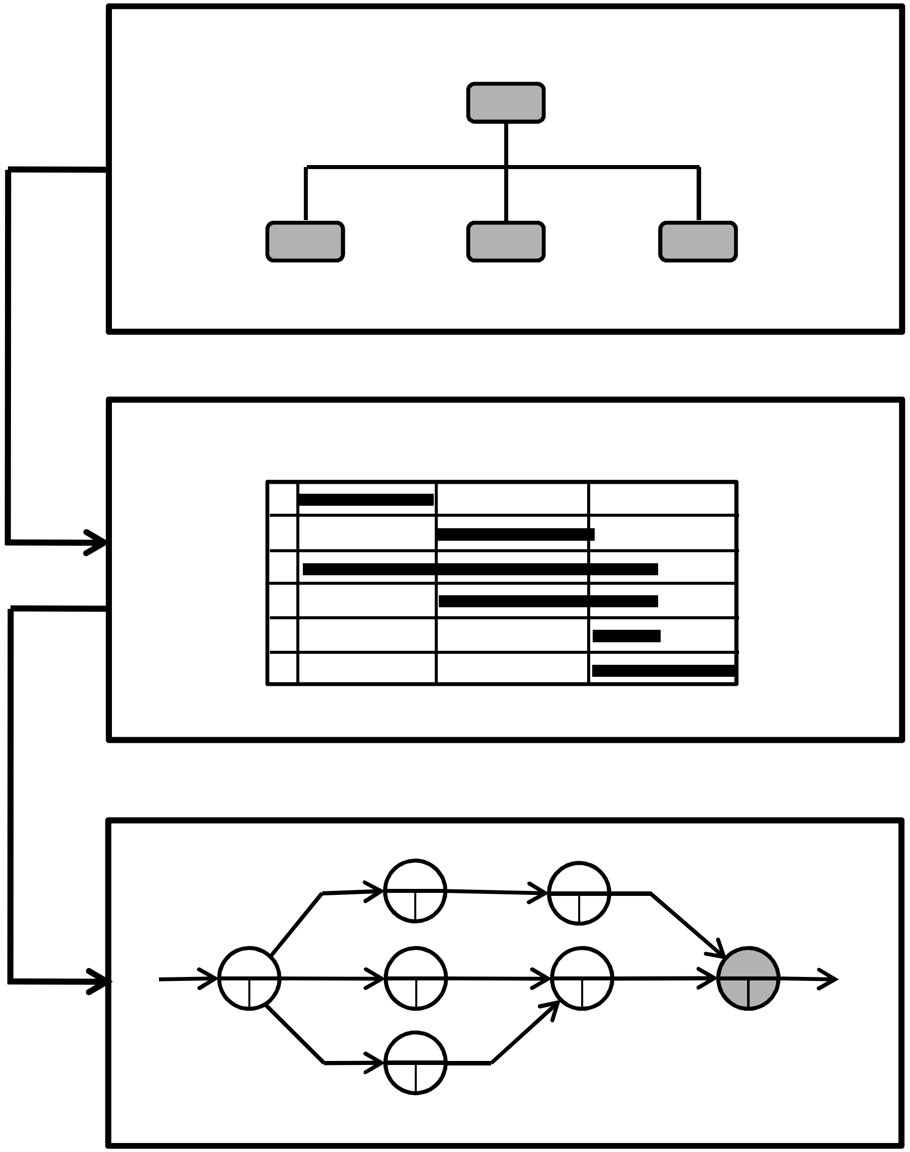
Structure Plan

Rough phase planning for important tasks to be solved.

Phase Plan

Detailed flow planning for each single work package.

CPM-Network

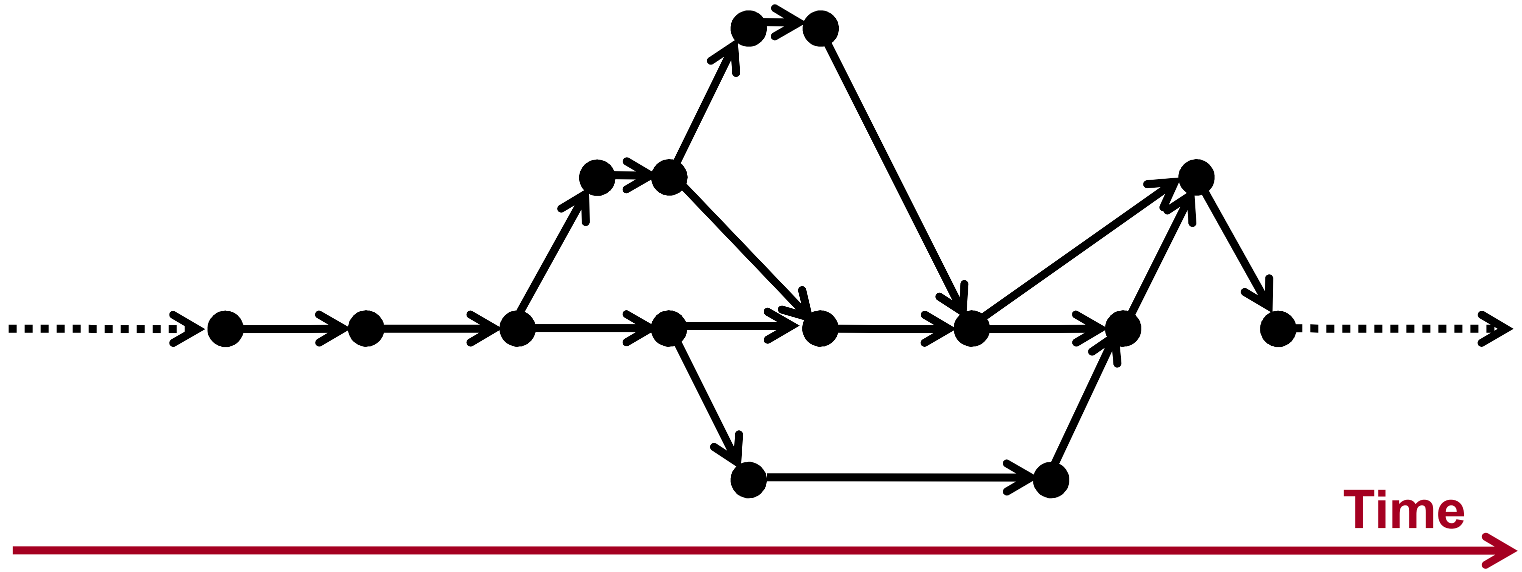


Rainer Buerstinghaus

Network Diagram, Connected, Directed Graph:

Two nodes are always connected by at least one arrow
(A directed edge course).

Unicursal, that means, exactly single-way passable networks:
The **paths** of the network are traversed exactly once along the given direction.
The net contains **no** self-contained (endless) loops.



Network Diagrams → **(MPM, PERT, CPM), Elements:**

Elements → Activities | Events

Activity → (**Period** of Time, Interval)

- **Activity**

Time-consuming process with defined start and defined completion (Includes a period).

→ Often: *Implementation* of the solution of a task.

Network Diagrams → **(MPM, PERT, CPM), Elements:**

Elements → Activities | Events

Event → (**Date**, Deadline)

- **Event**

Date at which a defined state is reached in the course of the project.

→ Example: Start or completion of a task solution.
→ Example: Achievement of a defined milestone.

Network Diagrams, **Input of Basic Data, Information:**

The network planning processes systematically answers to the following, time-related questions:

- When one can start with a defined activity at the **earliest**? **(ES, Earliest Start).**

- When one has to start with a defined activity at the **latest**? **(LS, Latest Start).**

Network Diagrams, **Input of Basic Data, Information:**

The network planning processes systematically answers to the following, time-related questions:

- When one can complete a defined activity at the **earliest**? **(EF, Earliest Finish).**

- When one has to be ready with a defined activity at the **latest**? **(LF, Latest Finish).**

Network Diagrams, **Input of Basic Data, Information:**

The network planning processes systematically answers to the following, time-related questions:

↓

- Which single activities have a **"time elasticity" ("slack time"),** because **LF-EF ≠ 0**?

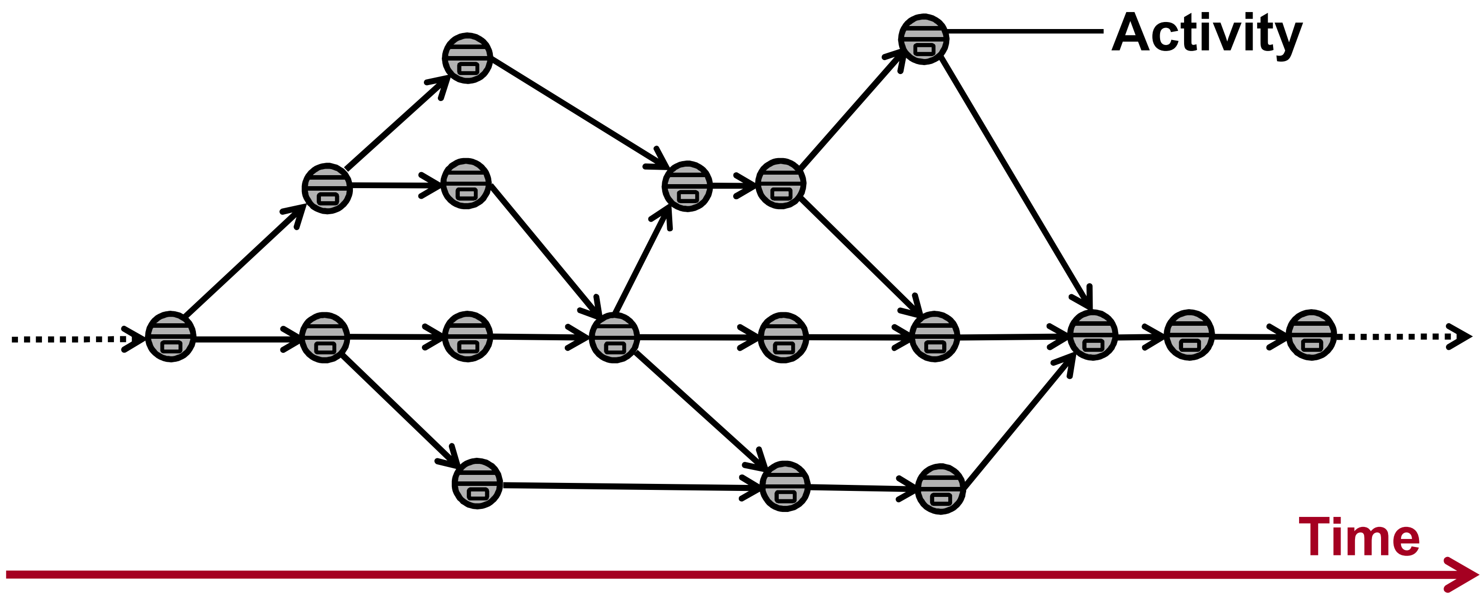
- Which single activities **without "time elasticity" (LF-EF = 0)** influence the final date in case of their lag?

- How big is the **time elasticity (total "slack time")** in the entire project?

Network Diagrams → **Methods:**

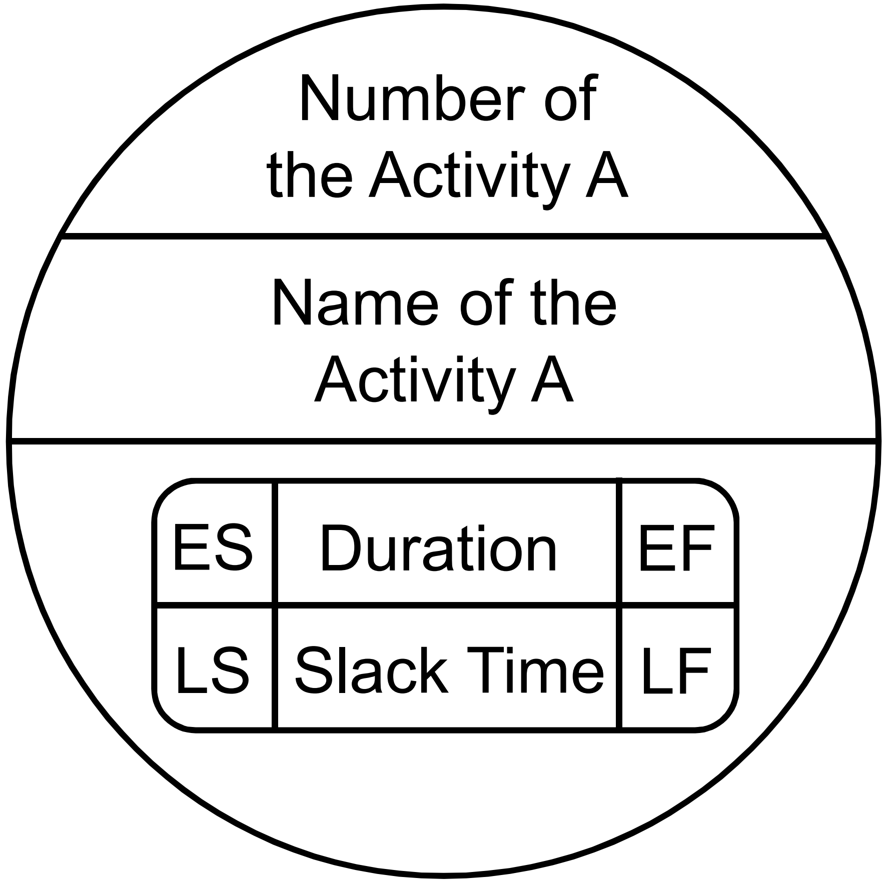
The ***activity-oriented*** network diagram contains only all activities in the project, their structural layout and their running order.

Activity-on-Node Diagrams, MPM, (**M**etra-**P**otential-**M**ethod):
The individual activities appear as nodes in the network.
The structural arrangements are illustrated by arrows (→).



Network Diagrams

Implementation of a Work Package ⟶ Activity A:



ES: Earliest Start Date; LS: Latest Start Date;
EF: Earliest Finish Date; LF: Latest Finish Date.

Rainer Buerstinghaus

Activity for "A 21 - HBC 52" (Registration at the ECHA*):

Example P1

HBC 52-78

Determination of acute peroral toxicity (rats).

58	16	74
70	12	86

*) European Chemicals Agency, Helsinki

[ES: Working Day in 2021; LS: Working Day in 2021;
EF: Working Day in 2021; LF: Working Day in 2021.]

Activity for "A 21 - HBC 52" (Registration at the ECHA*):

Example P1

HBC 52-79

Determination of the etching effect or irritation effect (in vitro tests with human keratinocytes. *)

86	03	89
88	02	91

*) Corneal Cells

[ES: Working Day in 2021; LS: Working Day in 2021;
EF: Working Day in 2021; LF: Working Day in 2021.]

Activity for "A 21 - HBC 52" (Registration at the ECHA*):

Example P1

HBC 52-80

Determination of skin sensi-tization (local lymph node test , LLNA*) with mice.

86	05	91
88	02	93

*) Local Lymph Node Assay

[ES: Working Day in 2021; LS: Working Day in 2021;
EF: Working Day in 2021; LF: Working Day in 2021.]

Rainer Buerstinghaus

Activity for "A 21 - HBC 52" (Registration at the ECHA*):

Example P1

HBC 52-81

Mutagenicity test (in vitro) on Salmonella microsomes (Ames *).

86	02	88
88	02	90

*) According to Bruce Ames

[ES: Working Day in 2021; LS: Working Day in 2021;
EF: Working Day in 2021; LF: Working Day in 2021.]

Rainer Buerstinghaus

Activity for "A 21 - HBC 52" (Registration at the ECHA*):

Example P1

HBC 52-82

Acute aquatic toxicity to green algae (selenastrum) and plankton crustacea (daphnia *).

86	01	87
88	02	89

*) Water fleas

[ES: Working Day in 2021; LS: Working Day in 2021;
EF: Working Day in 2021; LF: Working Day in 2021.]

Rainer Buerstinghaus

Activity for "A 21 - HBC 52" (Registration at the ECHA*):

Example P1

HBC 52-83

Determination of basic data on biodegradation behavior (metabolites, eco-persistence).

86	60	146
88	02	148

[ES: Working Day in 2021; LS: Working Day in 2021; EF: Working Day in 2021; LF: Working Day in 2021.]

Rainer Buerstinghaus

Activity for "A 21 - HBC 52" (Registration at the ECHA*):

Example P1

HBC 52-84

Collecting material characteristics (Fp, Bp, density ρ, vapor pressure P, distribution coefficient p in system octanol/water: $p = C_{Octanol} / C_{Wasser}$).

86	01	87
88	02	89

[ES: Working Day in 2021; LS: Working Day in 2021;
EF: Working Day in 2021; LF: Working Day in 2021.]

Rainer Buerstinghaus

Activity for "A 21 - HBC 52" (Registration at the ECHA*):

Example P1

HBC 52-85

Measurement of safety data (flash point, auto-ignition temperature, flammability, explosive and oxidizing properties).

86	10	96
88	02	98

[ES: Working Day in 2021; LS: Working Day in 2021;
EF: Working Day in 2021; LF: Working Day in 2021.]

Rainer Buerstinghaus

Activity for "A 21 - HBC 52" (Registration at the ECHA*):

Example P1

HBC 52-86

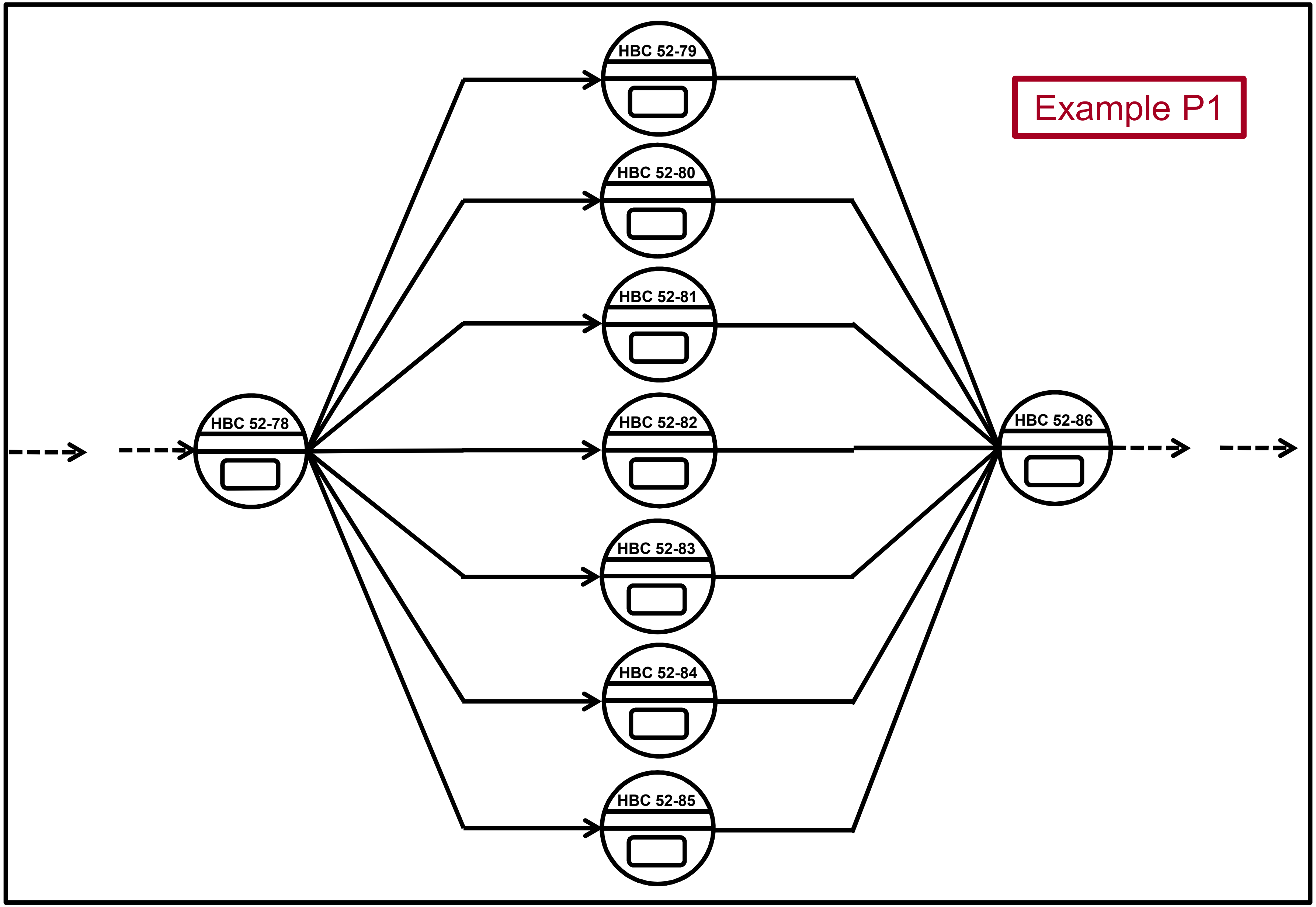
Evaluation and preparation of the REACH sub-dossier (Article 10 from **R**egistration, **E**valuation and **A**uthorization of **Ch**emicals).

148	30	178
148	00	178

[ES: Working Day in 2021; LS: Working Day in 2021;
EF: Working Day in 2021; LF: Working Day in 2021.]

Rainer Buerstinghaus

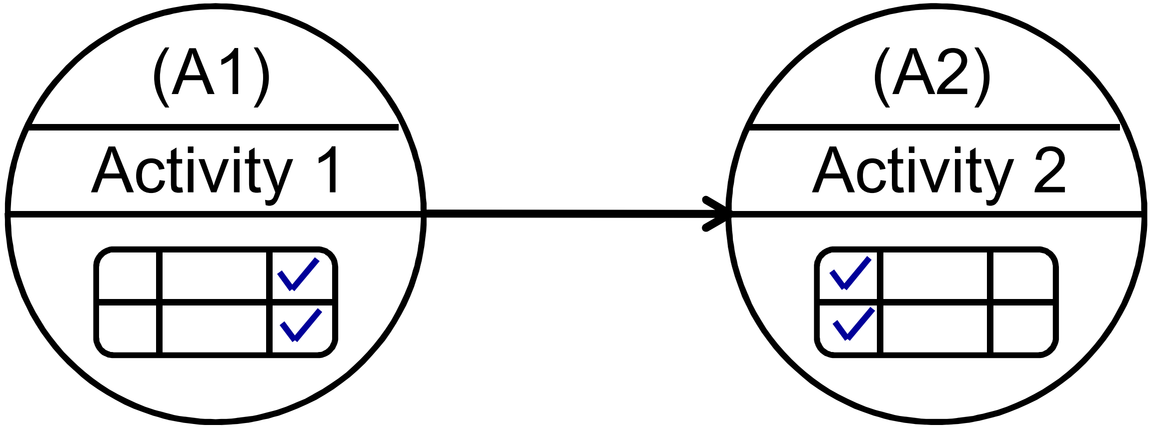
Network Diagrams | "A21 - HBC 52" MPM Diagram (Detail):



Rainer Buerstinghaus

Network Diagrams

MPM-Network Diagram, Structural Arrangements.
Normal Sequence (End-to-Start Relationship, DIN 69900):

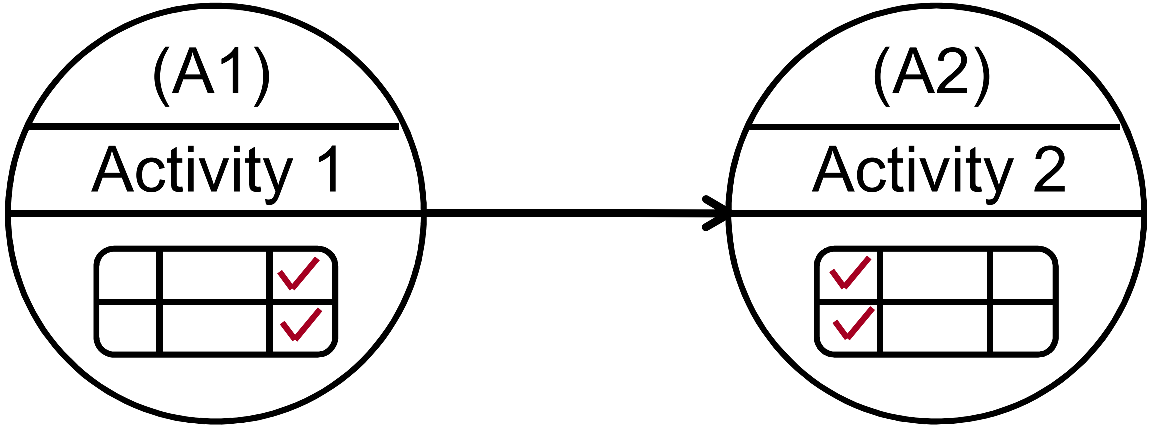


A1 must be completed,
before A2 can be started.

Rainer Buerstinghaus

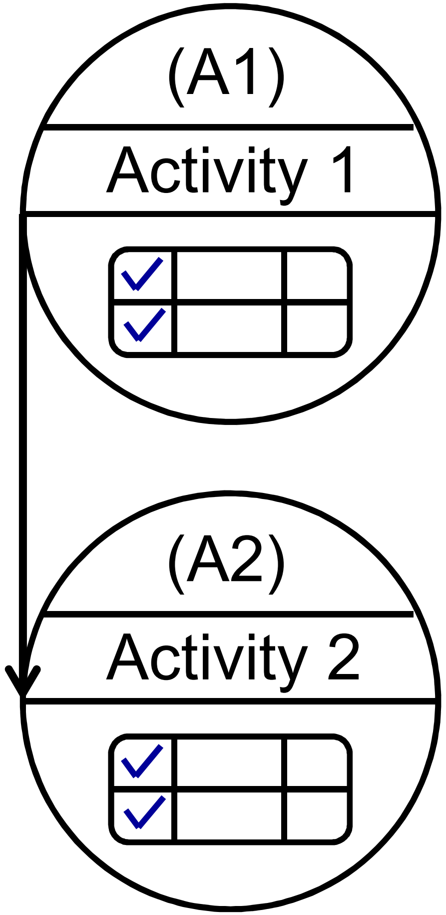
MPM-Network Diagram, Structural Arrangements. Normal Sequence (End-to-Start Relationship):

Example



20-step synthesis of a natural product molecule (non-convergent/divergent): Only when synthesis step 17 in the laboratory is fully completed, the synthesis step18 can be started.

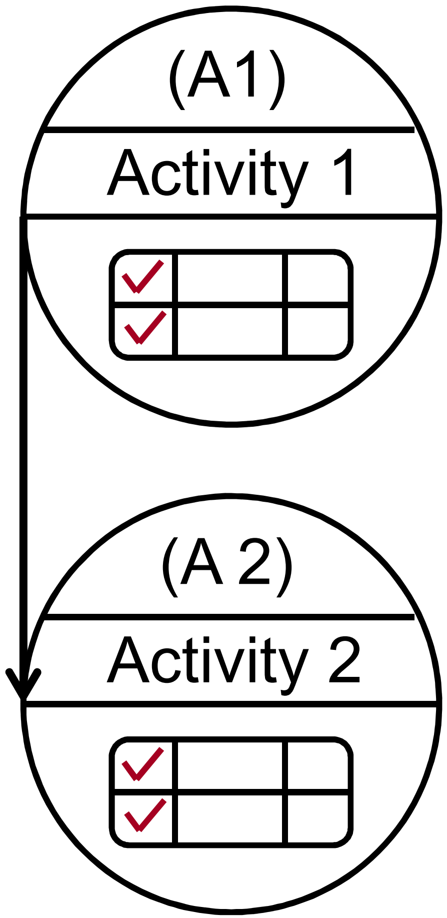
MPM-Network Diagram, Structural Arrangements.
Start Sequence (Start-to-Start Relationship, DIN 69900):



A1 must have been started before A2 can begin!

MPM-Network Diagram, Structural Arrangements.
Start Sequence (Start-to-Start Relationship):

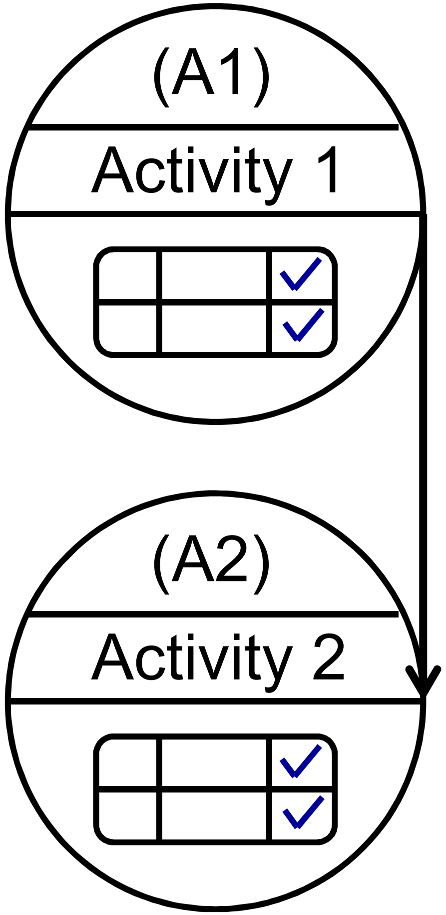
Example



Formulation of 30 new liquid clear coats.

Measurement of the elastic moduli of the resulting 30 clear coats in the AWETA.

MPM-Network Diagram, Structural Arrangements.
End Sequence (End-to-End Relationship, DIN 69900):

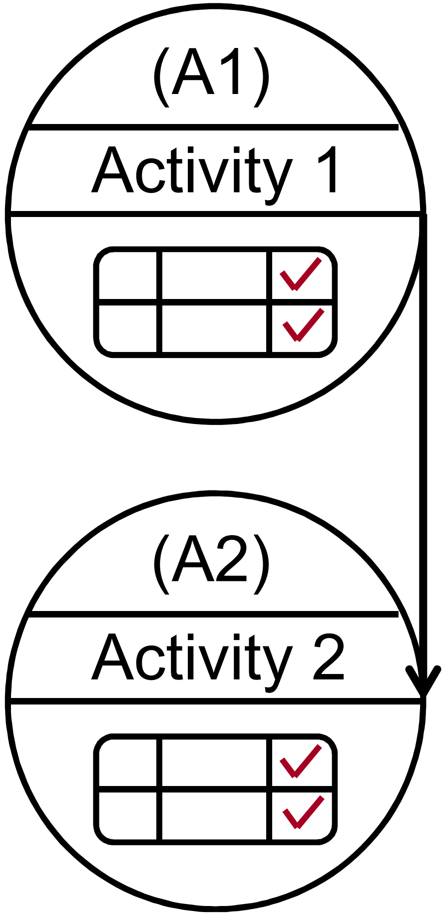


A 2 can not be completed until A1 has been finished!

Network Diagrams

MPM-Network Diagram, Structural Arrangements.
End Sequence (End-to-End Relationship):

Example



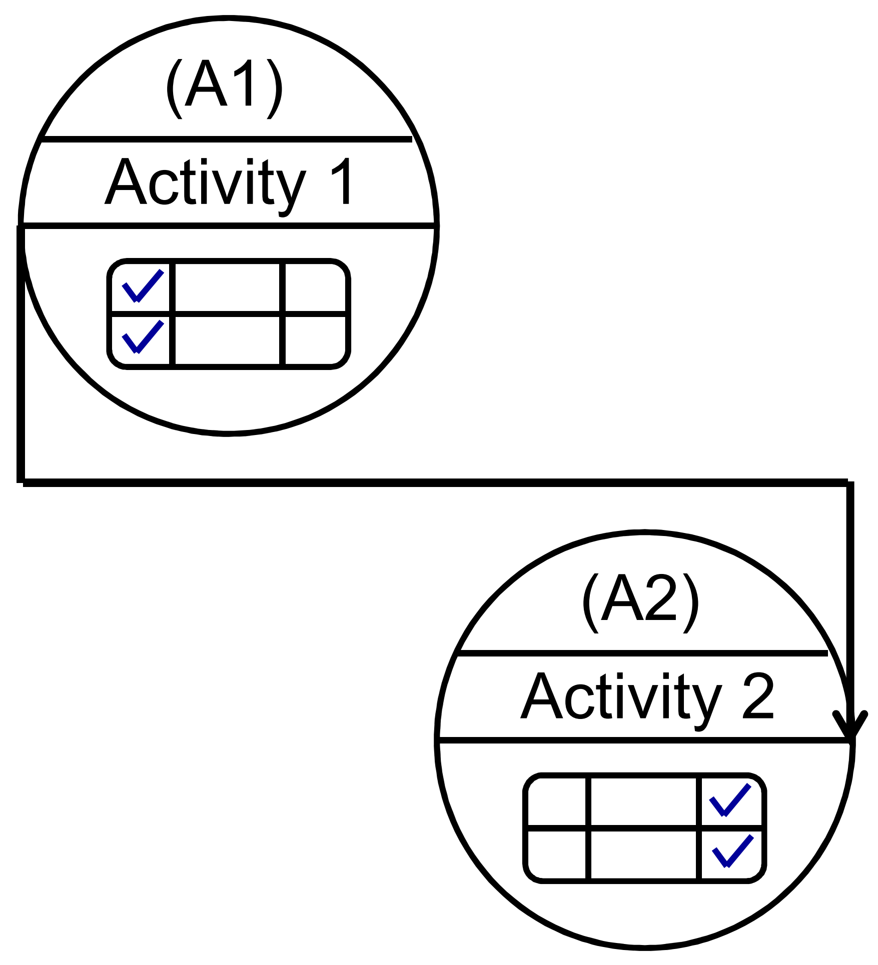
Syntheses of 40 new poly-acrylates for clear coats.

Measurements of the molecular weight distributions of these polyacrylates by means of gel permeation chromatography (GPC).

Rainer Buerstinghaus

Network Diagrams

MPM-Network Diagram, Structural Arrangements. "Jump Sequence" (Start-to-End Relationship, DIN 69900):



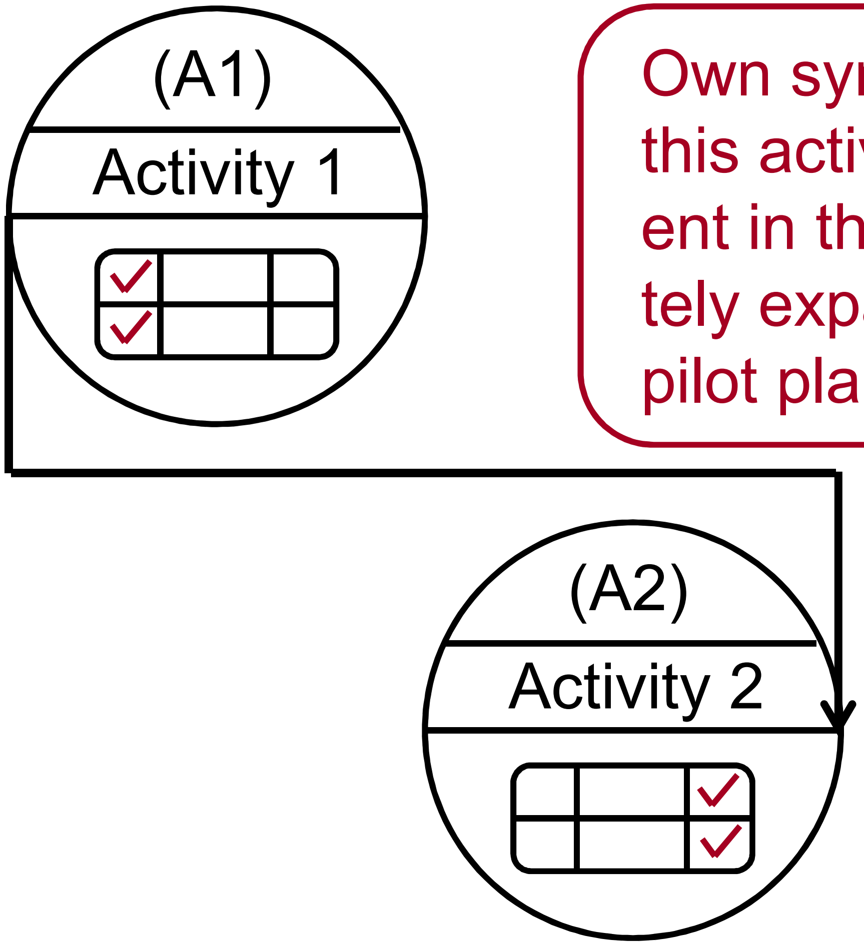
A2 can not be com-pleted before A1 has been started!

Rainer Buerstinghaus

Network Diagrams

MPM-Network Diagram, Structural Arrangements. "Jump Sequence" (Start-to-End Relationship):

Example



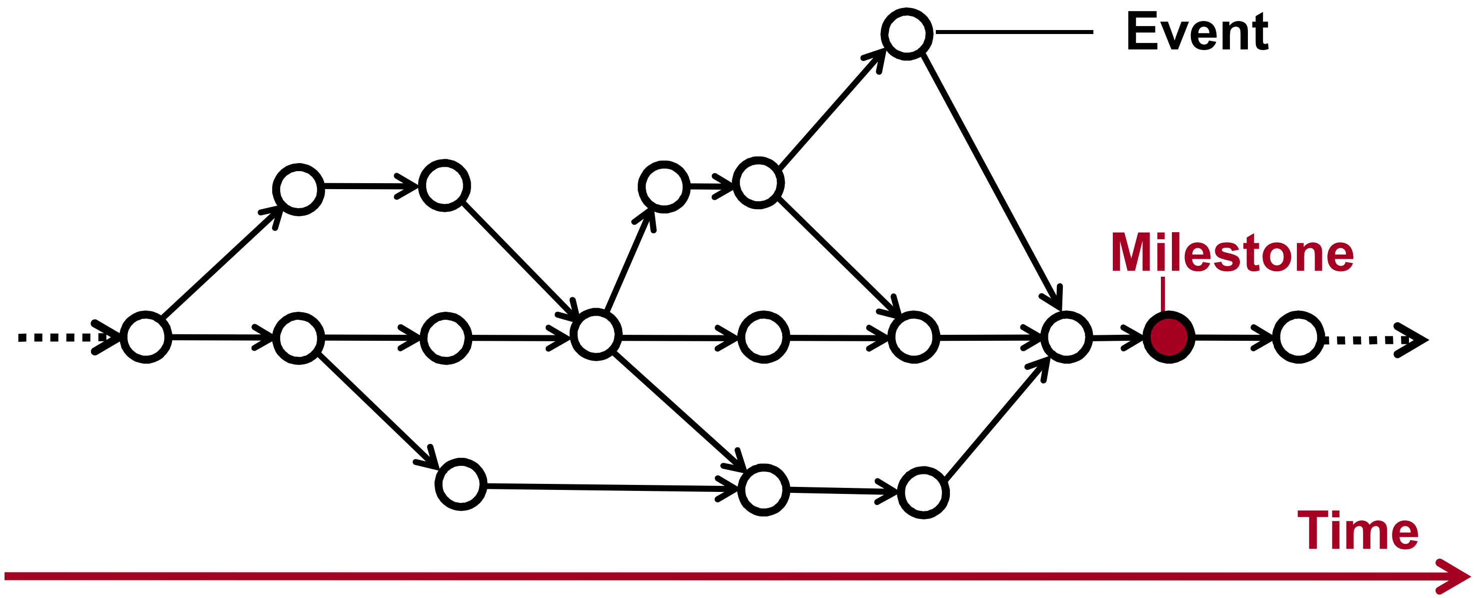
Own synthesis of this active ingredient in the completely expanded own pilot plant.

Order synthesis of an active ingredient (100 kg batches) by contract manufacturing.

Network Diagrams ⟶ **Network Technique, Types:**

The ***event-oriented*** network diagram contains all dates in the project, their structural arrangements and their order.

Event-on-Node Network, PERT (**P**rogram **E**valuation and **R**eview **T**echnique). The event-dates are represented by nodes ○ . The structural arrangements are illustrated by arrows (⟶):

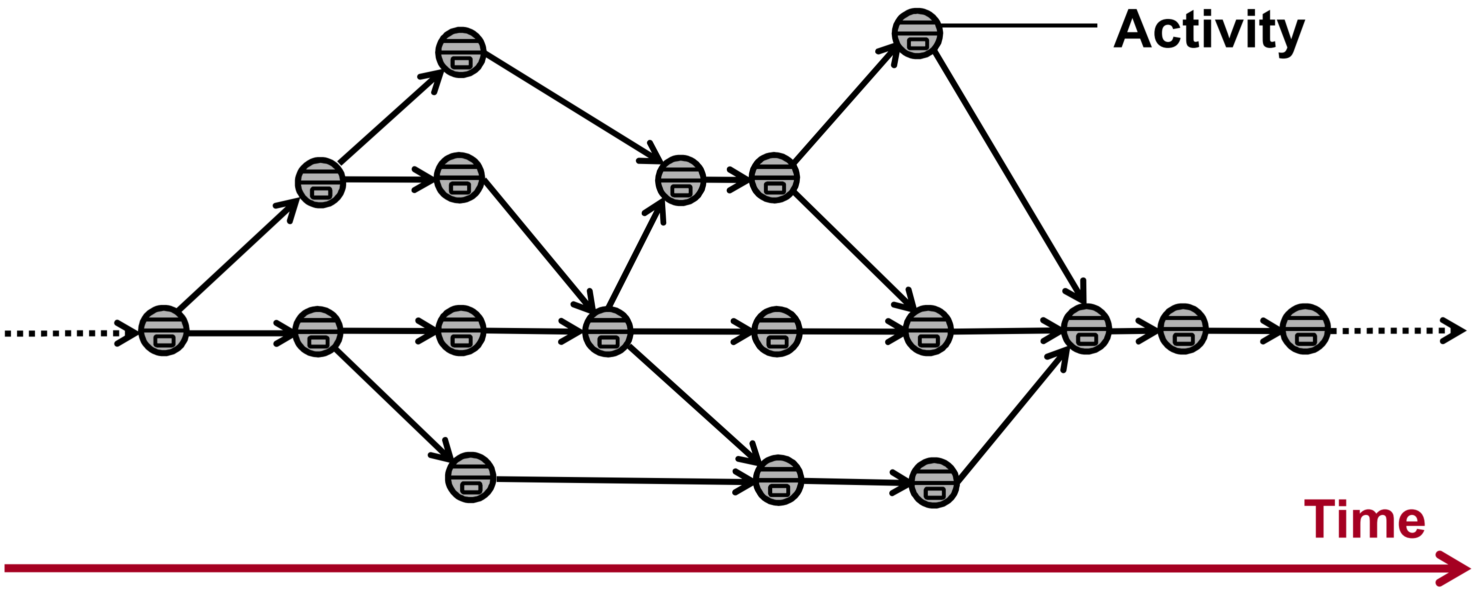


Rainer Buerstinghaus

Network Diagrams → **Network Technique, Types**

The ***activity-oriented*** network diagram contains only all activities in the project, their structural layout and their running order.

