# AN INTRODUCTION TO USING PROSIM
# FOR BUSINESS PROCESS SIMULATION AND ANALYSIS

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## ABSTRACT

This paper introduces PROSIM, a knowledge-based system for modeling processes, analyzing them using simulation and project management tools, and designing improved processes. Domain experts who are familiar with the various aspects of the system may be interviewed and process models can be developed based on the evidence collected using PROSIM. The tutorial focuses on the built-in simulation design support environment of PROSIM that enables building simulation models automatically from process models. The later part of the tutorial briefly covers extensions to PROSIM which permit information captured in PROSIM models to be leveraged for other analysis—project planning in a project management tool such as Microsoft® Project™. A purchase order processing system example is described to demonstrate the utility of PROSIM.

## 1 INTRODUCTION

PROSIM (KBSI 97a) can be used to support the analysis and design of manufacturing systems, business systems, logistics systems, command, control, communication, and intelligence systems, service systems, and information systems. It is a critical tool for realizing the monetary benefits of business process re-engineering and activity based costing.

Originally developed under a research contract from the National Science Foundation (NSF) (KBSI 92a), PROSIM pioneered the concept of process model simulation. PROSIM has since evolved into a process engineering workcenter providing assistance during all phases in the lifecycle of process management:

1. Modeling—descriptions of existing process are captured;
2. Analysis—performance metrics are estimated using simulation or static analysis;

3. Design—new "to-be" processes are developed, including integration of existing processes for formation of Virtual Enterprises.

As a complete process-engineering environment, PROSIM empowers the domain expert and reduces their dependence on highly trained analysts. Additionally, it permits the domain expert to focus on describing or improving the process instead of abstracting the process into a simulation model.

## 2 GENERATING PROCESS MODELS USING PROSIM

PROSIM enables a modeler to capture processes or situations as an ordered sequence of events or activities. It is designed to capture process descriptions of the precedence and causality relations between events/situations in a form that is natural to domain experts in an environment. One of the primary goals of the tool is to provide mechanisms for expressing domain expert's knowledge about how a particular process works.

PROSIM uses "*scenarios*" as the basic organizing structure for establishing the focus and boundary conditions for the process description. This feature is motivated by the tendency of humans to describe what they know in terms of an ordered sequence of observed activities within the context of a given situation.

The basic syntactic unit of PROSIM graphical process descriptions within the context of a scenario, is the *Unit Of Behavior* (UOB) represented by a rectangular box. Each UOB represents a specific view of the world in terms of a perceived state of affairs or state of change relative to the given scenario. Stated simply a UOB may represent an event, activity or process in the system of interest. UOBs are connected to one another via *junctions* and *links*. Junctions provide the semantic facilities for expressing synchronous and asynchronous behavior among a network

of UOBs. Links represent temporal precedence, object flow, and relations between UOBs. Each UOB can have associated with it both descriptions in terms of other UOBs (a decomposition of a parent UOB) and a set of participating objects and their relations (an elaboration).

Let us consider a situation of an analyst interviewing a purchase department manager to capture main activities involved in generating purchase orders at the company. The purchase department manager is mainly responsible for the processing of purchase request forms, finding existing suppliers for the part, inviting bids from potential suppliers, receiving bids, evaluating bids, placing purchase orders, and acquiring the material. First, the initiating department (typically design or process planning) formally requests the needed material. If the requested material has existing suppliers, a purchase order can be placed immediately. On the other hand, if the requested material is new, or the existing supplier no longer produces the part, then the purchase department has to invite bids from potential suppliers, receive the bids, evaluate the bids, and place a purchase order to the selected supplier. The process flow diagram that depicts the sequence of activities involved in the purchase order generation process can be captured using PROSIM and is shown in Figure 1.

## 3 GENERATING SIMULATION MODELS USING PROSIM

The intelligent support provided by PROSIM reduces the expertise required to design effective simulation models and perform simulation experiments. It provides an environment in which users can develop designs for discrete event simulation models from process descriptions and supports the conceptual modeling activities at various stages of the model design process. PROSIM can be used to support the analysis and design of manufacturing systems, business systems, logistics systems, command, control, communication, and intelligence systems, concurrent engineering systems, service systems, and information systems. It is a critical tool for realizing the monetary benefits of business process re-engineering and activity based costing.

