Modeling Information and Activities in Delivery of Power Plant Pipings

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Abstract

Piping is an uncertainty factor in power plant delivery. Although the cost of piping process is seldom more than one tenth of the total costs, it may vary up to 50 % from what it was estimated in the bidding phase. As a hypothesis it is presented that most of the variation between estimated and total costs originates in poor communication between organizations. Piping concerns most participants of a power plant project either directly or indirectly. Usually every company taking part in a project has individual, even tailor-made, programs for processing and storage of product data. Also conceptions and taxonomies about product data vary according to a participant's point of view. Multiple factors cause communication problems. This paper focuses on modeling two concepts: 1. information required and accomplished in design and erection 2. piping project activities.

Design organization and a company focused on piping assembly have different views of product data. Therefore establishment of a common conceptual model and unification of taxonomy is the goal of our research. Another goal is to evaluate and develop piping design and production process.

1. Introduction

Establishment of a power plant is a complex process. Before a power plant is built and ready to operate, multiple efforts have to be made in designing, procurement, manufacturing, assembling and inspectioning components, assemblies, devices and the plant as a whole. Generally both the product, i.e. plant, and the project are unique. A power plant project consists of sub-projects. These are usually divided according to the domain. One of them is the piping project.

Establishment of a power plant involves a great number of organizations and employees. It has been estimated that over a hundred companies take part in a typical power plant project. Moreover erection of a power plant usually requires over a thousand man-years. Experts of several domains of design, production and assembly are involved. Thus, to produce a power plant in limited period of time, as many activities as possible have to be done simultaneously. Since many activities are interdependent, activities and their relations have to be examined carefully in all design phases. Time of delivery cannot be reduced with indiscriminate overlapping of life-cycle activities. Many organizations take part in plant design process, which consists of numerous sub-processes like boiler, piping, electrical design etc. Therefore many information and data models are used. This appears in the number of different CAD-systems and -formats.

It is difficult to estimate costs of a piping project. Not seldom a piping project exceeds its budget and sometimes deviation from estimated cost has been up to 50% more than it was estimated in the bidding phase. Generally most of the product costs are determined in early stages of the life-cycle, i.e. where basics are founded to the project, and usually the are materialized at the final stages like procurement, manufacturing, assembly use and disposal [1, 2].

