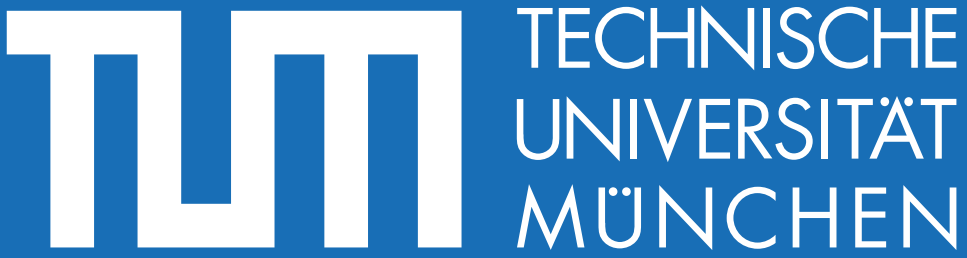
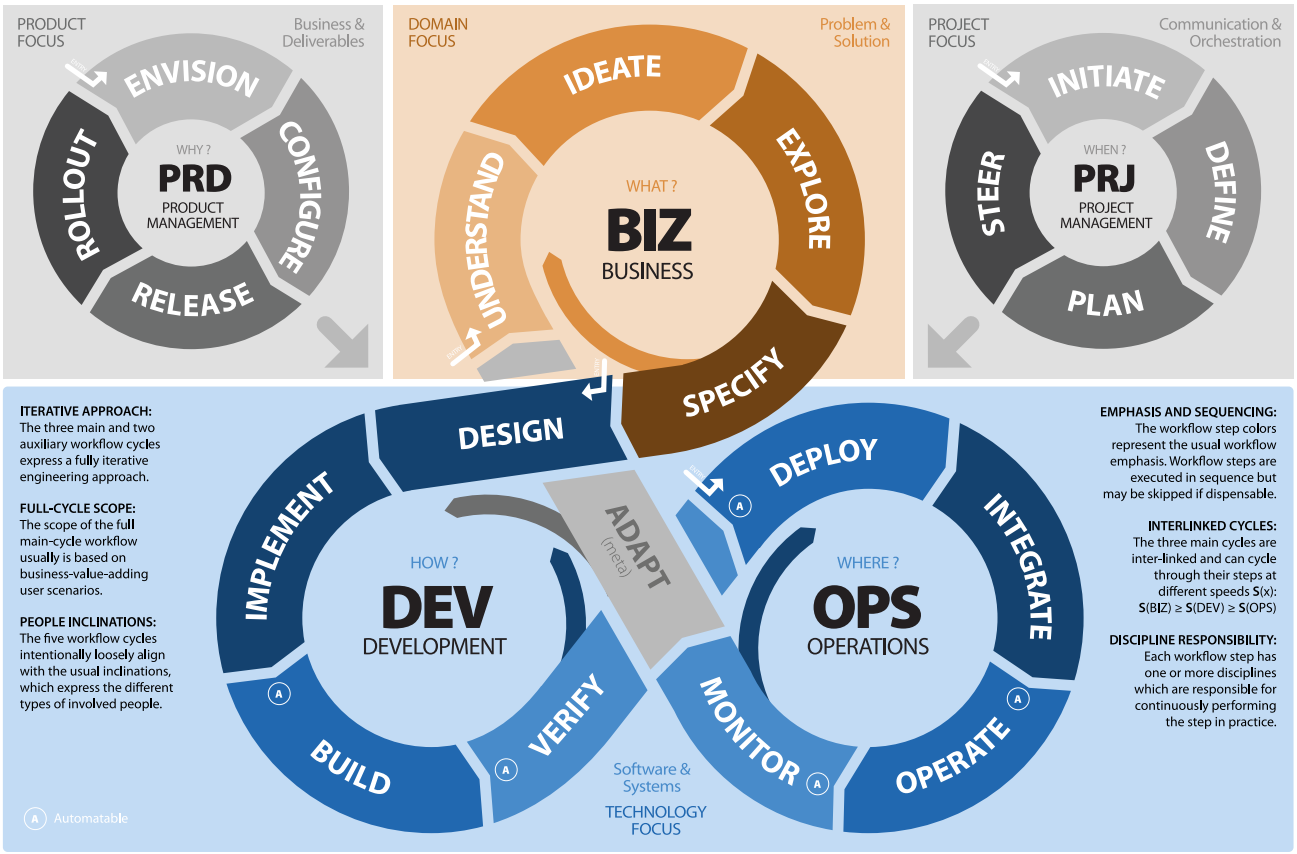


Software Engineering in Industrial Practice (SEIP)

Dr. Ralf S. Engelschall

Software Engineering Workflow



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The Workflow Model describes the work segregation in Software Engineering. In the **Workflow**, three main and two auxiliary workflow cycles express the iterative approach. The full main-cycle workflow is usually based on business-value-adding user scenarios.