Activity-on-Node Diagrams, MPM, (**M**etra-**P**otential-**M**ethod).
The individual activities  appear as nodes in the network.
The structural arrangements are illustrated by arrows (→):

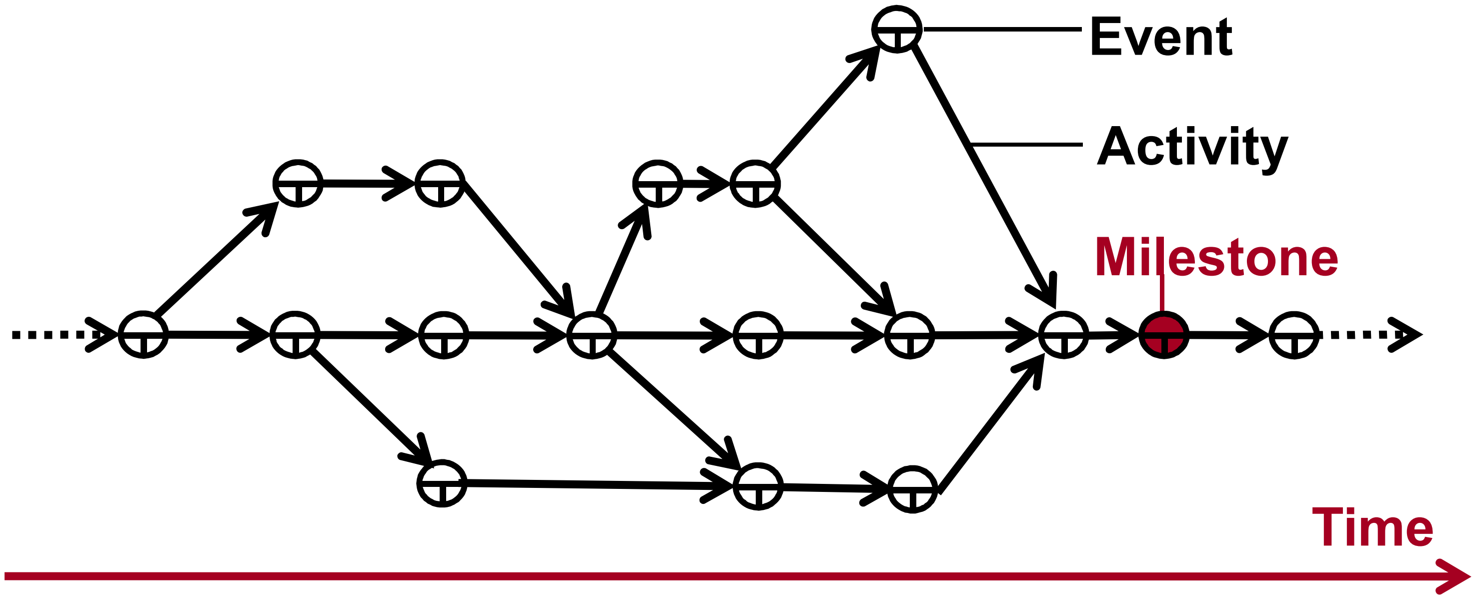


Rainer Buerstinghaus

Network Diagrams ⟶ **Network Technique, Types:**

The ***activity-oriented*** network diagram contains only all activities in the project, their structural layout and their running order.

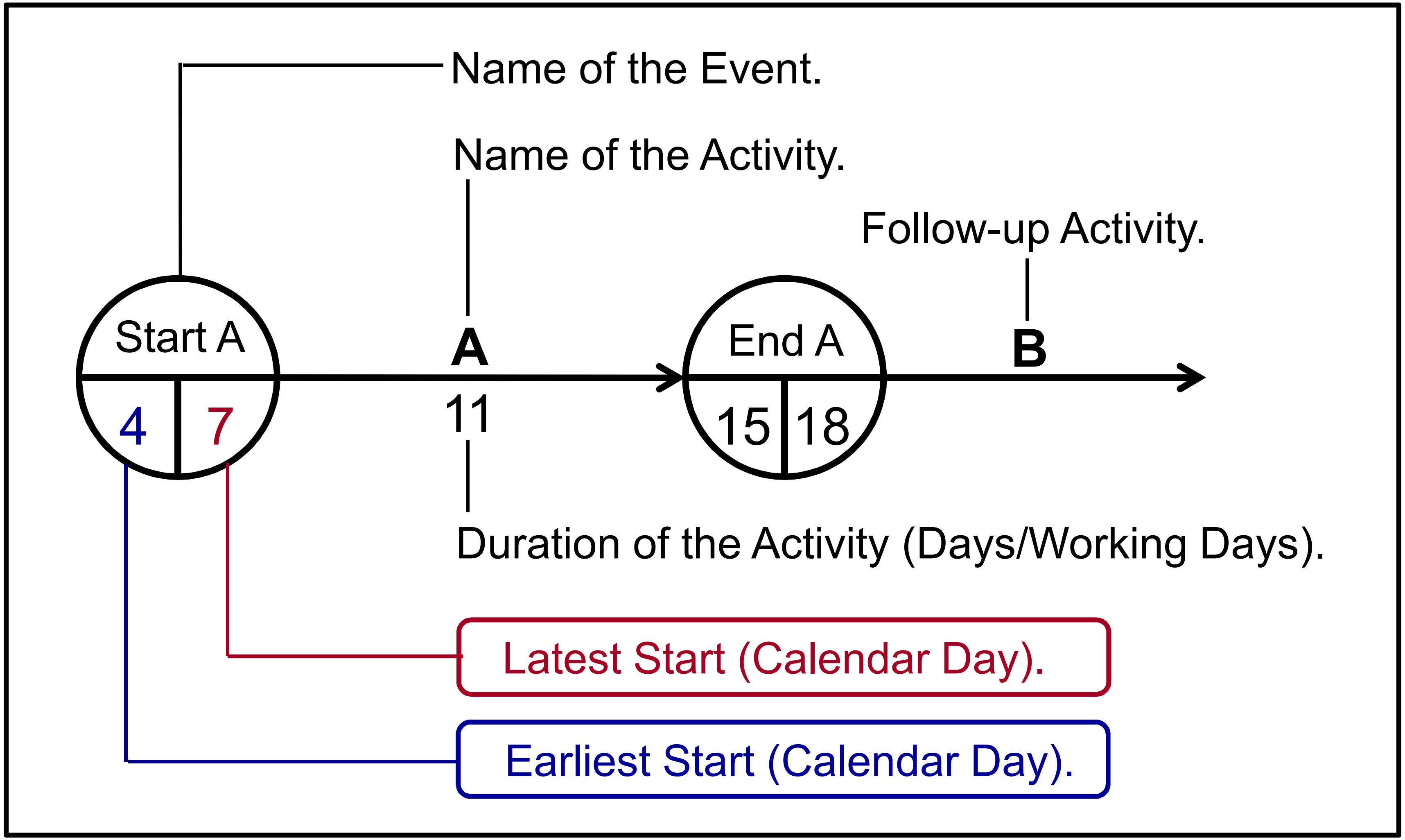
Process Arrows Network, CPM ("**C**ritical **P**ath **M**ethod").
All operations (execution of work packages) appear as arrows (⟶), all event times are represented by nodes ⊖ :



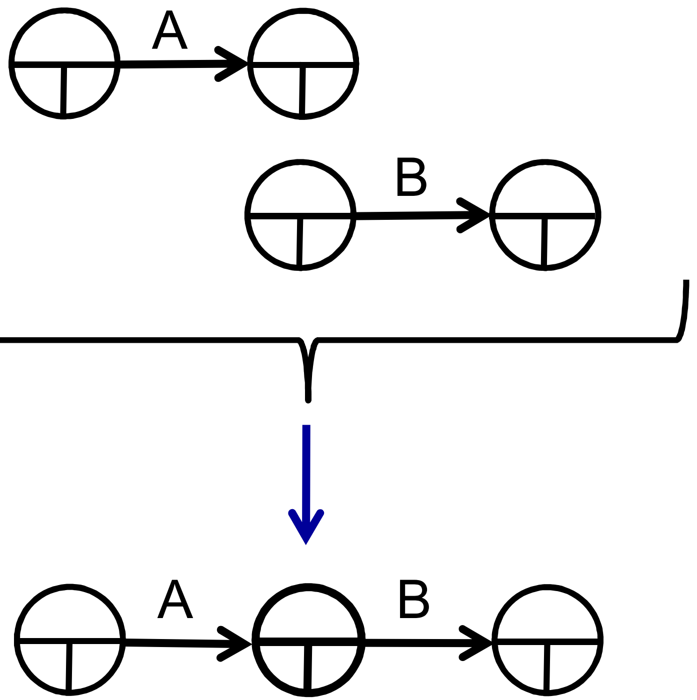
Rainer Buerstinghaus

Network Diagrams → CPM Network Technique

Graphic Representation of an Activity A:



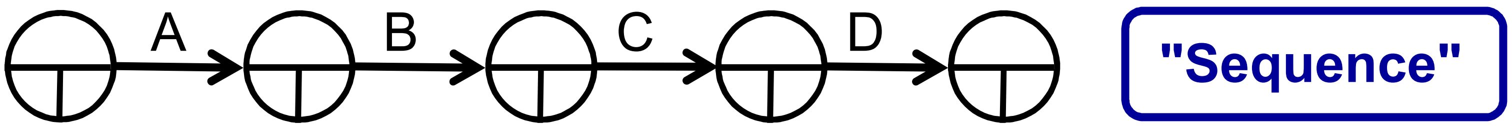
Activity-on-Arrow-Diagram, CPM, "Critical Path Method"
Construction Rules, Dependencies of the Activities:



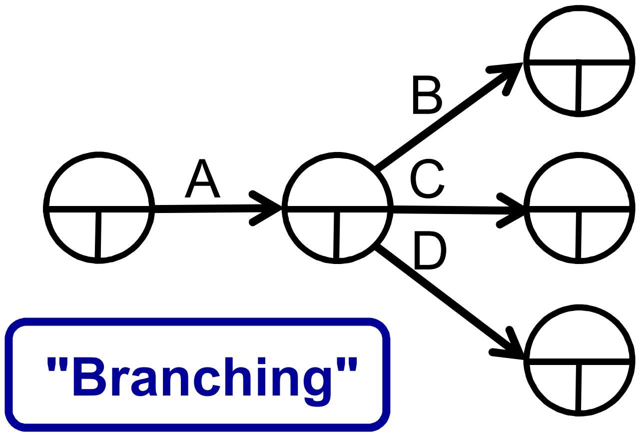
Convention: The completion event of an activity coincides with the start event of the immediate successor.

Network Diagrams ⟶ CPM Network Technique

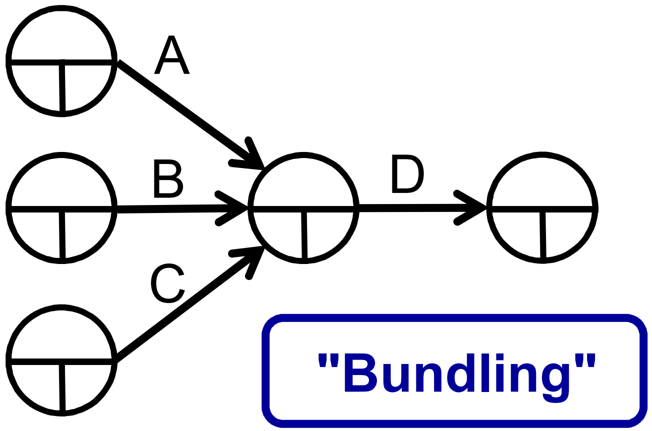
Activity-on-Arrow-Diagram, CPM, "Critical Path Method"
Construction Rules, Dependencies of the Activities:



Successive Activities A, B, C, D.



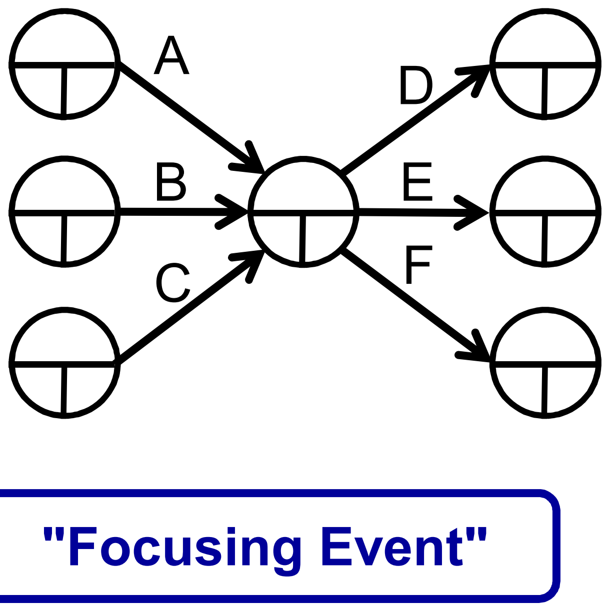
The Endpoint of A is the Start Point of B,C and D.

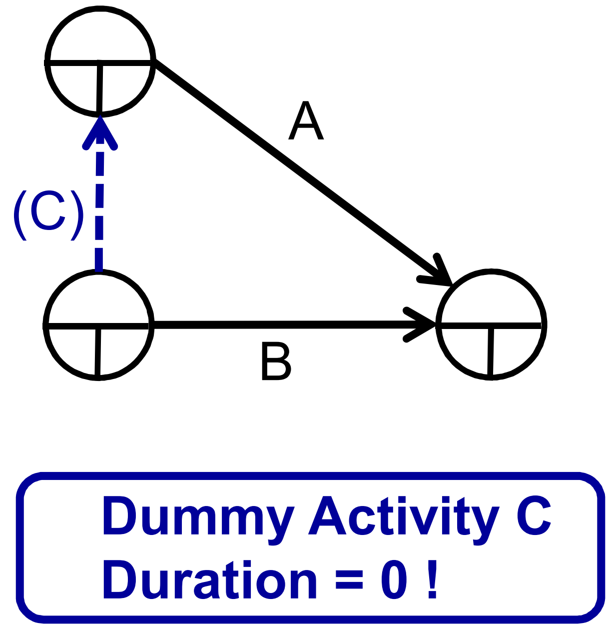


The Start Point of D is the Endpoint of A,B and C.

Rainer Buerstinghaus

Activity-on-Arrow-Diagram, CPM, "Critical Path Method" Construction Rules, Dependencies of the Activities:

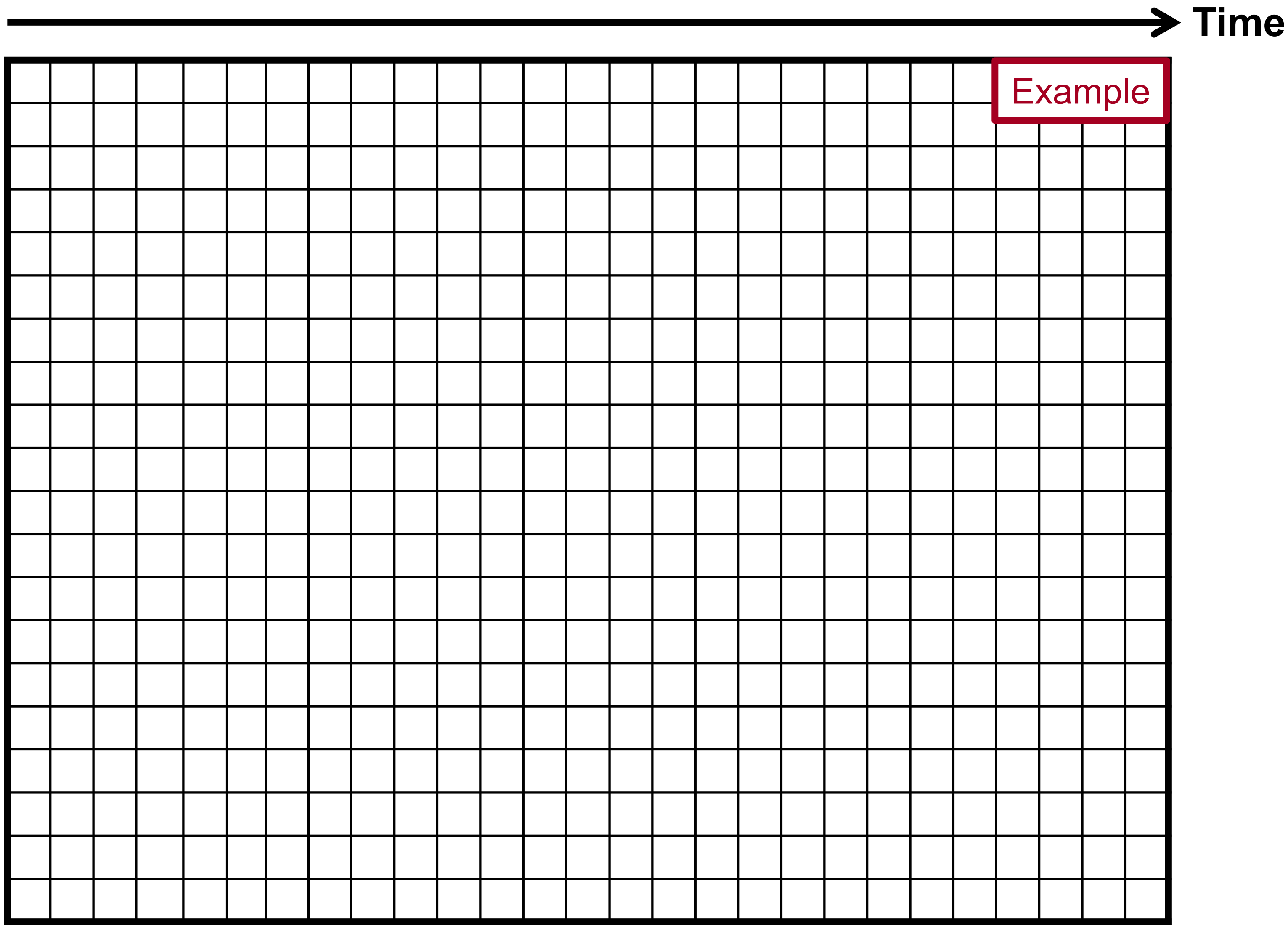




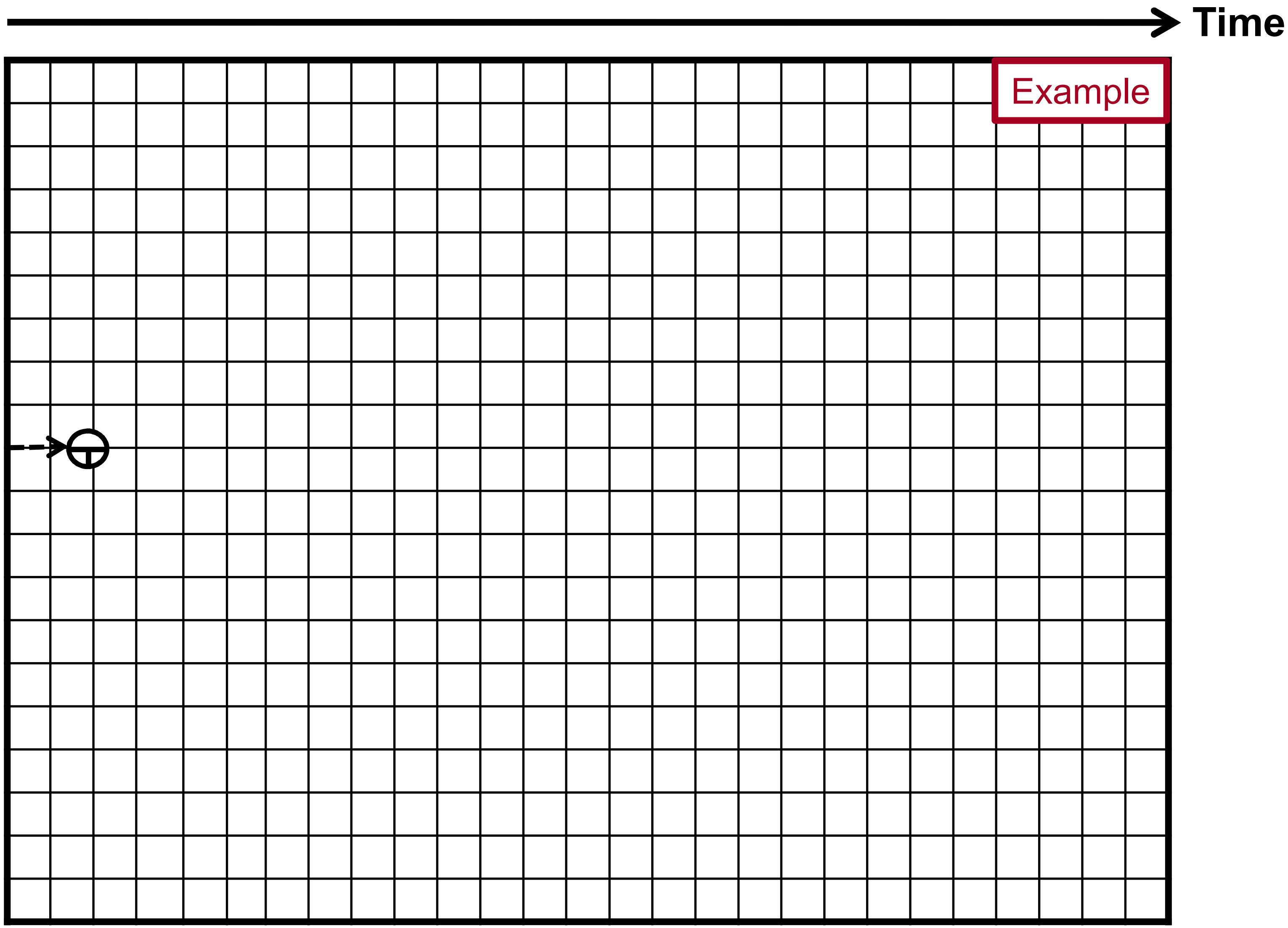
The Endpoint of A, B and C is the Start Point of D, E, and F

A and B are different activities and run simultaneously. Symbol: - - - ->

CPM Diagram; Activity: $\longrightarrow$ **; Dummy Activity:** $\dashrightarrow$

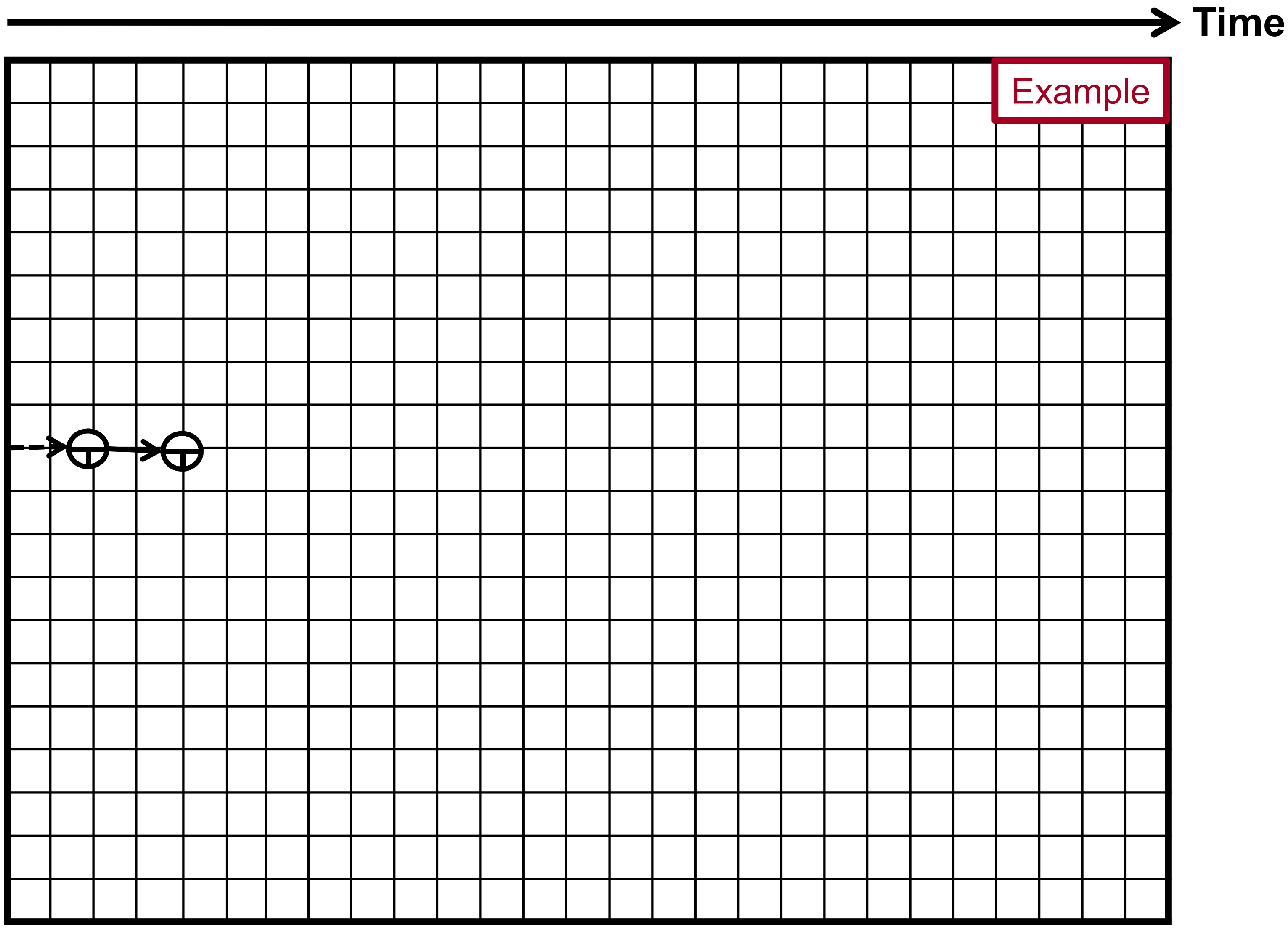


CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



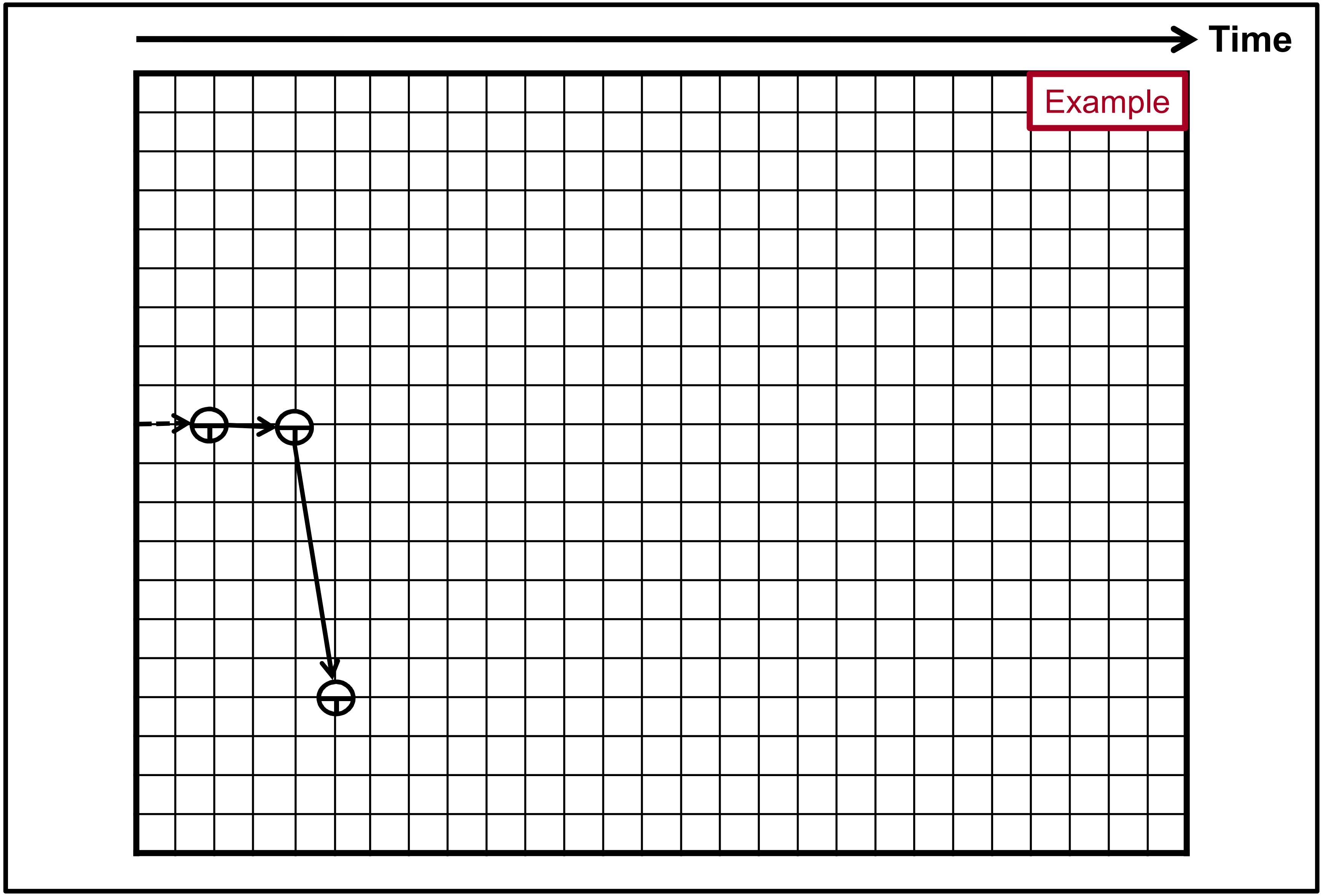
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



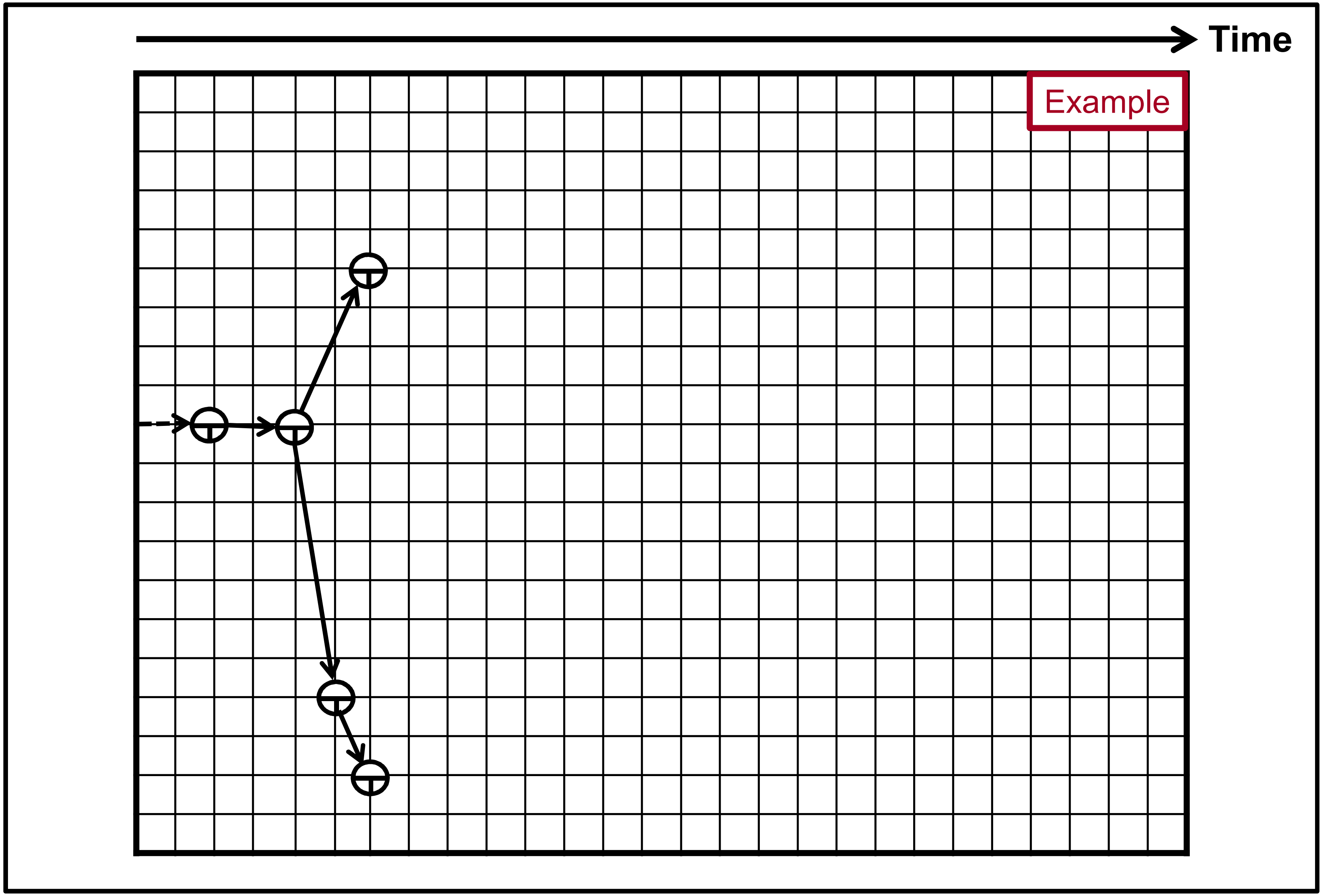
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



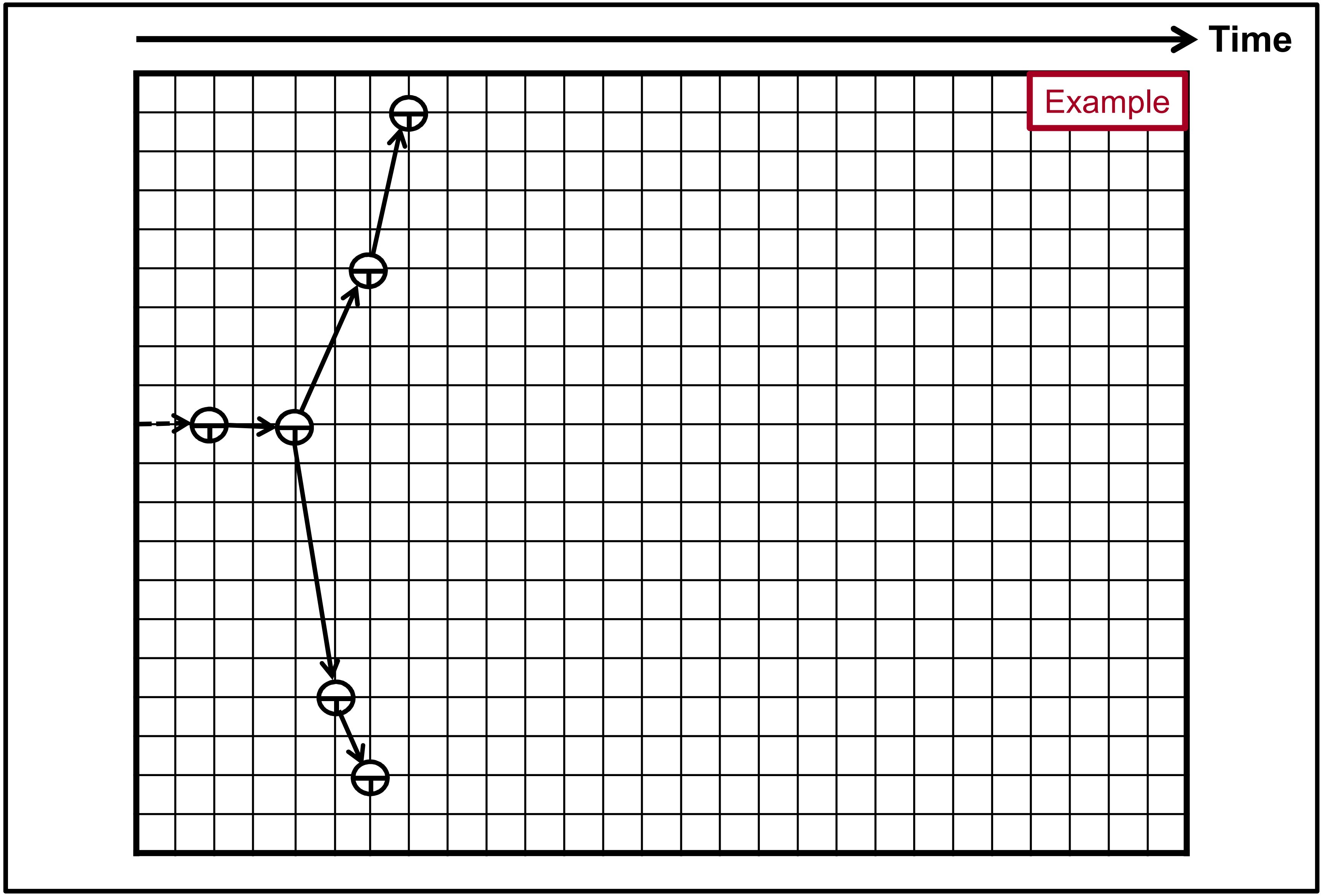
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



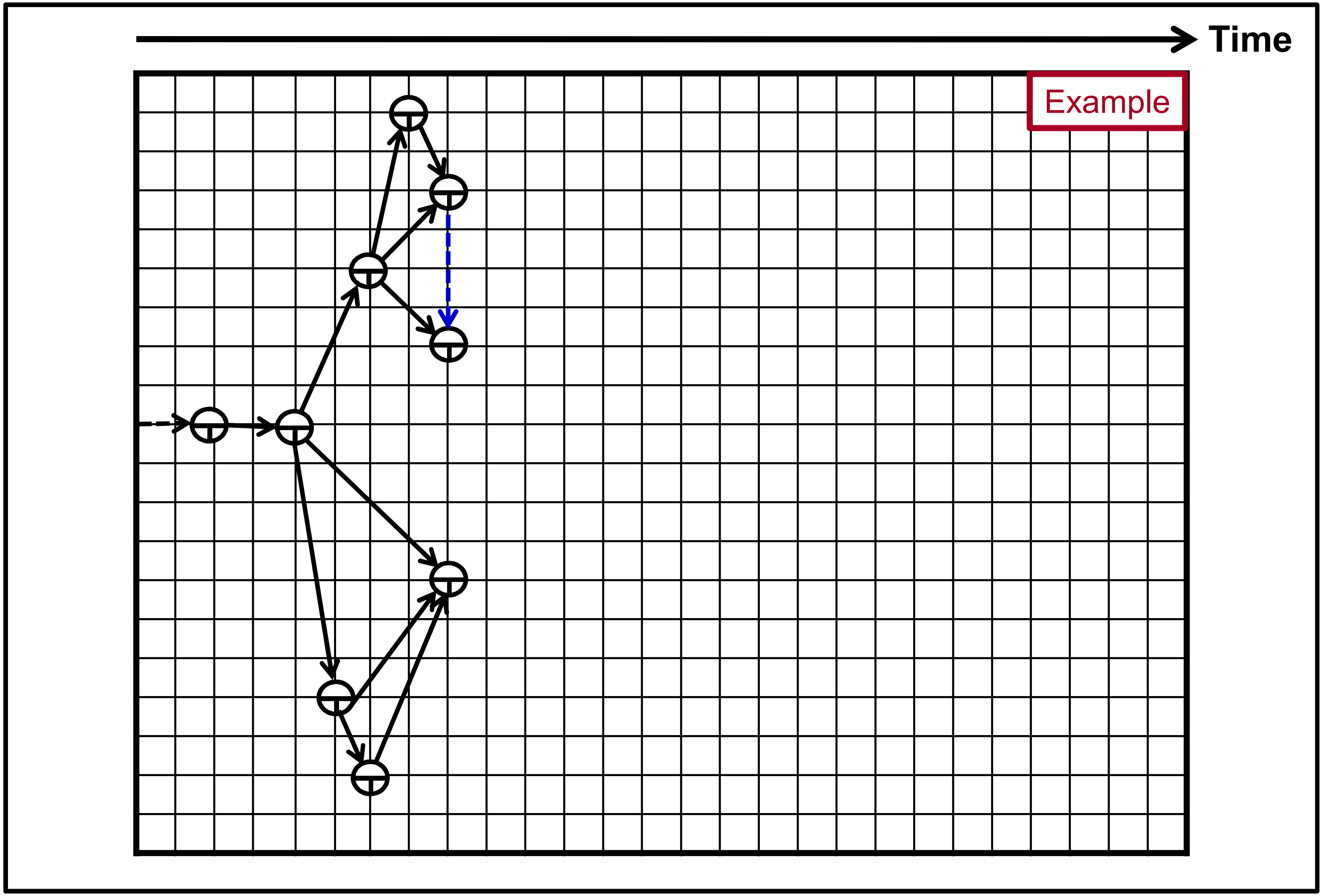
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



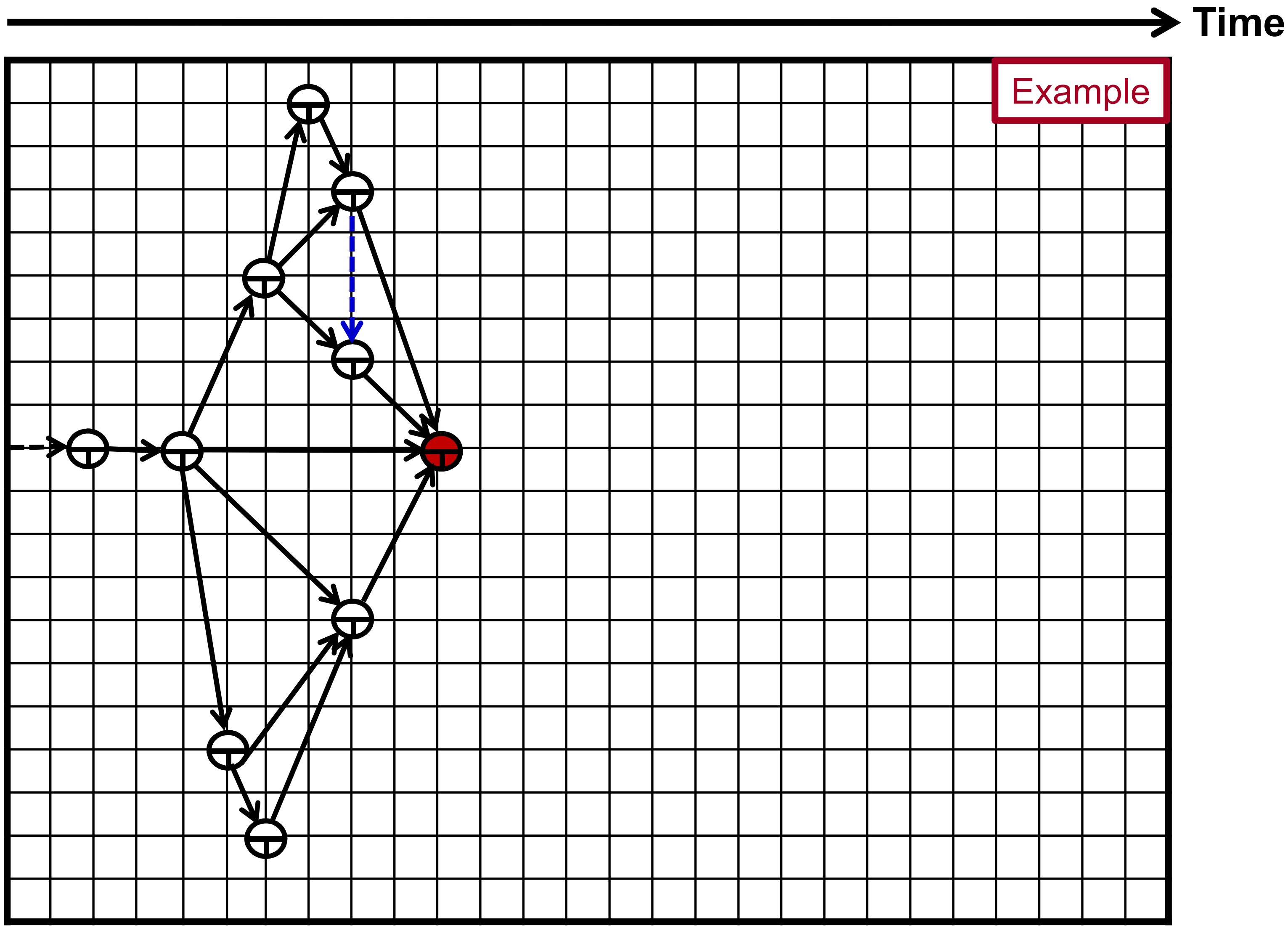
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



