PRICING STRATEGY AND GENERAL ADMISSION IN SPORT INDUSTRY: FEASIBILITY TO APPLY OVERBOOKING
&
EVALUATING THE IMPACT OF ENERGY MANAGEMENT SYSTEM IN THE STATLER HOTEL

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ABSTRACT

This thesis includes two projects. The first project explored the current pricing strategy applied in American sport industry and analyzed the feasibility to apply overbooking by setting General Admission (GA) district in stadiums; the second project tested and evaluated the impact of an Energy Management System (EMS) in the Statler Hotel.

Professional sport teams have been seeking all kinds of methods to make optimal pricing strategy and increase their ticket revenue. As one of the important technologies in revenue management, overbooking can be a potential approach to help sport teams achieve the goal of revenue maximization. A sample consisting of 89 baseball teams, 45 basketball teams and 22 soccer teams was created. Collected data was categorized into Pricing Variable, Performance Variable and Demographic Variable. Descriptive analysis was conducted to explore the pricing situation and how GA has been applied in sport industry. An estimation overbooking model was built to show the revenue increasing impact of overbooking by setting GA district in stadiums. Finally the feasibility to implement overbooking was discussed based on both analysis results and past research.

As a major part of energy consumption in hotels, heating, ventilation, and air conditioning (HVAC) is where the hotel can gain potential savings by sustainable technologies. EMS is a common choice hotels are applying. The second project tested and evaluated the saving impact of an in-room EMS named Cassia™. A 12-month dataset was gathered from Schneider Electric and Statler Hotel, where the system was tested, to calculate the actual saving by Cassia™ EMS. A Multiple Linear Regression was built to explore the impact of temperature setback, make more precise estimation of the system's saving impact on the HVAC runtime as well as the energy cost saving of the hotel. Results showed positive evaluation for the system. The system contributed to an average 20% energy saving on HVAC units and was expected to save 19,962 dollars when all the rooms in the hotel installed with the system.

BIOGRAPHICAL SKETCH

Yankang Yao was born March 16th, 1988 in Hangzhou, China. After graduating from the Hangzhou High School, he enrolled at University of International Business and Economics (UIBE) for a Bachelor of Management degree in Business Administration. In UIBE, he developed great interest in hospitality industry and gained solid experience through internship in hotels such as Crowne Plaza Hangzhou and Four Points by Sheraton Hangzhou. After four years of study, he moved to Cornell University and began his graduate education in Hotel Administration through a Master of Science program. At Cornell University, he concentrated on the field of revenue management and developed interest in sustainable development. He also joined the Management Trainee Program in Hilton Worldwide to enhance his skills and start his career in hospitality.

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CHAPTER ONE

PRICING STRATEGY AND GENERAL ADMISSION IN SPORT INDUSTRY: FEASIBILITY TO APPLY OVERBOOKING

SECTION 1: INTRODUCTION

According to the report by Szymanski (2003), in 1997, 41% of the United States' population (roughly 110 million people) attended at least one sport event each year. He also stated that Kagan Media estimated the annual household television viewing of sports events to be 77 billion hours per year. With such a huge market, it has been confirmed by some empirical studies from the U.S. major leagues that the professional team's main objective is to maximize revenue (Jones, 1969; Demmert, 1973). Dick and Brian (2007) argued that ticket sales was determined as an important source of income for sports teams such as Major League Baseball (MLB) and National Basketball Association (NBA), even though there are many fixed revenue streams like television and radio advertisement. Therefore, pricing strategy in professional sport industry has been taken seriously by sport team managers.

Sport teams have been making pricing strategy to increase ticket revenue. Brunkhorst and Fenn (2010) found that many professional sport teams (i.e., over 80% of the teams in National Football League) set ticket prices in a manner consistent with revenue maximization. Kang and Lee (2011) emphasized the need for professional teams to have sophisticated methods for devising pricing strategies in order to maximize ticket revenue. In their research, general adults, college students and middle and high school students were identified as three different fan segments; and player, coupon, point and price were selected as attributes for determining ticket prices in a given circumstance.

