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From Jan Fransoo

Planning bullwhip = vertical bullwhip

Within production planning, the lead time is a key control parameter in the planning hierarchy. It can be argued that the lead time is an exogenous parameter to the planning [3], while others argue that the lead time should be endogenous to the planning system and reflect the current state of the shop floor. In most of the planning systems deployed in industry, which are based on MRP-logic, lead time is an exogenous parameter to the planning system. That is, the user inputs a value for the lead time into the ERP-system, for each of the levels in the bill-of-materials. It is however not obvious, from a theoretical point of view, what should be the proper value of the lead time and if and how it should be updated. The main difficulty with a more or less regular update of the lead time is that the planning system can become instable, since a modification in a key planning parameter such as the lead time leads immediately to substantial changes in the planning and release policy, likely to have substantial effects on the actual lead time on the shop floor. This effect has been coined the "lead time syndrome" and later studied in a more formal and quantitative manner. Selcuk *et al.* [2006] demonstrate the existence of the lead time syndrome subject to certain assumptions regarding the updating behaviour of the planning parameters by the planner operating the ERP system. The effect has strong similarities to the supply chain bullwhip effect studied by Forrester [1961] and Lee *et al.* [1997], and hence the lead time syndrome can also be named the planning or vertical bullwhip.

Reference: Dieter Fischer, Jan Fransoo, and Philip Moscoso - 'Human planners, planning structure and the vertical bullwhip'. In: "Meeting diversity in ergonomics", edited by Ruud N. Pikaar, Ernst A.P. Koningsveld, and Paul J.M. Settels, Elsevier, Amsterdam, July 2006, pages 1854-1860. See also: <http://home.tm.tue.nl/jfransoo/IEAFFM.pdf>.

From: Christos Dimopoulos

Visualization

A graphical representation of data or concepts, which is either an internal construct of the mind or an external artifact supporting decision making.

References:

C. Ware, Information Visualization: Perception for Design. San Francisco: Morgan Kaufmann (Academic Press), p.1, 2000.

Melanie Tory and Torsten Möller, Human Factors in Visualization Research, IEEE Transactions on Visualization and Computer Graphics, 10(1):72-84, January/February 2004.

Interaction

A cyclic process in which two actors alternately listen, think, and speak.

Reference: Chris Crawford, The Art of Interactive Design, San Francisco: No Starch Press, Part One, Chapter 1, p.3, 2003.

Human Computer Interaction

A discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them.

Reference: Hewett, T., Baecker, R., Card, S., Carey, T., Gasen, J., Mantei, M., Perlman, G., Strong, G., and Verplank, W., ACM SIGCHI Curricula for Human-Computer Interaction, Report of the ACM SIGCHI Curriculum Development Group, ACM, 1992.

Multiobjective Scheduling

The allocation of limited resources to tasks over time that has as a goal the simultaneous optimization of more than one objective functions.

Reference: Michael Pinedo, Scheduling: Theory, Algorithms and Systems: New Jersey: Prentice Hall, p.1, 1995.

From Philip Moscoso

Planning structure

The planning structure is constituted by the amount, arrangement and types of internal and external relationships of the planning entities. One can distinguish between a *static* and a *dynamic view* of the planning structure. The second is only given as planning takes place. Together, both views show the order in time and space characterizing the planning system behaviour. Planning structure is therefore in a complementary relation to planning process, i.e. the planning structure enables the planning processes but is also the result of these processes.

From Hannes Günter

Relationship quality

(1) "High quality relationship [...] means that the customer is able to rely on the salesperson's integrity and has confidence in the salesperson's future performance because the level of past performance has been consistently satisfactory. Relationship quality, then, is viewed as a higher-order construct [...] composed of at least two dimensions, (1) trust in the salesperson [...] and (2) satisfaction with the salesperson... (p. 70)"

Crosby, L. A., Evans, K. R., & Cowles, D. (1990). Relationship quality in services selling: An interpersonal influence perspective. *Journal of Marketing*, 54(3), 68-81.

(2) "Our analysis considers relational quality as both an input to the success of the venture, and an output of the interactions between the partners. We model it as the sum of an initial store of goodwill – the result of external reputation and personal bonds established during the negotiation process – plus a term that accounts for actual observations of behavior over time in the context of the venture. The former corresponds to more standard static treatments of trust in inter-organizational relations [...] whereas the latter is a dynamic term that will require more importance as time progresses" (p. 322-323)

Ariño, A., de la Torre, J. (1998), "Learning from failure: towards an evolutionary model of collaborative ventures", *Organization Science*, 9(3), 307-25.

From Rüdiger von der Weth

Work system: humans and technical devices organised to perform work tasks.

Control capacity: The ability of a work system to cope with its actual and future tasks, can be subdivided as anticipative, operational, and structural control capacity.

Task: Specific demands on an anticipative, operational and structural level for a work system coming from a mandate or an order for this work system. It can be described as a relation between actual situation, goals and means.

Actor: Part of a work system, control capacity can also be measured for single actor

Relation: Describes organisational connections between actors.