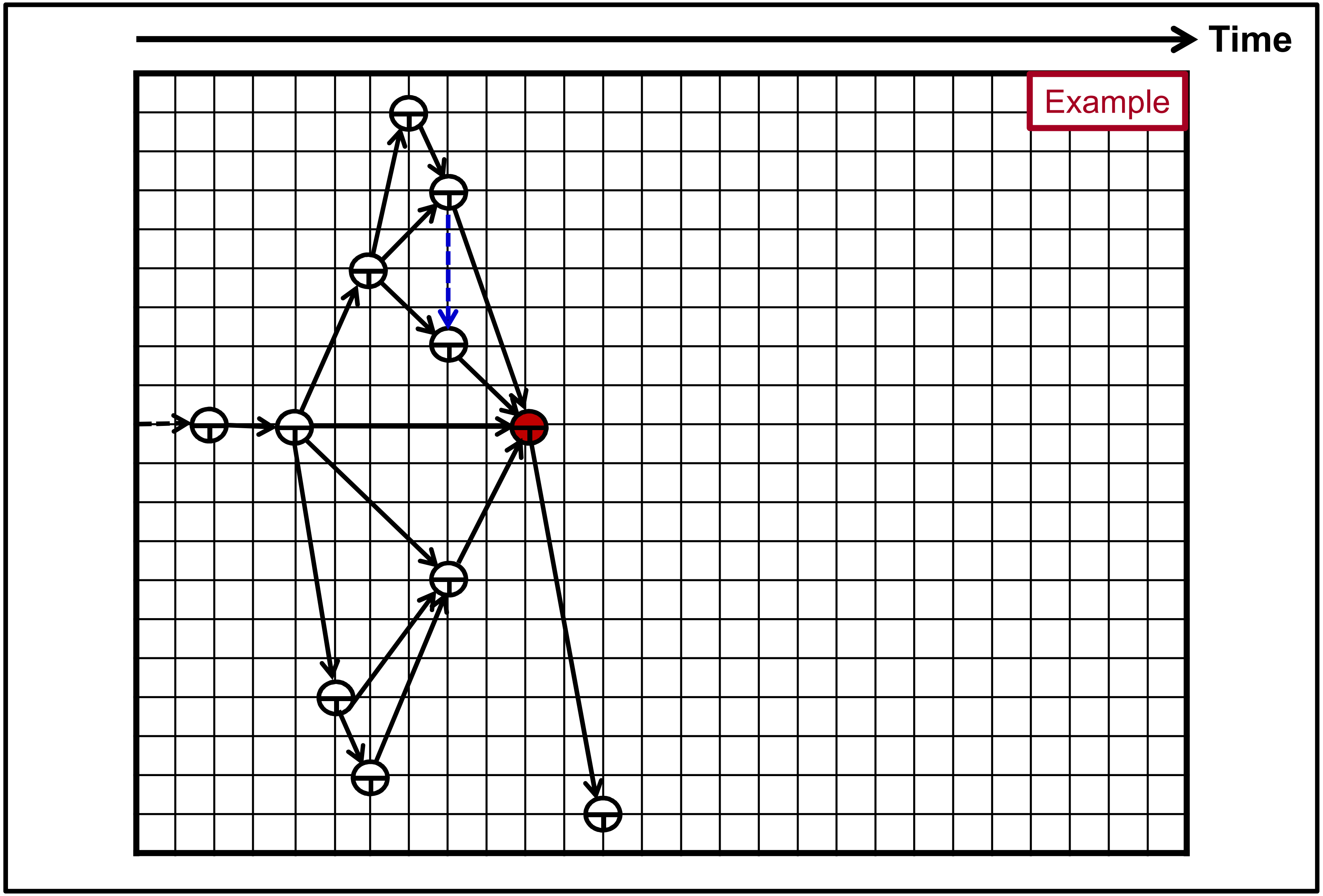
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



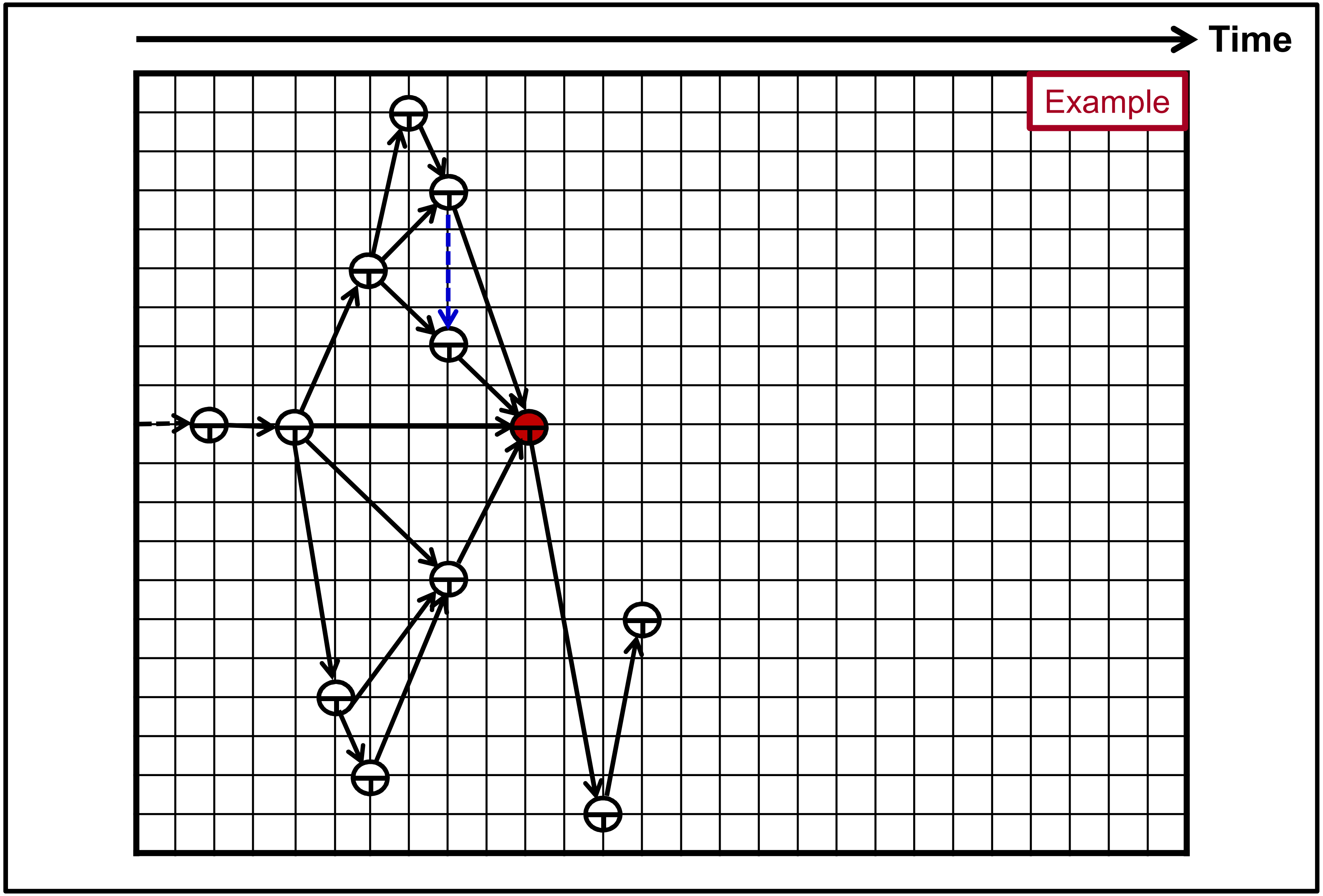
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



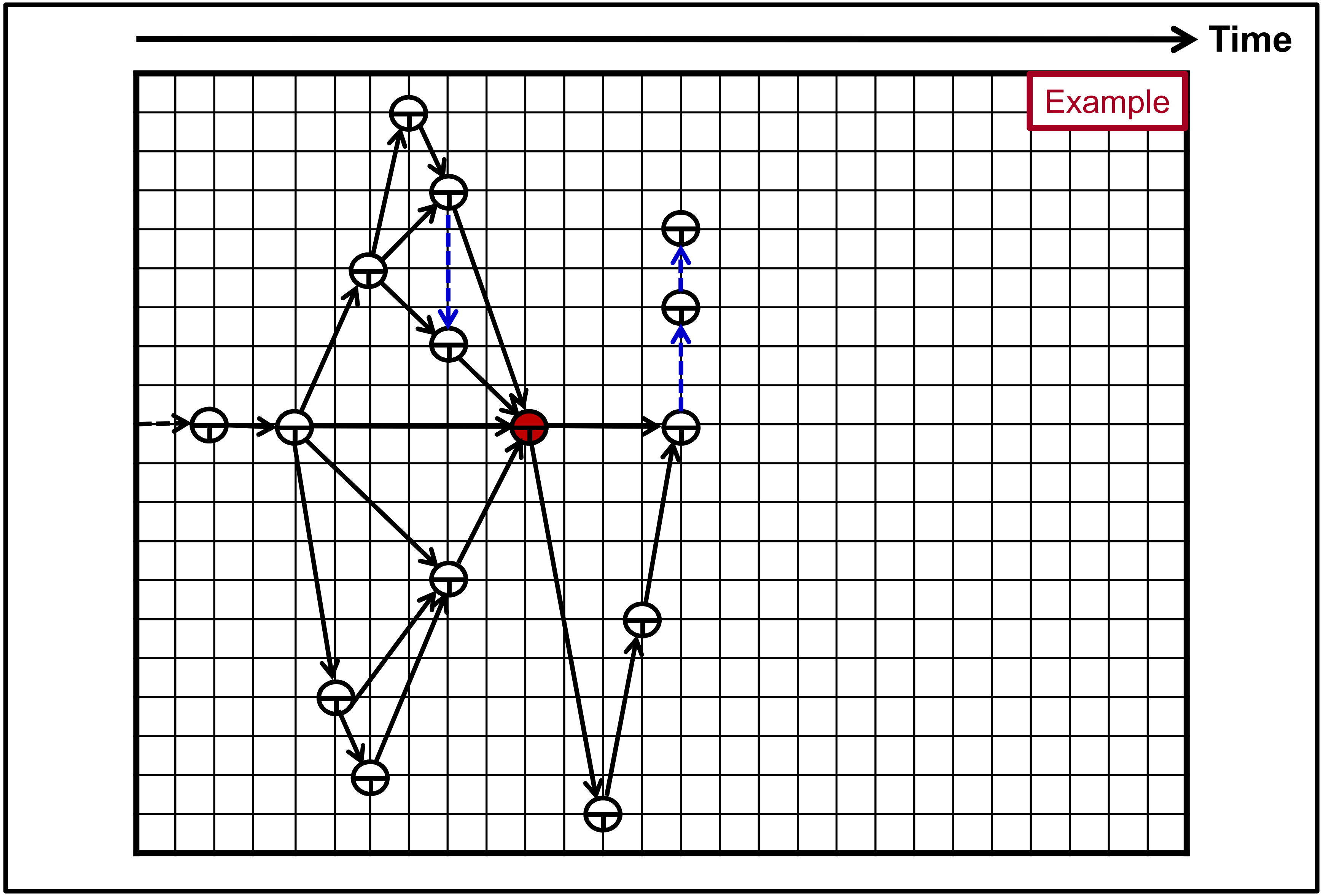
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - -›



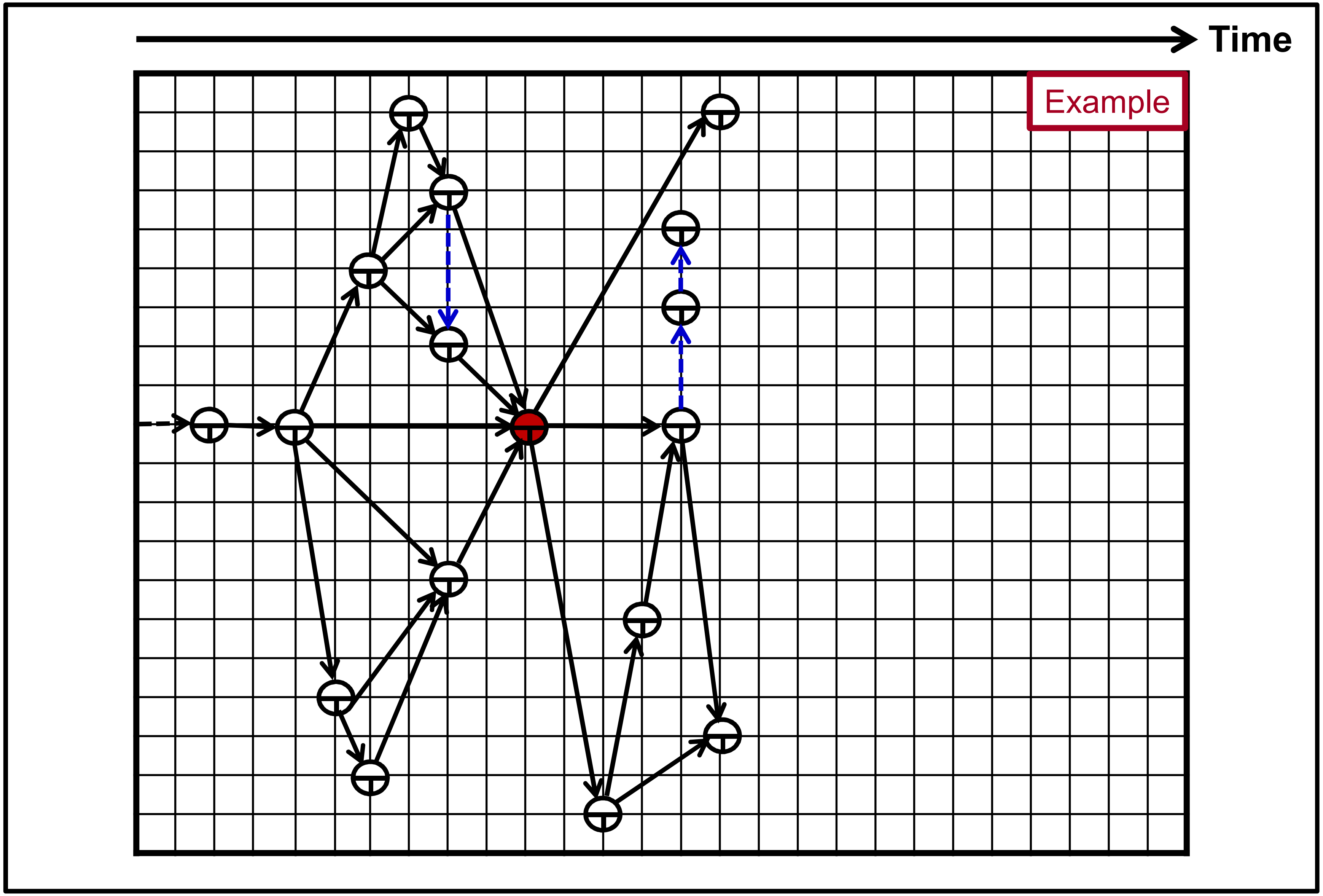
Rainer Bürstinghaus

CPM Diagram; Activity: → ; Dummy Activity: - - ->



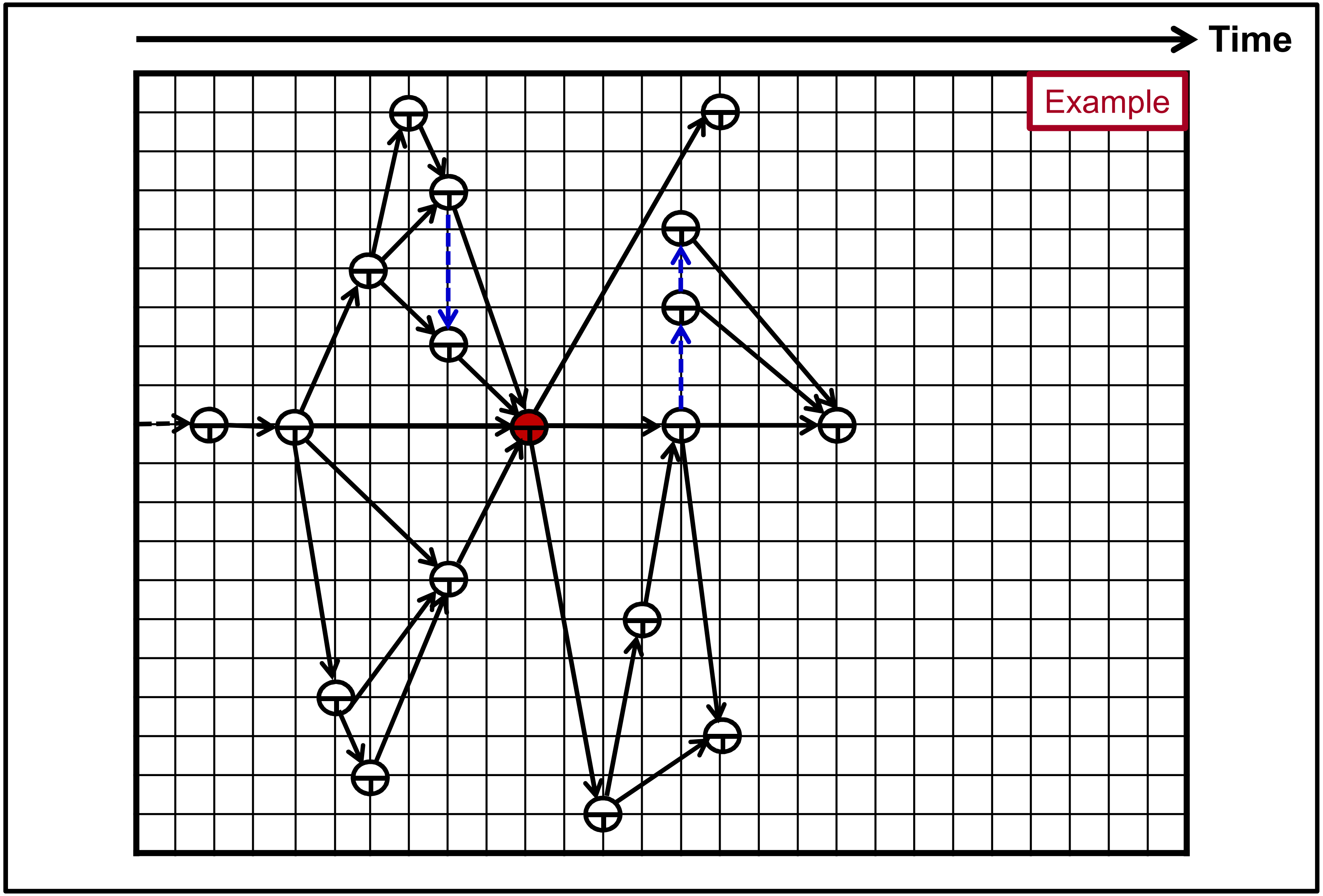
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



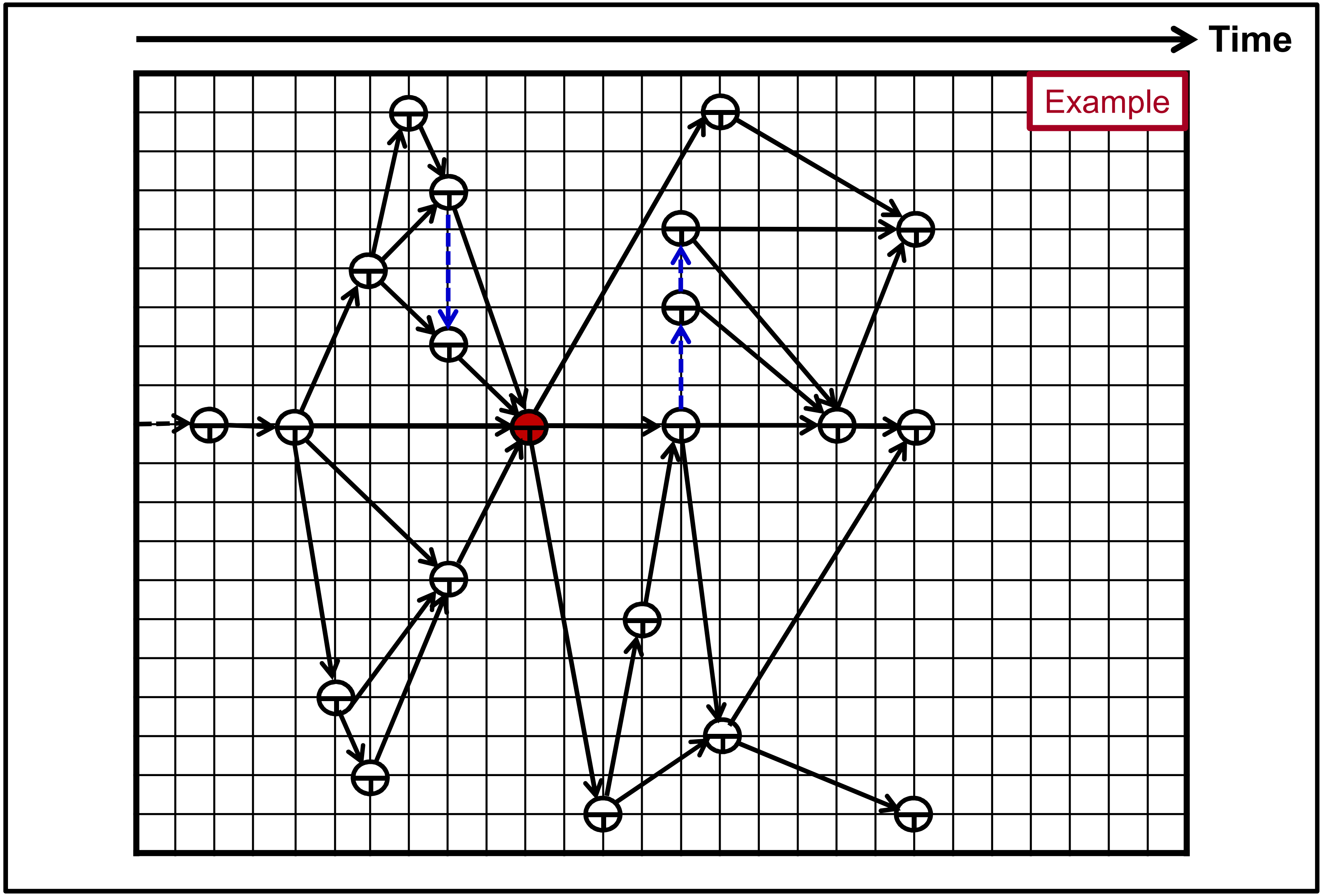
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



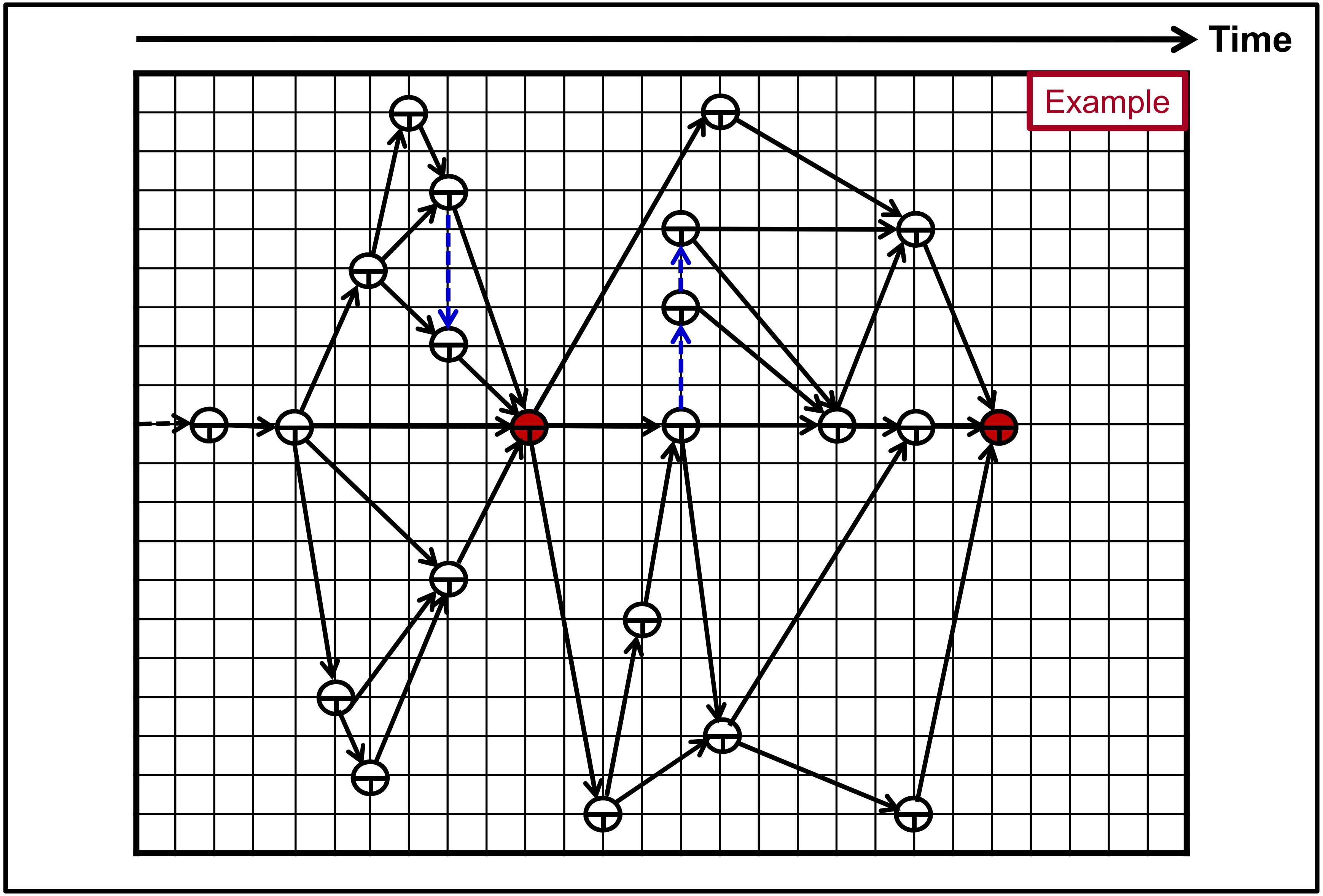
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - -›



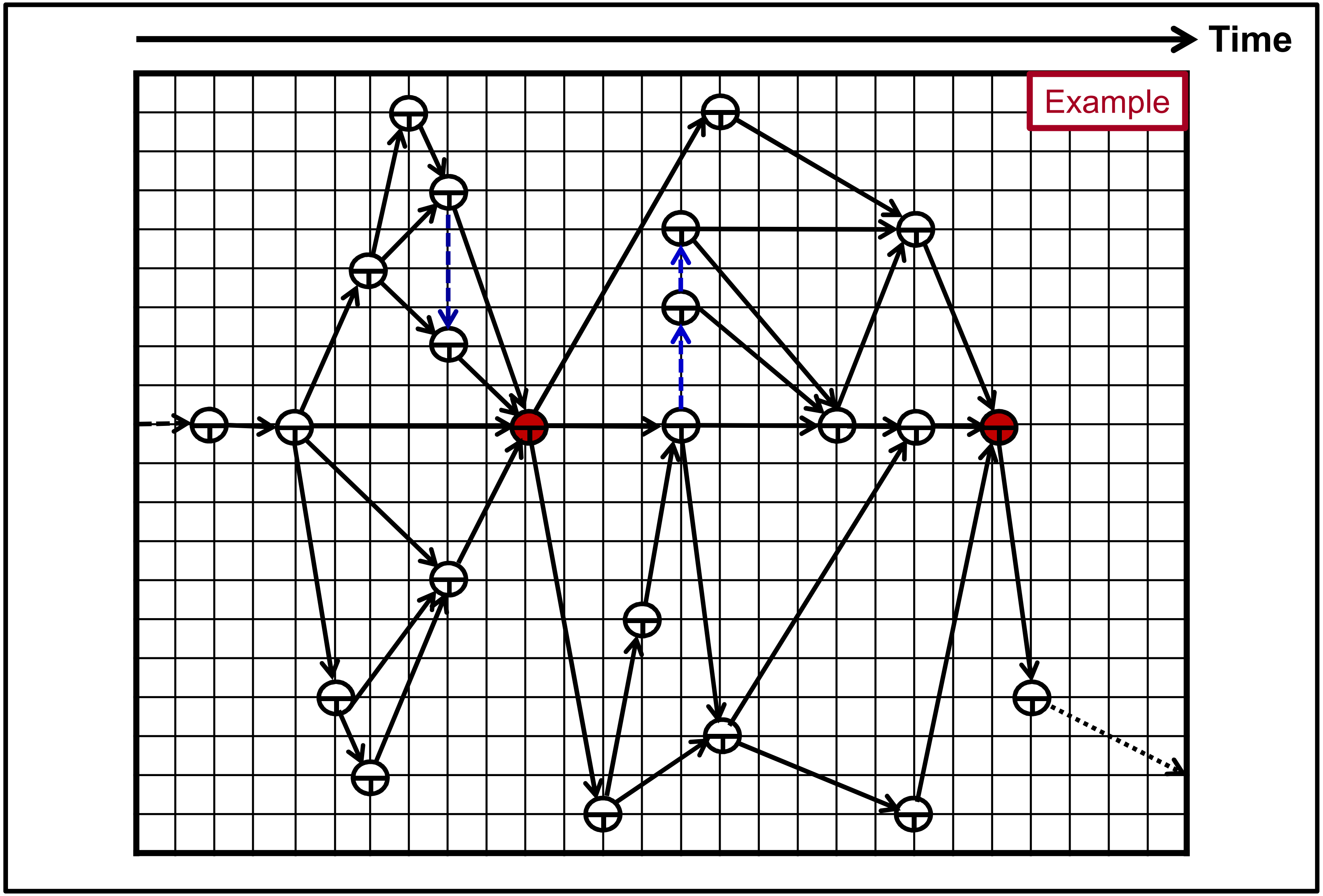
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



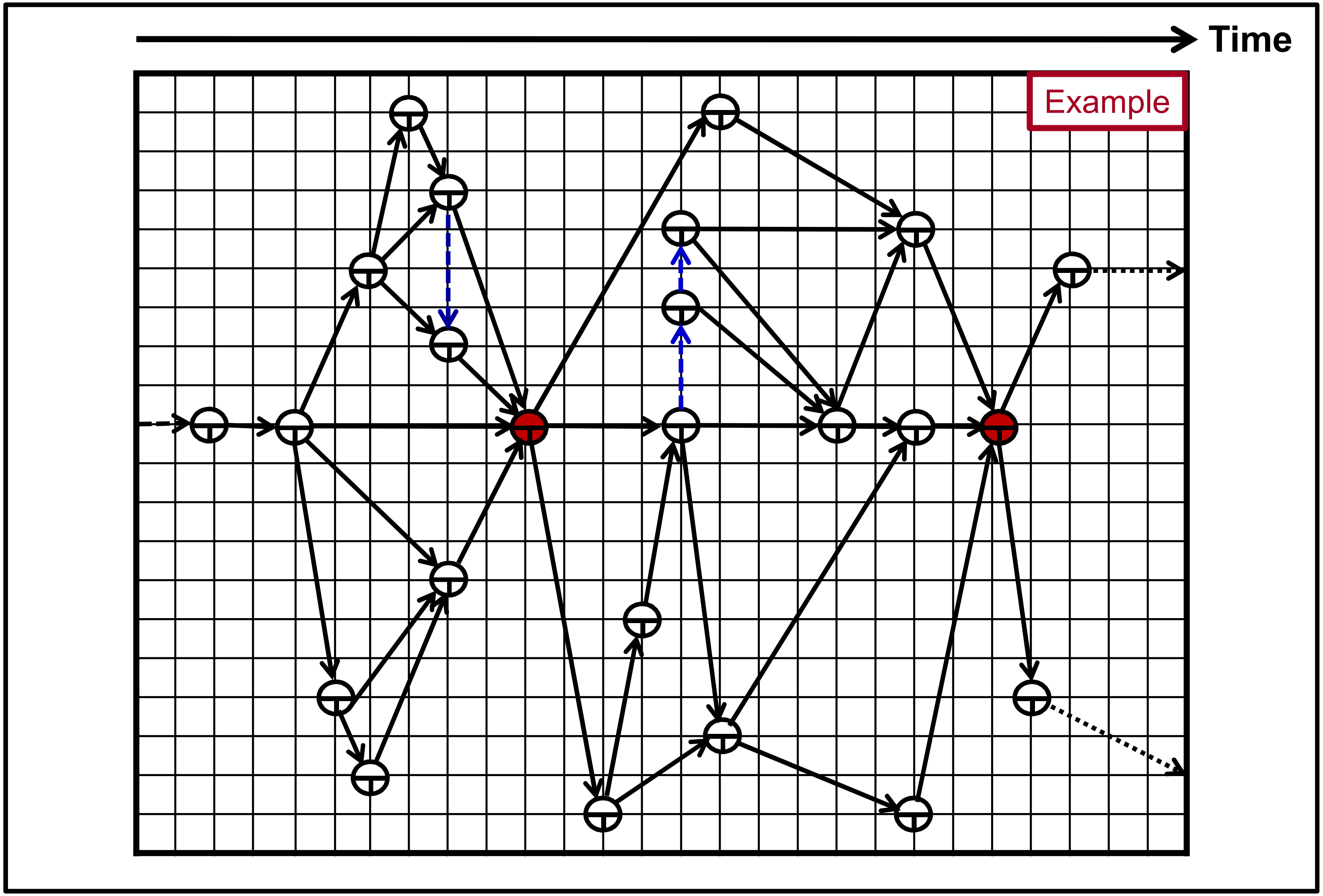
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



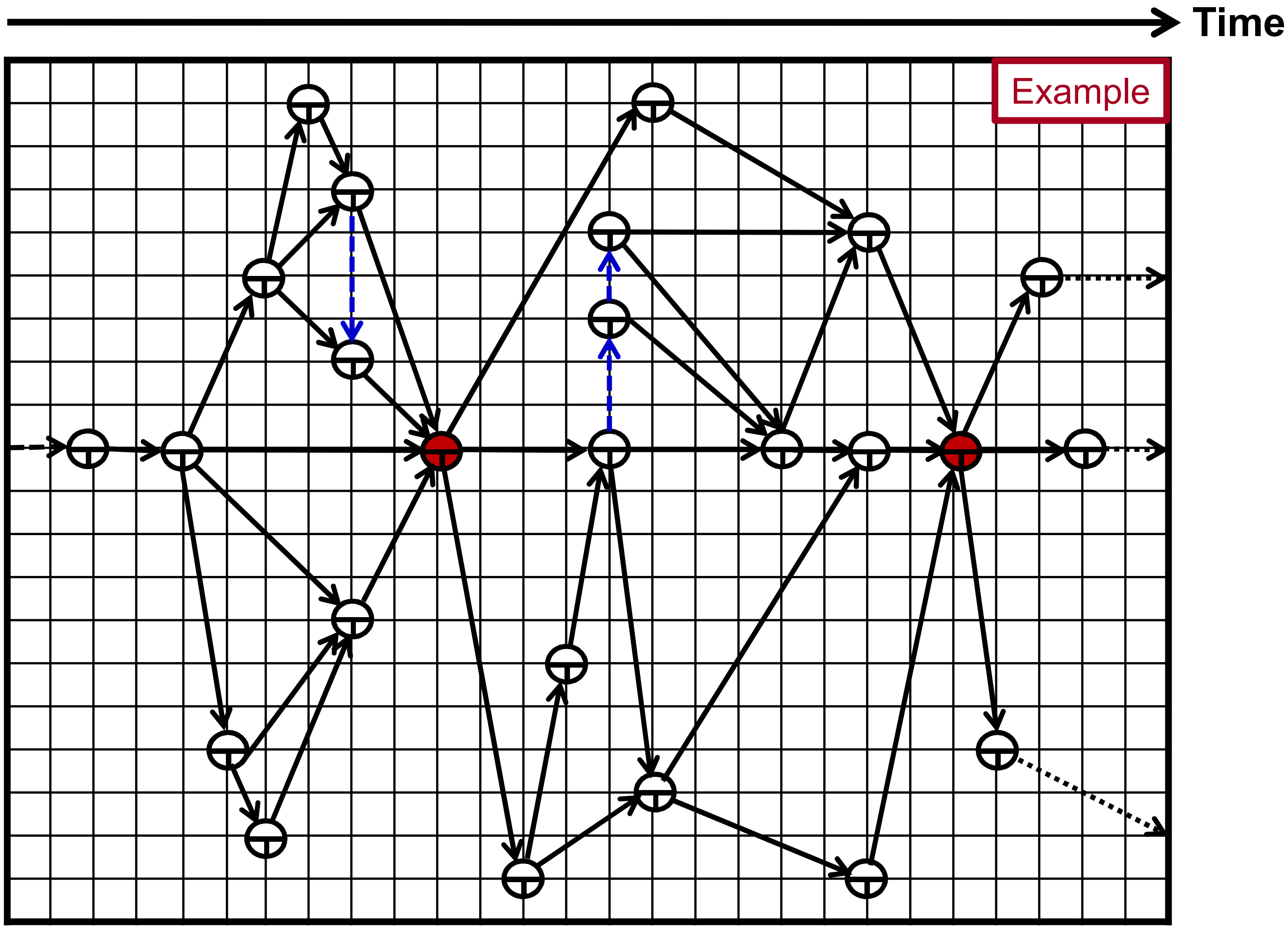
Rainer Bürstinghaus

CPM Diagram; Activity: ⟶ ; Dummy Activity: - - ->



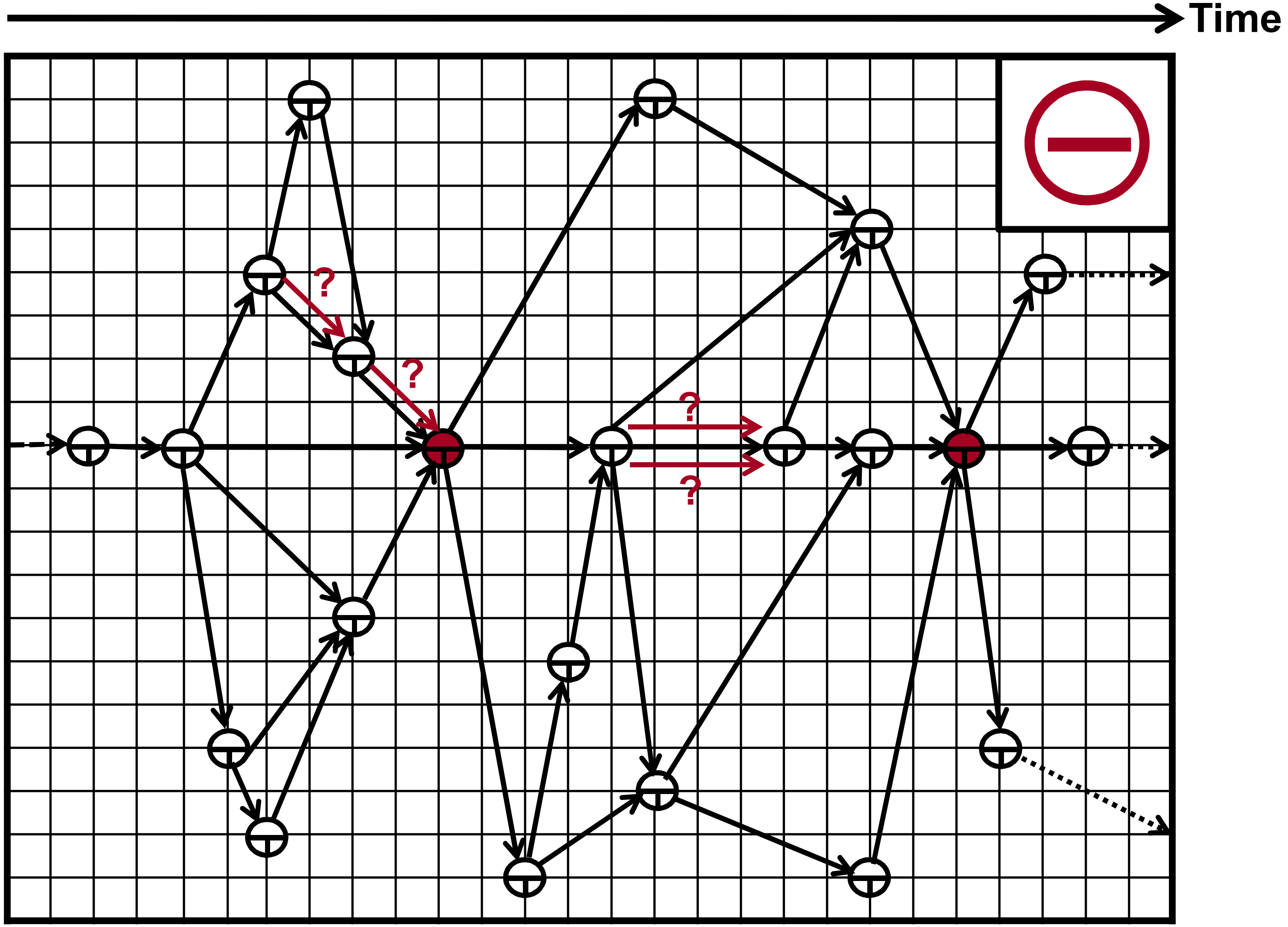
Rainer Bürstinghaus

CPM Diagram; Activity: ; Dummy Activity:



Rainer Bürstinghaus

CPM Diagram; Activities: ; **Lack of Clarity!**



Rainer Bürstinghaus

"CPM Diagram" (Critical Path Method). →

Table with the Basic Data for its Preparation:

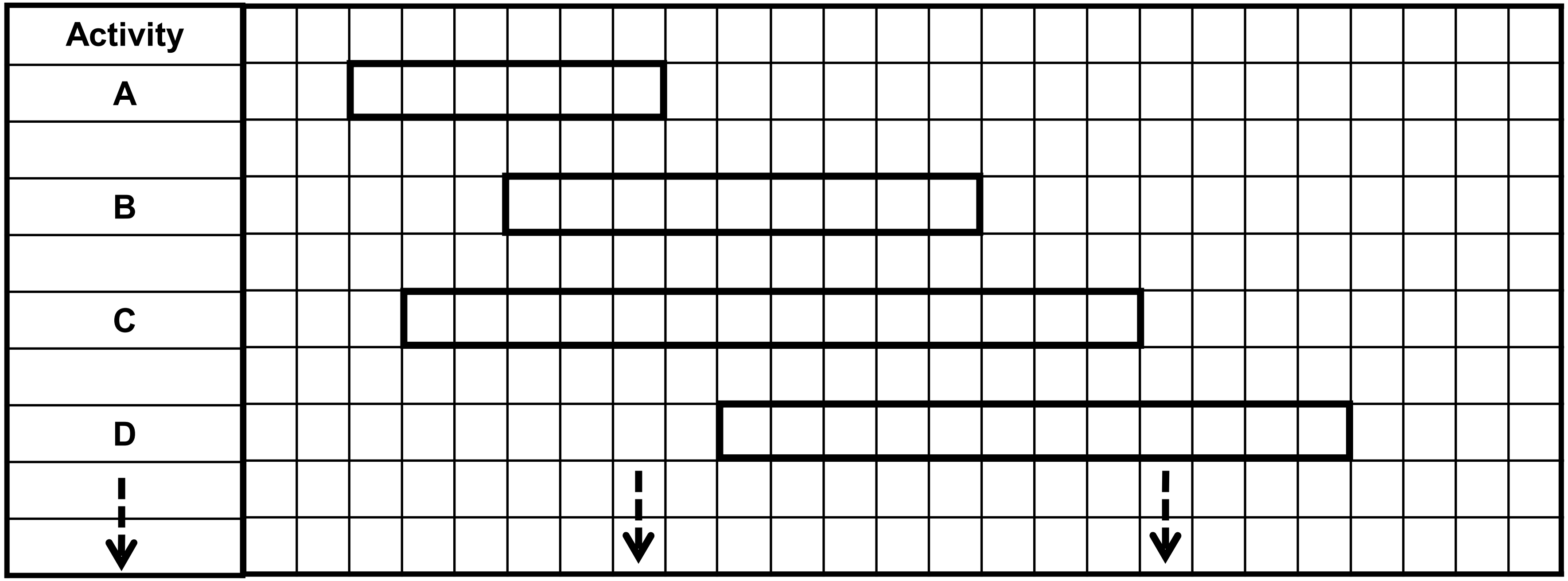
Activity: Name, Number	Total Duration (Days)	Direct Preceding Activity	Direct Follow-up Activity	ES	LS	EF	LF	Free Slack Time

Network Diagrams → CPM Network Technique

CPM Diagram, the Foresight in the Gantt-Chart.