The three main cycles are interlinked and can cycle through their steps at different speeds, S(x), with S(BIZ) greater then or equal to S(DEV), which in turn is greater then or equal to S(OPS). Because the cycles with earlier steps should not slow down the cycles with later steps.

The step colors represent workflow emphasis. Workflow steps are executed in sequence but may be skipped if dispensable.

The ten discipline areas of Software Engineering express the different roles of the involved people. The five inclinations express the different types of the involved people. Hence, the Workflow consists of exactly five cycles.

Questions

- What does the Workflow-Model of Software Engineering describe?

Software Engineering Steps

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Software Engineering, on an operational level, can be alternatively understood through 20 distinct **Steps** which are continuously performed within the **Software Engineering Workflow**. Each Step belongs to one primarily responsible Discipline and zero or more secondarily responsible Disciplines.

Workflow Steps are the adequate concept to understand which activities have to be performed in each iteration of a **Software Engineering Process**.

Questions

- Which concept allows one to best understand which activities have be performed in a Software Engineering Process?

ENGINEERING FUNDAMENTALS

Software Engineering Process

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EF 02.5

1. WORKFLOW CYCLES:
The workflow has five cycles which continuously iterate through their steps. Workflow steps are executed in each cycle in sequence, but may be skipped if dispensable in a particular iteration of the process. The length of an iteration is arbitrary, but can be e.g. about 1/3 of a Scrum sprint.

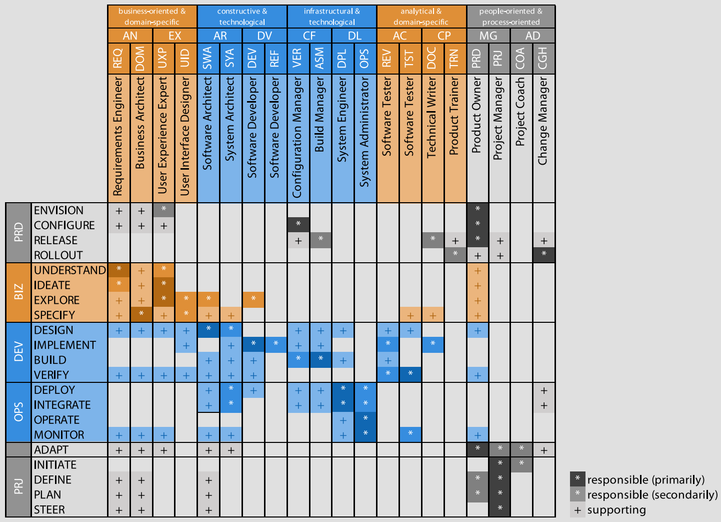
2. WORKFLOW STEPS:
The workflow steps describe a logical activity which has to be performed. Each step relates to one or more discipline areas and their corresponding disciplines, which express the operative responsibilities for each workflow step. In each discipline individual roles act.

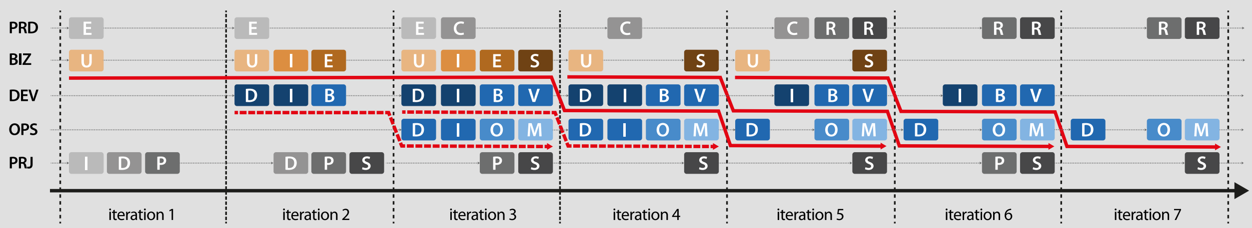
3. WORKFLOW ROLES:
The workflow roles are held by individual persons. Each role is primarily responsible for a particular workflow step. In addition, each role can be secondarily responsible for other workflow steps or at least actively support those steps.

4. PROJECT SCHEDULE:
To create a particular project execution schedule, the five cycles, their iterations and their steps have to be mapped onto a timeline. The cycles are mapped onto (horizontal) timeline tracks, the iterations are mapped onto (vertical) timeline phases, and the steps are mapped onto timeline activities.

5. PROCESS FLOWS (THE CRUX):
The activities across the cycles can (and should) be linked into individual (diagonal) waterfall-like flows, although the execution schedule, from the perspective of the cycles, is fully iterative. There are multiple such flows in parallel and they are usually highly interleaved on the project timeline in order to maximally utilize the team.

