Module 30, Architectural Reasoning Introduction

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Abstract

This module introduces Architectural Reasoning using Conceptual Modeling.

May 17, 2025
status: draft
version: 1.3

SEMA System Modeling and Analysis Course

by *Gerrit Muller* USN-SE
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Abstract

The SEMA course System Modeling and Analysis is a 5 day course. Core of the course is Architectural Reasoning Using Conceptual Modeling. This course uses the CAFCR+ model with 6 views. Qualities connect all views. Threads-of-reasoning capture the architectural reasoning across views and qualities. Conceptual models visualize and capture the context, the system and its design. Quantification is a means to make problem and solution space tangible.

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status: draft
version: 0.6

day 1	introduction to modeling	exploring the case
day 2	sample customer space	functions and parts
day 3	customer space analysis	quantification and concepts
day 4	business and life cycle	integration and reasoning
day 5	modeling	wrap-up

Course Program

day 1	introduction to modeling	exploring the case
day 2	sample customer space	functions and parts
day 3	customer space analysis	quantification and concepts
day 4	business and life cycle	integration and reasoning
day 5	modeling	wrap-up

Preparation for the Course

During the SEMA course you work in teams of about 3 persons. Smaller teams (even single persons) are acceptable as well.

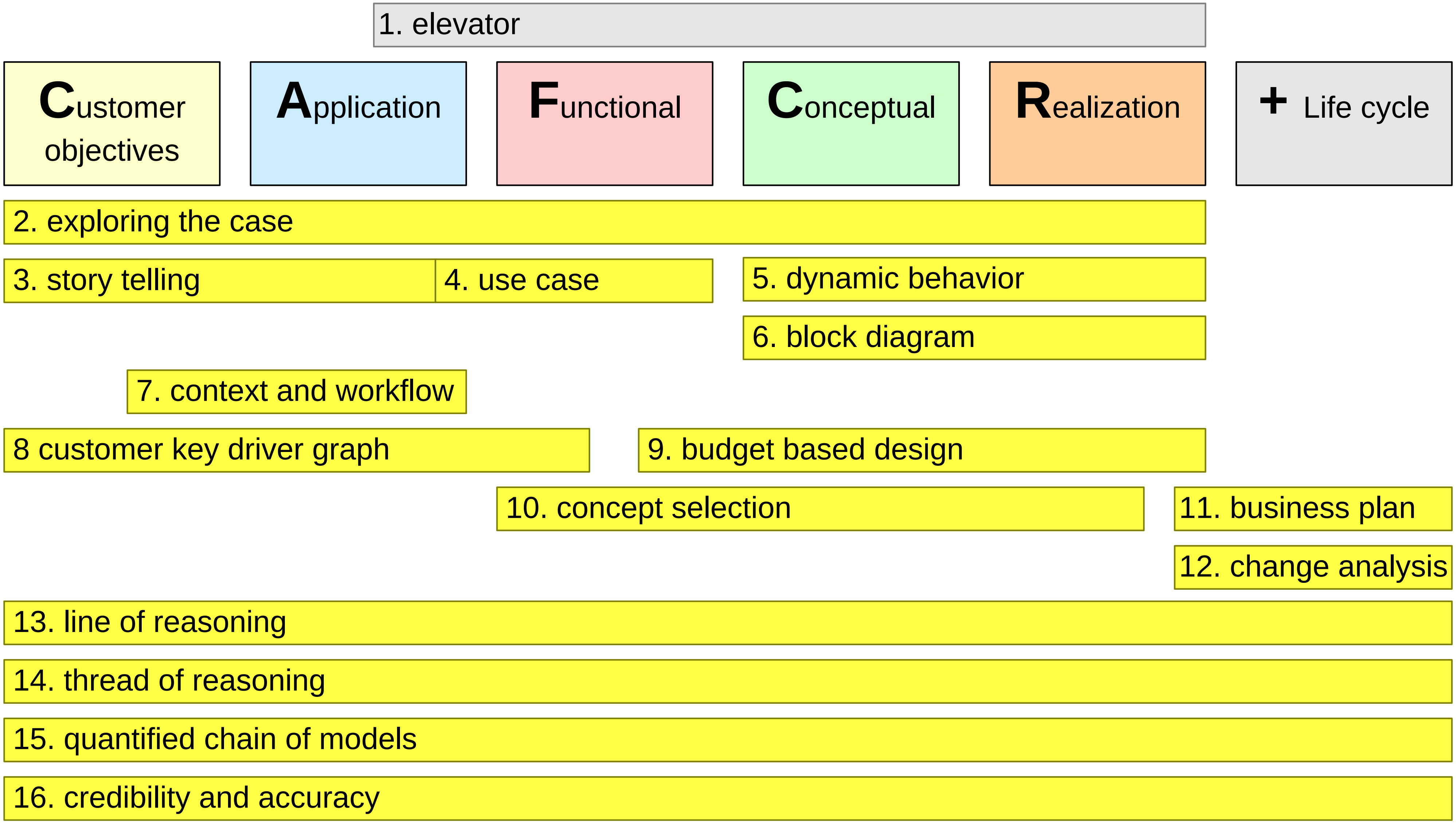
Every team preferably works on a real part of a system with some real development that goes on.

We start to model the status quo of the system and then we will model and analyze a change or addition that is being considered.

As preparation for the course I ask you the following:

- Look if the other participants are working on similar systems, such that you can work as team.
- Pick as team a system/component/function/project you will use during the course.
- For this system/component/function/project collect information about: who is the customer, what does the customer need, how is the system used, what technologies are used in the system, what are the main technological challenges et cetera. You do not have to be an expert when you come to the course, but you need to have some feeling for the system you will be working on during the course and presumably also in the 10 week project.
- If you are preparing your master project, then the master project case is probably a good option. This will boost your master project.

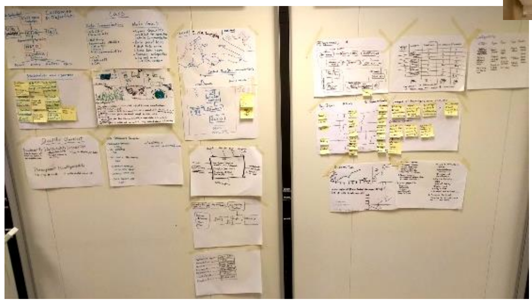
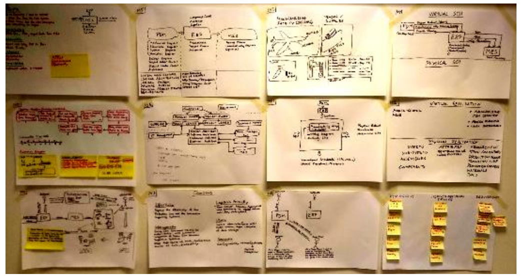
Assignments during the Course



The Classroom After the Assignments





SEMA course, September 2024
12 participants, 9 cases
using A3 paper, sharpies,
felt-tip pens, small yellow note stickers

Course Material Introduction

core

SEMA System Modeling and Analysis Course

http://www.gaudisite.nl/info/SEMAcourse.info.html

SEMA Basic Philosophy

http://www.gaudisite.nl/info/SEMAbasics.info.html

Physical Models of an Elevator

http://www.gaudisite.nl/info/ElevatorPhysicalModel.info.html

optional

Teaching conceptual modeling at multiple system levels using multiple views

http://www.gaudisite.nl/CIRP2014_Muller_TeachingConceptualModeling.pdf

Understanding the human factor by making understandable visualizations

http://www.gaudisite.nl/info/UnderstandingHumanFactorVisualizations.info.html

Dynamic Range of Abstraction Levels in Architecting

http://www.gaudisite.nl/info/DynamicRangeAbstractionLevels.info.html

Course Material CAFCR Scan

core

SEMA Method Overview

http://www.gaudisite.nl/info/SEMAmethodOverviewSlides.pdf

Short introduction to basic "CAFCR" model

http://www.gaudisite.nl/info/BasicCAFCR.info.html

InitialCAFCRscan

http://www.gaudisite.nl/info/InitialCAFCRscan.info.html

optional

Architectural Reasoning Explained

http://www.gaudisite.nl/ArchitecturalReasoningBook.pdf

Architectural Reasoning

http://www.gaudisite.nl/ArchitecturalReasoning.html

Iteration How To

http://www.gaudisite.nl/info/IterationHowTo.info.html

Modeling and Analysis: Iteration and Time-boxing

http://www.gaudisite.nl/info/MAiterationAndTimeboxing.info.html

Course Material Sample CA

core

Story How To

http://www.gaudisite.nl/info/StoryHowTo.info.html

Use Case How To

http://www.gaudisite.nl/info/UseCases.info.html

optional

Story Telling in Medical Imaging

http://www.gaudisite.nl/info/MIstories.info.html

Course Material Design Fundamentals

core
System Partitioning Fundamentals
http://www.gaudisite.nl/info/SystemPartitioningFundamentals.info.html
optional
Basic Working Methods of a System Architect
http://www.gaudisite.nl/info/BasicWorkingMethodArchitect.info.html
SubSea Modeling Example
http://www.gaudisite.nl/SubSeaModelingExampleSlides.pdf

Course Material Customer Space Analysis

core
Methods to Explore the Customer Perspective
http://www.gaudisite.nl/info/MethodsToExploreTheCustomerPerspective.info.html
Key Drivers How To
http://www.gaudisite.nl/info/KeyDriversHowTo.info.html
optional
Medical Imaging Workstation: CAF Views
http://www.gaudisite.nl/info/MIviewsCAF.info.html

Course Material Conceptual Design

core

Modeling and Analysis: Budgeting

http://www.gaudisite.nl/info/MAbudgeting.info.html

Concept Selection, Set Based Design and Late Decision Making

http://www.gaudisite.nl/info/ConceptSelectionSetBased.info.html

optional

The Tool Box of the System Architect

http://www.gaudisite.nl/info/ToolBoxSystemArchitect.info.html

Course Material Business and Life Cycle

core

Simplistic Financial Computations for System Architects.

http://www.gaudisite.nl/info/SimplisticFinancialComputations.info.html

Modeling and Analysis: Life Cycle Models

http://www.gaudisite.nl/info/MAlifeCycle.info.html

optional

How to present architecture issues to higher management

http://www.gaudisite.nl/info/ArchitectManagementInteraction.info.html

Course Material Integration and Reasoning

core

Qualities as Integrating Needles

http://www.gaudisite.nl/info/QualityNeedles.info.html

Threads of Reasoning

http://www.gaudisite.nl/info/ThreadsOfReasoning.info.html

Threads of reasoning illustrated by medical imaging case

http://www.gaudisite.nl/PresentationMITORSlides.pdf

Course Material Modeling

core
Modeling and Analysis: Reasoning Approach
http://www.gaudisite.nl/info/MAreasoningApproach.info.html
Modeling and Analysis: Analysis
http://www.gaudisite.nl/info/MAanalysis.info.html
optional
Modeling and Analysis: Measuring
http://www.gaudisite.nl/info/MAmeasuring.info.html
ASP Python Exercise
http://www.gaudisite.nl/info/ASPpythonExercise.info.html

Course Material Wrap-up

core
Consolidating Architecture Overviews
http://www.gaudisite.nl/info/ConsolidatingArchitectureOverviewsSlides.pdf
SEMA Homework Assignment
http://www.gaudisite.nl/info/SEMAhomeworkAssigmentSlides.pdf

optional
Guidelines for Visualization
http://www.gaudisite.nl/info/VisualizationGuidelines.info.html
Granularity of Documentation
http://www.gaudisite.nl/info/DocumentationGranularity.info.html
Light Weight Review Process
http://www.gaudisite.nl/info/LightWeightReview.info.html
Cookbook A3 Architecture Overview *by Daniel Borches*
http://www.gaudisite.nl/BorchesCookbookA3architectureOverview.pdf
How to Create an Architecture Overview
http://www.gaudisite.nl/info/OverviewHowTo.info.html

SEMA Basic Philosophy

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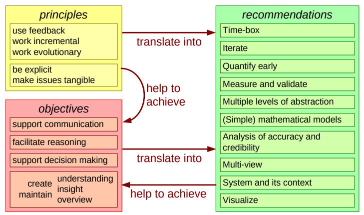
`www.gaudisite.nl`

Abstract

This presentation explains the basic philosophy behind the SEMA course. The SEMA course in the first place is a course that provides an approach to architectural reasoning. Core to architectural reasoning is the ability to make conceptual models and to use them in conjunction. The course discusses how to make conceptual mdoels, how to get input, and how to use them for analysis. Modeling is put in broader perspective, such as model evolution, simuation, and validation.

May 17, 2025
status: draft
version: 0.3



You will mostly be working!