Forward Planning:

Time →

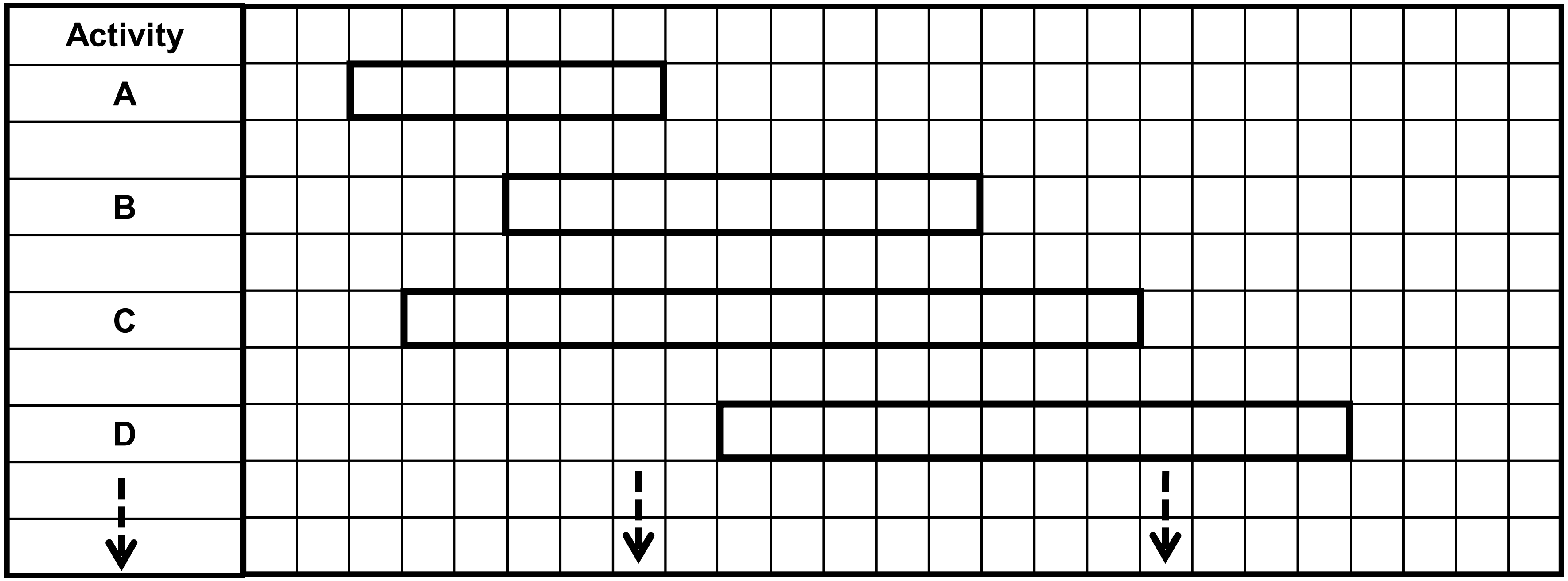


Network Diagrams → CPM Network Technique

CPM Diagram, the Retrospect in the Gantt-Chart.

Backward Planning:

Time ←



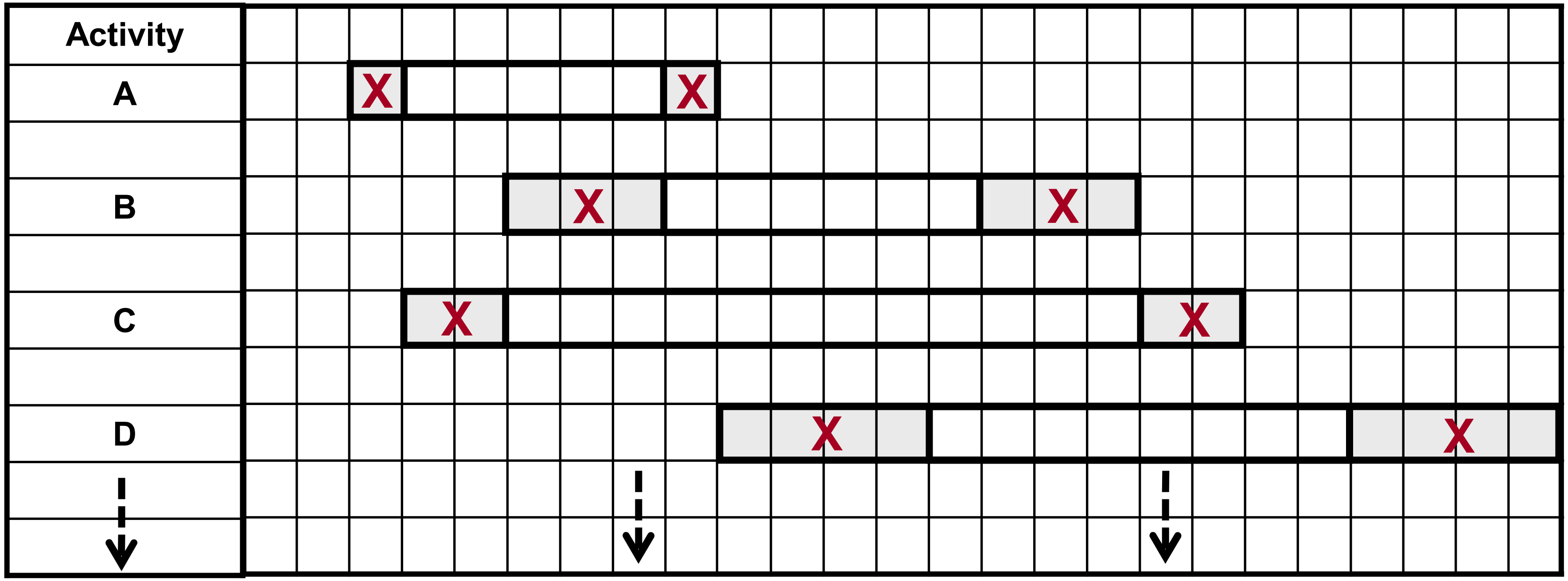
Rainer Buerstinghaus

Network Diagrams → CPM Network Technique

CPM Diagram, Slack Times in the Gantt Chart:
Δt Between Forward and Backward Plan Values.

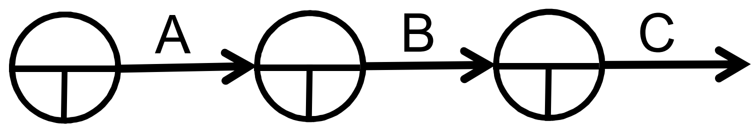
Slack Time X : Time Elasticity/Activity

Time ⟷



Rainer Buerstinghaus

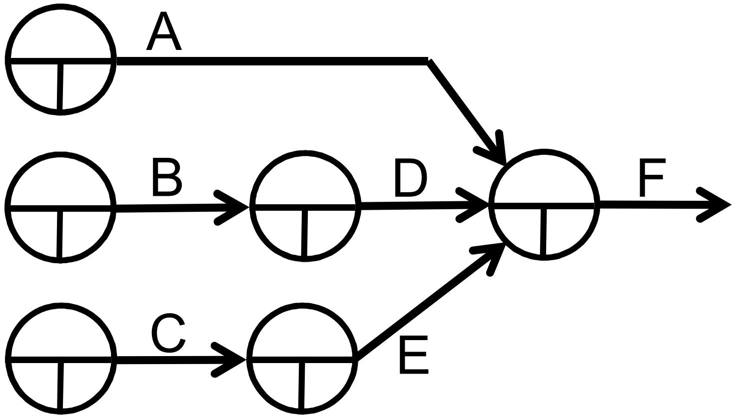
Flow Planning: CPM-Diagram, Construction Rules.



Rule 1:

One certain activity can not be started until all activities, necessary for it, have been completed. In this case, with the exception of the first activity, the start event of an activity **coincides** with the completion event of the preceding activity.

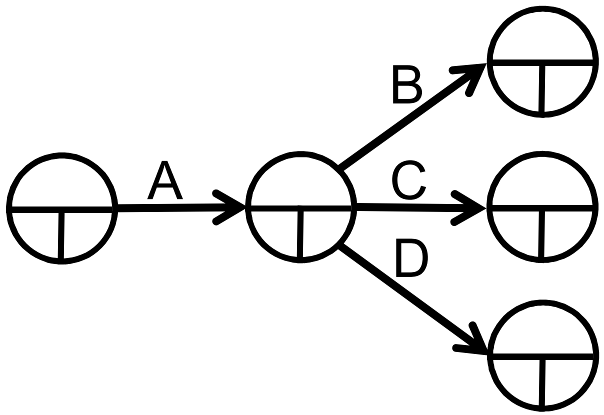
Flow Planning: CPM-Diagram, Construction Rules.



Rule 2:

If several activities **have to be completed** before a further, immediately succeeding activity can be started, they must end in the start event of the subsequent activity.

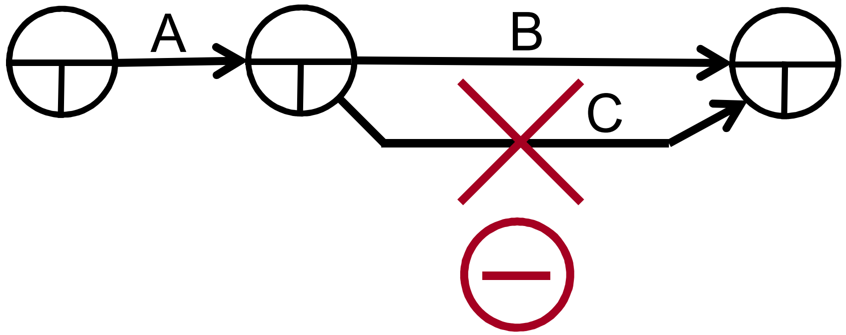
Flow Planning: CPM-Diagram, Construction Rules.



Rule 3:

If **several activities simultaneously will start** after a directly preceding activity has ended, they must start with the completion event of the preceding activity.

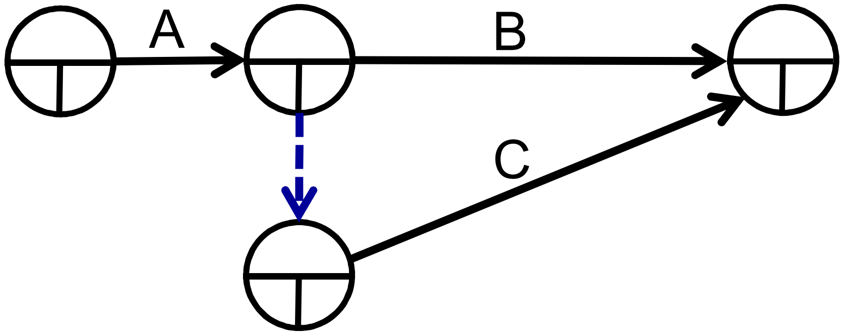
Flow Planning: CPM-Diagram, Construction Rules.



Rule 4:

If two or more activities have the same start date and the same end date, their unambiguous allocation must be ensured by inserting appropriate **dummy activities** (Time consumption: zero!). **Purpose: Better clarity!**

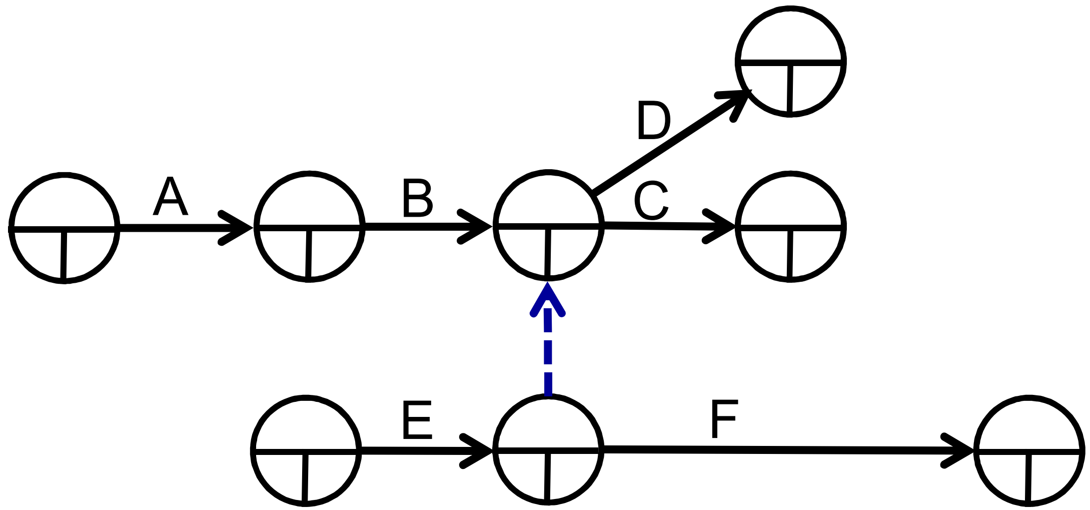
Flow Planning: CPM-Diagram, Construction Rules.



Rule 4:

If two or more activities have the same start date and the same end date, their unambiguous allocation must be ensured by inserting appropriate **dummy activities** (Time consumption: zero!). **Purpose: Better clarity!**

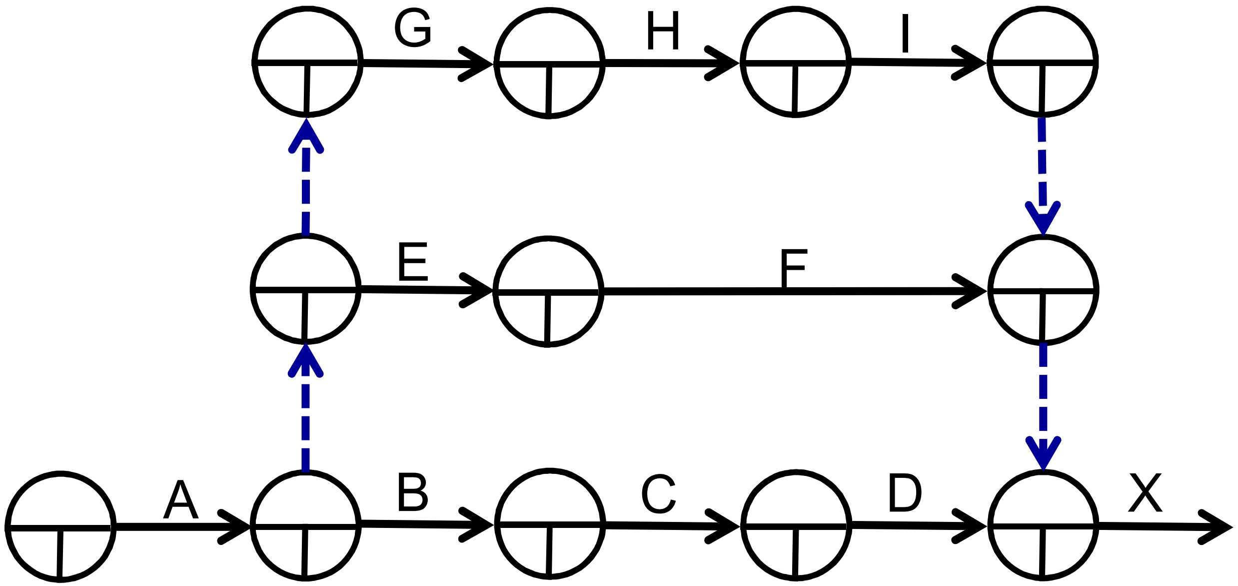
Flow Planning: CPM-Diagram, Construction Rules.



Rule 5:

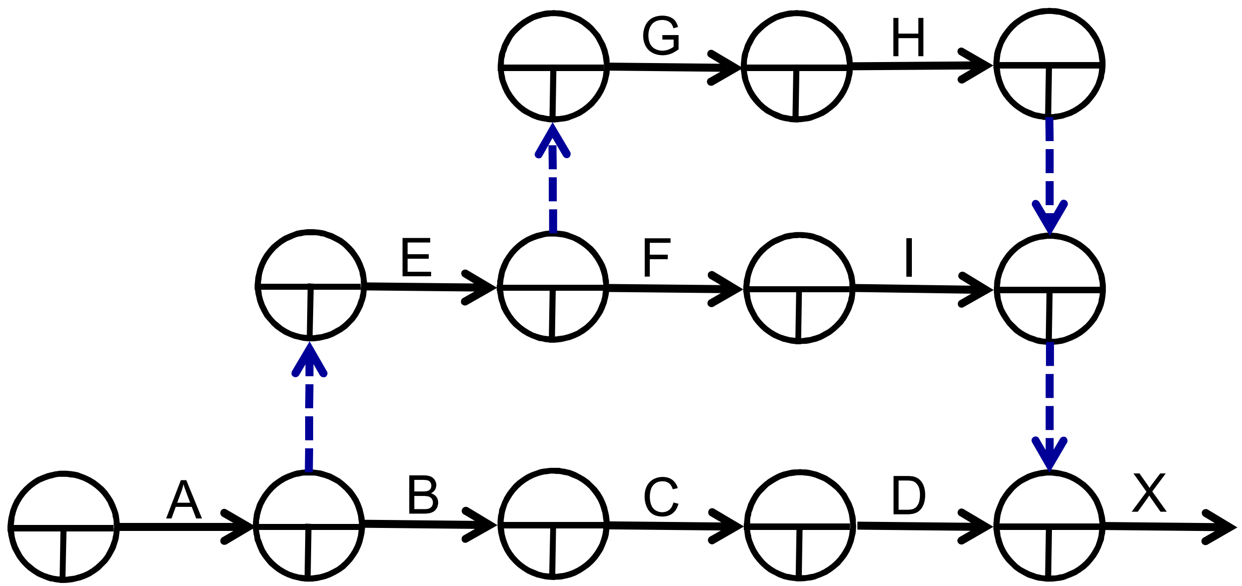
If **several activities** that are **not** all **interdependent** begin and end in each case with the same event, then the correct procedure must be represented by dissolving the respective independencies by means of a dummy activity.

Network Diagrams → **CPM-Diagrams, Construction Rules.**



Rule 6:

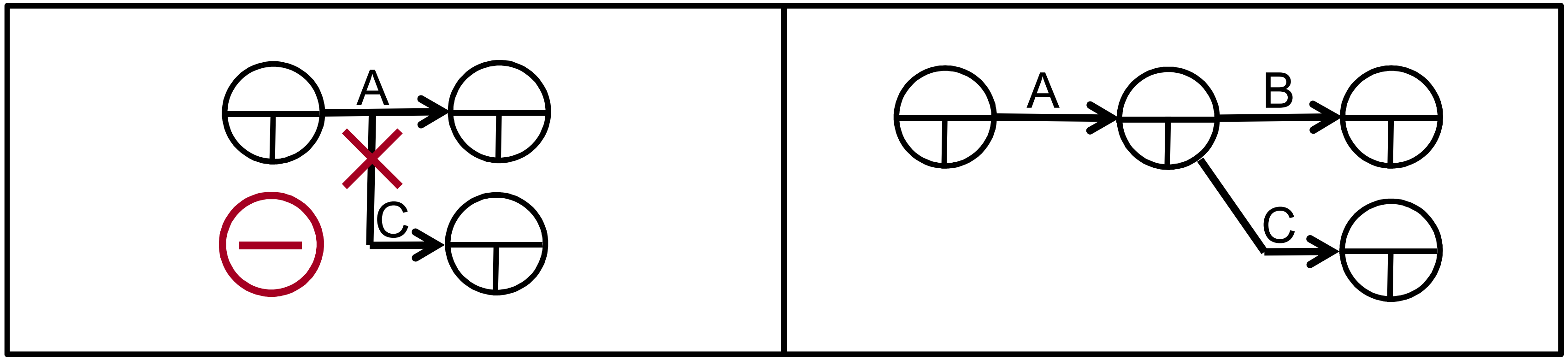
Numerous **dummy activities *can* be added** to a sequence of activities. In addition to the obvious logical connection, they serve for better clarity.



Rule 6:

Numerous **dummy activities *can* be added** to a sequence of activities. In addition to the obvious logical connection, they serve for better clarity.

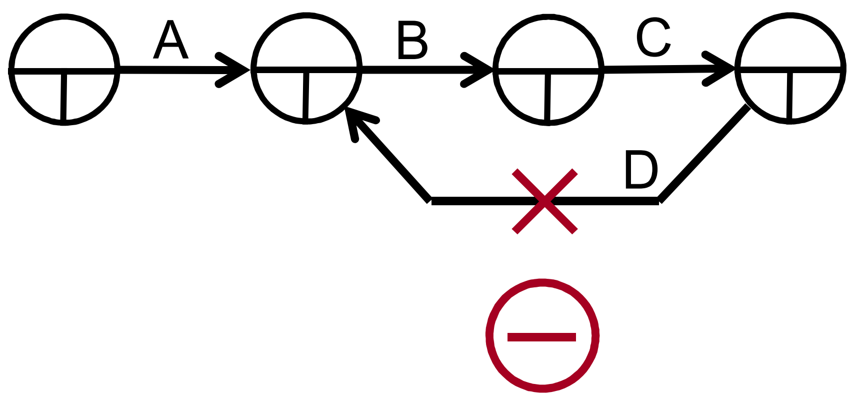
Flow Planning: CPM-Diagram, Construction Rules.



Rule 7:

If an activity can begin before the preceding activity has been fully completed, the preceding activity must be **further subdivided** so that an **intermediate event** can be defined.

Flow Planning: CPM-Diagram, Construction Rules.



Rule 8:

Each individual activity **can only take place once**.
Therefore, recursive "infinite loops" are not allowed.

Example P1

Elements of CPM-Network Diagrams (Partial View):

Project

"Highly Elastic Clear Coats for the OEM Automotive Sector".

Rainer Buerstinghaus

Network Diagrams, CPM, "Highly Elastic Clear Coats…"

Table with All Necessary Activities, Their Respective Total Duration and Their Event Time Points (ES, EF):

Activity		Total Duration (Working Days!)	Earliest Start Date	Earliest Finish Date
Formulation of 45 new clear coats.	**A**	**10**	**11.01.2020**	**22.01.2020**
Application and Cross-Hatch Tests.	**B**	**19**	**22.01.2020**	**17.02.2020**
Application and AMTEC-Tests.	**C**	**24**	**22.01.2020**	**24.02.2020**
Application and UVcon-Tests.	**D**	**57**	**22.01.2020**	**15.04.2020**
Analysis of the Cross-Hatch Tests.	**E**	**03**	**15.04.2020**	**19.04.2020**
Analysis of the AMTEC-Tests.	**F**	**03**	**15.04.2020**	**19.04.2020**
Analysis of the UVcon-Tests.	**G**	**07**	**15.04.2020**	**23.04.2020**
Preparation of the interim report.	**H**	**04**	**23.04.2020**	**28.04.2020**

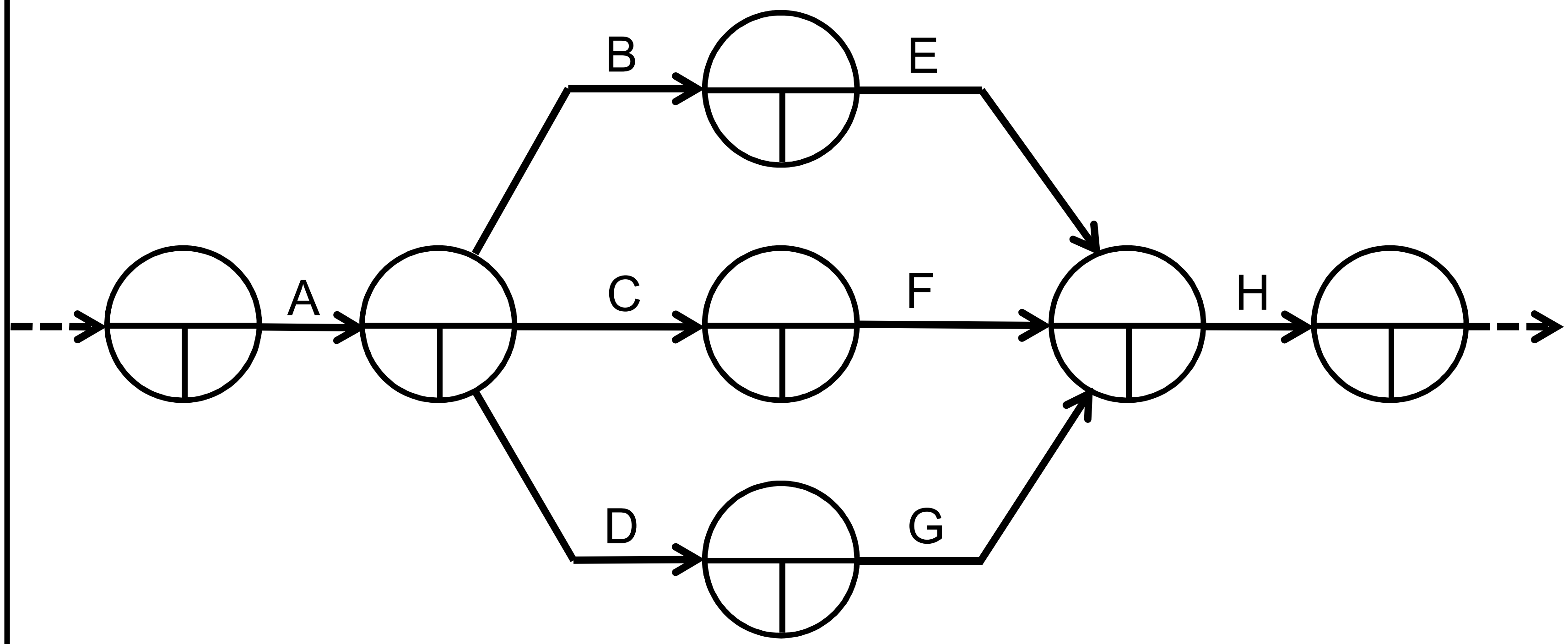
Network Diagrams, CPM, "Highly Elastic Clear Coats…"

Lining-up of the Network Plan → (Step 1)
Compiling of a Complete List of Activities/Sequences:

Activity		Duration (Days)	Preceding Activity	Follow-up Activity	ES	LS	EF	LF	Slack Times
Formulation of 45 new clear coats.	A	10	---	B,C,D					
Application and Cross-Hatch Tests.	B	19	A	E					
Application and AMTEC-Tests.	C	24	A	F					
Application and UVcon-Tests.	D	57	A	G					
Analysis of the Cross-Hatch Tests.	E	03	B	H					
Analysis of the AMTEC-Tests.	F	03	C	H					
Analysis of the UVcon-Tests.	G	07	D	H					
Preparation of the interim report.	H	04	E,F,G	---					

Network Diagrams, CPM, "Highly Elastic Clear Coats…"

Lining-up of the Network Plan → (Step 2)
Logical Link of All Activities in One CPM Net:

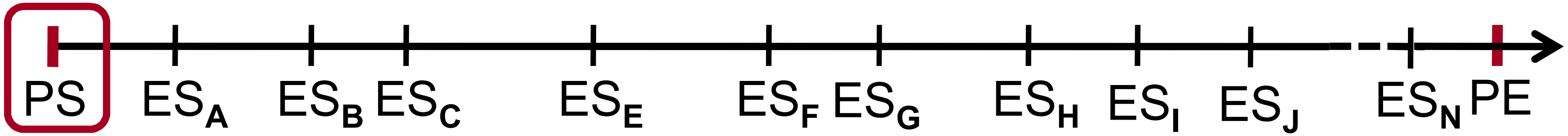


Network Diagrams, CPM, "Highly Elastic Clear Coats…"

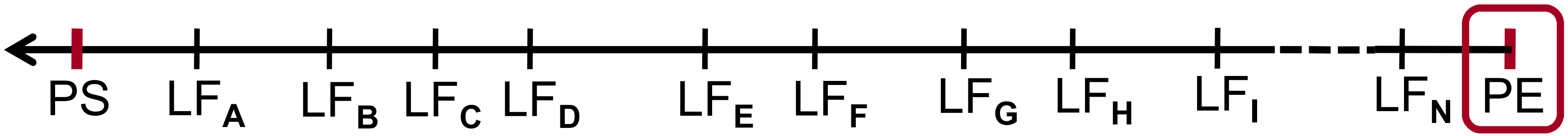
Lining-up of the Network Plan → **(Step 3)**

Estimation of All Points in Time (Forward/Backward):

- **Forward Calculation:** Addition of the duration for all activities according to their logical order (ES, Duration of the activity → EF).



- **Backward Calculation**: Subtraction of the duration for all activities according to their logical order. (LF, Duration of the activity → LS).



Rainer Buerstinghaus

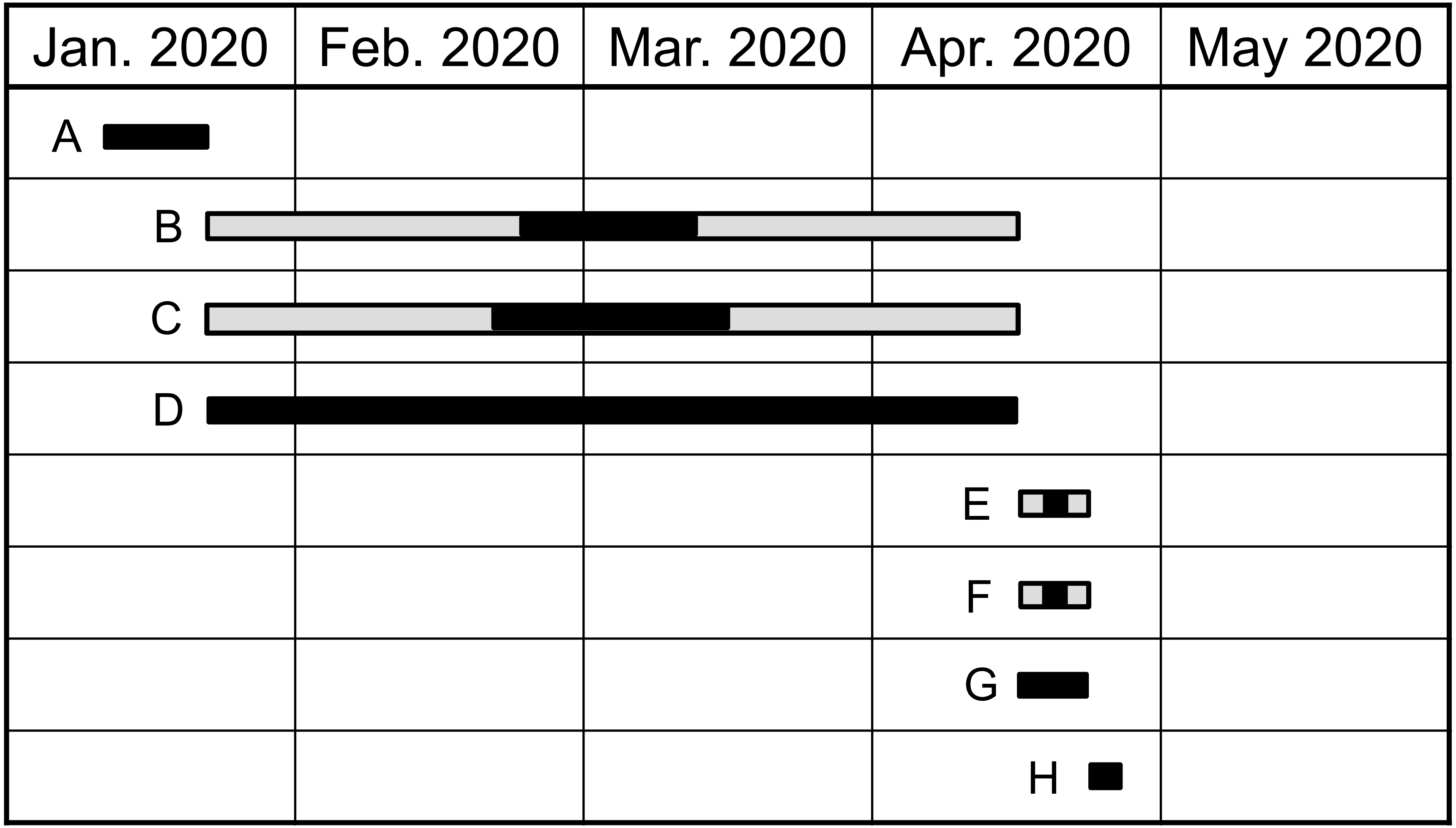
Network Diagrams, CPM, "Highly Elastic Clear Coats…"

Lining-up of the Network Plan → (Step 4)
Entry of All Time Coordinates (ES, LS, EF, LF):

Activity		Duration (Days)	Preceding Activity	Follow-up Activity	ES	LS	EF	LF	Slack Times
Formulation of 45 new clear coats.	A	10	---	B,C,D	00	00	10	10	00
Application and Cross-Hatch Tests.	B	19	A	E	10	52	29	71	42
Application and AMTEC-Tests.	C	24	A	F	10	47	34	71	37
Application and UVcon-Tests.	D	57	A	G	10	10	67	67	00
Analysis of the Cross-Hatch Tests.	E	03	B	H	67	71	70	74	04
Analysis of the AMTEC-Tests.	F	03	C	H	67	71	70	74	04
Analysis of the UVcon-Tests.	G	07	D	H	67	67	74	74	00
Preparation of the interim report.	H	04	E,F,G	---	74	74	78	78	00

Network Diagrams, CPM, "Highly Elastic Clear Coats…"

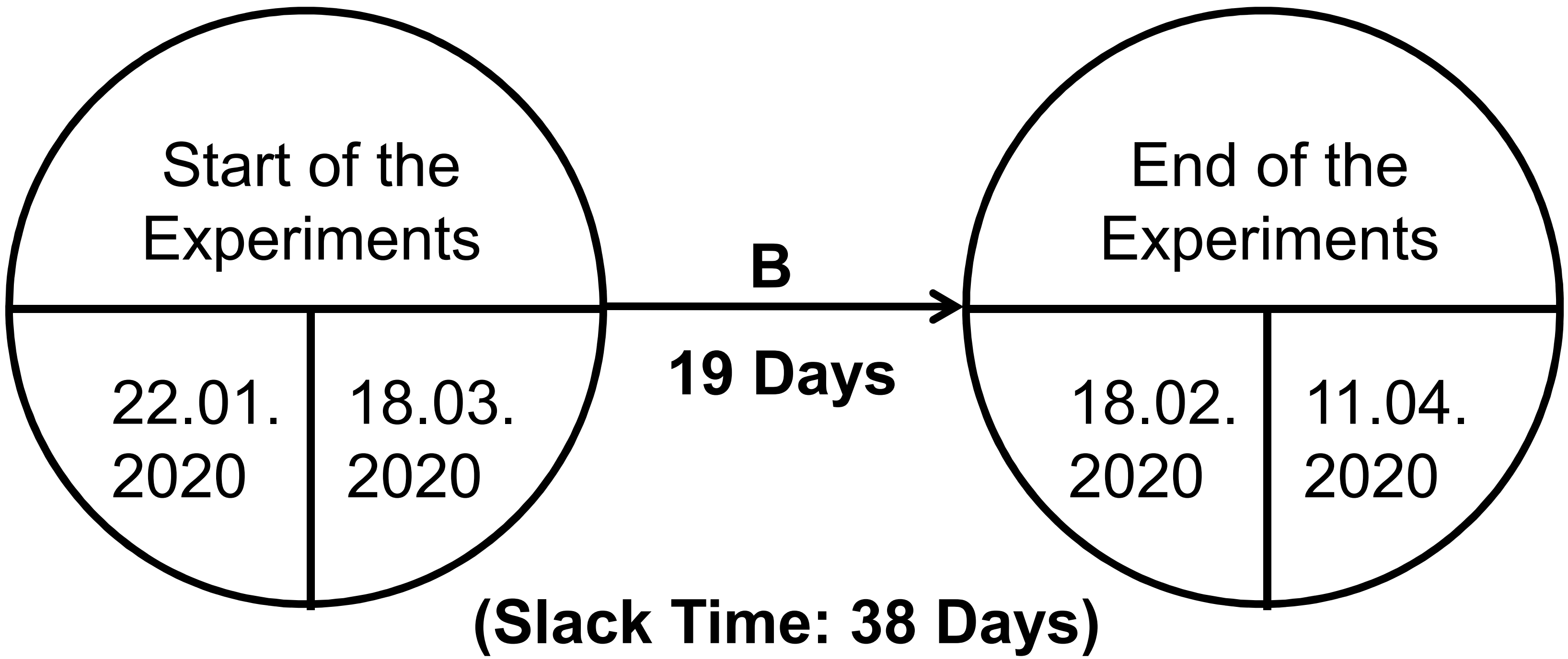
Lining-up of the Network Plan ⟶ Gantt-Chart with All the Buffer Times for the Clarity (Partial View):



Rainer Buerstinghaus

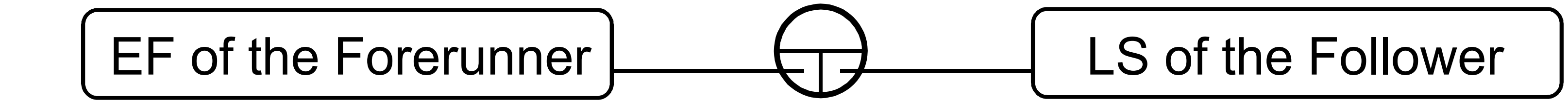
Network Diagrams, CPM, "Highly Elastic Clear Coats…"

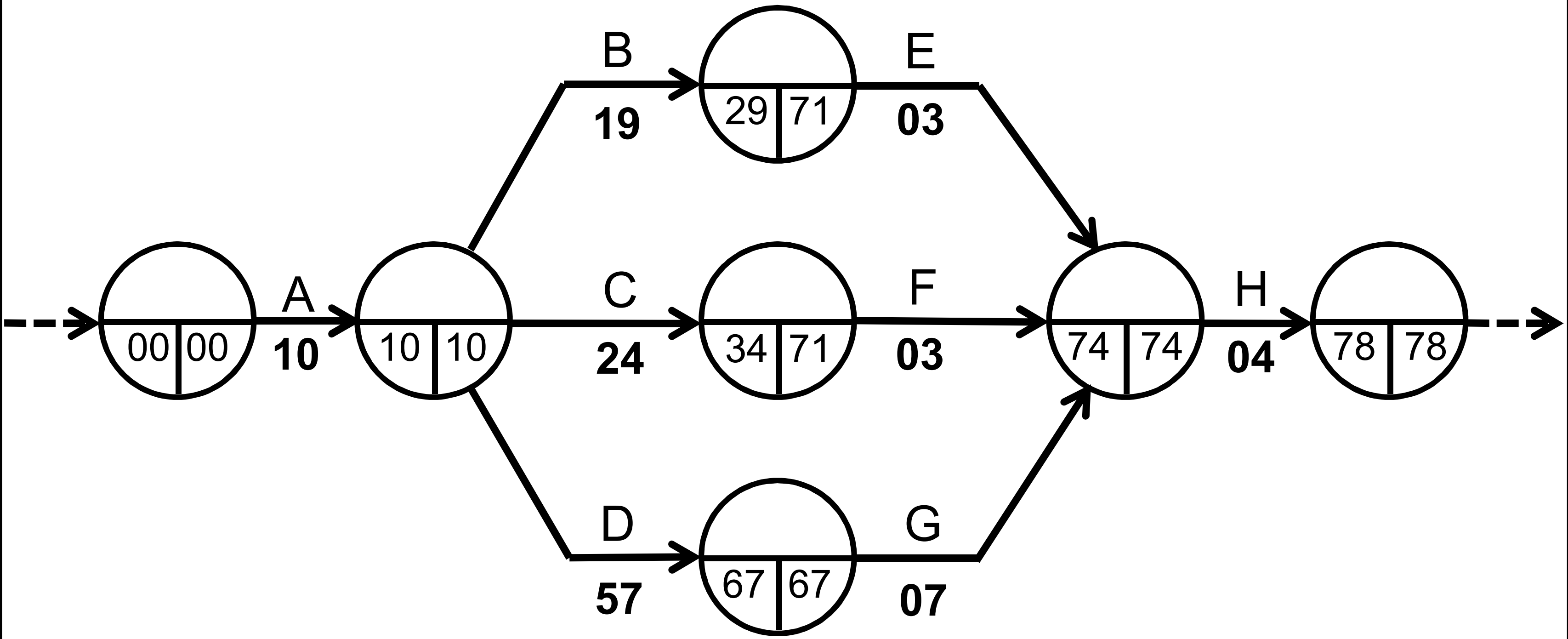
Pneumatic Spray Application of 40 HBC-Clear Coats on 20 cm X 40 cm - Steel Plates (20 Minutes Curing at 140°C; Layer Thickness: 40µm). Execution of all Following Cross Hatch Tests according to DIN/ISO 2049:



Network Diagrams, CPM, "Highly Elastic Clear Coats…"

