REPORT D1.1 9.2.2004 Version 1.0

Technical documentation processes in paper mill life cycle

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1 Abstract

In this paper is presented some preliminary findings from a research project (e-Business Supporting Paper Production Line Life-Cycle) ongoing within a paper mill industry. This study involves a highly complex, extra-organisational collaboration problem that is costing a great deal of money. On the surface, the losses are the result of an apparent inability of the organisations to exchange technical information smoothly with each other. At a deeper level, the losses appear to be the result of poor co-ordination between the companies involved in product development, service, and other technical information support functions. In addition, these co-ordination difficulties are being compounded by a number of reinforcing, feedback loops, which appear to be having an increasingly frustrating, impact on collaboration. Here are reported on efforts to model and analyse the business processes in question. A distinguishing feature of this modelling approach is that the focus is very much on usage of standard data model, factory model that could be used by involving companies.

Keywords and Phrases: Paper mill, Technical data exchange, Business process modelling, Extra-organisational collaboration.

2 Introduction

The PaperIXI project as a whole addresses the production, use, and maintainability of technical documentation exchange in paper mills. Special emphasis is given to company network collaboration and interoperation in the business processes where technical information is created, used and exchanged.

The documentation process in paper mill life cycle starts from creation of paper production line component documentation and ends when the mill is disposed. When implementing seamless data exchange, analysis of the product data flows from component deliverers to system integrators, consultants and finally to the paper mill is needed.

R&D engineers need information about components and systems that are used in the production line and equipment deliveries. The information available varies a lot. In some cases only basic technical specifications are available. Technical information that is needed in the different phases of the design and delivery process must be defined in order to enable efficient product data visibility.

The biggest challenges lay in collaboration processes between all the parties participating in a delivery project. When the processes cross the company borders the challenges are not only technical but also the legal rights concerning product data must be considered.

This paper, dealing with engineering processes in modernization, especially technical documentation processes, describes how paper mills, engineering consultants, system providers, component suppliers and service are to co-operate to achieve best possible results. In other words this paper describes the documentation processes and data flows during the paper mill life cycle so that at each phase of the process all the product data used is defined accurately enough to enable implementation of seamless data transfer. Systematic approach to documentation processes and information content gives a solid base for the product data application implementations. It also helps to avoid unneeded processes and overlapping documentation. This paper also suggests how an information model can be used for unifying mill item (for example valve) naming conventions, mill item hierarchical data structure and data formats.

2.1 Background

Organisational theorists propose that the organisation of the future will be networked across functions and designed around business processes rather than functional hierarchies (Kettinger et al., 1996, Glasson et al., 1994, Crowe et al. 1996). Business process re-engineering (BPR) is now being offered as a paradigm of organisational change necessary in order to achieve the requisite flexibility and competitiveness of the networked organisation (Jones, 1994). BPR is a strategy-driven organisational initiative to fundamentally re-examine and redesign business processes with the objectives of achieving competitive breakthrough in quality, responsiveness, cost, satisfaction and other critical process performance measures (Wysocki & DeMichiell, 1997, Pankowska & Sroka, 1998).

While business processes can be reworked without information technology (IT), recent technological advances have placed greater importance on IT as an enabler of BPR. Increasingly, BPR is being deployed in tandem with the use of IT to revamp or overhaul existing business processes that limit effectiveness. Technologies and standards such as Internet, XML, EDI, STEP are some examples of IT which now allow firms to achieve performance gains in the communications dimensions of business processes. Systems already in place must be selectively destroyed and replaced by cross-functional systems that allow many departments to share a single data warehouse (Kettinger et al., 1996).

Streamlining business processes in the e-World involves two imperatives: trust among business partners and agreement on standard ways of working, and agreement on a common data language that facilitates dialogue on mutual business events over the Internet (Norris et al, 2000).

In the manufacturing industry a lot of effort has been made in order to allow efficient product data transfer between companies. The standardization work that has been carried out especially in the STEP community has shown good results in several business areas. However, STEP has failed to break though among the paper production line manufacturers, equipment suppliers and engineering consultants. Current interest seems to concentrate more on new XML technologies developed directly on delivering information in the web.

In the PaperIXI project a group of major Finnish companies in paper mill business has realised that the value chain is one of the key issue when competing in this global market. There is no single company or organisation that could alone make significant improvements on the collaboration between the partner companies in the chain. The participating companies have announced the common understanding, that forces should be put together to streamline the value chain. The re-thinking of the processes including novel enabling IT technologies is targeting to a new way of collaboration not only in the participating companies but in many other companies in this paper mill business area, too.

IT is not the only solution to speed up the documentation process. As a matter of fact, participating companies have made their choices about software they use for producing, retrieving and storing the documentation. Totally new and across the company borders compatible software in each company is far beyond the economical possibilities. Thus, the solution is not related to new software. However, many common decisions are needed concerning collaboration between the companies, their processes and software.

2.2 Business Process Modeling

The business process modeling is done to gain a better understanding of a documentation process, to see threats or opportunities in the documentation process, to improve or innovate, and to act as a basis for other models (such as information system models). Models facilitate discussions among different people in the documentation process, helping them to reach agreement on the key fundamentals and to work toward common goals. The model of the documentation process is a simplified view of a complex reality. It means a creating an abstraction; it enables to eliminate irrelevant details and focus on one or more important aspects.

Process modeling is a technique used in order to achieve a visual conception of the activities performed (in e.g. an enterprise) seen from a determined point of view. In addition the technique is used to visualise the relationship between activities (internal and external), input, output, actors and tools used to perform the activities and clarify ownership and roles related to the activities.

The benefits of business process modeling can be depicted as follows:

- Increase knowledge related to what “we” are doing as part of the big picture (point of view into the modelling is important).
- Facilitate and ease communication by keeping focus on “the right point of view”.
- Achieve overview/holistic picture.
- Ascertain effective processes.
- Ascertain effective use of recourses.
- Achieve goals/objectives for the entity being modelled.
- Clarify who the actors in the process are by:
  - identifying the customer/supplier relationship
  - identifying who is contributing with what at any given time.
- Clarify what is influencing the process, in order to:
  - ascertain an effective management of the process
  - minimise the risk of making bad decisions

A process description should be a generic description, while an actual execution of a process executes a specific path in the process. This means that the description of a process should contain all the execution alternatives (i.e. including exceptions and error conditions that can occur). A process instance is an example of an execution, a specific way through the general description.

It is essential to define the following when modeling businesses in order to identify and specify the business processes (Eriksson & Penker, p 106):

- Which activities are required. These are specified as functions or activities in a process diagram.
- When are the activities performed, and in what order. This is specified through the control flow in a process diagram.
- Why are the activities performed; what is the goal of the process.
- How are the activities performed. This is specified in a process diagram, often by breaking down the processes into subprocesses that define the activities in more detail.
- Who or what is involved in performing the activities. This refers to the resources that participate in the process.
- What is being consumed or produced. This refers to the resources consumed or produced in the process.
- How must the activities be performed. This is defined through the control flow in a process diagram or through business rules.
- Who controls the process. This refers to the owner of process who runs the process or is responsible for its success.
- How is the process related to the organization of the business. This can be shown through the use of swimlanes in a process diagram.
- How does the process relate to other processes.

2.3 Challenges with Paper Mill Documentation Exchange

The documentation for the paper mill is usually stored in the computer system to provide information about the paper mill. Information consists of hundreds of folders of detailed technical information about the paper mill's subsystems.

There are many kinds of problems concerning such documentation:

- poor accessibility,
- they are difficult to maintain,
- costly delivery of new versions,
- Insufficient information content.

Accessibility problems result from the huge number of information; it is difficult to find a specific piece of information in documentation set consisting of tens of folders. This is intensified by the often-poor organization of the documents. The information is not structured and tends to be scattered around the documentation.

Frequent changes at paper mills - the process and its automation evolve constantly - cause additional problems. Updating documentation is laborious. The documentation may no longer reflect the current status of the paper mill and soon becomes outdated. Such inconsistencies easily lead to a situation where the documentation can not be relied on. Furthermore, there are several interest groups in a company running an industrial paper mill: the design organization (process design, automation design, electric design, etc.), maintenance staff (process maintenance, automation maintenance, instrumentation maintenance, etc.), operators, etc., who have their own needs of the documentation. Communication between these parties is far from ideal, and the changes made by one group are not always reported to the other parties.

According to this study the problems of the information exchange may be divided into following categories:

- language,
- versions,
- format,
- product data structures,
- co-operation,
- internet/ web-portal,
- ability to understand client's information needs and
- nomenclature and identification problems.

Language problems are due to mainly the need of multi-lingual product descriptions. Being a global business, products are sold all over the world, and there is a need for representation, especially service documentation, in many languages.

The problems of the document versions are due to mainly the concurrent engineering and manufacturing. The use of preliminary documents and their updates causes problems and lot of work. The difficulty arises when to use the preliminary document and when to replace it with certified document in the supply chain.

Format problems consist of applications that are used to describe product information. For example formats can be divided into:

- geometric format (f.ex. dxf, IGES, SAT, STEP 203, native formats),
- graphics format (f.ex. jpg, bmp),
- text format (f.ex. doc, xls, rtf),
- catalogue format (f.ex. pdf),
- other (html, xml,...).

Product data structures represent existing physical product structure. Companies in supply chain arrange product structures (and so product data structures) for their own individual needs. These needs differ and complicate smooth exchange of data through supply chain.

Co-operation problems seem to be more "soft" type of problems for example who to contact and when. And which way business partners are willing to help each other.

Internet and web-technologies are somehow two-fold. Internet/web-technology has provided lot of help, but at the same way modern portals are too massive to find specific information.

Ability to understand information needs in supply chain seem to be one of the biggest problems in technical data exchange. Usually it is the question of providing information that is suitable for client's needs. Probably it is the question of not knowing exactly which way the information has to presented so that is most useable in the data exchange.

Nomenclature and identification problems are arising because of missing global way to name product components and assemblies in different functional disciplines.

Technical documentation is one of the major sources of information for the mill operator. It is therefore of utmost importance that the documentation is available where most of the operator's work or the service provider's work is done. On-line documentation systems provide an excellent way to fulfil this requirement. However, on-line documentation systems for industrial applications have in most cases been separate systems with dedicated user interfaces. This requires the operator or the service provider to master several user interfaces, which is clearly an additional cognitive burden. Furthermore, the operators have been forced to turn to another system in order to explore documentation.

2.4 Current Trends

Companies are seeking new competitive edge and those companies who have been producing machines and equipment only, try to transform their business from machine suppliers via solution providers up to performance provider. This means transformation on the needed knowledge, too. The machine tool provider lives with the machine building technology. The performance provider needs in addition to this information communication technology and knowledge management.

From the products point of view in the future products will be modular and even more customer oriented by exploiting mass customisation principles. Product data management and product configuration will be supported by software, where product and mill or factory model is a key element. Enterprise resource planning together with supply chain management controls the business action even in SMEs. Internet as an enabling technology on future networking economy brings totally new opportunities for the value chain and value network combining the best possible knowledge and expertise.

