CONTROL IN STEEL

How semantic tools help to understand impact mechanisms and transfer potential in research projects

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2022-06-21, ESTEP Dissemination Event 2022

Research Fund for Coal & Steel

BFI
Excellence in Applied Research

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1. Introduction

CONTROLIN**STEEL**

- ControlInSteel is a dissemination activity focusing **advanced automation and control**

  - We selected around **46 (+5) former RFCS research projects** for a scientific analysis

  - Mission goals
    - 1. Analyze and understand **dynamics** of the **problem-**, **solution-** and **impact space** which also includes **barriers** and **issues**, as well as **physical interaction channels**
    - 2. Perform **dissemination events**, e.g. conference sessions and workshops to effectively distribute knowledge from and about these former projects
    - 3. Provide a **roadmap for future research**

Automation: Key Enabler for Process Industries

- Scheduling

- Optimization

- Complex process management

- Process control

- Throughput increase

- Product quality improvement
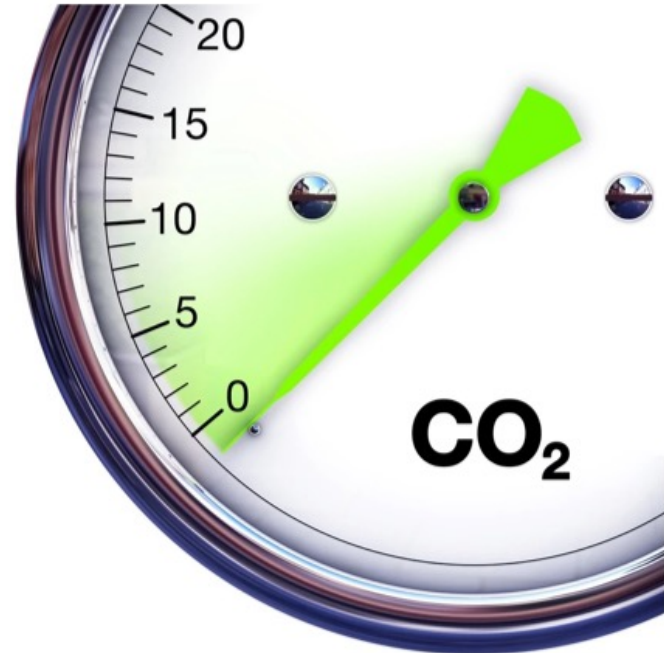
- CO2 reduction

- Energy optimization

- In general: producing towards ecological KPIs

2. Analysis based on semantic tools

*We want to know which **types of problems** are solved effectively by which **types of solutions** and generate what **types of impacts** by overcoming which **type of barriers and issues**.*

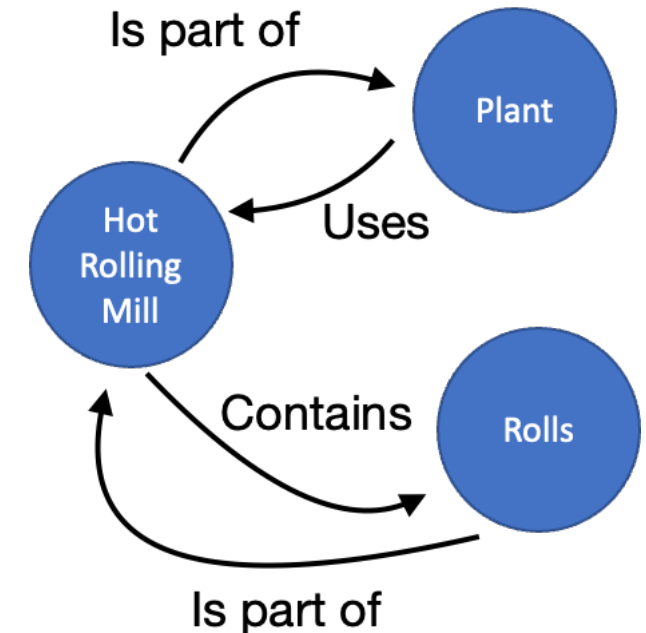*If we know this, we can **maximize the overall impact**.*
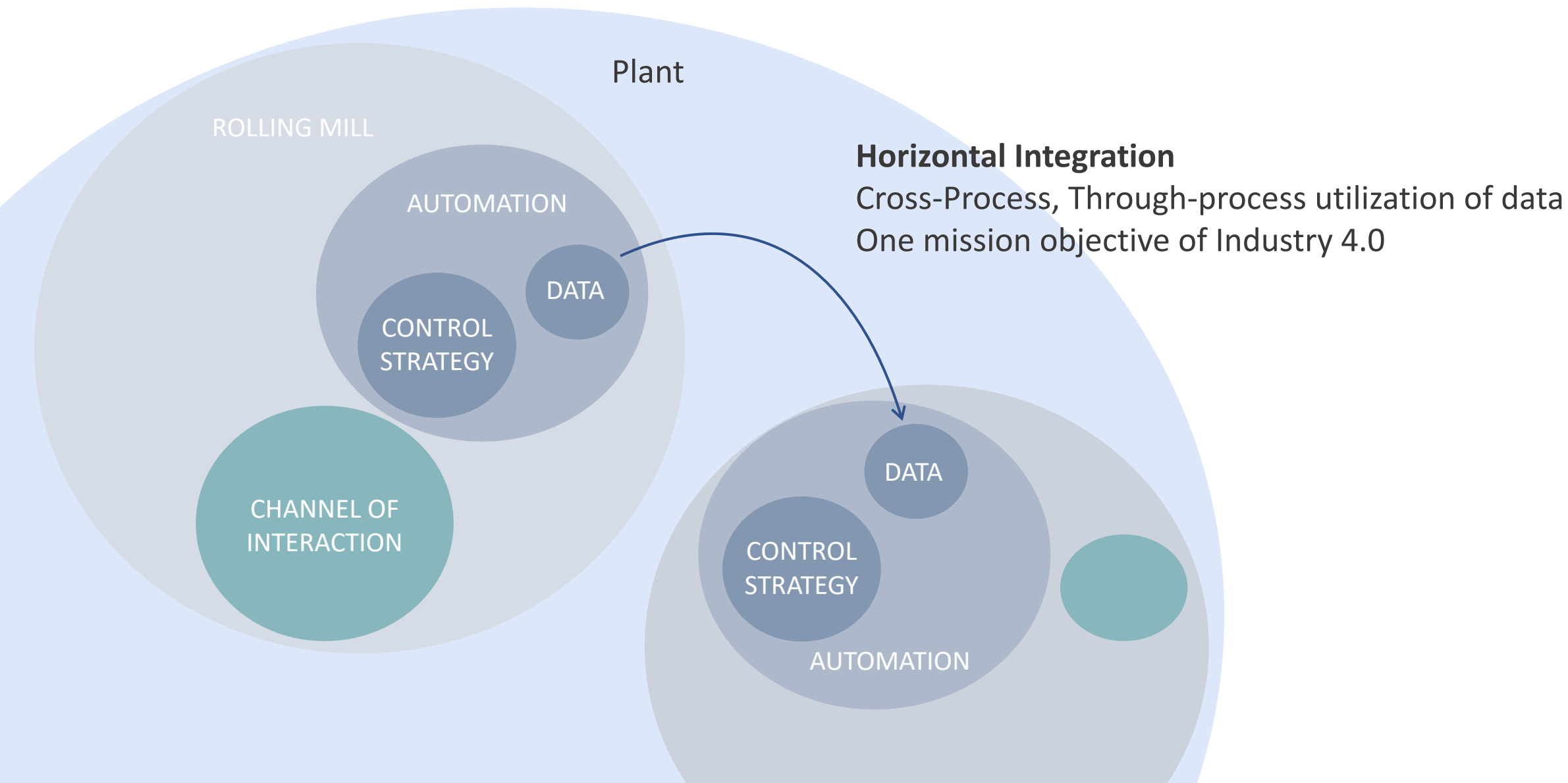
- Synonyms
- Taxonomies
- Ontologies