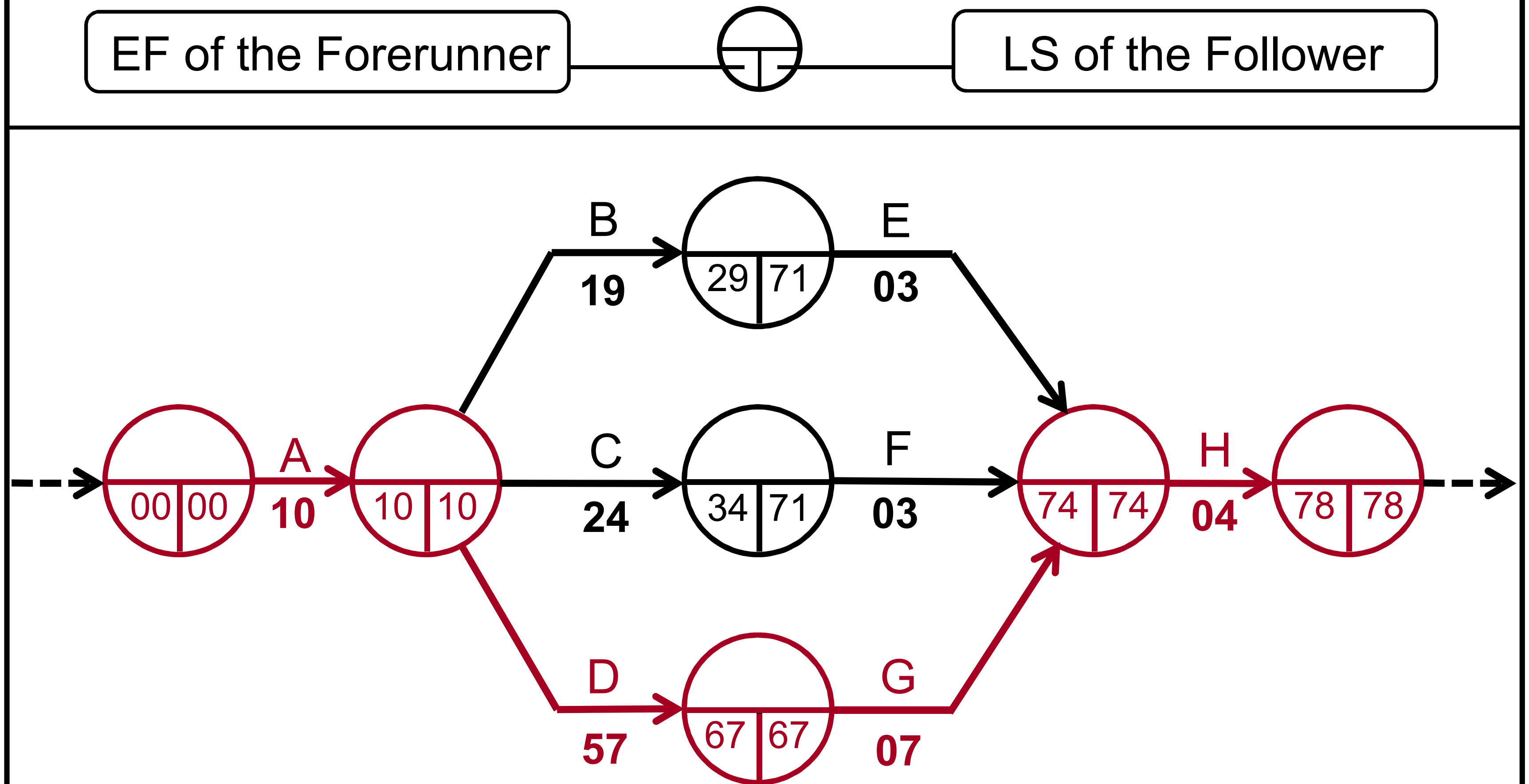
Lining-up of the Network Plan → (Step 5)
Entry of All Estimated Time Values Into the CPM Diagram:





Network Diagrams, CPM, "Highly Elastic Clear Coats…"

Lining-up of the Network Plan → **(Step 6)**
Colored Marking of the Critical Path(s):



Rainer Buerstinghaus

CPM-Network-Diagram, Critical Path:

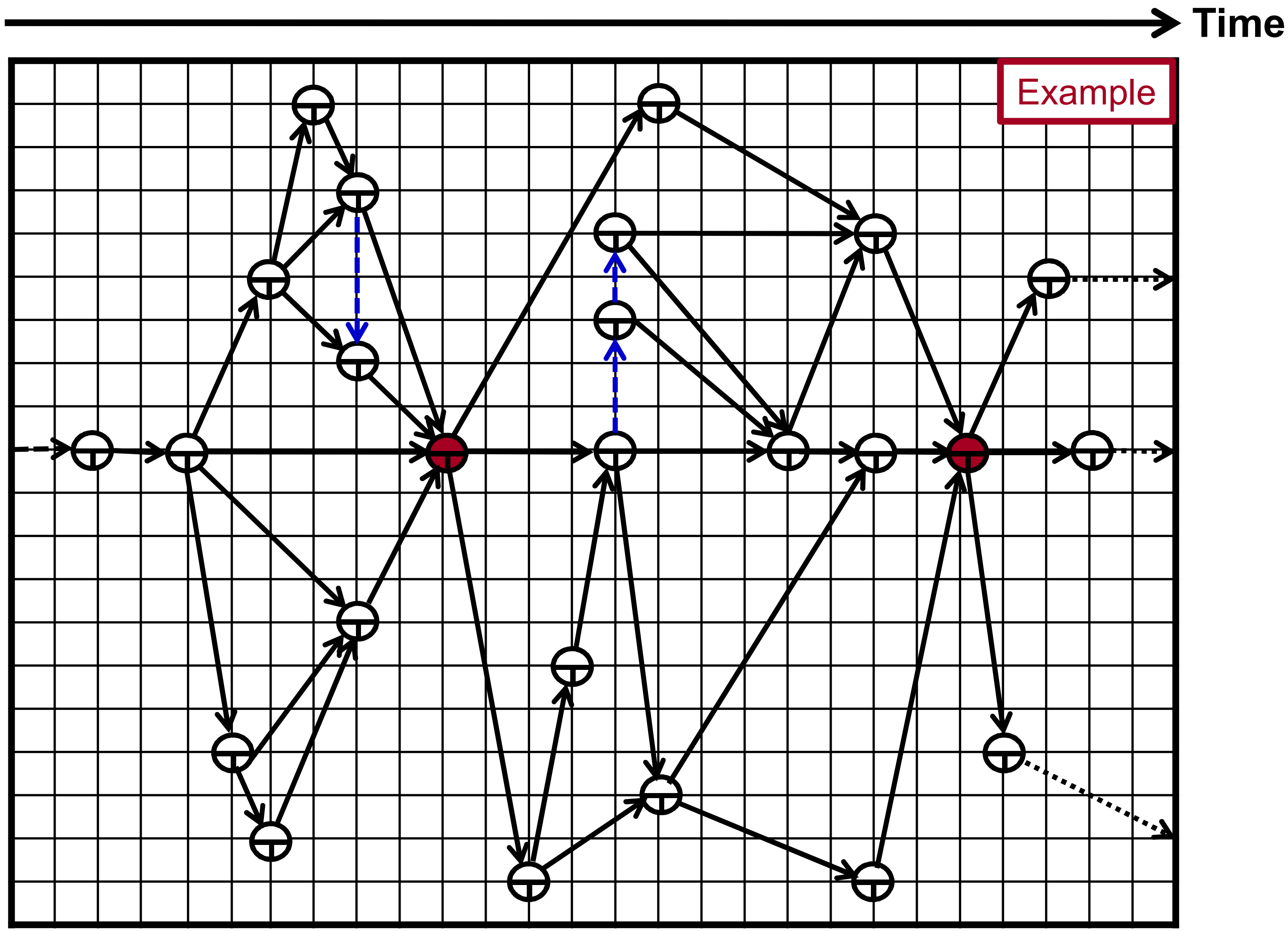
Critical Activity

An activity that must be completed on time to realize the time component in the target system of the project.
The **time buffers** for the start and end of the process are each **zero**. If a critical process is delayed, the end date of the project is endangered.

Critical Path

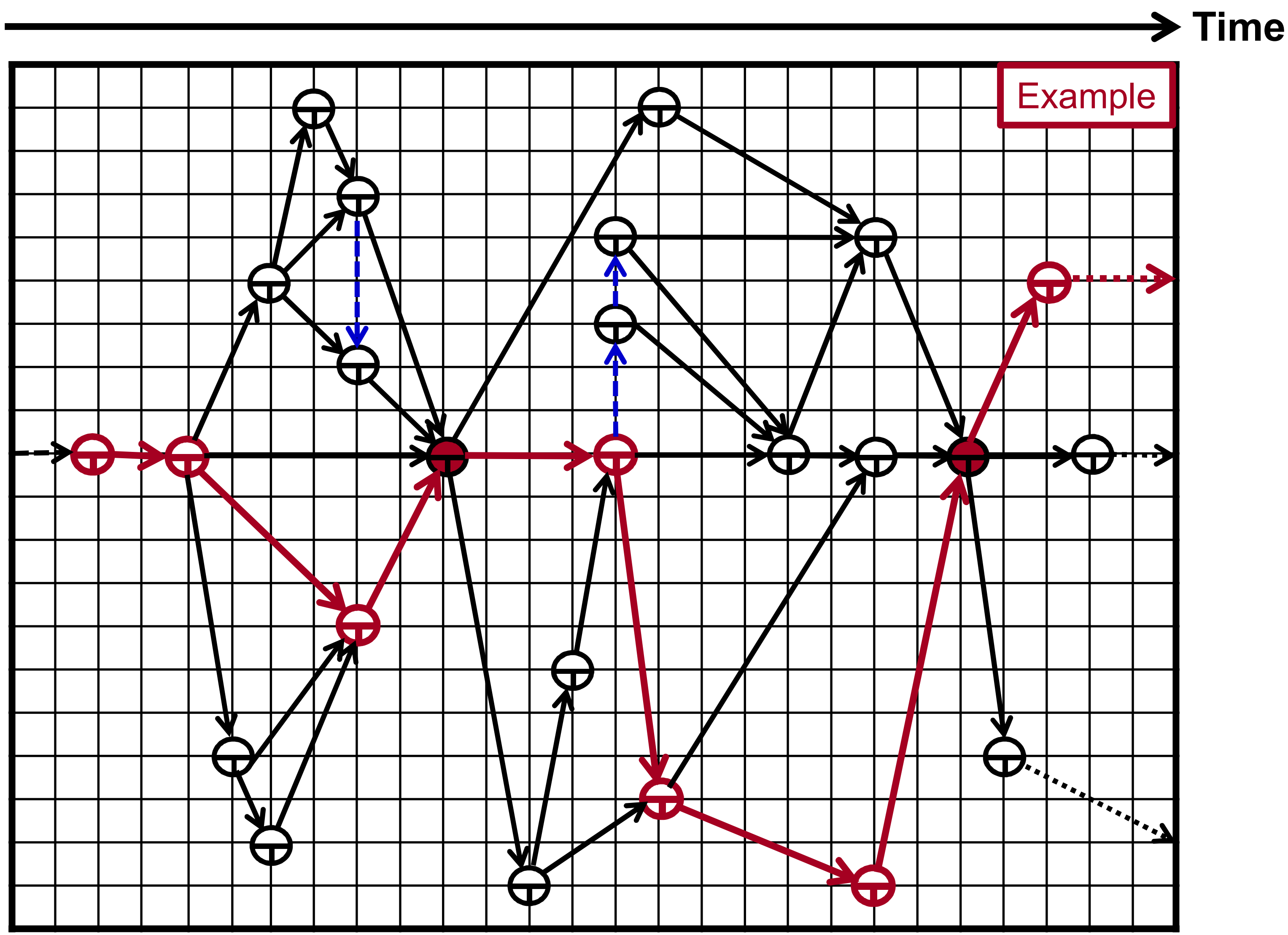
The sequence of operations that must be completed on schedule to complete the project on schedule.
***Every* process on the critical path is critical** and therefore requires intensive deadline monitoring.

CPM Diagram, Construction Rules, Activity-Sequences:



Rainer Buerstinghaus

CPM Diagram, Activity Sequences; Critical Path (→) :



Rainer Buerstinghaus

Network Diagrams, CPM, "Highly Elastic Clear Coats…"

CPM-Network-Diagram, Critical Activity:

Critical

Activity HBC 017 - 51

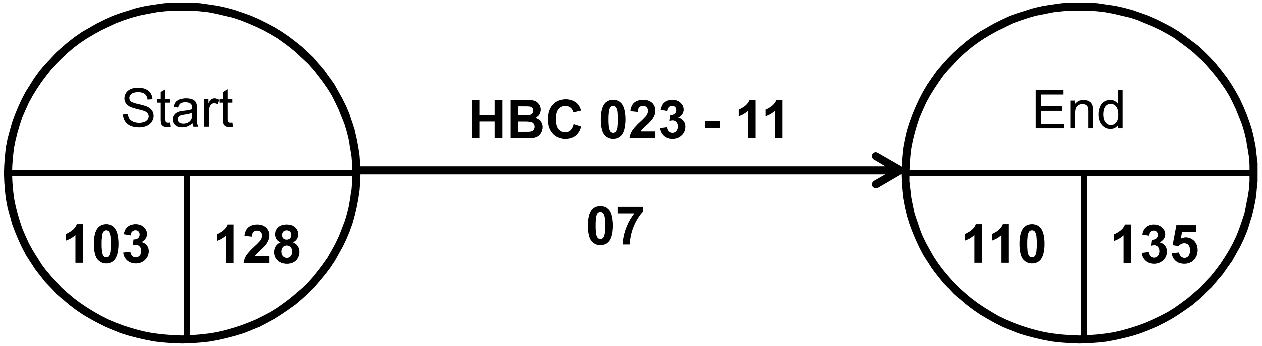
Application of further thirty HBC-liquid coatings and subsequent UVcon tests: 2000h, λ = 280nm, 50°C/70°C.

Rainer Buerstinghaus

Network Diagrams, CPM, "Highly Elastic Clear Coats…"

CPM-Network-Diagram, Noncritical Activity:

Noncritical



Activity HBC 023 - 11

Synthesis of 7.5 kg of cross-linker-oligomer HC 17 in order to fully characterize its physical properties.

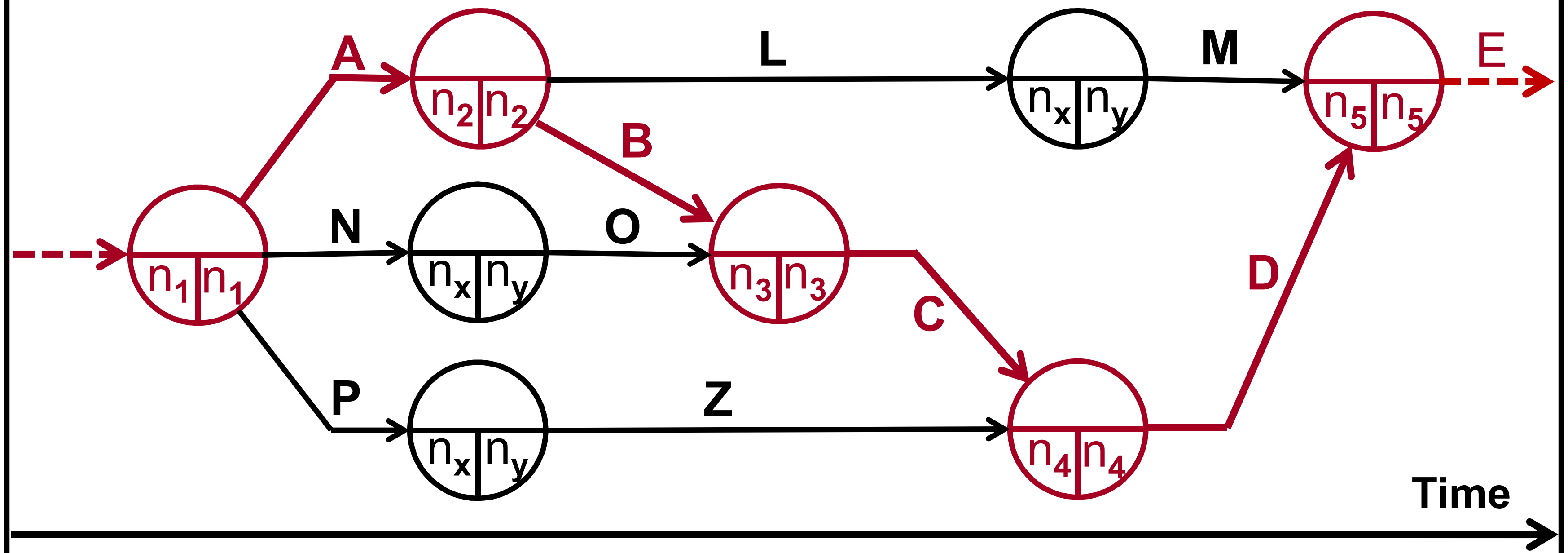
Network Diagrams, CPM, "Highly Elastic Clear Coats…"

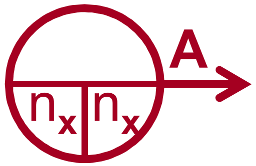
CPM-Network Diagram; Critical and Noncritical Activities:

Allocation	Activity
	Determination of daphnia-toxicity for HC 17 in the eco-laboratory.
	Optimization of the clear coat formulation for its application on standard water-based coating layers.
	Preparation of the documents for the ECHA-registration of HC 17.
	Lab synthesis (20 g) of the warmblooded animals metabolite HCC 217.
	ESTA-Applications at the pilot customer on the new paint line.
	Cross-hatch tests after spray application on steel plates.
	Synthesis of 1.5 kg crosslinker oligomer HC 17 in the pilot plant for the determination its physicochemical data.
	Technical synthesis of 50 kg poly acrylatole ST 2117 for in-house painting tests on model bodies.
	Customer delivery for its production start in the new plant.

Network Diagrams, CPM, "Highly Elastic Clear Coats…"

A Critical Path Contains No Slack Times! (Path A-B-C-D)!





Activities (A) without time elasticity (For example: season bound tests, deadlines by authorities/customers). An exceeded deadline means a longer project duration!

$n_x = 0, 1, 2, 3, ...; n_y = 0, 1, 2, 3, ...; n_x \neq n_y; n_y > n_x$

Rainer Buerstinghaus

R&D Project Management in the Chemical Industry

The Subject Matter

- Innovations: Characteristics, Measures for its Promotion, Process Variants.
- Three Examples for Innovation Projects (Chemistry and Technology):
  1. Highly Elastic Clear Coats for the OEM Automotive Sector.
  2. Nitrilase Catalyzed Synthesis of a Chiral Hydroxy-Carboxylic Acid .
  3. New Metal-Organic Frameworks for the Adsorptive Storage of Gases.
- Projects, Target Systems, Project Management in R&D.
- Appropriate Organization and Effective Structure Planning of R&D Projects.
- Project Flow Planning, Milestones, the Stage-Gate®-Process, Network Diagrams.
- **Effective Implementation and Control of R&D Projects, Trend Analyses.**
- Success Risks: Identification, Classification and Treatment.
- Recruitment and Lead of Project Staff:
  Chemists (m/f/d) – Team Players, Pacemakers and Executives in Projects.
- Project Manager (m/f/d): Tasks, Leadership Functions and Personality Profile.
- The Systematic Evaluation of Individual R&D Projects.
- R&D Strategy: The Planning of a Project Portfolio.

R&D Project Management in the Chemical Industry

Subject Matter →

Effective Implementation and Control of R&D Projects, Trend Analyses.

Aims and Objectives:

- Accurate and speedy completion of all operations listed in the project schedule.
- Earliest possible detection of plan deviations.
- Flexibility for necessary process changes.
- Effective parrying of failures/outages.
- Rapid dissolution of project blockades.

- **Realization of the project target system despite disruptions or "surprises" (research!) In the project!**

Effective Implementation and Control of R&D Projects

Basic Rules:

- Careful planning is the most effective "advance action" for project management.
- Complex projects are not purely intuitive, but always to steer with strict systematics.
- But: "soft" control variables (knowledge, experience, "wisdom" of individual team players) are particularly effective in combination with hard information (→ "Data").
- Achieving target systems, milestones or gates is more important than the meticulous adherence to single planning parameters.
- The control variables "Chemistry / Technology", "Costs" and "Dates" are to be regarded as a whole (system).

Basic Rules:

- Deviations from Planning must be identified as early as possible and communicated to all involved.
- The effective control is supported by quick and clear decisions.
- Every implemented control process is inevitably associated with "side effects" in the project.

- **All control measures must always have an impact at the level of individual activities (IAs)!**
(IAs: "Work Packages in Action", "WP`s in Action")!

Realized "WP`s", Importance for the Project Success.

"You do not just have to want it, you also have to do it!"	J. W. von Goethe (1749 − 1832)
"The real purpose of learning is not knowledge but action!"	Herbert Spencer (1820 − 1903)
"The only way leading to knowledge is the activity!"	G. B. Shaw (1856 − 1950)
"There is nothing good, unless you do it!"	Erich Kästner (1899 – 1974)
"Made things will overtake thought things!"	Numerous Sources

Realized "WP`s", Importance for the Project Success.

"I am not concerned with what has been done. I'm interested in ***what needs to be done."***	Marie Curie (1867 − 1934)

"Of the three main activities involved in scientific research, thinking, talking, and ***doing***, I much prefer the last and am probably best at it. I am all right at the thinking, but not much good at the talking"!	Frederick Sanger (1918 − 2013)

Realized „WP`s: Learning Programme „Action“.

"Tell me, and I will forget! Teach me, and I may remember! Involve me, and I will learn!"   (Benjamin Franklin, 1706 – 1790)

The members of a project team will remember that,

- what they read: ≈ 10 %
- what they hear: ≈ 20 %
- what they are looking at: ≈ 30 %
- what they look *and* hear: ≈ 50 %
- **what they present themselves: ≈ 70%**
- **what they do themselves: ≈ 90 %**

Effective Implementation and Control of R&D Projects

→ Checklist for the Execution of Project Activities:

What?	Target	Who?	With Whom?	Until When?	Result
Activity (A_n)	***Striven Result***	***Person Responsible***	***Persons Involved (i. n. Clique)***	***Deadline (Date)***	***Check (✓)***
↓	↓	↓	↓	↓	↓

Rainer Buerstinghaus

Effective Implementation and Control of R&D Projects

→ Checklist for the Execution of Project Activities:

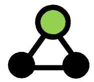
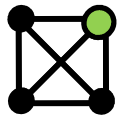
Example P1

What?	Target	Who?	With Whom?	Until When?	Result
Activity (A_n)	***Striven Result***	***Person Responsible***	***Persons Involved (i. n. Clique)***	***Deadline (Date)***	***Check (√)***
Crosshatch-Tests, CC 37c	Knowledge of Adhesion/System.	Dr. Aberg	—	17.07.2020	√ (90 %)
Lab-Syntheses, Series HBC 08c	Optimized Reaction Parameters.	Mr. Bermann	Dr. Hallert Mrs. Ihlers	01.10.2020	√
Peroral Toxicity HBC 11a, Rat	Knowledge of the Toxicity (REACH).	Dr. Cehaus	Dr. Jottner Dr. Karsten	01.12.2020	Still open
AMTEC-Test, SeriesCC 37	Scratch Resistances are known.	Mrs. Derkötter	Mr. Elmers	01.12.2020	√
H-NMR-Spectra, HBC Series 09	Proof of the Chemical Structures.	Mr. Effner	Mr. Bermann	03.07.2020	√
UV-con-Stability, Series CC 31	UV-Stabilities are clarified.	Dr. Gekamp	—	01.09.2020	Still open
↓	↓	↓	↓	↓	↓

Rainer Buerstinghaus

Effective Implementation and Control of R&D Projects

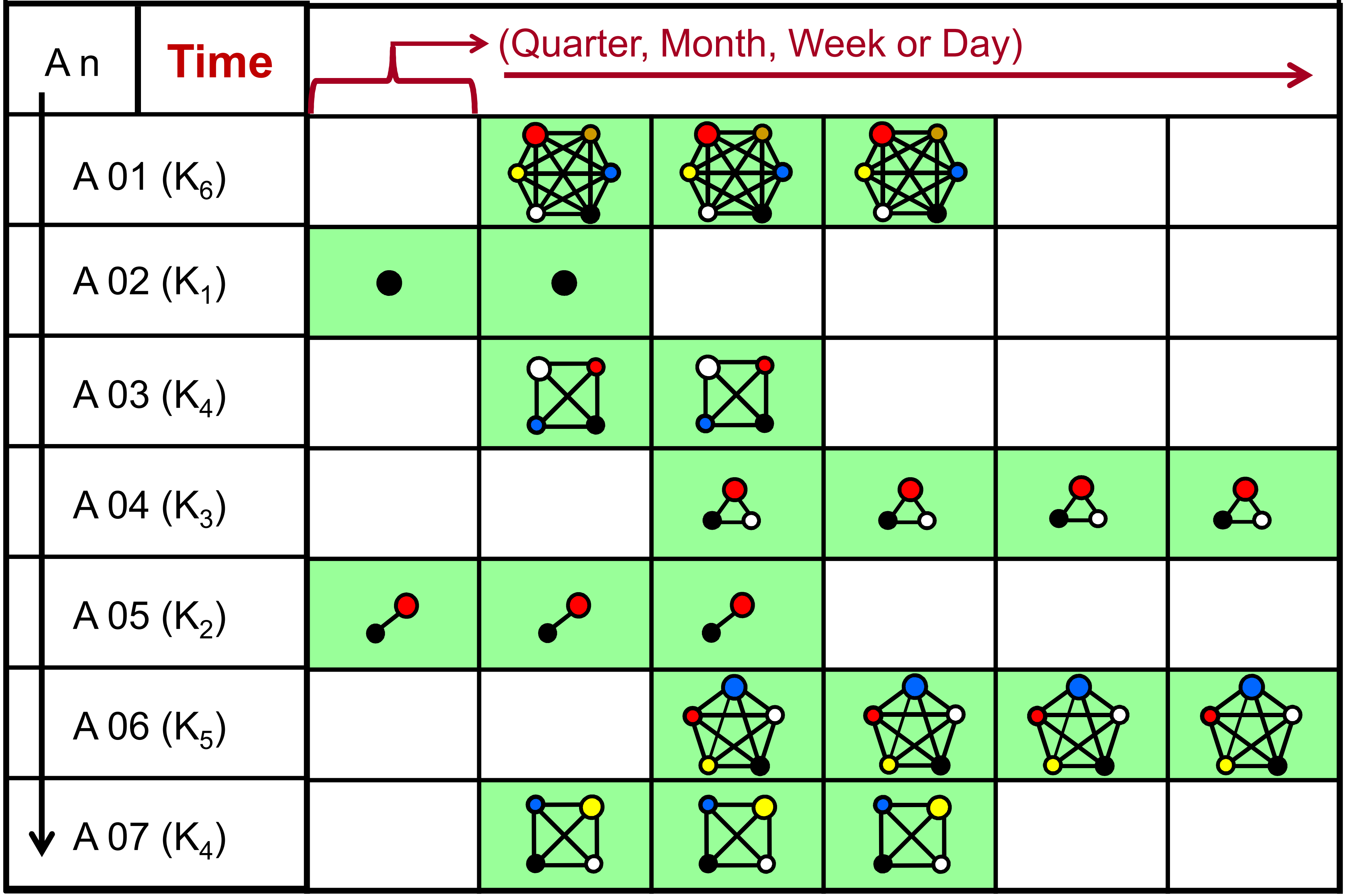
→ Checklist for the Execution of Project Activities:

What?	Target	Who?	With Whom?	Until When?	Result
Activity (A_n)	***Striven Result***	***Person Responsible***	***Persons Involved (i. n. Clique)***	***Deadline (Date)***	***Check (√)***
A_n	Result (n)			Date (n)	
A_{n+1}	Result (n + 1)			Date (n + 1)	
A_{n+2}	Result (n + 2)			Date (n + 2)	
A_{n+3}	Result (n + 3)			Date (n + 3)	
↓	↓	↓	↓	↓	↓

Rainer Buerstinghaus

Effective Implementation and Control of R&D Projects

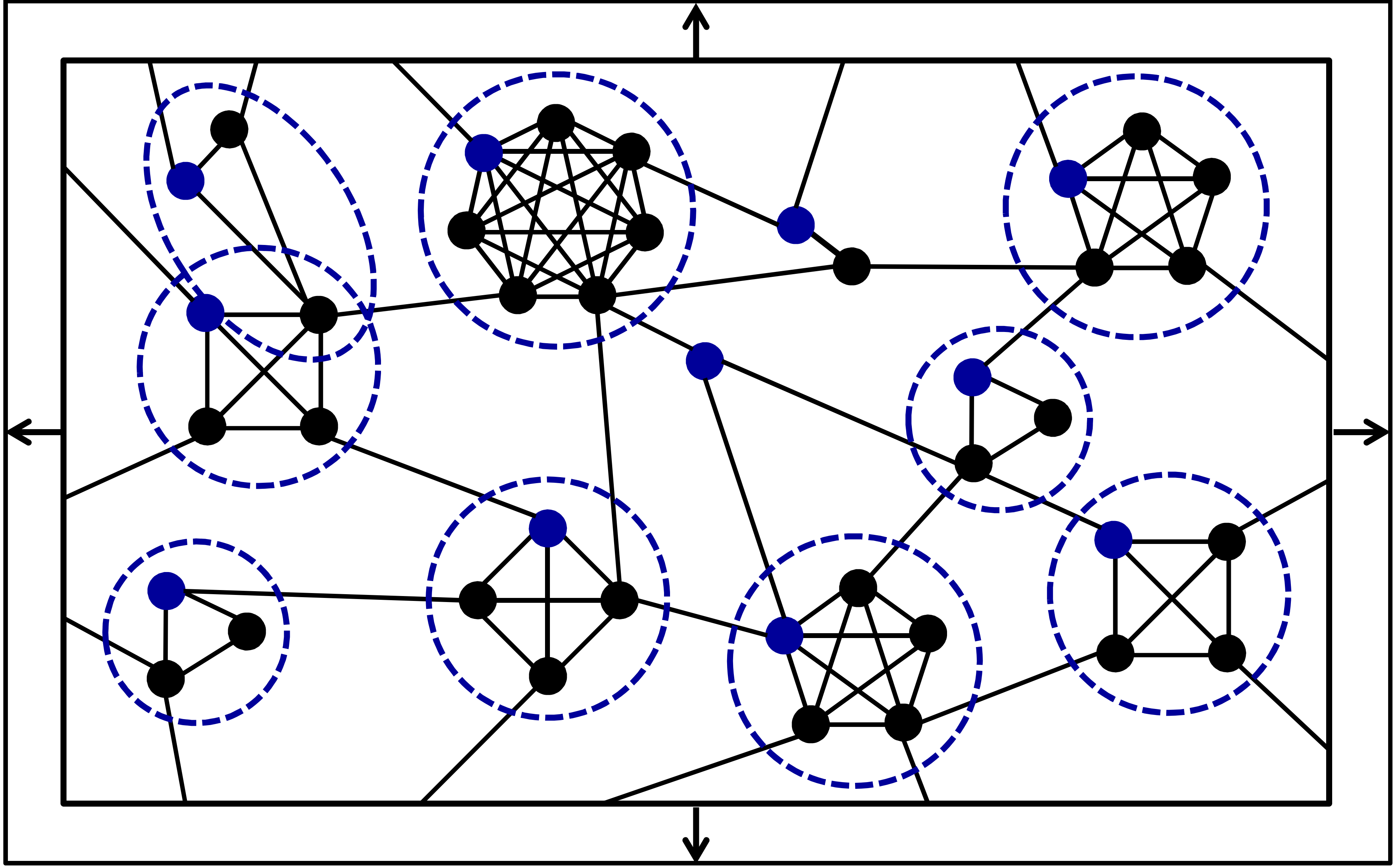
Gantt Chart with "Activity Cliques" (A 0n):



Rainer Buerstinghaus

Effective Implementation and Control of R&D Projects

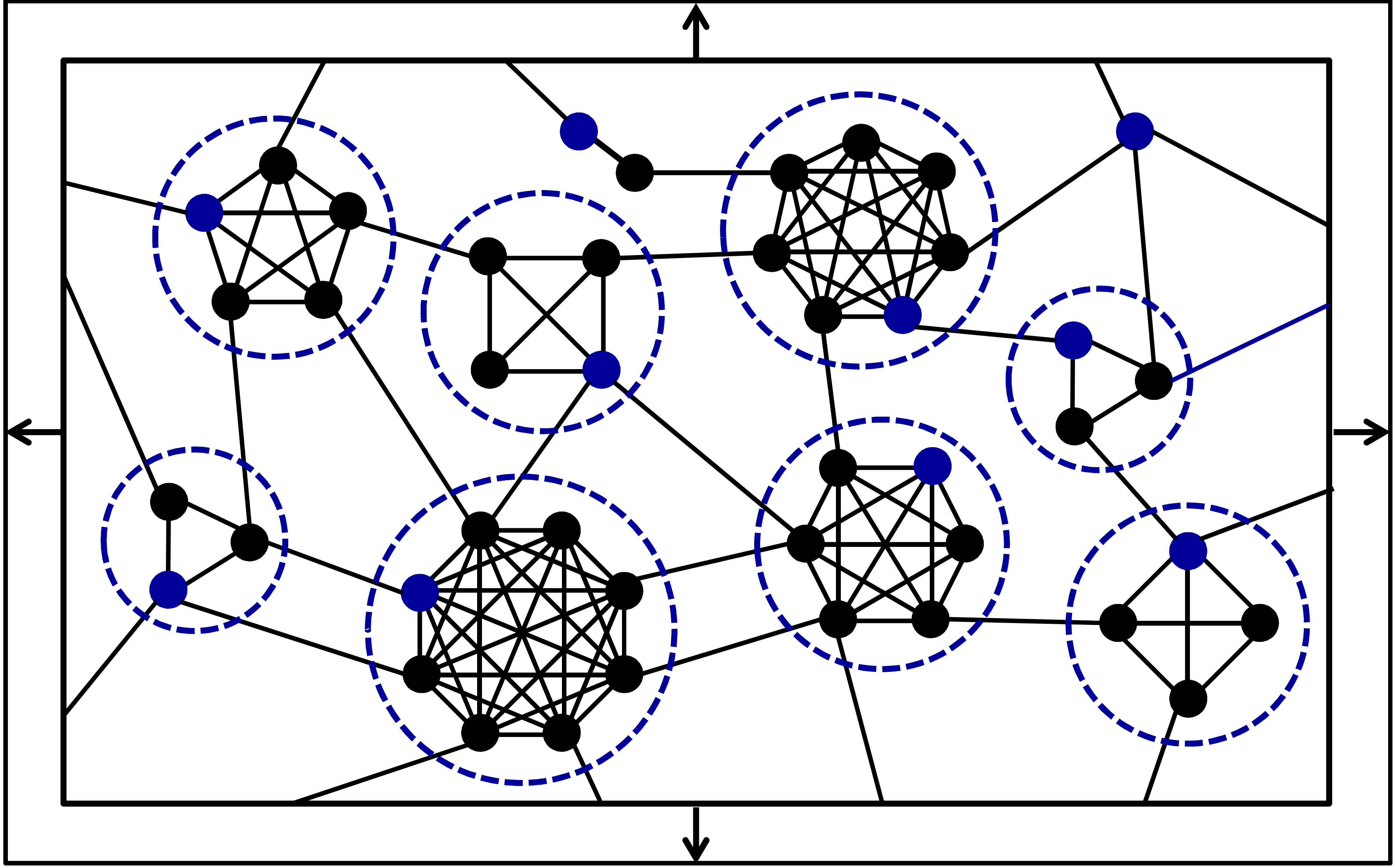
Implementation within a System of "Fluctuating Cliques":



Rainer Buerstinghaus

Effective Implementation and Control of R&D Projects

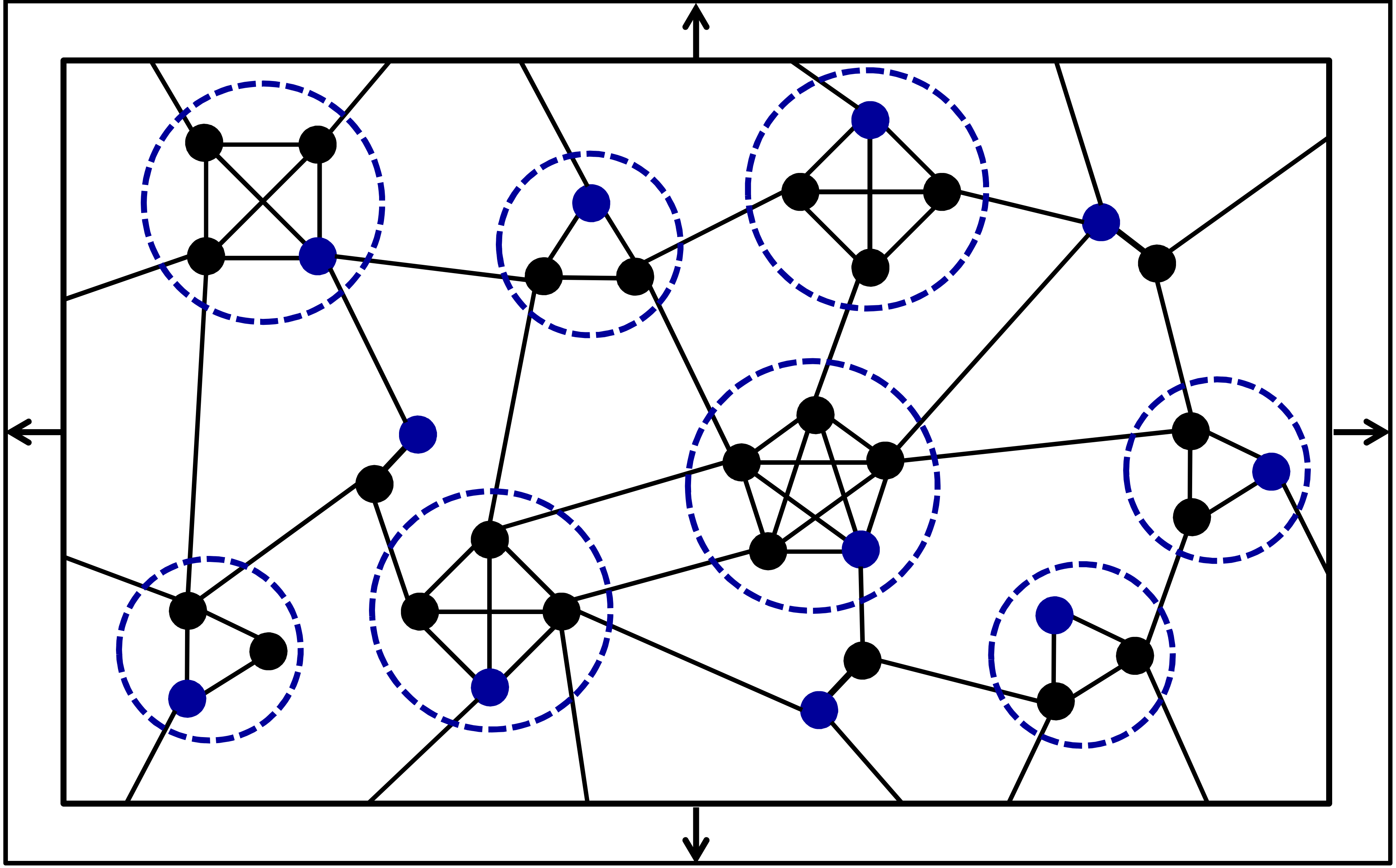
Implementation within a System of "Fluctuating Cliques":



Rainer Buerstinghaus

Effective Implementation and Control of R&D Projects

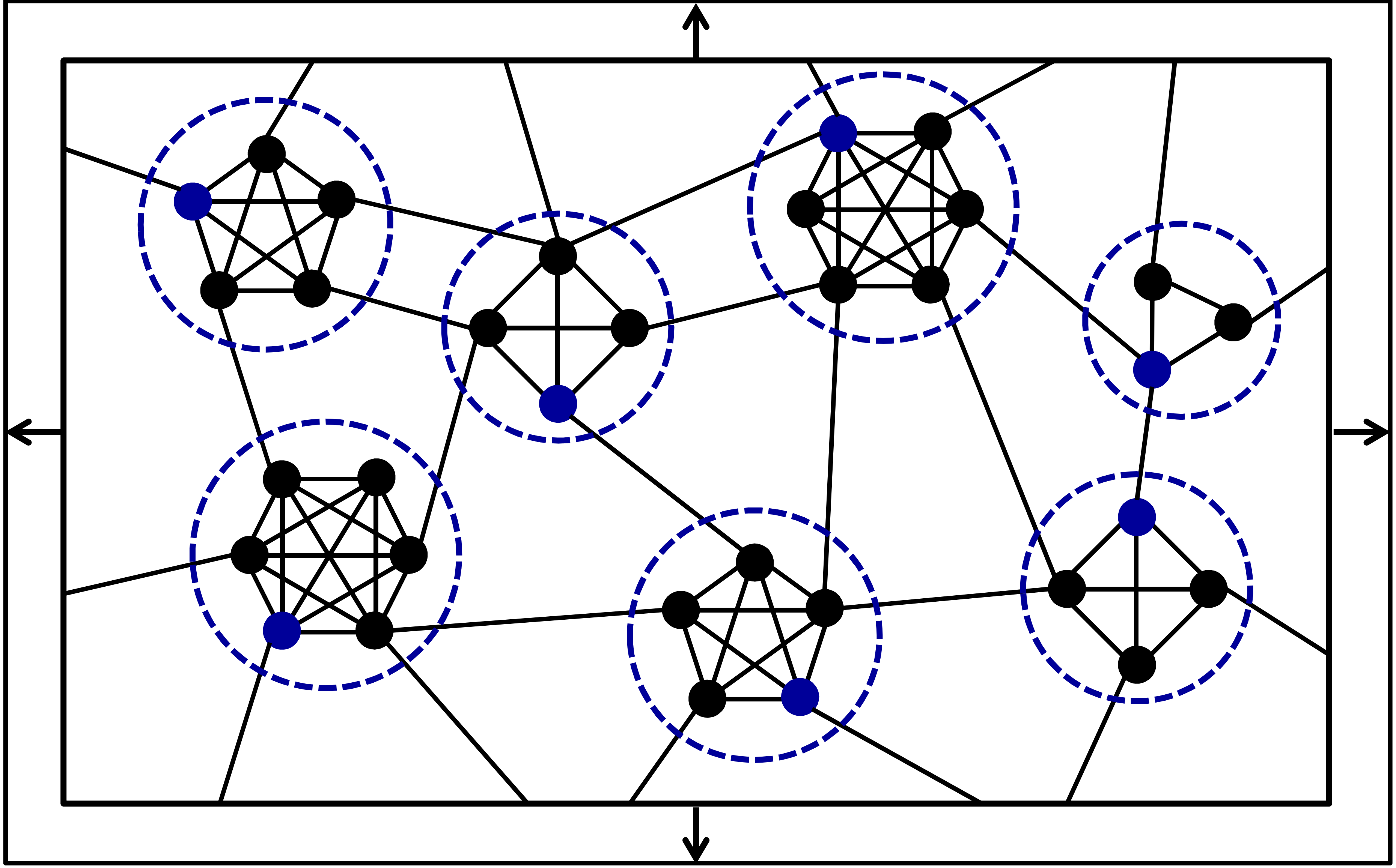
Implementation within a System of "Fluctuating Cliques":



