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A hybrid system for planning the development level of resort

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ABSTRACT

In today's world, a resort is a popular place that provides not only relaxation and recreation but also beautiful surroundings, high quality food, even facilities to exercise and do other healthy activities. Planning the development level is one of the more important processes in a resort development project. However, planners often subjectively overestimate the project or cater to the preferences of the investors, resulting in an over-developed or imbalanced development. This paper provides a system that helps the planner to search for near-optimal amenity development level. Integrating genetic algorithms and simulation, it employs a dual-loop optimization model to propose advice to be used in the planning stage. Because the complex and dynamic analysis is done by the system instead of by the planner, it speeds up the decision-making process of the planning stage.

1. Introduction

In the past few decades, resorts have become one of the preferred options for investment in the leisure industry. A resort provides not only relaxation and recreation but also beautiful surroundings, high quality food, facilities to exercise and do other healthy activities. A successful resort development project encompasses three crucial factors: (1) it ensures that the quality and level of each amenity and any combinations thereof are fully compliant with the present market needs; (2) the roles of the amenities are prioritized over the life cycle of the development; (3) the amenity costs and benefits are balanced by arranging the appropriate development level and schedules (Phillips, 1995). Inadequate development strategies and development level may lead to the failure of the resort project. It is evident from numerous resort projects in the past that investors usually overestimate the operation revenue and neglect possible risks. Such an attitude constitutes an inflated project and results in continuous investments for developing new facilities. Finally, the project is likely to end up in failure due to the excessive scale and budget deficits. Resorts have to keep expenditures in line with reasonable expectations of future revenue. Besides, adequate planning of the level of development of the amenities is conducive to the efficient use of the development site. However, the arrangement and space reservation of the amenities should be done in accordance with the best level of development in order to prevent insufficient or non-use of land space.

During the development of the project, it is open to the risks of increased construction costs and decreased operation revenue of each amenity. In addition, resources are shared by the amenities (e.g. the increase of attraction amenities calls for sufficient support for the infrastructure). Because of the many variables and the numerous possible combinations that need to be considered at the same time, it is difficult for planners to determine the best development strategy. Thus, support is needed to help planners make their decision for each development level and ensure that they clearly understand the influences of each variable in the project on the revenue. This assistance should also provide planners with the expected revenue of each investment combination of amenity, based on which the best development strategy can be determined.

Several decision models or problem-solving techniques for the project portfolio selection and plan optimization have been developed. Examples are the applied linear and integer programming (e.g. Gori, 1996), CAPM (e.g. Sandsmark & Vennemo, 2007), and, more recently, real options analysis (e.g. Carlsson, Fuller, Heikkila, & Majlender, 2007). Most of these techniques, however, still rely on a series of assumptions that limit the complexity of the model (Better & Glover, 2006). Besides, these models are unsuitable for resort development projects because they cannot simultaneously deal with selection, ordering, and planning the level and schedule of feasible investment items.

The purpose of this paper is to present a decision support system, by integrating simulation and genetic algorithms (GAs), so as to optimize the level of the amenities of resort development projects. In our proposed system, the project planner inputs the feasible range for the level of the amenities, the estimated

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durations of the activities, the costs and revenues, and the resource requirements. All these data are simulated and analyzed in order to predict the overall effectiveness of the project. Various levels and schedule combinations will be calculated to determine the best development strategy and provide the planner with a point of reference. This will help the planner overcome the complexities of the decision-making during the development of a resort amenity.

2. Resorts and amenities

2.1. Characteristics of resort development

The typical resort in North America at the beginning of the 20th century was a summer operation. The railroads were instrumental in opening up areas of the country that were previously inaccessible. Both railroads and resorts targeted the relatively few, very wealthy individuals (Mill, 2001). During the past several decades, a new type of resort has entered the marketplace – the mega resort or fantasy resort. These resorts combine lodging, meeting facilities and an array of amenities and activities, many with fantasy themes (McElyea & Cory, 2000).

Developing a resort is a complex process and involves many interdependent activities. First, a resort requires a comparatively large parcel of land. For instance, in most cases, a space where a boat can freely change its direction is around 100 times bigger than the space for the same boat to be anchored. As to boats with their hull longer than 10.7 m, it is quite reasonable for a 10-acre space to accommodate 12 boats (Phillips, 1995).

In addition, the construction of amenities requires a great deal of capital investment. For example, the cost of building a top-rated golf course runs between $US 3.6 million and $US 7.2 million – which may account for just about 10–12% of the total cost of building the entire resort (Mill, 2001). Therefore, their developments are often carried out in stages. Thus, it may be common in these resorts that some areas have begun to operate, while others are still under construction. The revenue gained from operating the amenities already built becomes an essential source of capital for financing the construction of the other amenities. A properly staged development plan can drastically reduce the initial capital requirements, as well as restrain the cash flow within secure conditions.

On the other hand, the development of a resort takes a long time during which a variety of amenities need to be constructed. Therefore many factors that may affect the profit of the project may change as time goes on. Examples are customer preferences (e.g. old-fashioned amenities might become less popular), the impact of the economic status on market demand and people's expenditure on recreational activities (e.g. other contenders invest in this region), and natural risks (e.g. natural disasters, climatic changes, earthquakes, and others). Taking a ski resort for example, the timing and the amount of snowfall has a direct impact on the number of skier visits (Vail Resorts Inc., 2006). Also, construction and operating costs of an amenity vary with the fluctuation of the price index.

2.2. Correlations between amenities

An amenity is "a rather broad concept that can encompass virtually any feature that is attractive to a given market and thus adds value to land (Phillips, 1995)". For a resort, continuous investment must be made to maintain its attractiveness to tourists. This characteristic means the use of considerable resources to develop new amenities or improve the current ones. Fig. 1 shows the relationship between different types of amenities and people, as well as some of the amenities commonly found in resorts. Customers in a resort consist of tourists, primary and second home buyers, and tenants. They all make expenditures for the attractions, food services, accommodations and commodities. The performance of those amenities encourages the transaction and tenanting in the real estate portion of the enterprise. During the operation of those amenities, the whole resort is facilitated by the infrastructure.

Attractions refer to amenities that can entertain customers, such as ski slopes, golf courses, and yacht harbors. Attractions tend to bring in considerable profits for the resorts. For example, for a ski resort, the sale of lift tickets and the fees for ski school courses usually account for their largest source of revenue. Attractions also play a crucial role in drawing real estate buyers.