Relationships

- Degree of complexity - - - - - - - - - - - - - - - - - - ▶

Synonyms for the word: GOOD

● Wonderful	● Astounding	● Astonishing	● Exciting
● First-rate	● Outstanding	● Impressive	● Delightful
● Fabulous	● Magnificent	● Awesome	● Dazzling
● Superior	● Beyond belief	● Splendid	● Breathtaking
● Superb	● Stupendous	● Majestic	● Glorious
● Excellent	● Amazing	● Grand	● Incredible

From: ESL Forums, eslforums.com, 2019

BLOOM'S TAXONOMY DIGITAL PLANNING VERBS

REMEMBERING	UNDERSTANDING	APPLYING	ANALYZING	EVALUATING	CREATING
Copying	Annotating	Acting out	Calculating	Arguing	Blogging
Defining	Tweeting	Articulate	Categorizing	Validating	Building
Finding	Associating	Reenact	Breaking Down	Testing	Animating
Locating	Tagging	Loading	Correlating	Scoring	Adapting
Quoting	Summarizing	Choosing	Deconstructing	Assessing	Collaborating
Listening	Relating	Determining	Linking	Criticizing	Composing
Googling	Categorizing	Displaying	Mashing	Commenting	Directing
Repeating	Paraphrasing	Judging	Mind-Mapping	Debating	Devising
Retrieving	Predicting	Executing	Organizing	Defending	Podcasting
Outlining	Comparing	Examining	Appraising	Detecting	Wiki Building
Highlighting	Contrasting	Implementing	Advertising	Experimenting	Writing
Memorizing	Commenting	Sketching	Dividing	Grading	Filming
Networking	Journaling	Experimenting	Deducing	Hypothesizing	Programming
Searching	Interpreting	Hacking	Distinguishing	Measuring	Simulating
Identifying	Grouping	Interviewing	Illustrating	Moderating	Role Playing
Selecting	Inferring	Painting	Questioning	Posting	Solving
Tabulating	Estimating	Preparing	Structuring	Predicting	Mixing
Duplicating	Extending	Playing	Integrating	Rating	Facilitating
Matching	Gathering	Integrating	Attributing	Reflecting	Managing
Bookmarking	Exemplifying	Presenting	Estimating	Reviewing	Negotiating
Bullet-pointing	Expressing	Charting	Explaining	Editorializing	Leading

From: Blooms Taxonomy, Terry Heick, 2018

Is part of

Plant

Hot Rolling Mill

Uses

Contains

Rolls

Is part of

Industry 4.0 in the mereologic perspective

CONTROL IN STEEL

Plant

ROLLING MILL

AUTOMATION

DATA

CONTROL STRATEGY

CHANNEL OF INTERACTION

DATA

CONTROL STRATEGY

AUTOMATION

Horizontal Integration
Cross-Process, Through-process utilization of data
One mission objective of Industry 4.0