6. PROCESS ADAPTION:
In the meta-step ADAPT, the process is adapted by choosing which workflow steps are required for the next iteration. The major input for this decision is the current solution state and the feedback on it by the customer.





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The workflow has five main cycles, which continuously iterate through their steps. Workflow steps are executed in each cycle in sequence but may be skipped if dispensable.

The workflow steps are annotated with discipline areas to express operative responsibilities. In each area, multiple roles act.

The workflow roles are held by individual persons. Each role is primarily responsible for a particular workflow step. In addition, each role can be secondarily responsible for other workflow steps or at least actively support those steps.

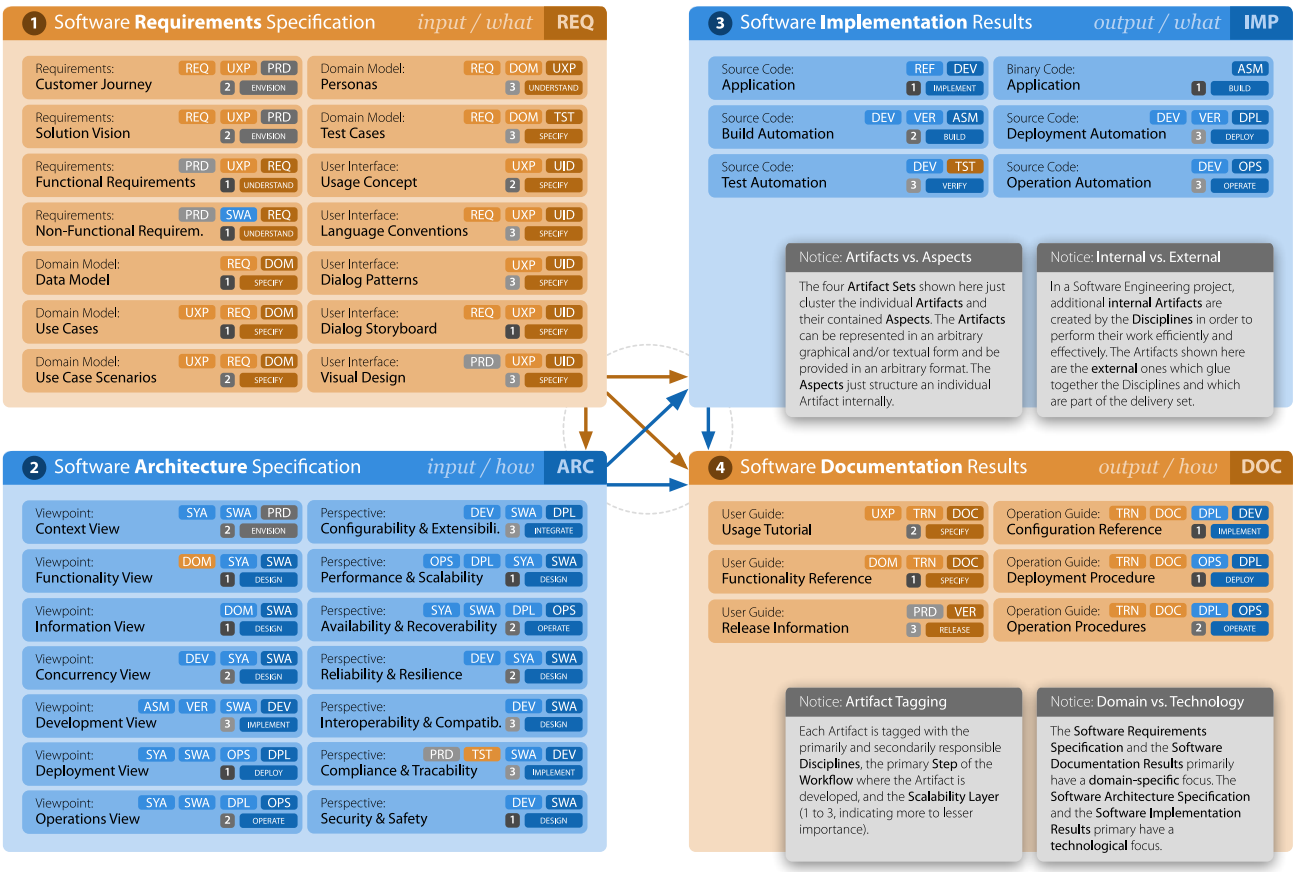
To create a particular project execution schedule, the five cycles, their iterations, and their steps have to be mapped onto a timeline. The cycles are mapped onto (horizontal) timeline tracks, and the iterations are mapped onto (vertical) timeline phases, and the steps are mapped onto timeline activities.

The activities across the cycles can (and should) be linked into individual (diagonal) waterfall-like flows, although the execution schedule, from the perspective of the cycles, is fully iterative. There are multiple such flows in parallel, and they are usually highly interleaved on the project timeline in order to maximally utilize the team.

