Strategic Modelling for Enterprise Integration

Eric Yu
University of Toronto
yu@fis.utoronto.ca

Abstract

*The successful application of advanced information technologies and systems relies on a good understanding of the target organizational environment. Modelling techniques are needed for expressing complex social and organizational relationships and to help reason about them. The **i*** modelling framework supports the modelling of strategic relationships among organizational actors. Actors depend on each other for goals to be achieved, tasks to be performed, and resources to be furnished. Networks of strategic dependencies can be analyzed for opportunities and vulnerabilities. Means-ends reasoning is used to help explore alternatives. Examples at different levels of enterprise modelling are given.*

1 Introduction

The use of appropriate modelling techniques is crucial to the success of complex systems. The vision of enterprise integration is predicated on the complex inter-working of many human, organizational, and technological systems. Models for enterprise integration therefore need to provide features that can express complex organizational issues as well as technological ones, and to support their analysis and design reasoning.

Today's enterprise environment is a fast-paced one, with frequent changes in business relationships and organizational structures. Work processes are being redesigned on an ongoing basis to adapt to changing conditions. Current techniques for enterprise modelling cover a wide range of capabilities [Vernadat97]. For example, in comprehensive frameworks such as CIMOSA or GERAM, the need for modelling and analyzing functional, informational, resource, and organizational aspects are recognized and supported. While these models can provide a quite elaborate description of an enterprise as it exists (or as it should be, if the models are interpreted prescriptively), they do not provide a good way of describing or understanding why it is (or should be) the way it is. Knowing the reasons behind the activities and structures of an enterprise is necessary for a deeper understanding of how it operates, and for assessing its strengths and weaknesses. This deeper understanding will allow an enterprise to be more adaptive and resilient, to be able to respond to exceptions and to accommodate departures from established routines, with actions directed at the achievement of objectives. More significantly, having an explicit understanding of the "whys" can improve the ability of an enterprise to evolve smoothly and swiftly. On the one hand, a successful enterprise needs to be constantly looking out for better ways to achieve its objectives, taking advantage of new technologies and methods. On the other hand, it needs to keep rethinking its objectives and strategies to respond to external conditions, while making good use of its internal resources and capabilities. To complement the existing types of enterprise models, we need models that can help recognize opportunities and vulnerabilities, explore alternatives, assess their implications, make tradeoffs, and target strategically significant issues.

The understanding of "whys" can be assisted by models that explicitly represent and deal with goals. One way to understand the structuring of a complex enterprise is in terms of a means-ends hierarchy of goals [March58]. However, complex organizations typically do not have a single set of coherent goals. The goals of an organization need to be traced to the goals of individual members and groups, and these are shaped by each other and by external forces. The attempt to model goals in an enterprise amounts to mapping and analyzing the complex web of strategic relationships among the many players in an enterprise and in its environment.

In this paper, the ***i**** modelling framework for supporting strategic reasoning in organizations is described. Organizations are viewed as consisting of semi-autonomous units called actors. It is assumed that the behaviour of actors are not fully controllable or predictable, but are regulated by social relationships. Actors have freedom of action within these social constraints. Most crucially, actors depend on each other for goals to be achieved, tasks to be performed, and resources to be furnished. By depending on someone else, an actor may achieve goals that would otherwise be unachievable. However, a dependency may bring along vulnerabilities since it can fail despite social conventions such as commitments. The explicit representation of goals allows the exploration of alternatives through means-ends reasoning. A concept of softgoal based on the notion of satisficing is used to provide a flexible interactive style of reasoning.

2 Modelling Strategic Actor Relationships and Rationales -- the *i** framework

The ***i**** modelling framework consists of two types of models – the Strategic Dependency (SD) model and the Strategic Rationale (SR) model.