Usually the professional sport teams have various types of tickets such as the ticket for a single game, the ticket for the partial season (sometimes also called Mini Plans), and the ticket for the full season. The holder of a season ticket has the access to all the games in one season without additional charges; the partial season ticket provides the holder the right to enjoy some games in one season without additional charges (Wang Shuo, 1998). For instance, New York Yankees offers a Summer Flex Plan which allows customers to choose between three and sixteen games from a game list on their team's website. These plans have a lower price per game to encourage people attend more games and contribute to a more stable revenue stream. Woodworth (2007) defined that ticket holders of sport industry as season ticket holders, flex-pack holders, single game ticket purchasers and luxury suite and Alpine Room ticket holders. According to Joris, Daniel and Chad (2012), prices do not reflect the true market demand for at least some of the seats in a stadium. They examined the underlying consumer demand and sport pricing using secondary market data and found that seat location and price changing over time had significant effect on the choice of potential consumers. Therefore managers of sport teams are facing the problem of how to allocate customers from different classes to different types of seats, with the target of revenue maximization.

As one of the most important technologies in revenue management, overbooking has been practiced by companies such as nearly all popular airlines and many hotels with high occupancy rate. Appropriate overbooking will compensate possible loss caused by cancellations and no-shows thus ensure a full utility of capacity and maximized revenue.

According to the attendance record on the website of Entertainment and Sports Programming Network (ESPN), the average attendance rate of MLB home games in 2012 is 71.5%, with two teams, Philadelphia Phillies and Boston Red Sox, having an attendance rate over 100%. It seems that the average attendance rate does not show an ideal situation for the implementation of overbooking. Besides, the seat is often assigned for each ticket, thus two customers may be allocated to the same seat even if the stadium has not been fully occupied yet. However, General Admission may be a potential approach to solve these problems, making it possible for managers to increase attendance and revenue by implementing overbooking in the GA district. General Admission (GA) is one of the tickets sold sport teams. Different from other tickets with assigned seats in the stadium, GA offers a specified district where a customer can pick any seat there as he or she likes as long as it has not been occupied. The earlier a GA ticket holder arrives, the more choices he or she will have. This thesis explores the current pricing strategy of baseball, basketball and soccer teams and the implementation situation of GA. Related to past research, the analysis results provide a discussion on the feasibility to implement overbooking in sport industry. An optimal overbooking model was built to show the revenue increasing impact of overbooking by setting GA district in stadiums.

SECTION 2: LITERATURE REVIEW

2.1 Revenue Management

Revenue management can be applied in many industries where the capacity is limited and perishable and the market has different segmentations. It is defined as the process of allocating the right type of capacity to the right kind of customer at the right price, thus to achieve revenue maximization (Kimes, 1989). In general, the airline industry is regarded as the first filed for the application of revenue management. Feng and Youyi (1995) listed examples of such industries where revenue management can be used: airline selling seats before planes depart, hotels selling rooms before midnight, theaters selling seats before curtain time and so on. They concluded these industries have sunk investments in capacity and low marginal costs of providing goods or services within capacity, and therefore it has become a paramount concern for managers to maximize the revenue. Mohammad and Mehdi (2009) concluded that revenue management can be implemented on any capacity allocation problem with three basic and common characteristics: (1) capacity is perishable and limited; (2) demand is stochastic; and (3) there are different customer classes. More specifically, there is a widely recognized seven-standard framework for determining whether revenue management can be used in problem solving (Kimes, 1989): (1) the ability to segment markets; (2) perishable inventory; (3) product sold in advance; (4) low marginal sales costs (5) high marginal production costs; (6) fluctuating demand and (7) predictable demand.

Revenue management has a core tactic of forecasting customer demands and their purchasing behavior, thereby optimizing price and the availability of the company's products (Robert, 1998). It is an integrated and systematic approach to revenue maximization by changing the prices and sometimes appropriately rejecting low value customers (Sanchez and Satir, 2005). For instance, when the occupation level of a hotel is 90%, the manager may decide to reject the luxury suite reservation from a “mean” customer who is known to consume little when staying in the hotel, and give the suite with even a lower price to another customer who joins the loyalty program of the hotel and usually contribute a lot to additional revenues.