Questions

- How can maximum utilization of the team be achieved in Software Engineering, despite a division of labor?

Software Engineering Artifacts



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The four **Artifact Sets** just cluster the individual **Artifacts** and their contained **Aspects**. The **Artifacts** can be represented in an arbitrary graphical and/or textual form and be provided in an arbitrary format. The **Aspects** just structure an individual Artifact internally.

In a Software Engineering project, additional **internal** Artifacts are created by the **Disciplines** in order to perform their work efficiently and effectively. The shown Artifacts are just the **external** ones which glue together the Disciplines and which are part of the delivery set.

Each **Artifact** is tagged with the primary and secondary responsible **Disciplines**, the primary **Step** of the Workflow where the Artifact is developed, and the Scalability Layer (1 to 3, indicating more to lesser importance).

The **Software Requirements Specification** and the **Software Documentation Results** primarily have a **domain-specific** focus. The **Software Architecture Specification** and the **Software Implementation Results** primarily have a **technological** focus.

Questions

- What focus has the **Software Requirements Specification**?

ENGINEERING FUNDAMENTALS

Software Engineering Efforts

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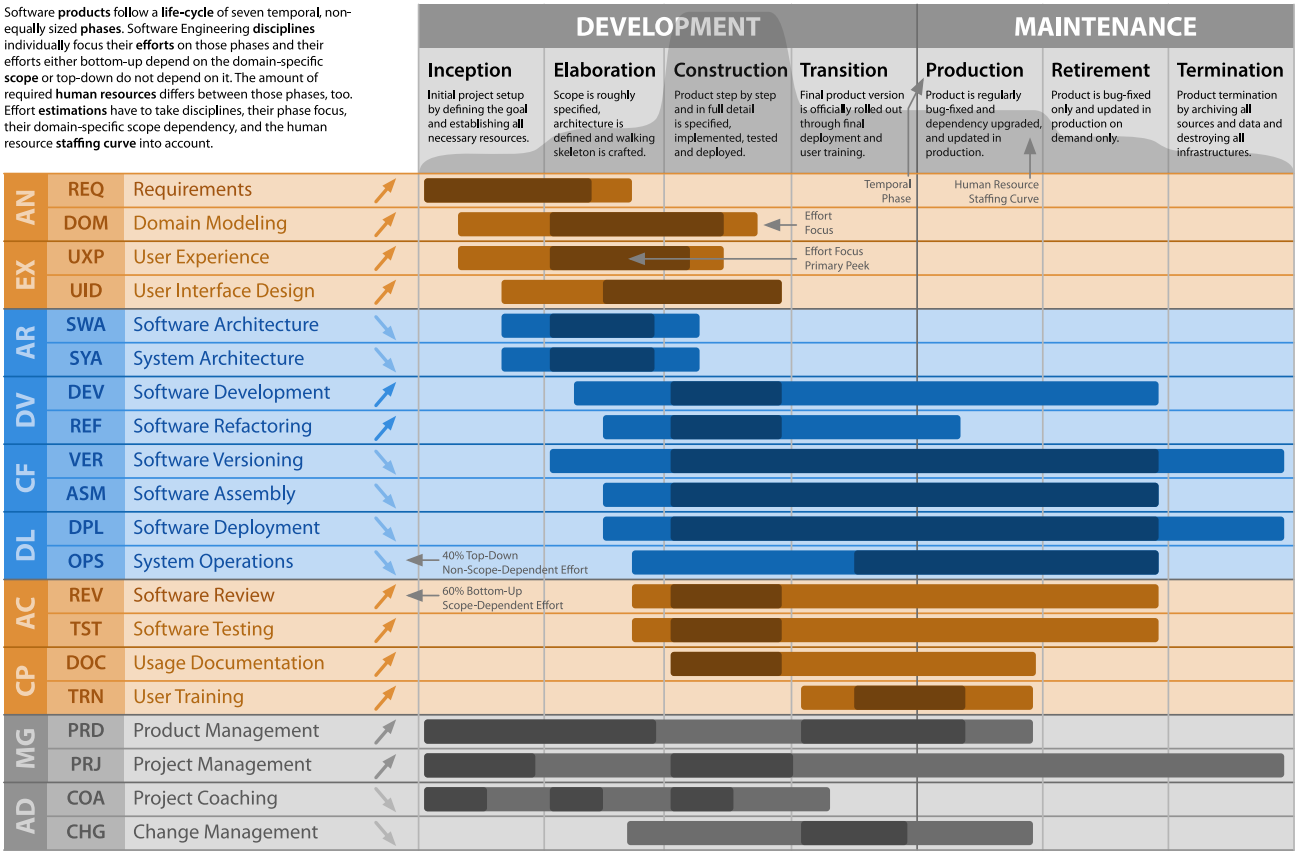
EF 03.1



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phases & efforts

Software products follow a **life-cycle** of seven temporal, non-equally sized **phases**. Software Engineering **disciplines** individually focus their **efforts** on those phases, and their efforts either bottom-up depend on the domain-specific scope, or their efforts top-down do not depend on it. The amount of required **human resources** differs between those phases, too.

