PLATO Helps Athens Win Gold: Olympic Games Knowledge Modeling for Organizational Change and Resource Management

D. A. Beis
Technology Division, Athens 2004 Olympic Organizing Committee (ATHOC), International Olympic Broadcasting Building, 37 Kifisias Avenue, 15123, Marousi, Greece, dabeis@athens2004.com

P. Loucopoulos
Information Systems Group, School of Informatics, University of Manchester, Manchester M60 1QD, United Kingdom, p.loucopoulos@manchester.ac.uk

Y. Pyrgiotis
Athens 2004 Olympic Organizing Committee (ATHOC), Greece, ynp@otenet.gr

K. G. Zografos
Transportation Systems and Logistics Laboratory, Department of Management Science & Technology, Athens University of Economics and Business, 47A Evelpidon Street, 11362 Athens, Greece, kostas.zografos@aueb.gr

Planning, designing, and implementing systems to support venue operations at the Olympic Games is complicated. The organizing committees must create designs that result in reliable, high-quality venue operations at reasonable cost. The organizational backdrop is unique. The organizing committee has a limited lifetime, it has no organizational memory, any learning disappears with its dissolution, and during its lifetime it must change rapidly from a function-oriented entity to a process-oriented one. The Athens 2004 Olympic Games Organizing Committee (ATHOC) used innovative techniques from management science, systems engineering, and information technology to change the planning, design, and operation of venues. We developed the Process Logistics Advanced Technical Optimization (PLATO) approach for the games. In the PLATO project, we developed a systematic process for planning and designing venue operations by using knowledge modeling and resource-management techniques and tools. We developed a rich library of models that is directly transferable to future Olympic organizing committees and other sports-oriented events. The direct financial benefit to ATHOC was the reduction of the costs of managing venue operations by over $69.7 million. The success of the games raised Greece's international profile in terms of capabilities in managing large and complex projects which, in the medium to long term, will yield financial, political, and social benefits. Internationally, the PLATO legacy of its Olympics knowledge base will enable future organizers of large-scale events to reuse and customize the knowledge to gain benefits and reduce the financial burdens on governments and society.

Key words: decision analysis: systems; simulation: application.

In the Athens 2004 Olympic Games, in 16 days, over 2,000 athletes from 28 different sports took part in 300 events across 36 venues located in the greater Athens area. They were watched by 3.6 million ticketed spectators, 22,000 journalists and broadcasters, and 2,500 members of international committees. The Athens games had an accumulated 34.4 billion global viewing hours, 1 billion more than those in Sydney. The Athens Olympic Games was the biggest sports event to date.

With a budget of $2.5 billion for the Athens Olympic Games Organizing Committee (ATHOC)

and $5.5 billion for the Greek government, and a workforce of over 130,000, including security personnel, the committee's task was to ensure the efficient and effective management of the games in all competition venues (stadia, competition halls, courses, and so forth) and to coordinate them with noncompetition venues (the airport, the Olympic village, and other facilities) and the city's infrastructure (such as transportation and city operations).

ATHOC had to plan, coordinate, and design systems for the 36 venues that would be delivered by

26

external contractors, operated by volunteers and paid staff, and managed by ATHOC personnel.

ATHOC needed a holistic solution to the problem because of the interdependence of processes, actors, and venues. The PLATO project's focus was not a single localized problem requiring optimization but rather a wide spectrum of problems requiring the development of methods, techniques, and tools to achieve the following objectives:

(1) To facilitate effective organizational transformation,

(2) To help decision makers plan and eventually manage resources in a cost-effective manner, and

(3) To document knowledge about Olympic Games venue operations formally so that ATHOC and future organizers can reuse it effectively.

The PLATO project was launched in the summer of 2001 by ATHOC's technology directorate with the endorsement of its board of executive directors. Over the subsequent 2.5 years, the PLATO project focused on competition venues and related issues, such as managing the accreditation of authorized personnel, transporting athletes, spectators, and other people, coordinating volunteers, and managing city operations around venues. The project involved experts in modeling, simulation, and information technology who worked together with stakeholders (persons from the 27 ATHOC functional areas).

In summary, the PLATO project

—Developed business-process models for the various venues,

—Developed simulation models that enabled generation of what-if scenarios,

—Developed software that assisted in the creation and management of these models,

—Developed process steps that guided ATHOC personnel in using the business-process and simulation models, and

—Developed generic solutions to transfer knowledge about venue operations across ATHOC and potentially to other users.

A dedicated team of model developers worked with members of most functional areas within ATHOC to develop and validate all simulation models. ATHOC used models extensively to design venue operations and to determine the resources they required. PLATO delivered over 25 venue-specific models, six noncom-

petition venue models, and 18 generic models that describe processes common to all venues for large-scale sports events.

Defining the Problem

We use the term *venue operations* to mean the systems, actors, and procedures in a venue (a competition venue or a support venue) within spatial and temporal constraints for different types of service to different types of customer groups.

The competition venues were the stadia in which sport events took place, categorized as simple or complex. A complex venue consisted of two or more individual competition arenas. The noncompetition venues were the Olympic village, accreditation centers, training grounds, the international broadcasting center, and the main press center.

Different functional areas of the organizing committee managed the services in each venue for such customer groups as spectators and athletes.

Venue operations are characterized by

—An extraordinary volume of demand for services to be provided in a very short period of time (within 16 days),

—Demand that must be accommodated within specific time windows (with no allowance for delays or postponement of sessions),

—A large variety of types of service to support many customer groups with specific requirements.

—Demand for services that has a spatial distribution (many venues for all customer groups), and

—Demand for services that has a temporal distribution (many sessions at different venues for all customer groups).

Designs for systems supporting venue operations must address functional requirements (the resources and procedures for their management) and nonfunctional requirements (the quality of the service provided) (Figure 1). In a generalized abstract sense, we can express the problem as follows:

Given the temporal and spatial distribution of demand generated by the needs of the various customer groups to participate in a variety of sessions (temporal dimension of demand) that take place at various venues (spatial dimension of demand), provide the system infrastructure needed to achieve a desirable level of service at an acceptable cost.
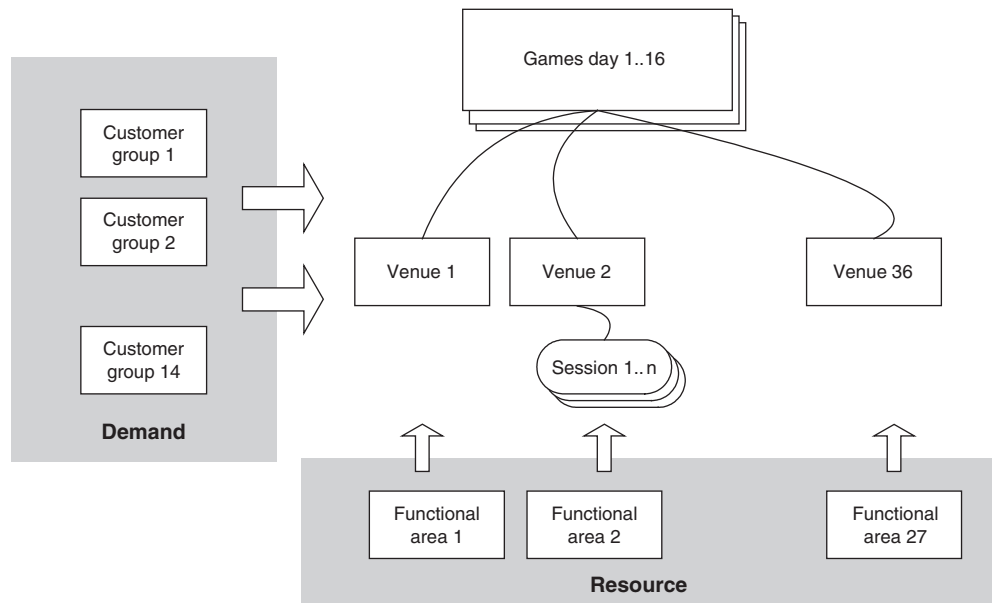
Figure 1: For each competition day, customers from 14 different groups imposed demands for service provided by one or more of the 27 functional areas.

The complexity of venue operations increased as the variability of demand increased. For example, many stakeholders were involved in coordinating the processes concerned with spectator services; for large venues, over 100 factors influenced the way a venue could operate.