One **Case** during the course and the home work assigment

Work in **teams** if possible

Select a case close to **your day-to-day practice**

Learning by Doing

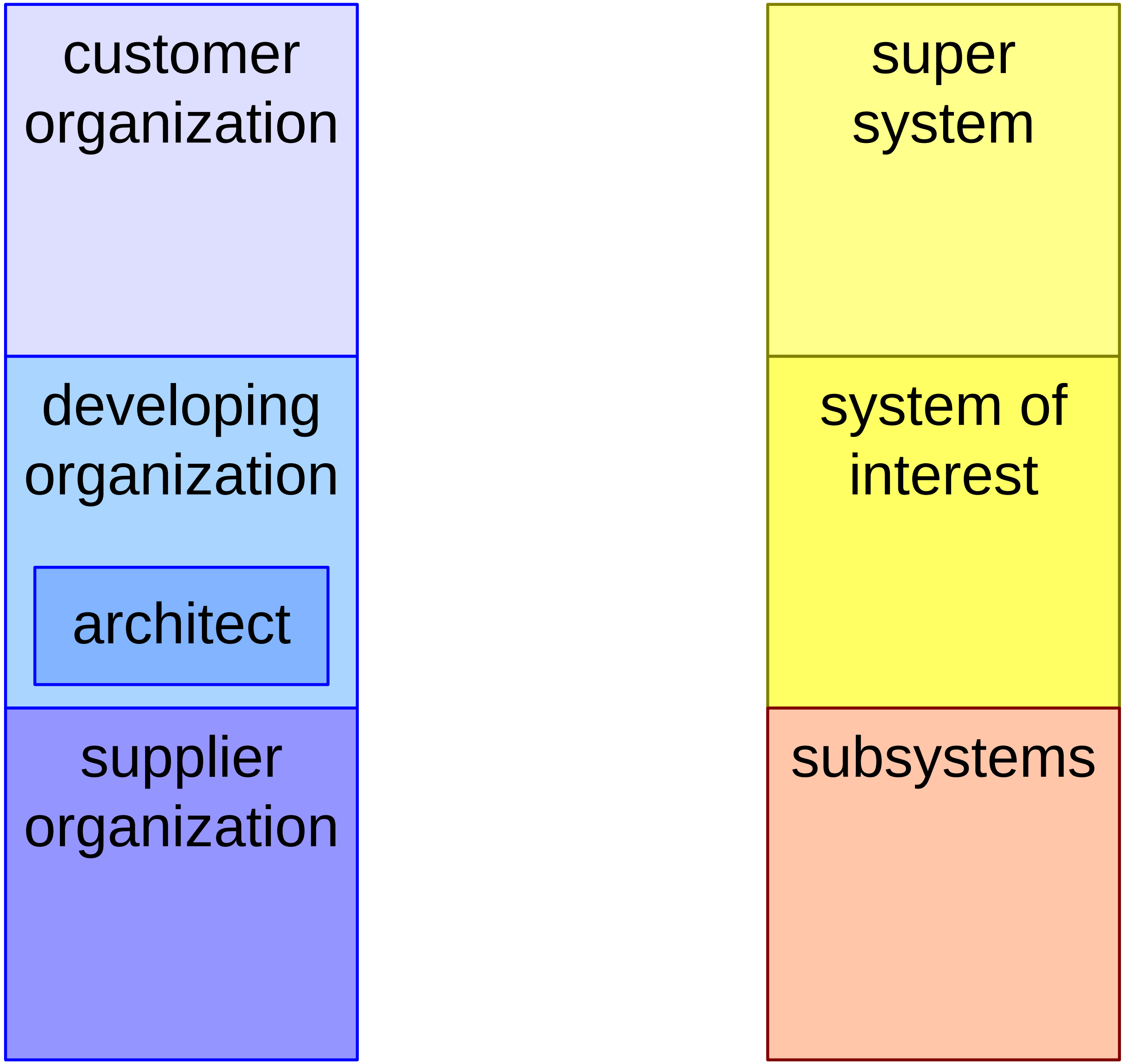
Some theory, apply on case

Case = System of interest + developing organization + some innovative change

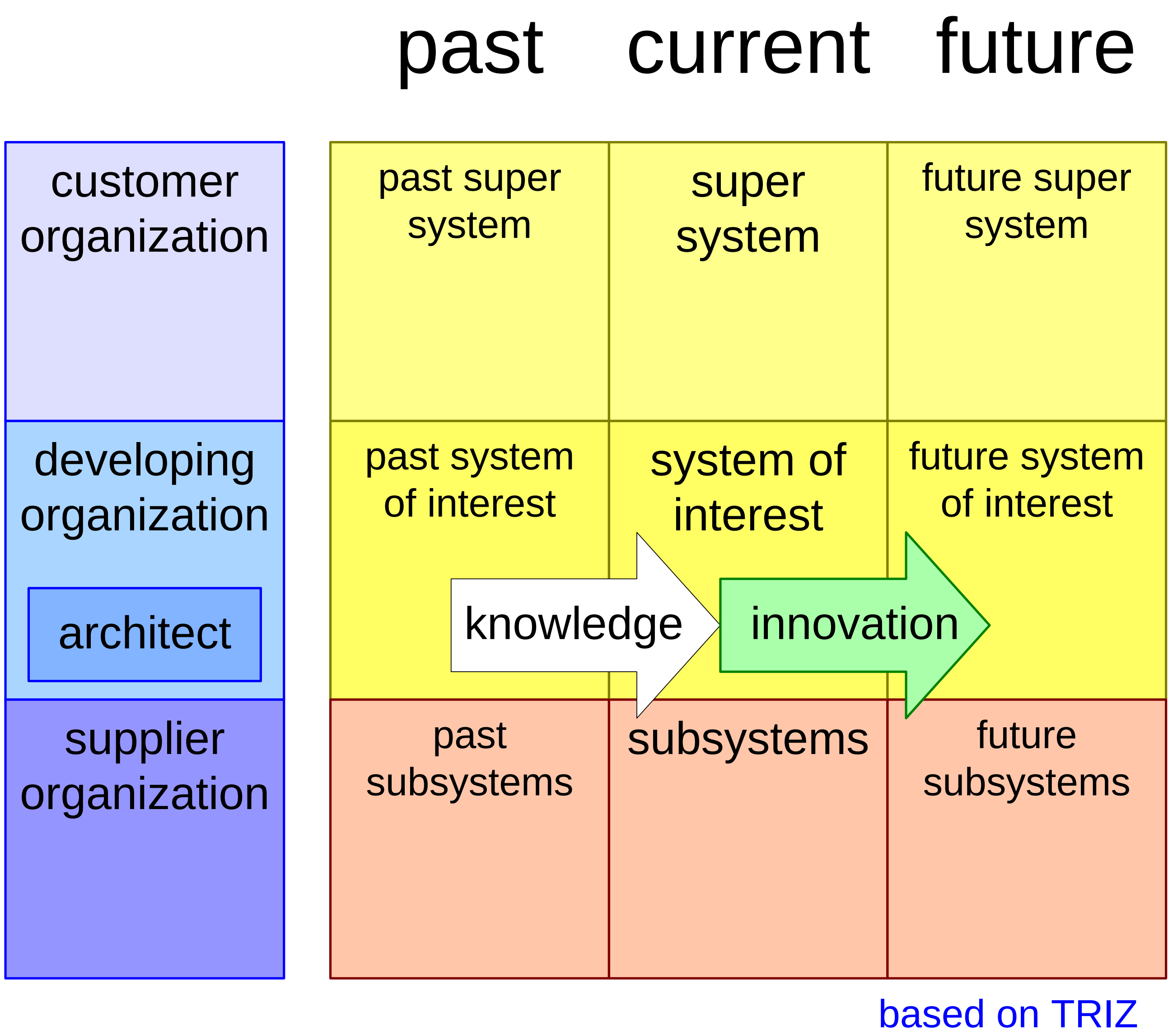
Choice of case is critical!