Making demand-management decisions was emphasized by Kalyan, Garrett, Itir and Gustavo (2009), categorized into three sections: (1) structural decisions, including the segmentations and product bundles; (2) price decisions, including price level setting across product categories, time and channels; (3) quantity decisions, including whether to accept or reject an offer to buy and how to allocate capacity to different segments. Cross (1997) also put forward a nine-step process which helped ensure the successful implementation of revenue management: (1) evaluate your market needs; (2) evaluate your organization and process; (3) quantify the benefits; (4) enlist technology; (5) implement forecasting; (6) apply optimization; (7) create teams; (8) execute, execute, execute; and (9) evaluate success. Choi and Kimes (2002) conducted a computer simulation to test the performance of an extended model for revenue management forecasting and optimization, considering the effects of the distribution channels. The test proved that pricing is the most important element in optimization since distribution channel did not present significant contribution to optimization.

2.2 Overbooking

First appeared in the US airline industry in the middle of the 20^{th} century (Netessine and Shumsky, 2002), overbooking is one of the most important technologies in revenue management and has been practiced by companies such as nearly all popular airlines and many hotels with high occupancy rate. To compensate possible loss brought by cancellations and no-shows, more reservations than the fixed capacity, which can be as high as 50% (Smith et al., 1992), are accepted where the demand is expected to exceed the capacity.

Amaruchkul, Kannapha and Sae-Lim (2011) stated that there are two broad types of overbooking models: dynamic overbooking model and static overbooking model. The dynamic model considers a dynamic pattern of customer reservations, cancellations and no-shows while the static model ignores them for simplicity. The static model is implemented in most of the commercial revenue management systems. They also defined the overbooking problem as determining an overbooking level such that expected cost is minimized. Therefore cost control can be regarded as the core of overbooking since the variation in cancellations and no-shows leads to the problem that overbooking may create oversales which often bring hurt to brand reputation and additional cost for problem solving.

A mass of overbooking models have been built in order to determine the most appropriate overbooking level with minimum cost of oversales and maximum revenue (i.e., Subramanian et al., 1999; Luo et al., 2009; and Sulima, 2012). What most of these models have in common is the assumption about the pattern of show demand, which determines the cancellation and no-show rate. For instance, Talluri and van Ryzin (2004) stated in their classic static overbooking model that the show demand followed a binomial distribution while Kasilingam (1997) assumed that the show demand should be the product of overbooking level and random show-up rate which followed a uniform distribution. Concluding the calculation of these models, the optimization result is based on the purchase price, show demand, capacity, cancellation or no-show rate, cost of oversales and overbooking level. With appropriate assumptions of fluctuating parameters such as show demand and cancellation rate, an optimal overbooking level will be obtained to maximize the revenue, taking into consideration of the possible cost of oversales.

Overbooking also has the risk of satisfaction decreasing. Customers behave in different manners when facing overbooking, such as downgrading, denied service, or upgrading. Toh (1985) stated that an overbooking level which is too high would lead to customer dissatisfaction and tested the measured negative effect of overbooking in his model. Wangenheim and Bayón (2007) also argued that the customers who experienced negative consequences of overbooking would significantly reduce the amount of their consumption of the service while upgraded customers exhibited only weak positive responses.

