Karlsruhe Institute of Technology

# Configuration and Change Process Maturity Improvement

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# Engineering Change Management - Essential for continued development of companies

**Definition of Engineering Change (EC):**

An engineering change is an alteration made to parts, drawings or software that **have already been released** to production. The change can be of any size or type; the change can involve any number of people and take any length of time (Jarratt et.al. 2004).

## Triggers for Engineering Change

**Emergent Changes**

- Error Correction
- Product Safety
- Change of Function
- Product Quality

**Initiated Changes**

- Customer Requirement
- Supplier Issues
- Product Support Enhancement

## Impact of Change Process

- Additional Cost
- Scheduling
- Supply Chain
- Product Performance
- Reliability
- Availability
- Maintenance
- Safety
- etc.

**Efficient and effective Engineering Change Management is a prerequisite for success in an ever more dynamic competitive environment**

# Cross-industry Configuration Management Maturity Assessment utilizing the developed CM Maturity Model

Evaluation of more than 67 organizations from various industry sectors such as Automotive and Aerospace


**Strategy & Performance**

The existence and alignment of CM strategy and policy with the overall strategy, vision and mission of the entreprise. The suitable performance indicators to measure this alignment and the achievement of CM goals.

**Processes**

The availability of standard processes that can stabilize the CM activities among all organizanional units during all lifecycle phases and the approach to test and measure the efficiency of such processes.

**Information Technology**

The information systems and tools being used by the entreprise and the level up to which their functionalities match the necessities. The level of integration of these information systems into the business processes of the organization.

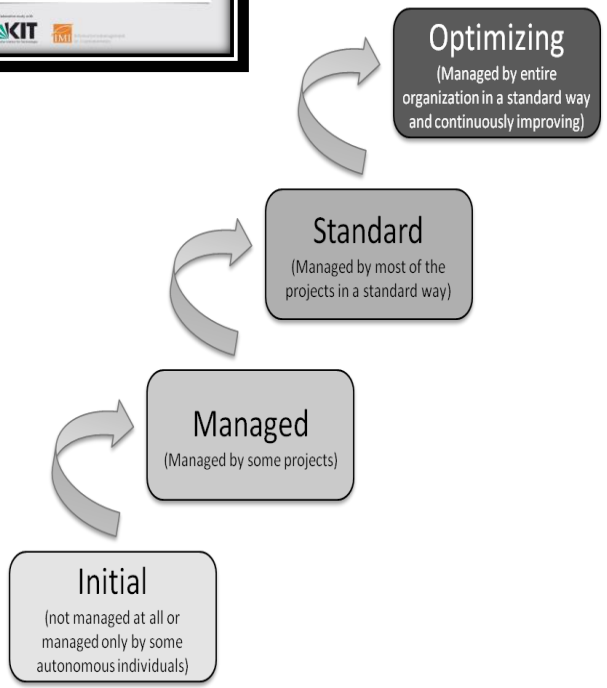
**Organization & Value-stream**

The organizational structure of the entreprise with respect to CM and the level to which the roles and responsibilities are defined. The way to cope with the CM complexities through the whole supply chain e.g. dealing with sub-contractors.

**Knowledge & Support**

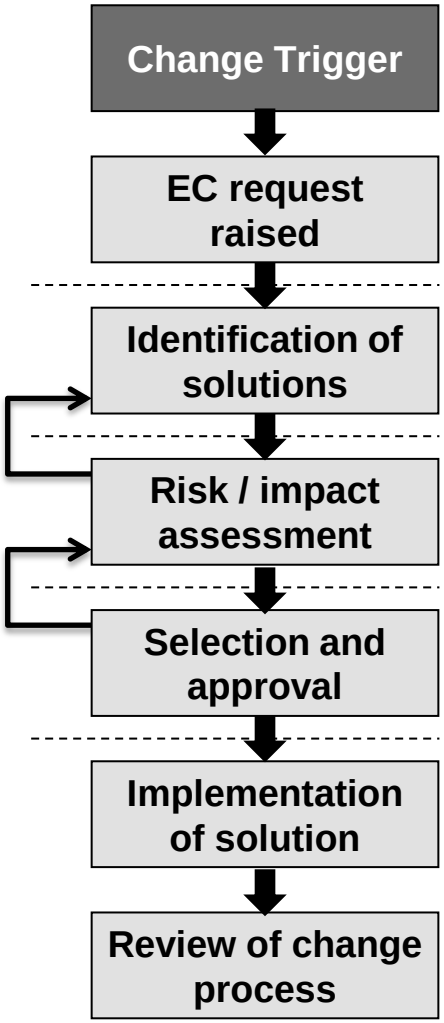
The level up to which the entreprise and key personnel are knowledgable in CM areas. The initiatives and efforts of the management in supporting the CM activities throughout the organization.