Our Primary Interest

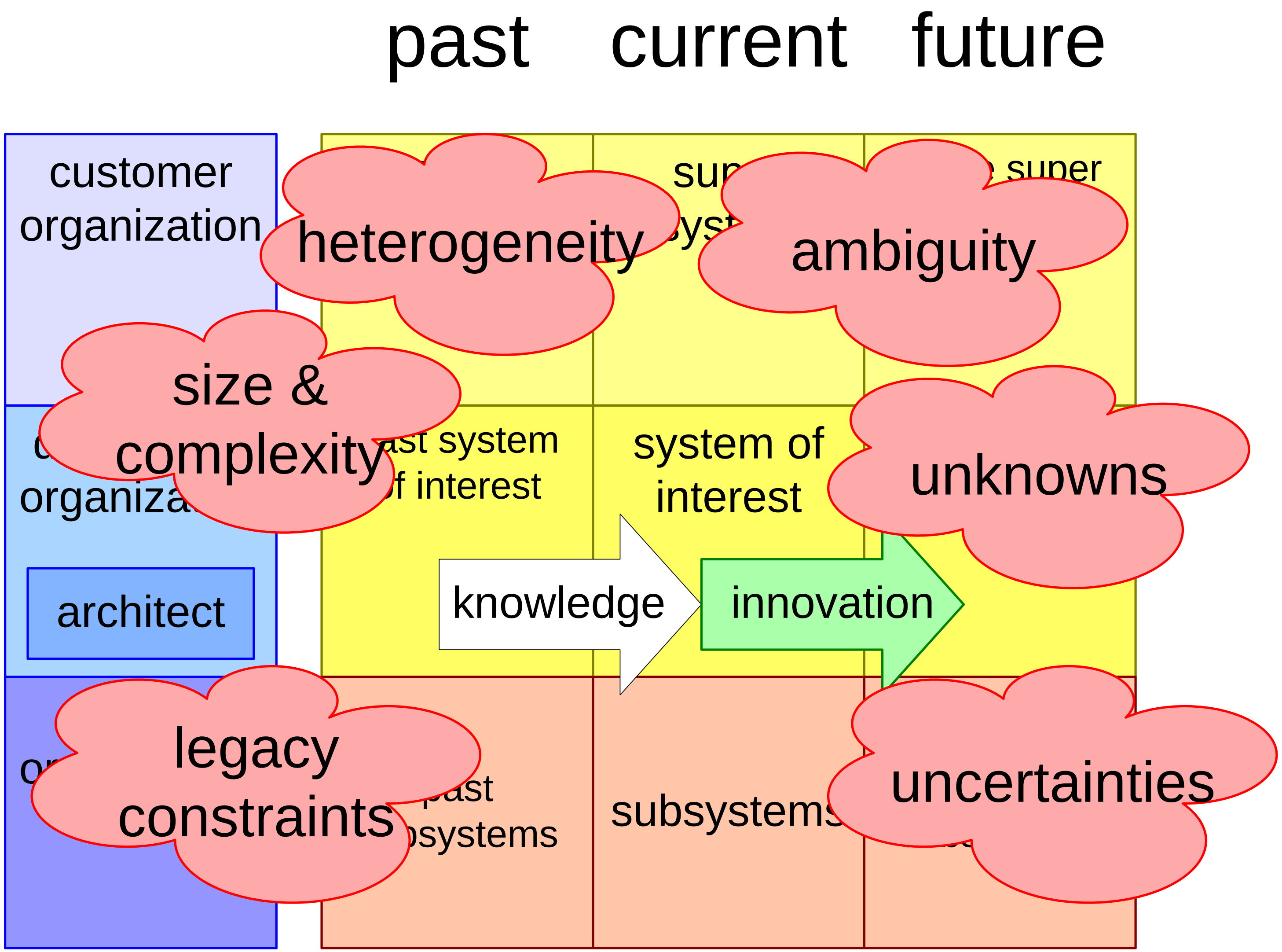
Context, Zoom-out and Zoom-in



Adding the Time Dimension

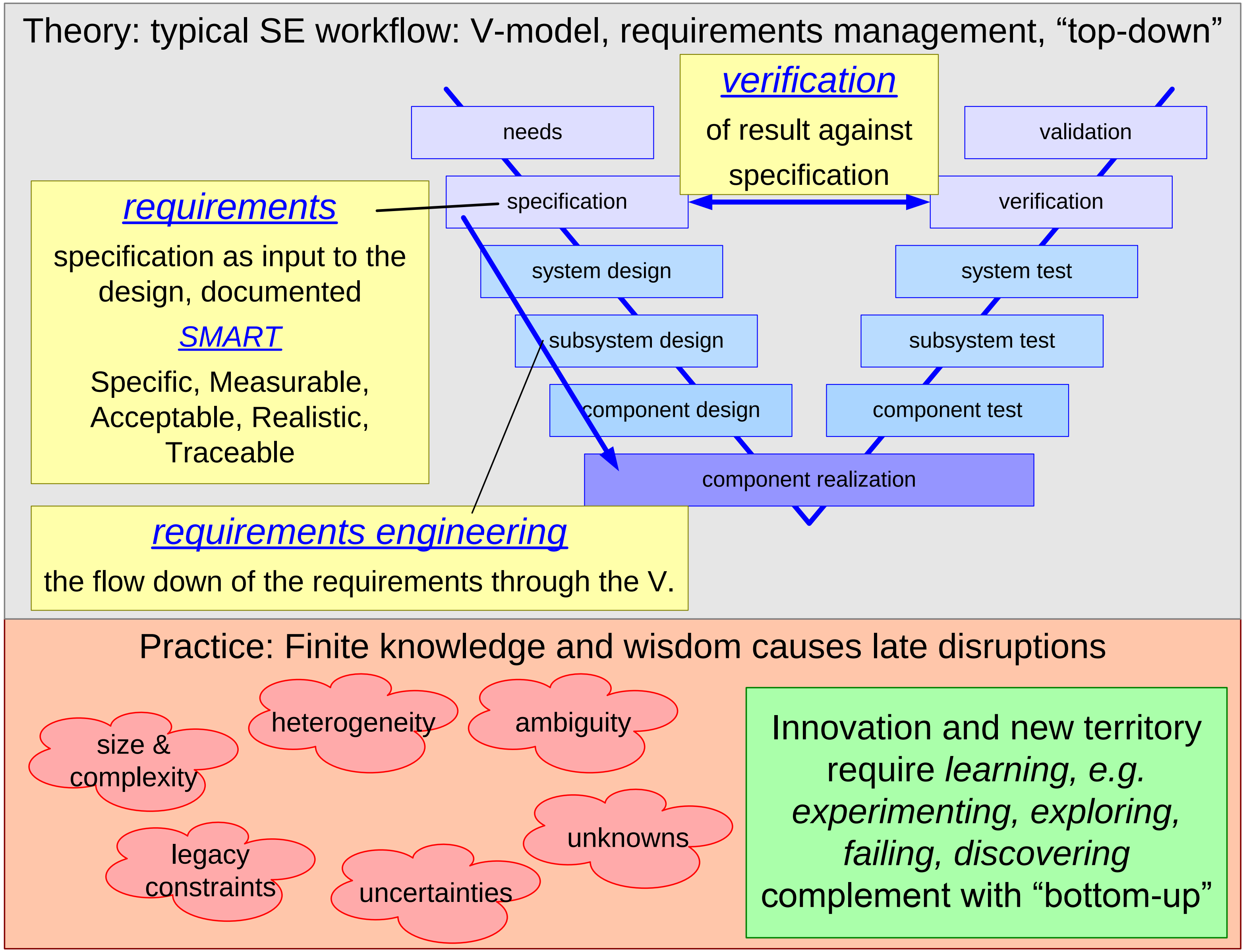


Challenges

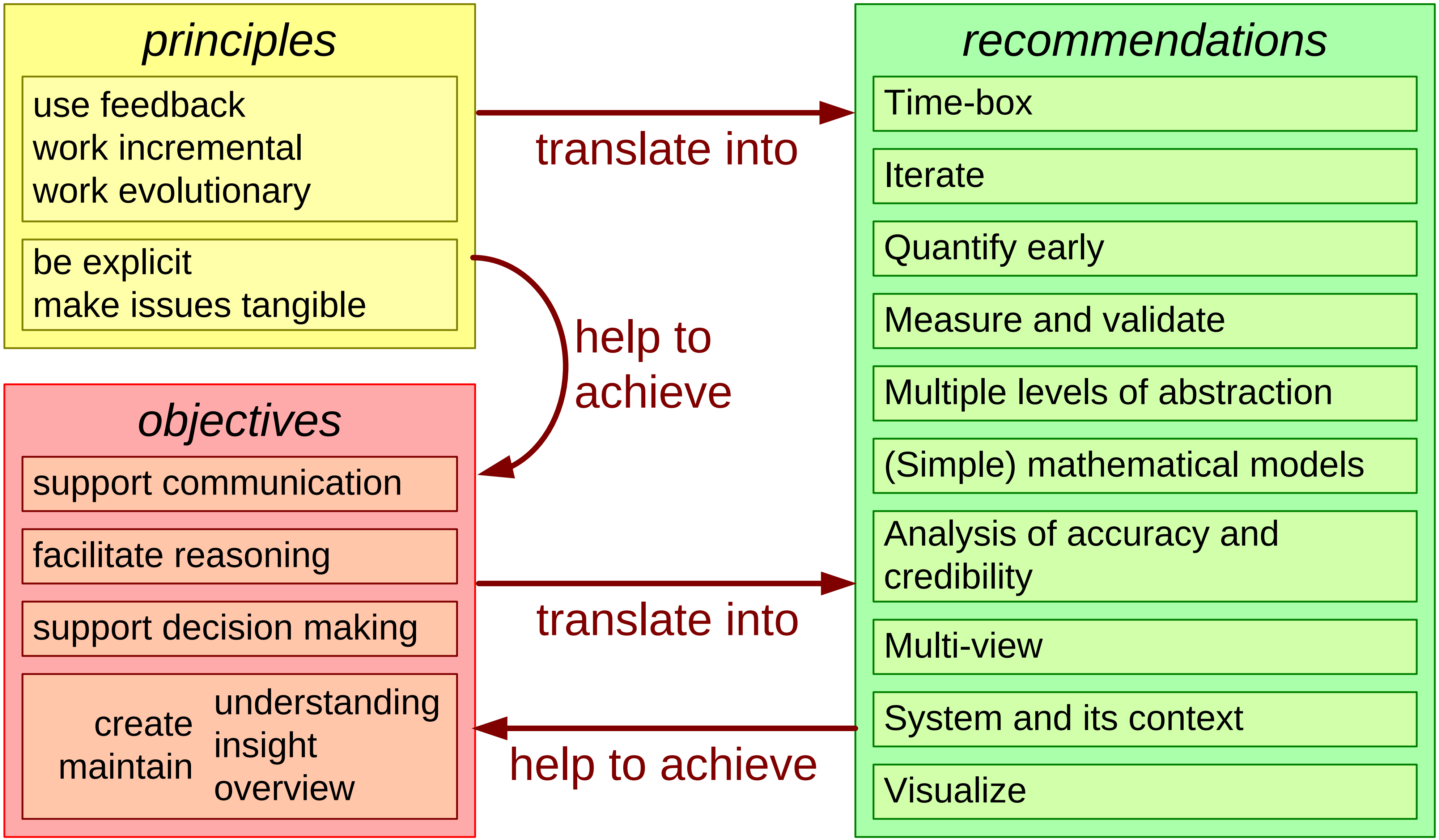


based on TRIZ

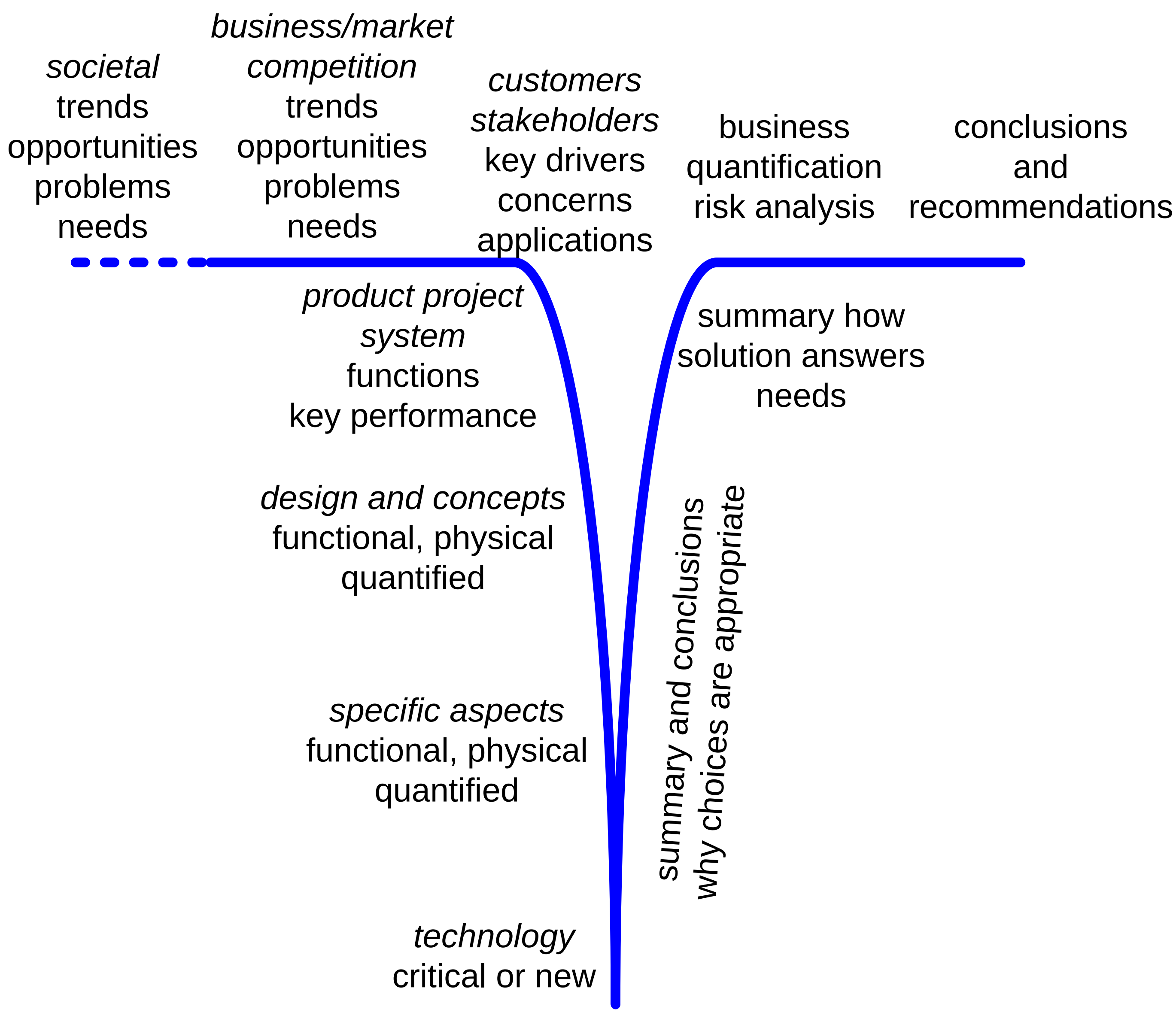
From Theory to Practice



Recommendations as Common Thread



Final Delivery: Presentation to Top Management



Project Overview How To

by *Gerrit Muller* USN-SE
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Abstract

A project overview shows the overview of a project on a single slide or sheet. The overview helps the team to share the same understanding of scope, objectives, and timeline.

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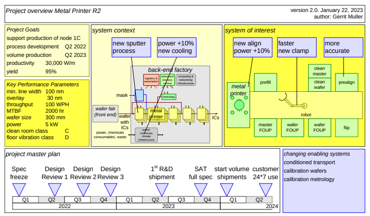
status: draft
version: 0.2



Project Overview Canvas

Project Title

meta information, e.g. version, date
author, owner

Project Goals

- specific and quantified

Key Performance Parameters

- specific and quantified

system context

- visualization (drawing, block diagram, 3D model, or photo) of the system context
- indication of changes in the context

system of interest

- visualization (drawing, block diagram, 3D model, or photo) of the system
- indication of changes in the system of interest

project master plan with timeline

- timeline with 5 to 10 milestones, especially deliverables
- specific and quantified

optional information, e.g.

- enabling systems
- stakeholders
- external or internal interfaces
- constraints, e.g. applicable legislation

Example Project Overview

Project overview Metal Printer R2

version 2.0. January 22, 2023
author: Gerrit Muller

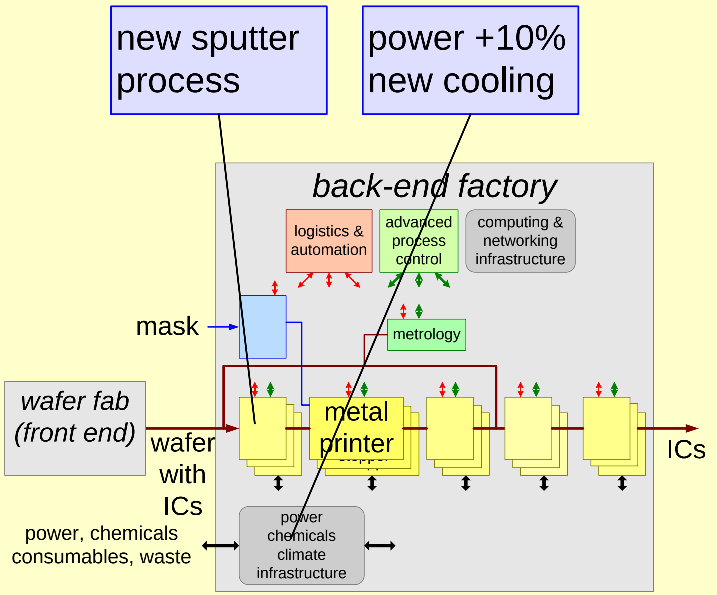
Project Goals

support production of node 1C	
process development	Q2 2022
volume production	Q2 2023
productivity	30,000 W/m
yield	95%