PROSIM has a built-in simulation model design support environment. In other words, it has an expert system programmed to provide expertise at a level comparable to that of a simulation-modeling expert. Process flow diagram constructs, UOBs, objects, and junctions, are required to be detailed within PROSIM in order to generate a simulation model. Consider the *request for bids* UOB in
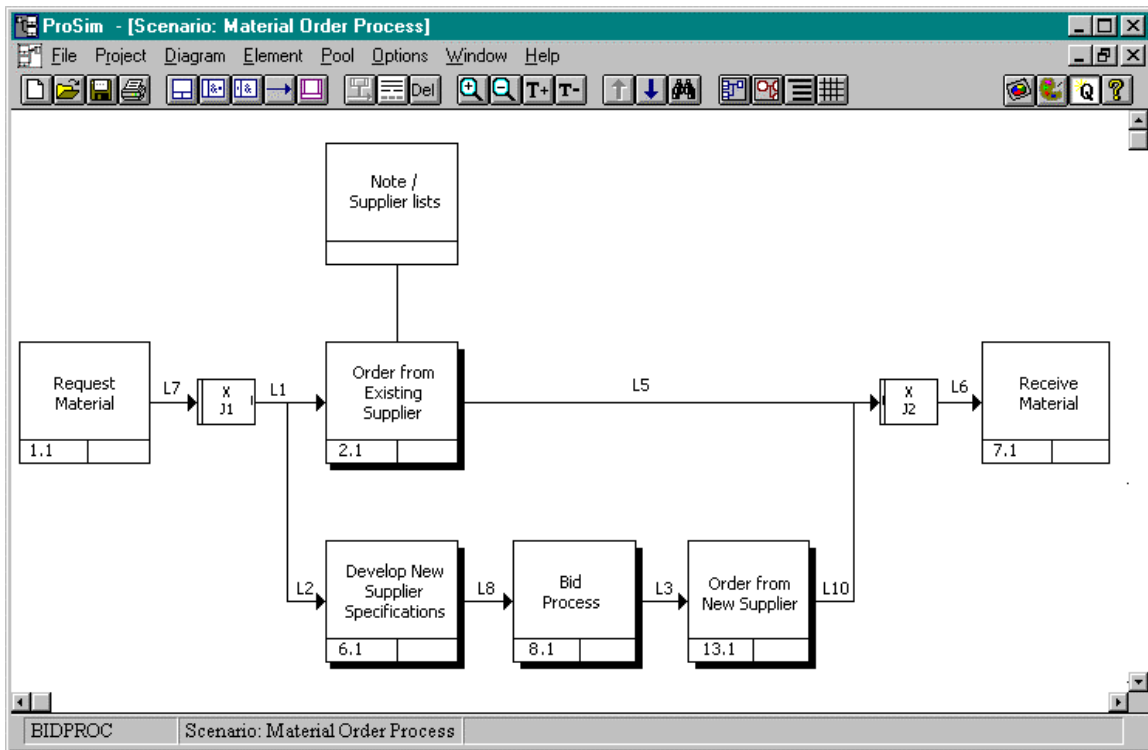


Figure 1: A Process Flow Diagram of the Purchase Order Process

the example process flow diagram in Figure 1. The real world objects that participate in the process of requesting bids are "Technical Package," "Purchase Department Manager," "Potential Supplier List," "Bid Package," and "Building 1." A "technical package" contains the technical data of the part to be ordered. The technical data of the part may include engineering specifications, tolerances, material to be used, special tools and jigs required to manufacture the part. A "Purchase Department Manager" requests a bid by sending a technical package along with the bid package to potential suppliers. The "Potential Supplier List" consists of details of all the potential
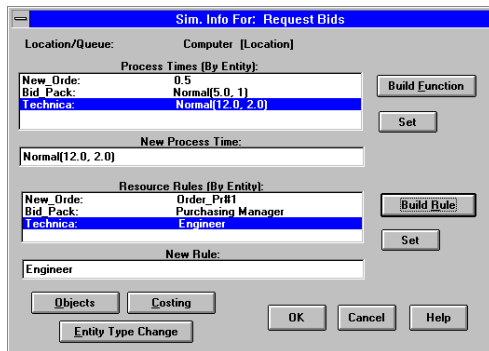


Figure 2: Dialog Box for Detailing a Unit of Behavior

suppliers such as "supplier code," "supplier name," "supplier address," "supplier manufacturing capabilities." The "Bid Package" consists of information about the requirements of the bid responses, financial details, and other contractual details. This activity is performed in the location "Building 1."