The traditional product development process is mainly sequential and characterized by numerous design changes and redesigning, late delivery of components, discovery of unpurchable components, loss of information in the long pipeline. In contrast, concurrent engineering advocates subprocesses of design and development concurrently performed with or without help of advanced computing technologies. By doing so, total lead-time can be substantially shorter. The reason for this is that unnecessary changes are eliminated and infeasible specifications were detected so that redesigning could be avoided. To perform concurrent engineering in real industrial setting, we can identify critical issues including:

- building a networked organizations focusing on a target product,
- facilitating communication among participants of networked organizations,
- bringing up considerations of later stages such as manufacturing, purchasing, operation, maintenance and recycling, to the discussion table

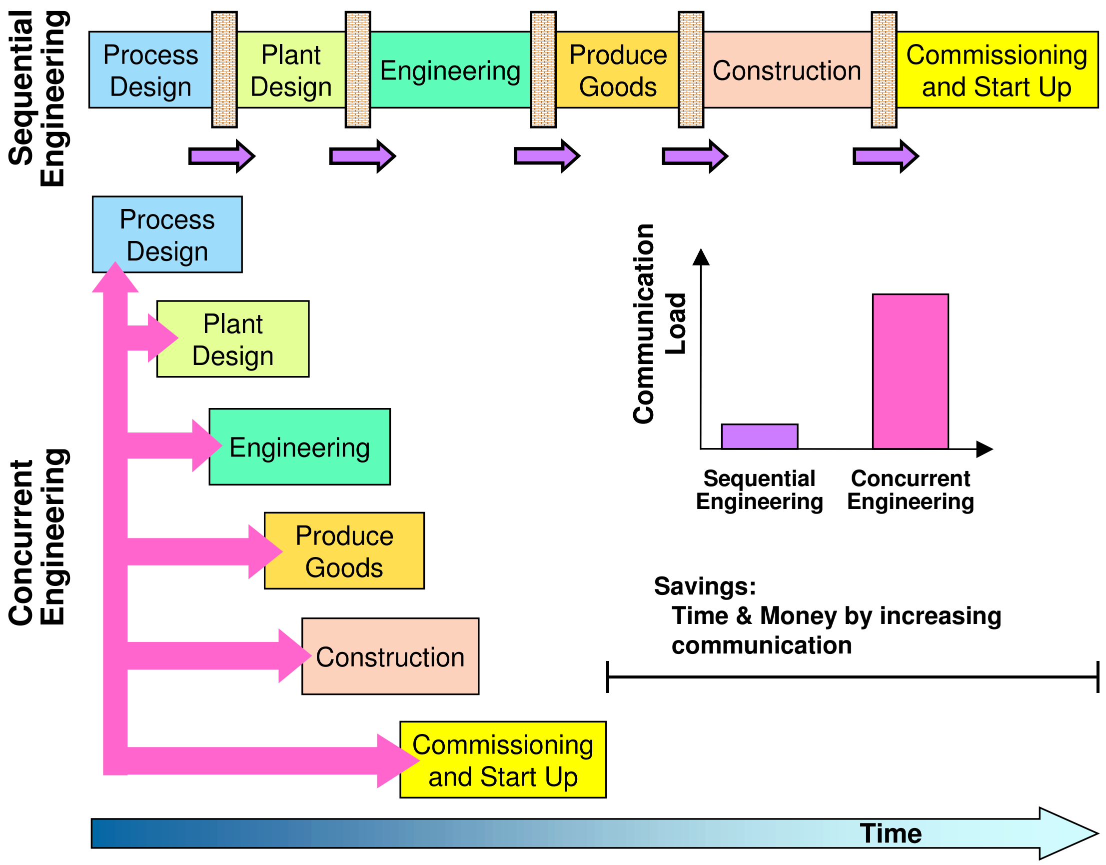
- developing a computational infrastructure to support these three issues.

Concurrent engineering improves design productivity, if productivity is measured by “design output/lead time”. However, if productivity is measured by “design output/man-months” the improvement is not that significant. For instance concurrent engineering methodologies necessitate organizing more meetings for design review involving a large number of participants. In an extreme case, while the total lead-time becomes shorter due to the elimination of unnecessary design changes and redesigns, concurrent engineering does not make individual subprocesses shorter. concurrent engineering increases communication and in the concurrent engineering the change management is challenge.

The amount of communication can be in this context:

- interpreted meetings,
- mutual verbal communication and
- transforming models between different engineering disciplines that are performing subprocesses.

Different engineering disciplines utilize computational tools to analyze, synthesize and evaluate the target product. So to keep overall design productivity the smooth exchange of models are needed in concurrent engineering process. Figure 1 shows the amount of communication in the traditional



engineering and in the concurrent engineering.

Figure 1. Subprocesses in the sequential engineering and in the concurrent engineering are represented in this principal picture. Subprocesses are simultaneously performed, thereby arriving at shorter lead-time than the traditional sequential process. However, the mutual communication among participants increases. This is the overlapping part between subprocesses.

ISO 10303, shortly STEP, aims to handle all kind of information relating to a product. A plant can also be seen as a kind of a product. STEP is an emerging mechanism for the exchange of engineering data. The purpose of STEP is to specify neutral mechanisms for the unambiguous representation and exchange of computer-interpretable product information to support storing, accessing, transferring and archiving that information over the life cycle of products.

STEP is briefly the general product data model. From this general product data model there are done many ISO standards for different applications, like

- Configuration Controlled 3D Design of Mechanical Parts and Assemblies,
- Electrotechnical Design and Installation,
- Core Data for Automotive Mechanical Design Processes,
- Plant Spatial Configuration and
- Technical data packaging core information and exchange.

The STEP standards are organized into application protocols (AP), which are unique sets of entities chosen for a specific product, process, or industry. For example, APs have been tailored to automotive, plant and aerospace industries. At the moment there are available application protocols that can support partly the enormous amount of information needed in the life-cycle of a plant.

Internal and external data readiness in the near future is shown in Figure 2 (The USPI-NL roadmap workgroup). External process integration and internal standards will be the important part of the supply chain.

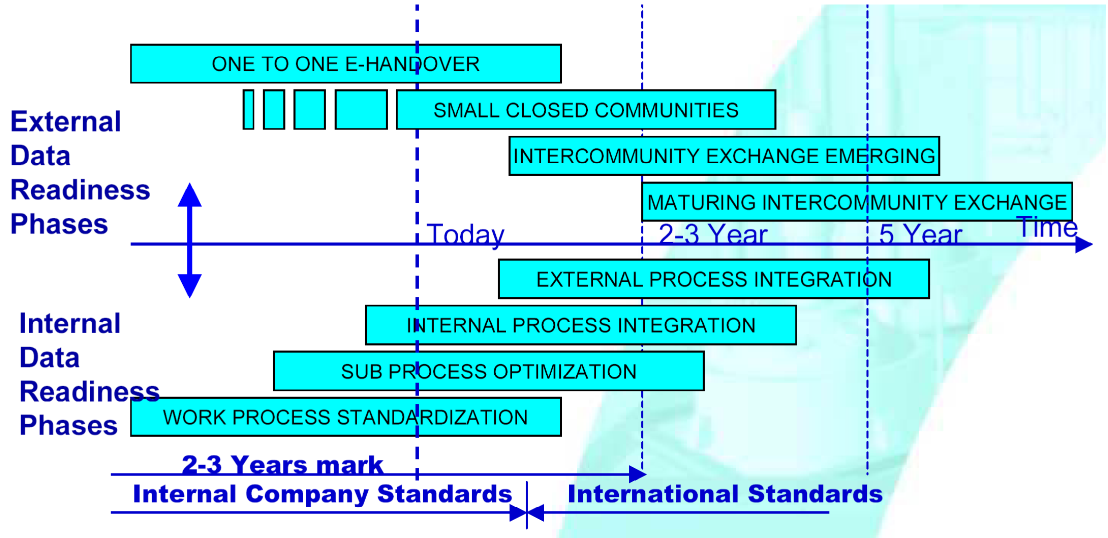


Figure 2. Roadmap to competitive advantage via sharing and storing plant lifecycle data 2002 (http://www.uspi.nl/).

The scenario distinguishes between internal and external data readiness. The way lifecycle data are organised within a company is important for exchanging data with other organisations. A paper-based company will not be capable of exchanging more than paper. Internal data readiness is therefore a key parameter in defining subsequent phases. Similarly, external data readiness – that is the capability to exchange lifecycle data with external parties – is also a key consideration.

For both internal and external data readiness, future developments have been divided into four subsequent phases. Each phase logically follows the preceding phase and is distinct from it.

Interrelationship between internal and external phases

The scenario combines internal data readiness phases and external data exchange phases. Interdependencies exist between the two. A company cannot exchange lifecycle data if it is not internally ready. This is particularly true for phases three and four in both the internal and external situations, when data are integrated between a company and partners in the chain.

The check point phases are necessarily consecutive steps that must be progressed through one at a time. A "big bang" in progress is unlikely.

The plotted timelines are based on the experience of members of USPI-NL. They represent a reasonable average of where the industry is today and where it could be in two to three years and in five years. A company's position on the roadmap will vary depending on its experiences, initiatives and projects.

3 Goals

The goal is to describe the business processes in the supply chain by using common and formal methods. Furthermore, visualizing processes increase common understanding and makes it possible to improve processes.

Documentation processes will be described using generally accepted methodologies, like IDEF0. More detailed descriptions are made in the process areas of the proof of concept implementations. Change management in the network is studied.

4 Methods

4.1 Analysis of current processes

The chosen method of clarifying business processes was to interview in the companies the key players dealing with technical documentation. The visited companies were: ABB (Espoo and Vaasa), Jaakko Pöyry, M-real (Lohja), Metso Paper (Järvenpää), Polarteknik PMC (Vantaa), Siemens (Espoo), SKF (Espoo), StoraEnso (Oulu), UPM-Kymmene (Rauma). Figure 3 shows the companies and the visiting dates. The method that is based on IDEF0 method (IDEF0, 1993) was selected to represent processes.

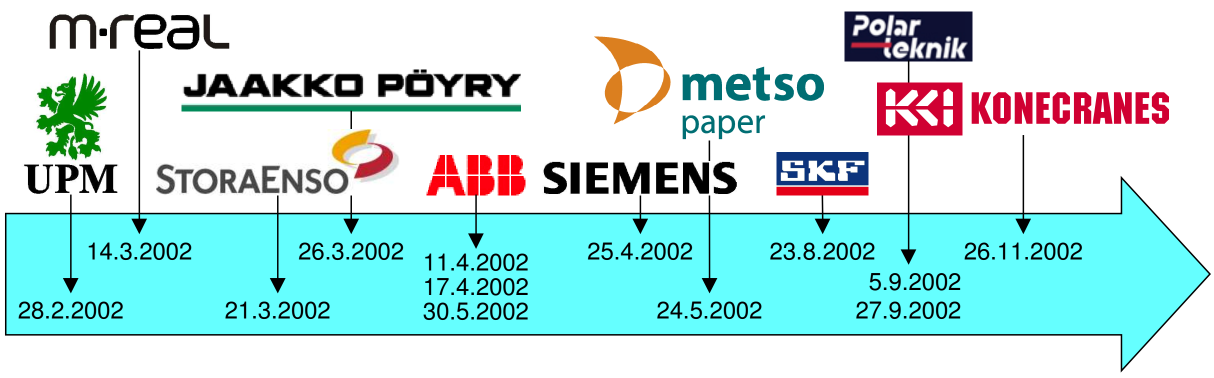


Figure 3. Companies and the dates of the visits.

The process descriptions of the companies are represented in appendixes 3 to 7.

4.2 The representation method of business processes

The selected method to represent the business processes is based on the IDEF0 that is widely used to represent processes. IDEF0 method was augmented with swimlanes that represent different companies or different roles inside a company. Swimlane helps to understand who are doing which actions in the whole supply chain.

IDEF0 method describes the detailing of activities clearly and interfaces between subprocesses. It is very easy to see, from the IDEF0 diagram, what are input and output of the subprocess, how to control the subprocess and what are the needed resources.

Boxes represent activities or functions in IDEF0 method. Every box contains a name and a number, used to represent a function. The name is the verb or verb phrase placed inside an IDEF0 box to describe the activity. The number placed inside the lower right corner of an IDEF0 box identifies uniquely the box on a diagram. If the node number is written beneath the lower right corner of an IDEF0 box, then it is detailed and to indicate which diagram details it. A node number is in the lower left corner of a diagram.

Arrows between boxes depict the information and material flow. The IDEF0 arrow has a label that is a noun or noun phrase. It is specifying its meaning. There are 4 arrow classes: Input Arrow, Output Arrow, Control Arrow, and Mechanism Arrow. The names of boxes and the labels of arrows are explained in the appendix 1.

In the process diagrams only main information flows are described due to the fact that concurrent engineering creates lots of information flows in the real life (Figure 1).

5 Results

5.1 Ideal processes

The process diagrams of the paper mill rebuilding in the supply chain are given in Figures 4 through 16. These diagrams represent the complete model of ideal processes.

The processes are created analysing the process descriptions of the companies, abstracting them and comparing the ISO 10303-227 standard. These process diagrams are called the ideal processes. The description of the processes is focused on the technical documentation of paper mill.

The top-level diagram is represented in Figure 4. This is the overview of the rebuilding project in the paper mill (for example the winder will be changed). The new technical documentation will be updated to the data system of the paper mill.