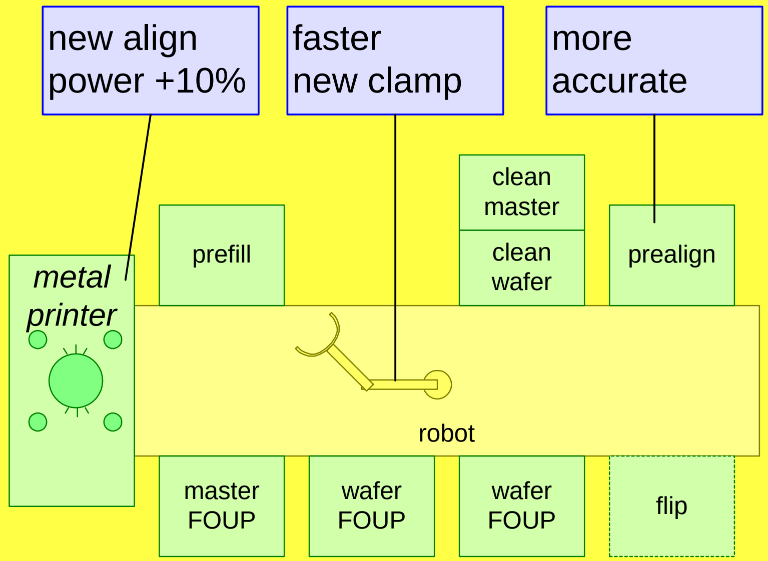
Key Performance Parameters

min. line width	100 nm
overlay	30 nm
throughput	100 WPH
MTBF	2000 hr
wafer size	300 mm
power	5 kW
clean room class	C
floor vibration class	D

system context



system of interest



project master plan

Spec freeze	Design Review 1	Design Review 2	Design Review 3	1st R&D shipment	SAT full spec	start volume shipments	customer 24*7 use

2022				2023				2024	
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2

changing enabling systems

conditioned transport
calibration wafers
calibration metrology

Project Overview Canvas

Project Title

meta information, e.g. version, date
author, owner

Work Breakdown Structure

- visualization
- *builds upon the Product Breakdown Structure*

Project Master Plan

- PERT plan with major milestones

project organization

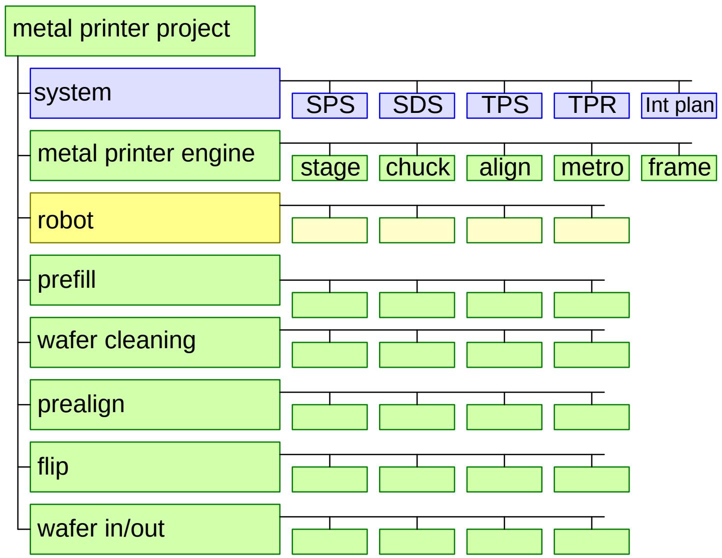
- allocation of roles
- specific additions or deviations

Example Project Overview

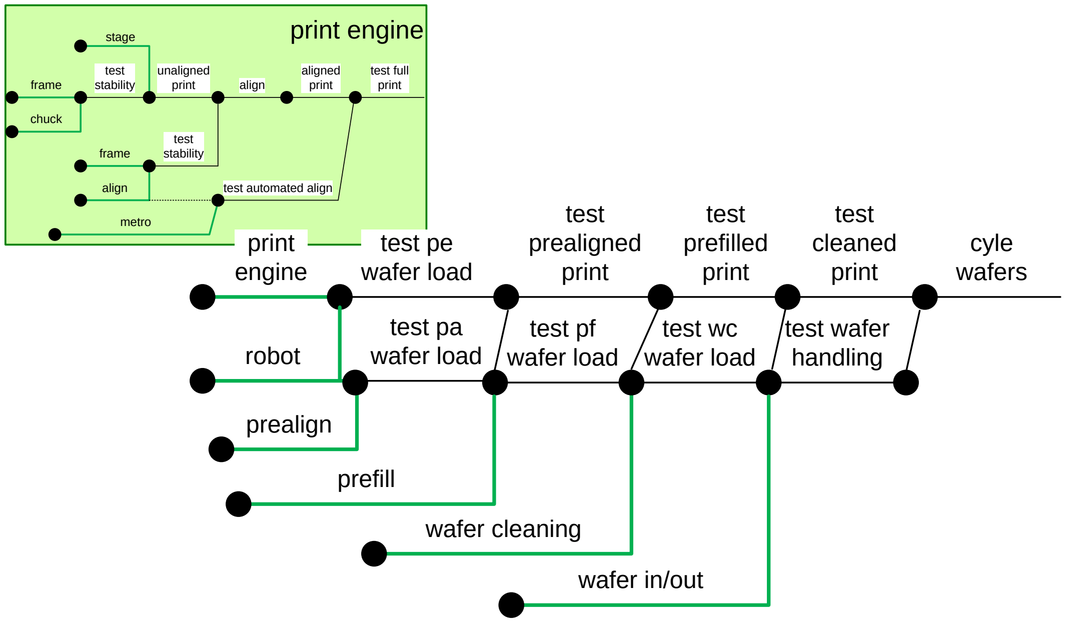
Metal Printer

version 0.1, 2023-02-11
author: Gerrit Muller

Work Breakdown Structure



Project Master Plan



project organization

Project Leader: P.L. Eader

Product Manager: P.M. Anager

Architect: Archie Tect

Case Selection

Determine the system of interest

Define your organization

Determine an innovative change to be architected

Sketch the System-of-Interest

Sketch the **System-of-Interest** in its **context**

- Show some of the internals of the system-of-interest
- Indicate the boundary of the system-of-interest

Physical Models of an Elevator

by *Gerrit Muller* University of South-Eastern USN-SE
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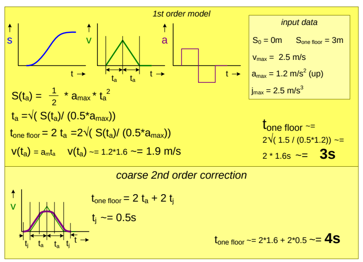
www.gaudisite.nl

Abstract

An elevator is used as a simple system to model a few physical aspects. We will show simple kinematic models and we will consider energy consumption. These low level models are used to understand (physical) design considerations. Elsewhere we discuss higher level models, such as use cases and throughput, which complement these low level models.

May 17, 2025
status: concept
version: 0.5




WARNING!
The elevator is slow,
but not broken.
Please allow extra
time for your journey.

Learning Goals

To understand the need for

- various views, e.g. physical, functional, performance
- mathematical models
- quantified understanding
- assumptions (when input data is unavailable yet) and later validation
- various visualizations, e.g. graphs
- understand and hence model at multiple levels of abstraction
- starting simple and expanding in detail, views, and solutions gradually, based on increased insight

To see the value and the limitations of these conceptual models

To appreciate the complementarity of conceptual models to other forms of modeling, e.g. problem specific models (e.g. structural or thermal analysis), SysML models, or simulations *warning*

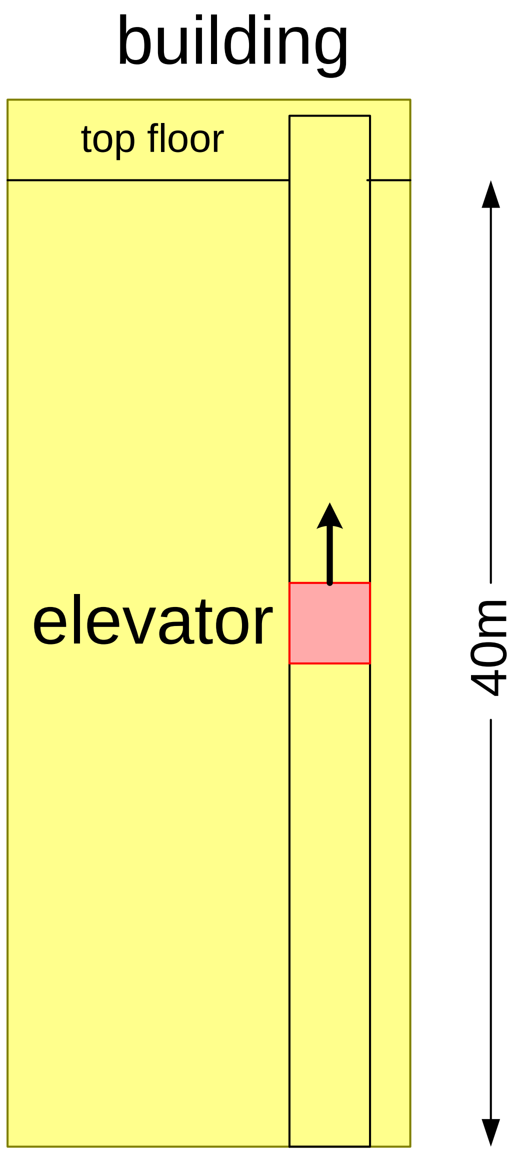
This presentation starts with a trivial problem.

Have patience!

Extensions to the trivial problem are used to illustrate many different modeling aspects.

Feedback on correctness and validity is appreciated

The Elevator in the Building



inhabitants want to reach
their destination fast and comfortable

building owner and *service operator*
have economic constraints:
space, cost, energy, ...

Elementary Kinematic Formulas

S_t = position at time t

v_t = velocity at time t

a_t = acceleration at time t

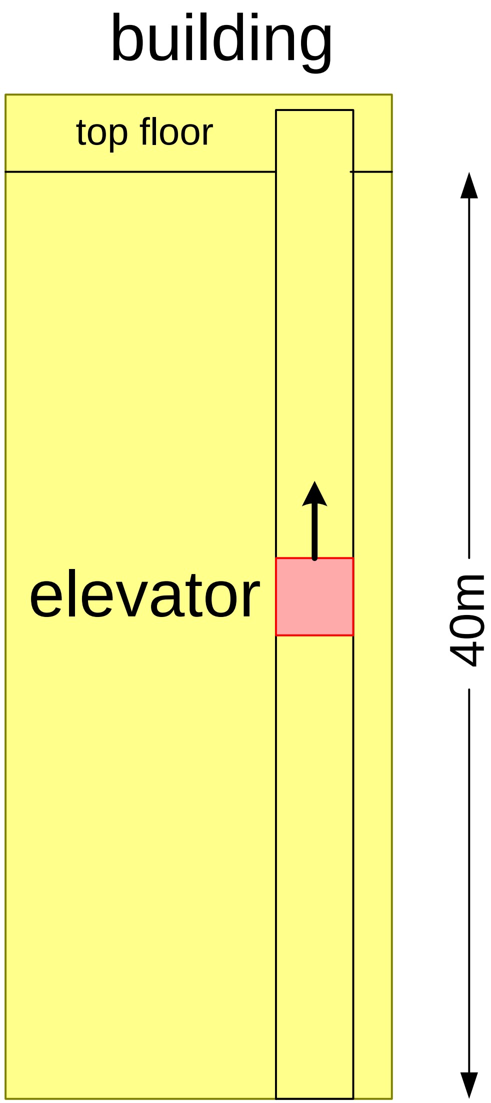
j_t = jerk at time t

$$v = \frac{dS}{dt} \qquad a = \frac{dv}{dt} \qquad j = \frac{da}{dt}$$

Position in case of uniform acceleration:

$$S_t = S_0 + v_0 t + \frac{1}{2} a_0 t^2$$

Initial Expectations



What values do you expect or prefer for these quantities? Why?