Food services, accommodations, and commodity sales are other substantial sources of profit in addition to the attractions. Accommodations, such as hotels and villas, may yield significant profits when there are sufficient attractions to entertain the customers for more than one day. However, on the other hand, the profits from food services, commodity sales, and accommodations are determined by the amount of tourists and the time they spend in the resort, which means they are greatly influenced by the overall customer-drawing capability of these amenities. Thus, the construction and operation of food services, commodity sales, and accommodations must be in line with the development levels of customer-drawing amenities to prevent wasting resources because of a too rapid development progress.

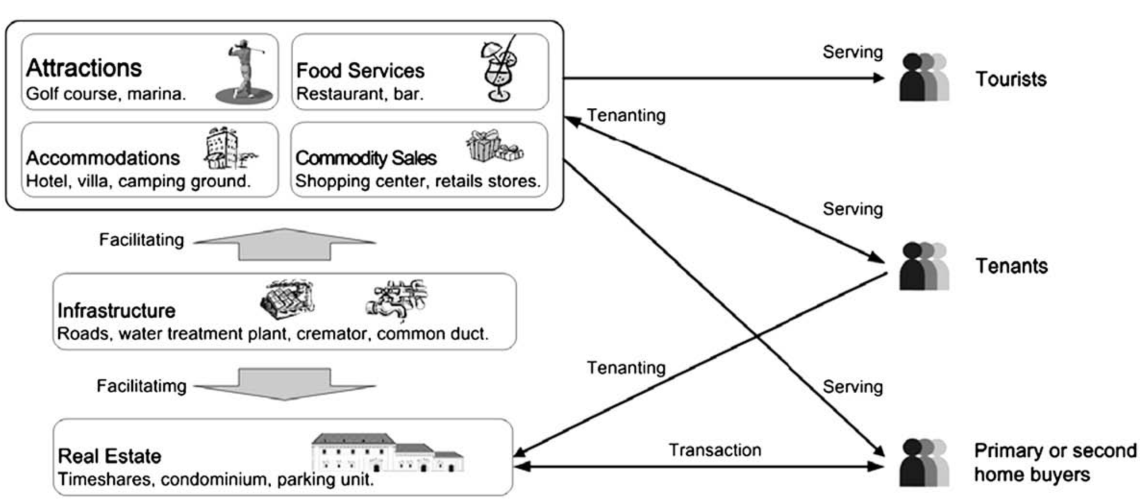

Fig. 1. The relationships between amenities and people.

Resort real estate products can be offered in many different forms including retirement homes, vacation homes, vacation rental units, fractional ownership, timeshare, commercial condominiums, and parking unit sales (Dvorchak, 2002). In addition to these activities, primary or second home buyers and tenants, same as tourists, also acquire the services from the other amenities in the resort, resulting in a close relationship between real estate revenue and the operating performance of the amenities in the resort.

The infrastructure refers to the amenities used by the tourists that are not of a recreational nature. It maintains the operation of the entire resort. Most of these amenities do not yield income, but they are crucial to the sound operation of the attractions, the food services, the commodity sales, as well as the accommodations. Usually, most of these amenities, such as roads, are necessary for the proper operation of resorts, but can be constructed stage by stage and in accordance with the development of the scale of the resort.

2.3. Development planning of amenities

Planning the development of the amenities in a resort consists of the development schedule and the investment level of the amenities. First, development must be timed such that the cost of constructing the amenities is balanced by the revenue generated (Mill, 2001). A cycle of "develop – operate, sell and rent – create income – invest income in further development" is created in the project scheduling in order to achieve optimal profits for the whole project. Second, in addition to a market study to verify market support and expected performance, the correlations between amenities must be considered while planning the investment level of these amenities. For example, since the income gained from operating a hotel strictly depends on the amount of customers and their average length of stay, the number of rooms must match the level of attractions in order to obtain optimal profits. Thus, a good amenity development plan also requires a carefully designed schedule.

3. Simulation technology support

Similar to most previous researches on portfolio selection (e.g. Terceno, Andres, Barbera, & Lorenzana, 2003; Ye & Tiong, 2000), we also use the net present value (NPV) for the decision support of resort development level. The NPV denotes the assets and the capital input and output from each activity in a resort project. In addition to the capital, the different flows of other resources in the planning, design, construction, and operation of each amenity form a dynamic process. A resource may be produced from the operation of one amenity (e.g. capital from the operation of the lifts in a ski resort) and be immediately used for the construction of another amenity (e.g. the construction of a hotel). Based on the flows of the resources, the start and finish dates of activities are decided as a simultaneous sequence. This makes it difficult to represent and solve an optimal development schedule and levels in terms of functions and mathematical operations.

Therefore, in this work we model the dynamic development and operation processes of the amenities using the simulation network technology. Each amenity involved in the development of a resort must be planned and designed, constructed, operated, closed, dismantled, and divested. In the project schedule, each stage is viewed as an individual activity that includes lead time, cost, and revenue. The cost and revenue of an activity are viewed as the input and output of capital resource. In addition to capital funds, resources are generated or utilized by other activities. For example, the operation of a horse-riding field may utilize the parking capacity created by operating a parking area. This study constructed simulation networks to describe the activities and resources in resort development projects. These simulation networks are based on the CYCLONE (Cyclic Operations Network), a simulation methodology proposed by Halpin (1974) specifically designed for construction. There are several implementations of CYCLONE as software tools, such as UM-CYCLONE (Ioannou, 1989), Micro-CYCLONE (Halpin, 1990) and DISCO (Huang & Halpin, 1995). STROBOSCOPE (Martinez, 1996) is another one of these tools that has additional programming capability, which makes dynamic activity prioritization possible, which is an important modeling technique required to make this research realistic.

3.1. Marina simulation network for example

The simulation network in Fig. 2 is designed for project activities involving a marina. The main elements of the simulation network are *Queue* and *Combi*. *Queues* hold the resources that are idle. Each *Queue* is associated with a particular resource type, and provides a position that allows units to be delayed pending *Combi* activities. *Combi*s represent tasks that start when certain conditions are met. At appropriate moments during simulation, *Combi*s are scanned (examined one by one) to determine if the necessary conditions exist for them to start (Martinez, 1996). Units arriving at *Combi* will be processed if units are available in each preceding *Queue* node (Cheng & Feng, 2003). The duration of each *Combi* in this figure occurs in the same time unit, which can be set as one month, one quarter, or one year.