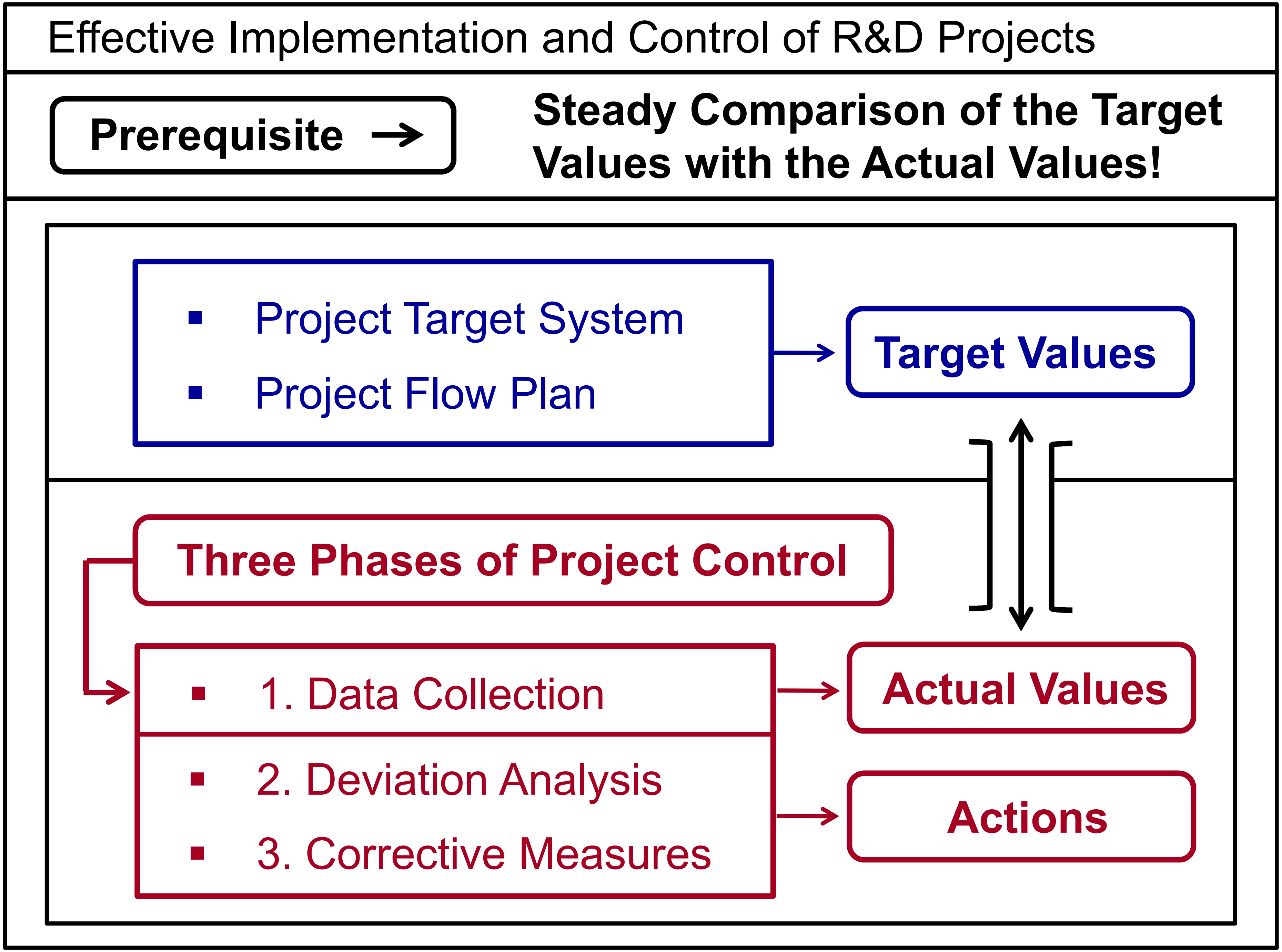
Rainer Buerstinghaus

Effective Implementation and Control of R&D Projects

Implementation within a System of "Fluctuating Cliques":



Rainer Buerstinghaus



Rainer Buerstinghaus

Clear Agreements on Project Activities as the Basis for Systematic Target-Actual Comparisons:

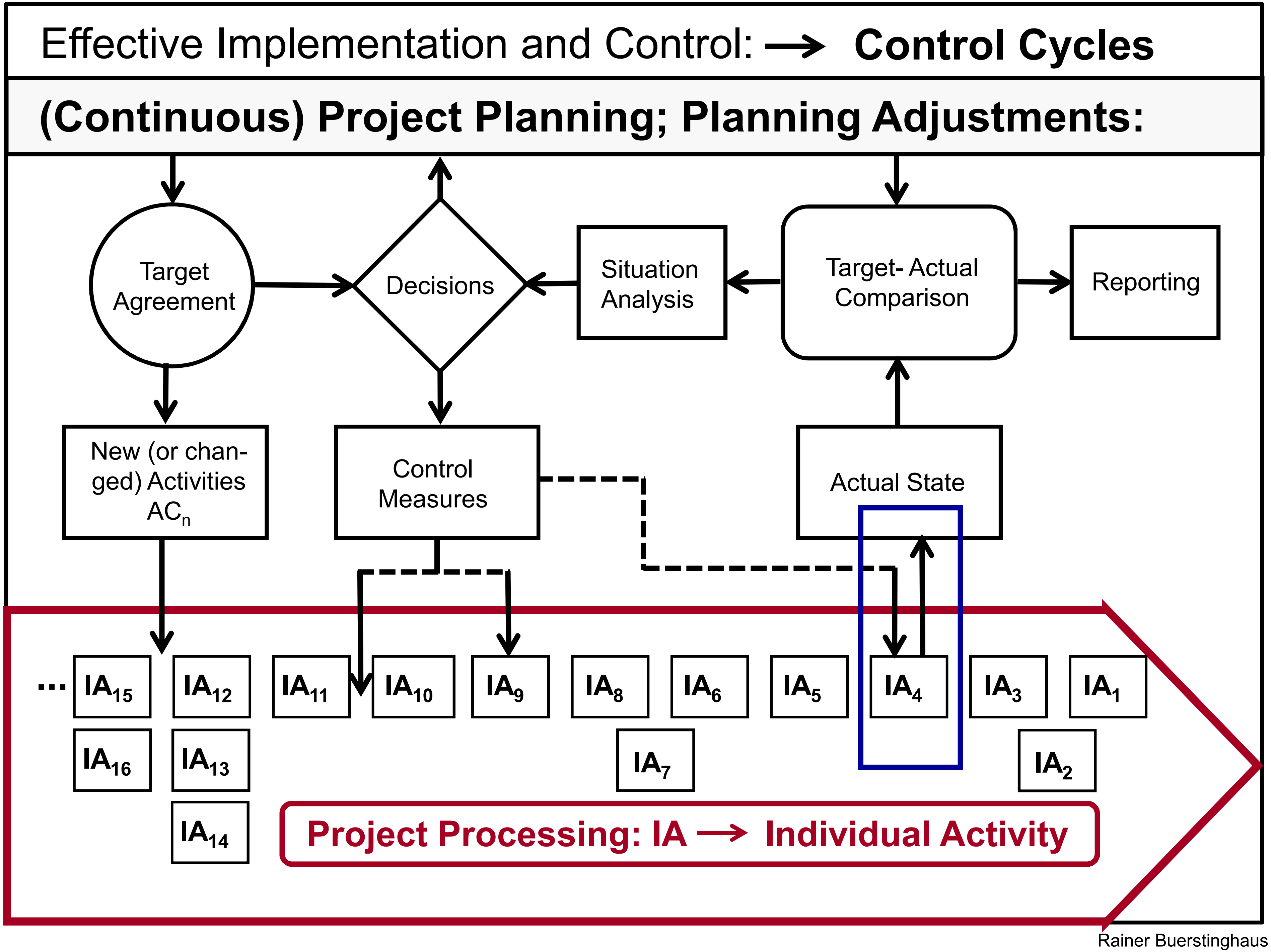
ACTIVITY:	**DATE:**
Responsible Person (m/f)	
Objective	
Task	
Results to be worked out	
Budget	
Frame Conditions	
Deadline, i. n. Milestone	
Signatur Principal (Project Manager)	
Signature (Responsible Person)	

ACTIVITY: **Recording and evaluation of Raman spectra of the 10 new T(P)MA-MOFs under H_2 at 80 K**	**DATE: 4.10. 2019** **Example P3**
Responsible Person (m/f)	Dr. Anna Oltermühlen
Objective	Knowledge of the H_2-adsorptions.
Task	Recording the spectra in the H_2 - cryo-Apparatus.
Results to be worked out	All Raman spectra are available and fully evaluated.
Budget	5.200 €
Frame Conditions	Availability of an experienced and specially trained laboratory technician.
Deadline, i.n. Milestone	12.12.2019
Signature Principal (Project Manager)	M.Pohlhans, 04.10.2019
Signature (Responsible Person)	04.10.2019 , Anna Oltermühlen

Measures taken by the Project Manager to Successfully Lead the R&D Project into the Defined Target System:

- Constantly adapt structure plans/flow plans! ⟷
- Problem solving and project management should be well coordinated! ⟷

- **Possibly, *early* "countermeasures" must be taken!**

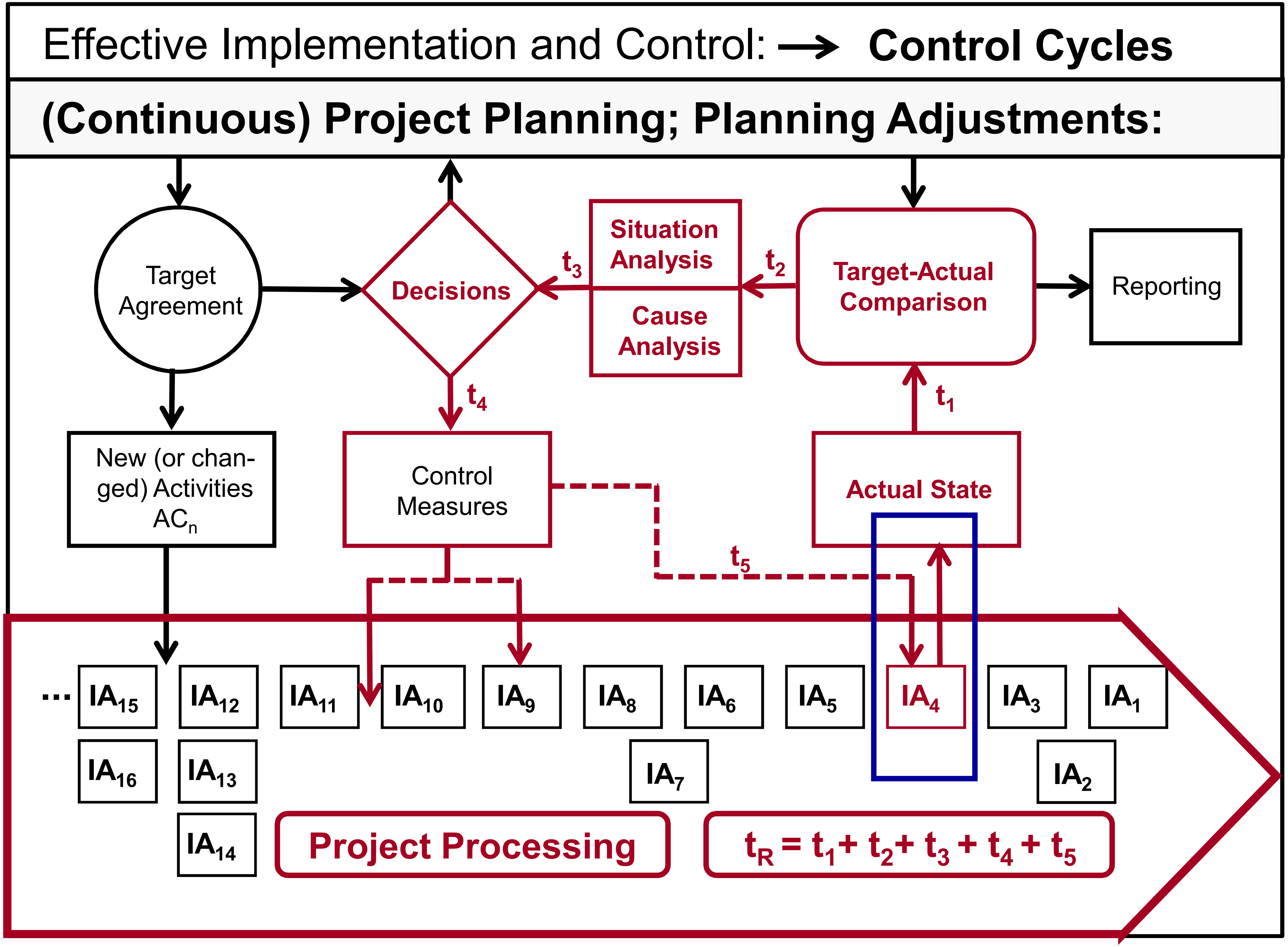


Effective Implementation and Control: → Control Cycles
(Continuous) Project Planning; Planning Adjustments:
Target Agreement
Decisions
Situation Analysis
Target- Actual Comparison
Reporting
New (or chan-ged) Activities AC_n
Control Measures
Actual State
… IA_{15}
IA_{16}
IA_{12}
IA_{13}
IA_{14}
IA_{11}
IA_{10}
IA_9
IA_8
IA_7
IA_6
IA_5
IA_4
IA_3
IA_2
IA_1
Project Processing: IA → Individual Activity
Rainer Buerstinghaus

Response Time for Control Measures.

The response time for project control measures is summarily composed of:

- Duration from the occurrence of a deviation until its recognition.
- Duration from cause analysis until development of potentially appropriate corrective measures.
- Duration for the decision.
- Duration until the initiation of the control measure.
- Duration until the effect of the control measure.



Rainer Buerstinghaus

Hard Data are Based on Facts from the Past.
They Document the Current Status of the R&D Project.

Hard Data, Examples:

- Chemistry: reactions, reaction parameters, yields.
- Product properties, physical data, effects.
- Number and type of components (in formulations).
- Previously incurred costs.
- Realized procurements and investments.
- Completed activities, deadlines.
- Planning of resources, personnel capacities, equipment(s).

Formal Steering

Soft data can typically only be described (diffusely). They are rarely to be substantiated with concrete facts and data. They describe general conditions and resulting attitudes. However, they have a clear influence on the future course of the project!

Soft Data, Examples:

- Atmosphere among the project participants/stakeholders.
- Motivation of each individual project participant.
- Degree of interpersonal understanding.
- Rumors, colportages, guesses.
- Mental and emotional "fitness" of the project participants.

Leadership Steering

Two Interconnected Control Circuits within an Ongoing R&D Project:

"Dyad"

(K_2) $\begin{bmatrix} 2 \\ 2 \end{bmatrix}$

Formal Steering

Targets, Deadlines.

Result(s), Quality.

Expense, Costs.

Capacities (FTE,€).

Budget.

Leadership Steering

Project Significance.

Targets, Internalization.

Motivation in the Team.

Budget Allocation.

Staff Productivity.

Rainer Buerstinghaus

Deviations from Planning in Ongoing R&D Projects:

Discrepancies Regarding:	
Laboratory Results	- Completeness. - Accuracy, Exactness, Quality, Validity.
Deadlines	- Respective Activity Completion. - Milestone Achievement. - Remaining Duration (Time to Completion).
Costs	- Costs of Individual Work Activities. - Distributions to Various Types of Costs - Remaining Effort (Cost to Completion).
HR-Productivity	- Individual Performance per FTE. - Quality of Personal Work Results. - Qualification/Expertise of the Staff.
HR-Capacities	- Actually Required Staff Costs.

Deviations from Planning in Ongoing R&D Projects:

- Unexpected chemical or technical results.
- Faulty chemical or technical results.
- Necessary target corrections (Example: Higher performance requirements from the customer).
- New environmental laws, stricter environmental laws (Consequence: Possible refusal of approval by ECHA).
- Social change (Consequence: the acceptance of the target product in the market has fallen - or increased).

Causes

Deviations from Planning in Ongoing R&D Projects:

- Planning errors
  (Example: The duration of single actions were assessed as too optimistic/pessimistic).
- Other solutions, newly published products, syntheses or processes (Consequence: suitably adapted work packages).
- Personnel risks (Example: Unforeseeable loss of staff).

Causes

Effective Implementation and Control of R&D Projects

Cost Overview (Target – Actual Comparisons):

PERIOD: **Project Start - Today**	**PLAN** **(x 10^3 €)**	**ACTUAL** **(x 10^3 €)**	**DEVIATION** **(Act. – Plan)**	**EVALUATION**
Staff, N.-T. Employees				
Staff, T. Employees				
Chemicals				
Solvents				
Equipment				
Laboratory Materials				
Internal Services				
External Services				
Rents (Offices, Labs)				
Travel Expenses				
TOTAL				

Effective Implementation and Control of R&D Projects

Cost Overview (Target – Actual Comparisons): Example

PERIOD: 01.03.2020-31.01.2021	PLAN (x 10^3 €)	ACTUAL (x 10^3 €)	DEVIATION (Act. – Plan)	EVALUATION
Staff, N.-T. Employees	1.840	1.804	− 36	Saving 02,0%
Staff, T. Employees	1.613	1.461	− 152	Saving 09,4%
Chemicals	345	313	− 32	Saving 09,3%
Solvents	180	185	5	Overdraft 02,8%
Equipment	57	40	− 17	Saving 30,0%
Laboratory Materials	89	78	− 11	Saving 12,4%
Internal Services	251	272	21	Overdraft 08,4%
External Services	180	190	10	Overdraft 05,6%
Rents (Offices, Labs)	17	17	0	On Target
Travel Expenses	4	3	− 1	Saving 25,0%
TOTAL	4.576	4.363	213	**Savings 04,7%**

Effective Implementation and Control of R&D Projects

Trend Analyzes as "Proactive" Measures:

Definition of the target values.

Carrying out experiments.

Record actual values.

In case of deviations: Initiation of control measures.

Monitoring: Reaction is possible only after the deviation has occurred!

Definition of the target values.

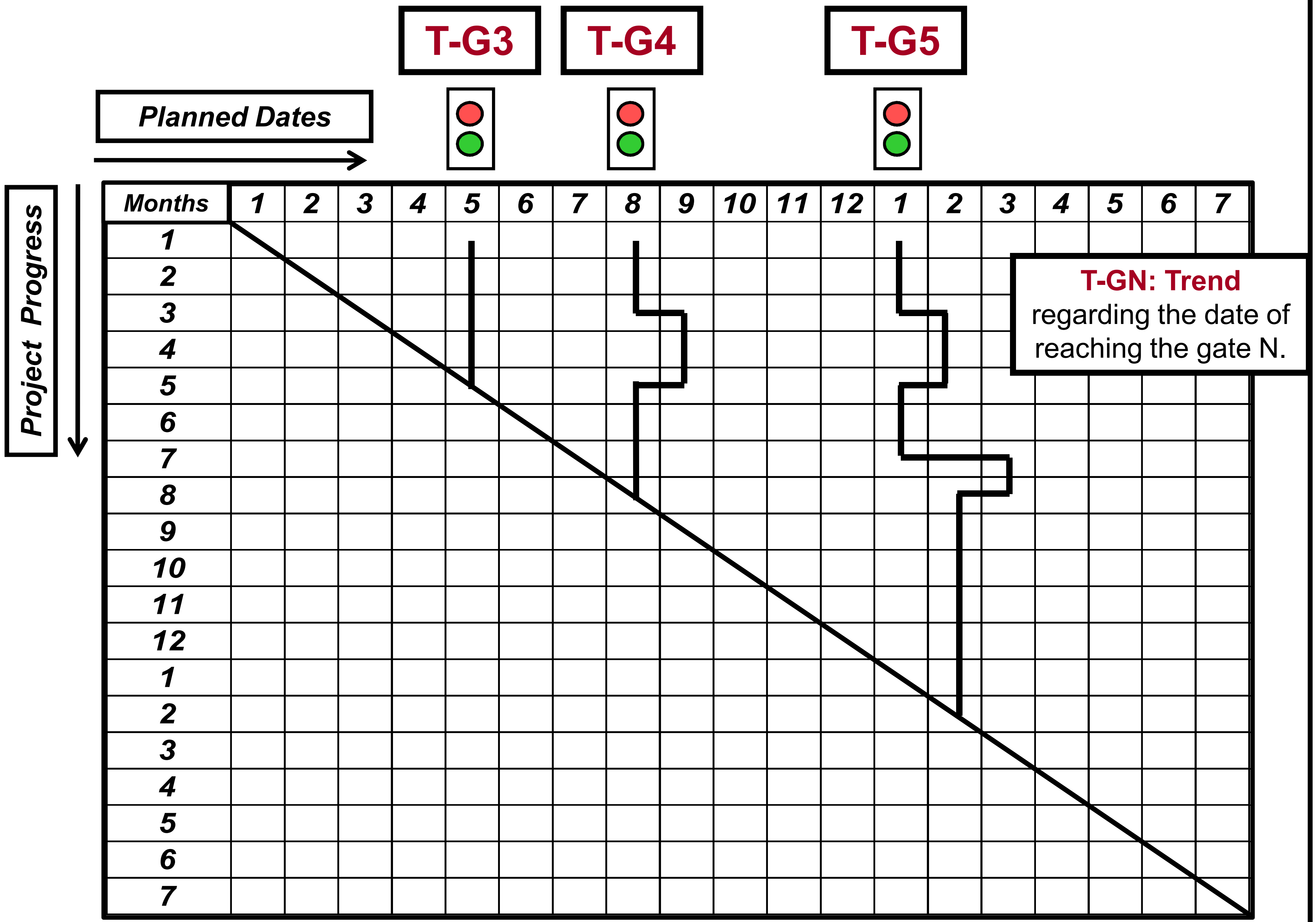
Carrying out experiments.

Trend estimation.

In case of **foreseeable** deviations: Initiation of control measures.

Trend analyzes: An action is possible even before the deviation occurs!

Effective Implementation and Control → **Trend Analyzes:**



Rainer Buerstinghaus

Effective Implementation and Control of R&D-Projects

Notification of Change During the Course of R&D Project:

Notification of Change

Project: A 021, Highly Elastic Clear Coats; Project Manager: Dr. Aberg

○ Change of the result ● Change of the deadlines ○ Change of the costs

Causes of the deviations::

Strike of truck drivers in France. Traffic blockades on the French highways!

The following deviation was found:

Time delay of four (4) weeks

New target value::

Project end: 31.08.2022

Activity/Work package:

Assembly of a stainless steel stirred tank in the pilot plant

● Change of the targets

○ Change of the planning/approach

For information:

● Project team

● StageGate-Keeper

● Steering Committee

For approval:

○ Project team

○ StageGate-Keeper

● Steering committee

Exact description of the deviation:

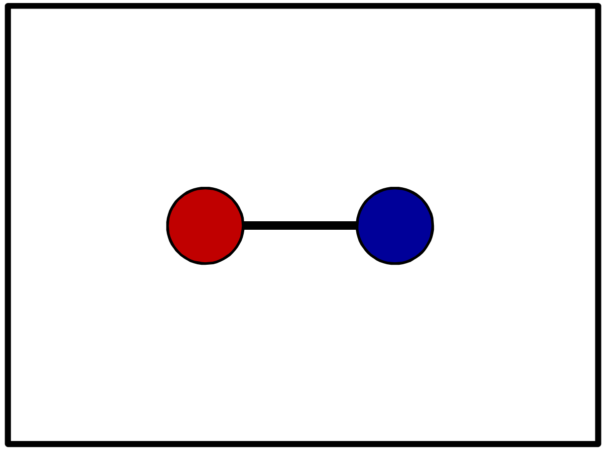
Due to unpredictable logistics problems on the road network, the required 1,000 l stainless steel stirred tank from [Reacteur…SARL1] (Lyon, F) can only be assembled by the supplier in the pilot plant with four weeks delay.

Date: 04.09.2020 **Signature:**

Effective Implementation and Control of R&D-Projects

Realization of the Target System, Derived Activities.

Target System



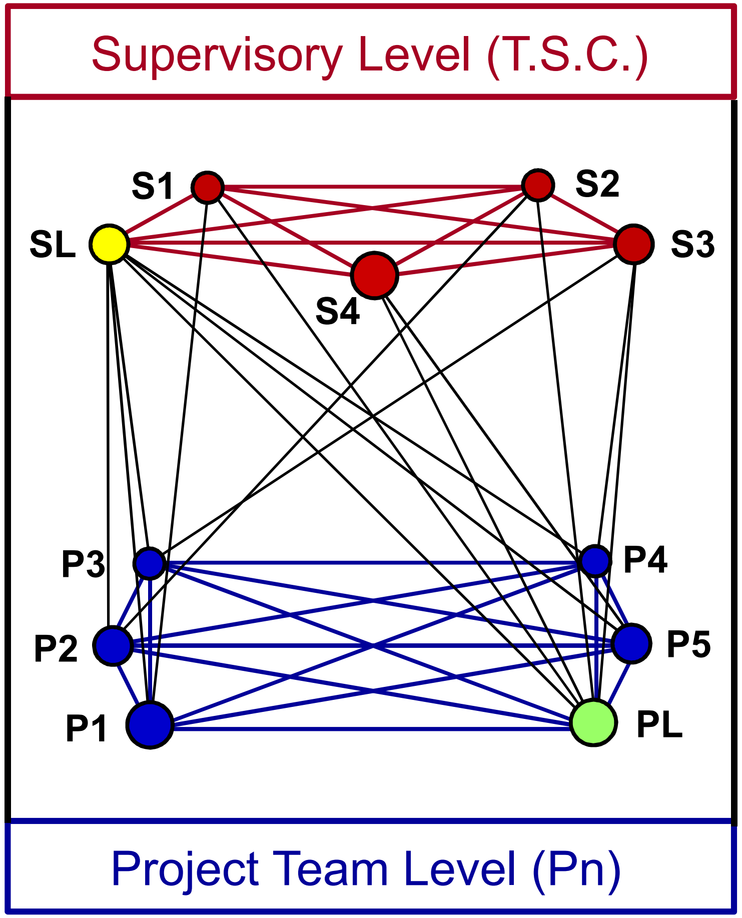
Activities

(K_2): $\begin{bmatrix} 2 \\ 2 \end{bmatrix}$

For an effective implementation and control of R&D projects, the target system ***and*** the activities derived from it must be continuously aligned!

Effective Implementation and Control of R&D-Projects

Interactions between Steering Committee and Project Team: Bipartite graph; Minimum number of connections (═), each with a steady and mutual exchange of information for an effective and efficient project progress.



🟡	SL: T.S.C. Leader (m/f/d) (GBU-Leader (m/f/d))
🔴	S1: Member T.S.C. (Research)
🔴	S2: Member T.S.C. (Development)
🔴	S3: Member T.S.C. (Production)
🔴	S4: Member T.S.C. (Sales)
🟢	PL: Project Leader (m/f/d)
🔵	P1: Project Team Member (Research)
🔵	P2: Project Team Member (Development)
🔵	P3: Project Team Member (Pilot Plant)
🔵	P4: Project Team Member (Production)
🔵	P5: Project Team Member (Marketing)

Rainer Buerstinghaus

Effective Implementation and Control of R&D-Projects

Interactions between Steering Committee and Project Team: Adjacency Matrix; Minimum number of connections (1), each with a steady and mutual exchange of information for an effective and efficient project progress.

	S1	S2	S3	S4	SL
P1	1	0	0	0	1
P2	0	1	0	0	1
P3	0	0	1	0	1
P4	0	0	1	0	1
P5	0	0	0	1	1
PL	1	1	1	1	1

SL: T.S.C. Leader (m/f/d) (GBU-Leader (m/f/d))
S1: Member T.S.C. (Research)
S2: Member T.S.C. (Development)
S3: Member T.S.C. (Production)
S4: Member T.S.C. (Sales)
PL: Project Leader (m/f/d)
P1: Project Team Member (Research)
P2: Project Team Member (Development)
P3: Project Team Member (Pilot Plant)
P4: Project Team Member (Production)
P5: Project Team Member (Marketing)

Paradigm Shift in Planning, Implementation and Control

The "agile" working method: With clocked iteration to the goal.

The *short-term* planning, implementation and control of the processes in "agile" development projects takes place within defined, manageable periods of time ("Time Boxes"), for example in periods of two weeks.

The "clocked" planning from "timebox" to "timebox" takes place in that the development team - *together with product management* - defines at the beginning of each "timebox" which individual activities are to be carried out with which priority in the next period (two weeks).

Paradigm Shift in Planning, Implementation and Control

The "agile" working method: With clocked iteration to the goal.

The total project term is divided into n two-week "timeboxes".
D: Development; **T**: Scale-up; **P**: Production. Sprint: Activity sequence (2 w.).

	Sprint 1	Sprint 2	Sprint 3	→ →	Sprint n	Goal
D				→ →		
T				→ →		
P				→ →		
	Timebox 1	Timebox 2	Timebox 3	→ →	Timebox n	

→ Time

The development team ***no longer*** plans: "How much time do we each need?"
Instead, it plans: "What would we like ***to have finished*** within 14 days?"

Rainer Buerstinghaus

Paradigm Shift in Planning, Implementation and Control

With clocked iteration to the goal: "Sprint Backlog (ToDo)".

Sprint Planning 1. The development team and product management clarify: Which *priority* individual activities can be implemented within next two weeks?

	Sprint 1	Sprint 2	Sprint 3	Sprint 4	
D	*)				→
T					→
P					→
	Timebox 1	Timebox 2	Timebox 3	Timebox 4	

→ Time

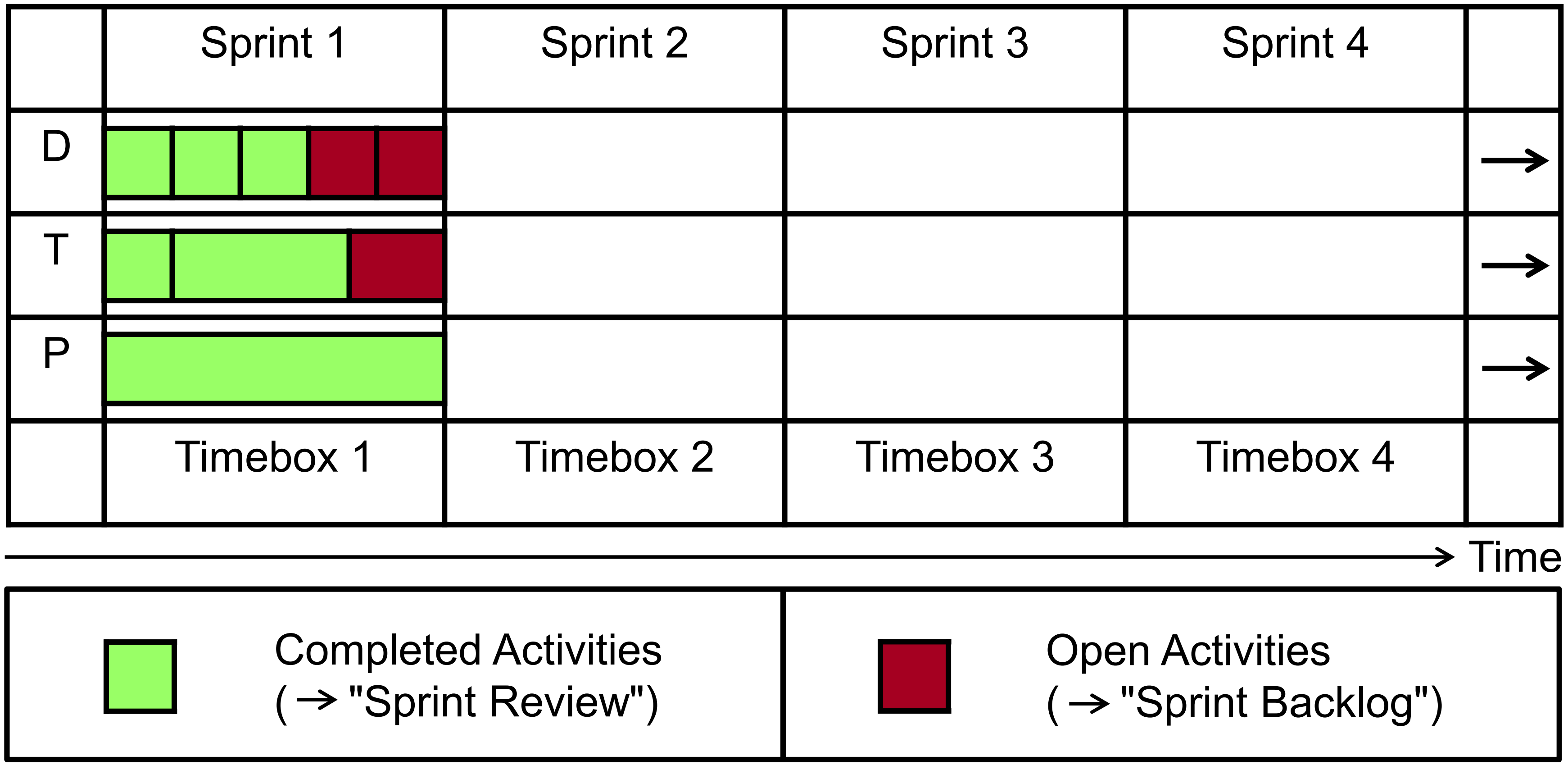
*) V_{01} | V_{02} | V_{03} | V_{04} | V_{05} → **Example 1**

Five priority individual activities that the team wants to implement within next two weeks.

Paradigm Shift in Planning, Implementation and Control

With clocked iteration to the goal: The "Sprint Review".

Review of Sprint 1. Development team and product management clarify:
1. Done / Open? 2. "Product Backlog"? 3. What's to be done in the next sprint?

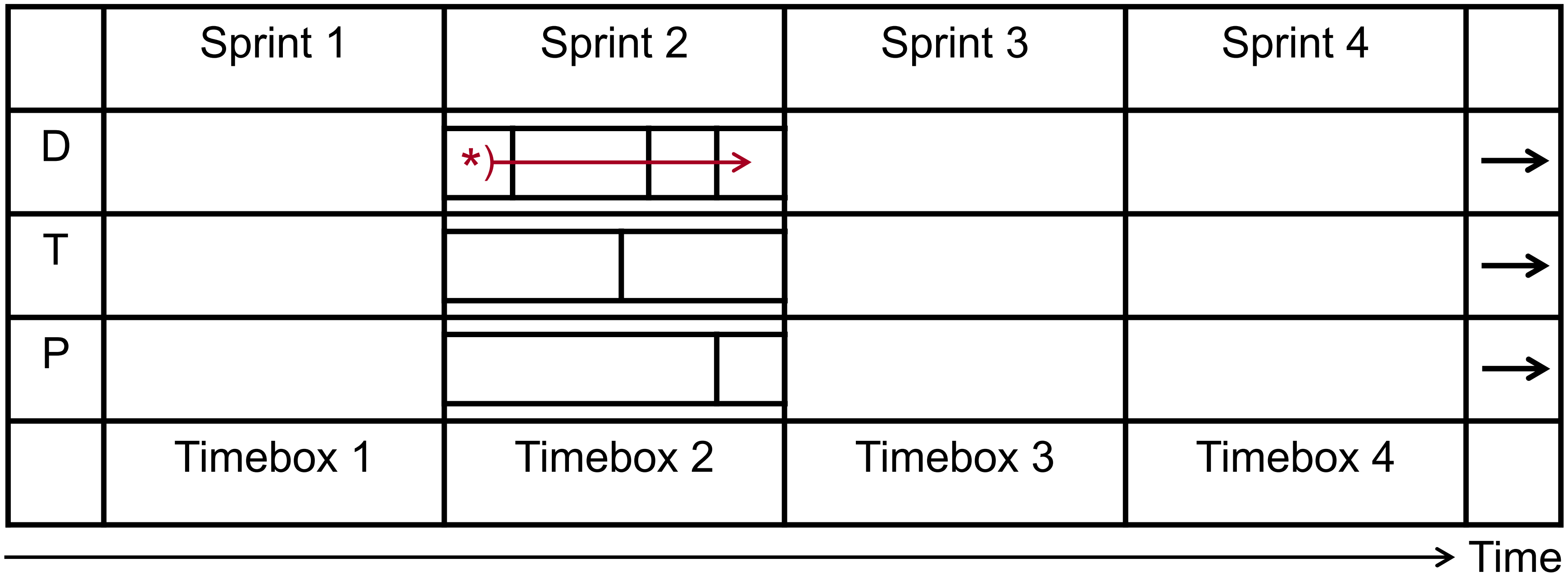


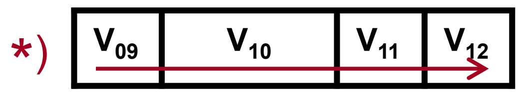
Rainer Buerstinghaus

Paradigm Shift in Planning, Implementation and Control

With clocked iteration to the goal: "Sprint Backlog (ToDo)".

Sprint Planning 2. The development team and product management clarify: Which *priority* individual activities can be implemented within next two weeks?





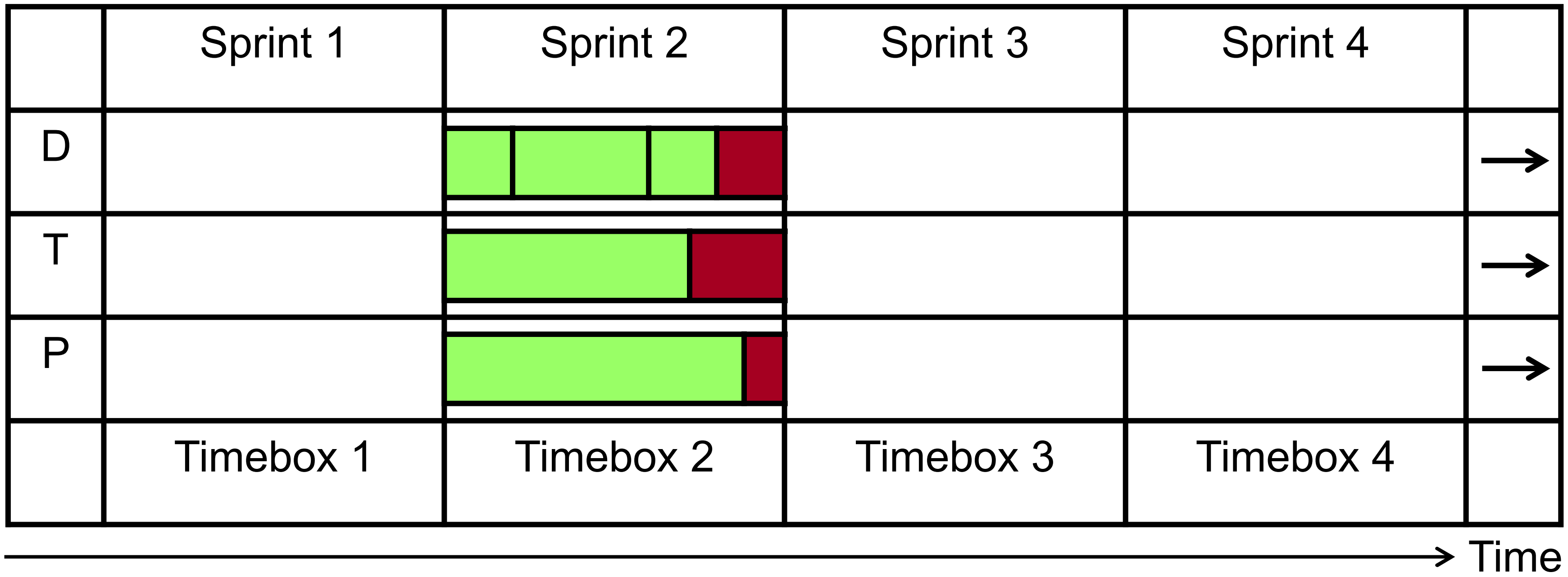
Example 1

Four priority individual activities that the team wants to implement within next two weeks.

Paradigm Shift in Planning, Implementation and Control

With clocked iteration to the goal: The "Sprint Review".

Review of Sprint 2. Development team and product management clarify:
1. Done / Open? 2. "Product Backlog"? 3. What's to be done in the next sprint?



Completed Activities (→ "Sprint Review")

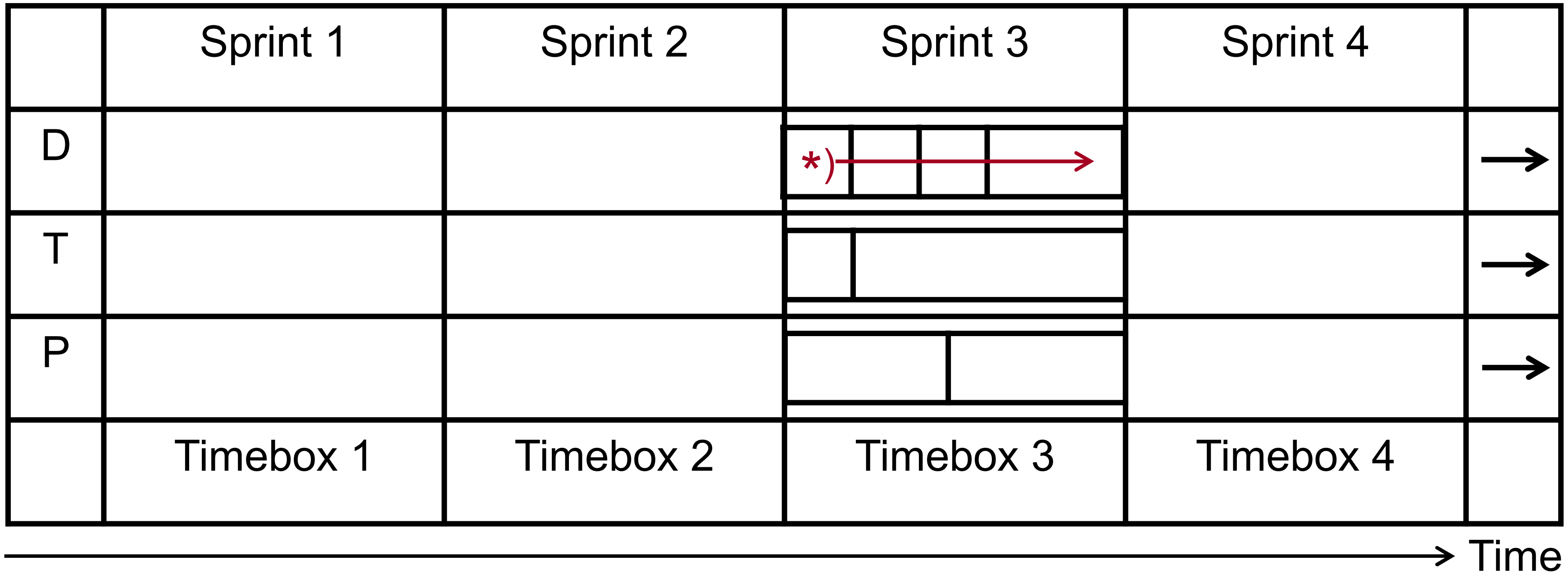
Open Activities (→ "Sprint Backlog")

Rainer Buerstinghaus

Paradigm Shift in Planning, Implementation and Control

With clocked iteration to the goal: "Sprint Backlog (ToDo)".

Sprint Planning 3. The development team and product management clarify: Which *priority* individual activities can be implemented within next two weeks?