2.1 Modelling intentional relationships among strategic actors – the Strategic Dependency model

The Strategic Dependency (SD) model is a graph, where each node represents an actor, and each link between two actors indicates that one actor depends on the other for something in order that the former may attain some goal. We call the depending actor the depender, and the actor who is depended

upon the dependee. The object around which the dependency relationship centres is called the dependum. An actor is an active entity that carries out actions to achieve goals by exercising its knowhow. In the SD model, the internal goals, knowhow, and resources of an actor are not explicitly modelled. The focus is on external relationships among actors.

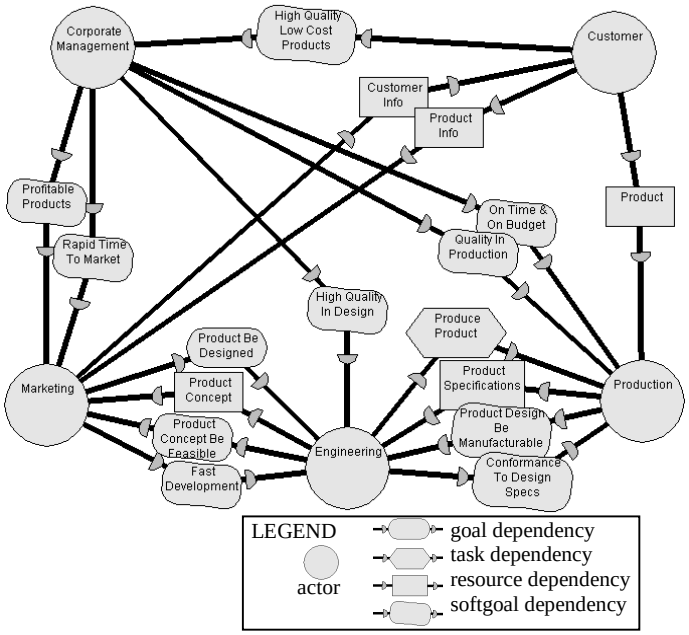

Figure 1: A Strategic Dependency model

Figure 1 shows an example of a Strategic Dependency model representing a hypothetical organization. It shows dependency relationships among organizational units such as marketing, engineering, production, and corporate management, as well as with the customer. Four types of dependencies are distinguished. In a *goal dependency*, the depender depends on the dependee to bring about a certain state of affairs in the world. The dependum is expressed as an assertional statement. The dependee is free to, and is expected to, make whatever decisions are necessary to achieve the goal (the dependum). The depender does not care how the dependee goes about achieving the goal. For example, Marketing depends on Engineering to have a product designed. Engineering has the freedom to choose how to do the designing, as long as the goal of getting the product designed is achieved.

In a *task dependency*, the depender depends on the dependee to carry out an activity. The dependum names a task which specifies how the task is to be performed, but not why. The depender has already made decisions about how the task is to be performed. Engineering depends on Production to produce the product according to some process, described in terms of activities and sub-activities, and possibly constraints among them, such as temporal precedence. (The graphical notation of the model only names the tasks. The contents of the tasks are given in the symbolic version of the model.) Note that a task description in ***i**** is not meant to be a complete specification of the steps required to execute the task. It is a constraint imposed by the depender on the dependee. The dependee still has freedom of action within these constraints. In the example, Production's freedoms are also constrained by the "Conform To Design Specs" dependency from Engineering, as well as dependencies from other actors.

In a *resource dependency*, the depender depends on the dependee for the availability of an entity (physical or informational). By establishing this dependency, the depender gains the ability to use this entity as a resource. A resource is the finished product of some deliberation-action process. In a resource dependency, it is assumed that there are no open issues to be addressed or decisions to be made. For example, Engineering treats Product Concept as a resource from Marketing, and the Customer treats the final Product from Production as a resource.