In PROSIM, a dedicated resource is categorized as either a *location* or a *queue*. The location label is provided whenever a non-waiting activity is represented by the UOB. If the UOB is used to represent a waiting activity, the dedicated resource is associated as a queue. Flow objects that participate in UOBs are called *entities*.

## 3.1  UOB Detailing

The dialog box shown in Figure 2 is used to record the process times for the *Request Bids* UOB. Process times are recorded for the entities that participate in the process. The names of the entity objects that participate in this UOB are New Material Request Form (labeled "New Order"), "Bid Package," and "Technical Package." The process time for "New Order" is a constant of 0.5 days. The process time for "Bid Package" is a normal random variable with a mean of 5 days and a standard deviation of 1 day. The process time for "Technical Package" is a normal random variable with a mean of 12 days and a standard deviation of 2 days. The Objects such as "computers," "personnel

manager" are categorized as *resources* in PROSIM. Resource objects, as well as other objects, can be shared between different UOBs in a PROSIM model.

## 3.2  Entity Detailing

Entities flow between UOBs in a scenario. The inter-arrival time distribution is an item of information required to simulate the behavior of entities in a system. Figure 3 displays how the details of "New Material Request Form" are recorded in a PROSIM model. Observe that the inter-arrival time for this entity is a negative exponential random variable with a mean of 10.0 time units. The arrival point is the first process visited by the entity as it flows through the scenario.
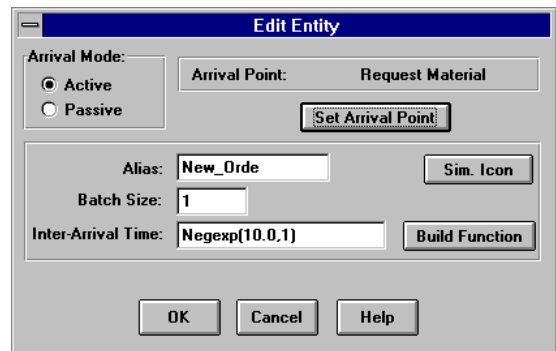


Figure 3: Entity Detailing

## 3.3  Decision Logic Specification

Junctions in PROSIM provide a mechanism to specify the logic of process branching. Different junction types are supported in PROSIM to aid in capturing the semantics of branching in real-world processes (Figure 4). Junctions support the description of 1) a process that splits into two or more process paths, or 2) two or more process paths converge into a single process. Junctions are classified in three different ways. First, they are classified according to the logical semantics involved: *AND* (&), *OR* (O), and *exclusive OR* (X). Junctions are further classified as either *fan-in* or *fan-out*, based on whether they represent a *convergence* or a *divergence* in the logic of the process description. They are also classified based on the coordination of the timing of the associated UOBs as either *synchronous* or *asynchronous* (KBSI 1992b).

An exclusive OR (X) junction is used to model decision logic. In our purchase order processing example, an exclusive OR junction is used to represent the logic that activity "request material" is followed exactly by one of the following two activities: 1) "order from an existing

