To cite this document:
Vareilles, Elise and Coudert, Thierry and Aldanondo, Michel and Geneste, Laurent and Abeille, Joël *Coupling system design and project planning: discussion on a bijective link between system and project structures.* In: 14th IFAC Symposium on Information Control Problems in Manufacturing, INCOM'2012, 23-25 May 2012, Bucharest, Romania.

Coupling system design and project planning: discussion on a bijective link between system and project structures

É. Vareilles * **T. Coudert** ** **M. Aldanondo** *** **L. Geneste** ****
J. Abeille †

* *University of Toulouse, Mines Albi-Carmaux, France (e-mail: elise.vareilles@mines-albi.fr).*
** *University of Toulouse, Eni Tarbes, France (e-mail: thierry.coudert@enit.fr).*
*** *University of Toulouse, Mines Albi-Carmaux, France (e-mail: michel.aldanondo@mines-albi.fr).*
**** *University of Toulouse, Eni Tarbes, France (e-mail: laurent.geneste@enit.fr).*
† *Pulsar Innovations, Toulouse, France (e-mail: joel.abeille@pulsar-innovations.fr).*

Abstract: This article discuss the architecture of an integrated model able to support the coupling between a system design process and a project planning process. The project planning process is in charge of defining, planning and controlling the system design project. A benchmarking analysis carried out with fifteen companies belonging to the world competitiveness cluster, Aerospace Valley, has highlighted a lack of models, processes and tools for aiding the interactions between the two environments. We define the coupling as the establishment of links between entities of the two domains while preserving their original semantic, thus allowing information to be collected. The proposed coupling is recursive. It enables systems to be decomposed into subsystems when designers consider complexity to be too high, and can also decompose projects into sub-projects. The coupling enables systematically links to be drawn between project entities and system entities. In this paper, we discuss the different possibilities of linking system and project structures during the design and the planning processes. Firstly, after presenting the results of the industrial analysis, the different entities are defined and the various coupling modes are discussed.

Keywords: System Design, Project Planning, Aiding Decision, Knowledge based System

1. INTRODUCTION

Because of the increasing complexity of products, the distributed nature of designers' skills, and the need to integrate management systems and tools, today's product or system design processes interact more and more closely with all other business processes in a company, such as supplier selection, purchasing, marketing, production planning, maintenance, etc. In such a context, the interactions between the building of a system design project and the design of the system itself have not been sufficiently investigated. There is a particular lack of integrated models and decision support systems. The building of design activities, from requirements definition to solution definition, and the planning and control of these activities are important tasks, see PMBOK 2004 . However, there are few works which propose integrated models and tools that can assist engineers in the task of building design projects in accordance with the design of systems, in planning the design activities and finally, in controlling their execution.

Design of a system and planning of a design project are usually considered as separate fields of study. Standard processes exist for each, and many studies have been carried out on these topics leading to adapted models and methodologies. However, few studies have focused on the interactions between these two processes. A decision made within the domain of system design can have important effects on project planning (e.g. choosing to explore one or more solutions can cause significant delay while these solutions are developed, or may affect particular - and not necessarily available - design resources). Reciprocally, a decision made within the project domain may have a strong influence on system design (e.g. a short delay or a lack of resources means that an existing component cannot be adapted in order to satisfy the requirements). Therefore, the coupling between these two processes requires the ability to propagate decisions from one environment to the other and to check that the modification of the tasks within both domains is consistent. In Abeille et al. 2010, the coupling and the meta-model describing coupled

⋆ The authors wish like to thank their partners in the ATLAS project, the French National Research Agency (ANR) and the 7^{th} Strategic Activity Domain (Architecture and Integration) of Aerospace Valley for their involvement in this project.

entities have been presented. Basic processes of coupling have been described. The present article is more a discussion about how to link systems and projects in order to formalize the synchronization between both domains and to avoid inconsistent information. The article is organized as follow: in section 2, the context of the study is described. In section 3, the background is defined and in section 4, proposals are discussed with regard to existing approaches.