In a *softgoal dependency*, a depender depends on the dependee to perform some task that meets a softgoal. A softgoal is similar to a goal except that the criteria of success are not sharply defined a priori. The meaning of the softgoal is elaborated in terms of the methods that are chosen in the course of pursuing the goal. The depender decides what constitutes satisfactory attainment ("satisficing", [Simon83]) of the goal, but does so with the benefit of the dependee's knowhow. In the example organization, Profitability, Fast Development, Manufacturability, and High Quality are issues negotiated between the relevant actors. They are modelled as softgoal dependencies. For example, Corporate Management's softgoal dependency on Marketing for Profitable Products indicates that Management chooses among the different ways which Marketing believes can achieve profitable products. If Marketing is given the freedom to decide, this relationship would be modelled as a (hard-) goal dependency.

These dependency types are used to indicate the nature of freedom and control in the relationship between two actors regarding a dependum. The model also provides for three degrees of strength of dependency: *open* (uncommitted), *committed*, and *critical*. These apply independently on each side of a dependency. These distinctions are described in [Yu95a].

The SD model is used to express the network of intentional, strategic relationships among actors. These relationships are intentional in that they deal with the desires, expectations, and commitments among organizational players. They are also strategic in that they indicate the opportunities that are available for actors to take advantage of – by making use of the abilities of other actors, and at the same time, the vulnerabilities that the actors will be exposed to, if the dependencies fail. Actors can assess the desirability of alternate configurations of relationships with other actors according to what they consider to be significant to them. The viability of a dependency can be analyzed in terms of *enforceability* (Does the other actor depend in return on me for something, directly or indirectly?), *assurance* (Are there other dependencies on that actor that would reinforce my confidence in the success of that dependency?), and *insurance* (Do I have back-ups or second

sources in case of failure?). Strategic dependencies can be analyzed in terms of loop and node patterns in the graph. Examples have been given in [Yu97b].

The generic concept of strategic actor outlined above can be further differentiated into the concepts of role, position, and agent [YM94]. A *role* is an abstract collection of coherent abilities and expectations. A *position* is a collection of roles that are typically occupied by one agent. An *agent* is an actor that has concrete manifestations such as human, hardware, or software, or combinations thereof. Agents, roles, and positions may also be composed into aggregate actors.

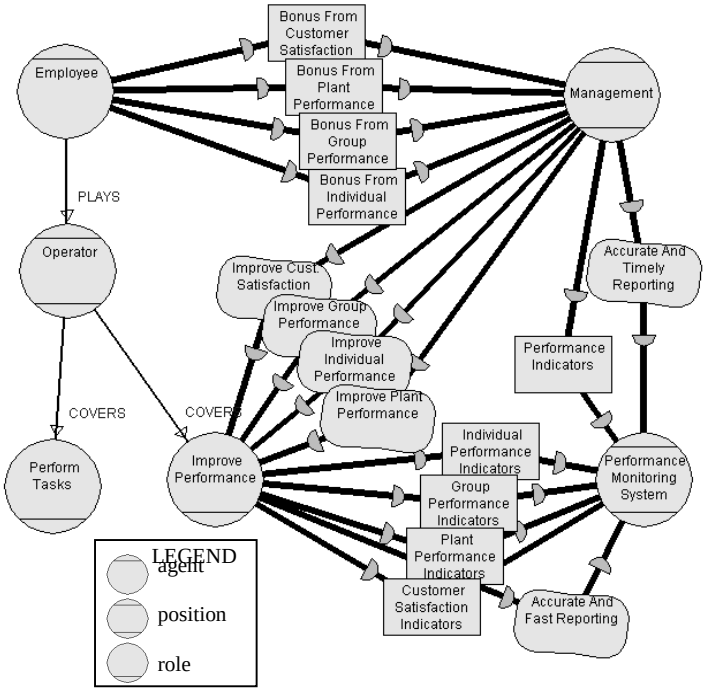

Figure 2: A SD model showing reward structure for improving performance, based on an example in [Majchrzak96]