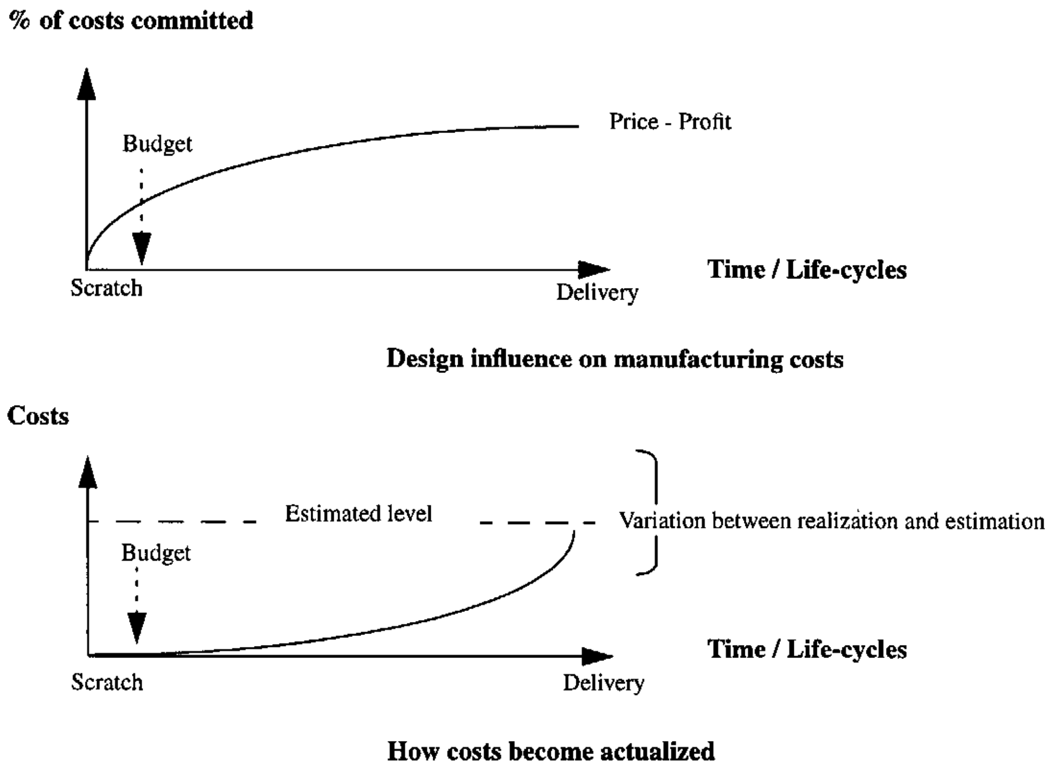

Figure 1: A Diagram representing variation of design costs

Companies personnel taking part in piping project usually have either very sharp understanding of detailed activities or very general conception of the piping process. Seldom one can comprehend relations of activities throughly. While both the structure of product and project is in constant change, modes and borders of delivery between each participant are not equal in all the projects. As a consequence of this the predictability of costs in piping project is poor. In a tightly competed market this may lead to drastic unexpected costs that can even cause risk of loss in piping project. The diagrams in the figure 1. represent that costs of piping project have to be estimated early with making of budget. To estimate costs properly one has to make decisions that have an profound effect on project. This should be done with minimum time and effort, but still it has to be done as correct as possible.

Typically those who estimate and actualize costs work in different life-cycles and usually they do not belong to the same organisation. Possibly there is no connection between these organisations. Usable information should be available to do estimation correctly. Companies have information from earlier projects, but it is difficult to acces. In fact participants of this project have been in the business for a long time and they usually have files by the metre of shelves. Usually it is difficult to acces these archives. Moreover access to another organisations archives is usually denied.

Another fact, readable from figure 1., is that poor preliminary design cannot be compensated with excellent work in detail design and latter phases, because many costs are committed already. Poor estimations usually originate in the lack of estimation tools and analysed records of previous projects. Major cause to this is the variation between projects. Thus management of design changes with one-of-a-kind products is essential [3]. Development of estimation tools and analysation of recorded information probably have been left too much dependent on personal interest and activity of companies employers. Personnel is typically loaded with tasks and typically the one who has knowledge about earlier projects is already intensely involved in another tasks. People who participate in projects simply do not have time for other efforts. Therefore there is a need for creating models covering both information and process.

This paper is divided into two sections. First the used methodology is explained. There a brief look is taken into theoretical background of design process and methods for information and process activity model are presented. In implementation part of these theories is used as the framework of methodology for information modeling. There a brief explanation on the usage of Design Structure Matrix (DSM) by Steven D. Eppinger is made [4, 5]. Information needed, processed and produced in piping design is modeled with object-oriented database. Then backround for the activity model and the interrelationship between these two models will be explained. Main references here are discussions with companies personnel and the PDXI-activity model presented by Pat Harrow [6]. Again activity model is established with object-oriented database. Usage of object-oriented paradigm benefits mainly by allowing more natural, i.e. similar to human conceptions, structure to the data [7].

2. Methodology

2.1. Design process

Design produces information for many life-cycle activities of an artifact that is sought-after. Since design, as a life-cycle activity, handles only information, it has more abstract nature than other ones. For instance, while in production inputs and outputs are both material, energy and information, design process requirements and outcomes are generally pieces of information and data. Therefore finding of interdependencies, causalities and structures of information is essential when examining design process.

Earlier activities like marketing, engineering and assembly were considered consecutive, separate activities. Each activity followed another in chronological order. Development efforts were addressed for each separate life-cycle activity. At the late seventies and early eighties a general framework for modeling design process was developed. Aim was to understand design process in general and to establish model valid for every design phase. In table 1 engineering phases according to product modeling by [8, 9] is presented.

These models apply to every product development case. There models exist, even if a development manager could not separately identify them. In piping design expert collects information about customer demands, environmental, proposed plant site and assembly conditions, local laws and regulations etc. A specification is made according to this information. Many of these information items have either direct or indirect effect on both the engineering process and the plant structure. For example welding conditions affect both on the ratio between preliminary prepared pipelines and the pipelines manufactured in site, and on the definition of how the welding itself has to be done. Designed entities may be tailor-made or standardized. Design processes then vary a lot depending on the product structure and selected solution principles.