2. CONTEXT OF THE STUDY

The research parameters were formalized by interviewing fifteen companies belonging to the world competitiveness cluster, Aerospace Valley. This task is a part of the ATLAS project that involves five academic institutions and two companies, funded by the French Government (ANR project).

The most important results of this benchmarking exercise can be summarized as follows: all the companies interviewed are confronted with this coupling problem but they have not implemented specific tools to support this coupling process. Most of the time, the coupling is performed by means of non-formalized human interactions. Even if some companies use procedures, their decisions are based on human experience. Only 18% of companies use software or collaborative tools. The majority of companies (50%) makes integrated decisions during meetings involving the different stakeholders. The use of standards or reference scenarios is also used by the most advanced companies. This concerns the use of generic models for designing different categories of systems, or the conversion of capitalized design solutions into databases. Meanwhile, the complexity of systems and projects is increasing. In a distributed multi-national context, the design of a system is often carried out in several sites involving several partners. Clearly, the use of adapted and integrated tools to manage these complex design projects is becoming a requirement in such contexts. These tools also need to be adapted to multi-responsibility projects.

To illustrate the global context of this study, it is considered that a project (associated with a system that needs to be designed) is under the responsibility of a program manager. The program manager interacts with (i) a design manager who works within a design system environment and (ii) a planning manager who works within a project planning environment. The difficulty involved in designing the system, as well as the complexity of the associated project, leads to them being hierarchically decomposed according to the axiomatic design approach, Yoshikawa (1989), Suh (2001) and Albano et al. (1992) . The different design approaches are discussed in section 3.1.1. In such cases, systems can be decomposed into subsystems, leading to the decomposition of associated development projects into associated (more exactly coupled) sub-projects. The corollary is that complex design projects can be decomposed into sub-projects leading to the decomposition of the coupled system in the same manner. In this context, the program manager, at his level, can be seen as a "coupling manager" who fixes orientations and objectives, makes decisions and defines decision parameters for the two other parts. (S)he is also in charge of resolving conflicts. Within this framework, considering two hierarchical levels, either the design manager of the upper level becomes the program manager of the lower level, or it is the planning manager who takes on this role. This outcome varies from company to company. It is also possible, in some cases at the lowest levels, to have only one person in charge of the three responsibilities.

3. BACKGROUND AND DISCUSSIONS

3.1 Definition of System Design and Project Planning

System Design Definition H. A. Simon (1969) first characterized design as a search process. Design can be seen as a project that aims at creating a new object or transforming an existing one (Huysentruyt et al. (2010)). Design is also considered as a knowledge discovery process in which information and knowledge of diverse sources are shared and processed simultaneously by a team of designers involved in the life phases of a product (Tang (1997) and Wang et al. (2006)) . Therefore, knowledge in design processes is a key factor. Brown and Chandrasekaran (1985) gives a taxonomy of design processes depending on three domains of knowledge: the domain of the object to design, the domain of the design process and the domain of requirements about the objects to design. This classification leads the authors to define three domains of design: routine, innovative and creative. In routine design, the three domains are well known and can be used. For innovative design, even if the structure of the objects to design is familiar, some new characteristics are required in order, for instance, to provide the market with innovations on existing products, leading design activity to investigate new technologies (better performance, new functionalities, etc.). On the other hand, when new technologies appear, innovation can lead the design activity to propose new applications. Creative design refers to the act of producing new ideas or concepts with a minimum of knowledge.

There are a lot of existing design methodologies described in the literature (see, for instance, the methodologies described in Suh (1990), Pahl et al. (1996), Dieter (2000) and Ullman (2003), or for a wide panorama, Blessing (1996) . Among the widely used methodologies, Axiomatic Design (AD) proposed by Suh (1990) is a top down and iterative approach that makes links between requirements or functions (functional requirements) to be fulfilled and technical solutions (design parameters and process variables). The design process zigzags between the four following domains: needs, solutions, tasks and resources. Pahl and Beitz (Pahl et al. (1996))describe a systematic approach for all design and development tasks. The design process is composed of the following four sequential stages guiding the design of a product from scratch to full specification: requirements clarification, conceptual design, embodiment design and detailed design. Requirements clarification defines customer or stakeholders requirements. Conceptual, embodiment and detailed design are activities that serve to develop products or systems gradually.