supplier", or 2) "request bids from new suppliers" with probabilities of 0.8 and 0.2, respectively (Figure 5).
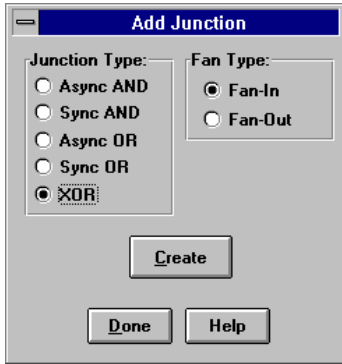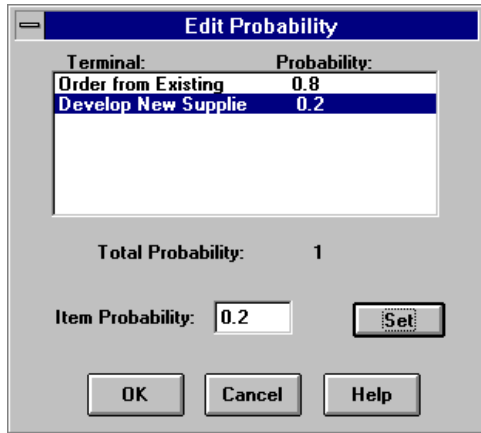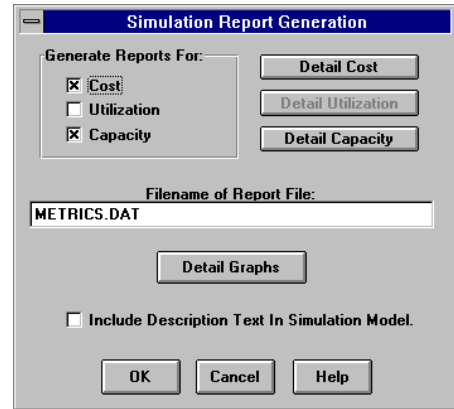
Figure 4:  Adding a Junction
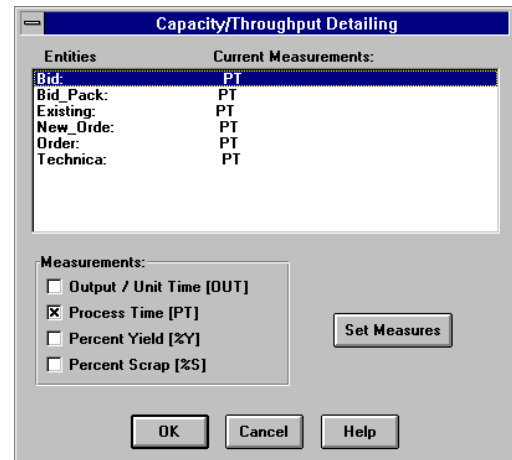
Figure 5: Junction Detailing

## 3.4  Performance Metric Specification

The goal in designing a simulation model is to generate data to answer a set of questions.  Examples of questions include, "What is the total process time?", "What is the resource utilization?".   PROSIM provides support for designing instrumentation to help answer these questions. In other words, PROSIM helps you select appropriate performance metrics that will automate the generation of output data to answer the questions.  For example, the performance metric used to answer the first question is *Process Time* for the UOBs "preparation of bid package," "preparation of technical package," "filling in new material request form," and "filling in the repeat material request form."   The PROSIM dialog boxes used to specify these performance metrics are shown in Figures 6 and 7.

Figure 6: Simulation Performance Metrics Specification

Figure 7: Metrics to Compute Process Time

## 3.5  Model Verification

In the context of PROSIM, model verification is defined as the process of ensuring that the minimum amount of information required to generate a WITNESS simulation model exists in the process model.  Model verification is performed using the *Model Verification* option in the Diagram menu in PROSIM.  A more detailed description is given in the *PROSIM User's Manual and Reference Guide* (1997).

## 3.6  Simulation Model Generation

PROSIM simulation model design specifications are now transformed to an equivalent representation in the WITNESS Command Language.  This is done by using the *Build Simulation Model* option in the PROSIM File menu.

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After the model has been generated, the next step is to open the application and load the model using the *Read Commands* option in the Model menu (see Lanner Group 1997). After the WITNESS model has been loaded, the user can run the model and generate the desired performance metrics. WITNESS provides state-of-the-art capabilities for simulation-based analysis and experimentation. An analyst knowledgeable in the WITNESS language may customize the PROSIM-generated model if necessary.

A unique feature of PROSIM is the ability to generate multiple simulation models from one process model. The value of this capability is immediately obvious when one realizes that there is no such thing as "the" simulation model; each model is built to answer specific questions. PROSIM not only permits a hierarchical process description but also allows simulation model to be generated at different levels of abstraction. In other words the user can specify whether to include activities contained in the decomposition of a high level activity (UOB) in the simulation model. For an initial analysis the process may be simulated at a high level and finer level of granularity may be specified for a more robust simulation later on.