The 14 customer groups all had different requirements and relied on different business processes. We tackled the problem by delineating interplay between participation, service type, and functional areas (Figure 2).

To describe participation, we had to identify and describe all customer groups' processes; for example, the processes for spectators included security-stop checking, ticketing, merchandising, and withdrawing money from cash machines. These processes functioned according to an agreed level of service; for example, a person queuing for security checking should not wait longer than three minutes. The level of service achieved depended on allocating adequate resources to that process; for example, by allocating 20 mag-and-bag security gates to a venue entry. Finally, to manage the resources, we coordinated functional area processes; for example, by allocating volunteers and security personnel to security gates.

The Traditional Approach and Its Shortcomings

Previous olympiads used peer-to-peer transfer of knowledge in structured stakeholder workshops. ATHOC used this method in the early stages of developing a prototypical design for the Peace and Friendship Stadium (SEF). It intended to use the findings from that prototype as an exemplar for all other venues. The outcome of the effort, which lasted six months, was voluminous documentation expressed in text and tables and the consumption of substantial resources (2,600 person/days) for just one of the 36 venues.

The traditional approach relied heavily upon stakeholders' workshops, brainstorming sessions, and focus-group discussions, using text documents and architectural diagrams of the various venues. These workshops facilitated the exchange of knowledge among the functional-area representatives, but the architectural and topographical designs, used as a common reference model, imposed constraints on thinking about providing customer-oriented services and led to loss of generality and a focus on specific operations taking place at individual venues. The resulting voluminous documentation made it unlikely that stakeholders would come to proper agreement,
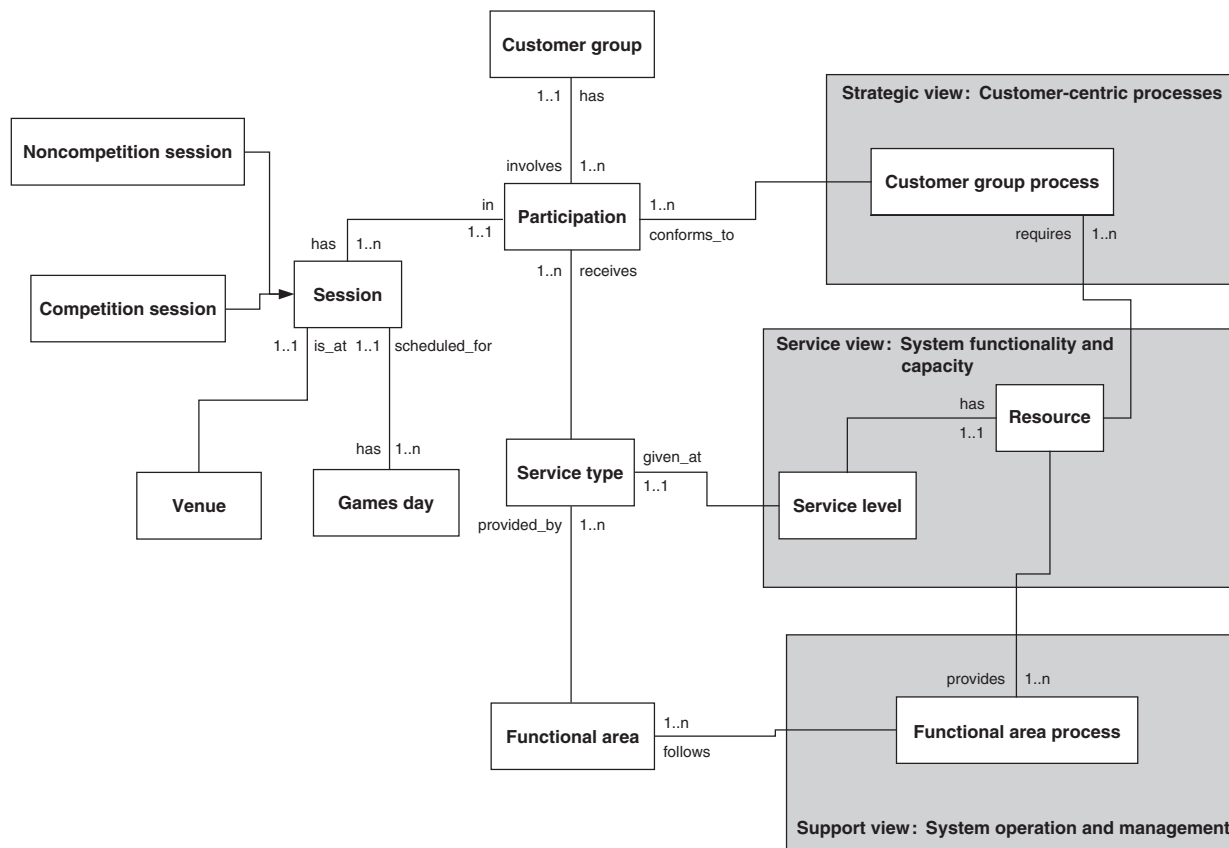
Figure 2: We delineated the relationship between customer group participation and service provision in the various functional areas.

associate resources with a required level of service, and coordinate implementation.

We evaluated the effectiveness of the traditional approach for ATHOC at the end of the prototypical design phase. We concluded that ATHOC needed a more systematic and systemic approach. The perceived shortcomings were (1) a costly planning and design process, (2) lack of understanding of the potential cross-functional influences, (3) lack of proper analysis for quantifying resources and expected levels of service, and (4) lack of generality and transferability of knowledge and expertise within ATHOC and to future potential users.

The PLATO Approach

The PLATO project consisted of three interrelated modeling activities: goal modeling, business-process modeling, and scenario modeling.

We used goal modeling to develop an understanding of stakeholders' goals for the intended systems, synergies between these goals, and contradictions and overlaps. Goal modeling facilitated our identification of key choices and objectives and potential costs and benefits. In PLATO, we exploited techniques from requirements engineering on elicitation (Loucopoulos 2004), representation (Kavakli and Loucopoulos 2005), negotiation (Easterbook 1994), and validation (Leite and Freeman 1991) of stakeholders' objectives. We analyzed these objectives to define the relationship of these objectives to functional and nonfunctional requirements for the intended systems.

We used business-process modeling to represent in a consistent and unified way knowledge pertinent to the application at hand. With business-process modeling, we focused our analysis and design on the value chain of customer groups and moved away from
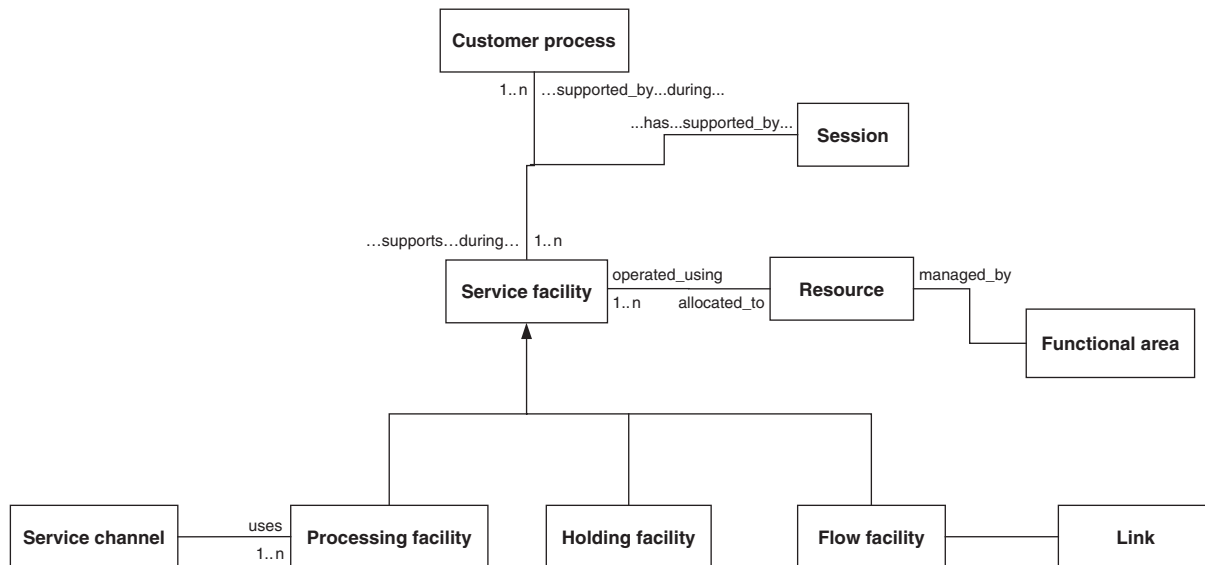
Figure 3: In PLATO, we considered processing, holding, and flow facilities. Each type of facility supports customer services offered by the relevant functional area(s).

thinking in terms of functions toward thinking about venues and organizational transformation. We based the business-process modeling on system dynamics (Forrester 1961, 1993, 1994; Sterman 2000).