Table 1: General design phases by different authors

Pahl & Beiz	Hubka
	Level 0 - Design Specification
	Level A - Technical System - Black Box
1. establishing of function structure,	Level B - Function Structure
2. searching for solution principles,	
3. combining solution principles to fulfil the overall function,	Level C - Organ Structure
4. selecting suitable combinations,	
5. firming up into concept variants and	
6. evaluating concept variants towards technical and economic criteria	Level D - Component Structure

Ullman classifies design activities according to the nature and complexity of the task. The classes are: 1. Selection design, 2. Configuration design, 3. Parametric Design and 4. Original Design [2]. Usually a design task includes also some redesign and different routine efforts. Pahl & Beitz categorize design processes in three classes: original, variant and adaptive design [8]. Another classification is: simple, complex, original, adaptive, variant, new and previously done design, design and selection tasks [10].

Design process may involve all mentioned classes. In a large project like design of a process plant usually all the classes exist. Not all that is done in designing a pipe system is heuristic by it's nature. Pipings can be regarded as a realization of original design, because pipings are usually one-of a kind products. Nevertheless piping design consists of several sub-tasks that lay in the area of selection, configuration and parametric design. Usually pipings are only partially originally designed and the process consists of phases similar from project to another.

Design of an artifact may also be analysed according to different product models. Generally valid classes of models established in design process are [2]:

- Semantic model - a verbal or textual representation of the object
- Graphical - a drawing of the object
- Analytic - equations, rules or procedures representing the form or function of the object
- Physical - a physical model of the object

With pipings all these models exist in different life-cycles. Piping specification can be regarded as a semantic model of pipes used, isometric drawing is a graphical model of the pipeline, FEM-models are analytical models and the achieved piping is a real physical object.

2.2. Information Model - Design Activity Model

A methodology presented by Eppinger offers tools for investigating which information items are interdependent and which stages of information creation, i.e. design, can be overlapped. Design Structure Matrix (DSM) is a well known model used for evaluating information interdependencies in design process [4,5].

Along DSM different diagrams representing data flow in design have been widely used. For example building design process has been represented with data flow model and DSM [11]. An IDEF 0 flow diagram (Integration Definition for Function Modelling) is made so that every diagram consists of boxes that represent activities. Arrows represent information flow into and out of a box in horizontal level, an arrow coming from upper edge of a box represents control and an arrow pointing to the lower edge represents the mechanism that will actualize the activity [5, 12].

In IDEF 0 -model, illustraded in figure 2., a design activity is a process where inputs and outputs are items of information. With IDEF 0 diagrams the design process activities can be broken down to the required level of concretization. DSM represents the interdependence of design activities. With these two models existence and significance of a single activity in both design, procurement, manufacturing and assembly process of pipings can be evaluated. Interfaces between companies in process can be examined.