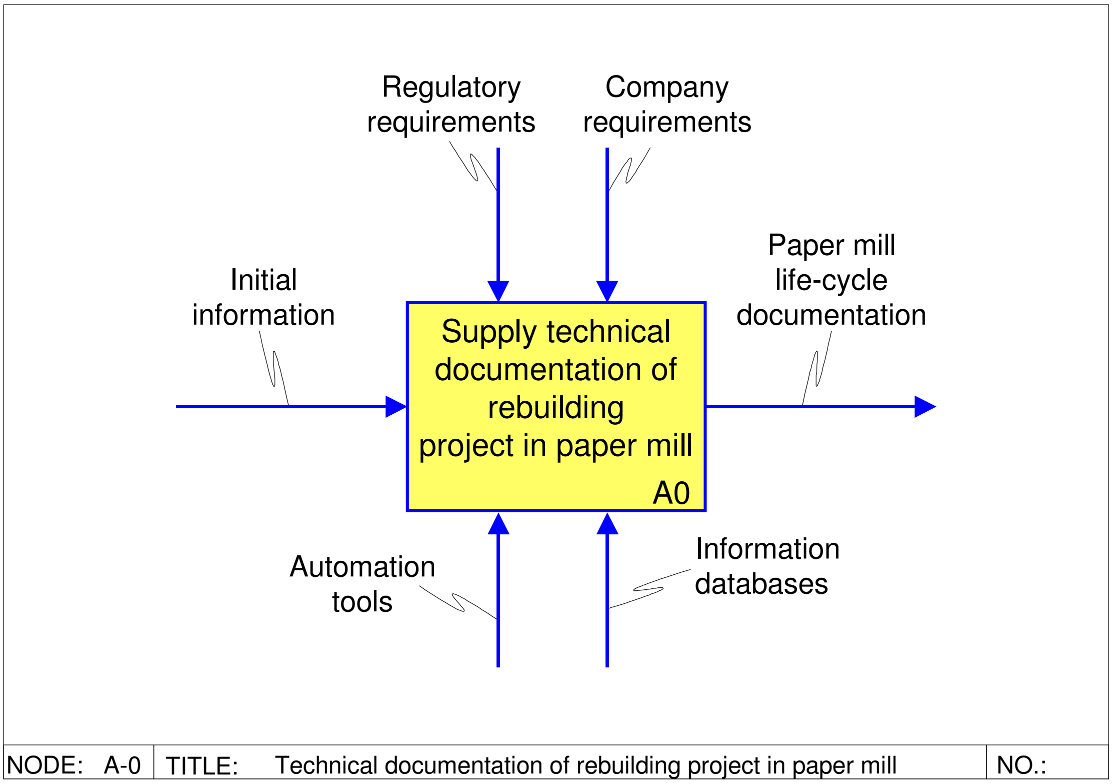


Figure 4. Technical Documentation of Modernisation Project in Paper Mill.

The first level diagram is in Figure 5. The paper mill makes plan and manages the rebuilding project. It utilises the engineering consultant and / or the system provider for designing, engineering, constructing and commissioning the rebuilding project. The system provider utilises component suppliers for producing goods and services.

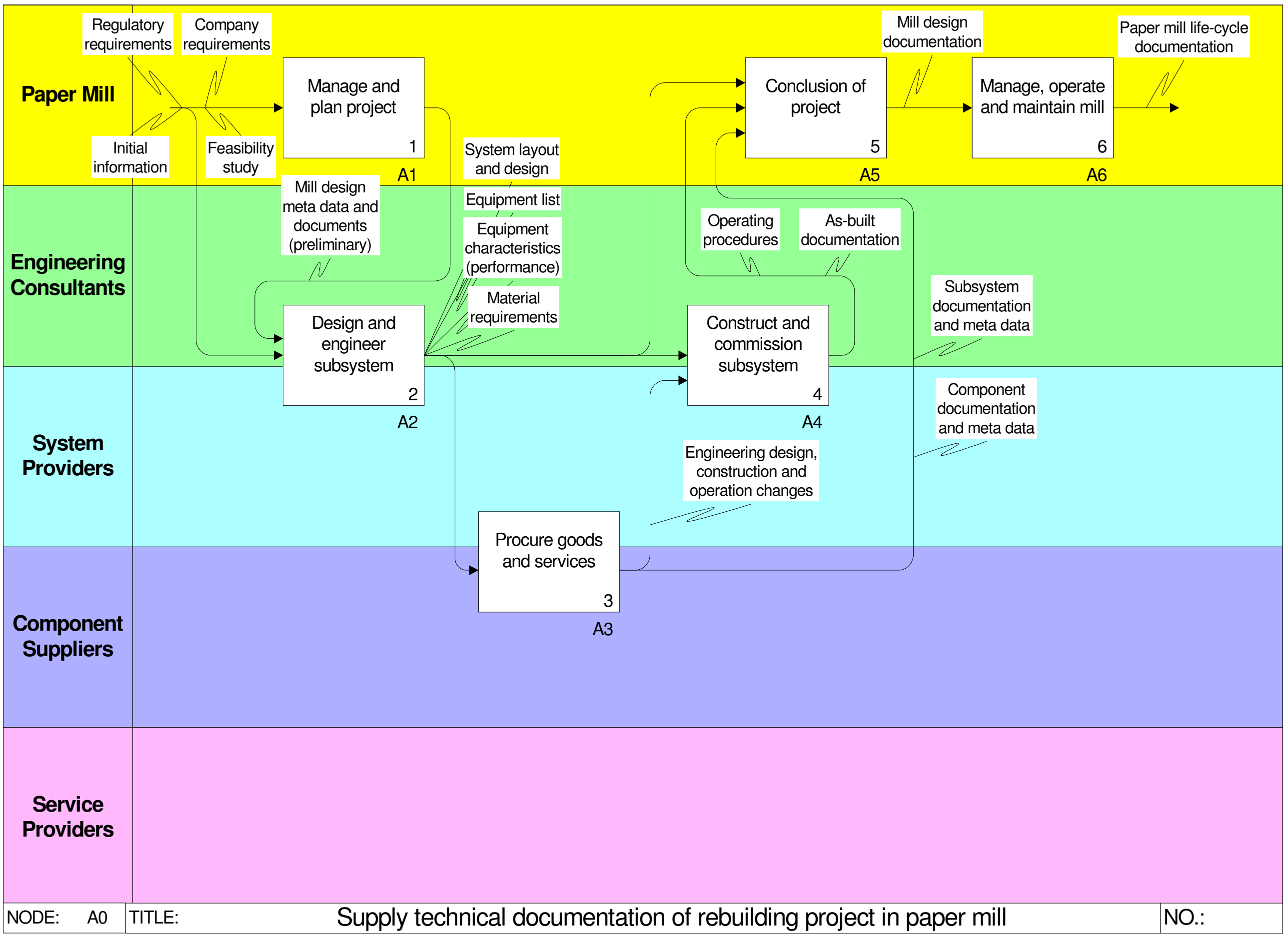


Figure 5. Main process diagram in the rebuilding of paper mill.

To achieve better understanding all verbs phrases and nouns are explained in the appendix 2. For example, one box "**Design and engineer changes**" is explained below, table 1:

Table 1. All terms are explained in Terminology table. Here is one part of this table.

Term	Description	Example / Note
Design and engineer changes	The activities required developing an appropriations request and generating a construction design specification for some modification to an existing paper mill or the construction of a new paper mill.	NOTE The appropriation request is submitted to company management for approval. Upon approval, the construction design specification is generated.

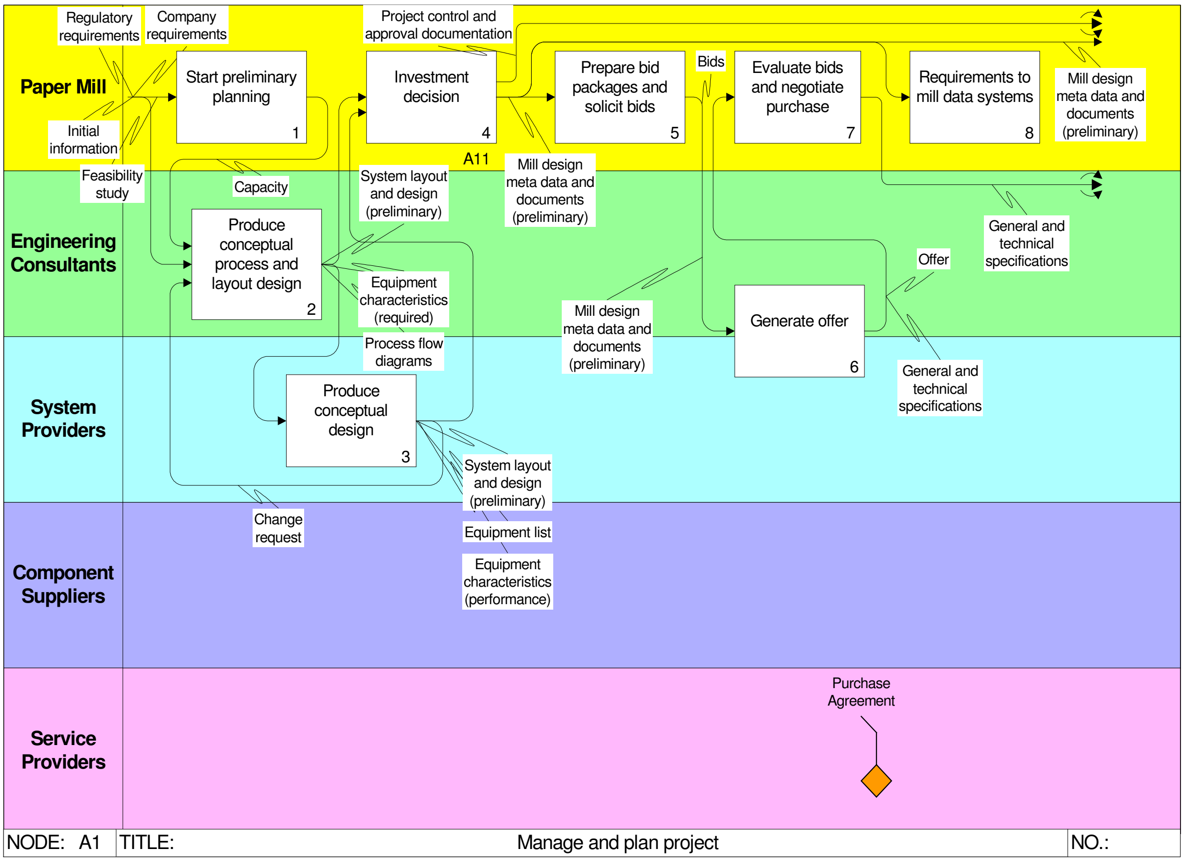


Figure 6. Manage and plan the project. Bids and offers include technical data.

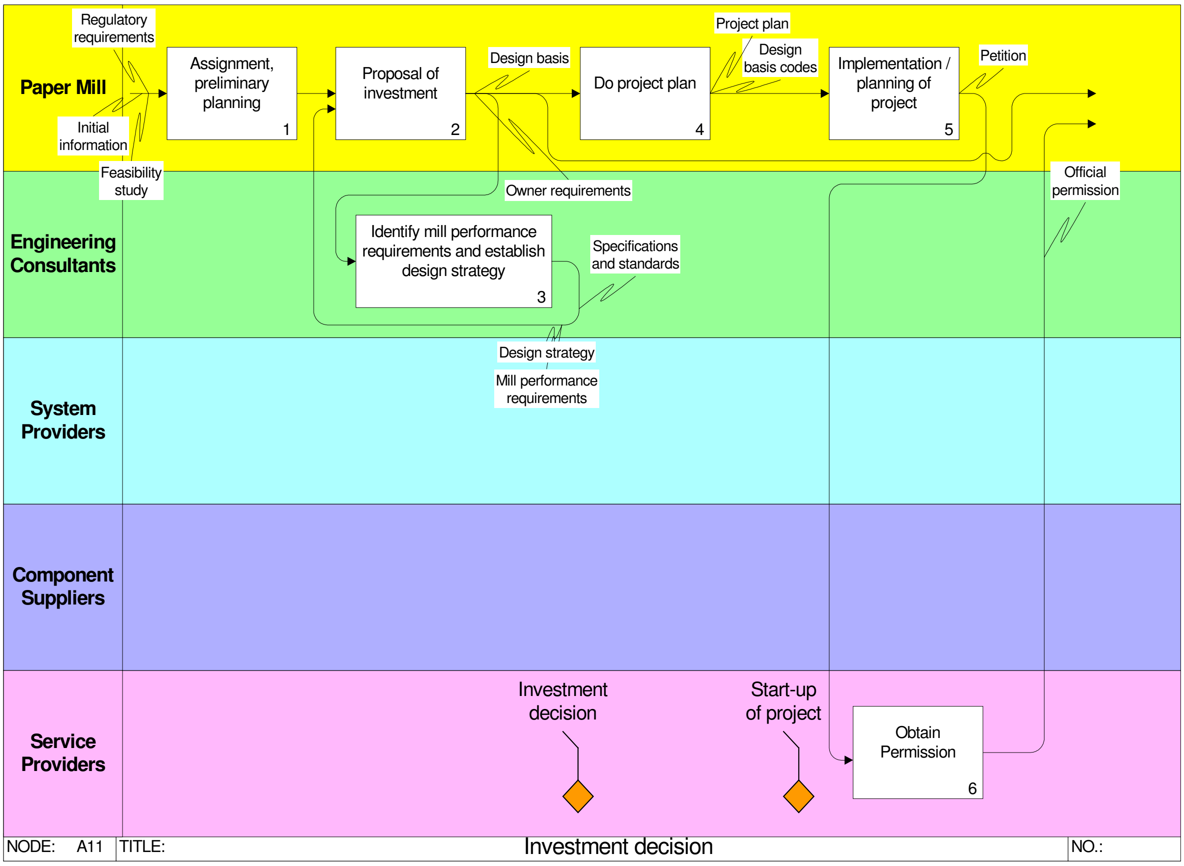


Figure 7. Investment decision.