We used scenario modeling to encourage group brainstorming, helping participants to imagine alternative solutions and envision how systems would behave (van der Heijden 1996, Moriarty 1998, Carroll 2002). We used scenario modeling to test models through simulation, which helped stakeholders to gain confidence about their choices with respect to levels of service and resource needs.

The complexity of venue operations (which include people's arriving by various modes of transportation, walking from the venue perimeter to the entrance gates, forming queues in front of the security gates, passing through security screens, walking inside the venue to take part in a wide spectrum of activities, such as, eating, shopping, and using an ATM, walking to the venue gates, and arriving at their assigned seats) did not allow for analytical queuing-theory modeling.

The simulation the PLATO team developed was based on a metamodel (Figure 3). Central to the simulation-modeling process was the concept of *service facility*, which we defined as the physical location and the associated resources provided by various

functional areas, that is, technical, human, and infrastructure. We considered three types of facilities: processing facilities, holding facilities, and flow facilities. In processing facilities, particular service processes, such as security or accreditation, took place. In holding facilities, such as lounges or locker rooms, various customer groups gathered. In flow facilities, customer groups moved between various venues' holding and processing facilities.

PLATO in Practice

PLATO experts developed 25 venue-specific models, six noncompetition venue models, and 18 generic models for use by members of ATHOC functional areas and venue managers. Hundreds of stakeholders throughout ATHOC who were responsible for planning, designing, and managing venue operations developed and used the models.

We developed the PLATO models in the following way:

(1) Expert knowledge modelers, working with stakeholders, developed an initial set of goal and business-process models for a given problem application. PLATO experts created visual descriptions of these models using appropriate software tools, for example, the map facilities of the iThink software system (Kreutzer 1990/1991).

(2) Representatives of all stakeholder sections reviewed and critiqued the models. PLATO employees developed story lines for the business-process models to lead stakeholders gradually through the complex business processes.

(3) If necessary, we revised the models and conducted further workshops until all participating stakeholders reached agreement about the business processes and their overall goals for support operations for these processes.

(4) Expert modelers developed computer-based simulation components for the business-process models with interfaces to help stakeholders use them.

(5) An expert modeler facilitated stakeholders' workshops to use the simulation components to create scenarios. Using simulation techniques, the stakeholders could then test their assumptions and observe their effects on their parts of the system. They could also see how their decisions would affect other functional areas.

(6) We tested the PLATO models and the assumptions we used, particularly regarding the simulation parameters, by collecting and analyzing data from sports events (known as test events) that took place in Athens from 2002 to 2003. During the test events, we used integrated measures to gather data for arrival and service patterns for a variety of processes. We used the values obtained to update the assumptions for the PLATO model (ATHOC 2003).

(7) We finished the PLATO models and based on them, made decisions about the resources each venue would need.

The Athens Olympic Stadium Complex

Spectators could enter and exit the complex at five points (see Figure 4). Once inside the complex, they could enter an individual venue or wander in the common area to visit various services (ATMs, catering outlets, information booths, and shops).

The transportation division created profiles representing the arrival and departure patterns (Figure 5) for the Athens Olympic stadium complex (OAKA) based on the daily competition schedules and the attendance patterns (number of spectators at various times) for the same types of sports events at previous Olympic Games. It derived the temporal and spatial distribution of demand based on the expected allocation of demand to the various transport modes (metro, train, bus, walkways) serving OAKA, and their schedules.
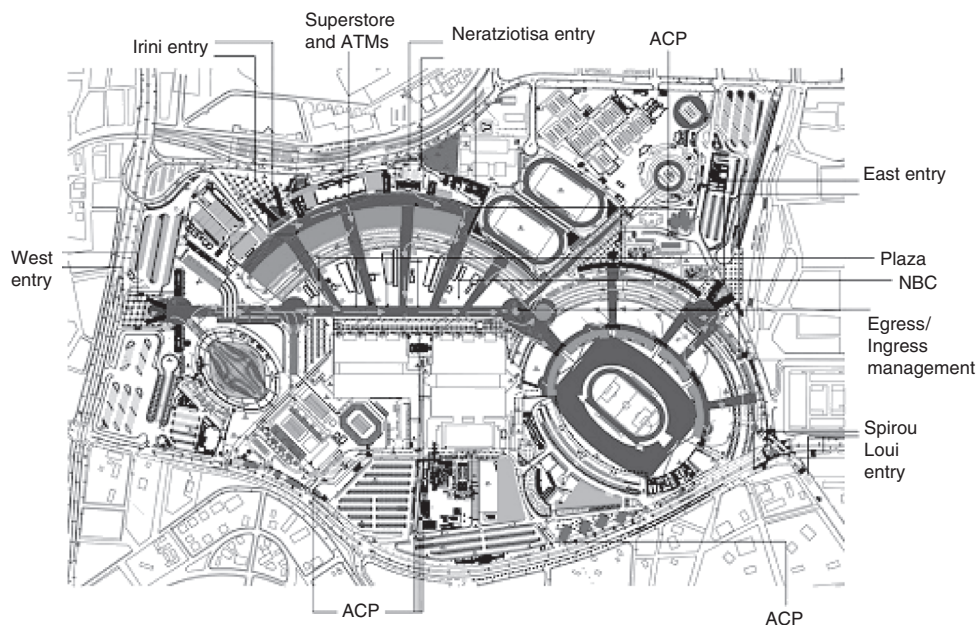

Figure 4: The Athens Olympic stadium complex (OAKA) contained the main athletics stadium, an indoor stadium, the velodrome, the aquatics center, and the tennis center.

For example, we based the arrival pattern profile for August 20, 2004 (Figure 5) on the assumption that 50 percent of the spectators would travel by metro, 10 percent by railway, 15 percent by buses arriving at the eastern terminal, 15 percent by buses arriving at the western terminal, and 10 percent by foot.

The arrival pattern represents the distribution of demand over time at the unloading areas for the different modes of public transportation and the demand for pedestrians. We defined the arrival pattern as the volume of passengers in 15-minute intervals, which is a parameter in the model (users could change it to any other time interval). For the departure pattern, we assumed a similar distribution of volume of spectators across the five modes of transportation, but the flow is the direct outcome of the modeled behavior of spectators during the time they are inside OAKA.

The arrival patterns at the processing facilities beyond the unloading areas were influenced by (1) the
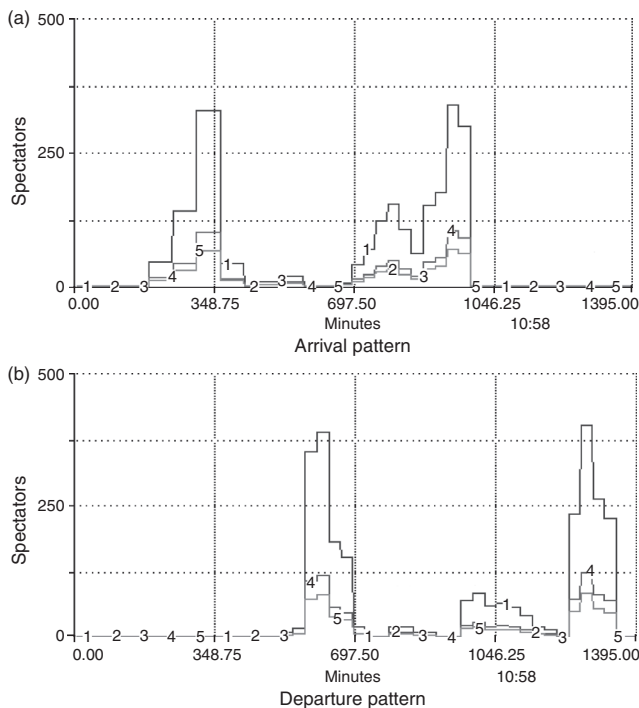

Figure 5: We estimated the arrival (5a) and departure (5b) profiles at the five transportation unloading and loading areas for the Athens Olympic complex based on the schedules and attendance patterns at previous Olympic Games.

arrival pattern of spectators at public transportation stations (Figure 5) and (2) the filtering that took place at the service facilities based on service rates. We represented pedestrian movements throughout OAKA by pedestrian-stream models using flow, speed, and density equations (Transportation Research Board 2000).