From a system engineering viewpoint, the works of the International Council on Systems Engineering (INCOSE) have been considered in detail. Among them, the EIA-632 standard (Martin (1998), EIA (1990))provides some structuring processes for system design widely used by companies in the electronics domain. It defines a global engineering process that makes it possible to transform customer requirements into technical solutions. The ATLAS project proposals are based on this standard, which provides an integrated set of fundamental processes to aid a designer in the engineering or re-engineering of a system. The approach is based on the following premises:

- a system consists of one or more products to be delivered, as well as sets of related enabling products (products that sustain the end products during their life cycle, e.g. a specific tool required to build a product);
- products are an integrated composite of hierarchical elements which need to meet the defined stakeholder requirements;
- the engineering of a system and its related products is accomplished by applying a set of processes to each element of the system hierarchy .

This approach is incrementally applied in an engineering life cycle framework that can be implemented during phases of an enterprise-based life cycle (for example, during production, operations, support, or disposal).

Therefore, the design process proposed in this article is structured as follows:

i) the definition and/or the specification of the requirements,
ii) the identification of the technological solutions which can fulfill these requirements,
iii) the associations requirements / solution,
iv) and according to the complexity, the decomposition of the design process up to a certain level of abstraction.

According to the level of detail of these activities, the proposed design process is compliant with the typology of Pahl and Beitz (Pahl et al. 1996) , in a "Conceptual / Embodiment / Detailed" design context as well as the EIA-632 standard requirements. The recursive decomposition of the design process also complies with a top-down cycle that zigzags between requirements and solutions in accordance with the recommendations of "axiomatic design" proposed by Suh (2001) . The result of the design process is then considered as a set of associations (i.e. specified requirements coupled with technological solutions) structured in a hierarchical way. Indeed, the specifications of requirements lead to some technological solutions and, when a system is decomposed into many sub-systems, a technological solution for a system leads to the specification of requirements for its sub-systems.

Project Planning Definition The project planning domain concerns the Project Time Management (PTM) process as defined by the Project Management Institute (PMBOK (2004)) . The PTM process is one of the nine processes proposed by the PMI that cover the six following activities: identification and sequencing of activities, estimation of resources and durations, scheduling of activities, and control of the execution of the schedule. In the proposed approach, the project planning definition is a top-down approach, where some kind of global planning is achieved at a high level and is progressively detailed at lower levels by means of sub-projects. This multi-level and multi-project approach makes it possible to perform adequate multi-level planning by considering simultaneously, at all planning levels, different objectives, constraints, degrees of aggregation, and capacity flexibility (see for instance Hans et al. (2005)for a study on hierarchical multi-project planning). In order to define a design project, we consider that project planning involves:

i) project activities definition,
ii) resource and duration identification,
iii) scheduling activities and resources,
iv) and if needed recursive decomposition at the lower level of some activities.

Scheduling of activities and resources is based on several techniques (see, for instance, Herroelen et al. (1998) or Kis (2005)) that are not detailed in this article.