Dimensions of Configuration Management Maturity Model (CM3)



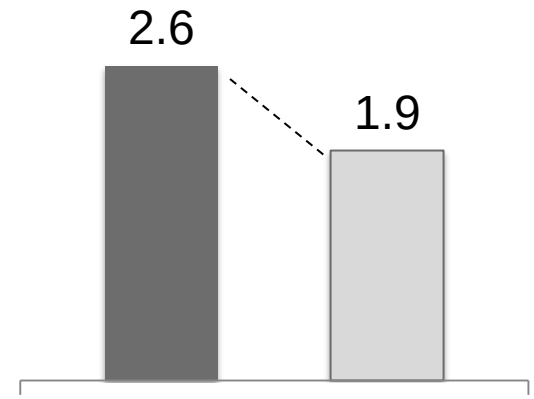

Configuration Management Maturity Levels

# High Engineering Change Process Maturity and low IT Tool Maturity indicate need for action




(Jarratt et.al. 2004)

- Engineering Change process is well understood and implemented in many organizations
- Competitive environment requires timely and high quality decisions
- With the growing complexity of products, production, organizations and value chains, fast and well informed decision making is getting increasingly difficult




**Support of risk / impact assessment needed to close gap between process and IT tool maturity**

----- Break Point ——— Iteration loop

(Nikham et. al. 2013)

# Engineering Change Mgmt. Decision Making not sufficiently supported by current tools

| IT System | Focus |
|---|---|
| PLM systems | Supporting the workflow and automation of the ECM processes |
| Computer Aided Design (CAD) | Analysis of the impact and mismatch of design changes based on geometrical values |
| Redesign IT [Ollinger & Stahovich 2001] | Generates proposals for redesign plans using a product model with relevant physical quantities and causal relationships |
| Change FAvourable Representation (C-FAR) | Examination of attributes and interactions between core elements of various entities in product models to predict propagation |
| Change Prediction Method [Clarkson et al. 2001] | Change Prediction Method (CPM) [Clarkson, Simons & Eckert 2001] |
| ADVICE [Kocar & Akgunduz 2010] | Virtual environment for ECM with the prioritization agents and propagation prediction techniques |
| Hamraz et al [2012] | Multidomain EC Propagation model utilizing DSM and Multidomain Matrices (MDM) for predicting the change propagation |