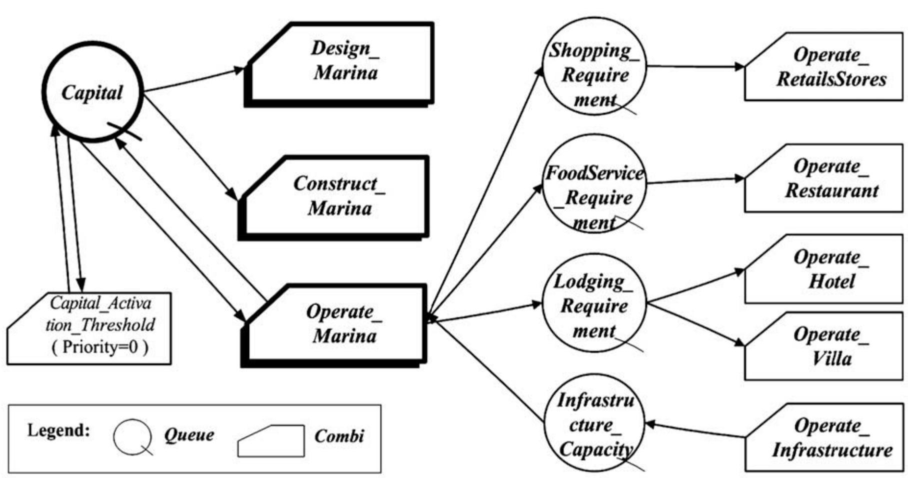

Fig. 2. Simulation network of a marina.

In Fig. 2, there are eight *Combis*, namely *Design_Marina*, *Construct_Marina*, *Operate_Marina*, *Operate_Infrastructure*, *Operate_Hotel*, *Operate_Villa*, *Operate_Restaurant*, and *Operate_ShoppingCenter*, as well as five Queues, namely Capital, *Infrastructure_Capacity*, *Lodging_Requirement*, *FoodService_Requirement*, and *Shopping_Requirement*. *Infrastructure_Capacity*, which is a result from the execution of *Operate_Infrastructure*, serves customers who are drawn by *Operate_Marina*. On the other hand, *Lodging_Requirement*, *FoodService_Requirement*, and *Shopping_Requirement* are a result from *Operate_Marina*, and these requirements may influence the revenues (which later become Capital) generated by *Operate_Hotel*, *Operate_Villa*, *Operate_Restaurant*, and *Operate_ShoppingCenter*.

Queues can be divided into accumulative and non-accumulative ones. Since the duration of each *Combi* is fixed as one time unit, the surplus of some resources may be accumulated to be used in the following time unit (such as *Capital*). However, some resources cannot be accumulated, such as *Infrastructure_Capacity*.

In the simulation network, executing activities requires resources. For example, in Fig. 2, the *Combi Operate_Infrastructure* produces resource *Infrastructure_Capacity*, which in turn provides the necessary resources for *Operate_Marina*. In our research, each *Combi* is assigned with a priority value between 0 and 1, which determines its priority for using resources when a resource conflict exists. For example, *Combis Design_Marina, Construct_Marina*, and *Operate_Marina* all require *Queue Capital* to be executed, and their specific execution order will be based on their priority value if *Capital* is not enough to support simultaneous execution.

3.2. Activation threshold

An activity can only be executed when there are enough resources that are required. However, in some cases, the execution of an activity may need to be postponed even when enough resources are available. An example is activities *Construct_Infrastructure* and *Operate_Infrastructure*, which produce *Infrastructure_Capacity*. *Infrastructure_Capacity* is only an amenity that supports the service of the main attractions, and will not bring profit by itself. Therefore, once *Infrastructure_Capacity* is sufficient for supporting the existing attractions, should not be continuously executed even though capital money is abundant because overcapacity in infrastructure not only cannot bring additional profit, but also increase unnecessary operation and maintenance cost.

Activation Threshold is used to determine whether the activity should be carried out or not. Each *Activation Threshold* is associated with a resource (e.g., *Capital_Activation_Threshold*, is associated to the *Capital* resource in Fig. 2). A comparison of the priority values between *Activation Threshold* and *Combi* that intend to use the resource in question is made to determine the priorities of resource utilization and allocation. The priority value of each *Activation Threshold* is 0 while those of the *Combis* that could be executed fall between 0 and 1. On the other hand, the *Activation Thresholds* hinder the execution of the *Combis* with a priority value of -1 by capturing all the corresponding resources, even when sufficient resources are available.

3.3. Priority to available development levels

A *Combi* is executed (or not) according to the availability of the resources required. In reality, the execution of a project shows different degrees of priority in the utilization of the same resource among different activities. For example, an infrastructure with limited capacity should be used for amenities that can generate a higher return. In STROBOSCOPE, each activity possesses a priority value, either fixed or variable. At a certain point in time, an activity with a higher priority value implies a higher execution moment. The execution value of an activity depends on the current or future "direct revenues derived as such" and "their contribution to facilitate the operation of other amenities". For instance, the operation of a hotel has an execution value because it provides direct revenue, while the operations of other facilities, such as a water treatment plant and roads also have their own execution value. Even though they may not yield a direct revenue they facilitate the smooth operation of the hotel that does bring an income. In other words, the revenue of the hotel shows all the execution values of the hotel, including the water treatment and the roads.

Because executing an activity requires resources, the availability of the required resources, along with the activity's priority value, determines the development level (i.e., construction speed or operation scale) of that activity. The start and finish dates of the activity can also be determined accordingly. However, due to the number of factors involved in evaluating the execution value of an activity, it is infeasible for human planners to find the optimal plan. This study implements a computer program that uses GAs to search for a near-optimal solution based on the combinations of the priority values of the activities.

4. Architecture of the Resorter

This study constructs a decision support system, named the Resorter, in order to facilitate the decision-making process of amenities planning. The system integrates GAs and simulations. GAs are applied in the optimizations, and simulations are executed to estimate the project NPV.

4.1. Dual-loop optimization model

The core of the Resorter for determining the development level of each activity is a dual-loop optimization model, as shown in Fig. 3. Given a set of constraints (e.g. size of available land), there may be more than one feasible combination of development level for the amenities. A combination set may lead to different NPVs if the execution schedules of the activities are different. The first loop uses a polyploidy GA (see Section 4.2.) to find the best schedule that results in the highest NPV for each combination set during the simulation. The evolution process of the GA stops when it reaches convergence and a near-optimal NPV is found. Chromosomes are used to represent the priority values of the activities in this process.