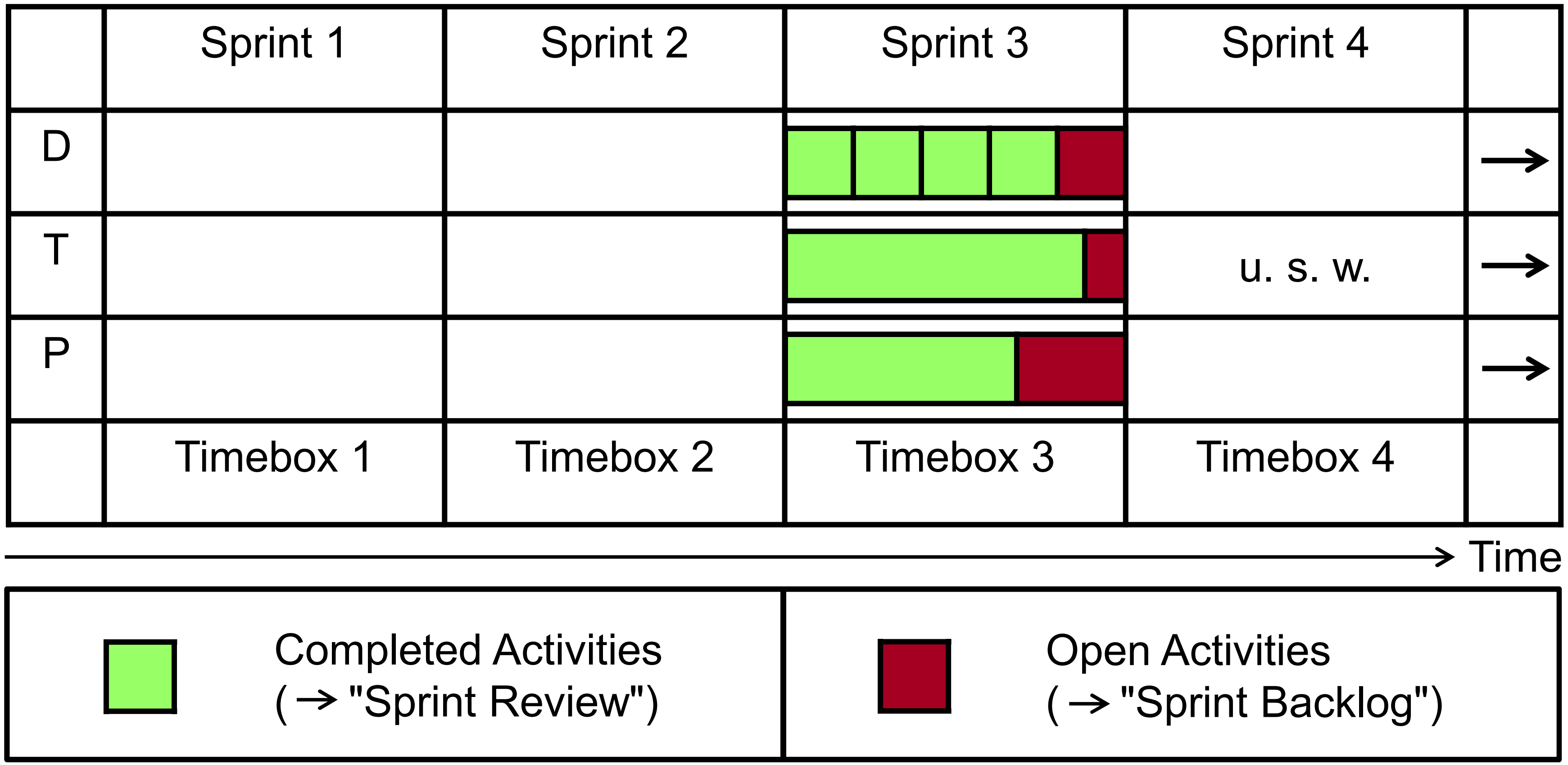


Four priority individual activities that the team wants to implement within next two weeks.

Paradigm Shift in Planning, Implementation and Control

With clocked iteration to the goal: The "Sprint Review".

Review of Sprint 3. Development team and product management clarify:
1. Done / Open? 2. "Product Backlog"? 3. What's to be done in the next sprint?

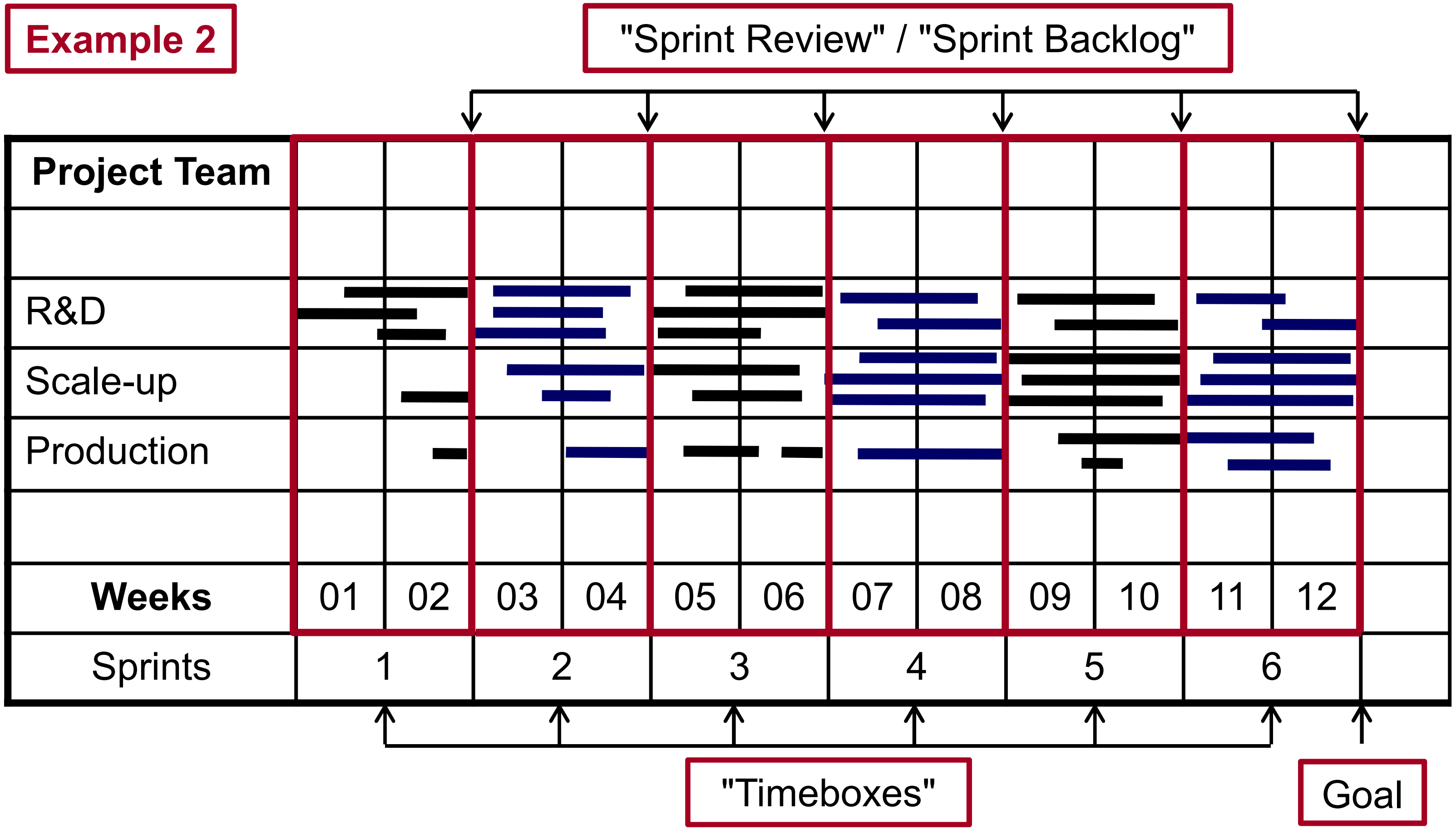


Rainer Buerstinghaus

Paradigm Shift in Planning, Implementation and Control

The "agile" working method: With clocked iteration to the goal.

Project Plan according to Henry Gantt: All subsequent activities (for a two weeks period) each have to be newly planned after each individual sprint!



Paradigm Shift in Planning, Implementation and Control

The "agile" working method: With clocked iteration to the goal.

Advantages: +

- Suitable for innovations using "modular systems".
- Accelerated development of new reactors, analysis devices or IT-based laboratory automation.
- Fast and market-oriented creation of complex formulations, recipes and mixtures of substances.
- Fast reactions to changes in external/internal framework conditions and to deviations from the plan.
- Constant market proximity, effective customer orientation.
- Strict and effective time management.
- Effective strengthening of motivation in the development team.

Paradigm Shift in Planning, Implementation and Control

The "agile" working method: With clocked iteration to the goal.

Disadvantages: ⛔

- Very limited applicability in basic research projects.
- In chemistry as an exact natural science, “80% solutions” before doing follow-up experiments are unacceptable.
- The results of *really* new chemical syntheses and process optimizations can hardly be estimated in advance.
- Hardly applicable for complex life sciences projects with extensive ecotoxicological test series.
- Unsuitable for projects with numerous regulatory requirements (e.g. EU chemicals regulation, REACH).
- Before customers can be involved in iterative product opti-mizations, detailed cooperation agreements are required.

Decisions, Phases of Decision Making:

1. Clarification of the Matter	Question
The exact definition of the thing to be decided, clarification of the starting position.	What exactly is up for decision? (A complete and precise description is important here!)

2. Search for Alternatives	Question
The identification of all meaningful and goal-oriented decision options.	What alternatives are available? (Uncompromising completeness is important here!)

Effective Implementation and Control of R&D-Projects

Decisions, Phases of Decision Making:

	3. Decision Criteria	Question
◇	Compilation of all criteria necessary for a goal-oriented decision.	Which decision criteria are really indispensable for the achievement of the target system?

	4. Risk Analysis	Question
◇	Showing the consequences of implementing the favored alternative.	What undesirable "side effects" or project relevant disadvantages can the associated decision entail?

Decisions, Phases of Decision Making:

	5. Decision	Question
	Decision and release of the processes derived from it for implementation.	How will the decision be announced (choice of communication path)? Who will be informed?

	6. Implementation	Question
	Determination of the measures to fully implement the decision made.	What is the action plan with a verifiable: "Who?" does "What?" with "Whom?" to "When?"

Effective Implementation and Control of R&D Projects

Diverse Types of Decision in an Ongoing R&D Project:

◇	**Consensus Decision**
⊕	Acceptance of *all* project participants. High realization potential. Fully discussed conflicts. The obstacles to implementation have been recognized and taken into account.
⊖	High time and coordination effort. Danger of a seeming consensus or a "shaky" compromise.

Rainer Buerstinghaus

Diverse Types of Decision in an Ongoing R&D Project.

◇	**„Democratic“ Decision**
+	A 2/3-majority for important decisions is useful if a 100%-consensus has not been found. An intensive exchange of arguments has taken place.
−	"Suppression" of minority opinions with subsequent "blockade mentality". Not all participants bring up all the important information. Purely "political" decisions are possible.

Diverse Types of Decision in an Ongoing R&D Project.

◇	**Decision by One Person (for Example by the Project Manager)**
+	Little expenditure of time, fast implementation of the necessary activities. Only useful in "emergencies" and situations with high time pressure. No discussions are necessary!
−	Possibly, low acceptance among the other project participants. The decision may not be revised, corrected or improved for reasons of "saving face".

Effective Implementation and Control of R&D Projects

Status Report as Information Source for the T. S. C.:

- **Current Project Status**
  - Technical progress (product, process).
  - Achievement of milestones/targets.
  - Deviations from the project plan.
  - Accumulated resource consumption.
- **Review** of the agreecd decisions/actions from the previous meeting.
- **Planned Actions.**
- **Required Resources** (personal/equipment).
- **Expected Project Profitability** ,CMI (3rd year)/total costs.
- **Decisions**, to be made by the Technical Steering Committee (T. S. C.).

Example P1

Status Report for the Project A021, […GmbH 1] (For Steering Committee Meeting on 28.06.2020).

Project	**"Highly Elastic Clear Coats for the OEM Automotive Sector".**
	→

Rainer Buerstinghaus

Status Report: Project A 021, […GmbH 1] (T.S.C.-Meeting on 28.06.2020).

Target Agreements: "Highly Elastic Clear Coats for the OEM…"

Technical Components (P, Excerpt):

- Gloss retention of the clear coats, AMTEC-Kistler-test: >90%.
- Nanoindentation-test: 95% Elastic recovery (AFM, at $\vec{F}$ = 80 µN).
- Elasticity of the 4-layer structure (Erichsen-test DIN-ISO 1520): 3,5 mm.
- UV-Resistance: 2000h UVcon-A (λ ≥ 320 nm), UVcon-B (λ ≥ 280 nm).
- Adhesion to the base coats, 20ºC; Cross-hatch test (DIN-ISO 2409): 0. → →

Temporal Components (T, Excerpt):

- Project Start: 01.08.2019; Project End: 31.07. 2022. → →

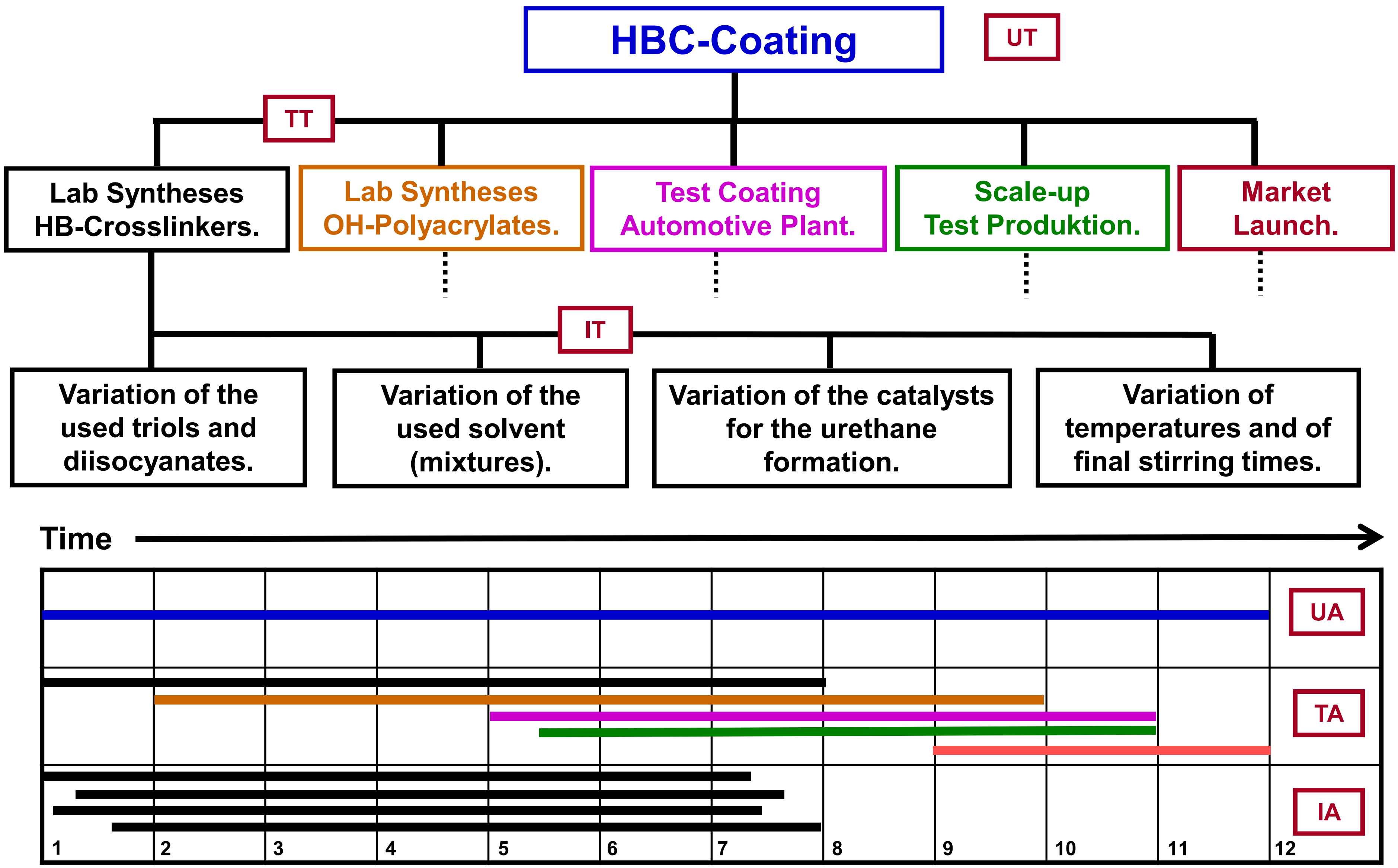
Economic Components (E, Excerpt):

- Market share for automotive-OEM clear coats within EU: 35%.
- System supplier at [Automotive…AG1], assembly line Munich.
- Project costs: 19.800.000 €; Return of investment period: From 01.04.2025.
- Production costs of the clear coat: Maximum of 5,70 €/kg. → →

Rainer Buerstinghaus

Status Report: Project A 021, […GmbH 1] (T.S.C.-Meeting on 28.06.2020).

Structure Plan/Flow Plan "Highly Elastic Clearcoats for the OEM…" :

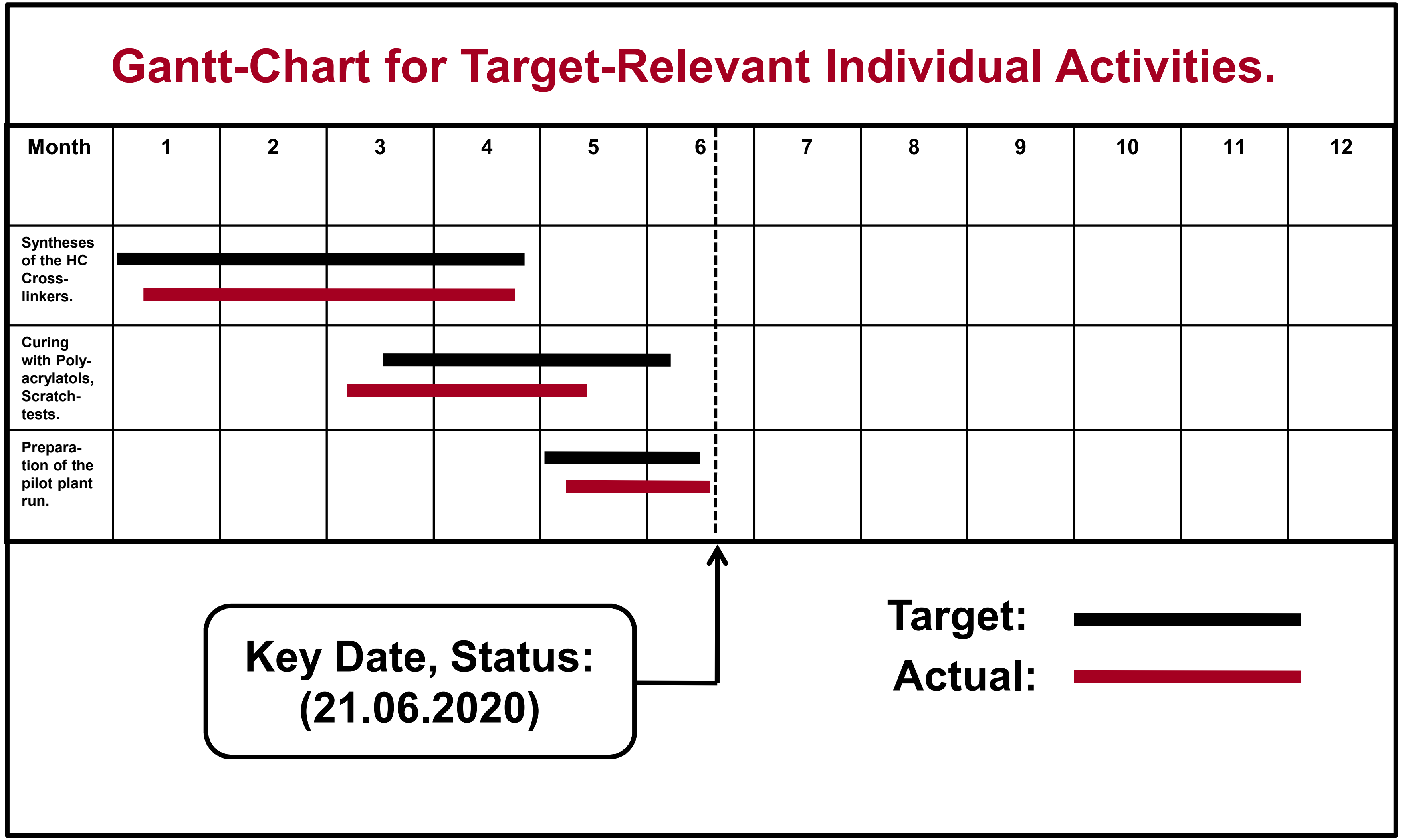


Status Report: Project A 021, […GmbH 1] (T.S.C.-Meeting on 28.06.2020).

Current Project Status; Technical Progress.

- A reproducible laboratory synthesis (500g) of the hyperbranched crosslinker HC 17 based on trimethylolethane and isophorone diisocyanate has been developed.
- After curing with 7% HC17, the OH-functional polyacrylate ST 2117 (OH number: 34) produces a specification-compatible, scratch-resistant coating film.
- The water resistance of the clear coat film could be increased to the required level by the insertion of 3% ethylhexyl acrylate.
- Preparations for the first technical run of the polymer ST 2117 in 10 kg-scale are completed.
- Technical purchasing department has requested PUR suppliers to clarify the delivery conditions for 98.5% IPDI by III/ 2020.
- The first 1 kg wet samples were handed over to [Automotive …AG1] for the check of a first turbo-bell application at 80 kV under conditions of line production.

Status Report: Project A 021, […GmbH 1] (T.S.C.-Meeting on 28.06.2020).



Rainer Buerstinghaus

Status Report: Project A 021, […GmbH 1] (T.S.C.-Meeting on 28.06.2020).

Review of the Agreed Decisions / Actions.

- Laboratory syntheses and initial coating testing with hyperbranched crosslinkers based on TMP, TME, glycerine, TDI, IPDI, HDI and MDI: **Done**.
- Using the technology of [Conveyor…AG2] and [Automotive …AG1], the first practical test applications were prepared: **Done**.
- The producer was contacted by the purchasing department regarding the delivery capability of glycerol in the tons -scale: Firm commitment: **Done**.

Planned Actions Until December 2020.

- Pilot plant synthesis of the OH-functional polyacrylate ST 2117 on a 500 kg scale.
- Laboratory synthesis of the hyperbranched Crosslinker HC 17 on a 5 kg scale.
- Determination of the functioning solvent combination and the suitable additive composition for the formulation of the liquid paint.

Status Report: Project A 021, […GmbH 1] (T.S.C.-Meeting on 28.06.2020).

Current Project Status; Achievement of Milestones.

Deadlines	Milestones	Check
01.08.2019	Project Start.	✓
31.01.2020	Laboratory syntheses of all hyperbranched crosslinkers.	✓
16.03.2020	Laboratory tests of the clear coats.	✓
20.09.2020	Synthesis of the new crosslinkers in 10kg-scale.	
30.11.2020	Completed, successful trial varnishing at [Automotive …AG1] after the use of professional line robotics.	
31.03.2021	Specifications compliant and reproducible pilot plant production (400 kg) of the crosslinker.	
16.09.2021	Complete data for the REACH registration of HC 17.	
30.11.2021	Production: 1t-Batch o.k.	
31.12.2021	Customer-approval from [Automotive…AG1].	
31.05.2022	Completed production decision procedure.	
15.06.2022	Continuous production, sales and customer service.	
31.07.2022	Project End.	

Status Report: Project A 021, […GmbH 1] (T.S.C.-Meeting on 28.06.2020).

Current Project Status; Deviations from Project Planning.

No significant deviations from project planning. Milestone A021/4 will probably be reached in time if the supply of raw materials for the pilot plant trial is guaranteed.

Project Status, Accumulated Resource Consumption.

[…GmbH1]-Department	FTE (N. T. E.)	FTE (T. E.)
SCF	05,00	08,00
SCE	04,50	06,00
SCP	00,00	05,00
SCS	00,80	00,00
Sum (Σ)	**10,30**	**14,50**

$\mapsto$ ~ **€ 4.792.000**

Rainer Buerstinghaus

Status Report: Project A 021, […GmbH 1] (T.S.C.-Meeting on 28.06.2020).

Required Resources for the Project Progress (Achievement of Milestone A021/5).

[GmbH1]-Department	FTE (NT)	FTE (T)
SCF	04,00	10,00
SCE	06,00	08,00
SCP	00,00	01,50
SCS	01,00	00,00
Sum (Σ)	**11,00**	**19,50**

Material Resource:
One 10 l resin reaction vessel (stainless steel) à € 11,200.00

Decisions of Technical Steering Committee.

Approval of the resources requested above.

Expected Project Profitability.

CM I (3rd Year/Total Costs): 3.15.

GmbH1 wants to become technology leader in the E.U. clear coat market.

Rainer Buerstinghaus

Written Quarterly Report (Q. R., Project A 021, [GmbH1]).

Essential components of the Q. R., Short Form:	Purpose, addressees of the Q. R., Short Form:
- **Objective(s)** ! - **Method(s)** - **Result(s)** - **Conclusion(s)** - **Further Proceeding**	The **short form** serves as a structured **information** for the **management**, all members of the **steering committee**, as well as for **executives** from the specialized units involved!

[...GmbH1]	**R&D – Project Report**	Quarter: **I/2020**

PROJECT CODE	PROJECT TITLE
A 021	**Highly Elastic Clear Coat for OEM Automotive...** **Subproject: "HBC-Crosslinkers".**

Required Human Resources (FTE/Quarter) in Period under Review.

Department	SCF	SCE	SCP	SCS			Total
PLANNED	13,0	14,0	1,0	0,0			28,0
REAL	12,5	11,5	0,5	0,0			25,5

Objective(s):
1. Humidity resistant coating films after 240h constant climate exposure: GT = 0; No visible blisters.
2. Reproducible laboratory synthesis of the hyperbranched crosslinker HC 17 in a 500 g scale.

Method(s):
1. Synthesis of an OH-polyacrylate with 3% ethylhexylacrylate (ST 2117). The latter must be freshly destilled before reaction. It is important to stirr the reaction mixture for a final period of 5h at 142°C.
The initiator must be azobisisobutyronitrile.
2. Equivalent quantities of isophorondiisocyanate and trimethylol-ethane were reacted in dimethylacetamide under nitrogen with a yield of 98%. The temperature of this mixture must be permanently kept below 0°C, particularly during the addition of the triole. The dimethylacetamide was finally removed at 80°C and a pressure of 0,1 mbar by means of a vacuum pump.

Results:
1. The cured coating films, basing on ST 2117 and HC 17 applied over waterborn base coats passed the humidity tests without any decrease of their scratch resistance.
2. 1,5 kilograms of HC 17 were produced in three portions of each time 500g with a purity of > 99%.

Conclusion(s):
The milestone "Finalization of the coatings testing in laboratory" will be achieved in time.

Further Proceeding/Prospects:
First coating trial at customer under line conditions. Transfer of the HC 17 -synthesis into the pilot plant.

Distribution:
SCF, SCE, SCP, SCS,
Technical Steering Committee, Keeper Gate 4
Project Team

Enclosure: 29 pages

Date. 04.04.2020

Signature:

Rainer Buerstinghaus

Example P1

Project Completion Report.

The Need for a Structured Summary:

Regardless of whether the project was successfully completed or terminated prematurely (NVP, ECV negative, StageGate® Process), a **project completion report** must be prepared!

The project-specific **know-how**, the project-related **results** (also the negative results!) as well as the **project experiences** during the term are documented. Thus, future mistakes, their repetition and the corresponding associated costs are avoided.

Project Completion Report: Structure and Contents:

1.	**Project Basic Data.**	Project name, project number, project manager (m/f/d), principal(s), total term.
2.	**Analysis of the Project Results.**	Target-actual comparison in the target system from a technical, temporal, economic point of view.
3.	**Assessment of the Course of the Project.**	Participants, pilot customers, systematic approach. Intermediate results, availability of resources.
4.	**Influencing Factors: Chances, Risiks.**	External and internal factors; Unforeseeable opportunities and/or risks during the project flow.
5.	**Cooperation in the Project Team.**	Role allocation, professionalism during the joint solution of goal-oriented tasks, flexibility.
6.	**Recommendations.**	"Lessons Learned", learning successes for comparable, future projects.

The Subject Matter

- Innovations: Characteristics, Measures for its Promotion, Process Variants.
- Three Examples for Innovation Projects (Chemistry and Technology):
  1. Highly Elastic Clear Coats for the OEM Automotive Sector.
  2. Nitrilase Catalyzed Synthesis of a Chiral Hydroxy-Carboxylic Acid.
  3. New Metal-Organic Frameworks for the Adsorptive Storage of Gases.
- Projects, Target Systems, Project Management in R&D.
- Appropriate Organization and Effective Structure Planning of R&D Projects.
- Project Flow Planning, Milestones, the Stage-Gate®-Process, Network Diagrams.
- Effective Implementation and Control of R&D Projects, Trend Analyses.
- **Success Risks: Identification, Classification and Treatment.**
- Recruitment and Lead of Project Staff:
  Chemists (m/f/d) – Team Players, Pacemakers and Executives in Projects.
- Project Manager (m/f/d): Tasks, Leadership Functions and Personality Profile.
- The Systematic Evaluation of Individual R&D Projects.
- R&D Strategy: The Planning of a Project Portfolio.

Rainer Buerstinghaus

R&D Project Management in the Chemical Industry

Subject Matter →

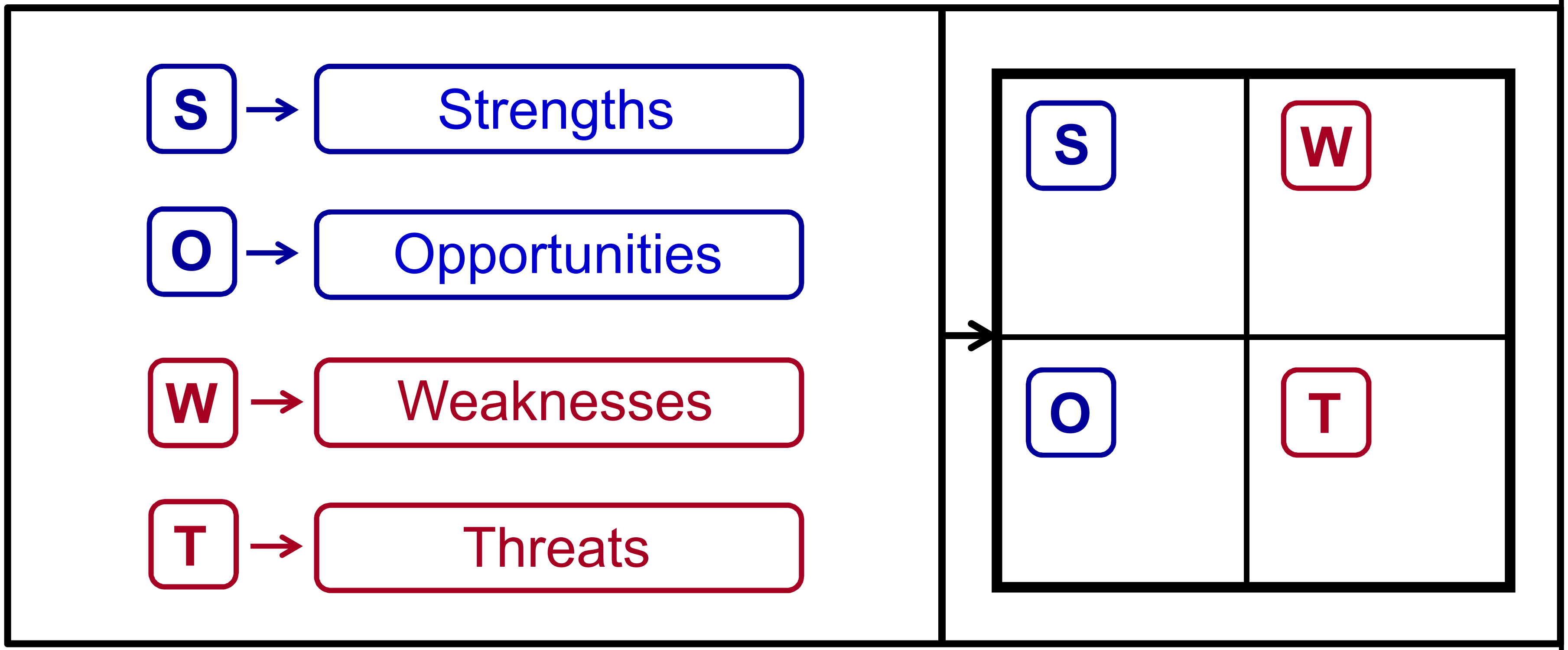
Success Risks: Identification.

Risiks, Definition, Characteristics:

- The **probabilities of potential failures** ***and*** their **effects** blocking the achievement of the project-target system.
- These potential deviations are ***not*** predictable by the project team during planning process.
- The responsibility for risk assumption lies solely at the principal (e. g. Steering Committee)!

Success Risks, Identification

"SWOT-Analysis", A Strategic Assessment Tool:

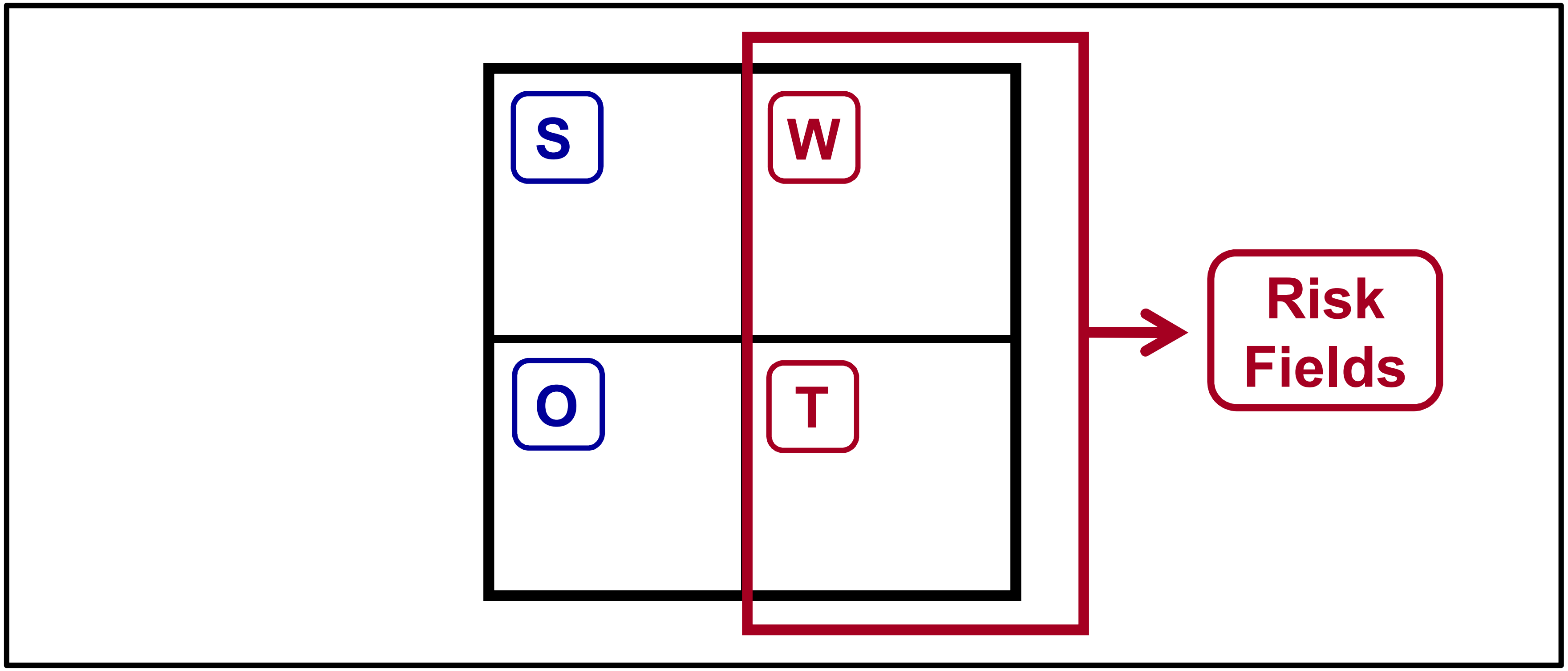


(Harvard Business School, since 1960)

Success Risks, Identification

"SWOT-Analysis", A Strategic Assessment Tool:

S → Strengths	W → Weaknesses
O → Opportunities	T → Threats



Rainer Buerstinghaus

Risk-Relevant Deviations in R&D Projects.

Checklist for potential deviations:
(Here: Chemical-Technical).

01. A synthesis step does not work in the laboratory.
02. A reaction step is not capable for scale-up.
03. Danger of explosion during manufacture/use.
04. Danger of poisoning during production/use.
05. Unintended side-effects when using.
06. Emissions to water, air, soil during manufacture/use.
07. Accidents due to non-compliance with safety regulations.
08. Raw materials or chemicals not (anymore) available.
09. Starting materials no longer available in the required purity.
10. Target product can not be produced in the required purity.

Risk-Relevant Deviations in R&D Projects.

Checklist for potential deviations:
(Here: Chemical-Technical).

11. Logistical problems internally, externally.
12. Installation delays due to insufficient infrastructure.
13. Failure of water, electricity / Energy supply is unreliable.
14. Competitors disclose new key patents.
15. The own patent has not been granted.
16. The companies of the competition are faster/better.

↓ **etc.** ↓

Risk-Relevant Deviations in R&D Projects.

Checklist for Potential Deviations:
(Here: Economical-Legal).

17. In total, the manufacturing costs for the product are too high.
18. The required starting materials are too expensive.
19. Unexpected price increases at suppliers.
20. Excessive investment costs for the production plant.
21. Excessive cost of market introduction.
22. Incalculable additional costs due to project change dynamics.
23. Currency risks, defaults by pilot customers.
24. Problems with customs regulations.
25. Dwindling market importance of the target product.

Risk-Relevant Deviations in R&D Projects.

Checklist for Potential Deviations:
(Here: Economical-Legal).

26. New legislation, prohibition of substances.
27. Refusal of regulatory approval.
28. Unclear contract formulations for cross company projects.
29. Insufficiently qualified personnel.
30. Unpredictable staff shortages.

↓ **etc.** ↓

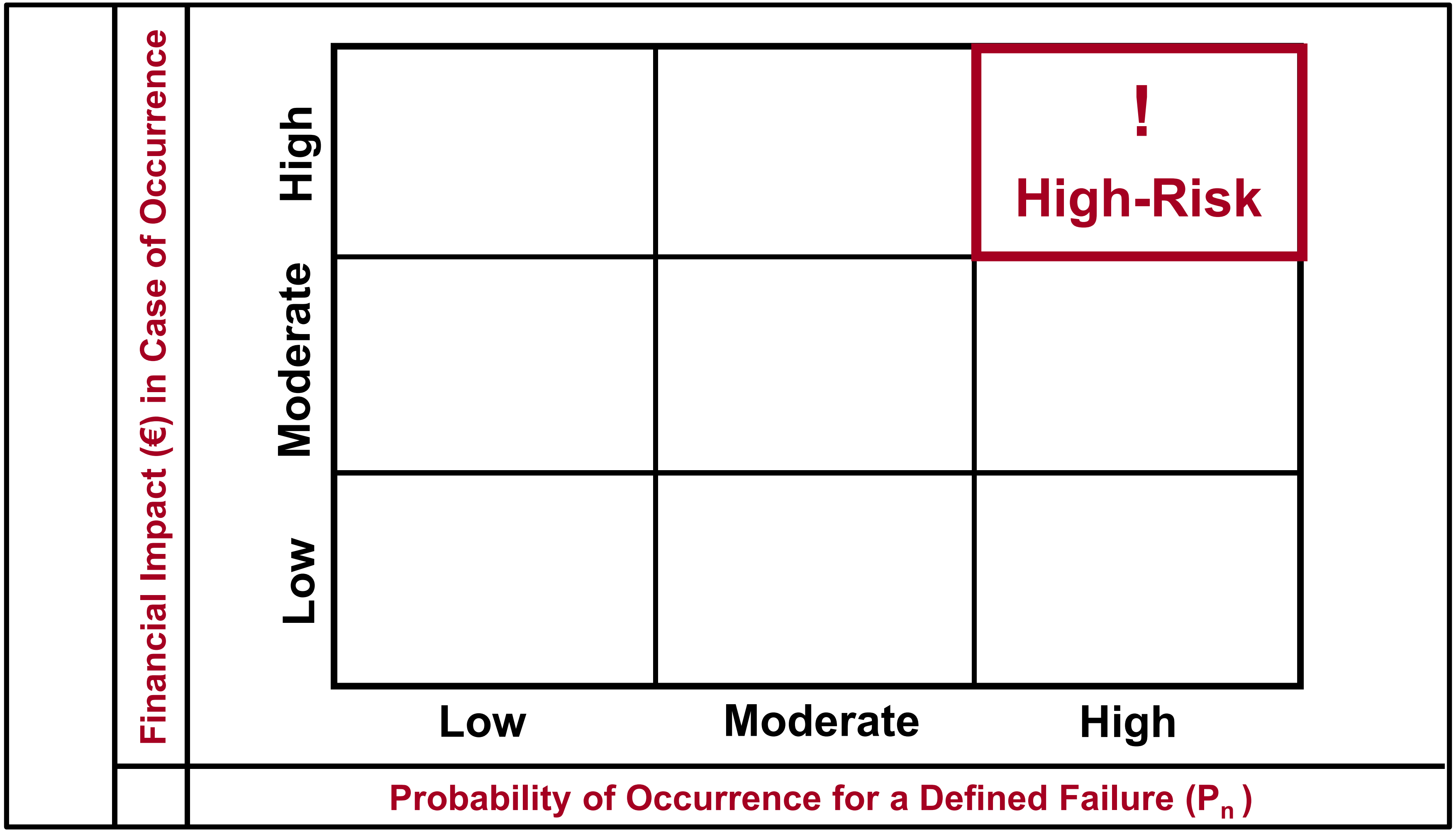
R&D Project Management in the Chemical Industry

Subject Matter →

Success Risks: Classification and Treatment.

Success Risks, Classification

Joint Assessment through R&D, Marketing, Sales, Production, Environmental Protection/Industrial Safety:



Success Risks, Classification

Probability of Occurrence for a Failure (P_n):

Estimated Value $0 \leq W_n \leq 1$

0	**< 0.05**	**0.05 - < 0.25**	**0.25 - < 0.60**	**0.60 - < 0.90**	**> 0.90**
Excluded	**Very Low**	**Low**	**Moderate**	**High**	**Very High**

Rough Classification

Success Risks, Classification → Risk Value

Definition: Risk Value R_n(€) =
Probability for a Failure (P_n) X Financial Impact (€).

The amount of risk associated with a defined failure is roughly estimated by means of **R_n(€)**.

Impact (€): Expected financial loss (€) on occurrence of the failure. →

- Subproject fails (Loss in the scope of the sub-budget).
- Project fails (Loss in the scope of the project budget).
- Losses beyond the scope of the project (For example, contractual penalties, loss of profit due to cancellation of all follow-up orders, image losses, price falls in the shares of own company, etc.).

Success Risks, Classification → Risk Value

Individual Risk Values.

Important:

It must be *clearly* defined, what includes the scope of the failure in each case (Evaluated in EURO)!

Complete extent of loss!

- Project Part(s). → (€)
- Overall Project. → (€)
- Company Part(s). → (€)
- Losses beyond that. → (€)

Success Risks, Classification

Individual R&D Project with a Total Budget B_P(€).

