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Steel-Making Plant Engineering Guide Development

for Feasibility Study and Concept Design Phases

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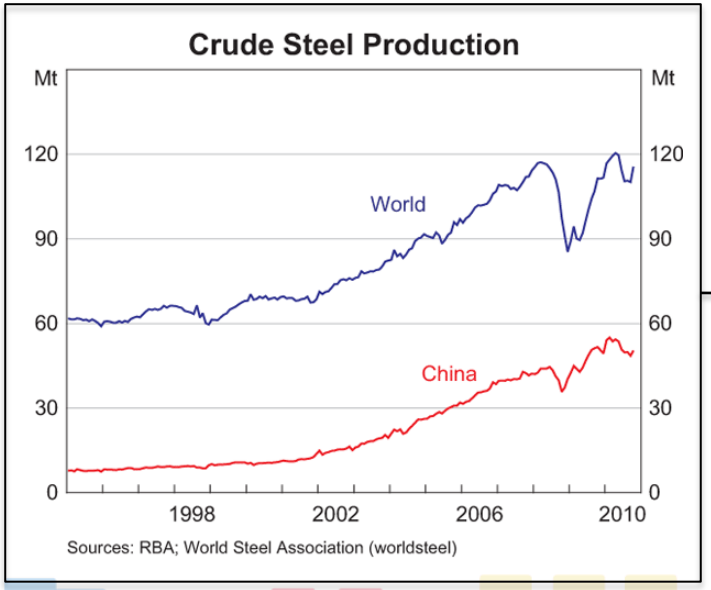
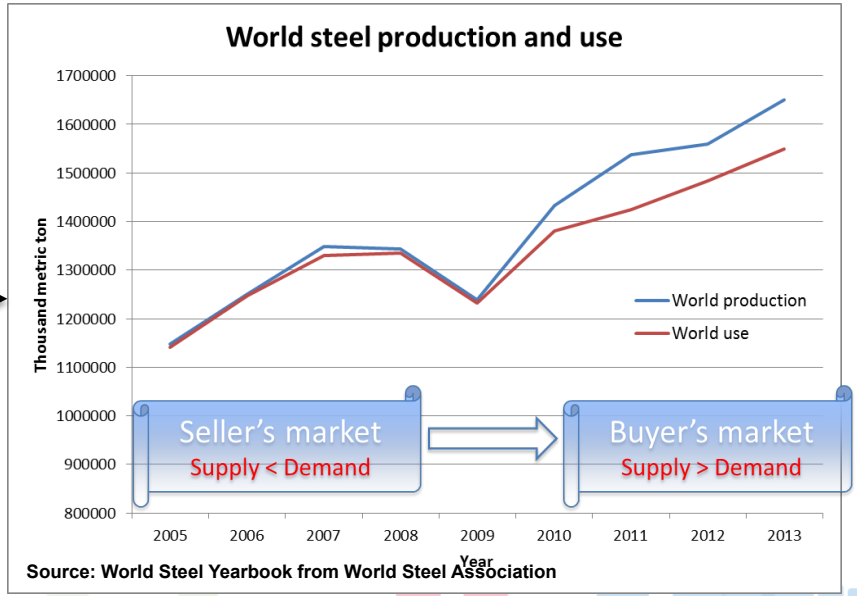
1. Introduction

- Background
  - Nature of world steel market **has changed from seller's to buyer's** due **to the oversupply of steel from China.**



causes

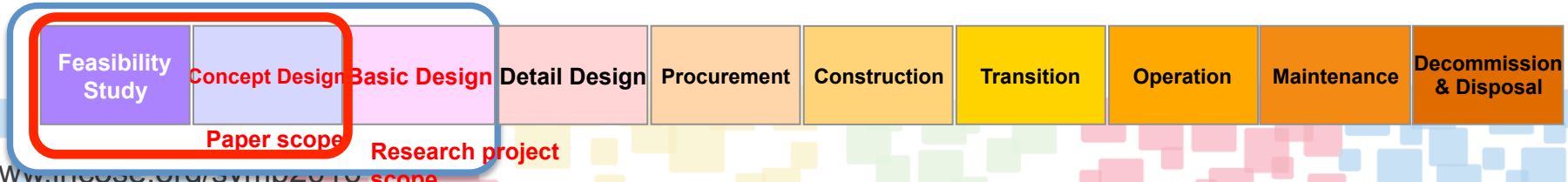


1. Introduction

- Motivation
  - Korean steel-makers are required to develop **premium quality** of steel to beat the competitors
  - The premium quality steel products **need New Technologies(i.e. premium technology) which designed in the steel making facilities** as well as alloying technologies.
  - The company **want to protect the premium technologies** from competitors.
  - Usually, they have been acquired the needed steel-making facilities **by a turn-key contract**. However the **divi ded multiple contract** is more appropriate, to protect the premium technology.
  - To support divided multiple contract, the acquire have to develop down to subsystem(or component) level spe cifications.
  - So, Korean steel-makers need to **perform engineering processes by their own efforts for the top-level de sign of each facilities in order to secure the premium technologies.**

A steel-making plant engineering guide is required to solve above needs

- Study scope
  - The steel-making plant engineering guide for the front-end engineering phases to support the top-level design.



2. Development strategy for Engineering process standard(guide) of a specific application industry

- The contents of Engineering process standard(or guide)

From ISO/IEC/IEEE 15288(2015)-System life cycle processes

- ISO/IEC/IEEE15288 provides a common framework of process descriptions for d escribing the life cycle of man-made systems. This standard provides life **cycle c oncept, system concept, process concept and a set of process descriptions** and associated terminology from an engineering viewpoint.

'The Steel-Making Plant Engineering Guide'

- 'The Steel-Making Plant Engineering Guide' provides defined **life cycle** for steel-making plant, defined steel-making **plant system breakdown structure**, a set of **process descriptions**, **input/outputs** of processes and **exit criteria** to support e ngineering of steel-making plant.

2. Development strategy for Engineering process standard(guide) of a specific application industry

- SE standard development methods overview(1/3)
  - ISO/IEC 24748-2 : Guide to the application of ISO/IEC 15288

ISO/IEC 24748-2 suggest three key uses of 15288 to organizational work.

Use 1 is a **direct application** of 15288 to organizational work.

Use 2 is for purpose of **creating appropriate organizational standards and domain standards** derived from the applicable concepts and requirements from 15288

Use 3 is for preparing appropriate documents describing organizational and domain-wide **methods, procedures and guidance for implementation** of organizational/domain standards or 15288.