Majchrzak et al [MW96] describes the importance of worker and management mind-set in changing from functional orientation to process orientation. They studied a number of U.S. electronics manufacturers to identify success factors in reengineered process organizations. Their results indicated that human, social, and organizational factors were critical. One example was the need to base rewards on unit or group performance rather than on individual performance alone. Figure 2 shows how the successful reward structure of one organization can be depicted in an SD model. The plant operator – modelled as a position – covers the two roles of Performing Task and Improving Performance. Performance is identified by management as including individual performance, group performance, plant performance, and customer satisfaction. All these components are reinforced by having monthly bonuses tied to each of them separately. Note that it is the physical agent – the human employee – who depends on management for the bonuses. In order for the workers to effectively improve performance, they need to have performance indicators available on each of these fronts. These information need to be accurate and up-to-the-minute, so that workers can take corrective action quickly. Management also depends on performance information, but they can be in more aggregate form for the purpose of monitoring and bonus calculation. This example illustrates how the modelling of human and organizational issues can lead to requirements on information systems – both functional requirements (e.g., what kinds of information to collect and to send from whom to whom) and non-functional requirements (accuracy, timeliness, etc.).

The strategic and intentional nature of relationships with external actors such as customers and suppliers can also be highlighted and analyzed using ***i**** modelling. For example, IKEA's reliance on customers to do final assembly at home and to do their own delivery involves not only changes in workflow, but also new expectations on each others' roles. In particular, this arrangement would not work unless Ikea's products are easy to assemble and easily transportable by the customer (Figure 3).

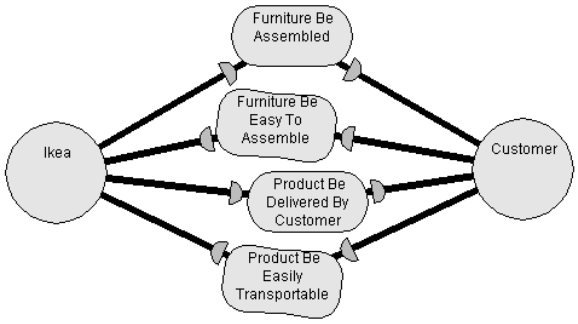

Figure 3: Some strategic dependencies between IKEA and its customers

2.2 Modelling the reasoning behind strategic relationships – the Strategic Rationale model

Whereas the Strategic Dependency model focuses on relationships between actors, the Strategic Rationale (SR) model provides support for modelling the reasoning of each actor about its intentional relationships. The SR model is a graph whose nodes are goals, tasks, resources, and softgoals. These may be connected by means-ends links or task-decomposition links. A goal may be associated, through means-ends links, with multiple, alternative ways for achieving it, usually represented as tasks. The means-ends links for softgoals, however, require more differentiation because there can be various types of contributions leading to a judgement of whether the softgoal is sufficiently met ("satisficing"). These include *make*, *break*, *help*, *hurt*, *positive*, *negative*, *and*, *or*, *unknown*, and *equal* [Chung98][Mylopoulos92]. (In the graphical notation of the current prototype tool in Figure 4, the first six contribution types