Risk values (€), each associated with individual failures:

(Probability of a **project** critical failure P_n) X (Project budget B_P(€)).

Risk Value R_n(€); **Formula: R_n(€) = P_n X B_P(€)**

Example P1

R&D Project "Highly Elastic Clear Coats…"

Risk Values

Failure 1: The HBC is not capable for scale up process.

P_1 = 0,10; B_P = 19.800.000 € → **R_1: 1.980.000 €**

Rainer Buerstinghaus

Success Risks, Classification

Individual R&D Project with a Total Budget B_P(€).

Risk values (€), each associated with individual failures:

(Probability of a **project** critical failure P_n) X (Project budget B_P(€)).

Risk Value R_n(€); **Formula: R_n(€) = P_n X B_P(€)**

Example P1

R&D Project "Highly Elastic Clear Coats…"

Risk Values

Failure 2: Several competitors are faster.

P_2 = 0,40; B_P = 19.800.000 € → **R_2: 7.920.000 €**

Success Risks, Classification

Individual R&D Project with a Total Budget B_P(€).

Risk values (€), each associated with individual failures:

(Probability of a **project** critical failure P_n) X (Project budget B_P(€)).

Risk Value R_n(€); **Formula: R_n(€) = P_n X B_P(€)**

Example P1

R&D Project "Highly Elastic Clear Coats…"

Risk Values

Failure 3: Diisocyanate (IPDI) is not longer available.

P_2 = 0,05; B_P = 19.800.000 € → **R_2: 990.000 €**

Success Risks, Classification

Estimation of P-Values by the "Delphi Method":

Probability P_x: A synthesis step is not capable for the scale up process.

Assessment by experts from pilot plants and from production.

50%	60%	10%	50%	70%	80%	60%

ø of P_x ≈ 54%

Explanation and detailed justification of the **extreme values**:

50%	60%	10%	50%	70%	80%	60%

Reassessment:

50%	60%	20%	60%	70%	70%	60%

ø of P_x ≈ 56% → i. n.: Additional Rounds!

Rainer Buerstinghaus

Success Risks, Classification

Estimation of P-Values by the "Delphi Method":

Probability P_x: A synthesis step is not capable for the scale up process.

Assessment by experts from pilot plants and from production.

30%	30%	05%	20%	50%	60%	40%

ø of P_x ≈ 34%

Example P1

Explanation and detailed justification of the **extreme values**:

30%	30%	05%	20%	50%	60%	40%

Reassessment:

30%	25%	15%	15%	45%	50%	35%

ø of P_x ≈ **31%** → i. n.: Additional Rounds!

Risks of Several Different Projects in Comparison.

Total risk values R_{Pn}(€) of these individual projects:

(Probability of the respective **project** failure P_{Pn}) X (Individual project budget B_{Pn}(€)).

Formula: R_{Pn}(€)= P_{Pn} X B_{Pn}(€)

Examples

R&D Project 1:
P_{P1} = 0,10; B_{P1} = 2.700.000 € → **R_{P1}: 270.000 €**

R&D Project 2:
P_{P2} = 0,80; B_{P2} = 850.000 € → **R_{P2}: 680.000 €**

R&D Project 3:
P_{P3} = 0,05; B_{P3} = 431.000.000 € → **R_{P3}: 21.550.000 €**

Success Risks, Classification

R&D-Projects, Classification in View of Risk and Benefit:

Strategic Benefit \ Risk Value	low	moderate	high
high	!!	!	⚡
mode-rate	!	?	O
low	O	–	– –

Success Risks, Classification

R&D-Projects, Classification in View of Risk and Benefit:

Strategic Benefit (€) ↑			
High	Attractive R&D Investment "Hot Project".	Good R&D Investment.	High-Risk Gamble.
Mode-rate	Good R&D Investment.	Questionable R&D Investment.	Unattractive R&D Investment.
Low	Irrelevant R&D Investment ("So what").	Unacceptable R&D Investment.	Unacceptable R&D Investment ("Dead Duck").
	Low	Moderate	**High**

→ **Risk Value (€)**

Rainer Buerstinghaus

Success Risks, Classification

ABC-Analysis, Names of the Risks, Risk Values:

Risk Name	Risk Value		
Risk 1	450.000 €		
Risk 2	800.000 €		
Risk 3	1.500.000 €		
Risk 4	3.500.000 €		
Risk 5	150.000 €		
Risk 6	900.000 €		
Total Risk	7.300.000 €		

ABC-Analysis, Weighting of the Risk Values:

Risk Name	Risk Value	Percent of the Total Risk Value	
Risk 1	450.000 €	006,3 %	
Risk 2	800.000 €	010,9 %	
Risk 3	1.500.000 €	020,5 %	
Risk 4	3.500.000 €	047,9 %	
Risk 5	150.000 €	002,1 %	
Risk 6	900.000 €	012,3 %	
Total Risk	7.300.000 €	100,0 %	

ABC-Analysis, Sorting According to Risk Values:

Risk Name	Risk Value	Percent of the Total Risk Value	
Risk 4	3.500.000 €	047,9 %	
Risk 3	1.500.000 €	020,5 %	
Risk 6	900.000 €	012,3 %	
Risk 2	800.000 €	010,9 %	
Risk 1	450.000 €	006,3 %	
Risk 5	150.000 €	002,1 %	
Total Risk	7.300.000 €	100,0 %	

Success Risks, Classification

ABC-Analysis, Accumulation and Weighting.

A-, B-, C-Risks, A Basis for Risk Management:

- **A-Risks:**
  Σ of the highest %-values **≥ 80%.**

- A-Risks + **B-Risks:**
  Σ of the highest %-values ≥ 95%.

- A-Risks + B-Risks + **C-Risks:**
  Σ of all %-values = 100%.

Success Risks, Classification

ABC-Analyis, A-Risks, B-Risks, C-Risks:

Risk Name	Risk Value	Percent of Total Risk Value	Addition of the Per-centages
Risk 4	3.500.000 €	047,9 %	047,9%
Risk 3	1.500.000 €	020,5 %	068,4%
Risik 6	900.000 €	012,3 %	080,7%
Risk 2	800.000 €	010,9 %	091,6%
Risk 1	450.000 €	006,3 %	097,9%
Risk 5	150.000 €	002,1 %	100,0%
Total Risk	7.300.000 €	100,0 %	**100,0%**

"Translation" of the 80/20 Relationship from V. Pareto:

Vilfredo Friderico Pareto (1848-1923, Italian Economist)

The Pareto principle, also called Pareto effect or 80-to-20 rule, states that 80% of the results are often achieved with 20% of the total effort. The remaining 20% of the results often require the most quantitative work, accounting for 80% of the total effort.

↓

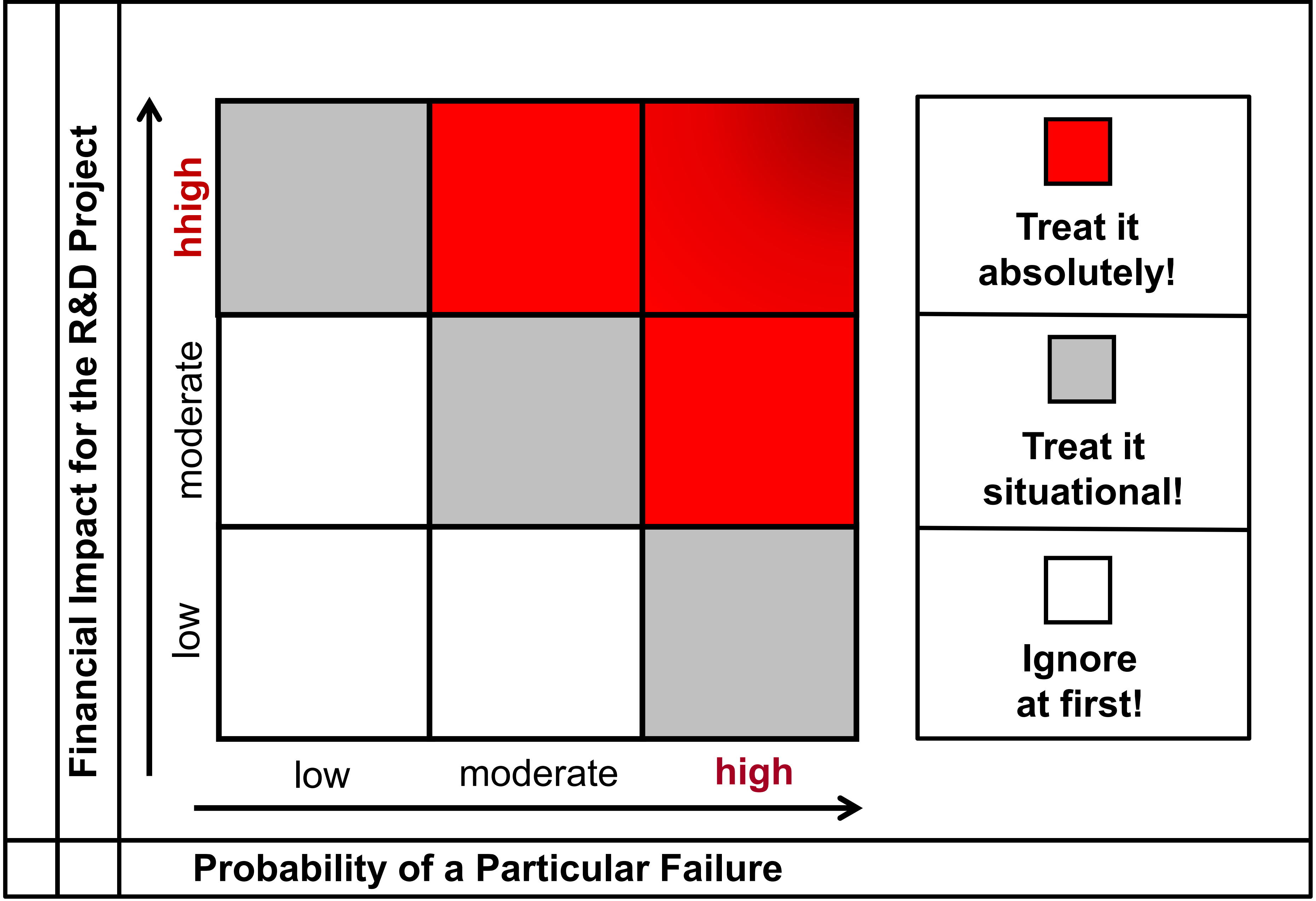
"In an innovation project, about 80% of the total risk value is caused by only about 20% of all risks."

Vilfredo Friderico Pareto
15.07.1848 - 19.08.1923

Engineering degree (Torino), till 1870

Trattato di Sociologia Generale: 1916

Success Risks, Treatment → **Analysis of the P-€-Matrix.**



Rainer Buerstinghaus

Checklist for the Control (Precautionary Strategy):

01. Complete clarification of the state of the art/science.
02. Early strategic patent applications.
03. Use of "Lessons-Learned-Archives".
04. Planning and implementation of strict quality assurance measures.
05. Audits of suppliers. If necessary: Supplier change.
06. Systematic design reviews.
07. Use of experienced employees in the project.
08. Target oriented qualification of project staff.
09. Clear definition of responsibilities (IMV).
10. Regular risk analyzes.
11. Expert surveys in the planning phases.
12. Precautionary development of alternative syntheses/processes.
13. Upstream feasibility studies on a laboratory scale.
14. Exit clauses in cooperation agreements.
15. Currency hedges.

→ →

Success Risks, Treatment

Checklist for the Control (Direct Interventions):

01. Additional individual activities have to be planned in advance.

02. Changes in individual activities.

03. Changes in the project resources.

04. Overtime for the completion of additional activities.

05. More frequent, action-oriented project reviews.

06. To obtain additional expert opinions.

07. Adjustment of the project budget.

08. On-site inspections, (Laboratory, production, customer facilities).

↓ **etc.** ↓

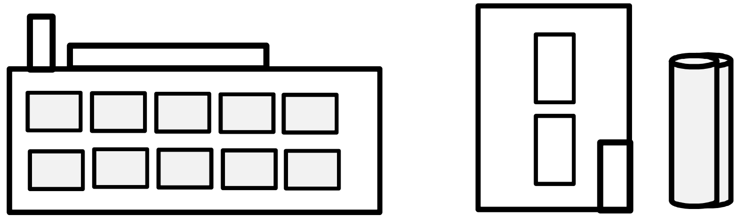
Example P2

Identification, Classification and Treatment of Risks in R&D Projects:

Project **"Nitrilase-Catalyzed Synthesis of a Chiral α-Hydroxycarboxylic Acid".**

Success Risks, Identification and Classification

R&D Project "Nitrilase-Catalyzed Synthesis….".



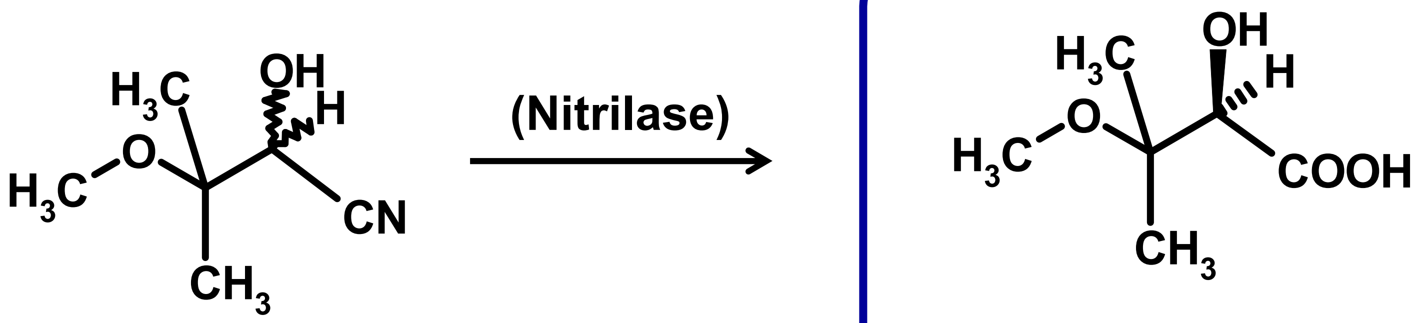
The Biotec Company: […GmbH 2], "Chipro" Manufacturer.

Size: Start-up company with 77 employees throughout Europe, including 15 (bio) chemists, 7 microbiologists, 13 engineers (FH), 4 engineers (TU).

Own research and development with attached production engineering. Active for 8 years in R&D, scale-up and manufacturing ChiPros using white biotechnology.

Specialties: Enantiomerically pure, optically active carboxylic acids, carboxylic esters and amines as intermediates for new drugs and crop protection agents.

R&D Project "Nitrilase-Catalyzed Synthesis of an Enantiomeric Pure α-Hydroxy-Carboxylic Acid".



(A)

(R)-2-Hydroxy-3-methoxy-3-methyl-butanoic acid (A).

Success Risks, Identification and Classification

SWOT-Analysis: "Nitrilase-Catalyzed Synthesis…"

S → Strengths

O → Opportunities

W → Weaknesses

T → Threats

S	W
O	T

Example 2 →

SWOT-Analyse, "Nitrilase-Catalyzed Synthesis…"

S	W
Optimal access to the latest biotechnology R&D results through an active, transnational research network of universities and research institutes. Solid raw material base through reliable and safe cyanohydrin deliveries within the company's own holding. Experience in the breeding, the scale-up and the cultivation of stable, transgenic microorganisms.	Dependence on the producers / suppliers of kanamycin resistance-inducing plasmid vectors. Toxicity of HCN traces against the microbes. So far, no own experience with the biotechnological production of larger quantities in continuous biotransformation plants. Additional investment in safety measures on a production scale.
O	**T**
Technology leadership for the synthesis of enantiomerically pure α-hydroxycarboxylic acids. Opportunity to become a preferred supplier of high quality intermediates to global pharmaceutical or crop protection companies. Image gain with the technical production of innovative, chiral intermediates. Significant increase in operating income and cash flow from the successful marketing of a specialty chemical in the high-price segment.	Collapse of cell cultures for biotransformation by transfections with malignant viruses or phages. Problems with the expression of nitrilase with introns and foreign codons in the host organism. Failure of REACH product approval So far undisclosed nitrilase patent applications from competitors. More efficient alternative syntheses, e.g. those with transition metal-catalyzed, stereoselective hydroformylations as a key step.

Rainer Buerstinghaus

Success Risks, Classification

"Nitrilase-catalyzed Synthesis of an α-OH-Carboxylic Acid": ABC-Analysis, Name of the Risks, Risk Values.

Risk, Name	**Risk Value**	Example P2	
Nitrilase patent applications of competitors.	6.260.000€		
No release of the production plant by the trade supervisory authority.	1.210.000€		
The scaling-up to continuous production does not work.	2.020.000€		
Transition metal-catalyzed, more efficient alternative syntheses.	2.630.000€		
Dependence on the suppliers of the most effective plasmids.	400.000€		
Transfection/Collapse of the cell culture in the bioreactor.	7.680.000€		
Σ, Total Risk Value	20.250.000€		

Success Risks, Classification

"Nitrilase-catalyzed Synthesis of an α-OH-Carboxylic Acid": ABC-Analysis, %-Weighting of the Risk Values.

Risk, Name	**Risk Value**	**Precent of the Total Risk**	
Nitrilase patent applications of competitors.	6.260.000€	031	
No release of the production plant by the trade supervisory authority.	1.210.000€	006	
The scaling-up to continuous production does not work.	2.020.000€	010	
Transition metal-catalyzed, more efficient alternative syntheses.	2.630.000€	013	
Dependence on the suppliers of the most effective plasmids.	400.000€	002	
Transfection/Collapse of the cell culture in the bioreactor.	7.680.000€	038	
Σ, Total Risk Value	20.250.000€	100	

Success Risks, Classification

"Nitrilase-catalyzed Synthesis of an α-OH-Carboxylic Acid": ABC-Analysis, Sorting According to Risk Values.

Risk, Name	**Risk Value**	**Precent of the Total Risk**	
Transfection/Collapse of the cell culture in the bioreactor.	7.680.000€	038	
Nitrilase patent applications of competitors.	6.260.000€	031	
Transition metal-catalyzed, more efficient alternative syntheses.	2.630.000€	013	
The scaling-up to continuous production does not work.	2.020.000€	010	
No release of the production plant by the trade supervisory authority.	1.210.000€	006	
Dependence on the suppliers of the most effective plasmids.	400.000€	002	
Σ, Total Risk Value	20.200.000€	100	

Success Risks, Classification

"Nitrilase-catalyzed Synthesis of an α-OH-Carboxylic Acid": ABC-Analysis, A-Risks, B-Risks, C-Risk.

Risk, Name	Risk Value	Precent of the Total Risk	Addition of the Percentages
Transfection/Collapse of the cell culture in the bioreactor.	7.680.000€	038	038
Nitrilase patent applications of competitors.	6.260.000€	031	069
Transition metal-catalyzed, more efficient alternative syntheses.	2.630.000€	013	082
The scaling-up to continuous production does not work.	2.020.000€	010	092
No release of the production plant by the trade supervisory authority.	1.210.000€	006	098
Dependence on the suppliers of the most effective plasmids.	400.000€	002	100
Σ, Total Risk Value	20.200.000€	100	100

Example P3

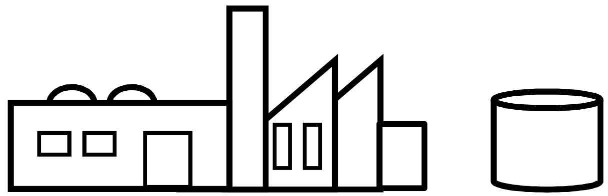
Identification and Treatment of Risiks in R&D Projects:

Subproject

"New Metal Organic Frameworks for the Adsorptive Storage of Hydrogen Gas".

→

R&D Subproject "New MOFs for the…of Hydrogen Gas".



The Company […GmbH 3], Manufacturer of Metal Organics.

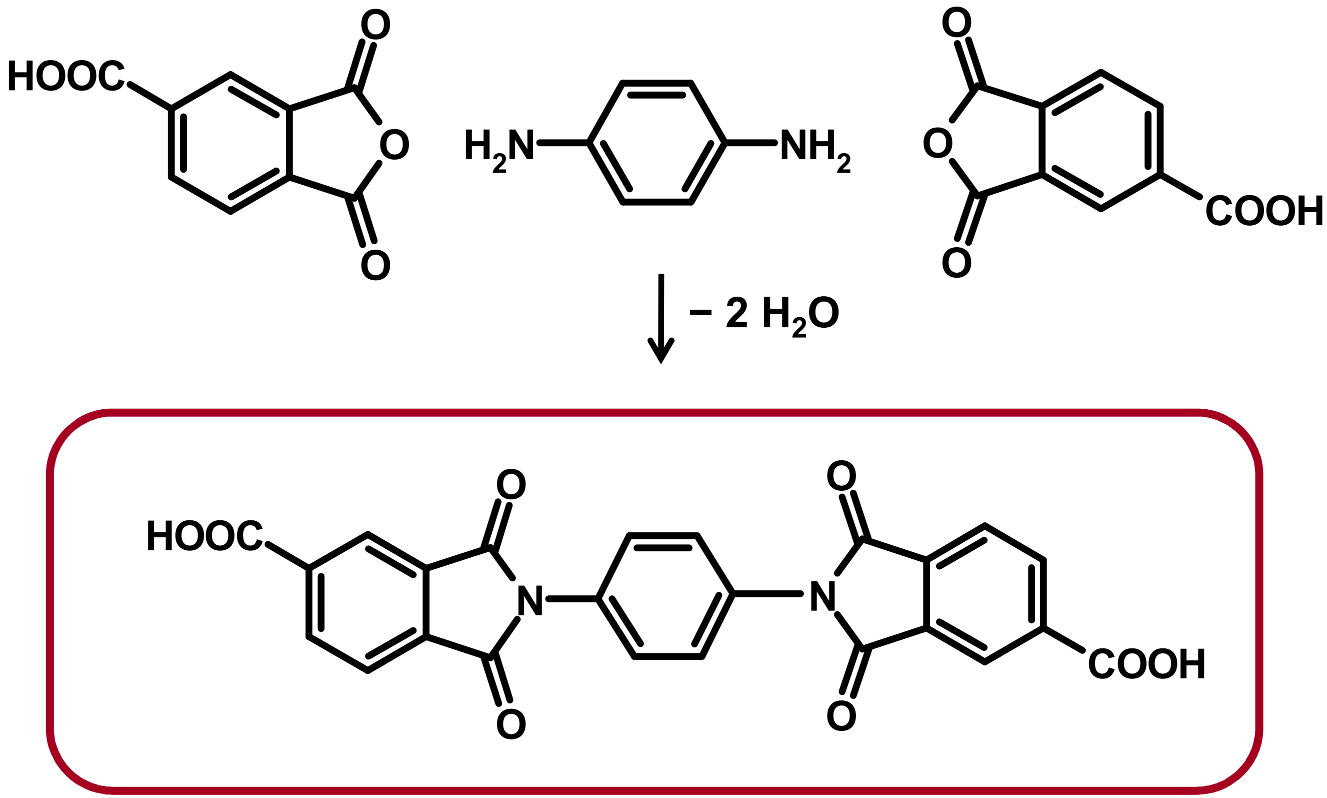
Size: Medium-sized enterprise, 127 employees throughout Europe, including 11 chemists, 17 engineers (FH), 5 engineers (TU). Manufacturer and distributor of special metal-organic compounds.

Own research and development, own production facilities.
Active for 12 years in R&D, scale-up and contract manufacturing of metal-organic compounds.

Organic specialities: Production and distribution of TMA (trimellitic anhydride) and PMA, (pyromellitic anhydride).

Success Risks, Identification and Classification

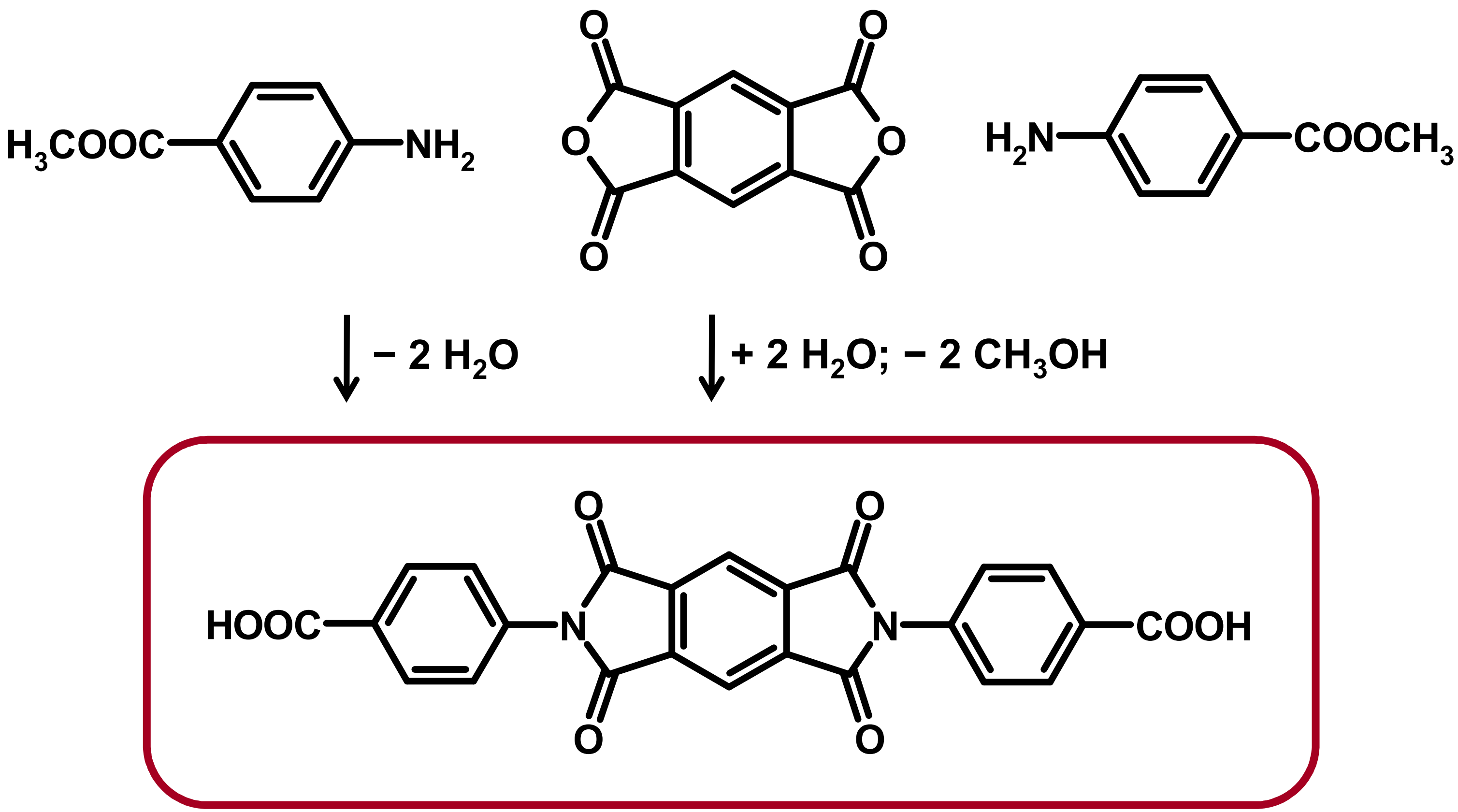
R&D Subproject "New MOFs for the…of Hydrogen Gas".



Rainer Buerstinghaus

Success Risks, Identification and Classification

R&D Subproject "New MOFs for the…of Hydrogen Gas".



Success Risks, Identification and Classification

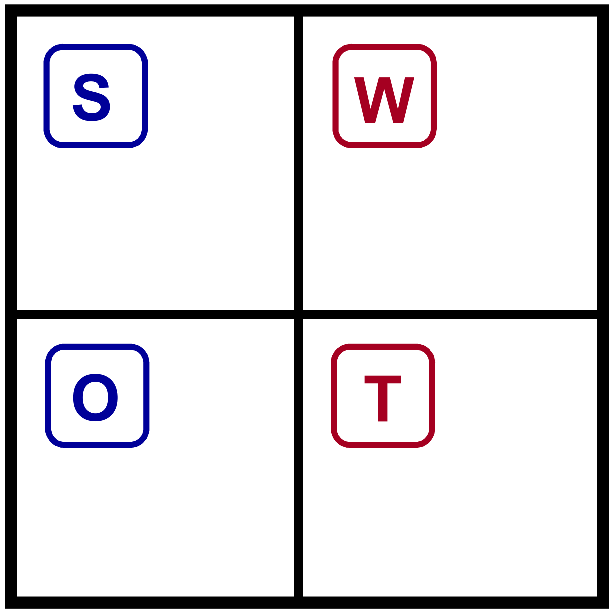
SWOT-Analysis: "New MOFs…Storage of Hydrogen Gas".

S → Strengths

O → Opportunities

W → Weaknesses

T → Threats



Example 3 →

Rainer Buerstinghaus

SWOT-Analysis: "New MOFs…Storage of Hydrogen Gas".

S	W
Very good access to the latest knowledge about Metal Organic Frameworks through an active, international research network, consisting of universities and research institutes. Strong raw material base: Own availability of TMA and PMA on an industrial scale. Experiences with the scale-up of MOFs and with electrochemical syntheses of highly porous materials.	Dependencies on the suppliers of the required metal salts for the "connectors". No own experience with technical drying processes of highly porous, ultralight materials. Unsolved recycling technology or disposal technology for the solvents used, in particular those for diethyl-formamide.
O	**T**
Technology leadership in the market for the adsorptive storage of hydrogen. Long-term prospects of success for combustion engines based on "hydrogen technology". Opportunity to distinguish oneself as a supplier to Daimler, VW, BMW and General Motors. Image gain as an innovative problem solver for gas storage technology.	So far, undisclosed MOF patent applications by (start-up) companies. Solar technology in combination with high-performance batteries as a more efficient alternative to hydrogen technology for vehicle propulsion. Unclear toxicology, unexamined fire and explosion behavior of MOFs and MOF-H2 adsorbates. The later approval by EChA is by no means certain.

Rainer Buerstinghaus

Success Risks, Classification

R&D Subproject "New MOFs for…Storage of H_2-Gas". ABC-Analysis: Name of the Risks, Risk Values.

Example P3

Risk, Name	**Risk Value**		
MOF patent applications of competitors.	4.671.000€		
Solar technology as a substitute for the hydrogen storage.	2.595.000€		
Fire risks with the material.	1.557.000€		
Explosion risks in the material.	1.038.000€		
Dependencies on the suppliers of the inorganics.	519.000€		
Risks of toxic contamination during use of materials.	6.920.000€		
Σ, Total Risk Value	17.300.000€		

Success Risks, Classification

R&D Subproject "New MOFs for…Storage of H_2-Gas". ABC-Analysis: %-Weighting of the Risk Values.

Risk, Name	**Risk Value**	**Precent of the Total Risk**	
MOF patent applications of competitors.	4.671.000€	27	
Solar technology as a substitute for the hydrogen storage.	2.595.000€	15	
Fire risks with the material.	1.557.000€	9	
Explosion risks in the material.	1.038.000€	6	
Dependencies on the suppliers of the inorganics.	519.000€	3	
Risks of toxic contamination during use of materials.	6.920.000€	40	
Σ, Total Risk Value	17.300.000€	100	

Success Risks, Classification

R&D Subproject "New MOFs for…Storage of H_2-Gas". ABC-Analysis: Sorting According to Risk Values.

Risk, Name	Risk Value	Precent of the Total Risk	
Risks of toxic contamination during use of materials.	6.920.000€	40	
MOF patent applications of competitors.	4.761.000€	27	
Solar technology as a substitute for the hydrogen storage.	2.595.000€	15	
Fire risks with the material.	1.557.000€	9	
Explosion risks in the material.	1.038.000€	6	
Dependencies on the suppliers of the inorganics.	519.000€	3	
Σ, Total Risk Value	17.300.000€	100	

Success Risks, Classification

R&D Subproject "New MOFs for…Storage of H_2-Gas".
ABC-Analysis: A-Risks, B-Risks, C-Risk.

Risk, Name	Risk Value	Precent of the Total Risk	Addition of the Percentages
Risks of toxic contamination during use of materials.	6.920.000€	40	40
MOF patent applications of competitors.	4.761.000€	27	67
Solar technology as a substitute for the hydrogen storage.	2.595.000€	15	82
Fire risks with the material.	1.557.000€	9	91
Explosion risks in the material.	1.038.000€	6	97
Dependencies on the suppliers of the inorganics.	519.000€	3	100
Σ, Total Risk Value	17.300.000€	100	100

Further literature on the subject of "R&D project management in the chemical industry". Selection of purchasable monographs and publications in journals or in internet.

- Leker, Gelhard, von Delft, Business Chemistry, Wiley & Sons Ltd., Oxford U. K., 2018.
- Hauschildt, Salomo, Schultz, Kock, Innovationsmanagement, Verlag Franz Vahlen, München, 2021.
- Vahs, Brem, Innovationsmanagement, Schäffer-Poeschel Verlag, Stuttgart, 2015.
- Gausemeier, Dumitrescu, et al., Innovationen für die Märkte von morgen, Carl Hanser Verlag, München, 2019.
- Cooper, Top oder Flop in der Produktentwicklung, WILEY-VCH Verlag, Weinheim, 2002.
- Russo, Gleich, Strascheg, Von der Idee zum Markt, Verlag Franz Vahlen, München, 2008.
- Loch, Kavadias, Handbook of New Product Development, Elsevier, Oxford, 2008.
- Bullinger, Fokus Innovation, Carl Hanser Verlag, München, 2006.
- Offermanns, "Steinheimer Gespräche" within the FCI, personal communications, Steinheim, 2002.

- Münch, Patente, Marken, Design von A bis Z, WILEY-VCH Verlag, Weinheim, 2012.

- Gassmann, Praxiswissen Projektmanagement, Carl Hanser Verlag, München, 2006.
- Kerzner, Projekt Management, Ein systemorientierter Ansatz, mitp, Redline Verlag, Heidelberg, 2008.
- Gessler, Kompetenzbasiertes Projektmanagement, GPM-Publikation, Nürnberg, 2016.
- Patzak, Rattay, Projektmanagement, Linde-Verlag, Wien, 2014.
- Jenny, Projektmanagement - Das Wissen für den Profi, vdf Hochschulverlag an der ETH, Zürich, 2020.
- Jenny, Projektmanagement - Das Wissen für eine erfolgreiche Karriere, vdf Hochschulverlag an der ETH, Zürich, 2020.
- Drees, Lang, Schöps, Praxisleitfaden Projektmanagement, Carl Hanser Verlag, München, 2014.
- Burghardt, Projektmanagement, Publicis MCD Verlag, Erlangen, 2018.

Further literature on the subject of "R&D project management in the chemical industry". Selection of purchasable monographs and publications in journals or in internet.

- Hesseler, Projektmanagement, Verlag Franz Vahlen, München, 2015.
- Stöger, Wirksames Projektmanagement, Schäffer- Poeschel, Stuttgart, 2019.
- Litke, Projektmanagement, Carl Hanser Verlag, München, 2007, new edition announced for 2023.
- Litke, Kunow, Schulz-Wimmer, Projektmanagement, Haufe-Lexware, Freiburg, 2018.
- Madauss, Projektmanagement, Theorie und Praxis aus einer Hand, Springer Gabler, Berlin, 2020.
- Bea, Scheurer, Hesselmann, Projektmanagement, UVK-Verlag, München, 2020.
- Braehmer, Projektmanagement für kleine und mittlere Unternehmen, Carl Hanser Verlag, München, 2009.
- Klein, Projektmanagement in der Praxis, Ebook, Verlag Interna, Bonn, 2012.
- Weichselbaumer, Bley, MS-Project 2013 in 13 Stunden, epubli GmbH, Stuttgart, Berlin, 2014.
- Dittmann, Dirbanis, Projektmanagement (IPMA®), Haufe, Freiburg, 2020.
- Schels, Seidel, Projektmanagement mit Excel, Carl Hanser Verlag, München, 2016.
- Tumuscheit, Überleben im Projekt, Redline Wirtschaft, Heidelberg, 2014.
- Tumuscheit, 55 Mythen des Projektmanagements, Orell Füssli Verlag, Zürich, 2013.
- Meyer, Reher, Projektmanagement, Springer Fachmedien, München, 2020.
- Drews, Hillebrand, Kärner, Praxishandbuch Projektmanagement, Haufe, Freiburg, 2015.
- Pautsch, Steininger, Lean Project Management – Projekte exzellent umsetzen, Carl Hanser Verlag, München, 2014.
- Cole, Barker, Brilliant Project Management, Pearson Education Ltd., London, 2015.
- Andler, Tools für Projektmanagement, Workshops und Consulting, Publicis Publishing, Erlangen, 2015.
- Hüsselmann, Lean Project Management, Schäffer-Poeschel Verlag, Stuttgart, 2021

Further literature on the subject of "R&D project management in the chemical industry". Selection of purchasable monographs and publications in journals or in internet.

- Schröder, Agile Produktentwicklung, Carl Hanser Verlag, München, 2018.
- Kuster et al., Handbuch Projektmanagement, Agil – Klassisch – Hybrid, Springer Gabler, Wiesbaden, 2019.
- Ziegler, Agiles Projektmanagement mit Scrum für Einsteiger, Independ. Published, ISBN 9781729408353, 2021.
- Cooper, Edgett, Kleinschmidt, Optimizing the Stage Gate Process, Res. Technol. Management, 45, 2002.
- Cooper, What`s Next After Stage-Gate? Res. Technol. Management, 157, 2014.
- Hirzel, Alter, Niklas, Projektportfolio-Management, Springer Gabler, Wiesbaden, 2019.
- Timinger, Modernes Projektmanagement, WILEY-VCH Verlag, Weinheim, 2017.
- www.projektmanagementhandbuch.de, PMH, 2021.
- www.projektmanagement-definitionen.de, 2021.
- www.projektmagazin.de, 2021.
- GPM Deutsche Gesellschaft für Projektmanagement e.V., Kompetenzbasiertes Projektmanagement (PM4), Handbuch für Praxis und Weiterbildung im Projektmanagement, Band 1, Band 2, Nürnberg, 2019.
- Lang, Wagner, Der Weg zum projektorientierten Unternehmen, Carl Hanser Verlag, München, 2019.

- Helm, Pfeifer, Ohser, Mathematik für Wirtschaftswissenschaftler, Carl Hanser Verlag, München, 2015.
- Grieser, Mathematisches Problemlösen und Beweisen, Springer Fachmedien, Wiesbaden, 2017.
- Krischke, Röpcke, Graphen- und Netzwerktheorie, Carl Hanser Verlag, München, 2015.
- Tittmann, Graphentheorie, eine anwendungsbezogene Einführung, Fachbuchverlag, Leipzig, 2003.
- Nitzsche, Graphen für Einsteiger, Vieweg + Teubner Verlag, Wiesbaden, 2009.
- Stegbauer, Häußling, Handbuch Netzwerkforschung, Springer Fachmedien, Wiesbaden, 2010.

Further literature on the subject of "R&D project management in the chemical industry". Selection of purchasable monographs and publications in journals or in internet.

- Festel, Hassan, Leker, Bamelis, Betriebswirtschaftslehre für Chemiker, Springer, Berlin, 2001.
- Festel, Söllner, Bamelis, Volkswirtschaftslehre für Chemiker, Springer, Berlin, 2000.
- Mühlbradt, Wirtschaftslexikon, Scriptor Reihe, Cornelsen Verlag, Berlin, 2008.
- Malik, Unternehmenspolitik und Corporate Governance, Campus-Verlag, Frankfurt/Main, 2013.
- Schierenbeck, Wöhle, Grundzüge der Betriebswirtschaftslehre, Oldenbourg Verlag, München, 2016.
- Wöhe, Einführung in die Allgemeine Betriebswirtschaftslehre, Verlag Franz Vahlen, München, 2020.

- Drucker, Die Kunst des Managements, Econ Verlag, München, 2000.
- Drucker, Alles über Management, Redline Wirtschaft, Heidelberg, 2007.
- Drucker, The Effective Executive, Verlag Franz Vahlen, München, 2014.
- Malik, Management, Das A und O des Handwerks, Campus-Verlag, Frankfurt/Main, 2013.
- Malik, Führen, Leisten, Leben, Campus-Verlag, Frankfurt/Main, 2019.
- Roth, Fühlen, Denken, Handeln, Suhrkamp Verlag, Frankfurt/Main, 2007.
- Sprenger, Mythos Motivation, Campus-Verlag, Frankfurt/Main, 2014.
- Sprenger, Vertrauen führt, Campus-Verlag, Frankfurt/Main, 2007.
- Freitag, Kommunikation im Projektmanagement, Springer-Gabler, Wiesbaden, 2016.
- Schulz von Thun, Miteinander Reden, Rowohlt Verlag, Reinbeck, 2019.
- Riemann, Grundformen der Angst, Reinhardt Verlag, München, 2019.
- Csikszentmihalyi, Flow im Beruf, Klett-Cotta Verlag, Stuttgart, 2012.

Further literature on the subject of "R&D project management in the chemical industry". Selection of purchasable monographs and publications in journals or in internet.

- Horx, Das Zukunftsmanifest, Ullstein Taschenbuch Verlag, Berlin, 2002.
- Bürkle, Aktive Karrierestrategie, Springer Gabler, Wiesbaden, 2013.
- Hesse, Schrader, Das große Bewerbungshandbuch, Stark Verlag, München, 2015.
- Hesse, Schrader, 1X1 - Das erfolgreiche Vorstellungsgespräch, Stark Verlag, München, 2014.
- Püttjer, Schnierda, Trainingsmappe Vorstellungsgespräch, Campus-Verlag, Frankfurt/Main, 2019.
- Püttjer, Schnierda, Das überzeugende Bewerbungsgespräch für Führungskräfte, Campus-Verlag, Frankfurt/M, 2019.
- Püttjer, Schnierda, Das große Bewerbungshandbuch, Campus-Verlag, Frankfurt/Main, 2019.
- Stärk, Erfolgreich im Vorstellungsgespräch und Jobinterview, GABAL, Offenbach, 2018.
- Hesse, Schrader, Die hundert häufigsten Fragen im Vorstellungsgespräch, Stark Verlag, München, 2013.
- Lüdemann, Lüdemann, Die 111 wichtigsten Fragen im Vorstellungsgespräch, Redline Wirtschaft, München, 2018.
- Rohrschneider, Lorenz, Müller-Thurau, Vorstellungsgespräche, Haufe, Freiburg und Planegg, 2018.
- Engst, Willmann, Professionelles Bewerben, Bibliografisches Institut, Berlin, 2019.

- Drewermann, Glauben in Freiheit oder Tiefenpsychologie und Dogmatik, Band 1, Walter-Verlag, Olten, 1994.
- Schuler, Psychologische Personalauswahl, Hogrefe Verlag, Göttingen, 2014.
- Kanning, Personalauswahl zwischen Anspruch und Wirklichkeit, Springer-Verlag, Berlin, 2015.
- Herrmann, Die Auswahl, Wiley-VCH Verlag, Weinheim, 2016.
- Riedel, Agile Personalauswahl, Haufe Fachbuch, Freiburg, 2017.
- Autorenkollektiv „Diagnostik- und Testkuratorium“, Personalauswahl kompetent gestalten, Springer, Berlin, 2018.

R&D Project Management in the Chemical Industry

End of Lecture Module 05

Rainer Buerstinghaus