References:

- Our Madrid presentation
- Rüdiger von der Weth (2001): *Management der Komplexität (management of complexity)*. Bern: Huber.

From Wout van Wezel

Task Analysis

The principle of a task analysis is to break down and study the elements of a task (Stanton, 2006). The usual goal is to improve the task execution by asking questions such as “why is the work performed as it is”, “what is needed to perform it in this way”, and “how can the work method be improved”. Task analyses are performed in the planning and scheduling domain as well. Cegarra & Van Wezel (2006) describe the overall characteristics of three well known methods that have been applied to planning and scheduling: Hierarchical Task Analysis, Cognitive Task Analysis, and Cognitive Work Analysis.

In 1960, Miller, Galanter and Pribram suggested that human behaviour is fundamentally goal directed and can be understood in terms of a hierarchical goal structure; the attainment of primary goals is served by the attainment of its subgoals, which could, at their turn, be decomposed into sub-subgoals. This idea has been expanded to the analysis of process control tasks, which lead to the method *Hierarchical Task Analysis* (Annett & Duncan, 1967; Annett, 2000). The designer’s goal is to describe the hierarchical goal-structure. Each level (goal or subgoal) is recursively decomposed in 3 to 10 immediate subgoal. For this decomposition to not happen indefinitely, it is common to consider the purpose of the analysis as a stop point. For example when studying teamwork, Stanton (2005) suggested to stop the hierarchical decomposition when the subtasks deal with the individual exchange of information.

During the 60s and 70s, there was a shift from the description of work analysis methods from purely physical tasks towards more cognitive-oriented tasks such as air traffic control or troubleshooting diagnosis (Hollnagel & Woods, 1983). Traditional task analysis only has an implicit formulation from the cognitive point of view (Annett, 2000). Cognitive Task Analysis appeared as an extension of traditional task analysis to yield information about knowledge, thought processes and goals that underlie task performance (Chipman, Schraagen & Shalin, 2000). Different authors applied a Cognitive Task Analysis in planning and scheduling, even if they do not necessarily refer to this method. Differently from the Usher and Kaber consideration of the hypothesized behaviour of the human, the Cognitive Task Analysis method resorts to field studies to gain insight into real practices.

Taking into account the importance of novelty in sociotechnical systems, Rasmussen and colleagues have developed a framework that is called the *Cognitive Work Analysis* (Rasmussen, 1986; Rasmussen, Pejtersen, & Goodstein, 1994; Vicente, 1999). This method has its root in *Ecological Psychology* (Gibson, 1979) that implies to adopt the human-environment system as the fundamental unit of analysis and to focus the analysis on the examination of constraints that the environment imposes on behaviour. So, in contrast with the two previous methods, the *Cognitive Work Analysis* does not focus on the human’s hypothesized or real practice, as was stressed by Vicente (2002, p.63): “A task can be defined as the set of actions that can or should be performed by one or more actors to achieve a particular goal. In contrast a work domain is the system being controlled, independent of any particular worker, automation, event, task, goal, or interface”. The decomposition in *Cognitive Work Analysis* is based on an abstraction hierarchy: the higher levels of the hierarchy describe functional information, whereas lower levels describe physical information. Besides this physical to functional decomposition, there is a part-whole dimension, which takes into account several levels of details (e.g., system, subsystem, components). Five different levels of abstraction are considered in Cognitive Work Analysis: functional purposes, abstract functions, generalised functions, physical functions and the physical form.

The following table summarizes the comparison of the task analysis frameworks. As can be seen, they have different objectives and hence focus on different aspects of the situation (task, activity, or domain). This has

consequences for their usefulness of the different characteristics of planning and scheduling (maps real practice, attention for individual differences, and applicability to design support).

	<i>Hierarchical Task Analysis</i>	<i>Cognitive Task Analysis</i>	<i>Cognitive Work Analysis</i>
Objective of the method	To model the tasks the human has to accomplish	To model the knowledge, thought processes and goals that underlie the task	To model the domain and its physical, functional interrelation
Unit of analysis	Task (designer's point of view)	Activity (human operator's point of view)	Domain (independent of the human operator)
Type of decomposition	Hierarchical (task to subtasks)	Network of human activities	Means-ends and part-whole decomposition of the system functioning
The focus on real practices	No, only formal tasks	Yes	No, focuses on the domain
The individual differences	No	No, but possible	Yes
The design of a support tool	Yes, for formal tasks	Yes	No
Applied by	Usher and Kaber (2000)	Van Wezel, Jorna and Mietus (1996); Crawford, MacCarthy, Wilson and Vernon (1999)	Higgins (1999; 2001)

Annett, J. (2000). Theoretical and pragmatic influences on task analysis methods. In J.M. Schraagen, S.F. Chipman & V.L. Shalin (Eds.), *Cognitive Task Analysis* (pp.25-37). Mahwah, NJ: Lawrence Erlbaum Associates.

Annett, J., & Duncan, K.D. (1967). Task analysis and training design. *Occupational Psychology*, 41, 211-221.