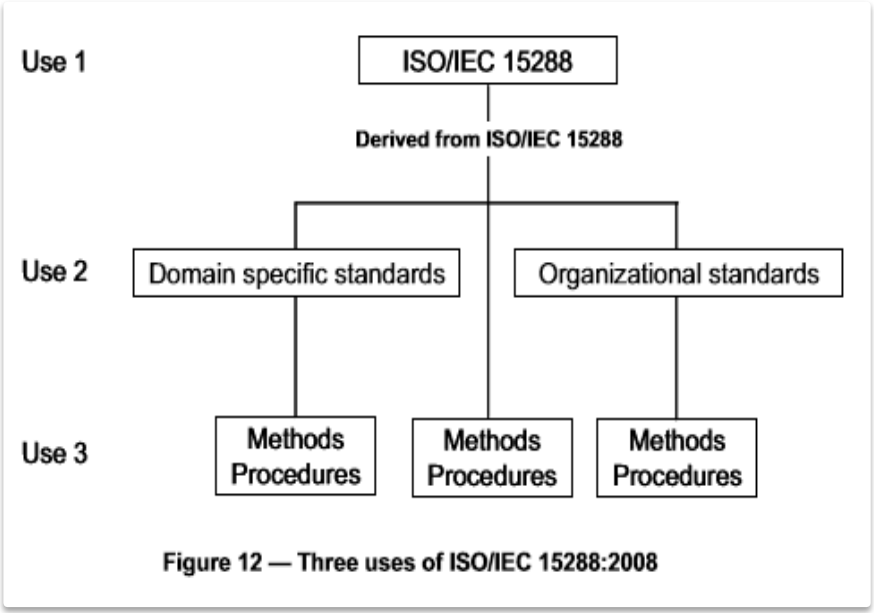
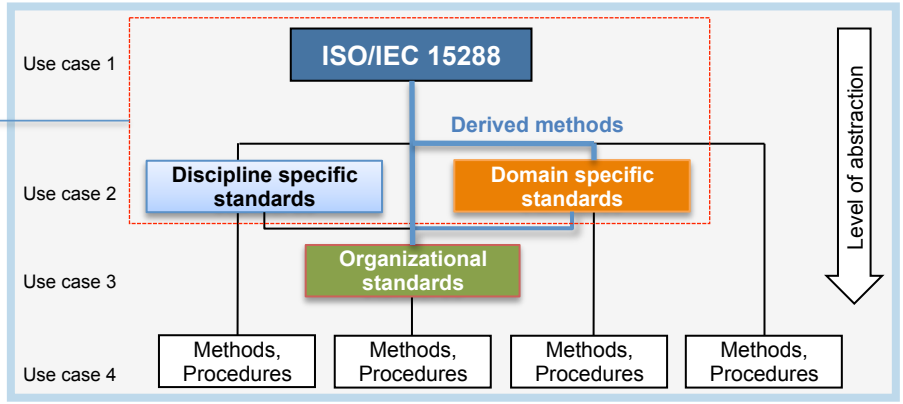


Figure 12 — Three uses of ISO/IEC 15288:2008

2. Development strategy for Engineering process standard(guide) of a specific application industry

- SE standard development methods overview(2/3)
  - Tailored from ISO/IEC 24748-2



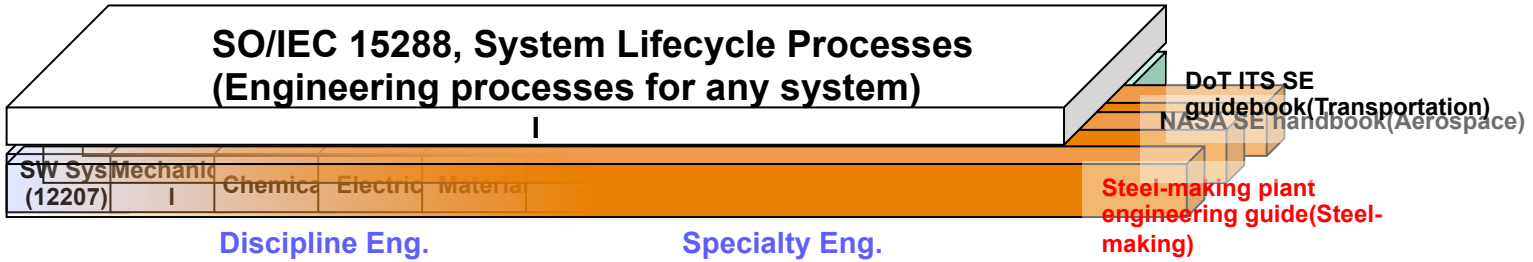
By tailoring three uses of 15288, following SE standard development concept is defined

Use case 1 : Direct application of 15288

Use case 2 : Application of either discipline or domain specific standards based on 15288

Use case 3 : Application of organizational standards based on either discipline/domain specific standards or 15288.

Detailed relationship among 15288, Discipline/Specialty specific standards and Domain specific standards



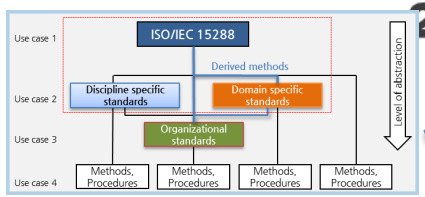
2. Development strategy for Engineering process standard(guide) of a specific application industry

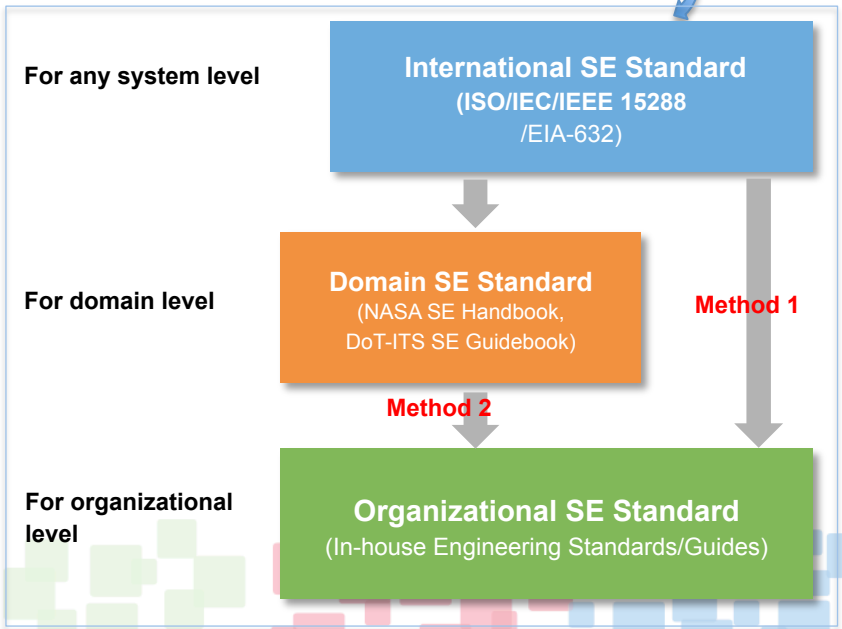
- SE standard development methods overview(3/3)
  - SE Standard development methods

From the concept of SE standard development methods, two methods are figured out as shown in the figure.

Method 1 is to utilize international SE standards directly for an organization's business through tailoring .

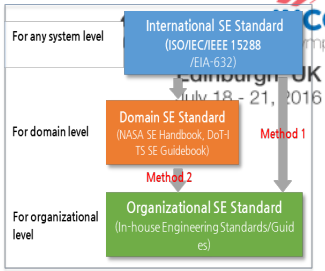
Method 2 is to develop an organizational standard from domain specific SE standards which have been developed based on international SE standards





2. Development strategy for Engineering process s tandard(guide) of a specific application industry

- Development sterategy of SE standard for an organization



Method 1 (Direct application)	Method 2 (Through domain specific SE standards)
15288 is written for any man-made syste ms. So the language used in 15288 is **too general to understand** for an organizatio n with no SE experiences. • This is not easy, if an organization don't familiar to the SE process or don't hav e SE'r of that domain.	**Domain specific concepts, processes and e xit criteria are provided.** So an organization in a corresponding domain can develop its own organizational standard/gu ide based on domain specific SE standards.

Need for steel-making plant engineering guide

Steel-making industry has no domain specific SE standard.

Once an appropriate steel-making plant engineering guide is developed, individual still-making company can develop its own organizational engineering standard by implementing method 2, which is more effective and requires less efforts than method 1.