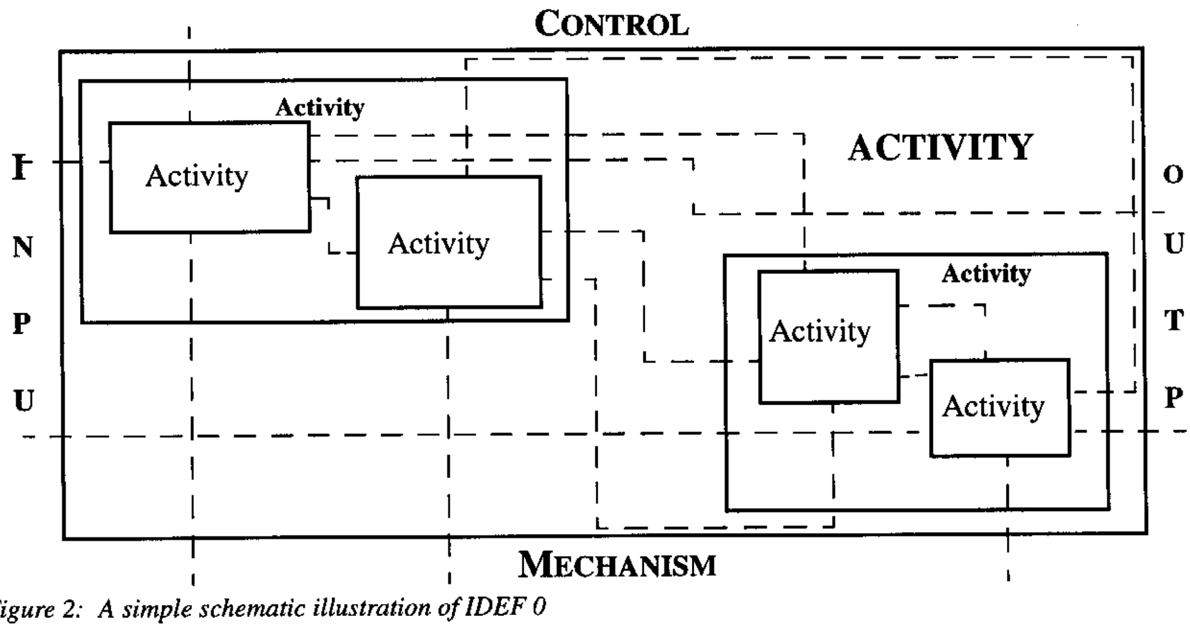

Figure 2: A simple schematic illustration of IDEF 0

As a synthesis design process can be evaluated with systematic methods and alternative shapes for design process structure can be generated. In a large scale design process definition of interdependencies between activities is somewhat cumbersome. In our research interrelations are modeled between information items, i.e. product data, documents, specifications, drawings, etc.

3. Implementation

We started our research with inquiries about information and data that is transferred in piping project. Discussions took place in the three companies involved in project and information relations were collected in questionnaries. To handle such a large collection of information all these items were modeled in object-oriented database (OODB) as instances of a class *information*. Interdependencies (couplings by Eppinger) were modeled with relations between instances. In *information* class following relations are possible: **need1**, **need2**, **need3**, **includes** and **included**. The last two relations express hierarchical representation and they are correspondent to part-of relation.

An ongoing effort is to collect information about design activities and construct a hierarchical model expressing design process similarly to method used with information items. Design process activities are modeled in OODB. Each activity is an instance of class *activity* and possible relations to it are **input**, **output**, **control** and **mechanism** similarly to IDEF 0-method. Design process limits can be modeled with **constraints**. These are methods that cover controlling of design process. In design activities inputs and outputs are generally information. Relations between instances of classes *activity* and *information* are created according to opinions of domain experts.

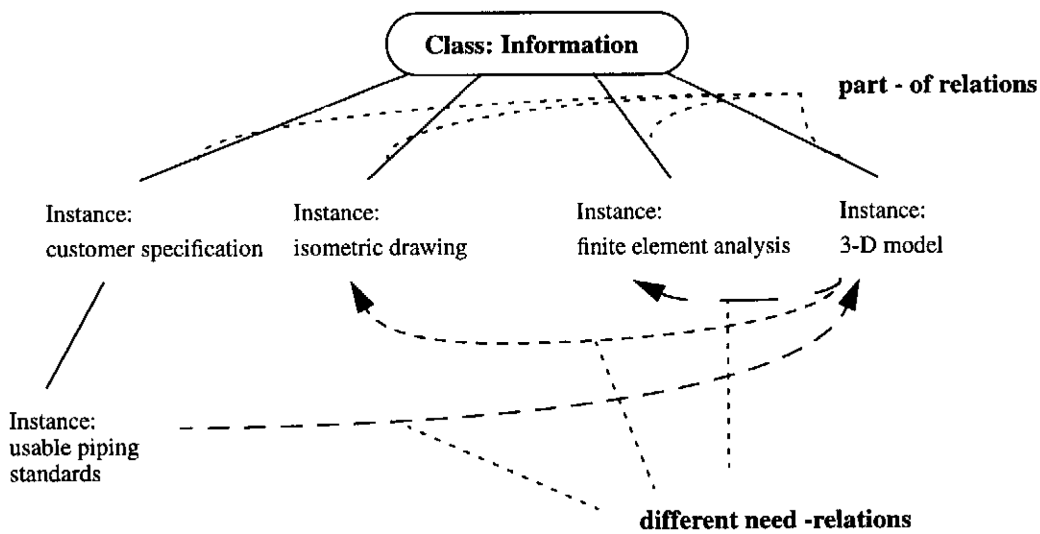

Figure 3: An illustration of information model relations

Data and structural information is stored in OODB. Connection to OODB is through www-webface. Webface is developed by Kari Tanskanen in TUT Machine Design Laboratory. Information can be accessed through internet with a password. Queries can be made using CLAN constraint language to produce different views to the data. Diagrams can be produced via public domain graph editor. An example of the browser window is in annex A where an information instance viewer is represented.