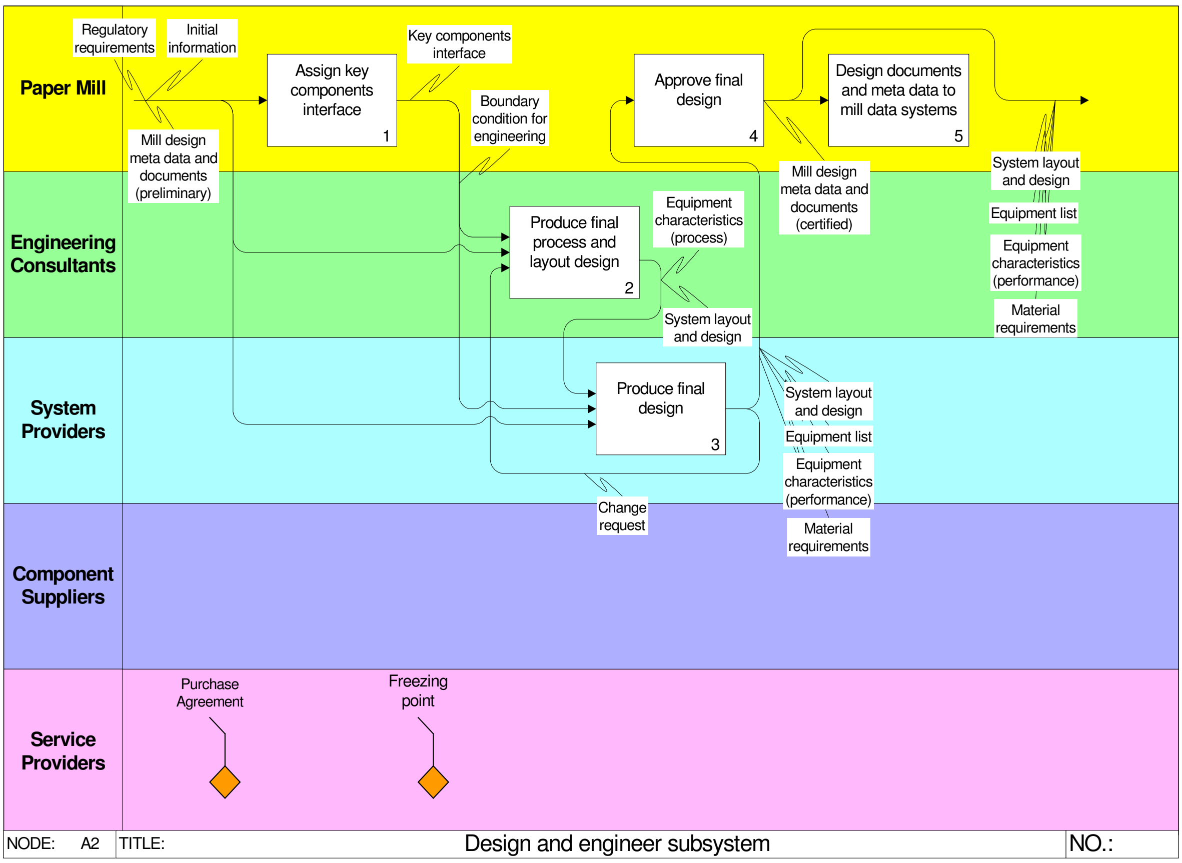


Figure 8. Design and engineer changes.

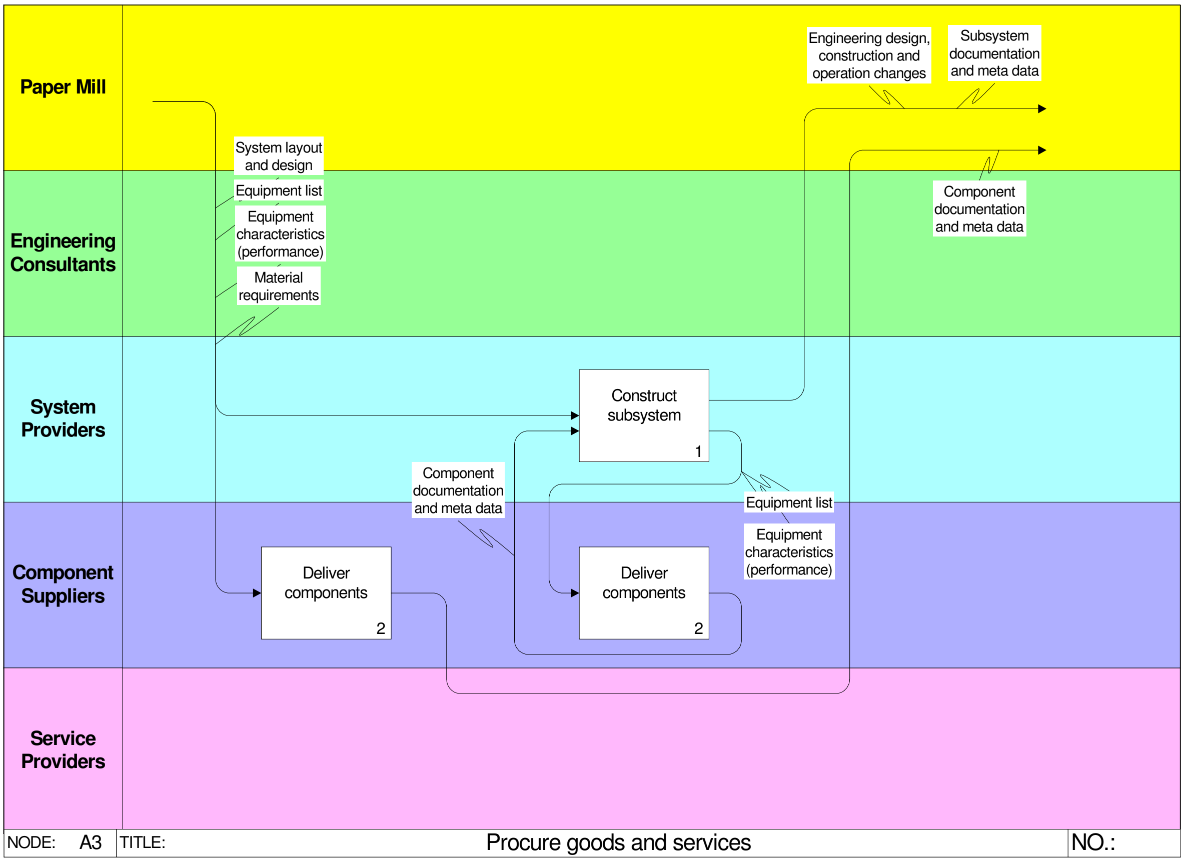


Figure 9. Procure goods and services.

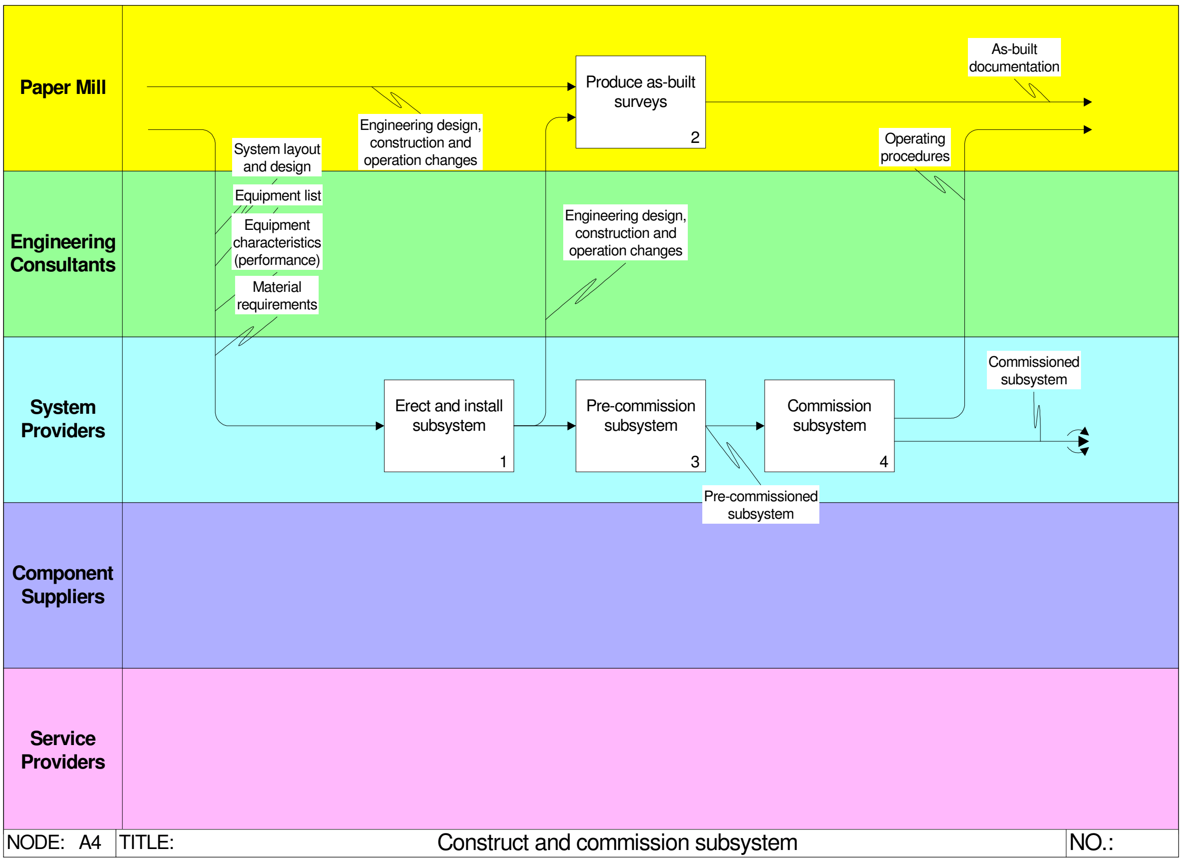


Figure 10. Construct and commission changes in the paper mill.