Goal Modeling

In eliciting the goals for this complex venue operations system, we tried to understand what determined its successful operation. To do this, we helped stakeholders to state their (sometimes implicit) goals and combined that knowledge with information from other sources, such as existing documentation and abstract descriptions of various systems and procedures.

To deal with the complexities of eliciting goals, we progressed in a stepwise, iterative manner, starting from high-level, sometimes fuzzy goals. We then elaborated on these goals with the help of the functional areas affected by them.

Using goal modeling, we coordinated different stakeholders' requirements, which could be compatible or often incompatible. For example, a high-level goal of Spectator Services was to move spectators out of the venues efficiently immediately after sporting events ended, whereas Merchandising wanted to attract spectators to merchandising outlets for some time after sporting events ended. We quantified the two goals as follows: to vacate the common area within 45 minutes of the end of an event and to achieve sales of up to 15 percent with a mean wait time of less than 12 minutes.

Business Process Modeling

We operationalized goals by modeling the business processes in detail (Figure 6).

As part of our systemic approach, we analyzed the impact the processes had on all stakeholders. This holistic view resulted in a model involving 384 microprocesses with 110 user-definable parameters that enabled all stakeholders to visualize alternative scenarios. The evident complexity of this problem arises not so much from voluminous information but rather from the intricate relationships between these microprocesses and the policies that control them. We made all of these intricacies explicit in the PLATO model.
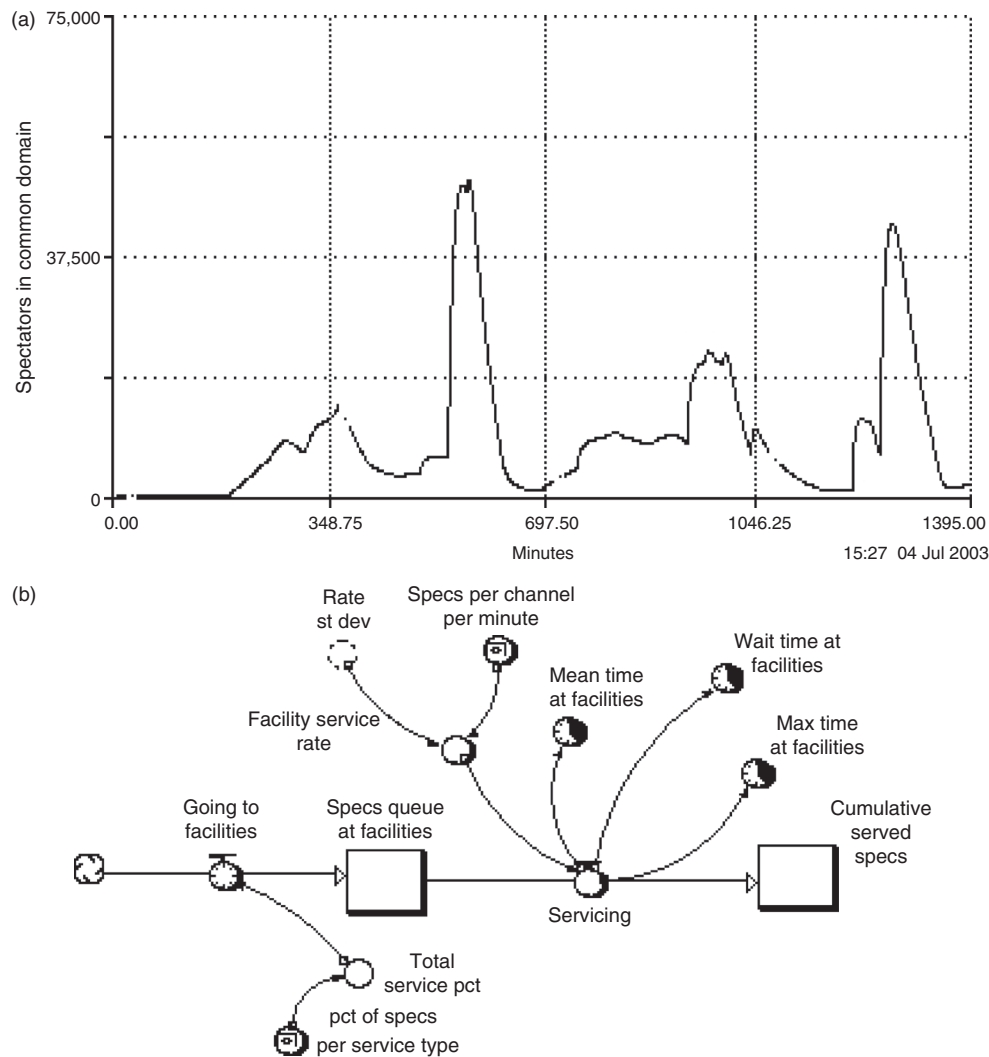
Figure 6: This fragment of the business-process model shows two processes in which spectators are involved, "arriving at transportation terminals" and "walking towards the entrance gates." We represented processes as "pipes" along which spectators flow and their rate of progress by "valves," which are driven by factors such as the facility service rate. The lines leading outward from the valves represent information feedback by which the states of the stocks are used in policy implementation. For example, we used a pedestrian-flow model on the geometrical characteristics of the flow facilities, that is, the path length and width, and the desired level of service in terms of the density and speed of the pedestrian stream. We used international standards defining pedestrian-movement level of service (Transportation Research Board 2000, DeNeufville and Odoni 2003).

Nothing was hidden or left to intuition. All the people responsible for designing OAKA operations shared the model.

The demand is determined in part through the percent of spectators per service type, a variable that expresses the number of spectators expected at each type of service facility per unit of time as a percentage of total spectator presence. Total spectator presence depends on overall spectator behavior in the venue area, which interacts with this model fragment through a number of feedback loops, which results in a profile of potential spectators in the common area where services are located (Figure 6).

The supply is determined by two parameters: the number of service channels available (for example, 10 stands selling food) and the service rate expressed

as spectators per channel per minute service rate (for example, two spectators served per service point per minute). According to this representation, spectators arrive at the service facility and are served following a normal distribution. We defined the values of the normal-distribution parameters based on previous experience and subsequently validated them with data collected during the test events.

Scenario Modeling

Generating different scenarios concerning each problem studied and simulating the scenarios with the help of the process models developed helped stakeholders to reach consensus about the level of service desired and the resources needed. As we were developing the models and the stakeholders were becoming aware of the different factors influencing each

problem, the range of possible values for each of these factors became evident, giving us starting points for different scenarios.

For example, in the components of the system model that dealt with services (such as ATMs, merchandising, and catering), we had a plethora of stakeholder-defined assumptions regarding the properties of the distributions used to describe the demand and service patterns. In PLATO we developed a multitude of models corresponding to a great variety of service processes and covering a wide spectrum of demand and service patterns.