The near-optimal NPV of each combination set determined in the first loop is then used as the fitness value in the second loop. Haploidy chromosomes (see Section 4.2.) are used to represent the combination sets in this process. The evolution process stops when a near-optimal NPV is found, thus the best amenity development level set is determined.

4.2. Polyploidy GA for scheduling optimization

Genetic algorithm (GA) was first proposed by Holland (1975). The GA is based on the mechanics of natural selection and genetics to search through decision space for optimal solutions (Goldberg, 1989). The metaphor underlying the GA is natural selection. In evolution, the problem each species faces is to search for beneficial adaptations in a complicated and changing environment.

In the real world, many problems feature multi-periods, multi-steps, or multi-situations. Traditional GAs usually apply the genetic structure of a haploid, in which single-dimensional genetic encoding is severely limited to express potential solutions. Therefore, a polyploidy genetic structure may express and reveal more practical solutions. The polyploidy genetic structure can be seen in genes composed of multiple chromosomes. In fact, the polyploidy structure is very common among creatures in nature (Wu, 2002).

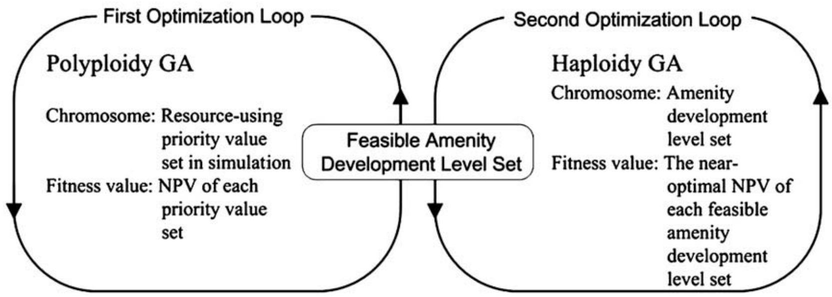

Fig. 3. Dual-loop optimization model.

Human genes, for example, are a diploid type with 23 sets. Haploid genes are usually utilized to express a biological appearance (such as skin color), while a polyploidy structure may be viewed as a combination of several haploid genes. Polyploidy structure provides various phenotypes or applicable behaviors, so that individuals may apply different strategies for survival during changes in the environment (Wu & Sun, 2002).

There are many studies on the applications and performances of polyploidy GA (including diploid GA) (e.g. Farley, 2007; Fonteix, Bicking, Perrin, & Marc, 1995; Uyar & Harmanci, 1999). For example, He and Wu found that diploid GA has a better performance in terms of preserving the diversity than haploid GA (He & Wu, 2006). Collingwood observed the process of searching for the optimal solution for the analytical comparison between the effects of a polyploidy and a haploid GA. He found that, since the polyploidy structure conserves more information, more opportunities to achieve better solutions may be obtained from it rather than from the haploid structure for the same issue (Collingwood, Corne, & Ross, 1996).

A polyploidy GA structure provides multiple representations for each chromosome. This feature allows us to represent and record the priority value of each activity at different times. In the first optimization loop, the near-optimal NPV must be found for each feasible amenity development level set by scheduling in simulation. This process has features of multiple periods and situations. Therefore, employing a polyploidy GA structure is an ideal approach to combine the development strategies of each period into a plurality of chromosomes.

In the present research we form a polyploidy chromosome structure for the priority values of activities. In each time unit T, each activity possesses a priority value. As T_i, activity A_1 has a priority value of $P_{1,i}$, and the priority value set of n activities (A_1, A_2, …, A_n) at T_i can be stated as $P_{1,i}$, $P_{2,i}$, $P_{3,i}$,…, $P_{n,i}$, and the genetic encoding of a chromosome is thus constructed. If a project spans a period of m time units (such as 120 months, 40 quarters, or 10 years) in total, then the genetic encoding of the priority value sets at each time unit combines into a polyploidy with multiple chromosomes, which can be used to describe the priority value of the resource utilization of each activity at each time unit, as shown in Fig. 4.

In a polyploidy GA, the priority value sets undergo selection, crossover and mutation, so as to produce priority value sets of the next generation. Dzeng and Lee (2007) applied the uniform-point crossover and time unit crossover of polyploidy GA for optimizing a theme park project schedule. In most cases, the crossover in a haploid may be performed in a one-point crossover, two-point crossover or uniform-point crossover, in which the exchange between each gene is independent from each other. As shown in Fig. 5, in addition to the crossovers in the haploid GA, the time unit crossover can be executed in the polyploidy GA. The time unit crossover is a kind of crossover performed by all chromosomes at the same time unit. The priority values of the same time unit became a chromosome of polyploidy, and their comparative size determines the order in which *Queue* provides resources to activities in this particular time unit. After several generations, some of the priority value sets in a certain time unit of an individual generation may have been excellent. A time unit crossover can maintain these superior chromosomes and prevent the chromosomes from being broken during crossover. Therefore, timely adoption of a time unit crossover in the selection through generations may very possibly figure out more ideal priority value sets. Further investigation on this hypothesis is discussed in the case study of this paper.

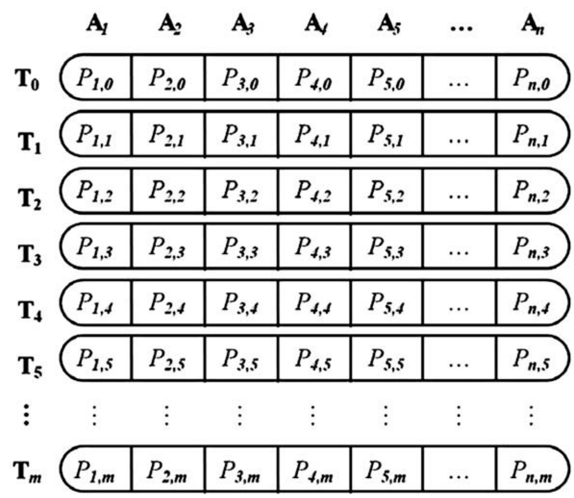

Fig. 4. Genetic code of priority value sets.