2.3 The Implementation of Revenue Management in Sport Industry

Courty (2000) pointed out the importance of the revenue management application in sports and entertainment industry since many organizations in the industry keep prices as announced and do not change them throughout the selling period. This leads to loss of potential revenue because of unsold seats. Serhan, Julie and Ertan (2012) also applied revenue management into sports and entertainment industry by testing the effect of dynamic switching times from season to single tickets. Joris, Stephen and Seoki (2012a) determined that sport industry can be an appropriate platform for the implementation of revenue management system by matching the industry's characteristics with the criteria set of revenue management put forward by Kimes (1989). According to their conclusion, the market segmentation of sport industry can be based on different characteristics such as gender, age and season status, indicating the ability to segment markets in the sport industry; the ticket unsold will become invalid once the game is over, indicating the inventory is perishable; sport game tickets are usually sold before the game starts and some teams in MLB and NBA even provide season ticket reservation for the next four years; large numbers of fans attending the sport games contribute to lower marginal sales costs; the capacity restriction in stadium determines that creating additional seats is often too expensive to be a realistic proposition; the demand is fluctuating because it can be influenced by various factors such as the day before the game and team performance, but the statistical records of many professional sports and the ease of access to other quantifiable demand factors also make it possible to estimate the demand.

2.4 Dynamic/Variable Ticket Pricing

The dynamic or variable ticket pricing strategy is the most successful and widely-applied revenue management technology in sport industry. Throughout much of the 20th century, as concluded by Joris, Stephen and Seoki (2012b), the majority of sport team managers implemented either a “one-size-fits-all” approach where every ticket in every game has exactly the same price or a seat location-based approach where prices are determined according to the proximity to the field. However, neither of the two approaches can satisfy the professional sport team’s need of revenue maximization as the awareness of new pricing strategy arises.

The impact of selling the appropriate inventory at the right place, price and time was noted by Kimes (1989) in her study on hotel revenue management. Shapiro and Drayer (2012) also tested factors such as time and seat location to identify effects on ticket price in both primary and secondary markets for baseball teams. Then in order to gain revenue and avoid potential loss, new ideas of pricing for sport games were put forward. The San Francisco Giants is the first professional sport team implementing Dynamic Ticket Pricing (DTP). DTP is a pricing strategy which changes everyday ticket prices by adding newly considered factors such as the team performance, player performance and weather (Joris et al., 2012b). Rascher, McEvoy, Nagel and Brown (2007), King (2003) and Rovell (2002) also put forward a similar idea which was called Variable Ticket Pricing (VTP), referring to changing the price of a sporting-event ticket based on the expected demand for that event. The new method helped the San Francisco Giants improve its revenue with 7% increase from 2009 to 2010 ("Forty under 40: Barry Kahn", 2011). As for more previous evidence of the advantage of DTP, ticket revenue could be increased by 2.8% by DTP based on 1996 MLB data; and ticket revenue could be raised by 1.2% with 5% price increase for every 10% increase in attendance (Rascher et al., 2007).

According to the definition and application of DTP and VTP, DTP focuses more on the game day variable and the demand change based on time period while VTP emphasizes more on setting various price levels for different seat types. However, these two technologies are quite similar since the factors considered by one will also be analyzed by the other. Researchers often do not differentiate one from the other, using either name in their studies. Managers and analysts are making every effort to allocate one customer in every seat and avoid possible loss, dealing with all kinds of variables which may have influence on ticket revenue in their pricing strategy. For simplification, this paper uses Dynamic Ticket Pricing (DTP) to represent the concept for both of these two technologies.

DTP has recently been a hot topic discussed much in the business of professional sport teams such as baseball, basketball and soccer. An increasing number of sellers of perishable goods, not only in sport industry, are using dynamic pricing strategies (Andrew, 2012). They change prices based on both inventory and time before product using. Besides, most of the teams in MLB and NBA are cooperating with ticket selling channels such as Ticketmaster, a company providing ticket information and ordering of concerts, sport games, shows and family events. These channels offer various ticket prices for different seat types, helping the team allocate desired seats to customers.

The DTP can be implemented successfully partly because technologies make it easier and cheaper to change prices as well as to track inventory. Also, a large amount of suitable data is available for the sellers, providing the base of consumer behavior modeling and demand forecasting. As mentioned in Andrew’s (2012) research, DTP can accurately describe pricing behavior in the MLB market. Furthermore, DTP created the possibility for teams to set higher prices for more attractive games which they predicted to have higher demand. Different variables such as game time and season (spring, summer or fall) were found to be significant in determining which games would have more fans (Shapiro and Drayer, 2012).