We developed a scenario-generation module for each model with an interface that would encourage stakeholders to participate and allow them to describe the parameters of the probability distributions for arrival and service patterns (Figure 7). We defined the
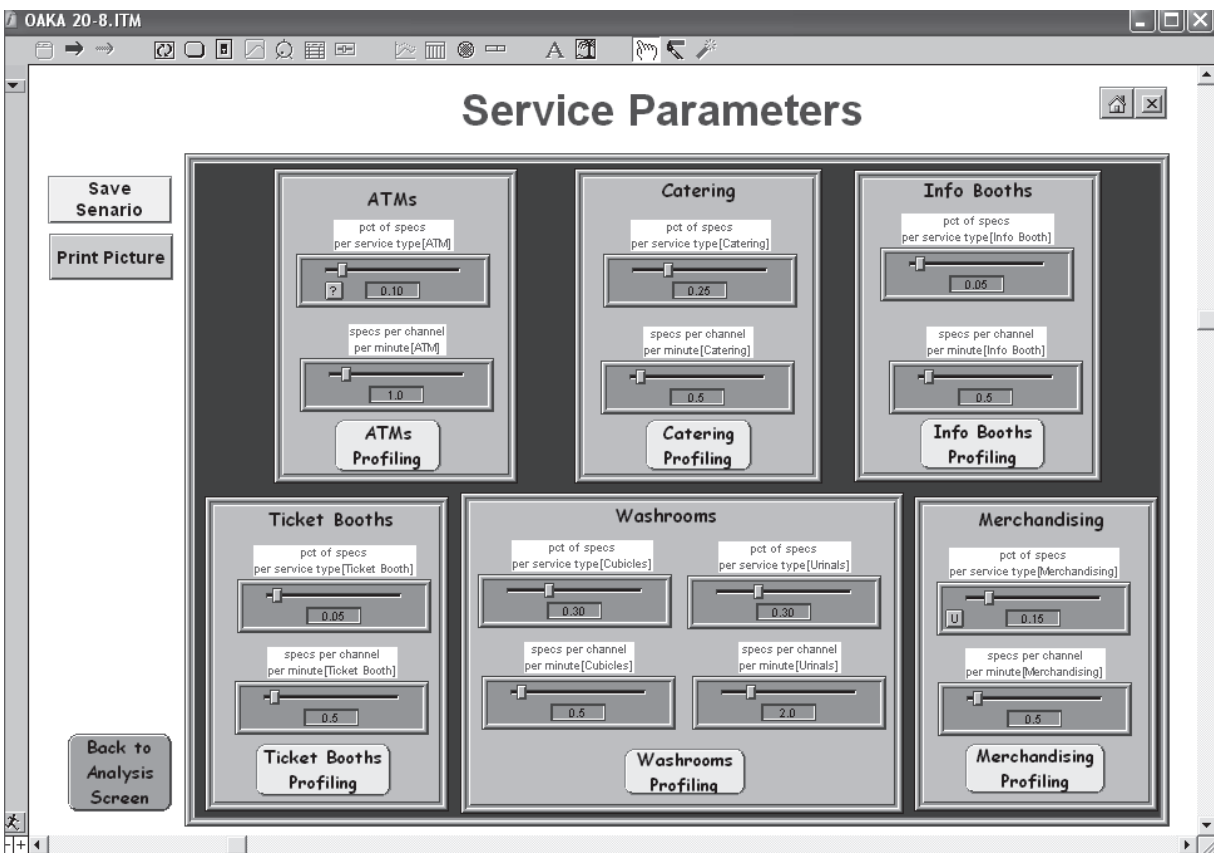

Figure 7: This interface of a scenario for the services sector allows users to define the arrival pattern and service rate for each service facility.

properties of the probability distributions representing the arrival and service patterns based on previous experience (where available) and subsequently fine-tuned them with data obtained during the test events.

PLATO developed similar interfaces and control panels for arrival and departure patterns, for security gates, and for each stadium inside OAKA. The control interfaces enabled users to store scenarios, thus enabling future users to retrieve any scenario from the database later and to reconsider it in the light of new experiences.

The software automatically annotated each scenario appropriately in the database to provide high-level information, such as the date and time of creation, the purpose, and the users. This information enabled users to retrieve a scenario at a future time to examine the assumptions made and the behavior of the model based on these assumptions.

While stakeholders specified some values, PLATO automatically supported other factors. During planning, we considered it prudent to put merchandising facilities in four geographical areas of the stadium. We then had to identify the likely presence of spectators in each geographical area, some percentage of whom (according to each scenario) would visit a merchandising outlet.

We handled this problem in PLATO by incorporating a gravity-type model (Drezner 1996) stating that the relative attractiveness of each geographical area is proportional to the number of facilities in each common area and inversely proportional to the distance to this service facility. We embedded this policy in the structure of the process model (Figure 8). We defined

the attractiveness generically so that the logic was applicable not just to merchandising or to a single sector of the common area but to all services and to all sectors.

In the model, we used the term *service points* to represent the number of service points for each of the seven service types in each of the four sectors of the common areas. We defined these points parametrically so that users could experiment with 28 different combinations of service and common area. In addition, we included in the model the number of spectators in the different parts of the common area given that at any time they could enter the complex, exit the complex, or enter and exit stadia.

This information also formed part of the model and in all models requiring this kind of analysis PLATO automatically calculated this information according to flow-conservation relations (Ahuja et al. 1993) (Figure 9).

We provided further user-defined values within the control interface for specific services (Figure 10). Users receive feedback about all merchandising outlets for all the areas for a given scenario.
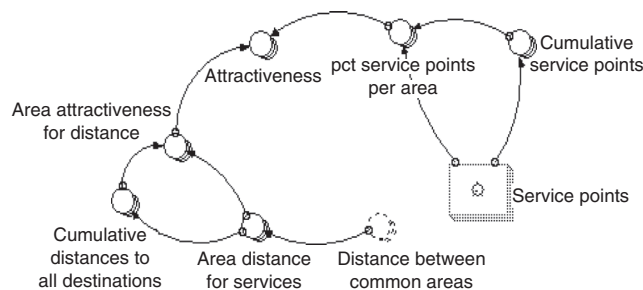

Figure 8: In the venue's common area, there are many different service points that could potentially attract spectators. Part of the process model deals with the concept of attractiveness by incorporating a gravity-type model.
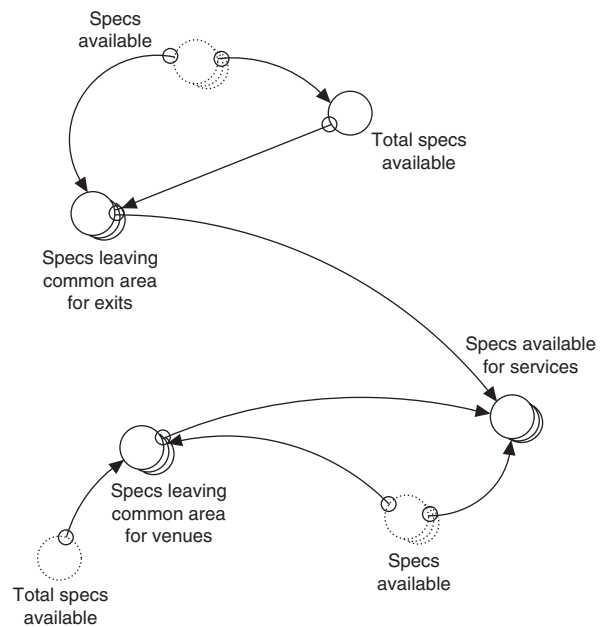

Figure 9: The process model incorporated logic that dealt with the flow of spectators in the common domain. We did this by incorporating a flow-conservation relations model.
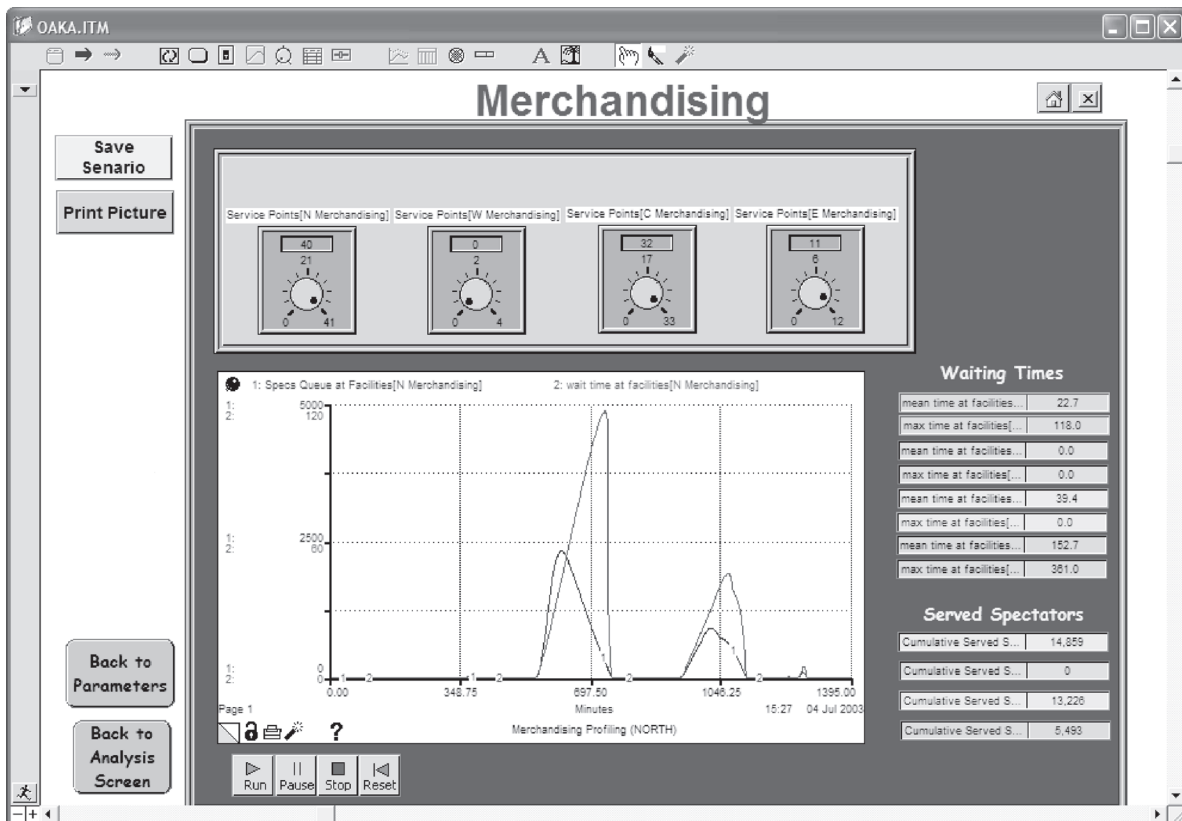
Figure 10: This user interface shows the results of experimenting with positioning outlets and service channels in the north, central, and east sections of the common area. The graph shows the results of the simulation run and particularly the load on the outlets on the north side together with the maximum and mean waiting times for the other sectors. The system allows users to switch between this page and other pages, hidden in this example. The three hidden pages show the results of the experiment for merchandising at the west, central, and east areas.