3.2 Interaction between Design and Planning Processes

The axiomatic design and the above-mentioned standards allow four interacting domains to be identified: (i) the requirements or specifications, (ii) the solutions, (iii) the tasks or activities and, (iv) the resources. The first two domains relates to the system design process and the last two domains to the project planning process. Although there are few studies that address this coupling problem, one can mention: (i) the studies initialized at M.I.T (Eppinger et al. (1991)) on the use of methods and techniques used on product design in order to facilitate project design. These studies are the source of scientific developments around DSM (Design Structure Matrix), such as those of Lindemann (2007) . The interactions between the four identified domains are defined; (ii) in the same way, axiomatic design identifies various domains (Customer Needs, Functional Requirements, Design Parameters and Process Variables) and sees them as interacting (Suh (2001)) . An example of implementation is presented in Goncalves-Coelho (2004) . The interactions between domains are clearly defined: design towards planning but also planning towards design; (iii) another approach, introduced by Gero (1990), proposes models based on three domains: Function, Behavior and Structure (FBS). The aim of this study is to take into account the product behavior (expected and effective) and to inventory in a formal way eight sub-processes of design. However, tools for interactions between processes are not considered explicitly; (iv) a study that is very close to the problem addressed was undertaken by Stewart and Tate (Stewart et al. (2000)) who were interested in the coupling of axiomatic design with project planning in the case of software engineering. Their idea was to associate design variables with the tasks of the development process. This approach was implemented with an ad hoc development coupled with the Microsoft Project® software package and tested in a software engineering context. The work of R. Lu (2007) describes an approach coupling task management and design. The structure of projects is represented by means of Working Breakdown Structure (WBS) and is related to a Product Breakdown Structure (PBS). A matrix represents relationships between both domains. In Sharon et al. (2008) and Sharon et al. (2009) the authors proposed a Project Product Lifecycle Management approach (PPLM). The aim of their work is to develop a methodology and a software environment for integrating the product that is being developed with the project as undertaken by the company.

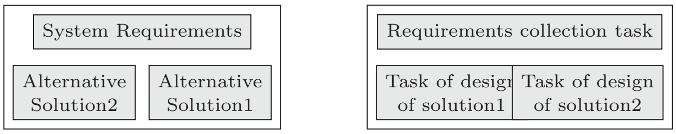


Fig. 1. System and Project Entities

All these studies indeed confirm the four reserved domains (requirements, solutions, tasks and resources) and the existence of causal links that involve interactions between these four domains. However, except in Steward et al. (2000)and Lu et al. (2007), no tools are provided to support or aid interactions between both design and planning processes.

4. DISCUSSIONS AND PROPOSALS

The integrated (meta-)model proposed in this article is inspired by the EIA-632 engineering standard. It is proposed with the objective of formalizing the methodological coupling between project planning and design. EIA-632 meta-model is, moreover, a high level model describing processes and entities with a low level of detail, and coupling is not clearly formalized. However, before describing the proposed integrated model, the different possible ways of coupling both domains are discussed. Two coupled entities are then considered: system entities and project entities (the corresponding meta-model is described in detail in section 5). A system entity is composed of one set of requirements, noted SR, and one or more solutions (or system alternatives), noted SA_i, as shown in the left part of Fig. 1. A project entity is composed of one task of requirements collection, noted TR, and one or more tasks of solution design (or alternative development task), noted TD_i, as shown in the right part of Fig. 1.

As mentioned in section 3.1.1, the proposed model is based on a structural and hierarchical decomposition of systems into sub-systems and/or projects into sub-projects (guided by their intrinsic complexity). Observing system entities and project entities, three kinds of coupling have been defined :

- one system entity is coupled with one project entity,
- one project entity is coupled with several system entities and,
- one system entity is coupled with several project entities.

These three kinds of coupling are discussed below.

- One system entity is coupled with one project entity (Fig. 2): in this situation, the design of a system entity is controlled by a single project and each subsystem design is controlled by a single coupled sub-project. The risk of conflicting system requirements can be controlled because only one project task is in charge of collecting requirements for a particular system, taking into account required resources. The decision to decompose into sub-systems can be taken during the design of a solution (or during the definition of a project). The sub-projects involved will be created at this time, necessarily adapted to plan and control required resources. Low project levels receive clear objectives from higher levels with a facilitated control of the former by the latter. However, for very complex systems with a great number of systems and subsystems, this systematic approach can lead to a large number of projects within one project, even for a very simple system.
- One project entity is coupled with several system entities. In this case, two situations have been identified:
  - · one project controls a system and its sub-system design simultaneously (Fig. 3(a)): the main advantage here is to factorize the project management for all the involved systems with only one planning manager. However, the development planning information about different systems is mixed: only single requirements collection task performed early for all the systems and subsystems. This can lead to problems since the requirements characterization of a sub-system can require a high level of expertise (and consequently, particular resources). Furthermore, the choice of decomposition into sub-systems can be difficult to anticipate before starting the design work.
  - · one project controls several sub-systems at the same hierarchical level (Fig. 3(b)): in this case, the planning manager can encounter difficulties in planning multiple interventions from (potentially distributed) designers for the different subsystems. Furthermore, information regarding the requirements of each sub-system is identified when performing a single task within the project, which could potentially lead to inconsistencies.
- One system entity is coupled with several project entities: two situations have been identified:
  - · one system is controlled by one project and its sub-projects (Fig. 4(a)): in such a case, the system to be designed is not considered complex enough to be decomposed, but the management of its design can not be done by only one level of project. The risk is to create duplicated tasks as well as conflicting responsibilities (several plan-