Effort estimations have to take into account disciplines, their phase focus, their domain-specific scope dependency, and the human resource staffing curve.

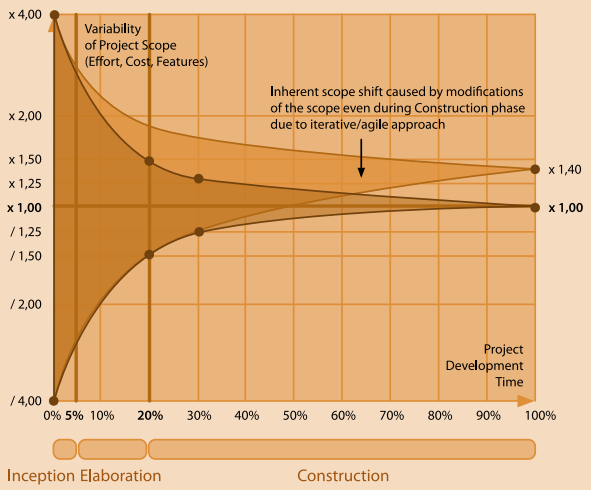
Furthermore, the seven sequential phases, especially, do not conflict with agile process models: agile time **periods** (named "sprints" in Scrum) merely subdivide the individual phases.

Questions

- What is the Software Engineering **Phase** called, which has the greatest personnel requirements and in which primarily the functionalities are realized?

Uncertainty & Elaboration

Cone of Uncertainty



The ***Cone of Uncertainty*** (*Steve McConnell*, 2006) tells how the variability of the project scope (measured in Effort, Cost or Features) in Software Development changes over time. Initially, it usually is within the range of +/- 400% of the final scope.

The early development phases Inception and Elaboration especially have to ensure that within the first 20% of the project, the variability is reduced noticeably to just +/- 50%. During the initial iterations of the Construction phase within the first 30% of the project, the variability usually can be further reduced to about +/- 25%.

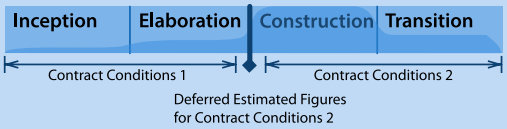
For iterative/agile approaches, experience showed that during the Construction phase inherently the final scope further shifts by about + 40% due to the just step-by-step learned required details of the required solution. This especially has to be taken into account for estimations.

Essential Elaboration Phase

Walking Skeleton:

The ***Walking Skeleton*** (or *Technical Breakthrough*) is the design and implementation of the bare technical foundation of an application, still *without* any domain-specific functionalities. It is made during the Elaboration phase with the primary purpose to establish a stable integration of all technical aspects (libraries, frameworks, build procedures, etc) onto which the domain-specific functionalities later can be successively put onto.

Agile Fixed-Price Contracts:



The ***Agile Fixed-Price*** is an agile variant of a fixed-price contract, *not* a fixed-price project with an agile development process.

There are two important inherent aspects:

First, the contract contains two types of conditions: one (usually *Time & Material* but fixed duration based) for the Inception and Elaboration phases in order to make experiences and to gather necessary figures, and one (usually Fixed-User-Story and/or Fixed-Price based) for the Construction and Transition phases based on deferred estimated figures, gathered in the Elaboration phase.

Second, the Fixed-Price aspect of the contract is actually based on an amount of User-Stories (resulting in costs by multiplying them with either an average hourly rate of an engineer or individual rates based on engineer job levels), which the customer can 1:1 *exchange* during the project for different deliverables.

The crux of an Agile Fixed-Price contract is: first, during the Inception and Elaboration phases the supplier can shrink the *Cone of Uncertainty* and this way its risks dramatically, and second, during the Construction and Transition phases the customer still remains flexible in scope.

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The **Cone of Uncertainty** tells how the variability of the project scope (measured in Effort, Cost or Features) in Software Development changes over time. The early development phases Inception and Elaboration especially have to ensure that the variability is reduced noticeably.

For iterative/agile approaches, experience showed that during the Construction phase, inherently, the final scope further shifts due to the just step-by-step learned, required details of the required solution.

The Elaboration phase is especially important for the creation of the **Walking Skeleton**, where all the technical integrations of libraries, frameworks, build procedures, etc., are done without already implementing any domain-specific functionalities.

Because of the **Cone of Uncertainty**, **Agile Fixed-Price** project contracts usually differentiate between the early phases Inception and Elaboration and the main phases Construction and Transition. The contract conditions of the latter usually depend on figures that can only be seriously estimated at the end of the Elaboration phase.