4.3. Integrated GAs and simulation

Because the integrated models of simulation and GA may yield a satisfactory result in the search for an optimal solution, they have been applied in many different fields, such as facility layout in manufacturing systems (Azadivar & Wang, 2000), resource optimization in construction projects (Hegazy & Kassab, 2003), scheduling (e.g. Cheu, Wang, & Fwa, 2004; Jeong, Lim, & Kim, 2006), and even the quality care of hospital (Yeh & Lin, 2007).

A similarity between resort development projects and other studies that applied simulation lies in the huge number of uncertainties and the probability distribution of the data (such as the revenue). On the other hand, the difference is that forecasting the project schedule is based on the execution value of the operations. Several researches (e.g. "Time-series combinatorial planning model for infrastructure planning" proposed by Hsieh & Liu (1997)) have attempted to solve similar problems using direct scheduling in the GA. This means that the start and the finish dates of each activity are incorporated into the genes. On the other hand,

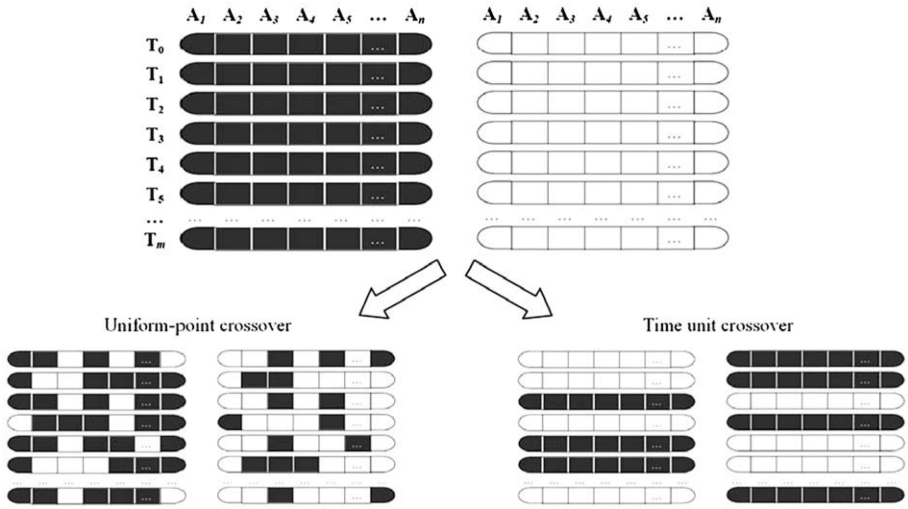

Fig. 5. Uniform-point crossover and time unit crossover.

our proposed approach calculates the priority value of each activity in each time unit, the priority value of each time unit is regarded as an independent chromosome, and all the chromosomes are combined to form a polyploidy. Thus, the structure can be better expressed with only one chromosome (haploid) than was the case in other studies.

4.4. The flowchart of Resorter

Resorter integrates the dual-loop optimization model, GAs and simulation. The following illustrates the operation of Resorter, as shown in Fig. 6.

(1) The user inputs the project data and the preferred optimization parameters:
   - Project total duration and discounting rate: Most resorts are sustainability-oriented and are expected to bring in profits and to be developed over the long-term. Nevertheless, an evaluation on the project-implementation efficiency is necessary, so we divide the project into several phases (or so-called planning horizons) to calculate its NPV. The total duration might be 20 years or longer, but this does not mean the resort will be closed in 20 years from now. Besides, it is also necessary to set the discounting rate in accordance with the development region and economic environment.
   - Amenities and their feasible ranges of level: The amenities that need to be developed in a resort mainly depend on the nature of the resort, e.g. amenities of a ski resort are greatly different from those of a golf resort. After the amenities are determined, the planner has to take into consideration the area, landform, and slope of the site and the relative location of every amenity in an effort to evaluate the feasible range of development level of each amenity. Within the range that the user sets, Resorter will conduct an optimization to find out the near-optimal amenity development level at which a near-optimal NPV can be gained.
   - Activities of amenities: In the resort project, every amenity brings on several activities. Generally the three major activities are planning and design, construction, and operation. The user must input the name and duration of every activity into the system since these data are necessary for simulation.
   - Resource requirements: In addition to activities, the other important elements in the simulation network are the resources required by the activities. The user has to input the name of each resource, and its input or output volume between activities. Take capital for example, some activities consume it, while the operation of some activities will also produce it.
   - Optimization parameters: There are two GA models for optimizations in the Resorter. The user has to input the GAs' parameters, including the initial number for population size, generation size, crossover rate, and mutation rate. Population size refers to how many chromosomes there are in a population (one generation). The generation size specifies the number of generations. The crossover rate is the recombination probability of the selected individuals. The mutation rate is the probability of the random alteration of each segment of chromosomes. The role of mutation in the GA is to prevent an irreparable loss of diversity (Dumitrescu, Lazzerini, Jain, & Dumitrescu, 2000).

(2) The system constructs a simulation network based on the data user input, and then randomly generates amenity development level sets to be the first generation in the second loop GA. The first loop GA searches the near-optimal NPV for each amenity development level set in the second loop GA. So the system randomly generates activity priority value sets to be the first generation in the first loop GA. The numbers of the first generation depend on the population sizes user input.

(3) In the first loop, simulations are executed to estimate the NPV. Then the GA process, including selection, crossover, and mutation, is applied repeatedly until the max NPV satisfies the GA convergence conditions. The system alternates the uniform-point crossover and time unit crossover to improve the optimization efficiency.

(4) When the first loop has found the near-optimal NPVs for each amenity development level set of a generation, these NPVs become the fitness value in the second loop GA. Similar to the first loop, the GA process is then applied repeatedly until the max NPV satisfies the GA convergence conditions.

(5) Through the dual-loop optimization, the near-optimal amenity development level set with the max NPV is found. This will be valuable advice and decision support for the user during project planning.