## Problems:

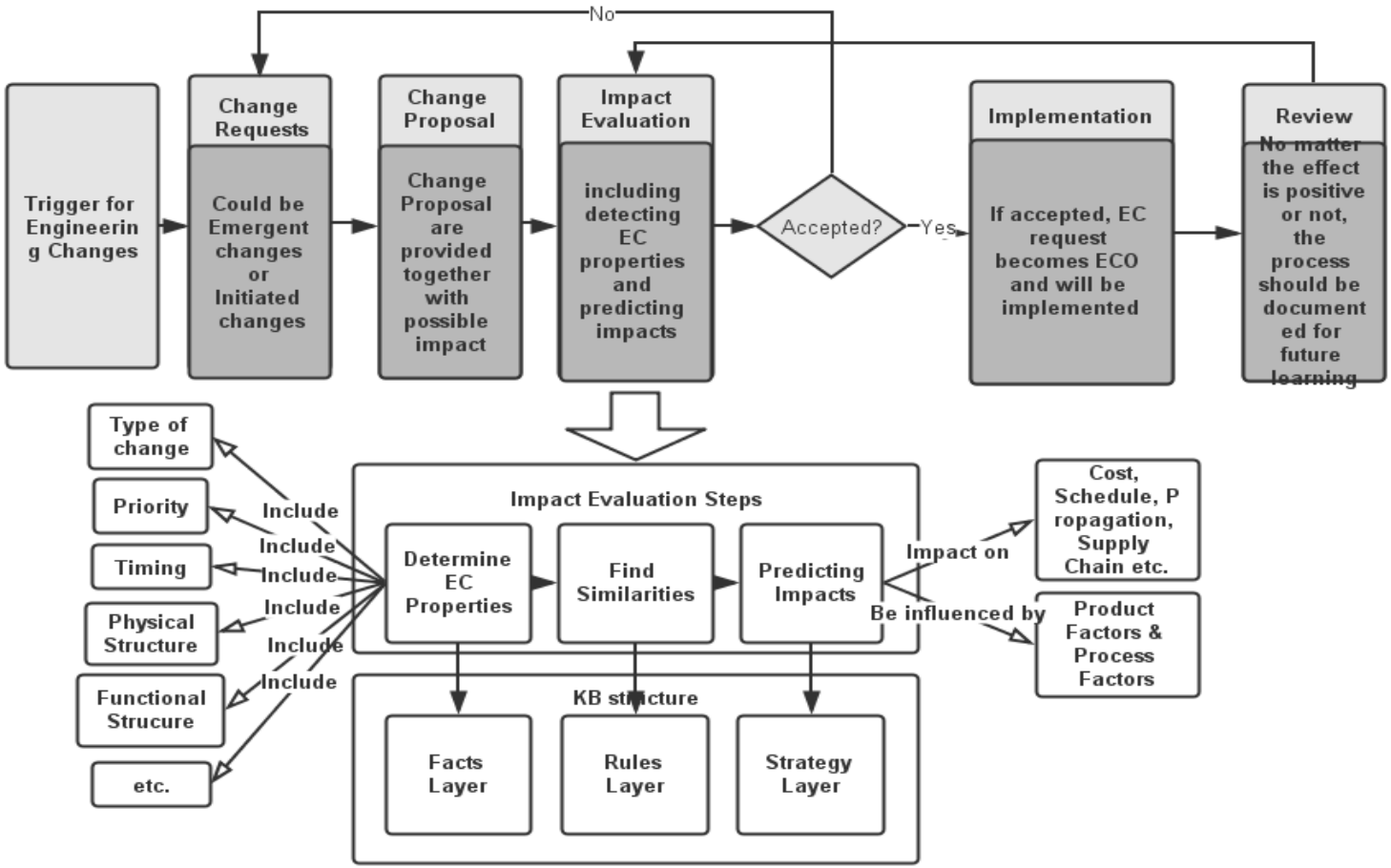
- Mostly focused on physical propagation
- Non-functional requirements not considered (safety, reliability, etc.)
- Tacit knowledge from experts not considered