When more sport teams are implementing DTP to maximize revenues, researchers have found that DTP determined the ticket prices' increases or decreases depending on various factors such as opponent's situation, day of the week, month of the year and even special event days (opening day, Memorial Day and so on). Serhan and Yusuf (2012) also studied the problem of dynamically switching between selling ticket bundles and selling individual tickets, and found that various tickets and dynamic decisions could improve the revenue over the best static decision. Dana Jr.'s (2001) also built a dynamic pricing model suggesting differential pricing is optimal in an environment where fixed pricing in advance of an event are required, which is consistent with the DTP strategy. McDonald and Rascher (2000) found variables such as day of the week, teams' winning% and weather to be statistically significant predictors of game attendance in a study including more than 50 independent variables in explaining MLB game attendance. Dennis and Thane's (2005) study also supported that teams with higher winning% would attract more fans per game than teams with lower winning%; and that attendance was quite price inelastic for professional sport teams, no matter whether price is measured using the seat price or the average gate approach. In addition, stadium capacity restriction was found to be another factor which may have influence on sport team's ticket pricing (Stefan and Wilfried, 2006). All the home games for a professional sport team can be regarded as unique products based on the above-mentioned characteristics such as time, weather and team performance, rather than just units of the same product (Rascher et al., 2007). Therefore these unique products will have their own prices individually according to the characteristics which determine their attractiveness to customers.

2.5 Game Attendance

Attendance increasing is one of the topics which have received the most attention in the empirical studies of the economics of professional sport industry. As the competition within the sports and entertainment industry increases, managers are using all kinds of marketing techniques to increase game attendance (Burton and Cornilles, 1998). Many researchers are also getting aware of the importance of game attendance. Demmert (1973) and Noll (1974) were the two earliest researchers who conducted attendance models for sport teams, each of whom found the effects of ticket prices to be problematic while population characteristics, team performance and the availability of substitutes had influence on the game attendance. Dick and Brian (2007) highlighted the contribution of the game attendance which directly determines other revenue streams such as parking, merchandise sales and sponsorship signage. In Woodworth's (2007) study, a significant positive correlation between loyalty and the number of games a fan attends was proved, indicating attendance brings long-term revenue. Jaume and Plácido (2002) specified the explanatory factors influencing on the game attendance and classified them into four groups: economic variables, variables representing the expected quality of the game, variables measuring the uncertainty of the result, and variables capturing the opportunity cost of attending a game. They also concluded in their test that the variables representing the expected quality of the game were the group with the highest effect on game attendance.

SECTION 3: RESEARCH QUESTIONS

The thesis focuses on the current pricing strategy in sport industry in the United States and the feasibility to implement overbooking by setting GA district in the stadium. Below are the research questions:

Research Question 1: How do U.S. professional baseball, basketball and soccer teams set prices and game packages?

Research Question 2: What kind of professional sport teams are applying general admission?

Research Question 3: Is it feasible to implement overbooking by setting GA district in the stadium to maximize ticket revenue?

SECTION 4: METHODOLOGY

4.1 Sample

Baseball, basketball and soccer are the three sports selected in this study considering both their popularity in the United States and the completeness of the data. Each sport team was considered as an observation, with different variables describing its characteristic. For each sport, teams in the major league and the second level league were selected to represent the professional level of the games. The study focused on American sports so all the teams selected are native teams in the United States and teams like Toronto Blue Jays were excluded.

For baseball, 87 teams in total were selected. Among them were 29 teams in the major league (Major League Baseball, MLB) and 58 teams in the minor league. The minor league teams are all in Triple-A and Double-A leagues, which represent relatively high performance level in the minor league. For basketball, 45 teams were selected, among which were 29 teams in the major league (National Basketball Association, NBA) and 16 teams in the minor league (NBA Development League). For Soccer, 22 teams were selected, with 16 teams in the major league (Major League Soccer, MLS). The other 6 teams were selected from North American Soccer League (NASL) because it is the second-level soccer league in America, even though there is no official minor league for soccer.