In addition to simulating a process at different levels of abstraction, PROSIM allows the user to generate two different types of simulation models: Location-constrained, and Activity-centered. In the former, PROSIM Locations, e.g., desk, department, machine, etc., are the focus of the simulation and an Entity may visit the Location several times to participate in the different Processes that occur at that Location. In the later approach, there is a one-to-one relationship between Processes, i.e., UOB, and Machine in WITNESS. A unique conceptual Location is created and assigned to each Process to build a process-centered simulation. During simulation, an Entity makes multiple visits to a Machine only if it participates in the same process more than once. Physical locations, such as desk, department, and machine, are modeled as Resources if they are a constraining factor. The Location quantity should reflect the number of parallel activations of the Process. In the case of unlimited parallel activations, the Location quantity should be at least equal to the maximum number of Resource available for performing that Process. This latter approach is useful in activity-centered analysis, which requires answering questions such as "Which activity (or process step) is the bottleneck in the purchasing process?"

## 4  MANAGING PROJECS USING PROSIM AND PROJECTLINK

PROJECTLINK (KBSI 1997b), an add-on module to PROSIM, enables information in a PROSIM process model to be leveraged for analysis using a project management tool, e.g., MS-Project. PROJECTLINK facilitates an alternative approach to process analysis since a detailed simulation-based analysis is often unnecessary in order to obtain an estimate of metrics such as resource utilization. Static analysis using the resource leveling function in project management tools may be adequate for identifying resource contention problems resulting from the process design. Additionally, Critical Path analysis may help identify process steps that need to be performed in parallel with other activities so that the overall cycle-time is reduced. A link between process modeling and project planning is also useful during the implementation of large, perhaps infrequently occurring processes such as a shuttle-launch at NASA.

Since PROJECTLINK is a two-way bridge between process modeling and project planning, it gives rise to other useful and interesting possibilities. Project planning analysis can identify limitations and mandate changes to the project plan. The resulting changes can then be brought back to the process model in PROSIM. Alternatively, an existing project plan can be imported into PROSIM for performing dynamic analysis using the PROSIM-generated WITNESS simulation model.

The implementation of PROJECTLINK makes the exchange of information between a process model and project plan (in either direction) transparent to the user. In most cases, only one piece of additional information is needed to go from a process model to a project plan: the user selects one path from the options available at each "OR" or "XOR" junction. The process model is then exported using the Export menu item in the File menu. PROJECTLINK is then activated from the Launch Application menu item. A file containing the project plan is generated in the Microsoft Project Export format (.MPX file) and the project management tool is launched using this file. Figure 8 shows the PROJECTLINK-generated project plan for the Purchase Order process model described earlier.
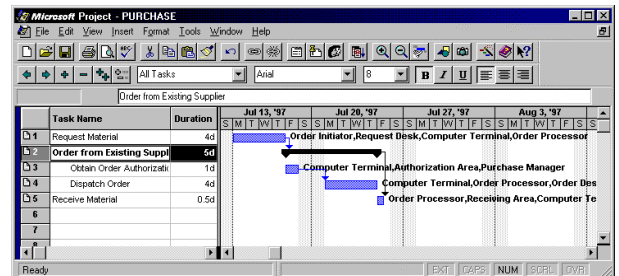


Figure 8: A Project Plan of the Purchase Order Process

Converting a project plan into a PROSIM process model is just as easy to do. The file is saved in the .MPX format and PROJECTLINK is launched by selecting the "Launch ProjectLink" menu item (appended to the Tools menu in MS-Project during installation.) When bringing in

a project plan into an existing process model the user has the option of merging the changes with the older process model, or creating a new process model.

## 5 IMPROVING PROCESSES USING PROCESS DESIGN ASSISTANT

The most recent extension to PROSIM is the Process Design Assistant (PDA): a knowledge-based design assistant that facilitates process design by analyzing process models for consistency, completeness, and potential improvement opportunities (KBSI 97b). A process designer can use the PDA to diagnose possible errors in the model and identify areas for improvement. Given a process model, PDA will check whether the information is complete and consistent with respect to the process design intent. It performs different kinds of qualitative and quantitative analysis and produces a variety of metrics that are useful for process improvement and re-design.