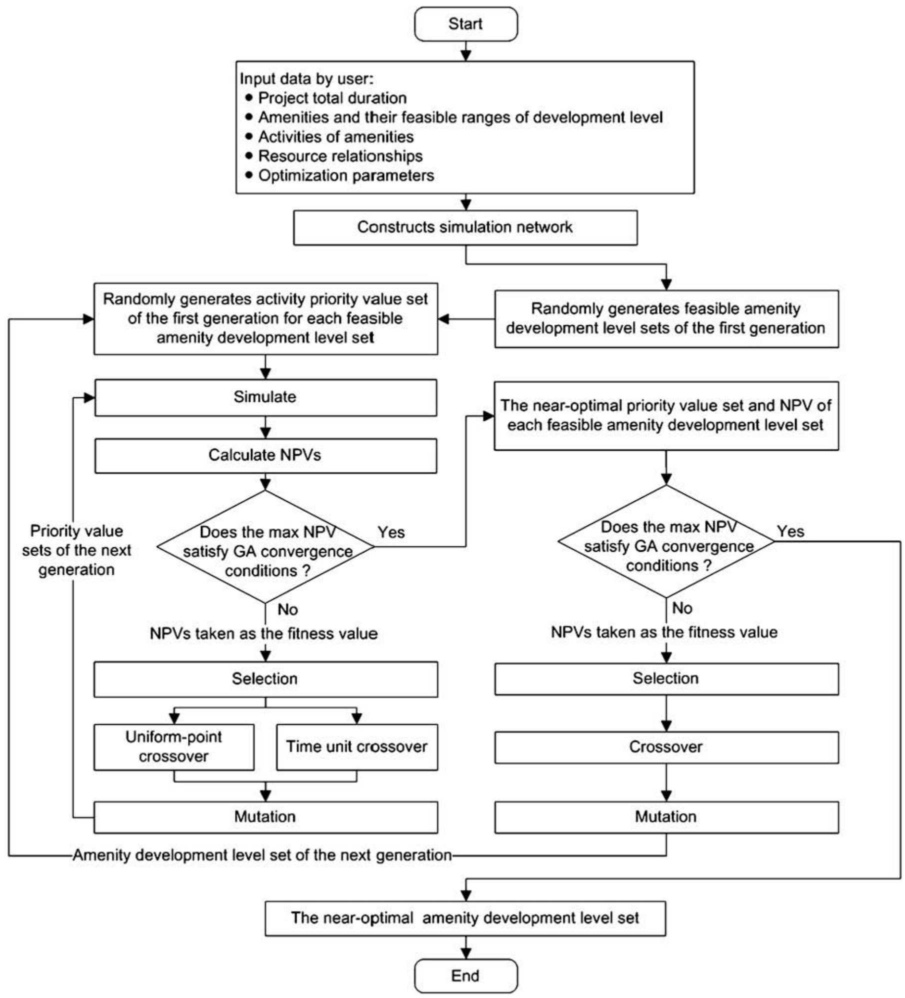

Fig. 6. The flowchart of Resorter.

5. Implementation and evaluation of the Resorter

5.1. Implementation

The Resorter is implemented using Microsoft Visual Basic 6.0, with STROBOSCOPE 2.0.3.0 (Martinez, 1996) as the simulation engine. It includes four major functions: (1) model setting, (2) amenity and activity, (3) resource edit, and (4) resource flow.

"Model setting" allows the user to input the total duration and the discounting rate of the project, while the preferred GAs optimization parameters. "Amenity and activity" enable the user to edit the data of the amenities and their activities. "Resource edit" allows the user to input the resource used in the project. The items and volumes of the resources provided to the activities can be edited in the interface of the "resource flow". After the project data and the preferred optimization parameters are inputted into the system, the user can start the optimization process by hitting the "Run" button. As shown in Fig. 7, we have project information and simulation parameters on the left, and the amenity development level set advice on the right. The records of the dual-loop optimization processes are shown below.

5.2. Evaluation

To evaluate the performance of the Resorter, we used a simplified version of the Dapeng Bay resort development project, located in the south of Taiwan, to compare the performance of the Resorter with human experts. The resort project consists of six main amenities, marina, indoor water park, lido facilities, hotel, retails stores, and the infrastructure. Table 1 is the amenities' feasible range of development level, activities, and estimated durations. The development levels are denoted by M_iLevel, where i is the index number of the amenity. Each amenity requires three activities, planning and design, construction, and operation. Thus, the project comprises 18 activities in total (i.e. from A1 to A18). Some durations of the construction activities depend on the corresponding amenity development level. For brevity, all durations are integers. For example, the duration of the construction of the indoor water park is the integer months of ($16 + 0.01 \times M_2$Level). Note that the start of the operation of each amenity is determined by the Resorter, and is assumed to continue to operate till the end of the project. Therefore, the duration of each operation activity is unknown prior to the simulation. With a planning horizon of 20 years, it is assumed that the total duration of the project is 240 months, the annual compounded interest rate is fixed at 6% (discounting rate), and each amenity is depreciated linearly over a period of 30 years with salvage value.

Table 2 is the estimated resource input and output of each activity. In Table 2, the total resource input and output volumes are shown for the planning and design activities and the construction activities of all amenities (i.e. A1, A2, A4, A5, A7, A8, A10, A11, A13, A14, A16, and A17). The total volume of the activity duration

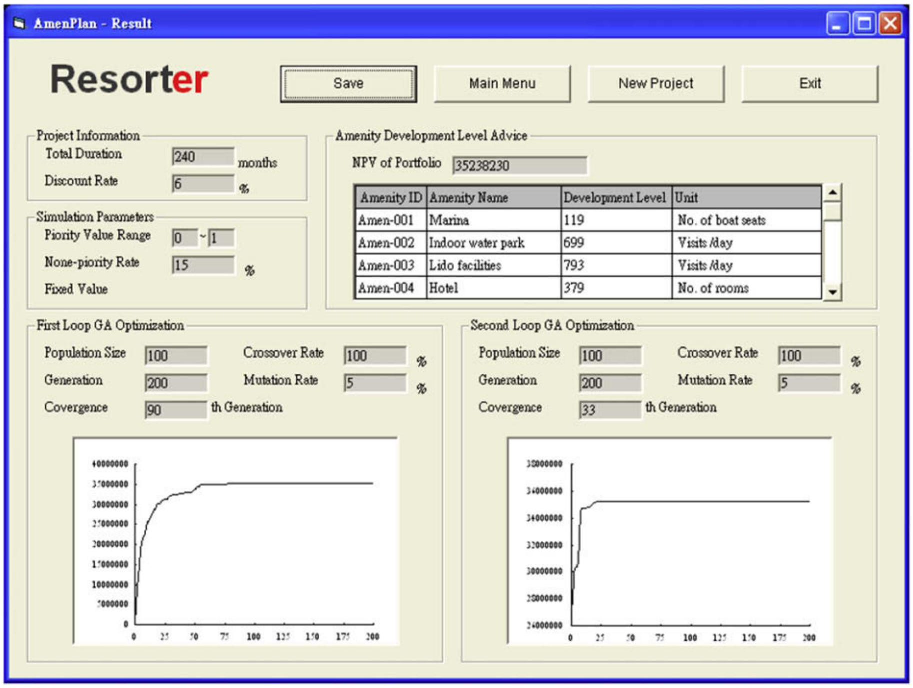

Fig. 7. The result for decision support in the Resorter.