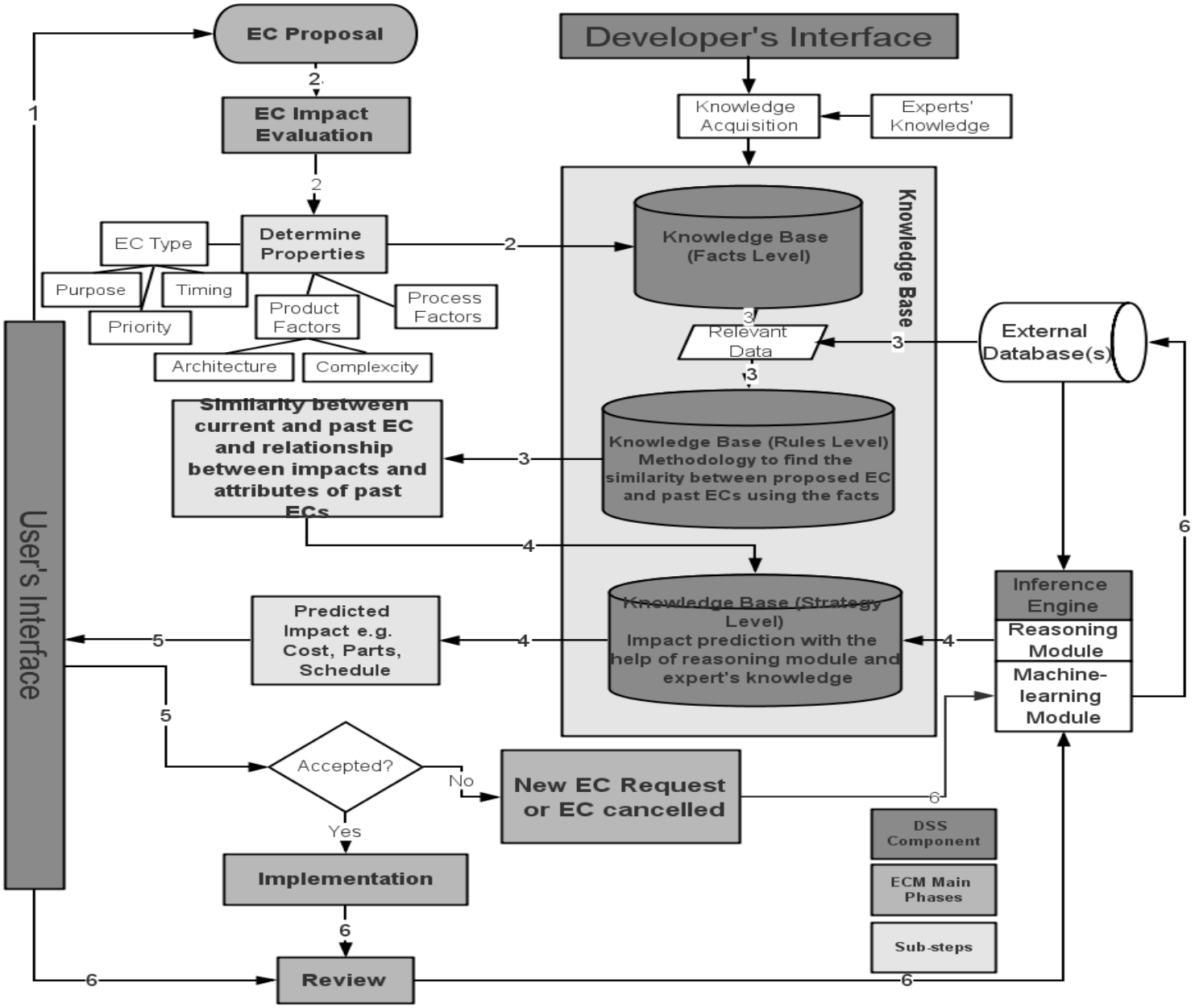
## Proposal:

- Utilizing knowledge from previous cases to estimate impact of proposed change
- Support of Decision Makers