4.2 Variable Explanation

In order to describe and measure the characteristic of each sport team, three groups of variables were collected: Pricing Variable, Performance Variable and Demographic Variable. Pricing variables present the pricing strategy of each team; performance variables show the team's performance and related results such as the ranking and attendance rate; and demographic variables reflect the demand situation of potential customers in the home city of each team. Table

1.4.1, 1.4.2 and 1.4.3 presented below are the explanations and measurements of these variables:

Table 1.4.1: Pricing Variable Explanation and Measurements

Pricing Variables

Number of Price Level	How many price levels for different seat locations a team has
Maximum Price	The highest Price in dollar a team sets
Minimum Price	The lowest Price in dollar a team sets
Price Range	The difference between the highest and lowest prices, in dollar
General Admission	Whether the team sells General Admission tickets or not: "1" = Yes, "0" = No; Some standing tickets in baseball games are also regarded as GA ticket since no seat is assigned
Group or Suites Ticket	Whether the team has discounted prices for group or suite customers: "1" = Yes, "0" = No
Full Season Pack	Whether the team sells full season tickets: "1" = Yes, "0" = No
2-5 Game Pack	Whether the team sells package with 2-5 games: "1" = Yes, "0" = No
6-15 Game Pack	Whether the team sells package with 6-15 games: "1" = Yes, "0" = No
16-30 Game Pack	Whether the team sells package with 16-30 games: "1" = Yes, "0" = No
31+ Game Pack	Whether the team sells package with more than 30 games: "1" = Yes, "0" = No

Table 1.4.2: Performance Variable Explanation and Measurements

Performance Variables

Rank	Team's 2012 ranking in the league
Percentage of Wins	Team's win rate in 2012 season
Win Home	Number of home wins in 2012 season
Loss Home	Number of home losses in 2012 season
Win Away	Number of away wins in 2012 season
Loss Away	Number of away losses in 2012 season
Home Attendance Rate	Team's average attendance rate of home games in 2012
Stadium Capacity	The capacity of the team's home stadium

Table 1.4.3: Demographic Variable Explanation and Measurements

Demographic Variables

Population in the City	Population in the team's home city
Household Number in the City	Household number in the team's home city
Civilian Employees Aged 16+	Number of civilian employees aged 16 or older in the team's home city
Percentage of Females	The percentage of females in the team's home city
Percentage of Males	The percentage of males in the team's home city
High School Aged 25+ %	The percentage of people aged 25 or older, with high school or higher education level
Bachelor Aged 25+ %	The percentage of people aged 25 or older, with bachelor degree or higher education lev
Median Age	Median age of people in the team's home city
Percentage of Whites	The percentage of white people in the team's home city
Percentage of Blacks	The percentage of black people in the team's home city
Percentage of Other Races	The percentage of other race people in the team's home city
Income Household	The household income level of the team's home city
Income per Capita	The per capita income level of the team's home city

4.3 Data Collection

Due to the lack of research in GA implementation in sport games, some primary data had to be collected manually while other data was drawn from secondary data source. Pricing Variables were all manually collected from the teams' official websites. The variable Price Range was calculated as the difference between the maximum price and minimum price. For Performance Variables, team's ranking, percentage of wins, win-loss numbers and attendance rate were collected from standing records on league websites; stadium capacity was recorded from Wikipedia. All the demographic data was drawn from the reports of United States Census Bureau. Detailed resource information will be provided in the appendix.

4.4 Pricing Analysis

Pricing Analysis aims to figure out the current pricing strategy applied by the professional teams in baseball, basketball and soccer leagues. The analysis consists of two steps. In the first step, the average value of the number of price levels, maximum price, minimum price, price range, number of teams selling GA and the percentage of teams selling GA were calculated. This step provided a basic description of the ticket pricing situation and compared the difference in GA implementing. In the second step, the percentage of teams selling different packages were calculated to present the popularity of ticket packages with different sizes.

For each step, average and percentage values were calculated based on both sport types and league levels. The sport-type-based part compared the pricing situation across baseball, basketball and soccer while the league-level-based part focused on the difference between major and minor leagues in each sport field.