Table 1
The amenities' feasible range of development level, activities, and estimated durations

Amenity	Feasible range of development level	Activity	Duration (Month)
M_1: Marina	M_1Level: 40 ~ 120 (no. of boat seats)	A1 planning and design of marina	6
		A2 construction of marina	Integer of [10 + 0.05 × M_1Level]
		A3 operation of marina	–
M_2: Indoor water park	M_2Level: 300 ~ 700 (visits/day)	A4 planning and design of indoor water park	12
		A5 construction of indoor water park	Integer of [16 + 0.01 × M_2Level]
		A6 operation of indoor water park	–
M_3: Lido facilities	M_3Level: 200 ~ 800 (visits /day)	A7 planning and design of lido facilities	3
		A8 construction of lido facilities	6
		A9 operation of lido facilities	–
M_4: Hotel	M_4Level: 65 ~ 400 (no. of rooms)	A10 planning and design of hotel	10
		A11 construction of hotel	Integer of [18 + 0.05 × M_4Level]
		A12 operation of hotel	–
M_5: Retails stores	M_5Level: 10 ~ 60 (no. of stores)	A13 planning and design of retails stores	10
		A14 construction of retails stores	18
		A15 operation of retails stores	–
M_6: Infrastructure	M_6Level: 1800 ~ 9000 (visits/day)	A16 planning and design of infrastructure	6
		A17 construction of infrastructure	11
		A18 operation of infrastructure	–

is divided in months. At the same time, the average volumes per month for the operation activities of all amenities are also shown (i.e. A3, A6, A9, A12, A15, and A18). Among the resource inputs and outputs, some are a fixed value such as the R1 (capital) input of A1 (planning and design of marina), and some depend on the amenity development level. For example, the R3 (accommodation requirement) output of A9 (operation of lido facilities) is 0.15 × M_3Level. Others, especially operation income, are limited by both total requirement output and the amenity development level. For example, the R1 (capital) output of A12 (operation of hotel) is 7272.72 × Min{Total R4 output, M_5Level}.

We also invited five human experts to plan the amenity development level and schedule the test project. The experts included one manager in a real estate development company, two project management consultants, and two resort managers. In Table 3, a comparison of the results shows that Resorter took 2.5 h, which is 62% faster than the average time of 6.5 h spent by the experts. In addition, the NPV Resorter proposed is 30% higher than the average of the human experts (i.e., increasing US$8,185,759 from US$27,052,471 to US$35,238,230). In addition, from the difference in the proposed amenity development level as set in Table 3, it is evident that the Resorter offers more precise values, which will be more beneficial for the decision-making of the resort planner. On the other hand, the values are rather rough since the human experts pondered on the basis of their personal experiences when estimating the amenity development level.

6. Conclusions

The determination of a good resort amenity development level is an issue seldom discussed because it is regarded as a task which can be done only by experienced senior planners. Our study analyzed the characteristics of a resort and its amenities, and the

Table 2
The estimated resource input and output of each activity

Activity	Resource input	Resource output
A1	R1: 121,200	–
A2	R1: 3,333,000 + 65,100 × M_1Level	–
A3	R1: 4050 + 10 × M_1Level R2: 2.8 × M_1Level	R1: 247 × M_1Level R3: 0.85 × M_1Level R4: 0.85 × M_1Level
A4	R1: 181,800	–
A5	R1: 7,575,000 + 7,570 × M_2Level	–
A6	R1: 40,990 + 11 × M_2Level R2: M_2Level	R1: 266 × M_2Level R3: 0.23 × M_2Level R4: 0.42 × M_2Level
A7	R1: 18,100	–
A8	R1: 75,700 + 270 × M_3Level	–
A9	R1: 4545 R2: M_3Level	R1: 45 × M_3Level R3: 0.15 × M_3Level R4: 0.3 × M_3Level
A10	R1: 187,800	–
A11	R1: 18,181,000 + 144,700 × M_4Level	–
A12	R1: 94,500 + 1450 × M_4Level R2: 2.6 × M_4Level	R1: 3,636.36 × Min{Total R3 Output, M_4Level}
A13	R1: 66,600	–
A14	R1: 454,500 + 45,450 × M_5Level	–
A15	R1: 2000 × M_5Level R2: 100 × M_5Level	R1: 7,272.72 × Min{Total R4 Output, M_5Level}
A16	R1: 34,800	–
A17	R1: 606,000 + 300 × M_6Level	–
A18	R1: 780 + 1.8 × M_6Level	R2: M_6Level

Note: R1: capital (US$168,000,000 at the start); R2: capacity of the infrastructure (visits/day); R3: accommodation requirement (rooms/day); R4: consumption requirement in retails stores (visits/day).

Table 3
Comparison of effectiveness between the Resorter and the experts

Result	Resorter		Planning by experts	
Time (hours)	2.5		Average: 6.5	
Estimated project NPV (US$)	35,238,230		Average: 27,052,471 Max. : 32,399,660 Min. : 19,989,898	
The proposed amenity development levels set			The one with max. NPV:	
	M_1Level: 119	M_2Level: 699	M_1Level: 100	M_2Level: 600
	M_3Level: 793	M_4Level: 379	M_3Level: 550	M_4Level: 250
	M_5Level: 59	M_6Level: 8761	M_5Level: 45	M_6Level: 9000

relationships between amenities and people. We found that the activities in a resort development project are executed based on the resources provided. In the past, the main financial analysis used by planners for a development project was NPV. But this analysis is static and does not consider the resources during the process of development of the resort and its operation. Our study applied the simulation network to present and calculate the dynamic resource flows for the total duration of the project. This method is closer to the real situation for solving complex planning problems.

In this study we also established a decision support system. In addition to the simulation model, the Resorter has a dual-loop optimization model. It combines the polyploidy GA and the haploid GA to search the near-optimal amenity development level set with the near-optimal NPV. Different from the traditional uniform-point crossover in GAs, a new crossover method, the time unit crossover, is applied to improve the efficiency of optimization.