Taxonomy for problem space

T1) Aggregate	Type	Product	Interaction
Casting	Continuous casting	Slab	physics:thermodynamic
Furnace	Slab reheating	Slab	physics:thermodynamic
	Walking bean reheating	Slab	physics:thermodynamic
	Billet furnace	Billet	physics:thermodynamic
Logistics	Transport	Slab	logistics:displacement
Annealing	Continuous annealing	Strip	physics:thermodynamic
	Bright annealing		physics:thermodynamic
	Batch annealing		physics:thermodynamic
Rolling	Roughing mill	Slab	pyhsics:forming; physics:thermodynamic
	Finishing mill	Strip	pyhsics:forming; physics:thermodynamic
	Cold rolling	Strip	pyhsics:forming; physics:thermodynamic
	Temper rolling	Strip	pyhsics:forming; physics:thermodynamic
	Plate mill		
Cooling	Cooling	Slab, Strip	physics:thermodynamic
Refinement	Hot dip galvanization	Strip	chemical:galvanisation, physics:thermodynamic
	Electro galvanisation	Strip	chemical:galvanisation, physics:thermodynamic
	Pickling mill	Strip	chemical:etching;
	Coating	Strip	chemical: bond; physics:adhesion
	Foiling	Strip	chemical: bond; physics:adhesion
	Skin pass	Strip	physics:cutting;
	Scarfing		
	Levelling	Strip	physics:forming;
Thru-process			
Topical	Descaling	Slab, Strip	physics:evaporation
	Flatness	Strip	physics:forming
	Quality		
	Long		
	Flat		
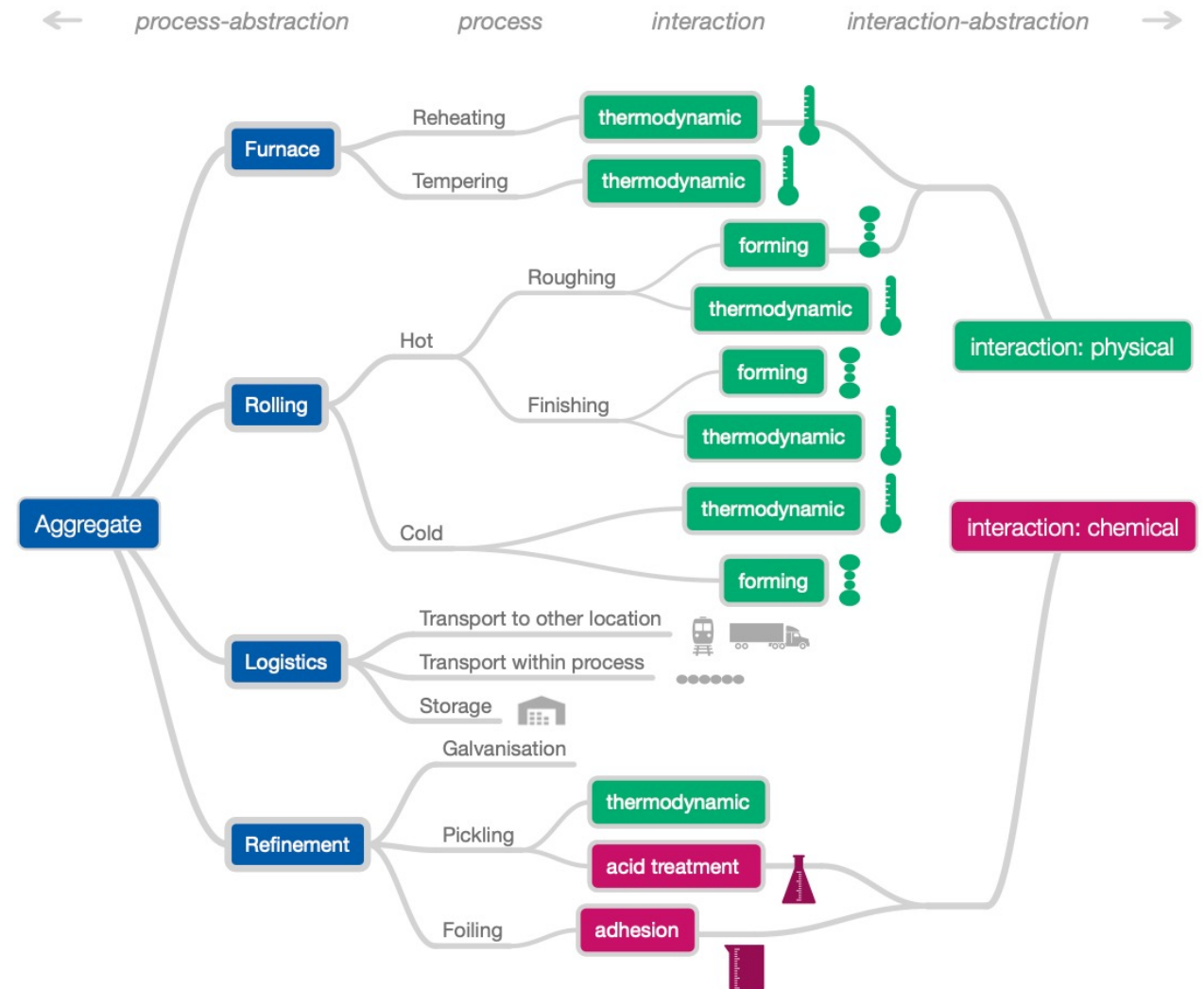
process-abstraction   process   interaction   interaction-abstraction
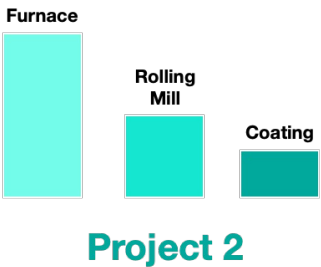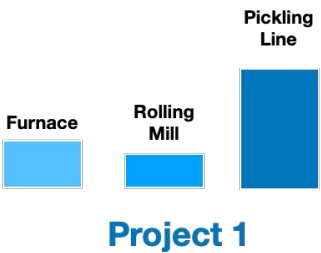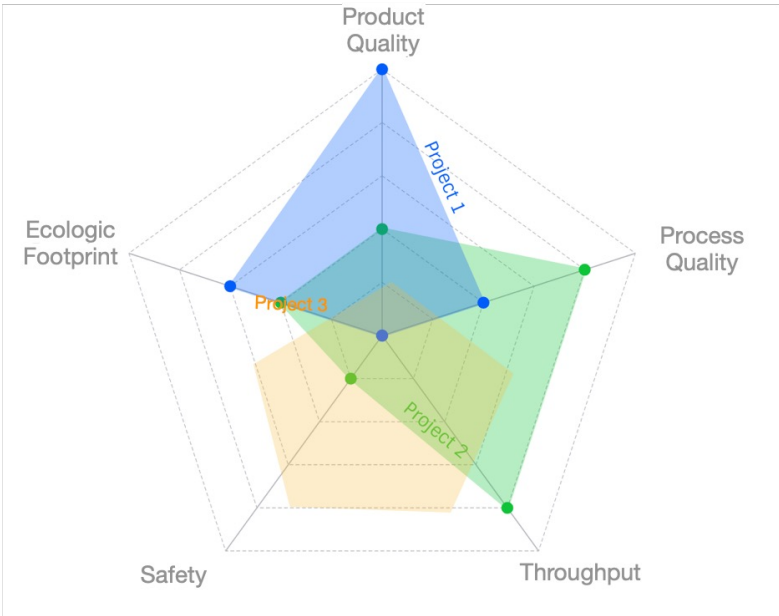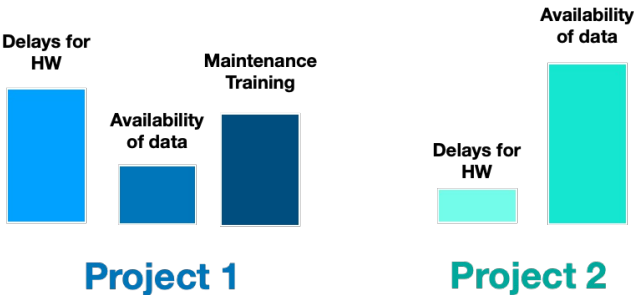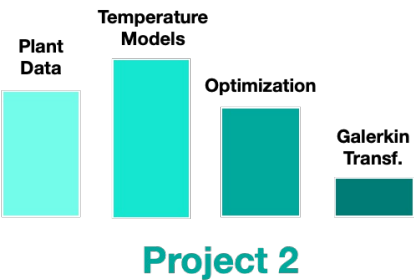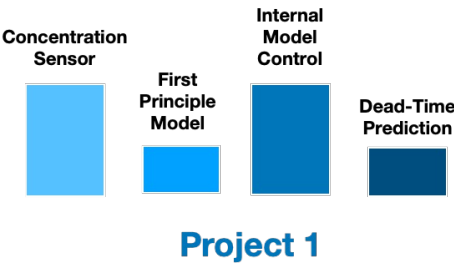
Idea of ControlInSteel