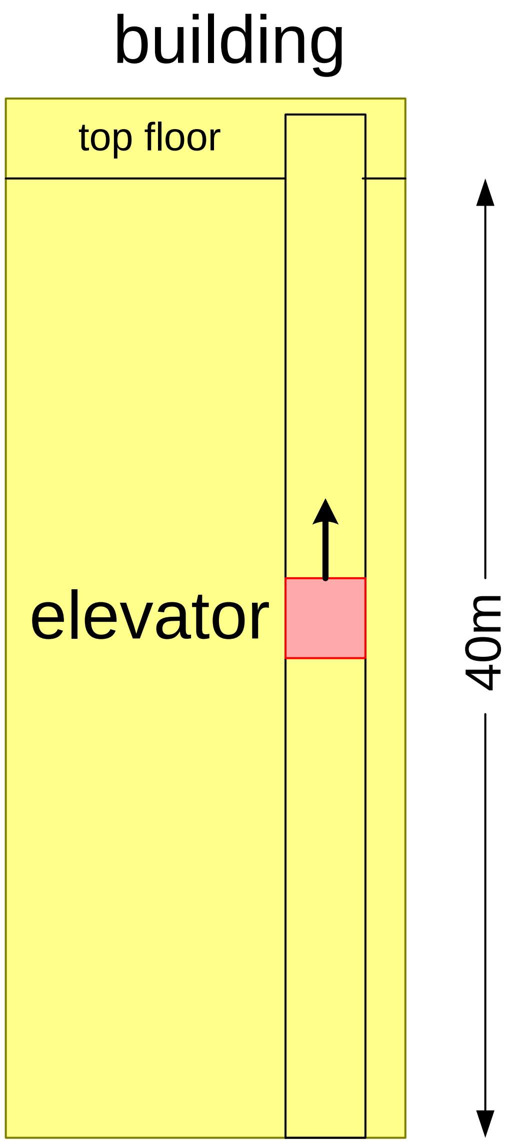
$t_{top\ floor}$ = time to reach top floor

v_{max} = maximum velocity

a_{max} = maximum acceleration

j_{max} = maximum jerk

Initial Estimates via Googling



Google "elevator" and "jerk":

$t_{top\ floor}$ ~= 16 s

v_{max} ~= 2.5 m/s

12% of gravity;
weight goes up

a_{max} ~= 1.2 m/s^2 (up)

relates to motor design
and energy consumption

j_{max} ~= 2.5 m/s^3 — relates to control design

humans feel changes of forces
high jerk values are uncomfortable

numbers from: http://www.sensor123.com/vm_eva625.htm
CEP Instruments Pte Ltd Singapore

Exercise Time to Reach Top Floor Kinematic

input data

$S_0 = 0m$ $S_t = 40m$

$v_{max} = 2.5$ m/s

$a_{max} = 1.2$ m/s^2 (up)

$j_{max} = 2.5$ m/s^3

elementary formulas

$$v = \frac{dS}{dt} \qquad a = \frac{dv}{dt} \qquad j = \frac{da}{dt}$$

Position in case of uniform acceleration:

$$S_t = S_0 + v_0 t + \frac{1}{2} a_0 t^2$$

exercises

$t_{top\ floor}$ is time needed to reach top floor without stopping

Make a model for $t_{top\ floor}$ and calculate its value

Make 0^e order model, based on constant velocity

Make 1^e order model, based on constant acceleration

What do you conclude from these models?

Models for Time to Reach Top Floor

input data

$S_0 = 0m$ $\quad S_{top\ floor} = 40m$

$v_{max} = 2.5\ m/s$

$a_{max} = 1.2\ m/s^2$ (up)

$j_{max} = 2.5\ m/s^3$

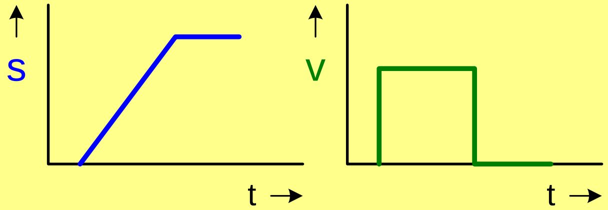
elementary formulas

$$v = \frac{dS}{dt} \qquad a = \frac{dv}{dt} \qquad j = \frac{da}{dt}$$

Position in case of uniform acceleration:

$$S_t = S_0 + v_0 t + \frac{1}{2} a_0 t^2$$

0^{th} order model

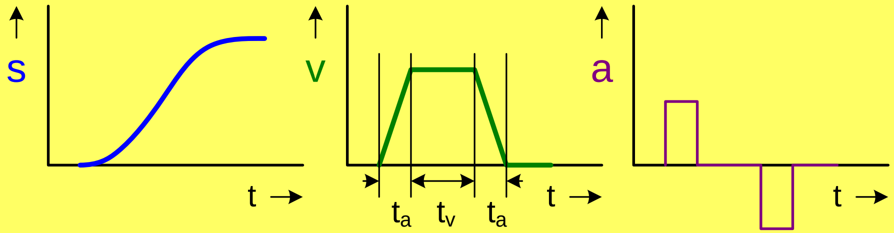


$S_{top\ floor} = v_{max} * t_{top\ floor}$

$t_{top\ floor} = S_{top\ floor} / v_{max}$

$t_{top\ floor} = 40/2.5 =$ **16s**

1st order model



$t_{top\ floor} = t_a + t_v + t_a$

$t_a = v_{max} / a_{max}$

$S(t_a) = \frac{1}{2} * a_{max} * t_a^2$

$S_{linear} = S_{top\ floor} - 2 * S(t_a)$

$t_v = S_{linear} / v_{max}$

t_a ~= 2.5/1.2 ~= 2s

$S(t_a)$ ~= 0.5 * 1.2 * 2^2

$S(t_a)$ ~= 2.4m

t_v ~= (40-2*2.4)/2.5

t_v ~= 14s

$t_{top\ floor}$ ~= 2 + 14 + 2

$t_{top\ floor}$ ~= **18s**

Conclusions Move to Top Floor

Conclusions

v_{max} dominates traveling time

The model for the large height traveling time can be simplified into:

$$t_{travel} = S_{travel}/v_{max} + (t_a + t_j)$$

Exercise Time to Travel One Floor

input data

$S_0 = 0m$ $S_{top\ floor} = 40m$

$v_{max} = 2.5\ m/s$

$a_{max} = 1.2\ m/s^2$ (up)

$j_{max} = 2.5\ m/s^3$

elementary formulas

$$v = \frac{dS}{dt} \qquad a = \frac{dv}{dt} \qquad j = \frac{da}{dt}$$

Position in case of uniform acceleration:

$$S_t = S_0 + v_0 t + \frac{1}{2} a_0 t^2$$

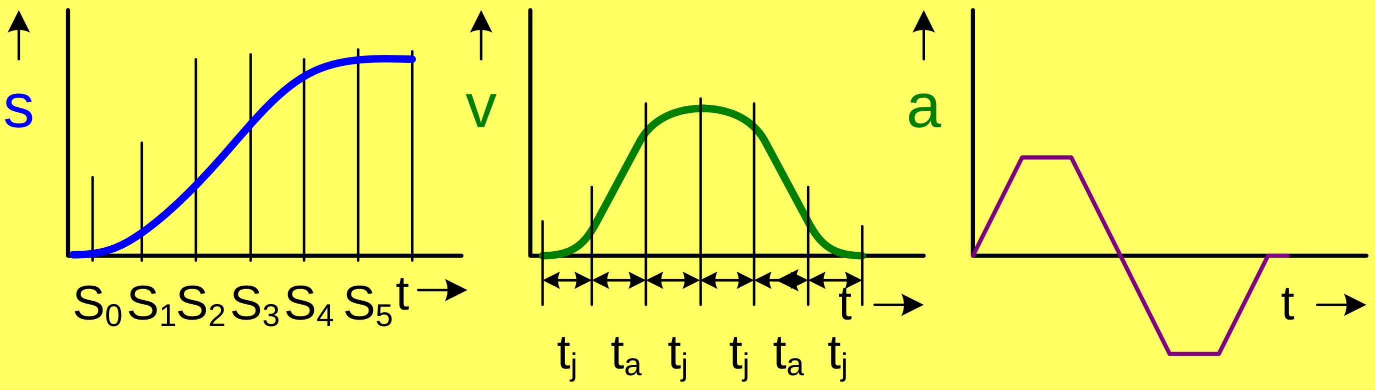
exercise

Make a model for $t_{one\ floor}$ and calculate it

What do you conclude from this model?

2nd Order Model Moving One Floor

2^{nd} order model



input data

S_0 = 0m

$S_{one\ floor}$ = 3m

v_{max} = 2.5 m/s

a_{max} = 1.2 m/s^2 (up)

j_{max} = 2.5 m/s^3

$t_{one\ floor} = 2\ t_a + 4\ t_j$

$t_j = a_{max} / j_{max}$

$S_1 = 1/6 * j_{max}\ t_j^3$

$v_1 = 0.5\ j_{max}\ t_j^2$

$S_2 = S_1 + v_1 t_a + 0.5\ a_{max} t_a^2$

$v_2 = v_1 + a_{max}\ t_a$

$S_3 = S_2 + v_2 t_j + 0.5\ a_{max} t_j^2 - 1/6\ j_{max} t_j^3$

$S_3 = 0.5\ S_t$

t_j ~= 1.2/2.5 ~= 0.5s

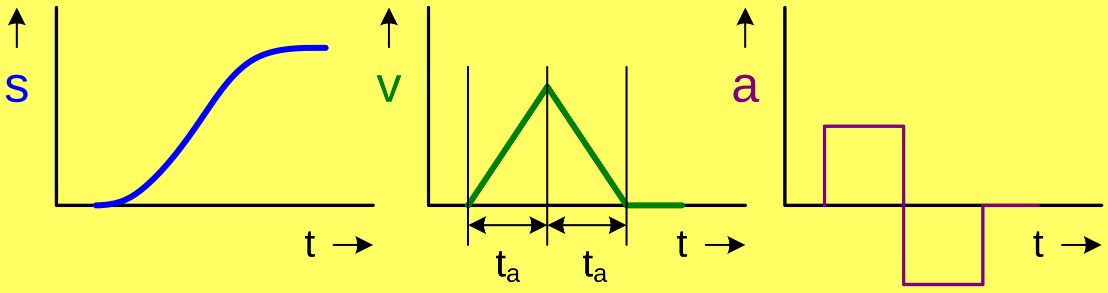
S_1 ~= 1/6 * 2.5 * 0.5^3 ~= 0.05m

v_1 ~= 0.5 * 2.5 * 0.5^2 ~= 0.3m/s

et cetera

1st Order Model Moving One Floor

1st order model



input data

S_0 = 0m $S_{one\ floor}$ = 3m

v_{max} = 2.5 m/s

a_{max} = 1.2 m/s^2 (up)

j_{max} = 2.5 m/s^3

$$S(t_a) = \frac{1}{2} * a_{max} * t_a^2$$

$$t_a = \sqrt{(S(t_a) / (0.5*a_{max}))}$$

$$t_{one\ floor} = 2\ t_a = 2\sqrt{(S(t_a) / (0.5*a_{max}))}$$

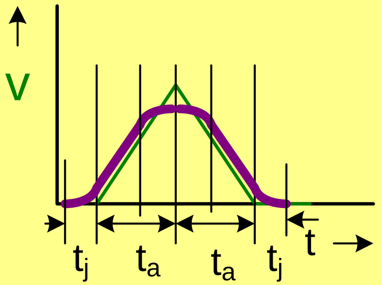
$v(t_a) = a_m t_a$ $v(t_a) \sim= 1.2*1.6 \sim= 1.9$ m/s

$t_{one\ floor} \sim=$

$2\sqrt{(1.5 / (0.5*1.2))} \sim=$

$2 * 1.6$s $\sim=$ **3s**

coarse 2nd order correction



$$t_{one\ floor} = 2\ t_a + 2\ t_j$$

$$t_j \sim= 0.5s$$

$t_{one\ floor} \sim= 2*1.6 + 2*0.5 \sim=$ **4s**

Conclusions Move One Floor

Conclusions

a_{max} dominates travel time

The model for small height traveling time can be simplified into:

$$t_{travel} = 2 \sqrt{(S_{travel}/0.5\ a_{max})} + t_j$$

Exercise Elevator Performance

exercise

Make a model for $t_{\text{top floor}}$

Take door opening and docking into account

What do you conclude from this model?