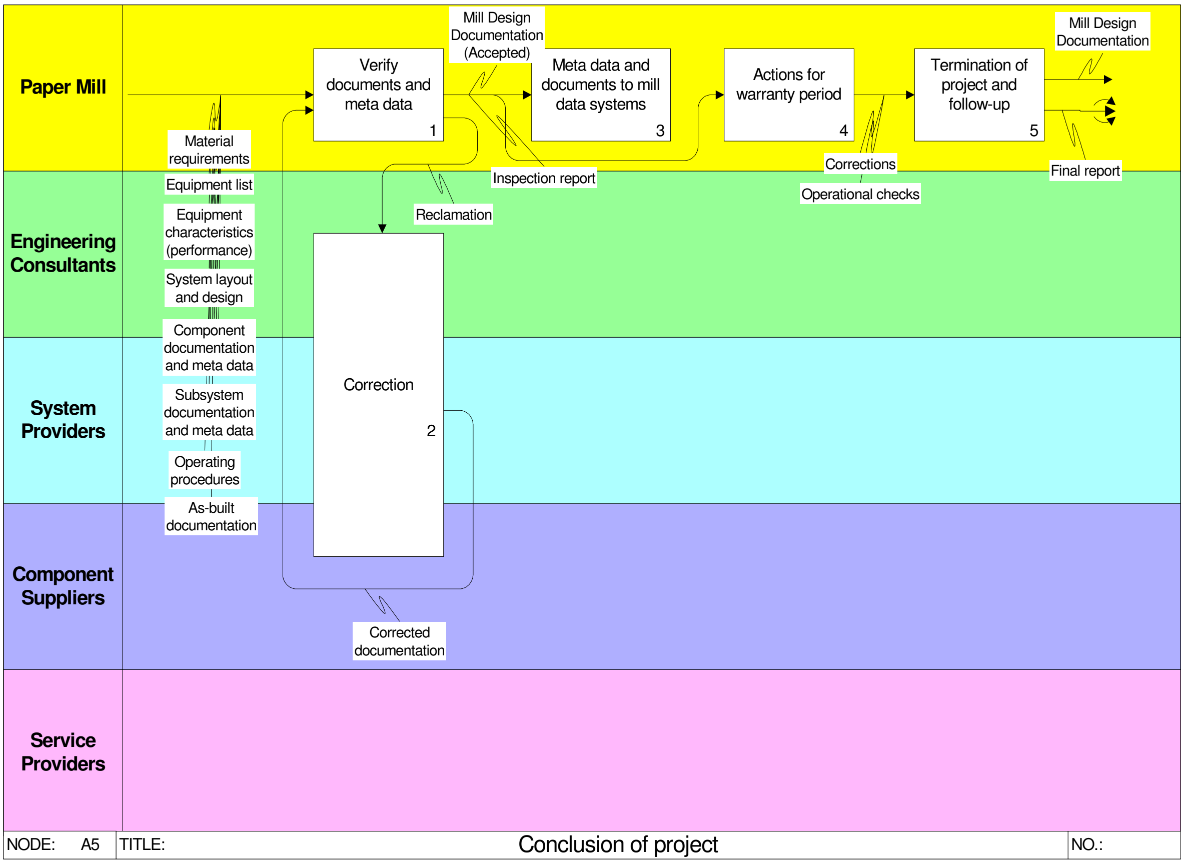


Figure 11. Conclusion of the investment.

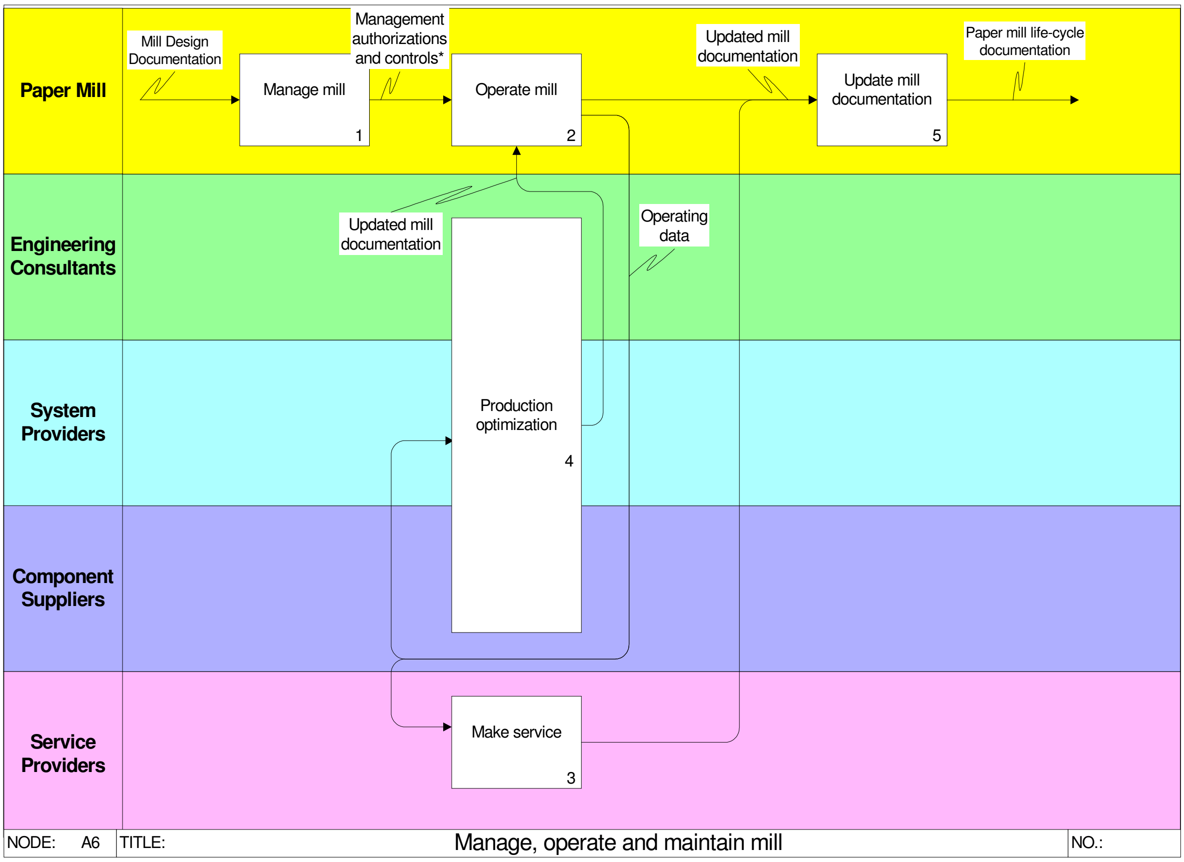


Figure 12. Manage, Operate and Maintain Mill.

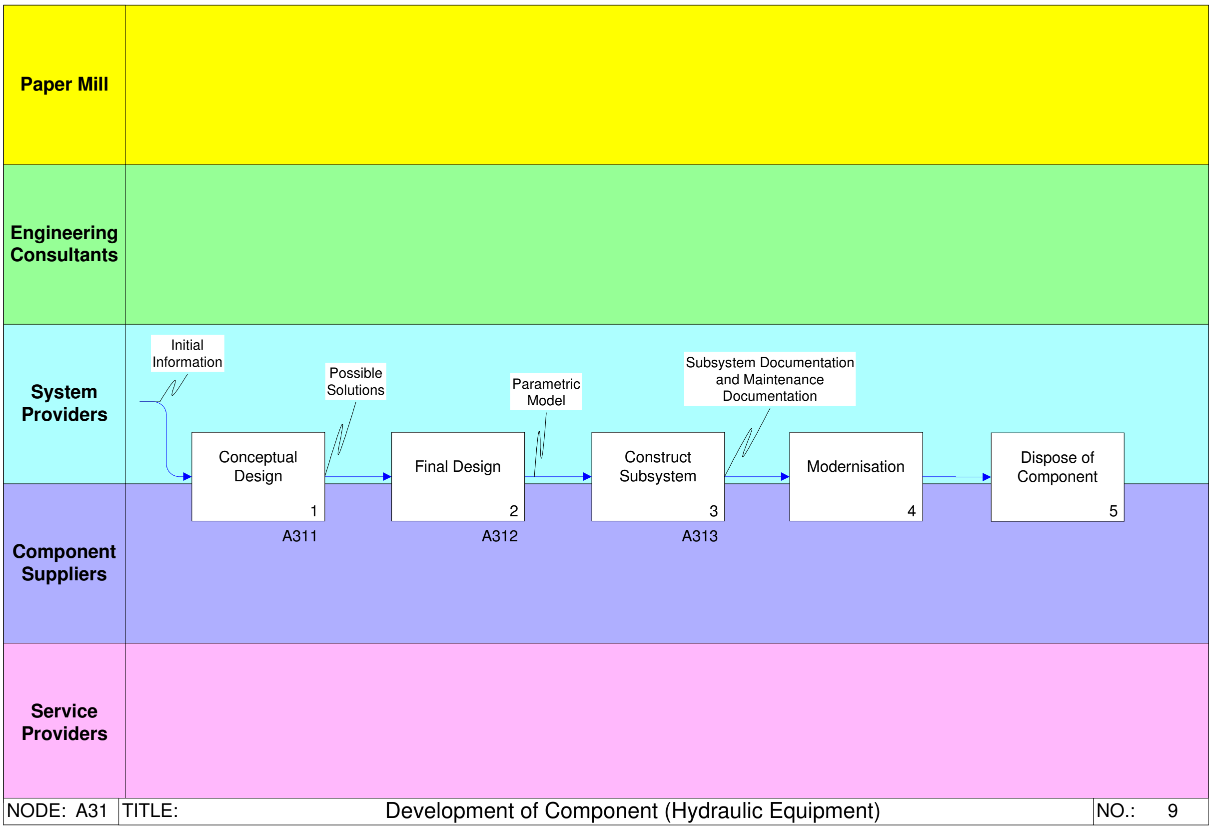


Figure 13. Development of component.

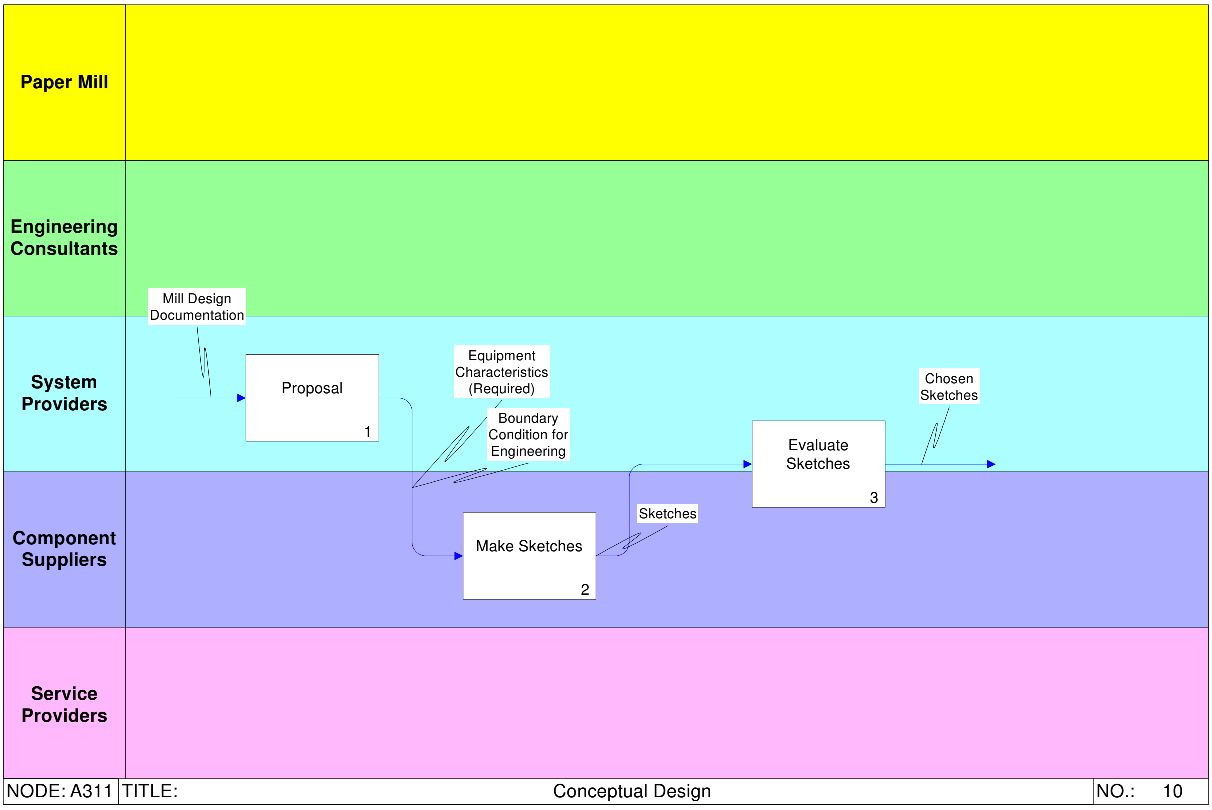


Figure 14. Conceptual design.