The simulation system we developed also offers high-level views to enable management to observe the behavior of an entire venue throughout a game day, according to different conditions (Figure 11).

According to the scenario shown in Figure 11, spectators arrive at the Olympic complex during the two hours preceding each competition session and leave the complex during the two hours following the session. The profile for spectator accumulation in the common domain provided useful information about the density of spectators throughout the day and supported decisions regarding crowd management and the layout of spectator service facilities. Decision makers used the provided information to design the OAKA operations to provide smooth operations

on that day. During that day (the peak day of the Olympics), no one reported operational problems.

Generalizing the PLATO Models

One of ATHOC's three major objectives was to impart knowledge about venue operations to the different stakeholders of ATHOC divisions and to future organizers. Indeed, transferring knowledge from one host city to another is a contractual obligation. In the PLATO project, we sought to meet this requirement by developing a library of reusable knowledge components. We developed 18 generic solutions to recurring themes. This library of generic solutions is available for use by future host cities with the guidance of PLATO experts. In the future, we plan to expand this
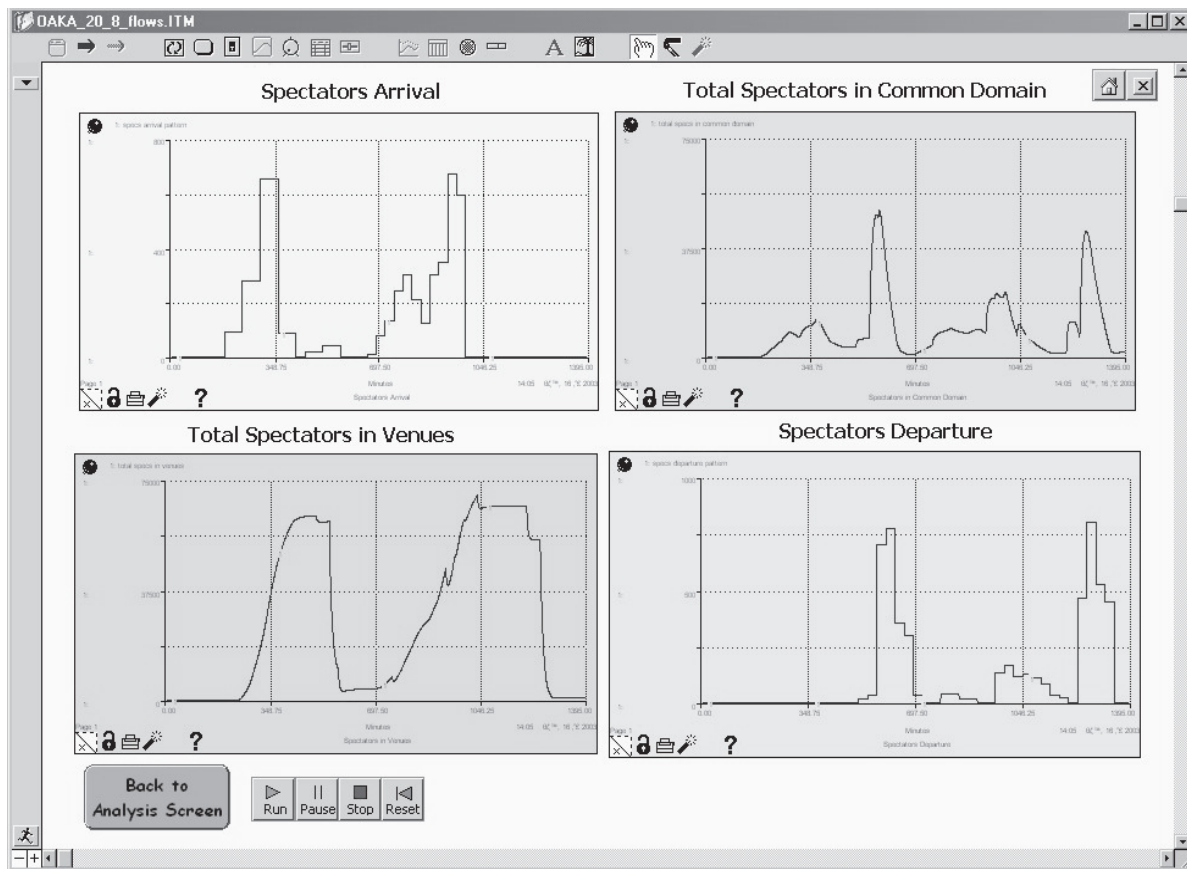
Figure 11: The profile of spectators' behavior for the entire day of August 4, 2004 at four key points of the complex: arrival, presence in the common area, presence inside venues and departure.

library of models to incorporate new information on venue-operations design.

The idea of generic reusable components, usually referred to as patterns, is a very powerful paradigm, and it has been successfully deployed in architecture (Alexander et al. 1977, Alexander 1979), in programming (Vlissides et al. 1996), in program design (Coplien and Schmidt 1995), in software architecture (Buschmann et al. 1996), in data modeling (Hay 1996), and in business-systems analysis (Fowler 1997, Seruca and Loucopoulos 2003).

The PLATO Benefits

Our development and use of PLATO produced many tangible and intangible benefits with far-reaching implications, scope, and beneficiaries (Table 1).

PLATO produced important benefits for ATHOC, for the nation, and for the world. The short-term benefits fall into two categories:

(1) benefits realized during the planning phase of the games, and

(2) benefits realized during the games.

The short-term benefits are associated mostly with ATHOC's management objectives. They include tangible benefits, such as resource savings, improved use of resources, and improved levels of service, and intangible benefits, such as human-resource development, efficient knowledge management, and the establishment of improved operational policies.

The long-term benefits of PLATO accrued mostly at the national and international levels. They include tangible economic benefits arising from improve-

Benefits	During planning	During games	Long term
ATHOC benefits	—Savings from reducing planning and design effort —Savings from reducing construction work —Savings from optimizing the use of infrastructure resources —Savings from optimizing technological resources —Improved knowledge management for planning venue operations —Shift of the organizational culture towards quantitative and fact-based management	—Savings from reducing number of volunteers —Savings from streamlining crowd-support facilities	Not applicable
National benefits	Not applicable	—Positive reporting in international media on management of the games —Worldwide focus on Athens and Greece	—Increase in foreign investments —Increase in tourism —Increase in the competitiveness of Greece to undertake the organization of large-scale events —Human resource development in the area of management
International benefits	—Reduction of planning cost for other Olympic Games organizing committees —Improved knowledge management for other Olympic Games organizing committees	—Improved estimation of resources needed for future Olympic Games	—Contribution to the long-term sustainability of the character of the games —Establishment of academic programs for sport and large-scale-event management

Table 1: PLATO provided benefits during the games and, mostly at the national and international levels, long-term benefits.

ments to the business image of the country organizing the games and intangible benefits related to the reinforcement of the games character, sustainability, and affordability by small and large countries alike.