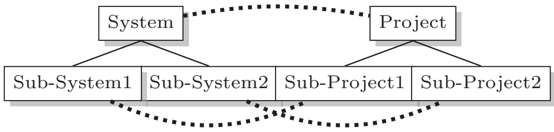
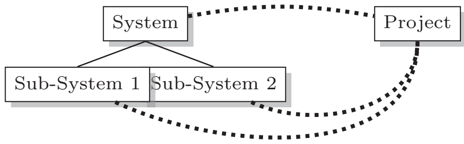
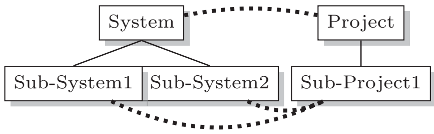


Fig. 2. Bijection between Design and Project Entities

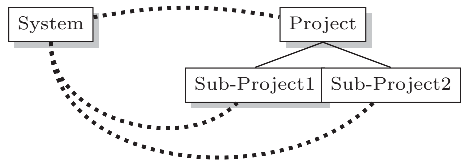


(a) Case I

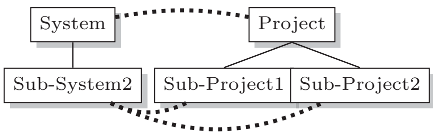


(b) Case II

Fig. 3. One Project Entity coupled with further Design Entities



(a) Case I



(b) Case II

Fig. 4. Further Projects Entities coupled with one Design Entity

ning managers for one system to be designed). It is then nearly impossible to formalize the relationships between different (non-formalized) parts of the system and the different sub-projects.

- one sub-system is controlled by several sub-projects (Fig. 4(b)): in such a case, the system and the project are decomposed, but there are several sub-projects managing the design of only one sub-system. The drawbacks of the above situation are the same.

Of these three kinds of coupling, the first one, based on a bijection between system and project entities, has been chosen for this study. This coupling is called structural coupling in the following parts of the article. It is very well suited to defining coupling relationships, because it keeps the same structure on both domains. This characteristic is very important in order to define and carry out consistent coupled planning and design processes by means of well suited decision aided tools. It is fully compliant with the Axiomatic Design of Suh (1990) and its zigzagging methodology (see section 3.2). It is also important to preserve the semantic of entities on both domains without mixing information. Furthermore, in this article we favor a progressive top-down design approach where sub-projects and sub-systems are defined only when required and when their context is well known. For instance, the decision to subcontract the design of a particular sub-system can be taken only after a suitable requirements analysis and when these requirements have been confronted with available resources. At this time, the choice of a subcontractor and the definition of the required sub-project, as well as its characteristics and constraints, can be established. More classical methodologies in this field consider that both hierarchies are first constructed independently and that links are drawn later on. Such an approach can lead to incompatibilities, because projects are defined outside of their real design context without taking into account the required resources, skills and distributed partners. Therefore, our proposal is based on the assumption of bijection between project and design entities.

5. PROPOSAL FOR AN INTEGRATED MODEL

In this section, we focus only on the integrated model supporting the bijective link coupling. Firstly, we present the structural coupling that ensures a bijection between systems and projects. This coupling corresponds to a kind of systematic mapping between system BOM [1] and projects WBS [2] and is the basis of all of our proposals.