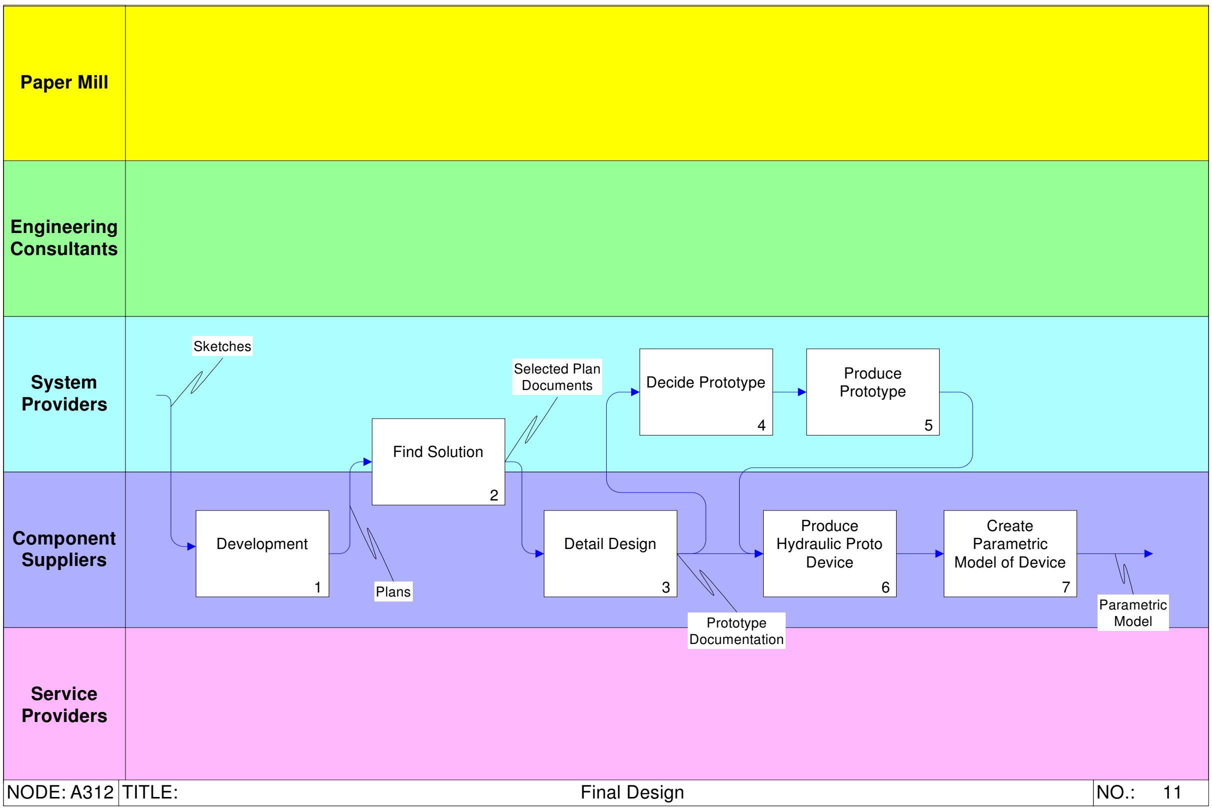


Figure 15. Final design.

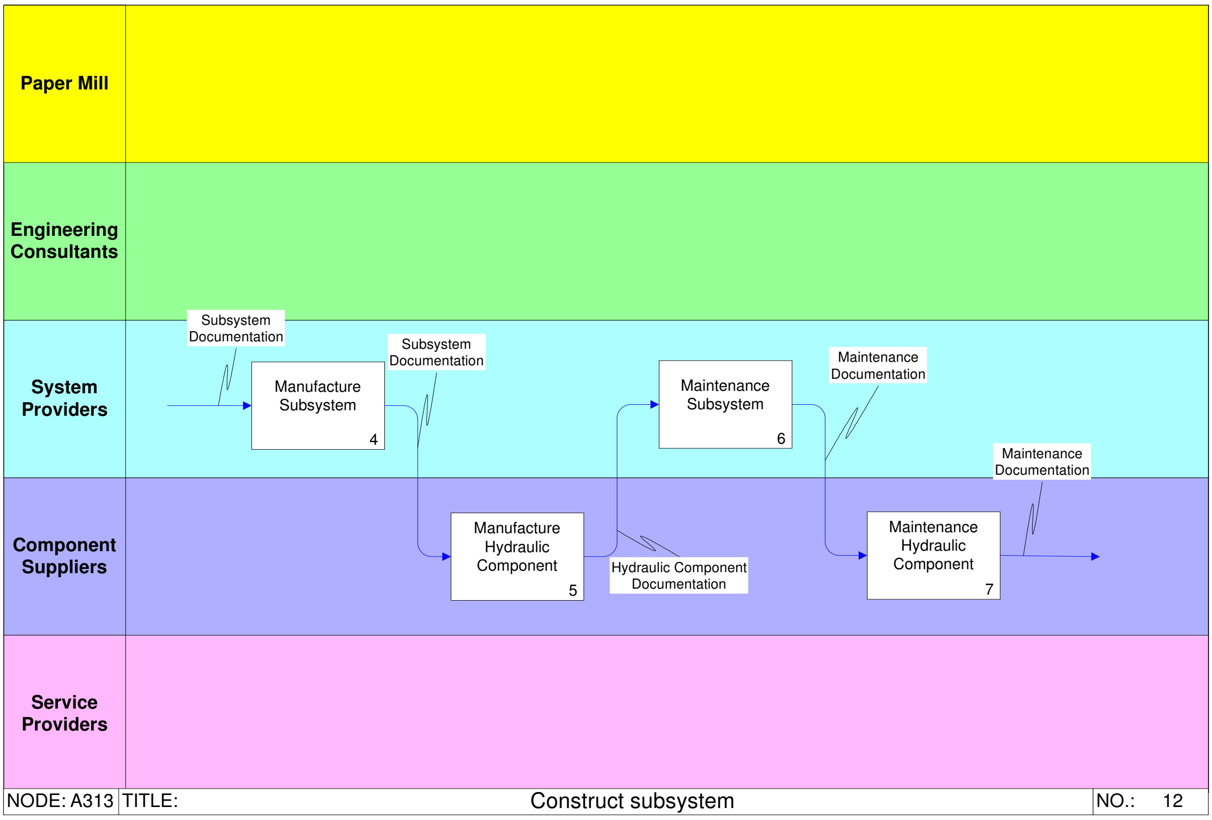


Figure 16. Construct subsystem.

6 Discussion

The goal of this project was to describe the business process, especially from the view of technical documentation exchange in the supply chain by using common and formal methods. The aim was to visualize and improve the processes.

Interviewing the paper cluster companies showed that processes, which describe the operation inside a company, are represented in many various ways. Also the processes across the supply chain were mainly limited to company's own point of view.

To solve this and and gaining a deeper understanding of the problem, it was developed the model of the relevant processes using IDEF0 augmented with "swimlane format". This process model was created using descriptions of companies, discussions in the companies and utilising activities described in ISO 10303-227 (Plant spatial configuration) standard.

All the individual process descriptions were assimilated into a common general process model. This model is called ideal processes. The ideal processes are an abstraction of activities of a paper mill's modernization project and are a simplified view of a complex reality.

To define the data that has to be exchanged in supply chain calls for more detailed process descriptions as was possible to carry out in this work package. But, there are available data models that could be used as a basis for the *universal mill model*.

The universal mill model is needed to improve the collaboration in paper mill supply chain. This model should represent meta data and technical data, as components, documents and relations between different elements of the universal mill model. This mill model should be based on international standards like ISO 10303 family. Otherwise this model is isolated and its maintenance and its interfaces to other systems will be in danger in the long run. The mill model that is based on standards will be more laborious to take in use than data models that are developed in Paperixi project scope. At the moment there are implementations for plant design ISO 10303-227: CCPlant by Dassault / IBM and PlantSpace by Bentley; and a 227 viewer by STEP Tools Inc. (in development phase there are softwares by f.ex. Cadcentre and Intergraph.). For system providers and component suppliers there exist ISO 10303-203 (Configuration controlled design) and ISO 10303-214 (Core data for the automotive mechanical design process) standards. All major commercial CAD systems support these two standards.

Furthermore, every company has its own naming system for the objects (a sub-system, a component, etc.) that causes communication problems. To improve the collaboration every company should use common naming systems in the supply chain, making the process much more straightforward. There are solutions, like Epistle, PSK, RosettaNet Technical dictionary and/or United Nations Standard Products and Services Code (UN/SPSC). Also, there are suggestions mentioned in Paperixi consortium that paper mill components should have an unique identifier throughout the whole life cycle, so called global identifier.

Additionally, practical problems are arising because of the multidiversity of data formats. Considering the whole life cycle of the mill (that may be half a century) so ASCII based text data formats, like XML (Extensible Markup Language) and ISO 10303-21, could be possible to exploit during the paper mill's life. The most promising data format is nowadays XML, because of there are plenty of XML tools available. XML is based on SGML (Standard Generalized Markup Language, ISO 8879). The World Wide Web Consortium has published the specification of XML 1.0.

The development of process models has been a worthwhile result. In particular, the model (the modelling process itself) has greatly assisted in familiarising the domain, and given an excellent opportunity to gain a deeper understanding of the framework and its application.

7 Conclusions

The developed business process model facilitate the collaboration between key players in paper mill modernization projects. This model development was achieved using common and formal method, IDEF0; to visualize and improve the business processes in question.

Process model increase knowledge related to what each company or an organizational unit in a company are doing as part of the big picture. One of the important things is identifying the customer/supplier relationship so that it seen who is contributing with what at any given time.

There are promising prospects to unify processes and use common ways of working in the supply chain. However, this calls for absorption of ideal processes as a basis of doing business between companies.

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Appendix 1

Overview of IDEF0-method: A structured approach to enterprise modelling and analysis

Function Modelling Method

IDEFØ (IDEF 0, 1993) is a method designed to model the decisions, actions, and activities of an organization or system. IDEFØ was derived from a well-established graphical language, the Structured Analysis and Design Technique (SADT). The United States Air Force commissioned the developers of SADT to develop a function modeling method for analyzing and communicating the functional perspective of a system. Effective IDEFØ models help to organize the analysis of a system and to promote good communication between the analyst and the customer. IDEFØ is useful in establishing the scope of an analysis, especially for a functional analysis. As a communication tool, IDEFØ enhances domain expert involvement and consensus decision-making through simplified graphical devices. As an analysis tool, IDEFØ assists the modeler in identifying what functions are performed, what is needed to perform those functions, what the current system does right, and what the current system does wrong. Thus, IDEFØ models are often created as one of the first tasks of a system development effort.

In December 1993, the Computer Systems Laboratory of the National Institute of Standards and Technology (NIST) released IDEFØ as a standard for Function Modeling in FIPS Publication 183.

IDEFØ Concepts

The IDEFØ method has basic concepts that address each of the needs previously discussed. The basic IDEFØ concepts include the following.

Cell Modeling Graphic Representation

The "box and arrow" graphics of an IDEFØ diagram show the function as a box and the interfaces to or from the function as arrows entering or leaving the box. To express functions, boxes operate simultaneously with other boxes, with the interface arrows "constraining" when and how operations are triggered and controlled. The basic syntax for an IDEFØ model is shown in Figure 1.

Communication

IDEFØ concepts designed to enhance communication include the following:

Diagrams based on simple box and arrow graphics.

English text labels to describe boxes and arrows and glossary and text to define the precise meanings of diagram elements.

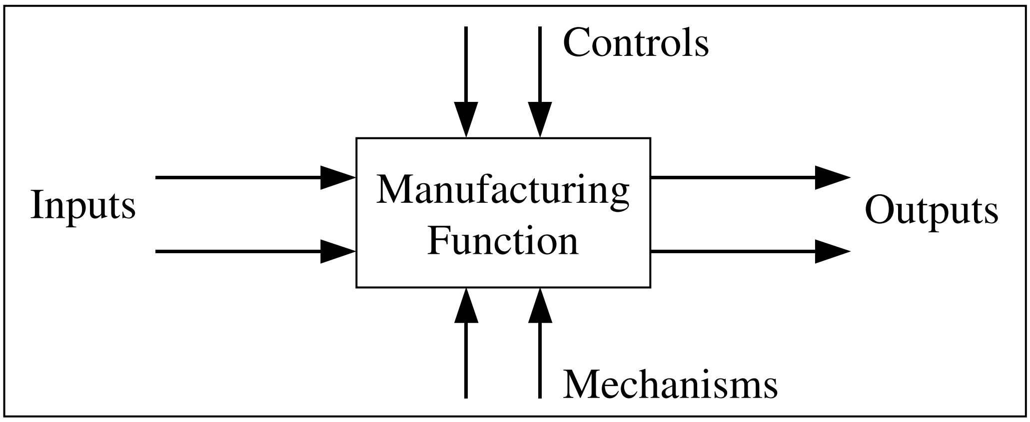

Figure 1. IDEFØ Function Box and Interface Arrows.

The gradual exposition of detail featuring a hierarchical structure, with the major functions at the top and with successive levels of subfunctions revealing well-bounded detail breakout.

A "node chart" that provides a quick index for locating details within the hierarchic structure of diagrams.

The limitation of detail to no more than six subfunctions on each successive function.