Attribute of an org's SE ST D

Use the organization's specifi c

- structure
- methods and tools
- technologies

3. Engineering guide development process a nd methods for Steel-making plant domain

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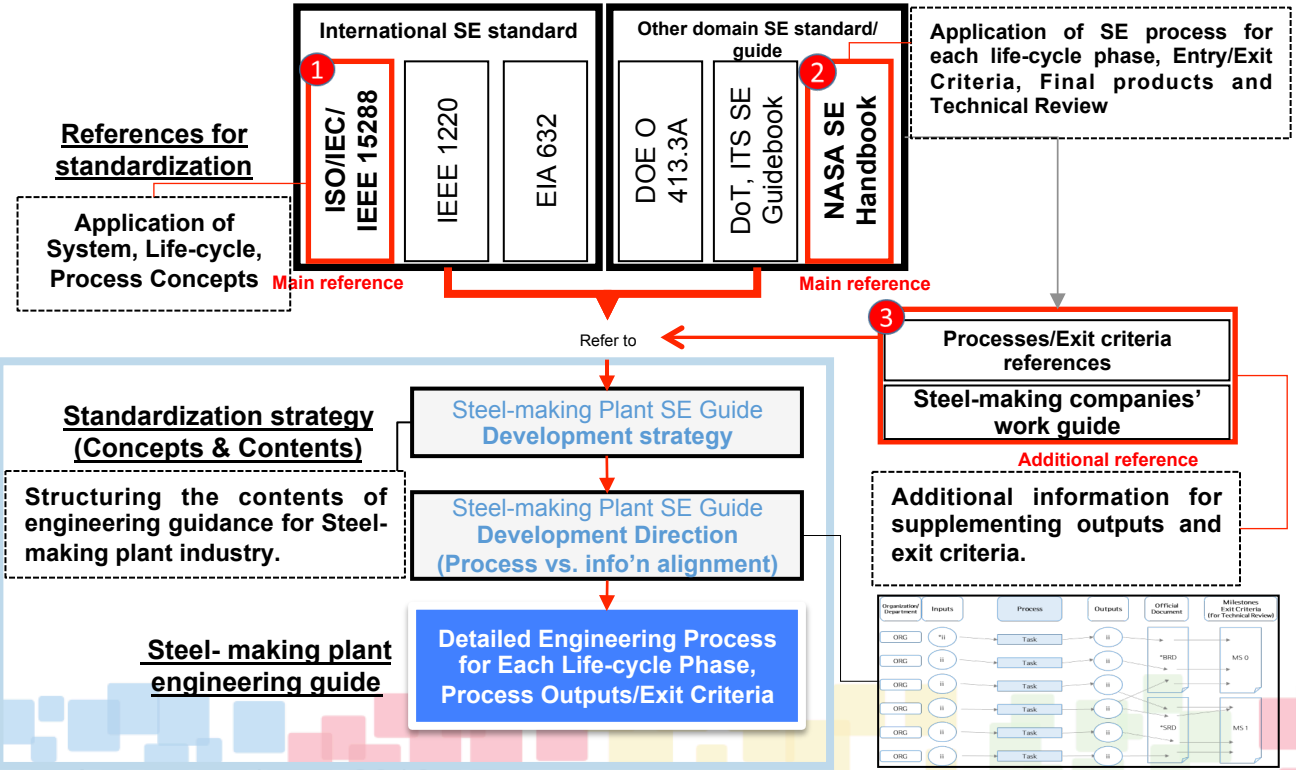
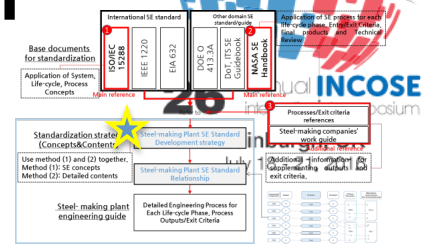
- Development process overview



1. Lifecycle, system and process concepts provided form 15288 are the main references of core concepts of the engineering guide.
2. **NASA SE handbook is chosen** as an main references of application domain industry. (This have more specific information relatively.)
3. Other SE guides/standards are used to refine contents of the engineering guide. (from NAVAIR, DoD, NOAA) Work guides of steel-making companies are also used for a customization of process descriptions

Final product of the research

3. Engineering guide development process and methods for Steel-making plant domain



- ★ Steel-making plant engineering guide development strategy
  - Process development strategy

1. Core concepts definition

- Define steel-making plant lifecycle
- Define steel-making plant product breakdown structure(PBS)

Based onISO 15288 : lifecycle/system concepts

2. Core process development

- Select/define mandatory processes and activities for each lifecycle phase (apply recursively)

3. Process refinement (Low level customization)

- Refine terminologies used in processes and process /activity descriptions of steel-making domain

Based on NASA SE Handbook :System Design Process

4. Process localization (High level customization)

- Customize all aspects(**adding domain specific tasks and information items including analysis** etc.) of process for the steel-making domain

Based on work guides of steel-making companies

5. Process consistency check & revision

- Check the consistency of process with exit criteria and revise if needed

3. Engineering guide development process a nd methods for Steel-making plant domain

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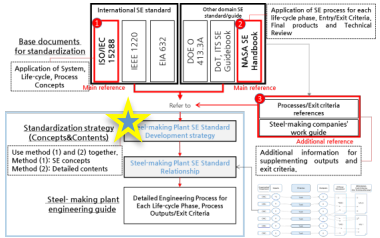
- Steel-making plant engineering guide development strategy
  - Exit criteria development strategy



1. Exit criteria categorization

- Define categories of exit criteria for milestones of lifecycle phases for steel-making plant

2. Analyze reference exit criteria

- Analyze each item of reference exit criteria and assess applicability to steel-making plant
- The references may include exit criteria of other domain as well as work guides of steel-making facility industry

3. Exit criteria selection

- Based on results of the analysis, choose items for exit criteria
- Classify each item of exit criteria according to categories defined at the first step

4. Exit criteria localization (High level customization)

- Customize descriptions/priority of exit criteria based on work guides of steel-making industry

5. Exit criteria consistency check & revision

- Check the consistency of exit criteria with processes and revise if needed

3. Engineering guide development process a nd methods for Steel-making plant domain

★ Steel-making Plant SE Guide Development Direction - Process vs. information item alignment

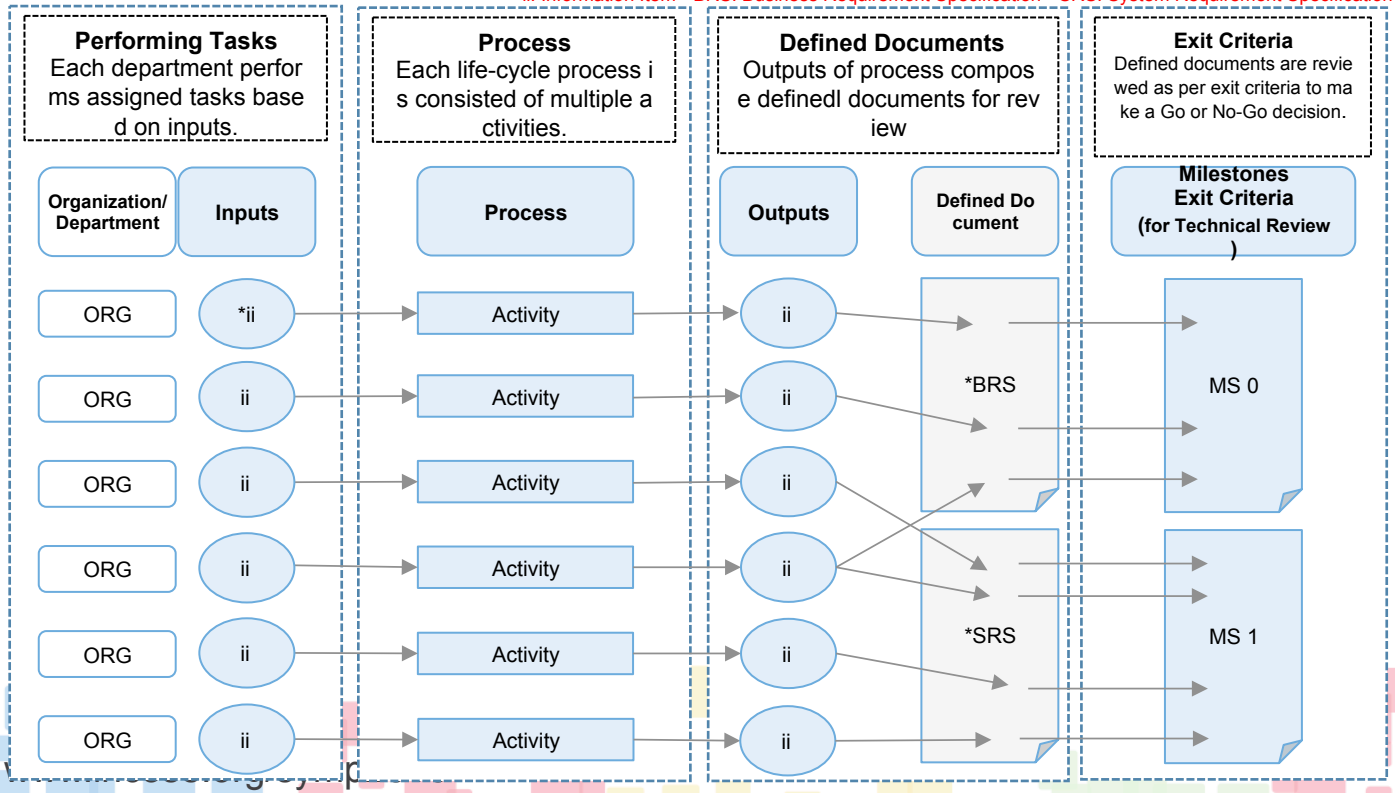
*ii: Information Item *BRS: Business Requirement Specification *SRS: System Requirement Specification