Problem space

Project 1

Project 2

Impact space

Product Quality

Process Quality

Ecologic Footprint

Project 1

Project 3

Project 2

Safety

Throughput

Solution space

Project 1

Project 2

Barriers & issues space
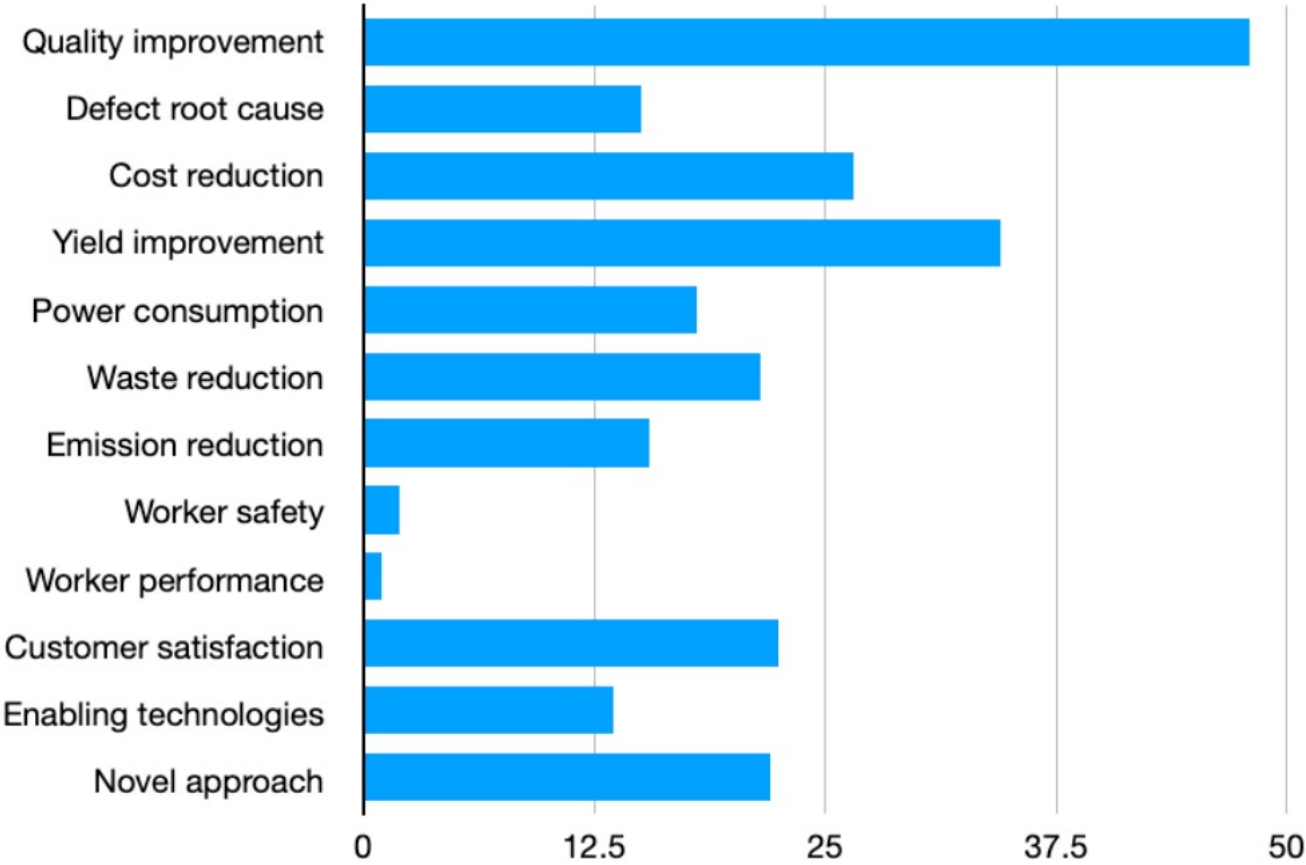