Rigor and Precision

The rules of IDEFØ require sufficient rigor and precision to satisfy needs without overly constraining the analyst. IDEFØ rules include the following:

Control of the details communicated at each level (three to six function boxes at each level of a decomposition).

Bounded Context (no omissions or additional out-of-scope detail).

Diagram Interface Connectivity (Node numbers, Box numbers, C-numbers, and Detail Reference Expression).

Data Structure Connectivity (ICOM codes and the use of parentheses).

Unique Labels and Titles (no duplicated names).

Syntax Rules for Graphics (boxes and arrows).

Data Arrow Branch Constraint (labels for constraining the data flow on branches).

Input versus Control Separation (a rule for determining the role of data).

Data Arrow Label Requirements (minimum labeling rules).

Minimum Control of Function (all functions require at least one control).

Purpose and Viewpoint (all models have a purpose and viewpoint statement).

Methodology

Step-by-step procedures are provided for modeling, review, and integration tasks. Formal training courses for transferring the methodology are available.

Organization versus Function

The separation of organization from the function is included in the purpose of the model and carried out by the selection of functions and interface names during model development. This concept is taught in the IDEFØ course, and the continual review of these concepts during model development ensures that organizational viewpoints are avoided.

Sequence and Timing Independence

Applying the IDEFØ method results in an organized representation of the activities and the important relations between these activities in a nontemporal fashion. IDEFØ does not support the specification of a recipe or process. Such detailed descriptions of the specific logic or timing associated with the activities requires the IDEF3 Process Description Capture Method.

Strengths and Weaknesses of IDEFØ

The primary strength of IDEFØ is that the method has proven effective in detailing the system activities for function modeling, the original structured analysis communication goal for IDEFØ. Activities can be described by their inputs, outputs, controls, and mechanisms (ICOMs). Additionally, the description of the activities of a system can be easily refined into greater and greater detail until the model is as descriptive as necessary for the decision-making task at hand. In fact, one of the observed problems with IDEFØ models is that they often are so concise that they are understandable only if the reader is a domain expert or has participated in the model development. The hierarchical nature of IDEFØ facilitates the ability to construct (AS-IS) models that have a top-down representation and interpretation, but which are based on a bottom-up analysis process. Beginning with raw data (generally interview results with domain experts), the modeler starts grouping together activities that are closely related or functionally similar. Through this grouping process, the hierarchy emerges. If an enterprise's functional architecture is being designed (often referred to as TO-BE modeling), top-down construction is usually more appropriate. Beginning with the top-most activity, the TO-BE enterprise can be described via a logical decomposition. The process can be continued recursively to the desired level of detail. When an existing enterprise is being analyzed and modeled (often referred to as AS-IS modeling), observed activities can be described and then combined into a higher level activity. This process also continues until the highest level activity has been described.

One problem with IDEFØ is the tendency of IDEFØ models to be interpreted as representing a sequence of activities. While IDEFØ is not intended to be used for modeling activity sequences, it is easy to do so. The activities may be placed in a left to right sequence within a decomposition and connected with the flows. It is natural to order the activities left to right because, if one activity outputs a concept that is used as input by another activity, drawing the activity boxes and concept connections is clearer. Thus, without intent, activity sequencing can be imbedded in the IDEFØ model. In cases where activity sequences are not included in the model, readers of the model may be tempted to add such an interpretation. This anomalous situation could be considered a weakness of IDEFØ. However, to correct it would result in the corruption of the basic principles on which IDEFØ is based and hence would lose the proven benefits of the method. The abstraction away from timing, sequencing, and decision logic allows concision in an IDEFØ model. However, such abstraction also contributes to comprehension difficulties among readers outside the domain. This particular problem has been addressed by the IDEF3 method.

Appendix 2

Terminology in the process description

Term	**Description**	Example / Note
Actions for warranty period	Actions during warranty period.	EXAMPLE Corrections, controls, guarantees, operational checks.
Approve final design documents	Prepare final design, check conformance to plans, and arrange for any corrective actions.	
As-built documentation	Site plans, detailed equipment descriptions, electrical instrumentation diagrams, and P&IDs that record the actual condition of a paper mill at a specific point in time.	EXAMPLE: Operation procedures Electrical drawings Hydraulic drawings Pneumatic drawings Turn up reports
Assign key components interface and create meta data	Paper mill gives documents and drawings of those equipment that are needed freezing the delivery. Design and engineer subsystem uses paper mill specific meta data. Paper mill creates this meta data.	EXAMPLE: Drive motor rpms AC-motor prints Trim information Reel spool, -coupling and crane hook drawings Core specification Winder main colour Meta data are for example: Documents names, Functions codes
Assignment, preliminary planning	The Assignment of the paper mill is to clarify the investment.	
Automation tools	The collection of software and hardware tools used to assist the activities involved in the life cycle of a process plant.	
Bids	Commercial proposal by supplier for provision of equipment, supplies, or services.	
Boundary condition for engineering	Control the engineering so that equipment works together.	EXAMPLE Interlocking to other systems Layouts/cut-outs for equipment supplied by others Roll discharge level Building layout drawings - winder area Location of control cabinets Location of control desk Location of hydraulic units and panels Location of vacuum blower Location of MCC- and drive cabinets Location of cable trays
Capacity	The capacity of the new subsystem.	
Change request	A request made by a user of data to revise the original or current version of something due to errors, omissions, or other reasons, such as new requirements.	NOTE 1 A request is followed by review, analysis, and approval. Change requests are tracked in terms of cost and schedule (a kind of mini-project within project).

Term	Description	Example / Note
		NOTE 2 Change requests may be made against a supplier list, process, paper mill, procedure, and design basis. NOTE 3 Change request originators include construction and operations.
Commission component	Test the functionality of the completed paper mill prior to operation, develop final operating and maintenance procedures, and obtain final regulatory approval to operate the paper mill.	
Commission subsystem	Test the functionality of the completed paper mill prior to operation, develop final operating and maintenance procedures, and obtain final regulatory approval to operate the paper mill.	
Commissioned subsystem	A paper mill that has been proven to be operational through commissioning procedures.	
Company requirements	Those managerial decisions that place constraints on the operations of the company, that give direction or emphasis on areas for development, or that dictate decisions outside the local decision making paths. The embodiment of policies and regulations that govern the operations of a company.	
Component documentation and meta data	Drawings, manuals, calculations, etc. received from a component supplier.	
Component supplier	A company that supplies (and manufactures) components.	NOTE In this context component supplier manufactures components too.
Conclusion of project	Transfer meta data and documents to the mills data system.	
Construct and commission subsystem	The process of building or retrofitting a physical plant, using plans and building materials. The layout drawings and material requirements are used to establish the physical arrangement and to procure the materials required. A plan for erecting the plant is determined from material schedules, heavy equipment schedules, labor schedules, and environmental conditions (such as weather). Temporary erection material (such as scaffolding) is procured as needed. Regulatory requirements and client requirements are used to plan and erect the plant, and for the final testing and certification for operation. The result is a completed plant that meets the testing procedures defined in the project control and approval documentation.	

Term	Description	Example / Note
Construct and install subsystem	Utilising plans, materials, services and labour, build a physical paper mill that conforms to the detailed design.	NOTE Major equipment is moved, often in pieces, and installed on foundations with supporting steel. Site permanent buildings are built, as are pipe racks and other permanent steel. Pipe runs and pipe spools are put in place with valves and miscellaneous equipment and welded or joined. Other items such as ducting, electrical, instrumentation are installed.
Construct subsystem	The system provider constructs the subsystem of the paper mill.	EXAMPLE Winder
Corrected documentation	The mill documentation that is improved.	
Correction	The supplier corrects faults in the documentation or supplier corrects the device.	
Deliver components	The supplier receives equipment list, equipment-required characteristics, and material requirements. The component supplier send off suitable components and their documents.	NOTE The component supplier can also design electrification for whole delivery / project.
Deliver layout, space and system connections and add meta data	Paper mill gives documents and drawings of those equipment that are needed freezing the delivery. Design and engineer subsystem uses paper mill specific meta data. Paper mill creates this meta data.	EXAMPLE: Drive motor rpms AC-motor prints Trim information Reel spool, -coupling and crane hook drawings Core specification Winder main colour Meta data are for example: Documents names, Functions codes
Design and engineer subsystem	The activities required developing an appropriations request and generating a construction design specification for some modification to an existing process mill or the construction of a new process mill.	NOTE The appropriation request is submitted to company management for approval. Upon approval, the construction design specification is generated.
Design basis	A document provided by the paper mill owner or developed by the architecture, engineering, and construction (AEC) contractors that establishes or defines the information and data that paper mill engineering is to be based upon. It consists of guidelines and requirements, corporate standards, codes, references to regulatory agreements, form of deliverables, and paper mill or production capacity.	EXAMPLE The design basis includes: design safety philosophy; environmental requirements; paper mill inputs (e.g., fuel, feedstock); paper mill license and permit requirements; paper mill operating requirements; paper mill process requirements; paper mill product or output (type and capacity); site parameters (geographical, meteorological, soils, hydrological); type of paper mill. It also addresses performance objectives for the paper mill such as: capacity;

Term	**Description**	Example / Note
		engineering quality; environmental; investment and project economics; safety and health; schedule; product and paper mill quality; product and raw material storage; project execution; technology. NOTE 1 Performance objectives usually take the form of a written document owned and maintained by the project team (consisting of members from the business, engineering, construction, and paper mill site). NOTE 2 The definition for design basis is from an owner's perspective.
Design basis codes	Design Basis Code composes whole or part of the identifying code for every equipment in Paper mill.	
Design documents and meta data to mill data collecting and exchange system	The design data and meta data is added / updated to the mill data collecting and exchange system.	NOTE This updates the factory model. F.ex. Document numbers and functional numbers
Design strategy	A description of major steps required completing enough design to obtain a budget estimate for business calculations as well as to begin the identification of process unknowns that may or may not require piloting. It encompasses building technology, mechanical technology, utility technology, automation technology, schedules, scope, standards and regulations, process definition, control philosophies, costs, benefits and timings, and project approach (e.g., architectural engineering, construction management, internal).	
Do project plan	The paper mill creates the plan to execute the investment / change.	
Engineering consultant	A company that produce a process design and a construction design specification.	
Engineering design, construction, and operation changes	Changes to the design of the paper mill arising from errors, omissions, new requirements, or other reasons during paper mill design, construction, or operation.	
Equipment characteristics (performance)	Describe or specify the performance requirements for the equipment: how much it is supposed to do it. They are items of information that describe the effect that equipment has on the process or	EXAMPLE For a pump, such information might include flow rate, total developed head, and efficiency. NOTE Calculations, Specifications for Mill Construction, Mechanical and

Term	**Description**	Example / Note
	other operational information.	Automation Specifications NOTE List of Motors, Request for Components, Documentation
Equipment characteristics (process)	A subset of equipment functional data that describe the contribution to the process desired from equipment. Such data is specified prior to the actual selection of specific equipment to fulfil the purpose.	
Equipment characteristics (required)	Needed functional, performance, physical, or process attributes of an item that have a name and measurable value.	
Equipment list	A list of equipment in the paper mill.	EXAMPLE An equipment list is comprised of, but not limited to: contract numbers (e.g., purchase, install); drawing references (e.g., P&IDs, paper mill arrangements); electrical load and type; identifier (e.g., tag); location (e.g., building, elevation, area, column row); name; service requirements (e.g., air, water, structural base, electrical power, control circuitry); spare requirements. NOTE The equipment list may not include all equipment. It does not include miscellaneous equipment and devices (e.g., y-pattern strainers, inline flow meters, instruments) or valves.
Erect and install component	The process of building or retrofitting a physical paper mill, using plans and building materials. The layout drawings and material requirements are used to establish the physical arrangement and to procure the materials required. A plan for erecting the paper mill is determined from material schedules, heavy equipment schedules, labour schedules, and environmental conditions (such as weather). Temporary erection material (such as scaffolding) is procured as needed. Regulatory requirements and client requirements are used to plan and erect the paper mill, and for the final testing and certification for operation. The result is a completed paper mill that meets the testing procedures defined in the project control and approval documentation.	As-built documentation
Erect and install subsystem	The process of building or retrofitting a physical paper mill, using plans and building materials. The layout drawings and material requirements are used to	As-built documentation