Elevator Performance Model

functional model

close doors

undock elevator

move elevator

dock elevator

open doors elevator

performance model

$$t_{top\ floor} = t_{close} + t_{undock} + t_{move} + t_{dock} + t_{open}$$

assumptions

$t_{close} \sim= t_{open} \sim= 2s$

$t_{undock} \sim= 1s$

$t_{dock} \sim= 2s$

$t_{move} \sim= 18s$

outcome

$t_{top\ floor} \sim= 2 + 1 + 18 + 2 + 2$

$t_{top\ floor} \sim= \mathbf{25s}$

Conclusions Performance Model Top Floor

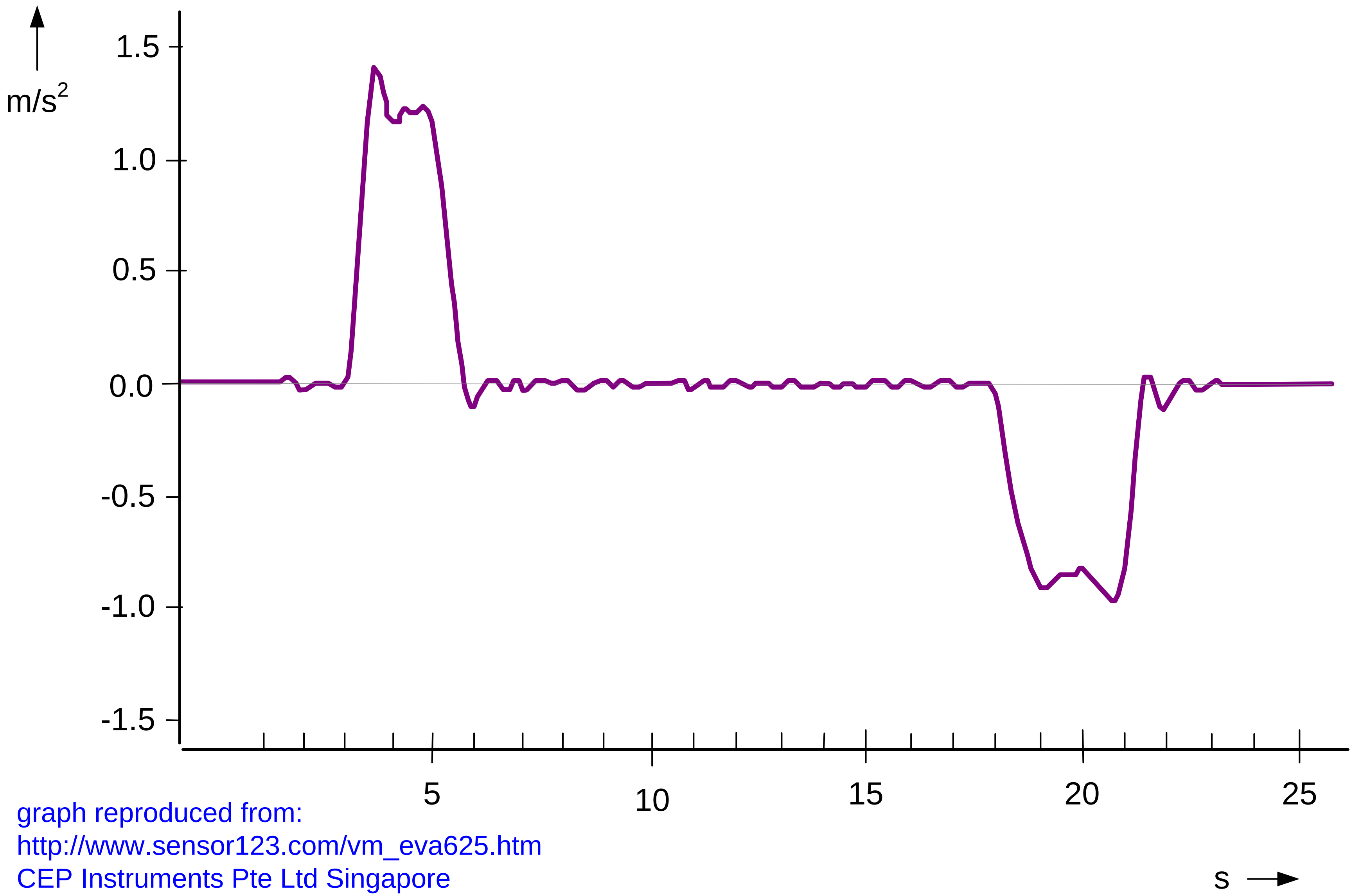
Conclusions

The time to move is dominating the traveling time.

Docking and door handling is significant part of the traveling time.

$t_{\text{top floor}} = t_{\text{travel}} + t_{\text{elevator overhead}}$

Measured Elevator Acceleration



graph reproduced from:
http://www.sensor123.com/vm_eva625.htm
CEP Instruments Pte Ltd Singapore

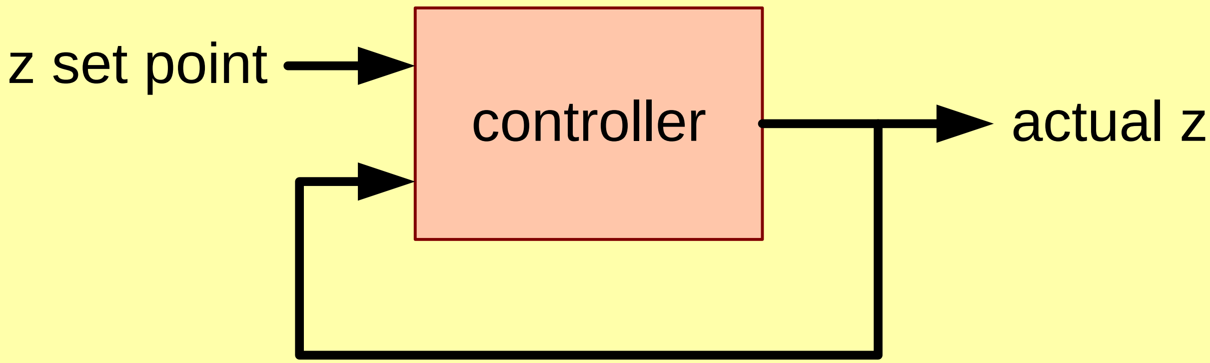
Theory versus Practice

What did we ignore or forget?

acceleration: up <> down 1.2 m/s^2 vs 1.0 m/s^2

slack, elasticity, damping et cetera of cables, motors....

controller impact



.....

Exercise Time to Travel One Floor

exercise

Make a model for $t_{\text{one floor}}$

Take door opening and docking into account

What do you conclude from this model?

Elevator Performance Model

functional model

close doors

↓

undock elevator

↓

move elevator

↓

dock elevator

↓

open doors elevator

performance model one floor (3m)

$$t_{\text{one floor}} = t_{\text{close}} + t_{\text{undock}} + t_{\text{move}} + t_{\text{dock}} + t_{\text{open}}$$

assumptions

$t_{\text{close}} \sim= t_{\text{open}} \sim= 2s$

$t_{\text{undock}} \sim= 1s$

$t_{\text{dock}} \sim= 2s$

$t_{\text{move}} \sim= 4s$

outcome

$t_{\text{one floor}} \sim= 2 + 1 + 4 + 2 + 2$

$t_{\text{one floor}} \sim= \mathbf{11\ s}$

Conclusions Performance Model One Floor

Conclusions

Overhead of docking and opening and closing doors is dominating traveling time.

Fast docking and fast door handling has significant impact on traveling time.

$t_{\text{one floor}} = t_{\text{travel}} + t_{\text{elevator overhead}}$

Exercise Time Line

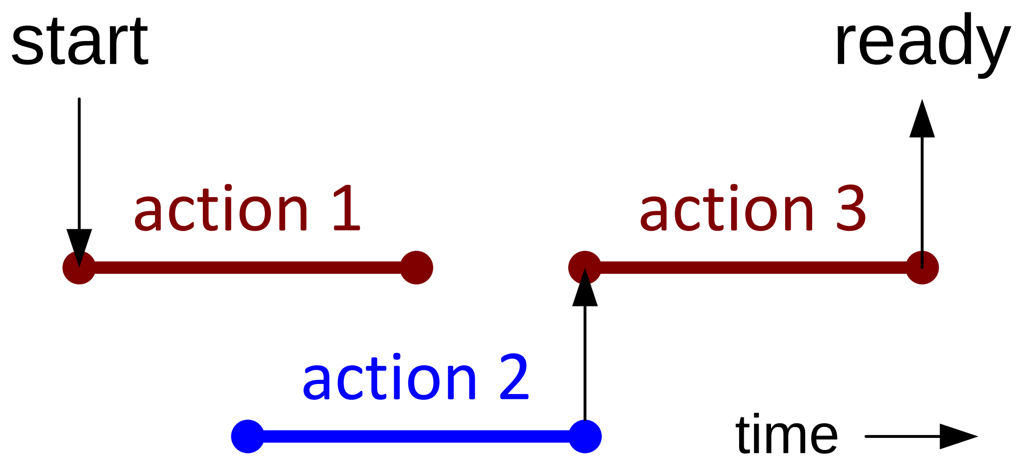
Exercise

Make a time line of people using the elevator.

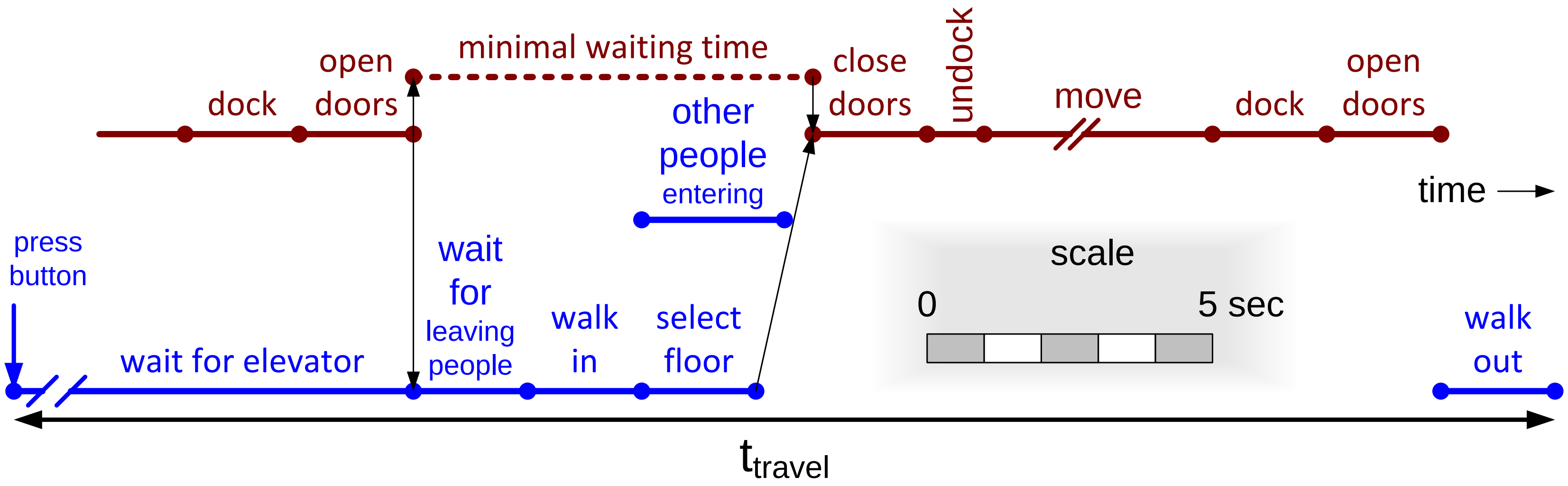
Estimate the time needed to travel to the top floor.

Estimate the time needed to travel one floor.

What do you conclude?



Time Line; Humans Using the Elevator



assumptions human dependent data

$t_{wait\ for\ elevator}$ = [0..2 minutes] depends heavily on use

$t_{wait\ for\ leaving\ people}$ = [0..20 seconds] idem

$t_{walk\ in} \sim= t_{walk\ out} \sim= 2$ s

$t_{select\ floor} \sim= 2$ s

assumptions additional elevator data

$t_{minimal\ waiting\ time} \sim= 8$s

$t_{travel\ top\ floor} \sim= 25$s

$t_{travel\ one\ floor} \sim= 11$s

outcome

$t_{one\ floor} = t_{minimal\ waiting\ time} + t_{walk\ out} + t_{travel\ one\ floor} + t_{wait}$

$t_{top\ floor} = t_{minimal\ waiting\ time} + t_{walk\ out} + t_{travel\ top\ floor} + t_{wait}$

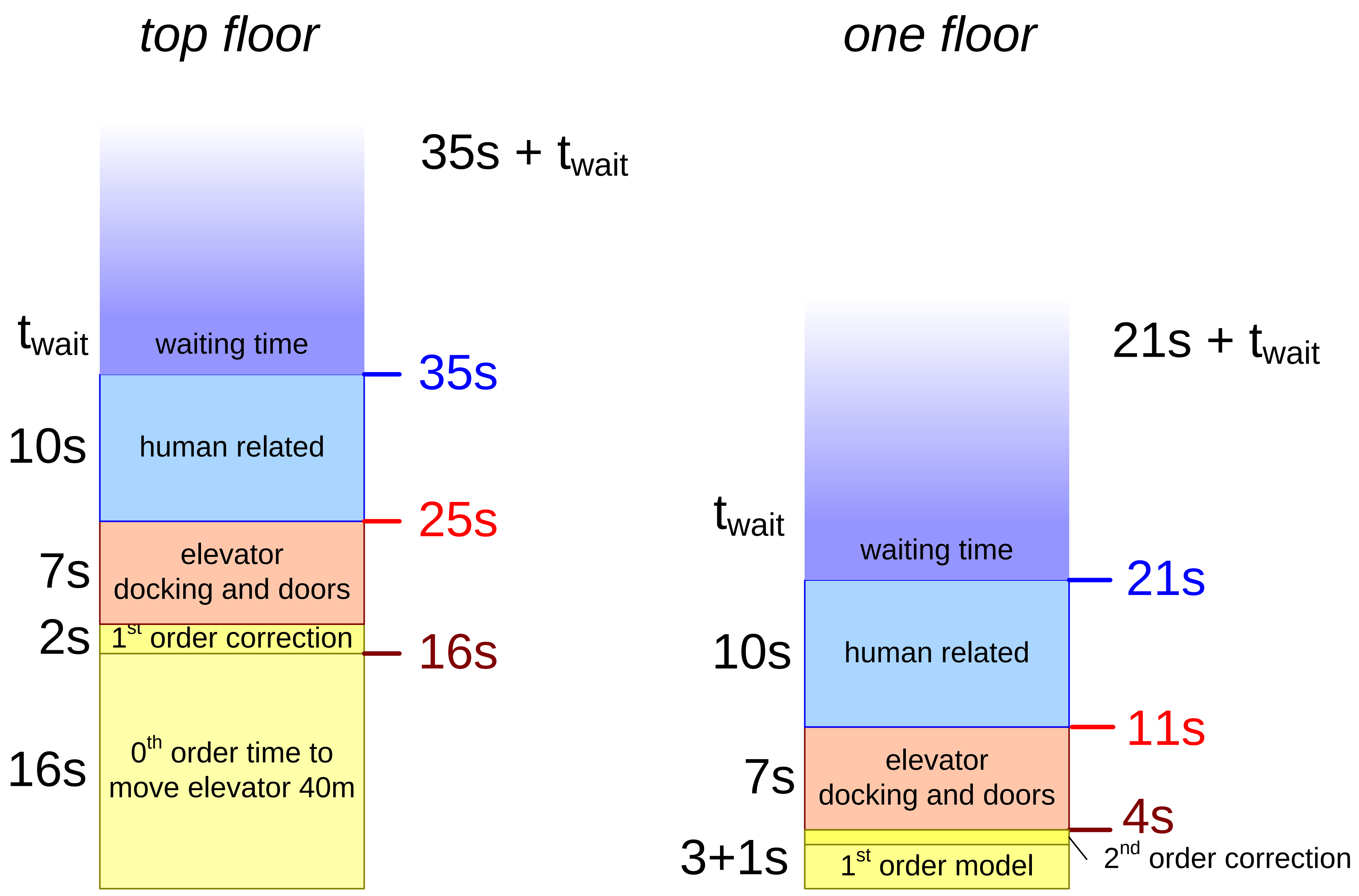
$t_{one\ floor} \sim= 8 + 2 + 11 + t_{wait}$

$\sim= \mathbf{21\ s} + t_{wait}$

$t_{top\ floor} \sim= 8 + 2 + 25 + t_{wait}$

$\sim= \mathbf{35\ s} + t_{wait}$

Overview of Results for One Elevator



Conclusions Time Line

Conclusions

The human related activities have significant impact on the end-to-end time.