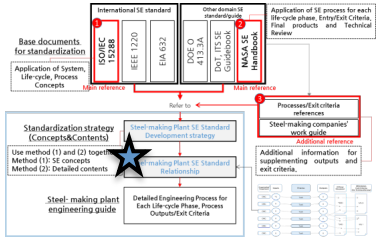
Performing Tasks
Each department perfor ms assigned tasks base d on inputs.

Process
Each life-cycle process i s consisted of multiple a ctivities.

Defined Documents
Outputs of process compos e definedl documents for rev iew

Exit Criteria
Defined documents are revie wed as per exit criteria to ma ke a Go or No-Go decision.





Relationship among the engin eering guide elements are def ined as shown in diag.

Done by the study

Future work

***Note**: Only types/descriptions o f defined documents are defined.

4. Steel-making plant engineering guide development case

- System of Interest(SoI) : Steel-making plant
  - SoI selected for the study is a steel-making plant
  - In our study, **the steel-making plant composed of facilities which perform following** functions:
    - Iron ore and coal preparation
    - Iron making : conversing ore to liquid iron
    - Steel making: conversing iron to liquid steel
    - Continuous casting: solidifying liquid steel continuously
    - Cold/Hot rolling: pressing steel plates
    - After rolling treatment: heat treatment, coating treatment, etc.

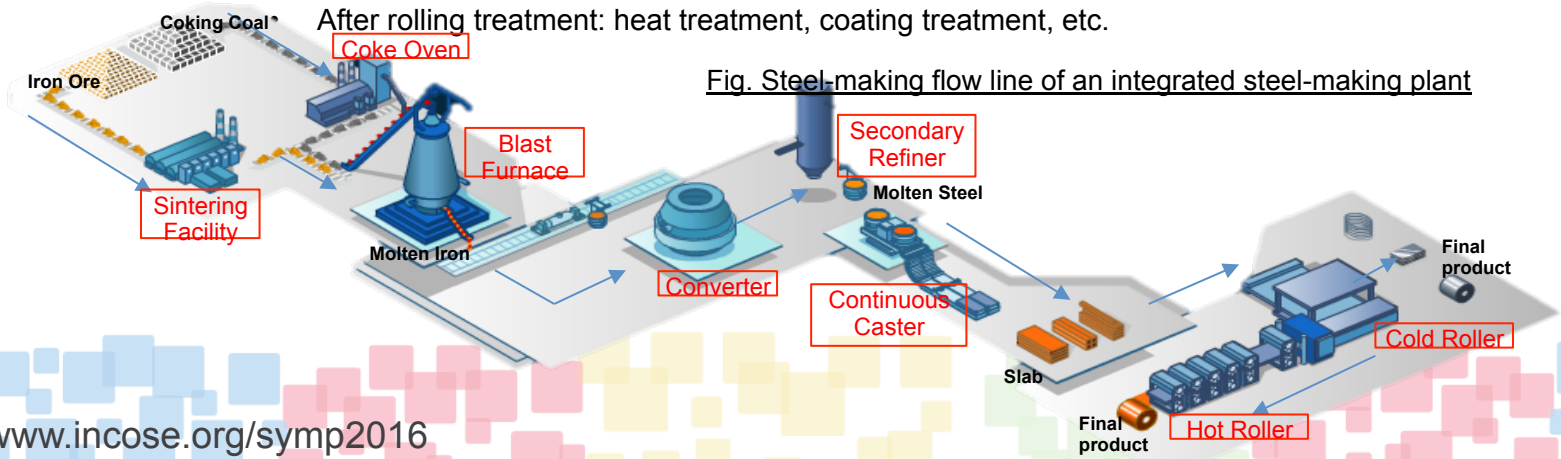
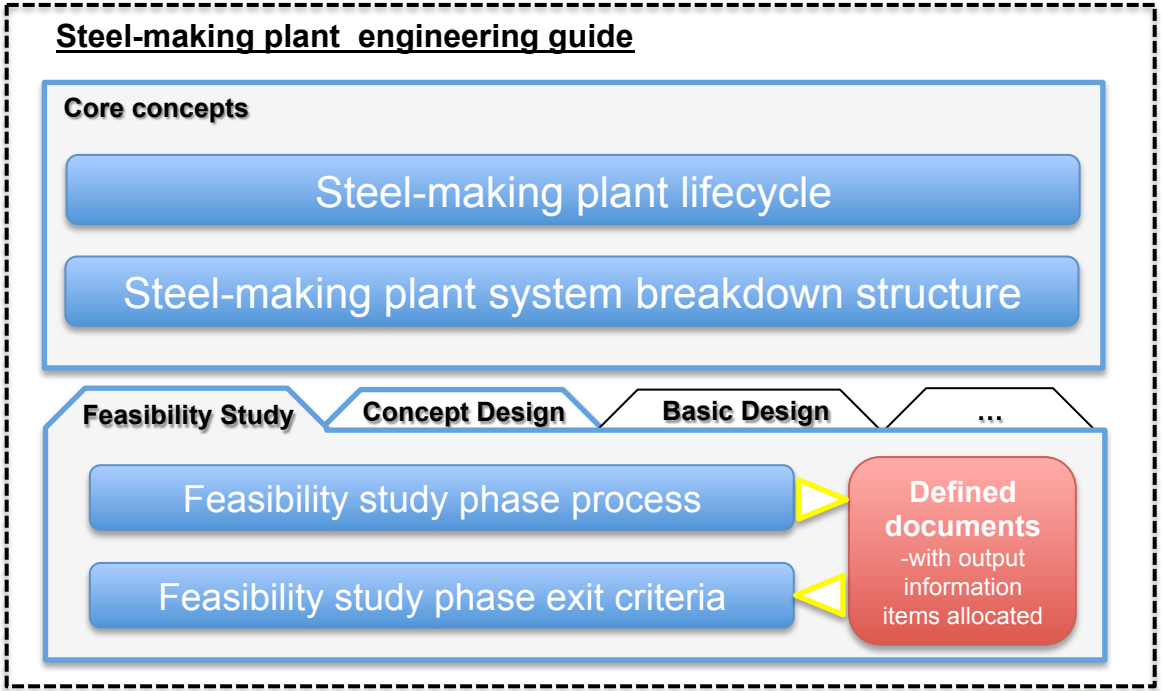


Fig. Steel-making flow line of an integrated steel-making plant

4. Steel-making plant engineering guide development case

- Overall structure of the steel-making plant engineering guide



Developed

Future work

This figure shows the overall structure of the steel-making engineering guide.