Cegarra & Van Wezel (2006). The design of human-machine cooperation in scheduling: A review of the applicability of task, cognitive task and cognitive work analysis. *Under preparation*.

Chipman, S.F. Schraagen, J.M., & Shalin, V.L. (2000). Introduction to cognitive task analysis. In J.M. Schraagen, S.F. Chipman & V.L. Shalin (Eds.), *Cognitive Task Analysis* (pp.3-23). Mahwah, NJ: Lawrence Erlbaum Associates.

Crawford, S., MacCarthy, B.L., Wilson, J.R., & Vernon, C. (1999). Investigating the work of industrial schedulers through field study. *Cognition, Technology & Work*, 1, 63-77.

Gibson, J.J. (1986). *The ecological approach to visual perception* (orig. publ. 1979). Hillsdale, NJ: Lawrence Erlbaum Associates.

Higgins, P.G. (1999). *Job Shop Scheduling: Hybrid Intelligent Human-Computer Paradigm*. PhD Thesis, University of Melbourne, Australia.

Higgins, P.G. (2001). Architecture and Interface Aspects of Scheduling Decision Support. In B.L. MacCarthy & J.R. Wilson (Eds.), *Human performance in planning and scheduling: fieldwork studies, methodologies and research issues* (pp. 245-279). London: Taylor & Francis.

Hollnagel, E., & Woods, D.D. (1983). Cognitive Systems Engineering: New Wine in New Bottles. *International Journal of Man-Machine Studies*, 18(6), 583-600.

Miller, G.A., Galanter, E., & Pribram, K. (1960). *Plans and the structure of behavior*. New York: Holt.

Rasmussen, J. (1986). *Information Processing and Human Machine Interaction: An Approach to Cognitive Engineering*. New York: North-Holland.

Rasmussen, J., Pejtersen, A.M., & Goodstein, L.P. (1994). *Cognitive Systems Engineering*. London: John Wiley.

Stanton, N.A. (2006). Hierarchical task analysis: Developments, applications, and extensions. *Applied Ergonomics*, 37, 55-79.

Usher, J.M., & Kaber, D.B. (2000). Establishing Information Requirements for Supervisory Controllers in a Flexible Manufacturing System using GTA. *Human Factors and Ergonomics in Manufacturing*, 10, 431-452.

Wezel W.M.C. van, Jorna, R.J. & Mietus, D. (1996). Scheduling in a generic perspective. *International Journal of Expert Systems; research and applications*, 3 (9), pp. 357-381.

Vicente, K. (1999). *Cognitive Work Analysis : Towards safe, productive, and healthy computer-based work*. NJ : Lawrence Erlbaum Associates.

Vicente, K.J. (2002). Ecological Interface Design: Progress and Challenges. *Human Factors*, 44(1), 62-78.

Cognitive Typology

A cognitive typology makes it possible to describe the situations according to factors that will directly determine the operators' strategies (see Cegarra, accepted). For example, in the case of a dimension associated with the structural complexity of the process, Cowling (2001) presents an illustrative situation: when the order list is full (what could be defined, from a cognitive point of view, as high structural complexity), the schedulers' strategies are directed towards the maintenance of production flow by avoiding delays caused by changing produced components. On the other hand, when the order list is not as full (i.e. lower structural complexity), the schedulers focus on production quality. So the use of a cognitive typology makes it possible to characterize situations (as a list of dimensions) on the basis of their implications for operators' strategies.

References:

- Cegarra, J. (accepted). A cognitive typology of scheduling situations: A contribution to laboratory and field studies. *Theoretical Issues in Ergonomics Science*.
- Cowling, P. (2001). Design and Implementation of an Effective Decision Support System: A Case Study in Steel Hot Rolling Mill Scheduling. In B.L. MacCarthy & J.R. Wilson (Eds.), *Human performance in planning and scheduling: fieldwork studies, methodologies and research issues*, (pp. 217-230). London: Taylor & Francis.

Ecological Validity

The quality of reproduction of conditions (in laboratory experiments) compared to those in real situations (Hoc, 2001).

Reference

Hoc, J.M. (2001). Toward ecological validity of research in cognitive ergonomics. *Theoretical Issues in Ergonomics Science*, 2, 278-288.

Task Analysis

see Hierarchical Task Analysis, Cognitive Task Analysis and Cognitive Work Analysis.

Hierarchical Task Analysis

In 1960, Miller, Galanter and Pribram suggested that human behaviour is fundamentally goal directed and can be understood in terms of a hierarchical goal structure; the attainment of primary goals is served by the attainment of its subgoals, which could, at their turn, be decomposed into sub-subgoals. This idea has been expanded to the analysis of process control tasks, which lead to the method Hierarchical Task Analysis (Annett & Duncan, 1967; Annett, 2000). The designer's goal is to describe the hierarchical goal-structure. Each level (goal or subgoal) is recursively decomposed in subgoals. For this decomposition to not happen indefinitely, it is common to consider the purpose of the analysis as a stop point.

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