Questions

- What is especially developed in the project phase “Elaboration”?

Effort Estimations

Estimation & Variability

Three-Point Estimation and Estimation Variability Classes:

$e = (b + 4 \times m + w) / 6$	expected effort (weighted average)
$s = (w - b) / 6$	standard deviation (effort variation)

b: best-case (optimistic)
m: most-likely (realistic)
w: worst-case (pessimistic)

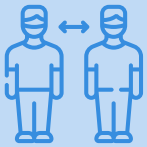
Insane Variability:	+/- 10%
Very Good Variability:	+/- 15%
Good Variability:	+/- 20%
Acceptable Variability:	+/- 25%

Conversion & Normalization

1. Ask Estimater:
"How many Person-Days do you need when you can focus on this task?"

2. Convert from Estimator to Performer:
(see also CAP model, http://cap-model.com)

Estimator \ Performer	Non-Linear Effort Reduction 0% Novice	10% Practitioner	25% Master	45% Expert	80% Guru
Novice	1,00	0,90	0,75	0,55	0,20
Practitioner	1,11	1,00	0,83	0,61	0,22
Master	1,33	1,20	1,00	0,73	0,27
Expert	1,82	1,64	1,36	1,00	0,36
Guru	5,00	4,50	3,75	2,75	1,00

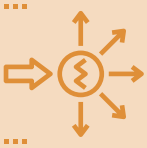


Sizes & Variability

Estimation Sizes and Estimation Variability:

T-Shirt-Size (Logically)	XXS	XS	S	M	L	XL	XXL	XXXL
Fibonacci-Size (PD or SP)	**0,50**	**1**	**2**	**3**	**5**	**8**	**13**	**21**
Size Variability (-)	0,25	0,25	0,50	0,50	1,00	1,50	2,50	4,00
Size Variability (+)	0,25	0,50	0,50	1,00	1,50	2,50	4,00	8,00

Notice: Estimations can be done in *Person-Days (PD)* or *Story-Points (SP)*. In both cases, keep in mind to use something like the *Fibonacci* numbers which increase in a non-linear fashion and express the increasing variability with the increasing total amount of estimated effort.



Risk Mitigation & Upscaling

3. Adjust for Reality:
Estimator Optimism: +30%
Performer Meetings: +20%

4. Adjust for Uncertainty:

Domain	Inception	Elaboration	Construction
unknown	30%	40%	20%
partially known	15%	20%	10%
fully known	0%	0%	0%

Technology	Inception	Elaboration	Construction
unknown	20%	60%	10%
partially known	10%	30%	5%
fully known	0%	0%	0%

Process	Inception	Elaboration	Construction
unknown	60%	40%	10%
partially known	30%	20%	5%
fully known	0%	0%	0%

People	Inception	Elaboration	Construction
unknown	60%	40%	0%
partially known	30%	20%	0%
fully known	0%	0%	0%

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Effort Estimations are usually based on a **Three-Point Estimation** where a weighted average of "best case", "most likely" and "worst case" are used. A good estimation variability in practice is about +/- 20%.

For **Expert Estimations**, a fixed scale of estimation sizes are usually used in practice, which is based on the **Fibonacci** sequence of numbers, to take into account the fact that higher estimated efforts also have higher estimation variability.

Additionally, one usually has to post-adjust the estimation of experts to further take into account the different skill and experience levels between the task estimator and the subsequent task performer, the usual human optimism of the estimator and the practical meeting and inevitable communication distractions of the performer.

In case of uncertainty because of entirely unknown or at least just partially known aspects Domain, Technology, Process and People, the total estimated efforts of the usual project phases have to be additionally upscaled.

Questions

- What variability does a **good** Estimation have?

ARCHITECTURE FUNDAMENTALS

Requirements Basics

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Requirements Specification

A binding document that specifies the requirements for a solution, by focusing on the WHAT and WHY of the solution — and *not* giving instructions for the HOW.

The documented set of requirements has to be: correct, unambiguous, complete, consistent, ranked, verifiable, modifiable, and traceable.

Requirement Classes

FR Functional (Shall Do)

A condition or capability that a solution must have to provide its service in terms of its behaviour and information. Think: Functionality.

NFR Non-Functional (Shall Be)

A condition, property or quality that a solution must have to satisfy a contract, standard, or other formally imposed obligation. Think: Constraints and "*-ilities".

Requirement Interdependencies

POS Positive (Backing)

One requirement supports the other (e.g. for NFRs: Maintainability and Comprehensibility usually support Adaptability, Portability, Modifiability, etc., and Scalability usually supports Availability, etc.)