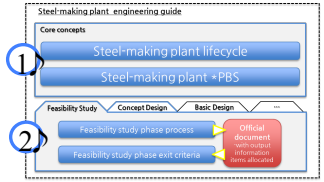
The engineering guide is made up of two main parts:

Core concepts and process/exit criteria for each lifecycle phase.

Blue boxed contents are within the scope of the paper: Feasibility study and concept design phases.

4. Steel-making plant engineering guide development case

- The steel-making plant engineering guide has two main purposes/usages



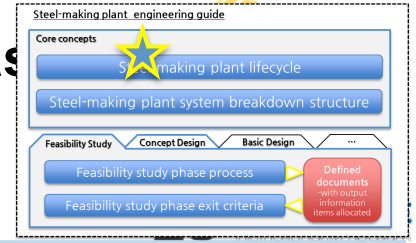
1. To provide a **standardized lifecycle(LC) definition** and a **system breakdown structure(SBS) definition** of a steel-making plant.

   All stakeholders of a steel-making facility development project can communicate with the uniform language based on the engineering guide.

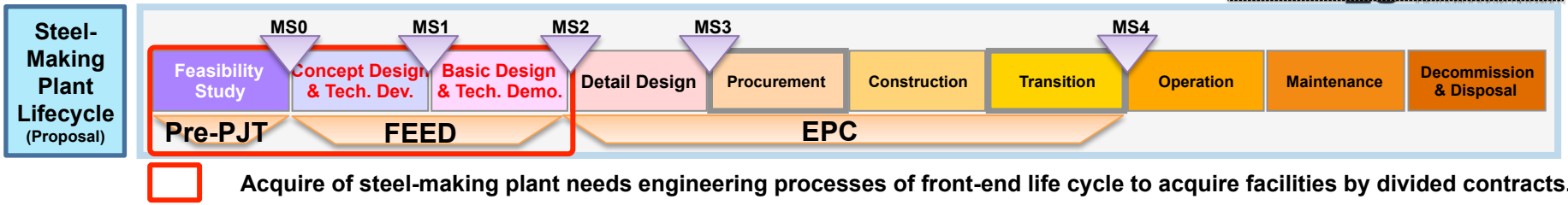
2. To provide **standardized processes and exit criteria of each lifecycle phase** based on SE processes and a lifecycle concept

   It guides a steel-making company to develop an effective organizational standard that helps to perform appropriate activities and task and to determine the degree of the performance for each lifecycle phase.

4. Steel-making plant engineering guide development case



- Core concept definition - Steel-making plant lifecycle



Acquire of steel-making plant needs engineering processes of front-end life cycle to acquire facilities by divided contracts.

The steel-making plant lifecycle has been determined with following criteria.

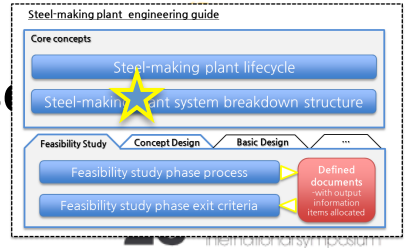
- Control the project risks (develop control points for go or no-go decision)
- Set up the design baselines
- Change of the prime responsible organization/department of each phase by official agreement.
- Identify major stakeholders, etc.

The procurement and transition phases are specific feature of the plant systems lifecycle.

- In plant industry, **procurement has high potential risks** due to its huge scale of a system. So procurement should be managed as a separated phase.(high cost/budget share)
- **Transition(including commissioning) is also important** in plant industry since commissioning people has important requirements and usually performed by independently arthorised organizations.

Ref.1 Concept Design & Technology Development Phase → as short form 'CD Phase'
Ref.2 Basic Design & Technology Demonstration → as short form 'BD Phase'

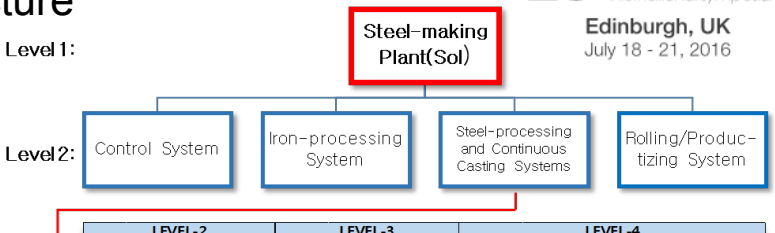
4. Steel-making plant engineering guide development case



- Core concept definition
  - Steel-making plant product breakdown structure

Steel-making plant engineering guide defined a **generic** steel-making plant **system breakdown st ructure(SBS) down to level 4** which is the contra ct level enough to hide premium technology.

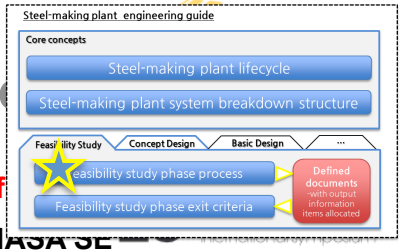
Based on this generic high level SBS the design **b aselines(design maturity) established accordin g to the front-end life cycle phases** especially fe asibility study, concept design and basic design ph ases.



LEVEL-2		LEVEL-3		LEVEL-4	
NO.	Name	NO.	Name	NO.	Name
C.1.2	Steel-processing and Continuous casting systems				
		C.1.2.1	Molten Iron Pre-processing System		
				C.1.2.1.1	Desilicated Slag Discharging System
				C.1.2.1.2	HMPS
				C.1.2.1.3	Pre-processed Slag Discharging System
				C.1.2.1.4	Torpedo Cleaning Center
				C.1.2.1.5	Pre-processing Control System
		C.1.2.2	Converting System		
				C.1.2.2.1	Raw Materials Charging System
				C.1.2.2.2	Converter
				C.1.2.2.3	Emitted Gas Processing System
				C.1.2.2.4	Heat Recovery System
				C.1.2.2.5	Converting Control System
		C.1.2.3	Second Refining System		
				C.1.2.3.1	BAP(Bubble & Powder injection)
				C.1.2.3.2	LF(Laddle Furnace)
				C.1.2.3.3	RH-OB Degassing System
				C.1.2.3.4	Refining Control System
		C.1.2.4	Continuous Casting System		
				C.1.2.4.1	Continuous Casting Control System
				C.1.2.4.2	Molten Steel Charging System
				C.1.2.4.3	Molding system
				C.1.2.4.4	Continuous Caster
				C.1.2.4.5	Steel Cutting System

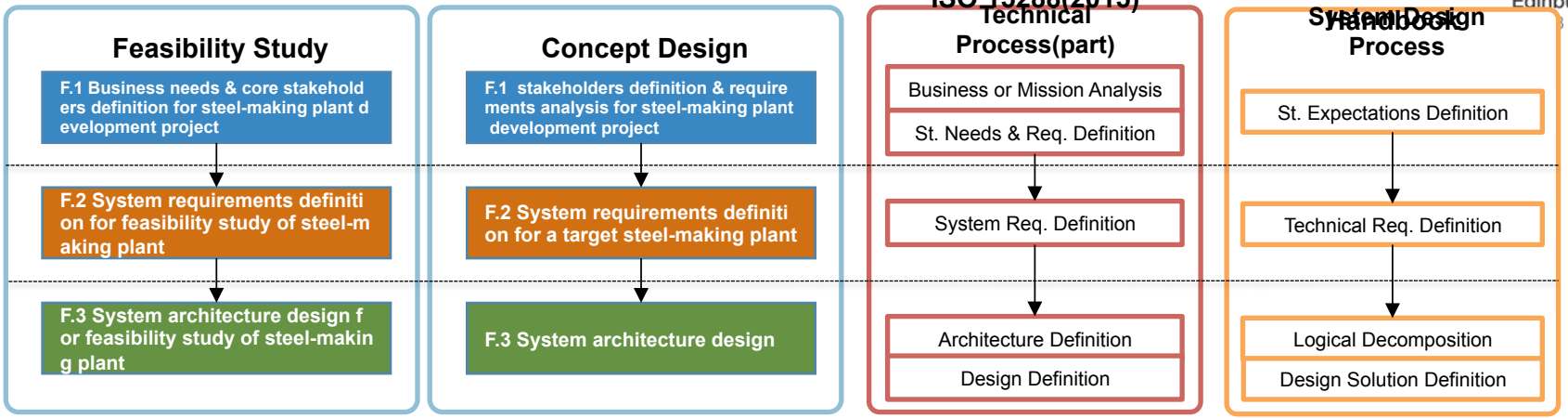
4. Steel-making plant engineering guide development case