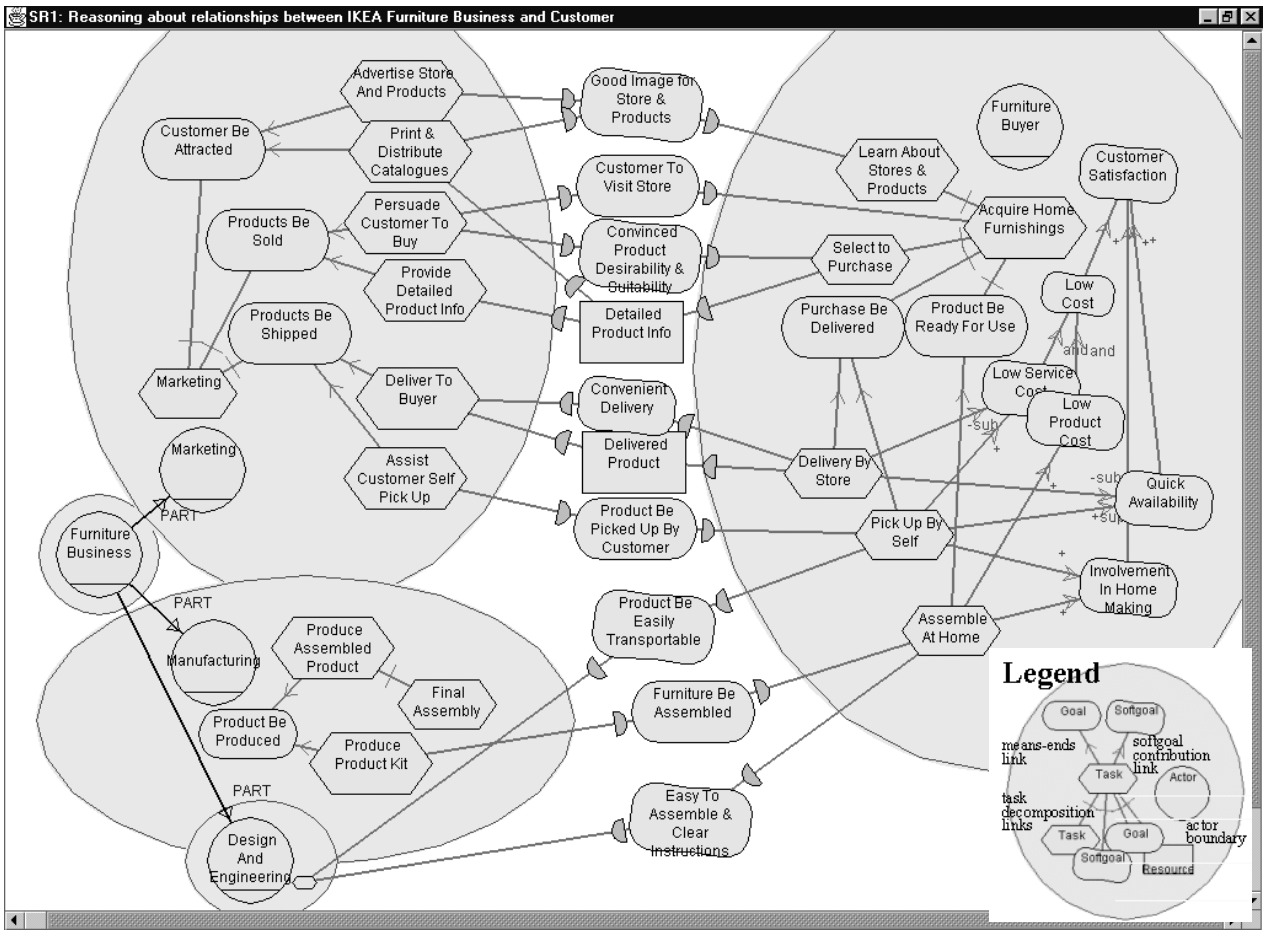

Figure 4: A Strategic Rationale model of some reasoning behind relationships between IKEA and customers

are indicated as +sup, –sup, +sub, –sub, +, and –). Task-decomposition links provide hierarchical decomposition of tasks into subtasks, subgoals, resources, and softgoals that make up the task.

Figure 4 is an SR model showing some of the reasoning behind possible ways of operating a furniture business. The business is taken to consist of three parts – marketing, manufacturing, and design and engineering, modelled as three roles. The overall task of marketing is decomposed into three subgoals. These subgoals can be met in different ways. A conventional furniture store might advertise on television or in newspapers about the attractiveness of the store and its products. Another way – central to the Ikea concept – is to distribute colourful catalogues widely so that they not only promote the image of the store, but provide detailed product information to help customers visualize their homes with selected products even before they visit the store. To achieve the goal that Products Be Sold, a conventional store might hire sales people to persuade customers of their products desirability and suitability to the customers needs. Another way is simply to provide detailed information about products to enable customers to make choices.