Project 1

Project 2

Impact analysis per project
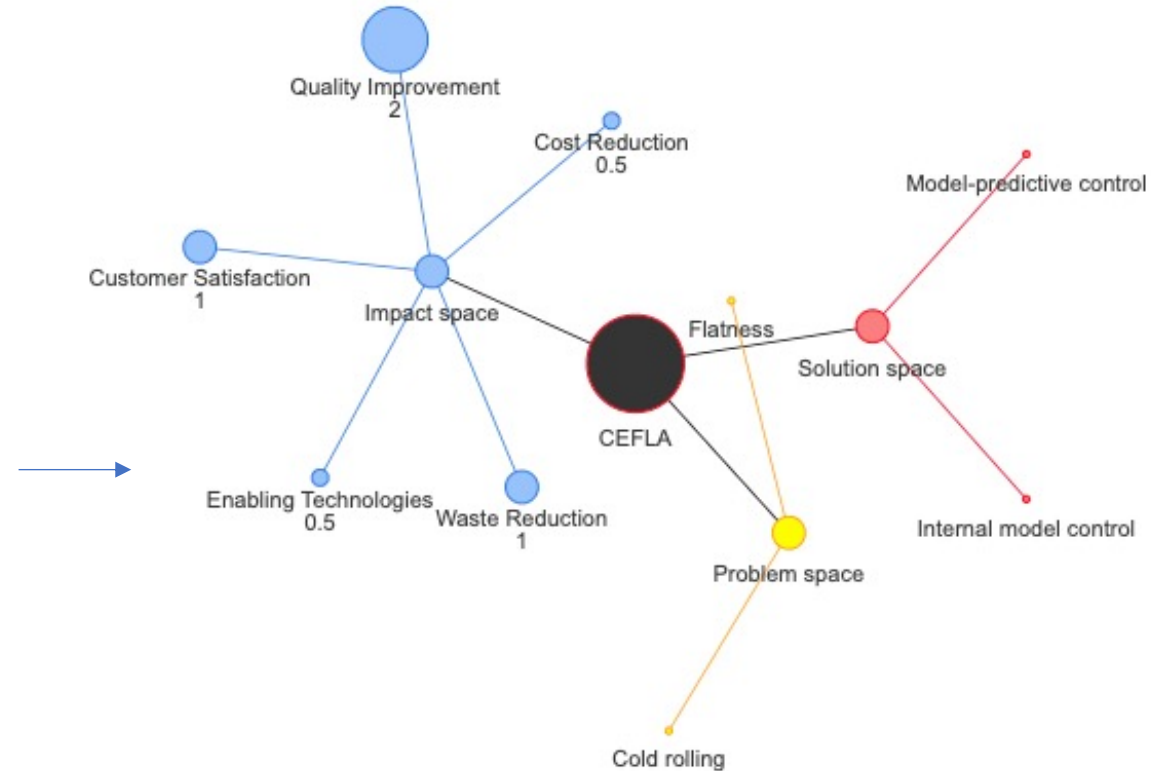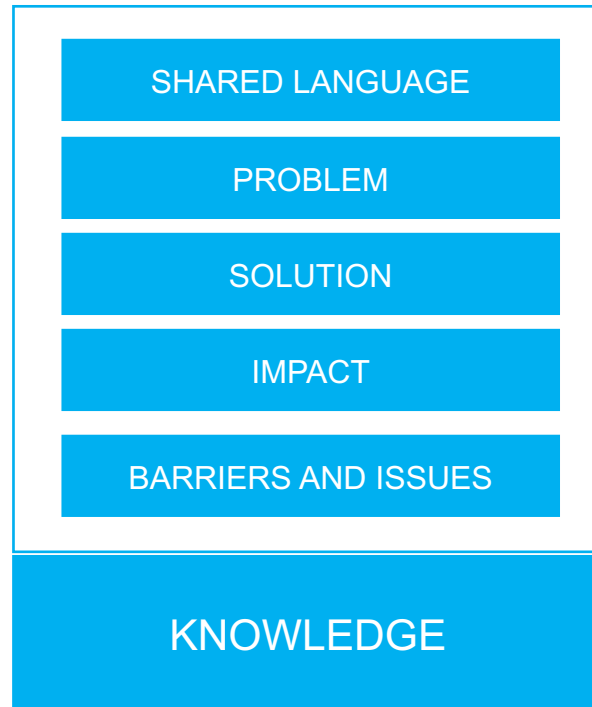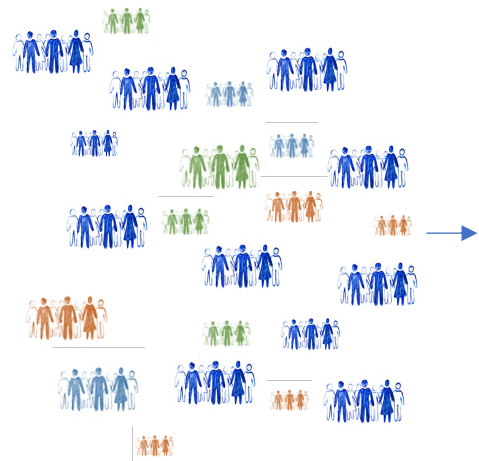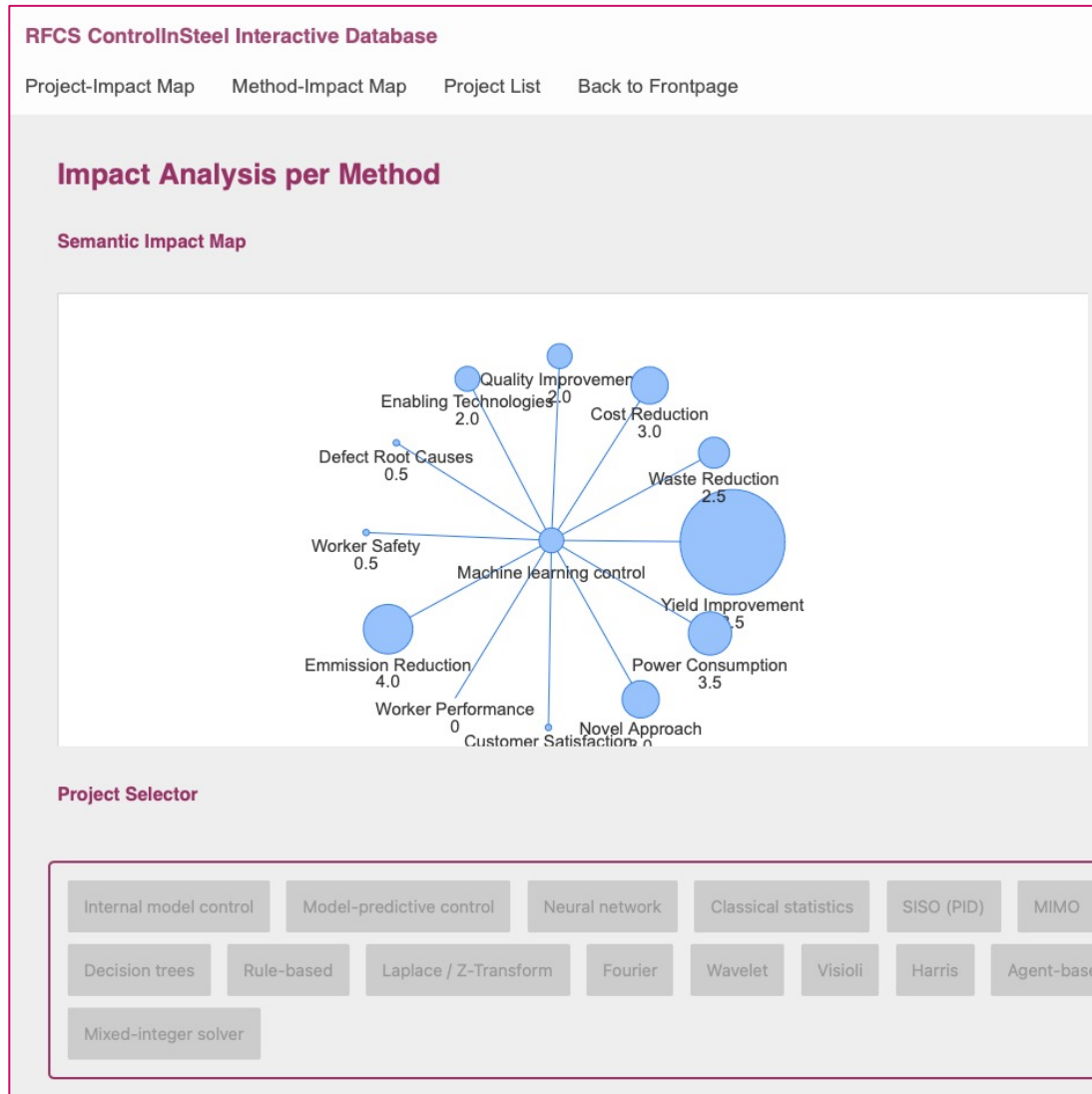
- Project website: www.controlinsteel.com