The waiting times have significant impact on the end-to-end time and may vary quite a lot.

$$t_{\text{end-to-end}} = t_{\text{human activities}} + t_{\text{wait}} + t_{\text{elevator travel}}$$

Exercise Energy and Power

Exercise

Estimate the energy consumption and the average and peak power needed to travel to the top floor.

What do you conclude?

Energy and Power Model

input data

S_0 = 0m　　S_t = 40m

v_{max} = 2.5 m/s　　$m_{elevator}$ = 1000 Kg (incl counter weight)

a_{max} = 1.2 m/s^2 (up)　　$m_{passenger}$ = 100 Kg

j_{max} = 2.5 m/s^3　　1 passenger going up

g = 10 m/s^2

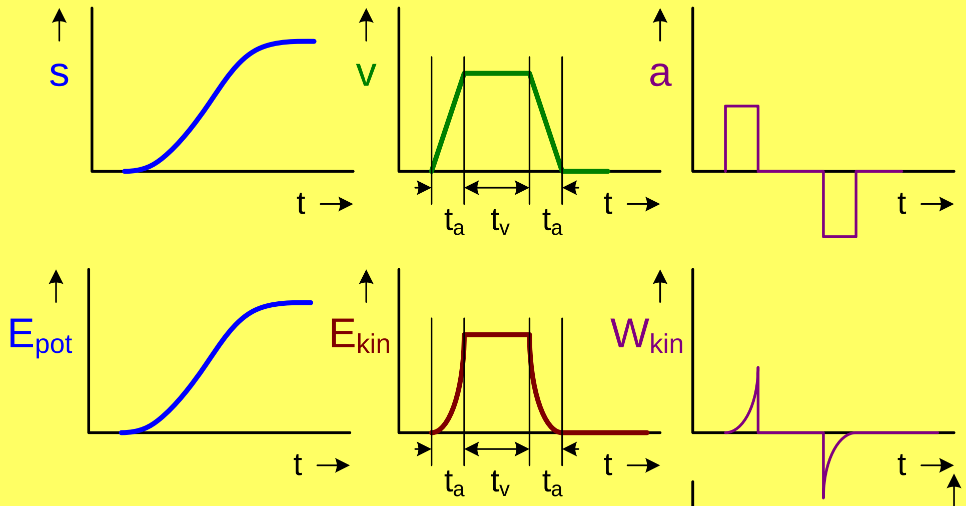
elementary formulas

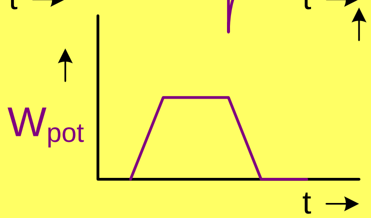
$E_{kin} = 1/2\ mv^2$

$E_{pot} = mgh$

$$W = \frac{dE}{dt}$$

1st order model





ignored:

friction and other losses

efficiency of energy transfer

$E_{kin\ max} = 1/2\ m\ v_{max}^2$

$\sim= 0.5 * 1100 * 2.5^2$

$\sim=$ **3.4 kJ**

$W_{kin\ max} = m\ v_{max}\ a_{max}$

$\sim= 1100 * 2.5 * 1.2$

$\sim=$ **3.3 kW**

$E_{pot} = mgh$

$\sim= 100 * 10 * 40$

$\sim=$ **40 kJ**

$W_{pot\ max} \sim= E_{pot}/t_v$

$\sim= 40/16$

$\sim=$ **2.5 kW**

Energy and Power Conclusions

Conclusions	
E_{pot} dominates energy balance	$E_{kin\ max} = 1/2\ m\ v_{max}^2$ $\sim= 0.5 * 1100 * 2.5^2$ $\sim=$ **3.4 kJ**
W_{pot} is dominated by v_{max}	$W_{kin\ max} = m\ v_{max}\ a_{max}$ $\sim= 1100 * 2.5 * 1.2$ $\sim=$ **3.3 kW**
W_{kin} causes peaks in power consumption and absorption	$E_{pot} = mgh$ $\sim= 100 * 10 * 40$ $\sim=$ **40 kJ**
W_{kin} is dominated by v_{max} and a_{max}	$W_{pot\ max} \sim= E_{pot}/t_v$ $\sim= 40/16$ $\sim=$ **2.5 kW**

Exercise Qualities and Design Considerations

Exercise

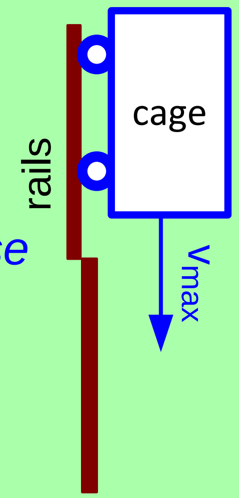
What other qualities and design considerations relate to the kinematic models?

Conclusions Qualities and Design Considerations

Examples of other qualities and design considerations

safety	v_{max}
acoustic noise	v_{max}, a_{max}, j_{max}
mechanical vibrations	v_{max}, a_{max}, j_{max}
air flow	?
operating life, maintenance	duty cycle, ?
...	

obstacles cause vibrations



Other Domains

applicability in other domains

kinematic modeling can be applied in a wide range of domains:

- transportation systems (trains, busses, cars, containers, ...)
- wafer stepper stages
- health care equipment patient handling
- material handling (printers, inserters, ...)
- MRI scanners gradient generation
- ...

Exercise Multiple Users

Exercise

Assume that a group of people enters the elevator at the ground floor. On every floor one person leaves the elevator.

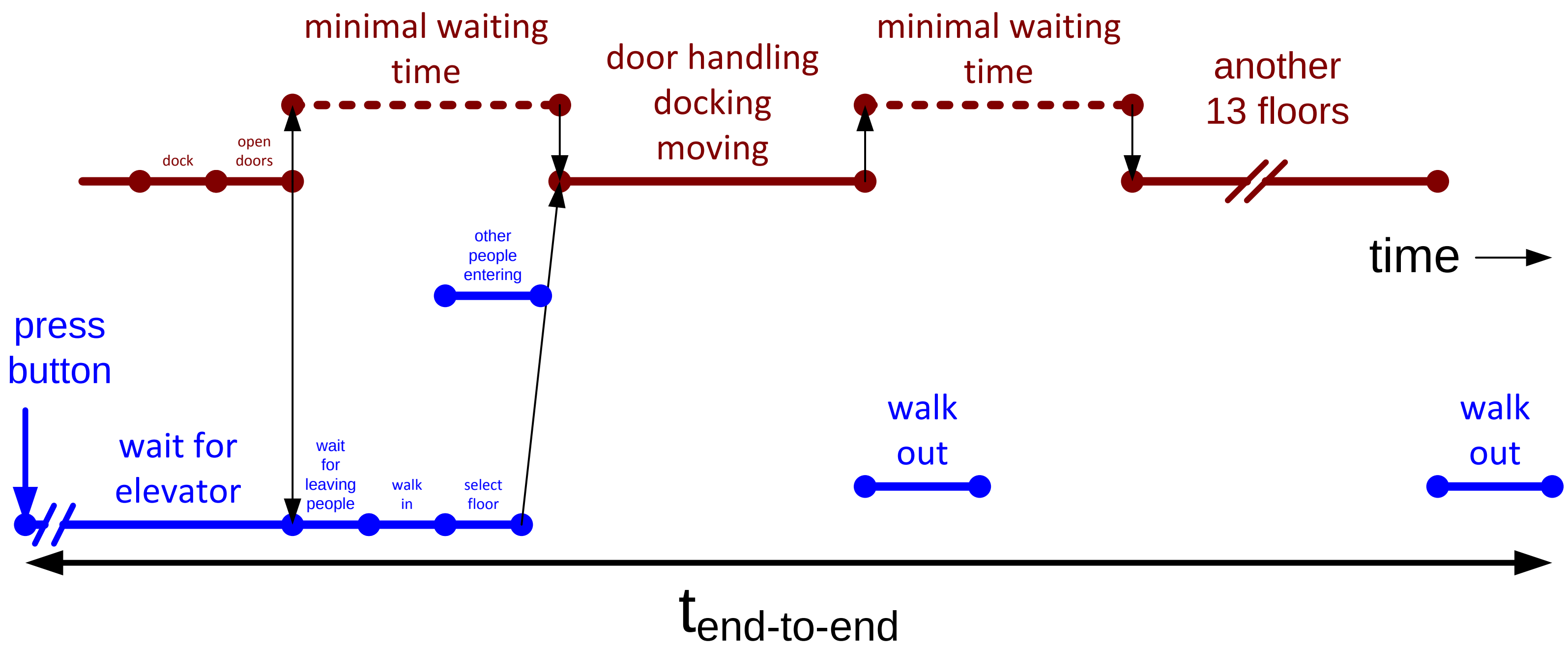
What is the end-to-end time for someone traveling to the top floor?

What is the desired end-to-end time?

What are potential solutions to achieve this?

What are the main parameters of the design space?

Multiple Users Model



elevator data

$t_{min\ wait}$ ~= 8s

$t_{one\ floor}$ ~= 11s

$t_{walk\ out}$ ~= 2s

n_{floors} = 40 div 3 +1 = 14

n_{stops} = n_{floors} – 1 = 13

outcome

$t_{end\text{-}to\text{-}end} = n_{stops}\ (t_{min\ wait} + t_{one\ floor}) + t_{walk\ out} + t_{wait}$