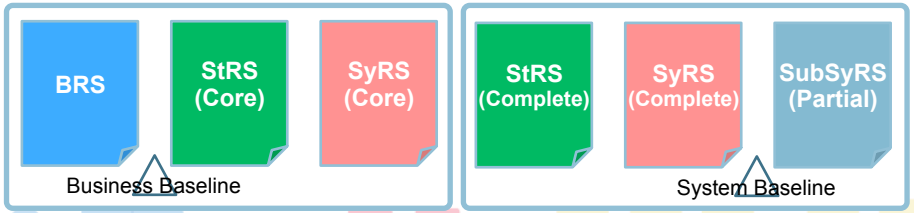
- Steel-making plant engineering processes-Top view



Process Flow with defined documents(outputs)

Corresponding SE processes f om standards





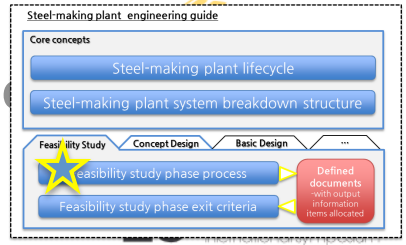
The recursive nature of SE lifecycle processes were instantiated to the process for each lifecycle phase.

The diagram shows that the process flow of the engineering guide and corresponding processes from SE standards.

Legend;

BRS: Business Requirements Specification
StRS: Stakeholder Requirements Specification
SyRS: System Requirements Specification
SubSyR: Subsystem Requirements Specification

4. Steel-making plant engineering guide development case



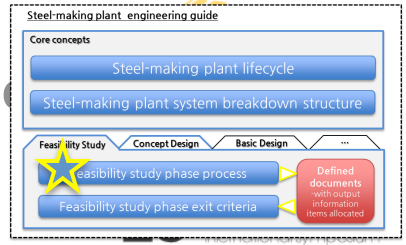
- Steel-making plant engineering processes example
  - Feasibility study process

The feasibility study phase is where **core stakeholders make an investment decision so economic, societal and schedule feasibility has more weight**. Each task of the process has its own name, description and defined information item input and output.

Feasibility study process [*process is developed down to activity level*]

Processes	Activities						
P.1 Business needs & core stakeholders definition for steel-making plant development project	A.1 Business need definition	A.2 Business objective definition	A.3 Business scenario definition	A.4 MOE definition	A.5 Core stakeholder definition	A.6 Core StR definition	A.7 C-StR validation req. definition
P.2 System requirements definition for feasibility study of steel-making plant	A.8 Business scope definition	A.9 Lifecycle enabling strategy def.	A.10 Core system requirements definition	A.11 MOP definition	A.12 Core system constraints definition	A.13 Core StR verification req. def.	
P.3 System architecture design for feasibility study of steel-making plant	A.15 Assessment selection criteria def.	A.15 Draft alternative concepts development	A.16 Functional Model development	A.17 Analyze alternative concept	A.18 Best PFD selevtion	A.19 Physcal architecture alternatives	A.20 Analyze physical architecture	A.21 Select best architecture

4. Steel-making plant engineering guide development case



- Steel-making plant engineering processes example
  - Feasibility study process comparison

There is only a few differences between the developed processes and existing standards when comparing both together.

Then what makes the engineering guide distinguished from others?

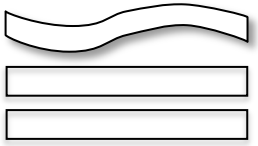
The engineering guide FS process

Process level

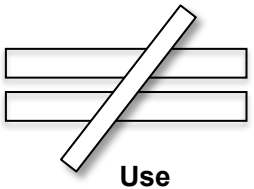
P.1 Business needs & core stakeholders d efinition for steel-making facility developm ent project

Activity level

- A.1 Business need definition
- A.2 Business objective definition
- A.3 Business scenario definition
- A.4 MOE definition
- A.5 Core stakeholder definition
- A.6 Core StR definition
- A.7 C-StR validation req. definition



The process concepts are fol lowing exist standards



Use

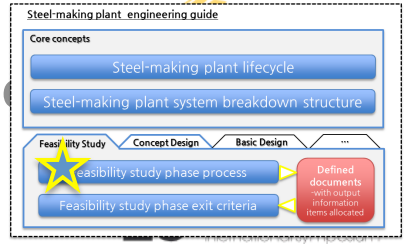
- **LC for the steel-making plant**
- **SBS of the steel-making plant**
- **Describe instantiated proces s of each LC phse**

NASA SE Handbook

4.1 Stakeholder expectations definition

- Establish list of stakeholders
- Elicit stakeholder expectation
- Establish Opscon and support strategies
- Define stakeholder expectations
- Analyze expectation statements for MOEs
- Validate that defined expectations
- Obtain stakeholder commitments
- Baseline stakeholder expectations

4. Steel-making plant engineering guide development case



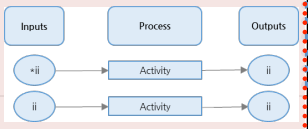
- Steel-making plant engineering processes example
  - Feasibility study phase process example

No.	Process/Activity	Activity Description	Input Information Item	Output information Item
P.1	**Business needs and core stakeholder requirements definition for steel-making facilities development/upgrade project**	**Define a business need and initial business concepts and define corresponding MOEs and core stakeholder requirements..**		
A.1	Business Need Definition	From identified business opportunities(either whole steel-making plant or facility development business), define needs for a selected business/ project up to understandable level. (*In terms of market needs, supply, cost, materials, production, technology maturity, funding capability etc.)	Business opportunity	Business Needs
A.2	Business Objective Definition	Define and shape business objectives in clear statements so that stakeholders of steel-making facilities can easily understand.	Business Needs	Business Objective
A.3	Business Scenario Definition	Define a business scenario. A business scenario is officially termed as Concept of Operations(ConOps) and it describes how an organization run a business in order to meet business needs. **Consider followings while defining a business scenario:** - **Applicability of technology, know-how, supply chain, brand value of companies in a same corporate group** - **Capability of board members** - **Raw materials(ore, coal): procurement, quality** - **Worst case, Changes in world market, politics and environment**	Business Needs, Business Objective	Business Scenario
A.4	Measure of Effectiveness(MOE) Definition	Define Measure of Effectiveness(MOE) clearly. MOE is an indicator to measure a degree of business achievement(How well business objectives are achieved). For steel-making industry, suggested MOEs could be follows: **annual crude steel production rate, availability, cost/profit ratio**, etc.	Business scenario	System MOEs

Aligned guiding:
- **input/output information items of each activity are defined.**

(This I/O information items used to trace the exit criteria of corresponding phase)