To get products transported to customers' homes, the store can offer a delivery service, but then must meet customers' desire for convenient delivery times since someone needs to be home to receive the delivery. Alternatively, the store can promote the concept of self delivery by the customer. From the customer viewpoint, either Delivery By Store or Pick Up By Self can meet the goal that the Product Be Transported Home. Self Pick Up contributes positively to Lower Service Cost, and also decidedly offers Quick Availability of the product at home. For Self Pick Up to work, the product needs to be transportable by the customer. This is something that can be offered by Design and Engineering. One approach is to let the customer do the final assembly at home. This contributes to lower product cost, which contributes to lower overall cost to the customer. Successful home assembly, however, depends on clear instructions and ease of assembly of the product.

Furthermore, it has been argued that self pick up and home assembly increases satisfaction by giving customers a greater sense of involvement in the process of setting up their home environment [Normann93]. The success of the Ikea concept is attributed to a radical rethinking of the dependency relationships between furniture maker and furniture buyer. Ikea depends on its customers to perform two key tasks traditionally done for

customers – final assembly and transportation. The two tasks are now shifted to the customer side, resulting in lower costs and higher customer satisfaction. However, this shift is workable only if accompanied by other requisite dependencies, such as ease of assembly and transport. These issues can be identified and analyzed using the SR model.

An SR model provides analysis in terms of notions of ability, workability, and viability. It supports the raising of issues, the identification and exploration of alternatives, recognition of correlated issues (good and bad side-effects), and the settling of issues. Generic knowledge codified in terms of methods and rules provide semi-automatic support from a knowledge base. An additional component supports the identification of assumptions and their justification [Yu95a].

3 Related Work and Discussion

Existing enterprise modelling languages are surveyed in [Vernadat96] and [Vernadat97]. The need for a goal/objective construct was recognized in [Smart97]. The Action Workflow approach [Medina-Mora92] [Schael97] also pays attention to the satisfaction of "customers", but does not analyze the network of strategic relationships or assists in the exploration of alternatives [Yu95b]. The incorporation of ***i**** into an overall enterprise modelling framework such as CIMOSA is being investigated [Petit97].

Unlike in most other enterprise modelling techniques, the SD and SR models need not be complete. For example, a task decomposition does not need to exhaustively enumerate its constituents. The purpose of the model is to highlight strategically significant elements and issues that would have a bearing on choosing among alternatives from an actor's point of view.

Strategic modelling and analysis can be applied at various levels in an enterprise. At the business process level, the various activity steps and their dependencies can be analyzed, not only in terms of information and material flows and temporal relationships, as is usually done in conventional models, but also in terms of their strategic relevance to overall end-to-end business process objectives [Yu96]. Strategic modelling that explicitly deals with goals and motivations are especially important for understanding human and organizational issues [Yu97b]. Degrees of freedom and control, discretion and initiative, incentives and rewards -- these are important factors that contribute to the success and failure of business processes.

Strategic modelling at the individual and work group level allows these issues to be explicitly identified and reasoned about. Strategic modelling and analysis applied to the information systems requirements level would allow systems decisions to be related more effectively to the goals of stakeholders and business objectives [Yu97a].

At the enterprise level, the strategic relationships among different potential configurations of players in a value chain or network can be modelled and analyzed. A producer considering disintermediation by bypassing distributors or retailers might consider the roles played by these intermediaries and why they have been effective in the past, and to recognize emerging opportunities.

As Internet technologies and electronic commerce infrastructures become more established, many businesses are reexamining their boundaries and relationships with their customers, suppliers, and other constituencies. The ***i**** models offer a systematic approach for examining and analyzing these relationships.

4 Conclusions and Ongoing Work

This paper has argued that modelling the intentional and strategic relationships among organizational actors offers a way for understanding and analyzing complex organizational issues. The ***i**** framework provides a set of concepts that complement existing approaches to organization modelling.

In this paper, the ***i**** models have only been presented in terms of a graphical notation. The modelling framework is also supported by the Telos modelling language which provides knowledge base management facilities, including structuring mechanisms such as classification, generalization, aggregation and time [Mylopoulos90]. A software tool to support ***i**** modellng and analysis is being constructed. The ***i**** approach is being tested in the field at a telecommunications company.