NEG Negative (Trade-Off)

One requirement interferes with the other (e.g. for NFRs: Security usually interferes with Efficiency, Usability, Performance, etc., and Orthogonality can interfere with Usability)

Requirement Characteristics

S Specific

The requirement is precise, unambiguous, and clear on what should be done.

M Measurable

The requirement can be verified when it has been achieved by use of a particular test.

A Achievable

The requirement is achievable given existing circumstances and feasible and viable solutions.

R Relevant

The requirement is relevant to the goals of the context.

T Time-Bound

The requirement can be achieved within a reasonable time frame.

Requirement Life-Time

E Enduring

The requirement lasts forever, as it is derived from core activities and organisational structures.

V Volatile

The requirement can be temporary, as it might change over time.

Requirement Expression

[<req-id>] <req-name>**:**
<subject/actor>
SHALL
<result/action/condition>
BECAUSE
<rationale>

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The **Requirements Specification** is a binding document in which primarily the WHAT and WHY of the solution is specified, however not the concrete technical HOW. The set of requirements must be correct, unambiguous, complete, consistent, prioritized, verifiable, changeable and traceable.

There are two types of requirements: **Functional Requirement** ("Shall Do", functionality) and **Non-Functional Requirements** ("Shall Be", Conditions, in English often expressed with words ending in "-ility"). The architect primarily takes care of the latter.

Requirements can also be reciprocally positive (backing) or negative (trade-off). The architect also primarily takes care of the latter.

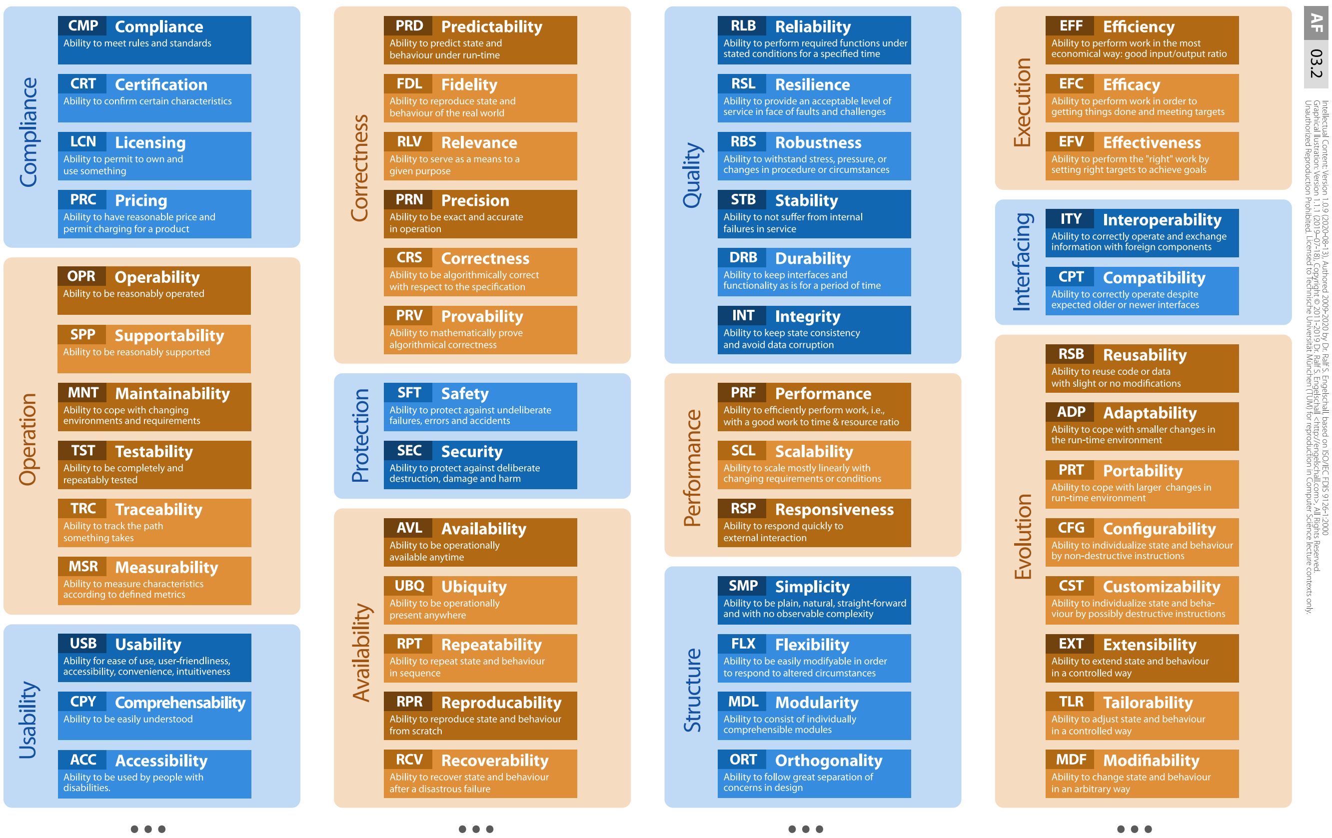
Requirements should be "SMART": **Specific**, **Measurable**, **Achieveable**, **Relevant** and **Time-Bound**.