6. CONCLUSION

The aim of this article was to discuss the architecture capable of supporting a coupling between the design process and the planning process. The context and the background of the study have been presented in section 2. The multi-level design process and planning process have been described in accordance with academic standards and with the EIA-632 standard used in companies. The different possibilities of coupling both domains have been proposed and discussed in section 3. Finally, the choice to preserve bijective relationships between system entities and project entities has been made and justified.

Firstly, perspectives of this work concern the integration of local decoupling mechanisms between both domains when required at lower levels of decomposition. Within section 3, we discussed the assumption about bijective relationships between both domains and this assumption has been maintained for all of our proposals. However, it can be difficult to maintain this kind of strict coupling for systems having many levels of decomposition. It requires systematically drawing links between entities, even when they are simple. A methodological problem can arise if a very simple system must necessarily be linked to its project. Therefore, an exception to this rule is possible, enabling managers to define a hierarchical decomposition of very simple systems with only one associated project when a certain level of decomposition is reached (this exception is not detailed in the proposals). In this case, the coupling could be carried out manually (the project manager explicitly constructs the links between entities) and could continue to work. Alternatively, no coupling is performed and is thus no longer supported by the integrated model. Clearly, this method of operation needs to be controlled and reserved to specific situations where designers of low levels want to decompose a very simple system to develop it without a framework given by the planning environment. It can not be generalized to a whole system.

Secondly, perspectives of this work concern the formalization of the coupling based on field knowledge. Another part of the ATLAS project concerns the use (or reuse) of contextualized knowledge stored in a data base and usable via a Case-Base Reasoning methodology and of formalized knowledge stored as a Constraint Based model (Aldanondo et al. (2010)). This kind of knowledge is called field knowledge and is very important in order to reduce the time required to develop new systems from requirements. This time gain can be achieved by reusing and adapting past solutions to fulfill new requirements. The reuse can be applied to systems and their alternatives as well as to the different development tasks, adapting them to the new context and to the new requirements (coupling by reuse). It can be also achieved by applying filtering methods to Constraints Satisfaction Problems limiting the authorized

[1] Bill Of Materials
[2] Work Breakdown Structure

domains of combinations of design variables. The solution space is then reduced in order to guide the decision makers.

A software mockup illustrating all couplings identified in the ATLAS project, and based on the bijective assumption, can be consulted at `http://193.51.2.246:5500/`. This mockup matches industrialists' expectations.

REFERENCES

[1] J. Abeille, T. Coudert, E. Vareilles, L. Geneste, M. Aldanondo, T. Roux, *Formalization of an integrated system/project design framework : first models and processes*, SPRINGER , pp.207-217, ISBN 978-3-642-15653-3, 1st International Conference on Complex Systems Design and Management CSDM2010, Paris, FRANCE, 2010. ok

[2] L. Albano, N. Suh, *Axiomatic approach to structural design*, Research in Engineering Design, Vol. 4, pp. 171-183, 1992. ok

[3] M. Aldanondo, E. Vareilles, M. Djefel, *Towards an association of product configuration with production planning*, International Journal of Mass Customisation 2010 - Vol. 3, No.4 pp. 316 - 332, 2010.

[4] L. T. M. Blessing, *Comparison of Design Models Proposed in Prescriptive Literature*, Proceedings of the COST A3 / COST A4 International Research Workshop on the role of design in the shaping of technology, Lyon, 1996. ok

[5] D. Brown, B. Chandrasekaran, *Expert system for a class of mecanical design activity*, In Gero, J. S., editor, knowledge engineering in Computer-Aided Design, pp. 259-282, Amsterdam: North-Holland, 1985. ok

[6] G. E., Dieter, *Engineering design - A materials and processing approach*, third ed., Mc Graw-Hill International Editions, 2000. ok

[7] EIA Standard, *Processes for Engineering a System*, Electronic Industries Alliance, 1999. ok

[8] S. D. Eppinger, D. E. Whitney, R. P. Smith D. A. Gebala, *Organizing the tasks in complex design projects.*, MIT Workshop on CAOPD, Springer-Verlag New York, Inc. 1991. ok