Existing standards

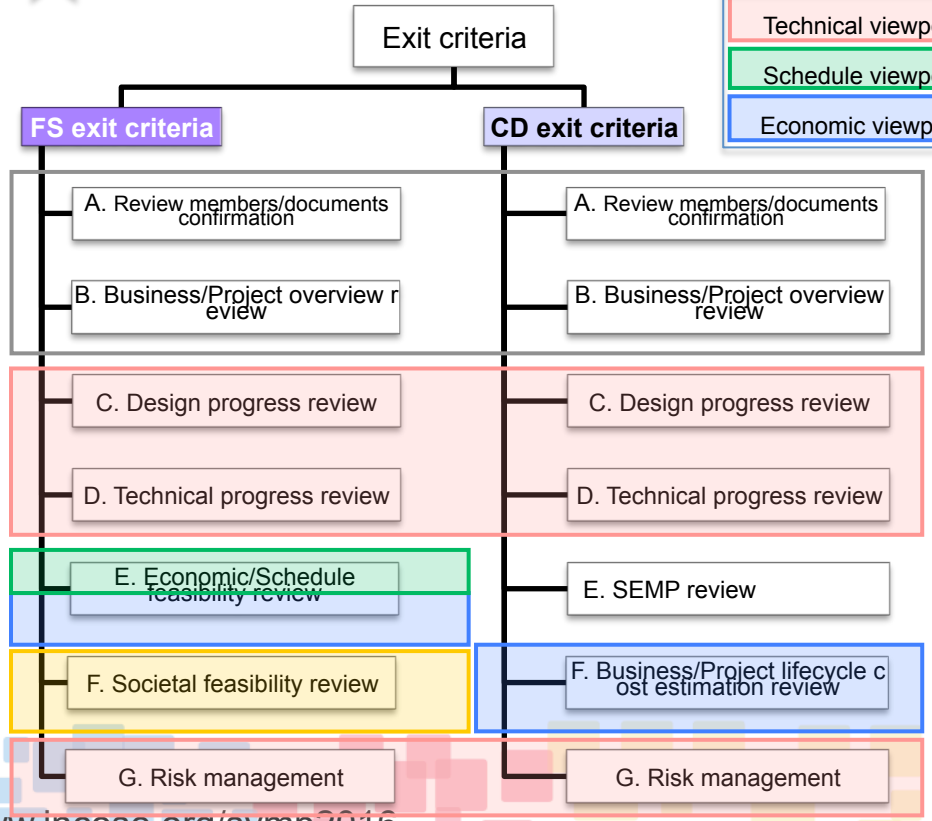


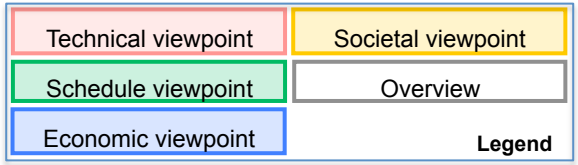
Developed guide

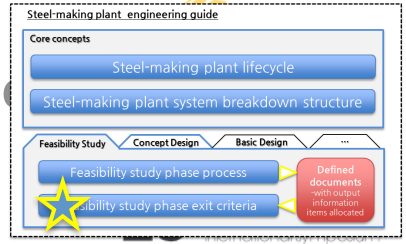
Terms and suggestions written in description of each activity are customized to be used in steel-making industry.

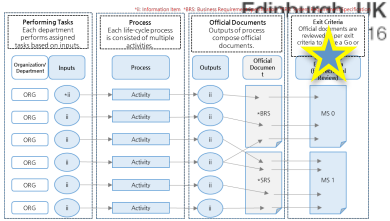
4. Steel-making plant engineering guide development case

Exit criteria of FS & CD phase top view







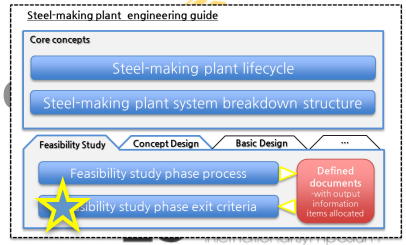


Both feasibility study(FS) and concept design(CD) phase exit criteria are consisted of 7 main sections

FS exit criteria put focus on economic, schedule and societal reviews as an investment decision is made at the end of FS phase. So more economic, schedule and societal review items are included

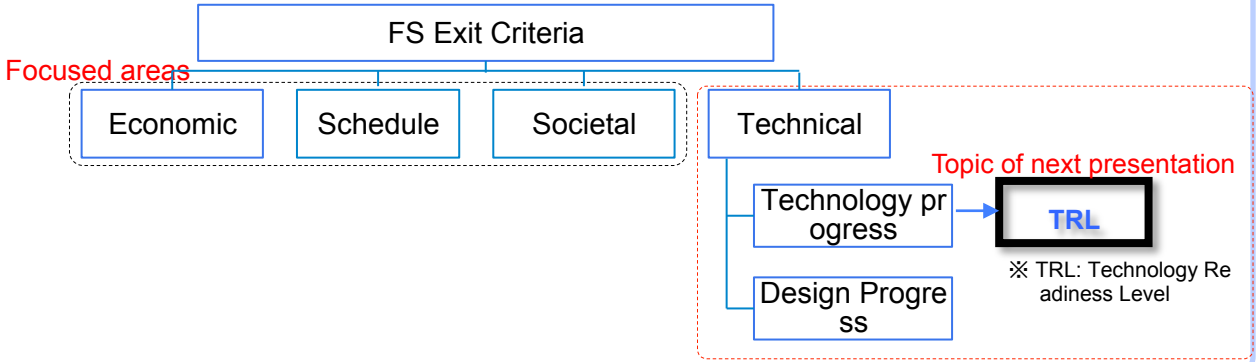
CD exit criteria is used for a review of a system specification developed during CD phase. So more technical review items are included.

4. Steel-making plant engineering guide development case



- Exit criteria example
  - Feasibility study phase exit criteria categories

- **FS Exit Criteria Categories**



As shown in the figure, **FS exit criteria is consisted of 4 categories: Economic, Schedule, Societal and Technical** categories. As mentioned earlier FS exit criteria put focus on economic, schedule and societal reviews as an investment decision is made at the end of FS phase.

We divided the technical category into 2 sections: Technology progress and Design progress. This classification is one of the main features of our exit criteria. The further information will be given in the next presentation.

4. Steel-making plant engineering guide development case

- Exit criteria example
  - Feasibility study phase exit criteria sample

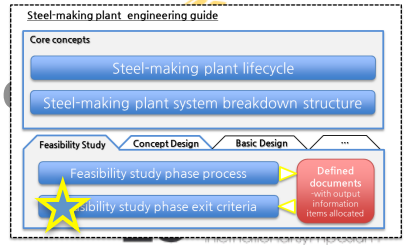
1) Score the importance of the item
2) Check the existence of corresponding information
3) Decide the level of achievement

Priority (1-3)	Level 1	Level 2	Level 3	Review item	Item Description	Importance (0-10)	Existence of Information (Y/N)	Achievement Level (0-5)
	A. Business/Project Overview/Scope Review							
		A.1 Business/Project Overview Review						
3			A.1.1	Business/Project Overview Definition	*Defined business objectives should coincide with company's long-term strategies and action plans.	1)	2)	3)
		A.2 Business/Project Scope Review						
	B. Design Progress Review							
		B.1 Review on Core Stakeholder Requirement Extraction & Transformation						
3			B.1.1	Core Stakeholder Req.s Definition	Core stakeholder requirements(C-StR) are extracted from core stakeholders. It is traceable from stakeholder requirements to stakeholders..			
3			B.1.2	Core System Req. of a Fac ility Definition	Core stakeholder requirements are transformed to core system requirements. *Core system requirements(C-SyR) are defined directly from core stakeholder requirements(C-StR). They are mainly composed of system functional/performance requirements.			
	C. Technical Progress Review							
		C.1 Technical Readiness Level(TRL) Review						
	D. Economic/Schedule Feasibility Review							
		D.1 Economic Feasibility Review						
3			D.1.1	Funding Review	Risks/Acceptability of funding scale are examined. *Decide the degree of achievement using following criteria. 5: Low funding is needed with affordable risk 4: Moderate funding is needed with affordable risk 3: High funding is needed with affordable risk 2: Funding is not yet definite 1: Large investment is needed (maybe more than one willing to risk) *Consider following things: Financial index(Interest rate/Liquidibility), Aff Methods(Loan cost, Loan method), Financial ratio change(Debt ratio, Ca possesion, Credit change			