~= 13 * (8 + 11) + 2 + t_{wait}

~= **249 s** + t_{wait}

$t_{non\text{-}stop}$ ~= 35 s+ t_{wait}

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EPMmultipleUsersTimeLine

Multiple Users Desired Performance

Considerations

desired time to travel to top floor ~< 1 minute

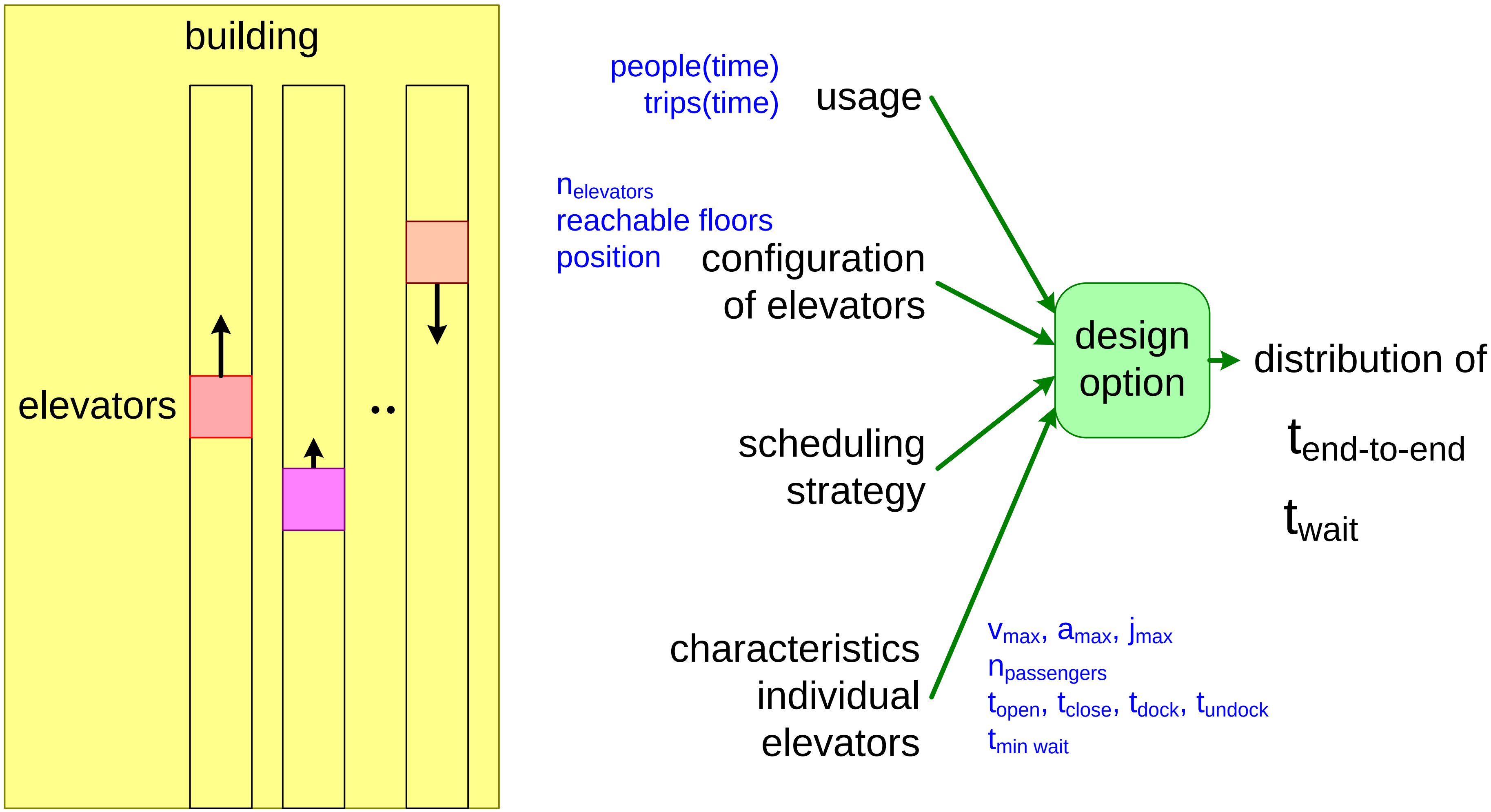
note that $t_{wait\ next} = t_{travel\ up} + t_{travel\ down}$

if someone just misses the elevator then the waiting time is

$t_{end\text{-}to\text{-}end} \approx \underbrace{249}_{\text{missed trip}} + \underbrace{35}_{\text{return down}} + \underbrace{249}_{\text{trip up}} = 533s \approx 9$ minutes!

desired waiting time ~< 1 minute

Design of Elevators System



Design of a system with multiple elevator requires a different kind of models: oriented towards logistics

Exceptional Cases

Exceptional Cases

non-functioning elevator

maintenance, cleaning of elevator

elevator used by people moving household

rush hour

special events (e.g. party, new years eve)

special floors (e.g. restaurant)

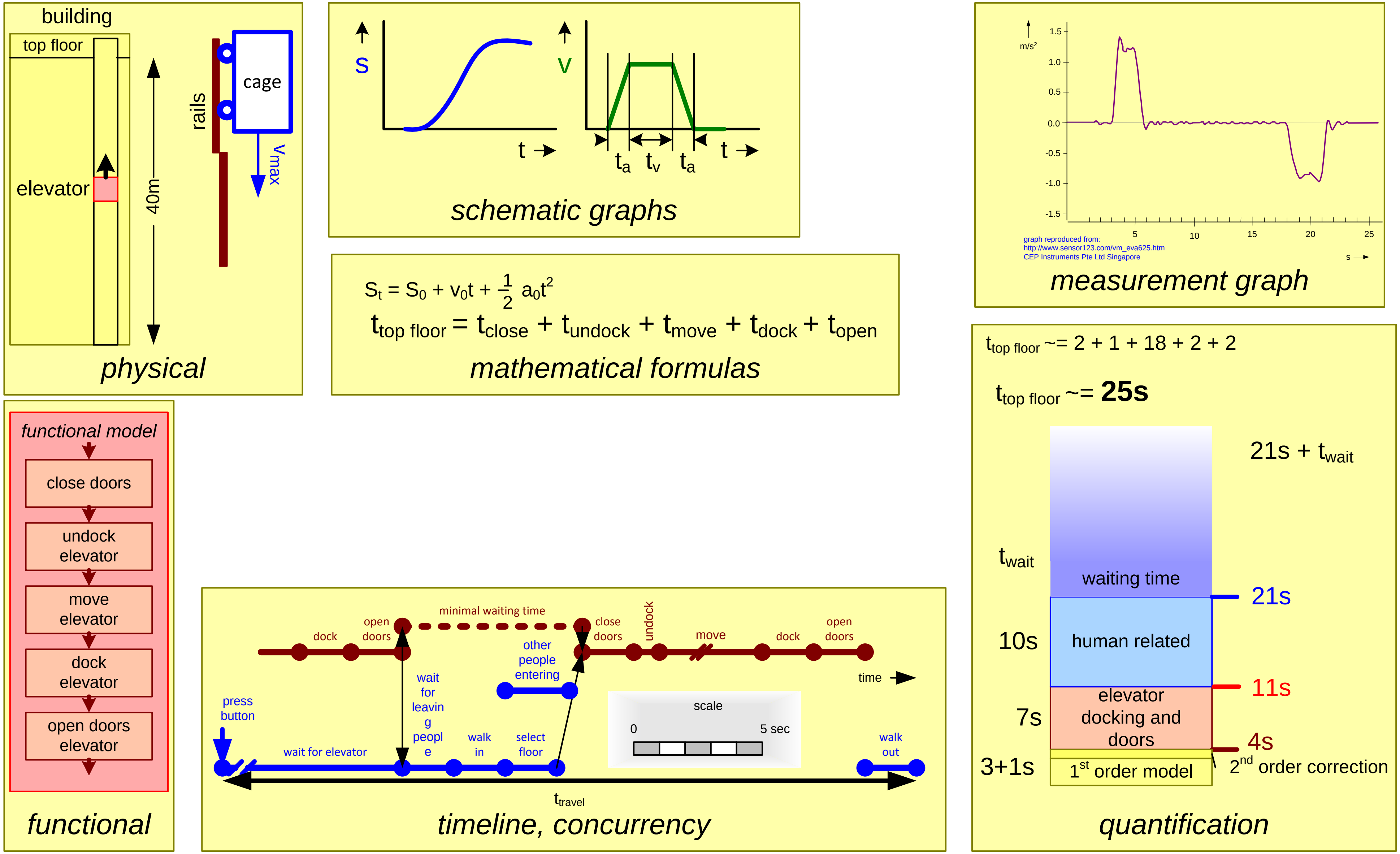
many elderly or handicapped people

playing children

Wrap-up Exercise

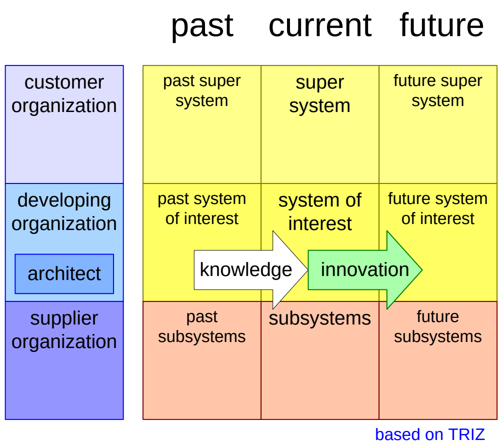
Make a list of all *visualizations* and *representations* that we used during the exercises

Summary of Visualizations and Representations

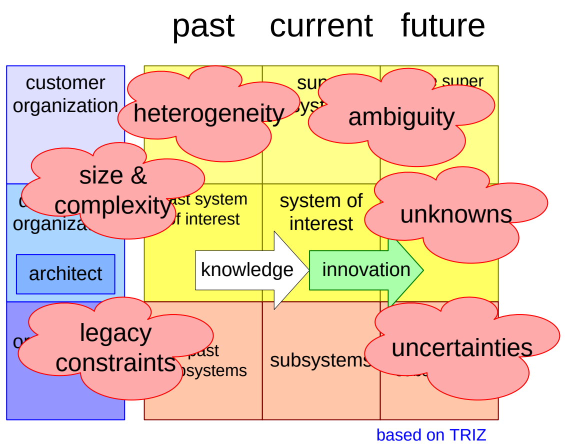


Architecting Scope and Challenges

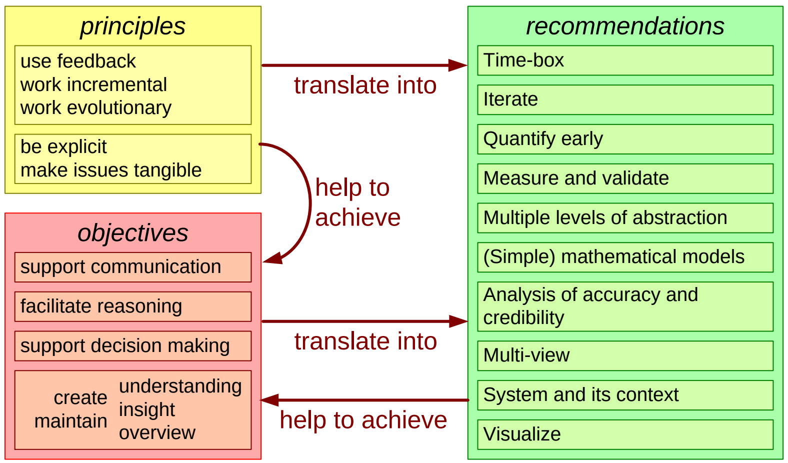
Scope



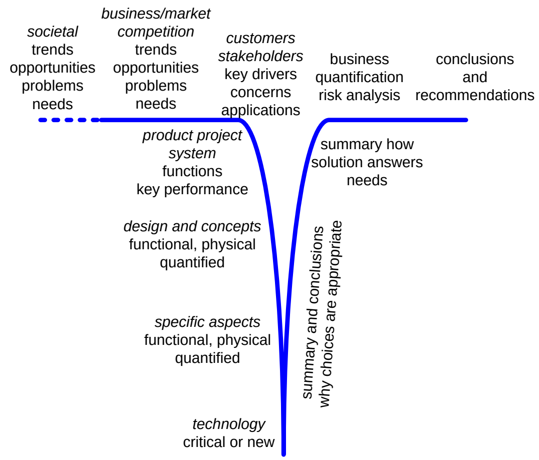
Challenges



Recommendations

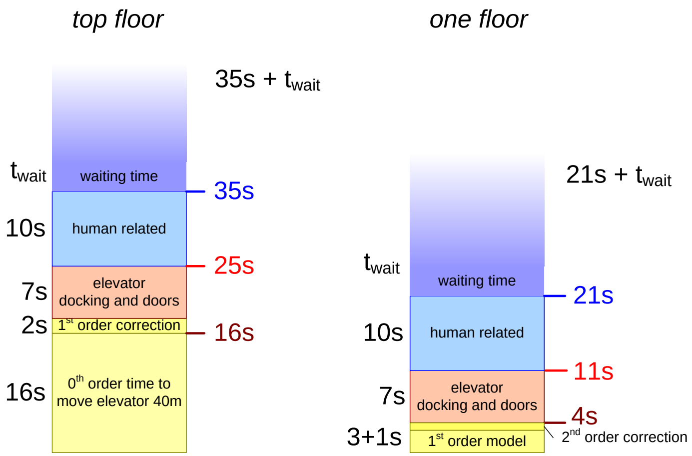


Final Top-Down Delivery

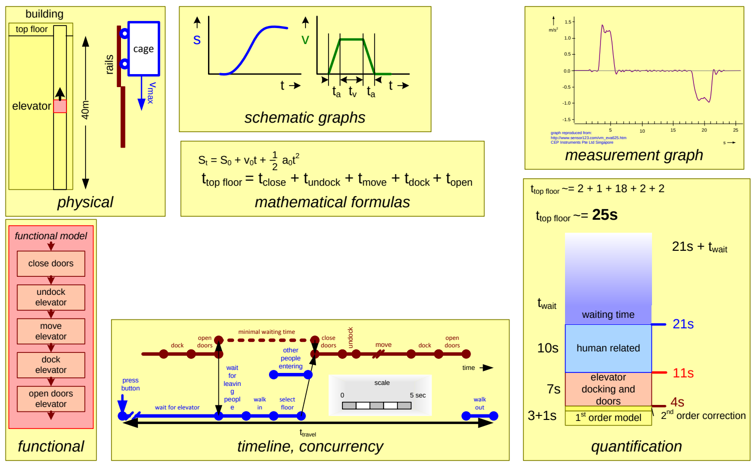


Introduction Conceptual Modeling

Zooming Out



Complementary Visualizations and Representations



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