References

[Chung98] Chung, K.L., Nixon, B., Mylopoulos, J., Yu, E. *Non-Functional Requirements in Software Engineering*. Forthcoming monograph.

[ICEIMT97] Kosanke, K., Nell, J.G. (eds.), *Enterprise Engineering and Integration: Building International Consensus*. Proceedings of ICEIMT'97, Int. Conf. on Enterprise Integration and Modeling Technology. Springer-Verlag, 1997.

[Majchrzak96] Majchrzak, A., Wang, Q. Breaking the Functional Mind-Set in Process Organizations. *Harvard Business Review*. Sept-Oct 1996, pp. 92-99.

[March58] March, J.G. and Simon H.A. *Organizations*, Wiley, 1958.

[Medina-Mora92] Medina-Mora, R., Winograd, T., Flores, R., Flores, C.F. The Action Workflow Approach to Workflow Management Technology. *Proceedings of the 4th Conf. on Computer-Supported Cooperative Work*. ACM, 1992. 281-288.

[Mylopoulos92] Mylopoulos, J., Chung, K.L., Nixon, B., Representing and Using Non-Functional Requirements: A Process-Oriented approach, *IEEE Trans. Soft. Eng.* 18(6), June 1992.

[Mylopoulos90] Mylopoulos, J., Borgida, A., Jarke, M., Koubarakis, M. Telos: Representing Knowledge about Information Systems. *ACM Trans. Info. Systems*., 8(4), 1991.

[Normann93] Normann, R., Ramirez, R. From Value Chain to Value Constellation: Designing Interactive Strategy. *Harvard Business Review*. Jul-Aug 1993, pp. 65-77.

[Petit97] Petit, M., and Dubois, E. Defining an Ontology for the Formal Requirements Engineering of Manufacturing Systems. In [ICEIMT97], 378-387.

[Porter85] Porter, M.E. *Competitive Advantage: Creating and Sustaining Superior Performance*. Free Press. New York, 1985.

[Schael97] Schael, T. Cooperative Processes and Workflow Management for Enterprise Integration. In [ICEIMT97], 496-509.

[Simon81] Simon, H.A. *The Sciences of the Artificial*. 2nd ed., MIT Press, 1981.

[Smart97] Smart, P.A. (ed.), Ferreira, J.J.P., Kosanke, K., Schael, T., Zelm, M. Enterprise Modelling – User Semantics, Report of Workshop 4, Working Group 1, in [ICEIMT97], 123-134.

[Vernadat97] Vernadat, F.B., Enterprise Modelling Languages. In [ICEIMT97], 212-224.

[Vernadat96] Vernadat, F.B., *Enterprise Modeling and Integration: Principles and Applications*, Chapman & Hall, London, 1996.

[YM94] Yu, E., Mylopoulos, J. Understanding Why in Software Process Modelling, Analysis, and Design. *Proc. IEEE Int. Conf. Soft. Eng.*, Sorrento, Italy, 1994.

[Yu95a] Yu, E. *Modelling Strategic Relationships for Process Re-Engineering*, Ph.D. thesis. Department of Computer Science, University of Toronto, 1995.

[Yu95b] Yu, E. Models for Supporting the Redesign of Organizational Work. *Proceedings of Conf. on Organizational Computing Systems*. Milpitas, Calif., 1995. 225-236.

[Yu96] Yu, E., Mylopoulos, J., and Lesperance, Y. AI Models for Business Process Reengineering. *IEEE Expert*. August 1996. 16-23.

[Yu97a] Yu, E. Towards Modelling and Reasoning Support for Early-Phase Requirements Engineering, *Proc. IEEE Int. Symp. on Requirements Engineering*, Annapolis, Maryland, January 1997. 226-235.

[Yu97b] Yu, E. and Mylopoulos, J. Modelling Organizational Issues for Enterprise Integration. In [ICEIMT97], 529-538.