A methodological difficulty associated with estimating PLATO's benefits stems from the characteristics of the event itself and the characteristics of the organizations that undertake their organization. Differences among the national and city settings for the Olympic Games prevent comparison of the resources required for providing a specific level of service for participants. Thus, we cannot realistically compare the costs of the games in Athens to the costs in other Olympic cities to assess PLATO's contribution to reducing the cost of the games.

A category of benefits for which we can quantify before-and-after costs concerns planning the games without and with PLATO support. In other instances, estimating PLATO's quantifiable benefits depends on reassessing the resources required to organize the games using PLATO.

ATHOC Benefits—Organizational Transformation and Enterprise Integration

The estimated direct financial benefits to ATHOC amounted to $69.7 million. These benefits can be subdivided into (1) savings due to efficiencies in the planning and design processes and (2) savings due to improvements in the decision-making process for managing resources.

Benefits Due to Improvements in Planning and Design

The savings in effort during the planning stages are equivalent to $14.7 million. ATHOC started planning and designing venue operations using the traditional approach and under the guidance of stakeholders and consultants from previous olympiads who acted as facilitators in workshops. PLATO gave participants from the 27 divisions of ATHOC a generic and consistent method that encouraged them to make their mental models explicit and helped them to evaluate their

assumptions, to observe the effects of their decisions on the overall system performance, and eventually to reach agreements based on rational decisions.

We calculated the effort in using PLATO at 645 person-months and the saving in effort at 1,333 person-months. We calculated the savings in effort as worth $14.7 million in salary, calculated at US$11,000 per person-month (including contributions and overhead). We based our estimates of savings on the comparison of the costs of the traditional method and the PLATO approach. We compared the costs by extrapolating to all venues the cost savings calculated for the model venue.

In addition, the PLATO project produced a less tangible major benefit in changing organizational culture. Future committees are likely to continue ATHOC's adoption of a systematic and quantifiable approach to venue operations. Although ATHOC's lifetime was short, its innovative management approach should benefit Olympic organizers for a long time.

Benefits Due to Improvements in the Estimation Process

ATHOC's upper management estimated the total benefits from using PLATO to estimate and allocate resources as roughly $55 million. These savings accrue from (1) reducing the number of volunteers, (2) efficient planning for crowd-support facilities, (3) optimizing the use of technological resources, (4) avoiding construction work, and (5) avoiding purchasing land adjacent to venues.

PLATO contributed substantially to rationalizing resources by providing well-grounded estimates of the infrastructure, technological, and human resources needed, and also, for the first time, an explicit and formal way of exploring trade-offs between resources and the resulting levels of service.

ATHOC used the PLATO simulation module throughout the planning phase of the games to support it in estimating and allocating resources. The types of decisions PLATO supported included the following:

—Screening capital-intensive facility-construction projects by checking the adequacy of existing facilities (for example, evaluating the adequacy of an existing pedestrian underpass and examining a proposal for building a new pedestrian bridge).

—Checking the operational performance of alternative layouts for different functions that affect venue space requirements (for example, for catering facilities and service channels).

—Estimating and allocating human resources for various processes at various venues and estimating the technological resources needed for various processes (for example, the copy machines and personnel needed to produce and distribute games results).

These analyses helped us to save money in three areas. By optimizing the arrival, departure, and entry areas in venues and thus avoid additional construction work, we saved. This optimization also yielded further savings of $6 million due to the avoidance of land purchases around venues. Within venues, savings of $5.8 million were accrued due to the optimized use of technological resources (for example, security systems, results-printing systems, and press-operations support equipment).

We also made substantial savings by planning for efficient use of volunteers, reducing the number of volunteers by 19,000 from the 2000 Sydney Olympic Games. This is a weighted difference between the number at the Sydney Games (65,000 volunteers) and the number at the Athens Games (43,000) taking into consideration the difference in ticketed spectators (5 million in Sydney versus 3.5 million in Athens), and the topology of the venues (greater concentration of venues in Sydney than in Athens). This reduction saved $27.2 million, based on a cost for each volunteer of $1,450 for expenses on uniforms, travel, subsistence, and use of accommodations.

National-Level Benefits

From an economic point of view, the major motivation for a country to undertake the organization of the Olympic Games is to increase its visibility in the international business arena and to become an attractive destination for tourists and business investments. Host cities expect that the accumulation of these long term economic benefits will offset the costs of the games.

Before and during the Olympic Games, the host country is always under the continuous scrutiny of the international community and receives enormous coverage from the international mass media. *Business Week* reported on September 13, 2004 that

the viewership of the Athens 2004 Olympic Games exceeded the corresponding viewership of the Sydney 2000 Olympic Games by more than 10%, attracting more than four billion viewers, while the NBCOlympics.com Web site registered 12.2 million visitors, which represents an increase of 230% over Internet traffic for the Sydney 2000 Olympic Games.

Besides the viewers and the international mass media, other important groups that influence international opinion were the participating athletes, spectators, officials, and visitors to Athens during the games. The image of the country projected by all these groups and the opinion formed by television viewers are major factors for achieving the country's strategic economic objective in organizing the games. An undisputable factor influencing the perception of international mass media is the organizational success of the games, to which PLATO made a major contribution.

The universally accepted organizational success of the Athens Olympic Games was eloquently described by the president of the International Olympic Committee, Jacques Rogge, in his closing ceremony speech "…Athens organized unforgettable games, dream games." The consensus of the participants and observers worldwide was that the Athens 2004 Olympic Games were an unqualified success in every aspect of planning, organization, and operation. As a result, we expect further long-term economic benefits for the country. Experience from previous successfully organized Olympic Games suggests that Greece will very likely enjoy an increase in inward investment as well as in tourism (Figure 12).

The Athens experience is likely to be similar to that of Barcelona (both Greece and Spain consider tourism an important driving force of their economies). Spain experienced a 40-percent increase in tourism in the two years following the Barcelona Olympics. If the trend observed for the previous four Olympic Games is repeated for Greece, the comparative inward investment and increase in tourism are likely to yield substantial economic benefits. Another potential national benefit stemming from Greece's successful organization of the Athens 2004 Olympic Games is its increased competitiveness to undertake the organization of other large-scale sports, cultural, and trade events.
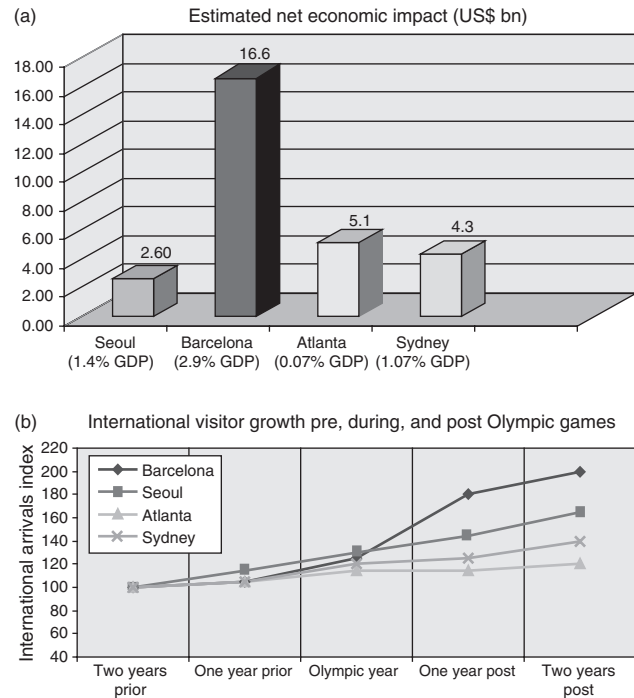

Figure 12: The impact of the Olympics on four previous host countries in terms of general economic impact and impact on tourism (LaSalle 2001) has been profound.

International-Level Benefits
While our primary motivation for developing the PLATO system was to address crucial management issues in planning and organizing the Athens 2004 Olympic Games, PLATO's capabilities and benefits are not limited to ATHOC and Greece. The PLATO set of models represents a formal encoding of Olympic Games knowledge, and it is transferable and reusable with minor adjustments to the organization of any future Olympic Games and other large-scale venue-based sports, cultural, and trade events (for example, the World Cup, European soccer games, and world trade fairs).