- Link to interactive result presentation

- Automatic Python code that runs on top of our assessment

- Full compatibility with former dissemination activities like DissI2M (where DissI2M data is currently merged in the CIS database

3. Project Results

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- Each project could score up to 5 impact points

- Each point could be allocated to either one or multiple impact categories

- Advantage: the analysis is able to fully reproduce the **distribution of impact** of the considered projects

	Quality improvement	Defect root cause	Cost reduction	Yield improvement	Power consumption	Waste reduction	Emission reduction	Worker safety	Worker performance	Customer satisfaction	Enabling technologies	Novel approach
SOFTDETECT	1	2	1	0.5	0	0	0	0	0	0	0	0.5
IMGALVA	2	0	0.5	0.5	0	0.5	0.5	0	0	0.5	0.5	0
SensoCont	1	0	0	0.5	0.5	0.5	0.5	0	0	1	0	1
Smartfire	1	0	0.5	0.5	0.5	0.5	1	0	0	0	0.5	0.5
FinalPlateFlatness	2	0	0.5	0.5	0	0.5	0.5	0	0	1	0	0
Awicco	1	0.5	1	0.5	0	0.5	0	0	0	1	0	0.5
HIGHPICK	1	0	0.5	1	1	0.5	0.5	0	0	0.5	0	0
Linecop	1	0.5	0.5	1	0.5	0.5	0.5	0	0	0.5	0	0.5

Impact Development as Function of Time
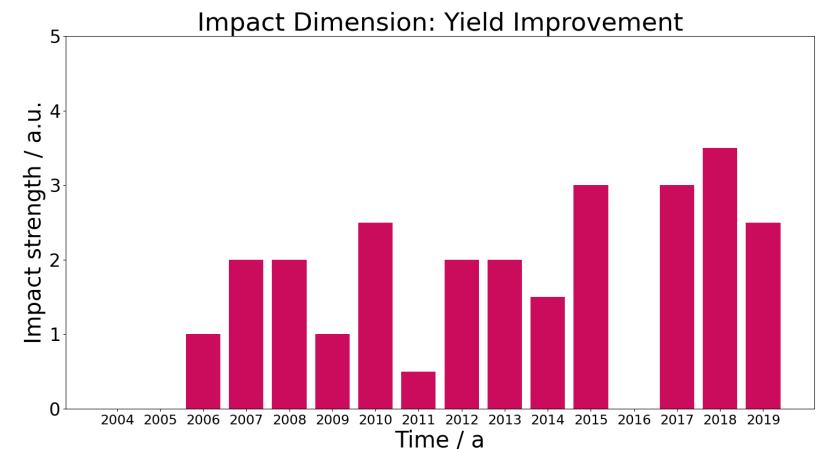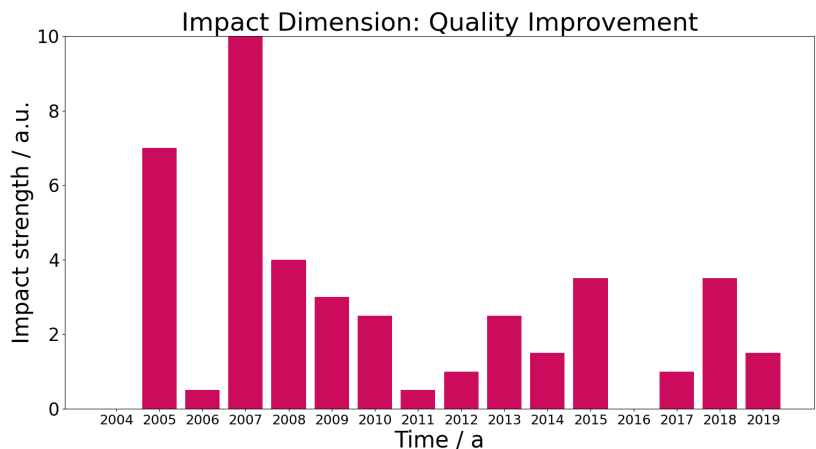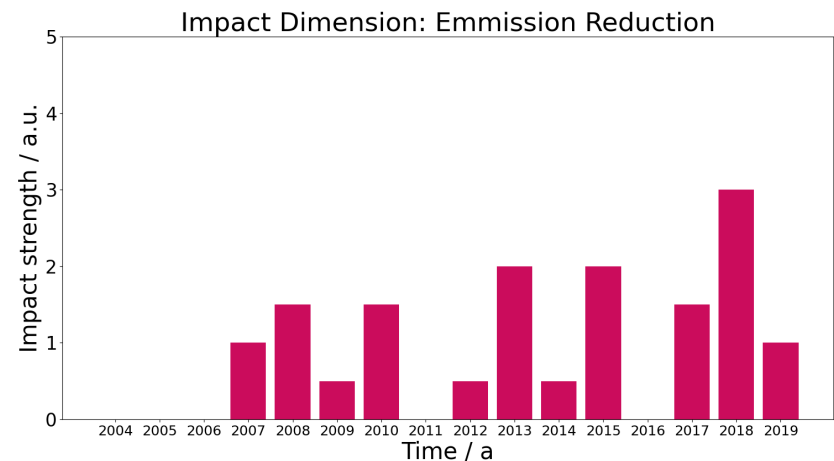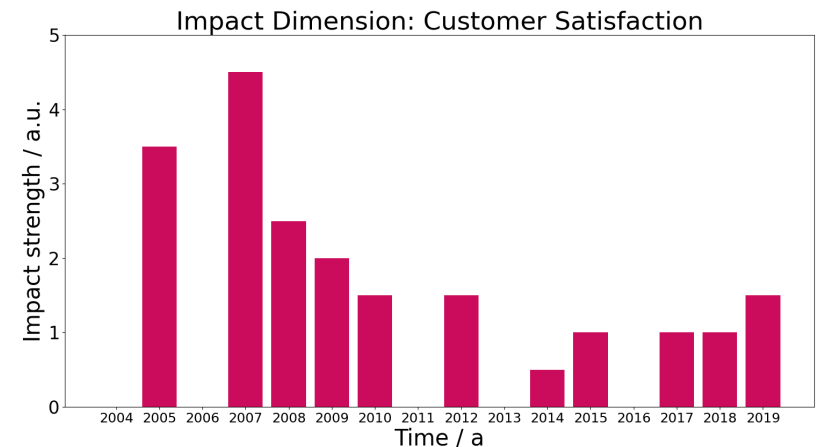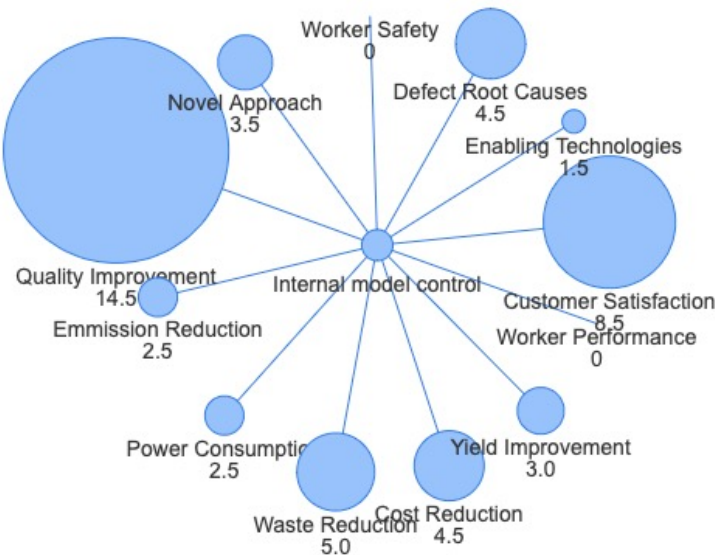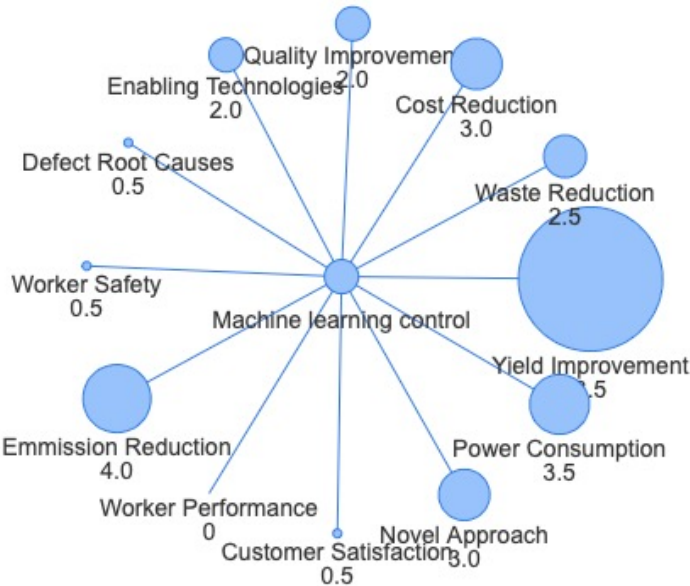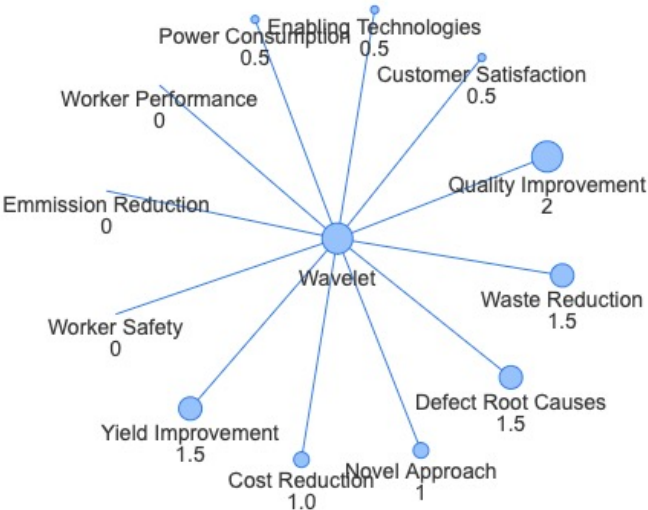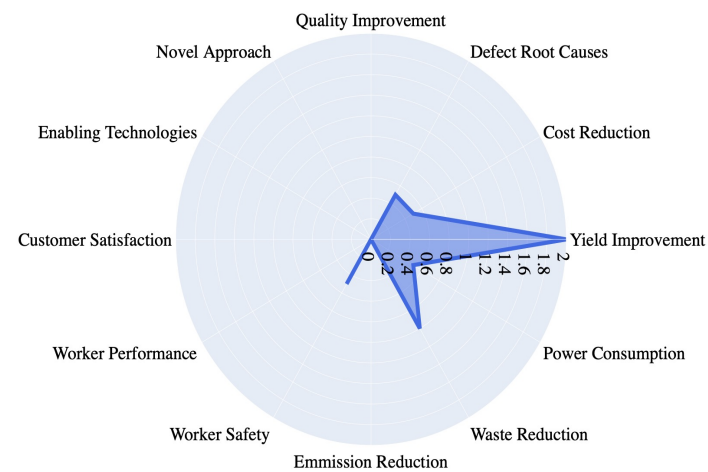
- Internal Model Control
- Machine Learning Control
- Wavelet Transform