FS Exit criteria

- Minimum application(Severity level 3): 13 items
- Normal application(Severity level 3&2): 41 items
- Full application(Severity level 3&2&1): 84 items

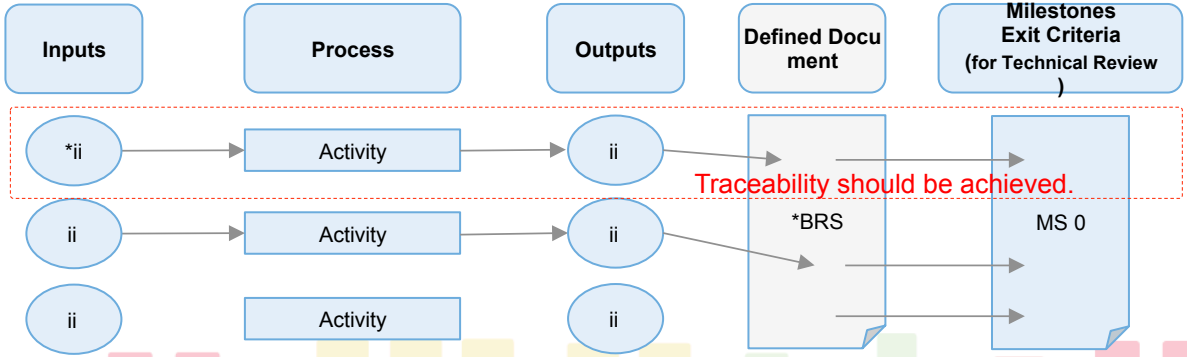
4. Steel-making plant engineering guide development case



Edinburgh, UK
July 18 - 21, 2016

- Exit criteria: Lessons learned
  - **Process & Exit criteria consistency**

    As explained in chapter 3, output information items from process compose defi ned documents and defined documents are reviewed according to exit criteria.
    So it is important for all process activities/tasks and exit criteria items to be linked together.
    By doing that any unnecessary process activities/tasks and exit criteria items c an be figured out.



4. Conclusion & Future works

- Conclusion

  We have developed an engineering guide for steel-ma king industry so that organizations in steel-making indu stry can use it as a reference to develop their own orga nizational standards.

  Through the study, we have reached following conclusi ons:

  <u>For organizations to work with SE processes</u>,

  - **A domain specific SE standard written in a corr esponding domain's language is needed.**

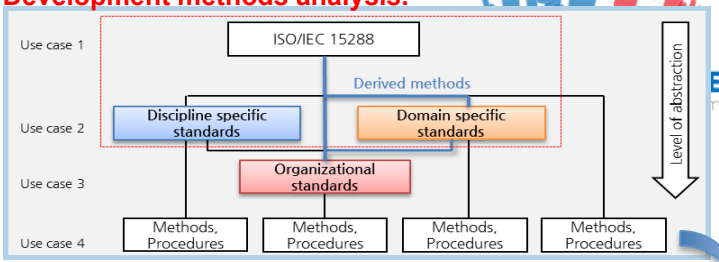
    (Customization)

  - **The traceability from processes to exit criteria s hould be achieved. So that there are less misun derstandings and confusions.**

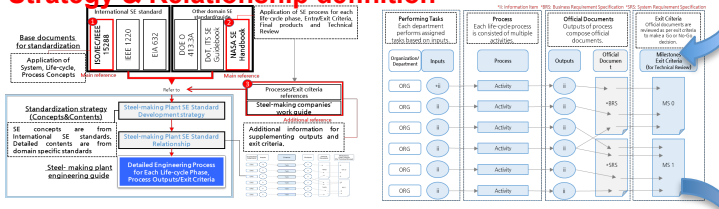
    (Consistency)

  Based on conclusions, following future works are f igured out.

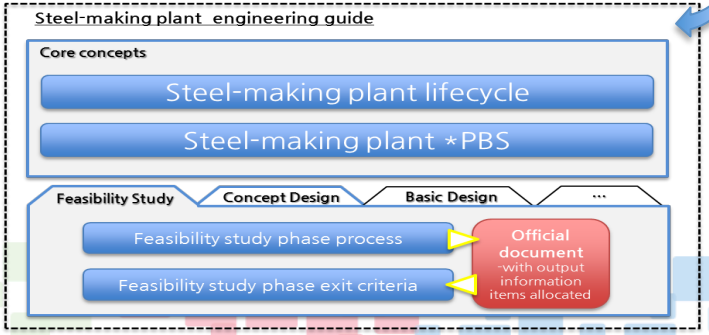
Development methods analysis.



Strategy & Relationship definition



Final product

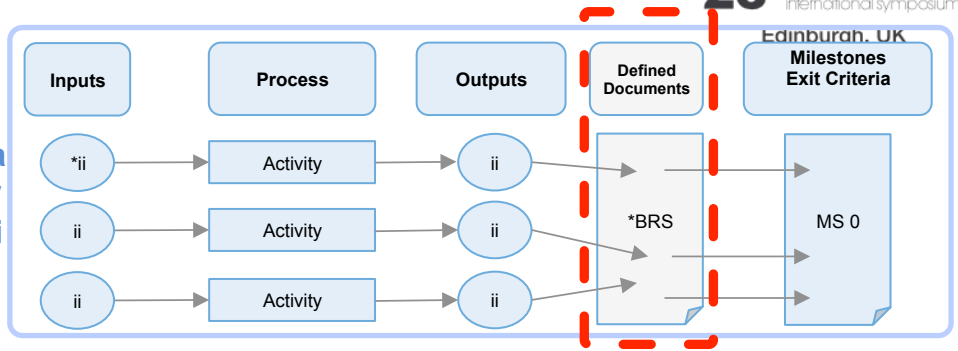


4. Conclusion & Future works

- Future works: short term

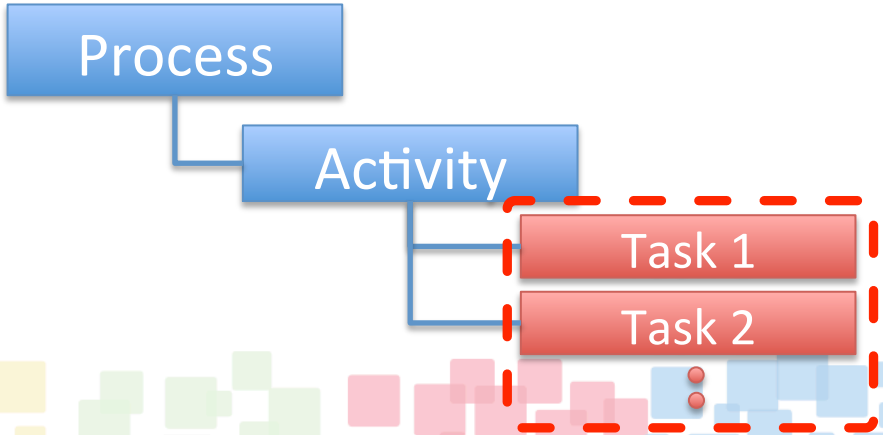
1. Developing contents of defined documents

Output information items from process should be a llocated to appropriate defined documents in order to maintain the traceability from process to exit cri teria.



2. Defining more detailed process

Currently the steel-making engineering process is dev eloped down to the activity level. **Detailed tasks unde r activities should be developed** to increase the over all consistency of the steel-making engineering guide.



Thank you

Future roadmap