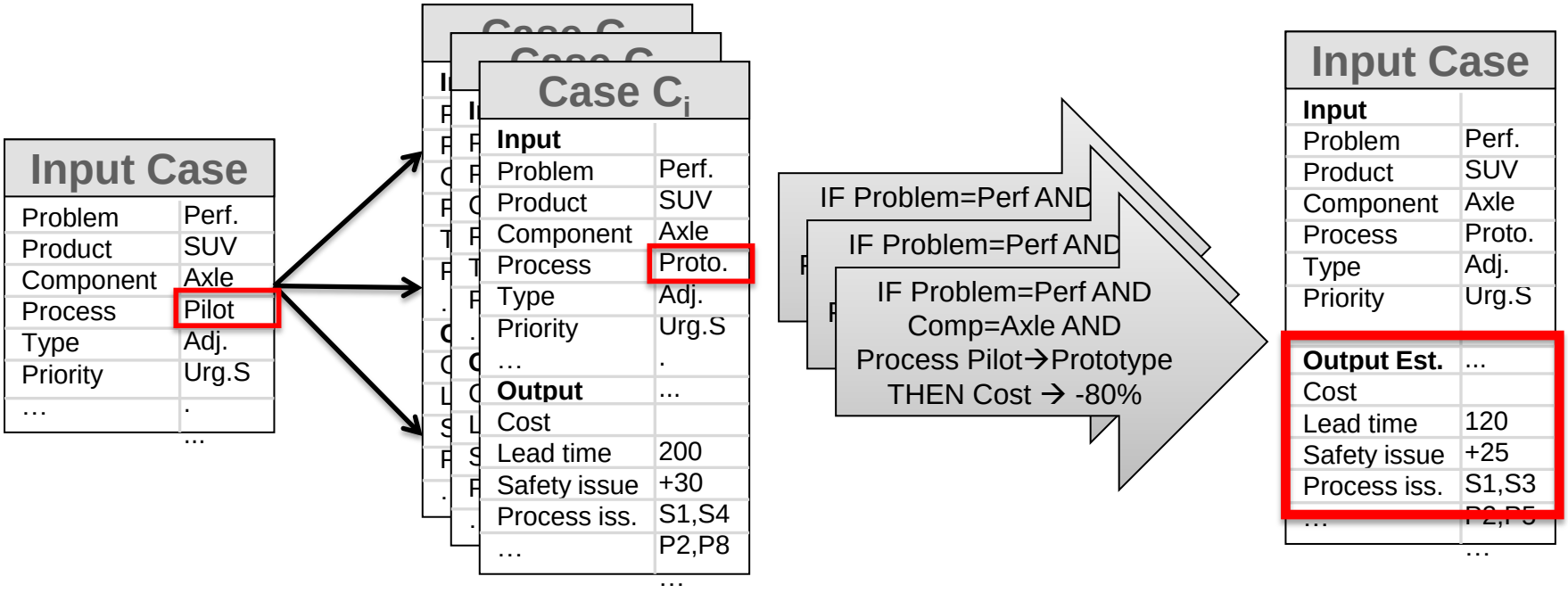
# Proposed ECM Process

Backup





# Case Based Reasoning identifies and adjusts similar cases to estimate implications on case




**Input**

## Identify similar cases

- Calculation of similarity measure based on ontological description of case features
- Use of input values only

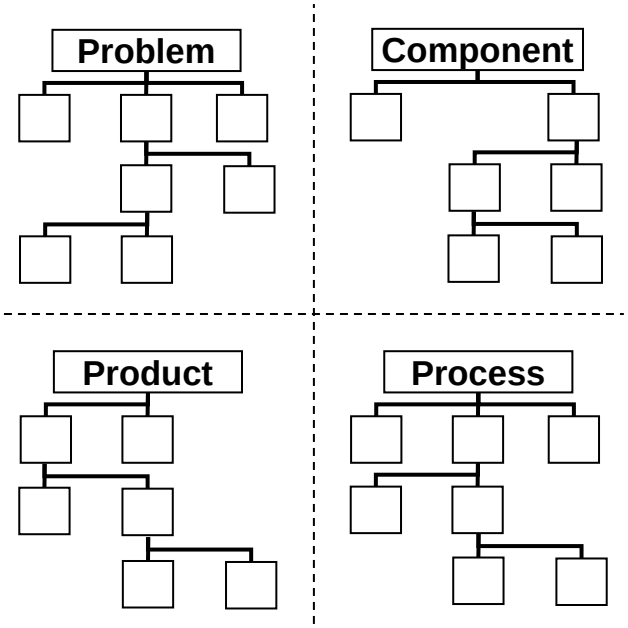
## Adjust cases via rules

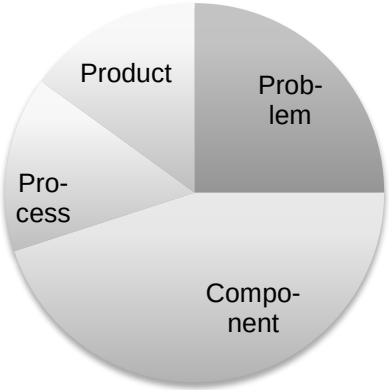
- Adjustment of cases to match input case
- Rules induced from case base with impact on output variables

## Estimate Impact

- Combine Values of similar cases to achieve high information level
- Include case similarity in impact weighing

# Similarity assessment uses Ontology based representation of cases




$$Sim(C_1, C_2) = \frac{\sum_i w_i \cdot d_i \cdot sim_i(c_{1,i}, c_{2,i})}{\sum_i w_i}$$