Term	**Description**	Example / Note
	establish the physical arrangement and to procure the materials required. A plan for erecting the paper mill is determined from material schedules, heavy equipment schedules, labour schedules, and environmental conditions (such as weather). Temporary erection material (such as scaffolding) is procured as needed. Regulatory requirements and client requirements are used to plan and erect the paper mill, and for the final testing and certification for operation. The result is a completed paper mill that meets the testing procedures defined in the project control and approval documentation.	
Evaluate bids and negotiate purchase	The process whereby bid packages are evaluated, a supplier is selected, and an agreement is entered into for the acquisition of the paper mill item(s).	
Feasibility study	A study that provides the foundation for further decision-making.	A feasibility study is the due diligence that should be done before starting any project. A feasibility study is vital before the implementation stage. A well-prepared and researched study can help reduce the risk. By giving a true measurement of that risk, feasibility studies help pinpoint market opportunities and pitfalls.
Final report		
Freezing point	The conceptual design is closed. The paper mill and the provider are agreeing about the delivery.	
General and technical specifications	All the addition information which is needed to start delivery project.	NOTE There is for example: Documentation delivery schedule Project schedule (general) Spare parts list Standard components (spec.) Painting specification (spec.) Preliminary list of equipment (motors) (spec.)
Generate offer	The company creates an offer; witch includes general and technical specifications. General specification includes in delivery schedule, project schedule, spare parts list and capacity calculations. Technical specifications includes among others standard components, equipment list (preliminary), preliminary calculations and utility requirements.	
Identify mill performance		

Term	**Description**	Example / Note
requirements and establish design strategy		
Implementation / planning of project	The paper mill creates project plan.	
Information databases	Those elements of information collections comprising literature references, physical and transport properties, symbology sets, equipment specifications, and equipment costs that assist in the conception, design, construction, operation, and disposal of a process plant.	
Initial information	Any knowledge available at the start of the process to build or modify a paper mill.	EXAMPLE This includes information about the site, regulatory agreements, owner requirements, and approved suppliers.
Inspection report		
Investment decision and order	Prepare bid packages and solicit bids: The process whereby the technical and commercial requirements for a paper mill item are compiled and sent out for pricing by multiple suppliers. Generate offer: The company creates an offer; witch includes general and technical specifications. General specification includes in delivery schedule, project schedule, spare parts list and capacity calculations. Technical specifications includes among others standard components, equipment list (preliminary), preliminary calculations and utility requirements. Evaluate bids and negotiate purchase: The process whereby bid packages are evaluated, a supplier is selected, and an agreement is entered into for the acquisition of the paper mill item(s).	
Key components interface	Those documents in the paper mill that are needed to install new equipment or services.	EXAMPLE Sub-systems layouts.
Layouts and system connections	Those documents in the paper mill that are needed to install new equipment or services.	EXAMPLE Sub-systems layouts.
Make service	All actions that are done to each equipment in the maintenance.	EXAMPLE Lubrication.
Manage and plan project	Managing the project requires that sufficient resources be provided to execute the project and check that the execution is done in accordance with the plans and regulations. Planning the project is the activity that establishes a detailed	

Term	**Description**	Example / Note
	technical plan and a financial plan that are consistent with the engineering, construction, and commissioning activities required to fulfil the project objectives.	
Manage mill	Direct and administrate the operations, maintenance, and disposal of the mill.	
Manage, operate, and maintain mill	The activities required to manage, operate, and maintain the mill safely, efficiently, and according to operating procedures and regulations.	
Management authorizations and controls*	Management authorization, imperatives, directives, and procedures for initiating and executing plant management activities.	
Manufacture components	The component supplier manufactures components and their documents.	
Meta data and documents to operative mill data systems	The paper mill has its own operative data system so the information must transform to the suitable form. The obsolete data must remove from mill data system.	
Mill design meta data and documents (certified)	All certified documents related to the process of designing the subsystem of the paper mill.	NOTE Paper mill design documents include the approved design methodologies, basic data describing physical properties and their correlation's used in the design, kinetic data and kinetic models used in the design, corrosion data and methodology used in selecting materials of construction, supplier performance data, capital and operating cost estimates, and appropriations requests. EXAMPLE Process flow diagrams System layout and design Equipment characteristics (required) Equipment list Equipment characteristics (performance) Material Requirements
Mill design meta data and documents (preliminary)	All documents related to the process of designing the subsystem of the paper mill. The status of those documents is preliminary.	NOTE Paper mill design documents include the approved design methodologies, basic data describing physical properties and their correlation's used in the design, kinetic data and kinetic models used in the design, corrosion data and methodology used in selecting materials of construction, supplier performance data, capital and operating cost estimates, and appropriations requests. EXAMPLE Process flow diagrams System layout and design (preliminary) Equipment characteristics (required)

Term	Description	Example / Note
		Equipment list Equipment characteristics (performance) Material Requirements
Mill design documentation	All documents related to the process of designing the paper mill.	NOTE Paper mill design documents include the approved design methodologies, basic data describing physical properties and their correlation's used in the design, kinetic data and kinetic models used in the design, corrosion data and methodology used in selecting materials of construction, supplier performance data, capital and operating cost estimates, and appropriations requests. EXAMPLE Design and Engineering Life-cycle Data Maintenance Instructions Operations Documents Construction Documents Reviewed Supplier Data Engineering Design, Construction, and Operation Changes
Mill design documentation (accepted)	All documents that the paper mill has accepted.	
Mill performance requirements	A quantitative description of the quantity and quality of a product to be produced by the paper mill in a yearly time period.	NOTE Performance requirements are usually stated as units of product per unit time. Additional qualifications are made regarding the quality of the Paper mill, such as time between major shutdowns for continuous processes, percent uptime required, and expected yield.
Obtain permission	Authorities make environmental impact assessment and grant a license with definite conditions.	
Offer	The offer includes all the information that the paper mill need to pay a subsystem.	
Official permission	Official Permission includes environmental load etc.	
Operate mill	Conduct and monitor the activities required to operate the paper mill.	
Operating data	The data that is needed to operate mill and to development the production.	
Operating procedures	Documentation that covers many different phases and aspects of paper mill operation that is necessary to run the paper mill safely.	
Operational checks		
Order	Prepare bid packages and solicit bids: The process whereby the technical and commercial requirements for a paper mill	

Term	**Description**	Example / Note
	item are compiled and sent out for pricing by multiple suppliers. Generate offer: The company creates an offer; witch includes general and technical specifications. General specification includes in delivery schedule, project schedule, spare parts list and capacity calculations. Technical specifications includes among others standard components, equipment list (preliminary), preliminary calculations and utility requirements. Evaluate bids and negotiate purchase: The process whereby bid packages are evaluated, a supplier is selected, and an agreement is entered into for the acquisition of the paper mill item(s).	
Owner requirements	An initial statement of paper mill requirements provided by the owner.	NOTE Owner requirements are an aggregation of items such as design requirements and client general specifications. The owner requirements may be provided at any level of abstraction from very general to very specific.
Paper mill	A portion of an installation (or the entire installation) required operating to produce paper products.	
Paper mill life-cycle documentation	The collection of all project management, design, contractual, regulatory, and disposal documents produced during the life cycle of a process plant.	NOTE This includes all data retained past the end of the plant life cycle.
Petition	The paper mill sends the petition with necessary information to the approving authority.	
Pre-commission subsystem	Resolve any differences between the detailed design and the as-built paper mill, perform all testing required by regulatory agencies and the client, resolve any problems that were discovered during testing, and obtain regulatory permission to start-up the paper mill for functional testing.	
Pre-commissioned component	A paper mill that is completed and ready for check out. Mechanical systems are complete, transfer of ownership and operation remain.	
Pre-commissioned subsystem	A paper mill that is completed and ready for check out. Mechanical systems are	

Term	**Description**	Example / Note
	complete, transfer of ownership and operation remain.	
Prepare bid packages and solicit bids	The process whereby the technical and commercial requirements for a paper mill item are compiled and sent out for pricing by multiple suppliers.	
Procure goods and services	The process whereby needed paper mill items, equipment, or services are purchased or acquired.	
Produce as-built documents	The detail design drawings and other documents are updated to reflect the changes to the paper mill.	Operation procedures Electrical drawings Hydraulic drawings Pneumatic drawings Turn up reports
Produce as-built surveys	The completed paper mill is given a physical inspection to determine whether the paper mill conforms to the detailed design. The detail design drawings and other documents are updated to reflect the changes to the paper mill discovered during the inspection.	As-built documents
Produce conceptual design	The activity of extending the conceptual process design into a preliminary paper mill spatial configuration.	NOTE Here pre-engineering means the same that Conceptual Design.
Produce conceptual process and layout design	The activity of defining the basic parameters of a paper mill flow scheme.	
Produce final design	The activities required generating a construction design specification from the paper mill requirements.	NOTE The activities include designing the mechanical, electrical, and civil engineering systems of the process, designing the detailed instrumentation systems, producing piping and instrumentation diagrams and detailed equipment layout through isometric drawings or three-dimensional computer-aided design (CAD) models. NOTE Produce Final Design is same as Engineering.
Produce final process and layout design	Integration of conceptual process and paper mill designs to fully define parameters of a paper mill flow scheme.	
Process integration	All changes that improve the production.	
Project control and approval documentation	A set of documents that define the standard procedures, standard software modules, or standard forms adopted to ensure that all activities in the project comply with organisational constraints. The documents indicate how all activities are to be implemented and approved and identify all constraints that must be met.	NOTE The constraints include financial limitations, accounting, legal and regulatory restrictions, socio-economic factors, and business practice throughout the paper mill life cycle.
Project plan	This is the project plan of the paper mill.	

Term	Description	Example / Note
Proposal of investment	Before the investment is the proposal of the investment, where different effects are considered.	
Purchase agreement	Contract between two parties to provide a service or item for a designated payment.	
Regulatory requirements	Federal, state, or local laws, codes, or standards that impact various activities related to the paper mill.	NOTE Regulatory requirements may apply to, but are not limited to, permitting, engineering, construction, operations and decommissioning.
Requirements to mill data systems	The functional model of the subsystem is put to the mill data system.	NOTE This is a functional part of the factory model. F.ex. docs, calculation sheets.
Service	All actions that are done to each equipment in the maintenance.	
Service provider	A company that produce services that are needed to operate or to maintain the paper mill.	
Spare part list	Spare parts. The system provider delivers the spare parts list.	
Specifications and standards	Consensus or mandated technical descriptions of paper mill hardware or systems that control the design or construction of a paper mill.	
Start-up of project	This is one milestone.	
Start preliminary planning	The preliminary planning starts conceptual design (process, layout, ...) for the investment decision.	
Subsystem documentation and meta data	Drawings, manuals, calculations, etc. received from a system provider.	EXAMPLE Design and Engineering Life-cycle Data Maintenance Instructions Operations Documents Construction Documents Reviewed Supplier Data Engineering Design, Construction, and Operation Changes NOTE Statuses assigned to supplier documentation include: preliminary (in-process design information); certified (information from the supplier is warranted to correctly describe the as-delivered functional or physical data); released for fabrication or construction.
Supply technical documentation of rebuilding project in paper mill	All technical documentation and meta data what is needed in the rebuilding project in the paper mill.	
System layout and design	The definition and representation of the physical components or items and spatial configuration of the system in sufficient detail to support construction.	NOTE 1 This definition results from the use of the system design basis, P&IDs, specifications, and other documentation or information.

Term	**Description**	Example / Note
		NOTE 2 The definition of the term "system" is broader than common usage, e.g., it encompasses structural systems. NOTE 3 System layout and designs can be viewed or categorised according to the following breakdowns: evolutionary phase a) Initial; b) Design; c) Final. system type a) Piping; b) HVAC; c) Electrical; d) Instrumentation and Control; e) Structural and Civil; f) Architecture; g) Safety. functional views a) Conceptual arrangement; b) Spatial information; c) Schematic diagram; d) Piping and instrumentation diagram (includes piping connectivity and sequencing). EXAMPLE The final HVAC spatial information system design and layout will specify the definition, physical dimensions, location coordinates, and characteristics for all HVAC components that occupy space in the Paper mill. Only those physical dimensions, location coordinates, and characteristics required to specify the spatial instance of each component are included in this definition.
System layout and design (preliminary)	The initial definition and representation of the physical components or items and spatial configuration of the system.	
System provider	A company that provides (and manufactures) systems.	
Terminate project	The paper mill evaluates the project and does the follow-up. Actions during warranty period.	EXAMPLE Corrections, controls, guarantees, operational checks.
Updated mill documentation	All mill design documents that are updated.	
Update mill documentation	Add / replace meta data and documents to mill data systems.	
Verify documents and meta data	Paper mill checks the mill design documentation: all needed and agreed information has delivered. The supplier corrects faults in the documentation.	