Although these events are organized with a given periodicity (four years for the Olympic Games), their planning is a perpetual process because host cities are decided a few years in advance (almost seven years in advance for the Olympic Games) and the process is repeated continuously. Therefore, the need for decision-support tools like PLATO for planning and organizing these events is continuous. An early example of this potential transfer of the

PLATO results can be found in the European best-practice project ECOSPLAN (http://www.ecosplan.org) (Zografos 2004) funded by the European Commission under the EU-China Digital Olympics initiative.

Another potential international benefit of PLATO is its contribution to the long-term sustainability of the character of the Olympic Games. It is evident that as the complexity, the service-level requirements, and the associated costs for organizing these events grow enormously, smaller countries may not feel capable of organizing these types of events. One of the major objectives of such events, however, is to bring the international community together and to develop a spirit of cooperation among all countries and people. Thus, the lack of interest and motivation in smaller countries to seek the organization of these types of events may prove detrimental to the long-term future of these events. The successful planning and organization of the Olympic Games with the use of sound management science principles by a small country like Greece should encourage other small countries to actively seek to stage such events.

Conclusions

Staging Olympic Games gives the host city the opportunity to take advantage of the unprecedented level of coverage and exposure that it receives before, during, and after the games. The Olympic Games are one of the very few endeavors that have both a financial and a social impact. If the international community perceives that the games have been successful, the potential financial and social benefits to the host country can be enormous.

Six months after the Athens Olympics, reports of its success still appear. In an article titled "Games were a Grecian earner for Athens," Gideon Brooks of the *London Daily Express* wrote on February 16, 2005, "At about 15 degrees, the temperature in Athens yesterday plummeted from the blistering heat of the summer, but the Olympic Games have left a warm glow among the people of the capital . . . . Tourism was boosted to the tune of a 15% rise in hotel bookings for the year and is expected to increase in line with other Games for the next five years on the back of the small matter of 4 billion pairs of eyes who saw

what Greece had to offer. There is no doubt that the best thing it (the Games) gave the people of Athens was a sense of pride."

The degree of success of the Athens games has to be set against a backdrop of skeptical reporting prior to the games. This skepticism, however, soon turned to enthusiasm once the games got under way. One of the most significant factors in the change in perception was arguably the effective management of venue operations; the smooth, effective, secure, and friendly manner in which all customer groups were provided with high-level service. The PLATO project provided the framework, techniques, and tools for managing that important part of the planning process. The impact of the PLATO project was visible right across many venues and multiple processes, resulting in economies of scale, effective organizational transformation, and cost-effective resource management. The PLATO project benefited not only ATHOC but also the participants in the games and the visitors to Athens.

The PLATO project has proved that the combined use of sound management science principles and information systems technology can provide substantial benefits in planning and organizing such complex events as the Olympic Games.

References
Ahuja, R. K., T. L. Magnati, J. B. Orlin. 1993. *Network Flows: Theory, Algorithms and Applications*. Prentice Hall, Englewood Cliffs, NJ.

Alexander, C. 1979. *The Timeless Way of Building*. Oxford University Press, New York.

Alexander, C., S. Ishikawa, M. Silverstein, M. Jacobson, I. Fikdahl-King, S. Angel. 1977. *A Pattern Language*. Oxford University Press, New York.

ATHOC. 2003. Internal Report on Test Events Measurements. ATHOC, Athens, Greece.

Buschmann, F., R. Meunier, H. Rohnert, P. Sommerlad, M. Stal. 1996. *Pattern-Oriented Software Architecture—A System of Patterns*. John Wiley and Sons, Chichester, West Sussex, UK.

Carroll, J. M. 2002. Scenarios and design cognition. *Proc. IEEE Joint Internat. Conf. Requirements Engrg.* (*RE'02*), IEEE Computer Society, Essen, Germany, 3–5.

Coplien, J. O., D. C. Schmidt, eds. 1995. *Pattern Languages of Program Design*. Addison-Wesley, Menlo Park, CA.

DeNeufville, R., A. Odoni. 2003. *Airport Systems: Planning, Design and Management*. McGraw-Hill, New York.

Drezner, Z. 1996. *Facility Location: A Survey of Applications and Methods*. Springer Series in Operations Research, Springer-Verlag, New York.

Easterbook, S. 1994. Resolving requirements conflicts with computer-supported negotiation. M. Jirotka, J. Goguen, eds. *Requirements Engineering: Social and Technical Issues*. Academic Press, London, UK, 41–65.

Forrester, J. W. 1961. *Industrial Dynamics*. Productivity Press, Cambridge, MA.

Forrester, J. W. 1993. The next great frontier: Designing managerial and social systems. *The Systems Thinker* **4**(1) 1–5.

Forrester, J. W. 1994. System dynamics, systems thinking, and soft OR. *System Dynamics Rev.* **10**(2/3) 245–256.

Fowler, M. 1997. *Analysis Patterns: Reusable Object Models*. Addison-Wesley, Menlo Park, CA.

Hay, D. 1996. *Data Model Patterns: Conventions of Thought*. Dorset House, New York.

Kavakli, E., P. Loucopoulos. 2005. Goal modeling in requirements engineering: Analysis and critique of current methods. J. Krogstie, T. A. Halpin, K. Siau, eds. *Information Modeling Methods and Methodologies*. Idea Group, Hershey, PA, 102–124.

Kreutzer, B. W. 1990/1991. ithink: The visual thinking tool. *The Systems Thinker* **1**(7) 8–9.

LaSalle, J. L. 2001. Reaching beyond the gold: Impact of the Olympic Games on real estate markets (1). http://www.research.joneslanglasalle.com.

Leite, J. C. S. d. P., P. Freeman. 1991. Requirements validation through viewpoint resolution. *IEEE Trans. Software Engrg.* **17**(12) 1253–1269.

Loucopoulos, P. 2004. Goals and business rules in requirements engineering. J. Clarkson, C. Eckert, eds. *Design Process Improvement—A Review of Current Practice*. Springer, Berlin, Germany, 116–139.

Moriarty, T. 1998. Scenario-based analysis: Exploring the business through stories. *Database Programming and Design* (June). Retrieved December 6, 2005 from http://www.dbpd.com/vault/9806src.htm.

Seruca, I., P. Loucopoulos. 2003. Towards a systematic approach to the capture of patterns within a business domain. *J. Systems Software* **67**(1) 1–18.

Sterman, J. D. 2000. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. McGraw-Hill, Boston, MA.

Transportation Research Board. 2000. *Highway Capacity Manual*. Special report 209, National Research Council, Washington, DC.

Van der Heijden, K. 1996. *Scenarios: The Art of Strategic Conversation*. John Wiley and Sons, New York.

Vlissides, J. M., J. O. Coplien, N. L. Kerth, eds. 1996. *Pattern Languages of Program Design 2*. Addison-Wesley, Menlo Park, CA.

Zografos, K. 2004. Identification of European good practices related to Olympic Games planning. Olympic City Forum, Nice, France (November 22).

Jacques Rogge, president of the International Olympic Committee, writes: "The successful outcome of the Athens Games owed a lot to the management philosophy and approach adopted by ATHOC.

"The planning, design and operation of venues benefited enormously by using Management Science, and Information Technology in innovative ways such as the PLATO project."

Gianna Angelopoulos-Daskalaki, president of ATHOC, writes: "The unqualified success of the Athens Olympic Games was the outcome of the efforts of many individuals who worked relentlessly for many years adhering to the highest professional standards.

"ATHOC management realized early in the process that the successful planning of the 2004 Olympic Games required the use of systematic and scientific management principles and that advanced management tools should be made available to all ATHOC decision makers.

"The PLATO project can be singled out as one of the tools that contributed substantially to the successful planning and organization of the Athens Games. PLATO led to plans and implementation procedures that made cost/effective use of the available resources.

"PLATO also provided a framework that helped ATHOC to transform from a function-oriented organization to a venue-focused organization resulting in systems that exhibited high reliability during the Games.

"Through PLATO, ATHOC leaves a legacy of knowledge that can be usefully deployed by future organizing committees. It is living evidence of the powerful use of management science methods and techniques for solving complex management problems with far reaching economic and social implications."