**Similarity assessment for each ontology → $Sim(C_1,C_2)$** | **Adjustment for weight[1)] (*w*) and depth (*d*) of ontology** | **Use previous cases with $Sim(C_1,C_2)$ > Threshold Sim.**

- ⊕ Ontology based assessment with higher performance
- ⊕ Automatic calculation of concept similarity from previous cases in case base
- ⊕ Consideration and weighing of different ontologies and concept similarities
- ⊕ Flexibility for adjustment of ontologies
- ⊖ High effort for Analytic Hierarchy Process

1) Weights determined with Analytic Hierarchy Process

# Adjustment rules automatically drawn from existing case database

| Case $C_j$ | |
|---|---|
| **Input** | |
| Problem | Perf. |
| Product | SUV |
| Component | Axle |
| Process | Proto. |
| Type | Adj. |
| Priority | Urg.S. |
| … | … |
| **Output** | |
| Cost | 200 |
| Lead time | +30 |
| Safety issue | S1,S4 |
| Process iss. | P2,P8 |
| … | … |

**IF** Problem=Perf **AND** Comp=Axle **AND** Process=Pilot **THEN** Cost=200

**IF** Problem=Perf **AND** Comp=Axle **AND** Process Pilot→Prototype **THEN** Cost → -80%

| Case $C_j$ | |
|---|---|
| **Input** | |
| Problem | Perf. |
| Product | SUV |
| Component | Axle |
| Process | Proto. |
| Type | Adj. |
| Priority | Urg.S. |
| … | … |
| **Output** | |
| Cost | 200 |
| Lead time | +30 |
| Safety issue | S1,S4 |
| Process iss. | P2,P8 |
| … | … |

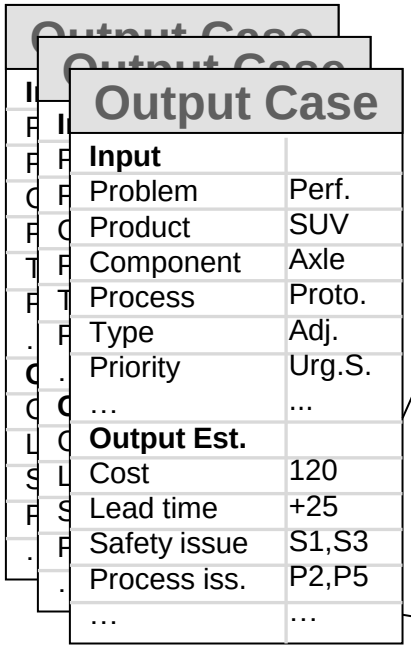
**IF** Problem=Perf **AND** Comp=Axle **AND** Process=Pilot **THEN** Cost=40

- Automatic generation of adjustment rules by using information contained within the case base
- Discovery of rules through machine learning algorithms
- Candidate methods include:
  - Multilayer Perceptron
  - Multiclass Support Vector Machine
- Application of rules that meets high required support and confidence levels

**Support (AB) = P (A U B)**
**Confidence (AB) = P (B | A)**

# Combination of several previous cases enhances Information quality

**Several estimations of Engineering Change Impact** → **Combination based on similarity and confidence** → **High quality information basis for EC Decision Maker**




**Output Estimation**

Cost
Lead time
Safety issues
Process issues

- Deny EC request
- Demand reiteration
- Accept EC request

- Weighing of output estimates based on similarity measure and rule confidence
- Completed Cases are reviewed and serve as input for machine learning
- Decision Support System allows for faster and higher quality decisions

# Improved Decision Speed and Quality justify additional Effort for DSS Implementation

- ⊕ Consideration of input from previous cases allows for reuse of (tacit) knowledge
- ⊕ Constantly expanding case base allows for dynamic update of knowledge
- ⊕ Applicability of system to various fields

- ⊖ Accuracy of predicted impacts highly dependent on data quality and used algorithms
- ⊖ Comparatively high effort for implementation and information gathering

**Further Study**

- Evaluation of suitable algorithms
- Identification of data sources and formats
- Practical implementation and validation

**Development of Knowledge-based Decision Support System strongly supports more efficient and effective Engineering Change Management**


Thank You!