Radar chart overview of individual projects

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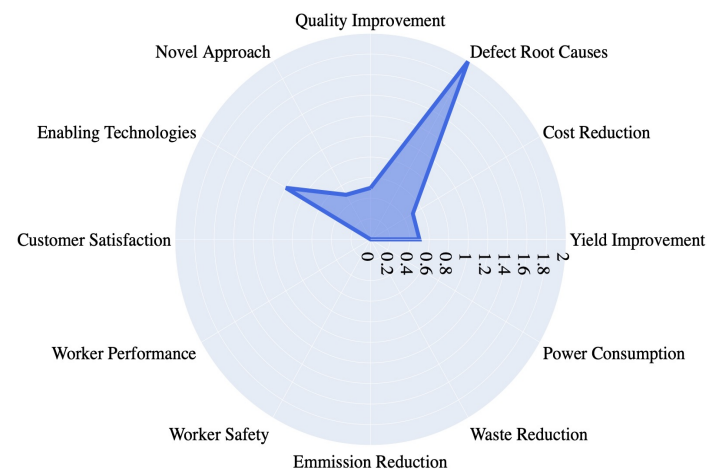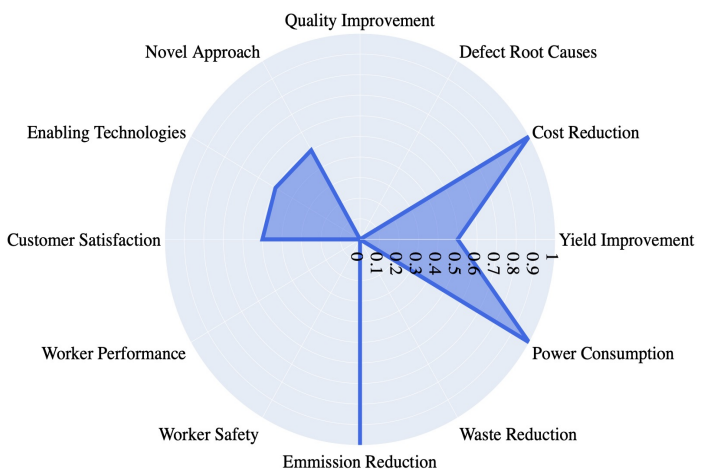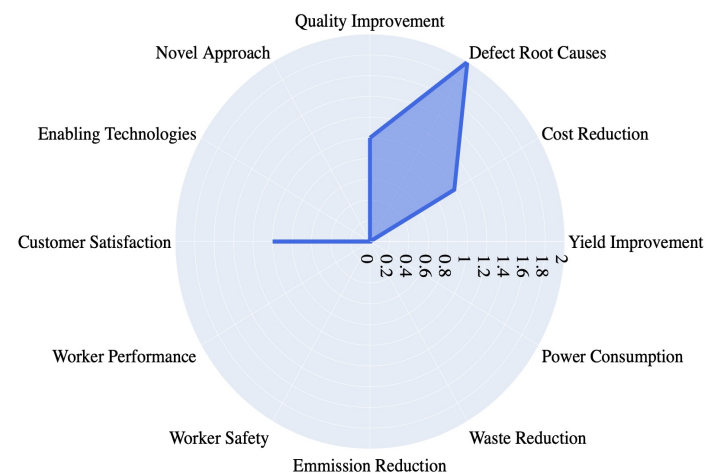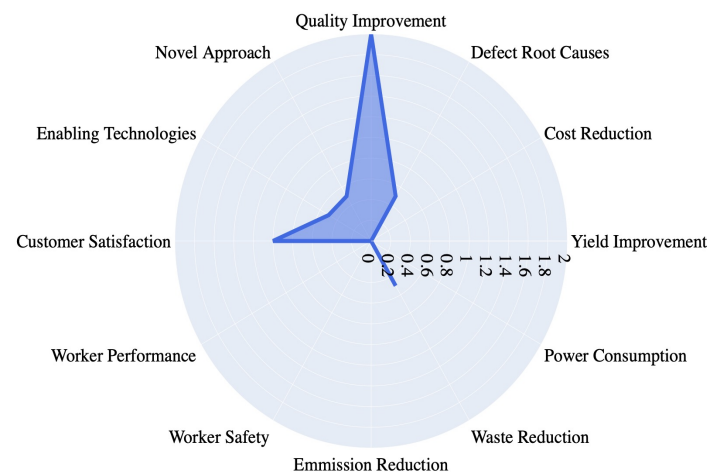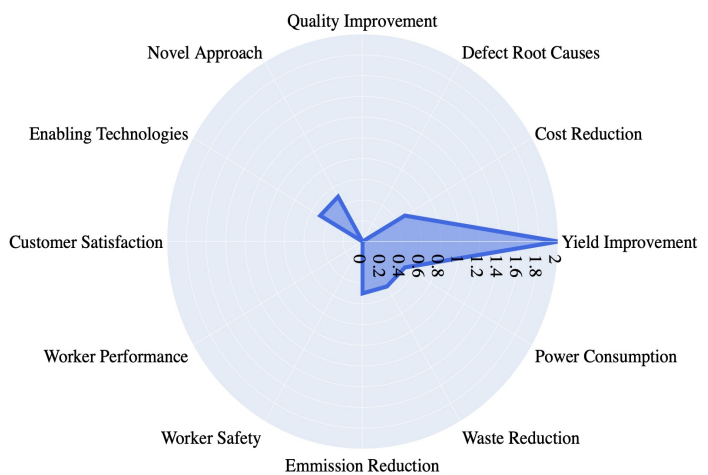
- **Project idea**

    - Dissemination and impact maximization of various RFCS projects in the field of advanced automation in the downstream process chain

    - Taxonomical approach to structure four distinct vocabularies for problems, solutions, impact and barriers

    - Systematic analysis of all projects with respect to these vocabularies

    - Project ends in December 2022)

- **Dissemination**

    - Upcoming workshops are published at www.controlinsteel.com

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Transferability Analysis

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0 – no transferability can be expected, not transfer has been reported

1 – same aggregate, same plant direct transfer was possible

2 – same aggregate, different plant transfer

3 – different aggregate, same plant transfer

4 – different aggregate, different plant

5 – different Industry, similar aggregate

6 – different Industry, diverse aggregates

- Each project got an transferability index
- First rigorous assessment of transferability in a quantitative way

	Primary Transfer Channel	Transferability Index	0	1	2	3	4	5	6
CEFLA	Rolling mill	1							
7210-PR/33B	Rolling mill	1							
7210-PR/339	Rolling mill	1							
7215-PP/076	Rolling mill	1							
CASTDESMON	Caster	2							
IPCDS	Rolling mill monitoring system	2							
SHAPEHPM	Rolling mill	1							
AUTOCHECK	Zinc layer thickness control	4							
S5	Strip shape monitoring	2							
GLOBALSHAPECONTROL	Rolling mill	1							
SOFTDETECT	Soft sensor	4							
IMGALVA	Galvanisation	2							
SensoCont	Pickling line operation software	4							
Smartfire	Furnace	3							
FinalPlateFlatness	Rolling mill	2							

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Aknowledgments...

... goto **Dr. Alexander Ebel**, who broadly introduced semantic techniques at the BFI and who was inspirational in continuing work in these topics.

- Taxonomies

  - T_1 – problem space

  - T_2 – solution space

  - T_3 – impact space

$$\mathbf{f}_\lambda(i) = [(f_{\lambda 0}(i), f_{\lambda 1}(i), ...] = \mathcal{T}_\lambda(i)$$

$$f_{\lambda j}(i) = \mathcal{T}_\lambda(i, j)$$

- Algorithm for retrieving conditional probabilities out of taxonomy entry combinations

$$P(j, T_\lambda | m = 1 \text{ with } m \in T_\rho) = \sum_{i \in \Pi} \sum_{k \in T_\lambda} \sum_{r \in T_\rho} f_{\lambda j}(i) \delta_{kj} \delta_{mr}$$

- Semantic graphc constructor, formal edge definition

$$\phi_\lambda : E_\lambda(i) \to \{(f_{\lambda j}, \lambda) | f_{\lambda j} = \mathcal{T}_\lambda(i, j)\}$$

$$\phi_T : E_T(i) \to \{(\lambda, \pi(i)) | \lambda \in (1, 2, 3) \wedge \pi(i) \in \Pi\}$$