[9] J. S. Gero, *Design prototypes: a knowledge representation schema for design*, AI magazine. Vol. 11 n4, 1990. ok

[10] A. Goncalves-Coelho, *Axiomatic Design and the Concurrent Engineering Paradigm*, Proceedings of COSME, Brasov, Romania, 2004. ok

[11] H. Hans, W. Herroelenb, R. Leusb, G. Wullink, *A hierarchical approach to multi-project planning under uncertainty*, The International Journal of Management Science, Vol. 35, pp. 563 - 577, 2005. ok

[12] W. Herroelen, B. De Reyck, E. Demeulemeester, *Resource-constrained project scheduling: a survey of recent developments*, Computers and Operations Research, Vol.25, No. 4, pp. 279-302, 1998. ok

[13] J. Huysentruyt, D. Chen, *Contribution to the development of a general theory of design*, Proceedings of the 8th International Conference of Modeling and Simulation - MOSIM10 - May 10-12, 2010 - Hammamet - Tunisia, 2010. ok

[14] T. Kis, *Project scheduling: a review of recent books*, Operations Research Letters, Vol. 33, Issue 1, pp. 105-110, 2005. ok

[15] U. Lindemann, *A vision to overcome "chaotic" design for X processes in early phases*, Int. Proc. of Conference on Engineering Design (ICED), Paris, France, 2007. ok

[16] J. N. Martin, *Evolution of EIA-632 from an interim standard to a full standard*, Proceedings of INCOSE 1998 Symposium, 1998. ok

[17] G. Pahl, W. Beitz, *Engineering Design: a Systematic Approach*, Springer-Verlag, 1996. ok

[18] PMBOK Guiden *A Guide to the Project Management Body of Knowledge*, Third Edition, Project Management Institute, 2004. ok

[19] R. Lu, W. Peng, C. Wang, *Integration of Product Design Process and Task Management for Product Data Management Systems*, in proceedings of IFIP International Federation for Information Processing, Volume 254, Research and Practical Issues of Enterprise Information Systems II Volume 1, eds. L. Xu, Tjoa A., Chaudhry S. (Boston: Springer), pp. 207-218, 2007. ok

[20] H. A. Simon, *The science of the artificial*, MIT Press, 1969. ok

[21] A. Sharon, V. Perelman, D. Dori, *A Project-Product Lifecycle Management Approach for Improved Systems Engineering Practices*, Proc. Eighteenth Annual International Symposium of the International Council on Systems Engineering (INCOSE), Utrecht, the Netherlands, 2008. ok

[22] A. Sharon, O. de Weck, D. Dori, *Is there a Complete Project Plan? A Model-Based Project Planning Approach*, Proceedings of the Nineteenth Annual International Symposium of the International Council on Systems Engineering (INCOSE), Singapore, 2009. ok

[23] D. Stewart, D. Tate, *Integration of Axiomatic design and project planning*, Proc. of first Int Conference on Axiomatic Design, Cambridge USA, 2000. ok

[24] N. Suh, *The principles of Design. Oxford series on Advance Manufacturing*, Oxford University Press, New York, 1990. ok

[25] N. Suh, *Axiomatic Design: Advances and Applications*, Oxford Series, 2001. ok

[26] M. X. Tang, *A knowledge-based architecture for Intelligent Design Support*, International Journal of Knowledge Engineering Review, vol. 12 (4), pp.387-460, 1997. ok

[27] D. G. Ullman, *The mechanical design process*, third edition, McGraw-Hill, Higher Education, New York, 2003. ok

[28] J. X. Wang, M. X. Tang, B. Gabrys, *An Agent-Based System Supporting Collaborative Product Design*, R.J. Howlett, L.C. Jain (Eds.): KES 2006, Part II, LNAI 4252, pp. 670 - 677, Springer-Verlag Berlin Heidelberg, 2006. ok

[29] H. Yoshikawa, *Design philosophy: the state of the art*, CIRP annals manufacturing technology, 38(2) : pages 579-586, 1989. ok