We also evaluated the Resorter using a realistic project and compared it with the planning carried out by five human experts. The results showed that the Resorter can propose a better plan faster than the human experts. With regards to the dynamics of resources and activities, the human experts could not provide a thorough consideration in their planning, while the Resorter provided a fully integrated proposal. Because the complex calculations are done by the system instead of by the planner, and because the planning advice is proposed by the system, the decision-making process of amenity planning has become substantially easier.

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References

Azadivar, F., & Wang, J. (2000). Facility layout optimization using simulation and genetic algorithms. *International Journal of Production Research, 38*(17), 4369–4383.
Better, M., & Glover, F. (2006). Selecting project portfolios by optimizing simulations. *The Engineering Economist, 51*(1), 81–97.
Carlsson, C., Fuller, R., Heikkila, M., & Majlender, P. (2007). A fuzzy approach to R&D project portfolio selection. *International Journal of Approximate Reasoning, 44*(2), 93–105.
Cheng, T. M., & Feng, C. W. (2003). An effective simulation mechanism for construction operations. *Automation in Construction, 12*(3), 227–244.
Cheu, R. L., Wang, Y., & Fwa, T. F. (2004). Genetic algorithm-simulation methodology for pavement maintenance scheduling. *Computer-Aided Civil and Infrastructure Engineering, 19*(6), 446–455.
Collingwood, E., Corne, D., & Ross, P. (1996). Useful diversity via multiploidy. In *Proceedings of international conference on evolutionary computing* (pp. 810–813).
Dumitrescu, D., Lazzerini, B., Jain, L. C., & Dumitrescu, A. (2000). *Evolutionary computation*. CRC Press. p. 145.
Dvorchak, M. E. (2002). From casino to resort: Understanding the entertainment hierarchy. ERA White Paper, Economics Research Associates.
Dzeng, R. J., & Lee, H. Y. (2007). Activity and value orientated decision support for the development planning of a theme park. *Expert Systems with Applications, 33*(4), 923–935.
Farley, A. M. (2007). Choice and development. In *Proceedings of the 2007 GECCO (genetic and evolutionary computation conference) conference* (pp. 2468–2474).
Fonteix, C., Bicking, F., Perrin, E., & Marc, I. (1995). Haploid and diploid algorithms, a new approach for global optimization: Compared performances. *International Journal of Systems Science, 26*(10), 1919–1933.
Goldberg, D. E. (1989). *Genetic algorithms in search, optimization and machine learning*. Reading, MA: Addition-Wesley.
Gori, E. (1996). Portfolio selection of capital investment projects in the Durban Metropolitan region. *Construction Management and Economics, 14*(5), 451–456.
Halpin, D. W. (1974). CYCLONE – a graphical method for simulation modeling of construction operations. In *Proceedings of the second inter-American conference on systems and informatics, Mexico City, Mexico* (p. 15).
Halpin, D. W. (1990). *Micro-CYCLONE user's manual. Department of Civil Engineering*. Lafayette, ID: Purdue University, W.
He, L., & Wu, Y. G. (2006). Research on mutation operator of diploid genetic algorithm and its dynamic adaptation strategy. In *Proceedings of the fifth international conference on machine learning and cybernetics* (pp. 2117–2122).
Hegazy, T., & Kassab, M. (2003). Resource optimization using combined simulation and genetic algorithms. *Journal of Construction Engineering and Management, 129*(6), 698–705.
Holland, J. (1975). *Adaptation in natural and artificial system*. Ann Arbor, MI: University of Michigan Press.
Hsieh, T. Y., & Liu, H. L. (1997). A multi-objective heuristic approach for infrastructure portfolio with limited resources. *Journal of Infrastructure Systems in Civil Engineering, 3*(4), 134–142.
Huang, R. Y., & Halpin, D. W. (1995). A graphical-based method for transient evaluation of construction operations. *Journal of Construction Engineering and Management, 121*(2), 222–229.
Ioannou, P. G. (1989). *UM-CYCLONE user's guide. Technical report UMCE-89-12*. Ann Arbor, MI: Department of Civil Engineering, University of Michigan.
Jeong, S. J., Lim, S. J., & Kim, S. K. (2006). Hybrid approach to production scheduling using genetic algorithm and simulation. *International Journal of Advanced Manufacturing Technology, 25*(1), 129–136.
Martinez, J. C. (1996). STROBOSCOPE: State and resource based simulation of construction processes. PhD Thesis, Department of Civil Engineering, University of Michigan, MI.

McElyea, J. R., & Cory, G. L. (2000). Resort investment and development an overview of an evolving market. ERA Issue paper, Economics Research Associates.

Mill, R. C. (2001). *Resorts: Management and operation*. John Wiley & Sons.

Phillips, P. L. (1995). *Developing with recreational amenities – golf, tennis, skiing, marinas*. USA: The Urban Land Institute.

Sandsmark, M., & Vennemo, H. (2007). A portfolio approach to climate investments: CAPM and endogenous risk. *Environment Resource Economics, 37*(4), 681–695.

Terceno, A., Andres, J. D., Barbera, G., & Lorenzana, T. (2003). Using fuzzy set theory to analyse investments and select portfolios of tangible investments in uncertain environments. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 11*(3), 263–281.

Uyar, S. E., & Harmanci, A. E. (1999). Investigation of new operators for a diploid genetic algorithm. In *Proceedings of SPIE* (pp. 32–43).

Vail Resorts, Inc. (2006). *Vail resorts 2005 annual report, Vail Resorts, Inc., USA* (pp. 21–30).

Wu, M. D., & Sun, C. T. (2002). Fuzzy modeling employing fuzzy polyploidy genetic algorithms. *Journal of Information Science and Engineering, 18*, 163–186.

Wu, M. D. (2002). Evolution of complex structures: Employing structural adaptation and polyploidy in solving multi-state problems. PhD Thesis, Department of Computer and Information Science, National Chiao Tung University, Taiwan.

Ye, S., & Tiong, R. K. (2000). NPV-at-Risk method in infrastructure project investment evaluation. *Journal of Construction Engineering and Management, 126*(3), 227–233.

Yeh, J. Y., & Lin, W. S. (2007). Using simulation technique and genetic algorithm to improve the quality care of a hospital emergency department. *Expert Systems with Applications, 32*(4), 1073–1083.