PDA consists of a repository of rules that can be executed on selected process models. Each of the rules checks for some desired feature of a complete, comprehensive and valid process model. PDA was developed in a manner to facilitate addition of new rules and customization of how the rules are organized. The screen below provides a means to organize, manipulate, select and execute rules. The rules in PDA are organized into two classification schemes: based on Rule Class and based on Rule Domain. Rule Domain refers to the domain of application such as BPR, CPI, lean logistics, concurrent engineering, CALS/EDI, etc. Rule Class refers to the basic rule types such as completeness, consistency, cycle-time improvement, quality improvement, coordination, metrics, etc. These two classification schemes are used to help browse through the rules and select the most appropriate rules for execution. The PDA rules may be customized for different domains by indicating which rules classes are relevant.

During execution the user simply selects the process model to be analyzed and selects the set of rules to be executed as shown in Figure 9. PDA executes all selected rules sequentially on the selected process models and identifies the problems or potential improvement opportunities with the selected model. The analysis results are displayed as shown in Figure 10. PDA also contains an Agenda Manager, which can be used to keep track of the tasks to be performed to fix problems with different process models. PDA analysis results can be automatically updated as action items in the Agenda Manager for the selected process model.
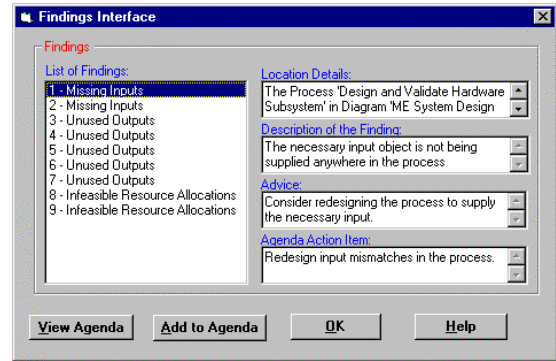
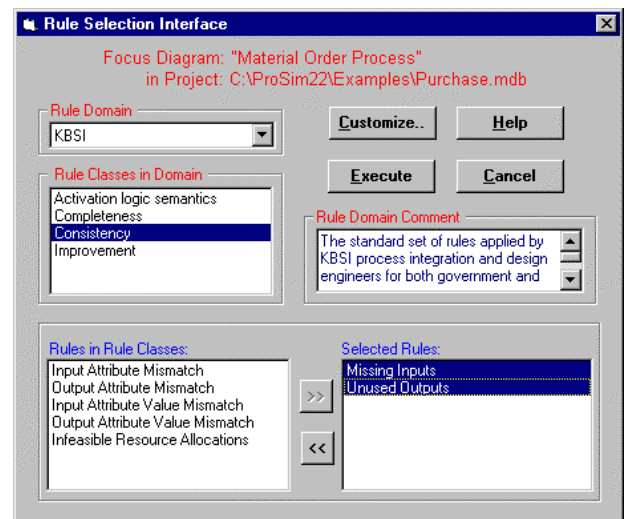Figure 9: Rule Selection in PDA

Figure 10: Results from a PDA Process Analysis

## 5 POTENTIAL BENEFITS OF USING PROSIM

PROSIM provides an integrated approach to enterprise process engineering through the integration of: 1) modeling methods with performance analysis methods, and 2) qualitative and quantitative techniques. As a simulation model generator, PROSIM has the following potential benefits: 1) it enables novice simulation modelers to develop and use complex simulation models, 2) it encourages and promotes the use of simulation as a decision support tool among a wide group of users from a variety of application domains, 3) it substantially reduces time and effort needed to develop simulation models, and 4) it facilitates the capture and retention of simulation model design rationale.

# 6    SUMMARY

This paper described salient features of PROSIM, a knowledge-based tool for process engineering.    An example of purchase order processing system is provided to demonstrate the procedure of building process models from domain experts' descriptions and then generating a simulation model from this process model.  The paper also described extensions to PROSIM including PROJECTLINK a two-way bridge between process modeling and project management tools, and a Process Design Assistant to facilitate improved process design.

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## AUTHOR BIOGRAPHIES

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