In addition, requirements are either **Enduring** (fixed) or **Volatile** (unstable). The architect should pay attention to the latter.

Questions

? What kind of **requirements** should the architect primarily keep in mind and should be explicitly addressed by him in the solution finding?

Non-Functional Requirements



AF 03.2
Compliance
CMP Compliance
Ability to meet rules and standards
CRT Certification
Ability to confirm certain characteristics
LCN Licensing
Ability to permit to own and use something
PRC Pricing
Ability to have reasonable price and permit charging for a product
Operation
OPR Operability
Ability to be reasonably operated
SPP Supportability
Ability to be reasonably supported
MNT Maintainability
Ability to cope with changing environments and requirements
TST Testability
Ability to be completely and repeatably tested
TRC Traceability
Ability to track the path something takes
MSR Measurability
Ability to measure characteristics according to defined metrics
Usability
USB Usability
Ability for ease of use, user-friendliness, accessibility, convenience, intuitiveness
CPY Comprehensability
Ability to be easily understood
ACC Accessibility
Ability to be used by people with disabilities.
Correctness
PRD Predictability
Ability to predict state and behaviour under run-time
FDL Fidelity
Ability to reproduce state and behaviour of the real world
RLV Relevance
Ability to serve as a means to a given purpose
PRN Precision
Ability to be exact and accurate in operation
CRS Correctness
Ability to be algorithmically correct with respect to the specification
PRV Provability
Ability to mathematically prove algorithmical correctness
Protection
SFT Safety
Ability to protect against undeliberate failures, errors and accidents
SEC Security
Ability to protect against deliberate destruction, damage and harm
Availability
AVL Availability
Ability to be operationally available anytime
UBQ Ubiquity
Ability to be operationally present anywhere
RPT Repeatability
Ability to repeat state and behaviour in sequence
RPR Reproducability
Ability to reproduce state and behaviour from scratch
RCV Recoverability
Ability to recover state and behaviour after a disastrous failure
Quality
RLB Reliability
Ability to perform required functions under stated conditions for a specified time
RSL Resilience
Ability to provide an acceptable level of service in face of faults and challenges
RBS Robustness
Ability to withstand stress, pressure, or changes in procedure or circumstances
STB Stability
Ability to not suffer from internal failures in service
DRB Durability
Ability to keep interfaces and functionality as is for a period of time
INT Integrity
Ability to keep state consistency and avoid data corruption
Performance
PRF Performance
Ability to efficiently perform work, i.e., with a good work to time & resource ratio
SCL Scalability
Ability to scale mostly linearly with changing requirements or conditions
RSP Responsiveness
Ability to respond quickly to external interaction
Structure
SMP Simplicity
Ability to be plain, natural, straight-forward and with no observable complexity
FLX Flexibility
Ability to be easily modifyable in order to respond to altered circumstances
MDL Modularity
Ability to consist of individually comprehensible modules
ORT Orthogonality
Ability to follow great separation of concerns in design
Execution
EFF Efficiency
Ability to perform work in the most economical way: good input/output ratio
EFC Efficacy
Ability to perform work in order to getting things done and meeting targets
EFV Effectiveness
Ability to perform the "right" work by setting right targets to achieve goals
Interfacing
ITY Interoperability
Ability to correctly operate and exchange information with foreign components
CPT Compatibility
Ability to correctly operate despite expected older or newer interfaces
Evolution
RSB Reusability
Ability to reuse code or data with slight or no modifications
ADP Adaptability
Ability to cope with smaller changes in the run-time environment
PRT Portability
Ability to cope with larger changes in run-time environment
CFG Configurability
Ability to individualize state and behaviour by non-destructive instructions
CST Customizability
Ability to individualize state and behaviour by possibly destructive instructions
EXT Extensibility
Ability to extend state and behaviour in a controlled way
TLR Tailorability
Ability to adjust state and behaviour in a controlled way
MDF Modifiability
Ability to change state and behaviour in an arbitrary way
• • •
• • •
• • •
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There are potentially many **Non-Functional Requirements.** For any solution, one must therefore first determine the actual quantity of such Requirements. This quantity must be minimized by the Architect!

For every contractually stipulated Requirement, one should take into account that it is clearly defined since there are great similarities between Requirements and the differences are sometimes very subtle.

A few of the Non-Functional Requirements that almost always have to be considered in practice are **Maintainability**, **Usability**, **Security**, **Availability**, **Reliability**, **Performance**, **Responsiveness** and **Adaptability**.

Questions

? Name 3 in practice frequently considered **Non-Functional Requirements!**