Attributes of class *information* describe the information entities name, discussion date, interviewer, interviewee, interviewees duty and employer, who produces information, to whom it is addressed, what is the information form and type, additional information about information and relations to other instances. Class *activity* has attributes: name, cost, duration and additional information. Also mentioned relations are visible in the form of clickable links.

4. Discussion

As the project is still proceeding all the objectives have not been reached. Allthough information model includes more than 150 instances some of them are duplications having the same meaning. Current interest is in establishment of piping process activity model including all the instances that use data created in piping design. This work is under development and currently researchers are expecting to have industrial partners comments on the draft version of an activity model. We expect that some unidentified iteration loops will be revealed when the models will be decomposed and attached like figure 4 illustrades.

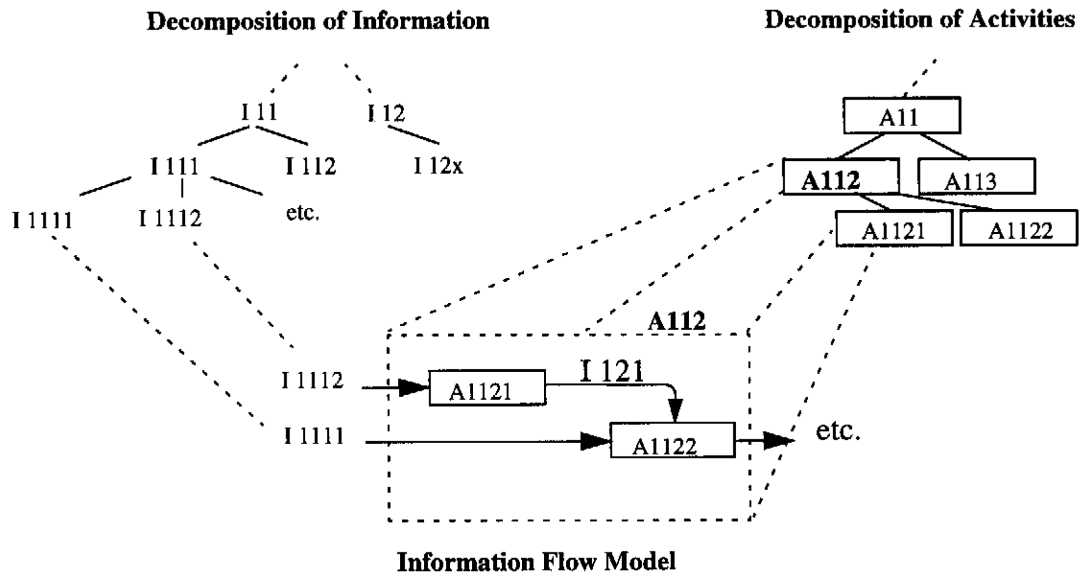

Figure 4: Interrelation of information and activity models

Database of piping design process can be used to give better overall picture of the design process. When a designer is either unfalimiar with the design activity or does not know all the information requirements on the corresponding information instance he or she will be able to make queries to database in order to find relations of activities and information. This property will probably be more important when new designers are introduced to the domain.

A problem with the uniqueness of the piping process cannot be solely taken into consideration with methods presented. This may probably be solved with attaching design activities and product information items to product structure in the object-oriented database. Since piping project is generally composed from different design types, with process breakdown method routine design tasks can be found. Typically pipings are products of an original design process, but selection, variation and parametric design efforts can be found with design process decomposition methodology. Hopefully established database may be used in future projects at least to some extent.

5. References

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Netscape: ANNEX A – INFORMATION INSTANCE VIEWER

File Edit View Go Bookmarks Options Directory Window Help

Instance of INFORMATION

Name	isometric drawing
Discussion date	12.01.1996
Interviewer	JE
Interviewee	BE
Interviewee's duty	project manager
Interviewee's employer	Acme Inc.
Who produces information	designer A
Information form	paper
To whom it is addressed	procurement manager
Information type	graphic
Additional information	is typically printed from 3–D model
What is needed (very sensitive)	
What is needed (quite sensitive)	
What is needed (slightly sensitive)	NIL
Where is needed (very sensitive)	NIL
Where is needed (quite sensitive)	NIL
Where is needed (slightly sensitive)	NIL
Includes	NIL
Included in	NIL

INSERT	UPDATE	DELETE

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