4.5 General Admission Analysis

General Admission Analysis was conducted in order to describe the characteristics of teams which are implementing GA and compare them with those not selling GA tickets. Together with the literature reviews, the current situation of GA implementation helped explain what kind of teams GA can be applied to and the feasibility to apply overbooking. Pricing variables (i.e., price range), performance variables (i.e., ranking) and demographic variables (i.e., population in the city) were used to describe the team characteristics.

Basketball teams were not taken into consideration in this analysis because there are only two teams which sell GA tickets. Baseball and soccer teams were separately analyzed and categorized into four groups based on league levels: major league baseball teams, minor league baseball teams, major league soccer teams and minor league soccer teams. For each group, average values of the variables mentioned above were calculated based on whether the team sells GA ticket or not. Then the difference between teams with GA and teams without GA was compared according to the result, using the percentage of difference between teams without GA and teams with GA. For instance, according to the results, the price range of major league baseball teams selling not GA ticket is 27.5% higher than that of the teams selling GA ticket.

4.6 Overbooking Model Analysis

An estimation model for overbooking was built to show the revenue increasing impact of this technology. Assume that the team is applying overbooking by setting GA in a district of its stadium. With assumed values for parameters, linear Programming was used to get the highest revenue with an optimal decision of the overbooking level. Revenue with overbooking was then compared to that with normal pricing. Below are the detailed assumptions and calculations:

- The capacity of the district is "N" seats;
- The normal price for this seat level is "P_1"dollars while the GA ticket price is "P_2"dollars;
- All N tickets will be sold in advance but the average show rate is "$\alpha\%$";
- Customer spend averagely "A_1"dollars on food and beverage, "A_2"dollars on parking and "A_3"dollars on merchandise shopping such as souvenir and cheer equipment;
- An estimated walk cost of "C" dollars occurs in terms of dispute and dissatisfaction when customers find no seat due to oversale;
- "n" seats will be overbooked when GA is set in this district.

If overbooking is not applied, the ticket revenue will be:

$P_1 * N + (A_1 + A_2 + A_3) * N * \alpha\%$ Formula (1.4.1)

When overbooking is applied with GA tickets, the revenue will be:

$P_2 * (N + n) + (A_1 + A_2 + A_3) * N – C * [(N + n) * \alpha\% - N]$, in case that more customers than capacity come Formula (1.4.2)

$P_2 * (N + n) + (A_1 + A_2 + A_3) * (N + n) * \alpha\%$, in case that the district is still not full even with overbooking strategy Formula (1.4.3)

SECTION 5: RESULTS

5.1 Pricing Analysis Results

According to Table 1.5.1, baseball, basketball and soccer leagues in the United States are all segmenting their customers by providing with on average 7 different ticket levels in different locations. Basketball League has 10 levels on average, providing the most various choices for customers. Accompanied is the largest price range, 134 dollars on average, twice as much as the 70 dollar price range in baseball and soccer leagues. However, basketball league seldom provides GA while both baseball and soccer leagues have more than 40% of the teams selling GA tickets.

Table 1.5.1: Pricing Analysis across Sports

	Baseball	Basketball	Soccer
Number of Price Level	8.4	10.3	7.0
Maximum Price	79.4	148.4	90.1
Minimum Price	7.5	14.0	18.0
Price Range	71.9	134.4	72.2
Percentage of Teams with GA	42.5%	4.5%	40.9%
Number of Teams with GA	37	2	9

The collected data shows that all the teams in the sample have full season tickets and discounted prices especially for group customers. Table 1.5.2 also indicates that more teams in baseball and soccer leagues are providing ticket packages than in basketball leagues to attract customers to attend more games with a lower price for each game. Baseball teams also provide smaller packages with more different sizes, probably because of its larger number of games in each season. Basketball and soccer teams often offer packages with fewer games than baseball teams because there are fewer teams in a league, especially the minor league, and therefore the number of games in each season is limited.

Table 1.5.2: Percentage of Teams Selling Different Packages across Sports

	Baseball	Basketball	Soccer
2-5 Game Pack	17.2%	8.9%	63.6%
6-15 Game Pack	75.9%	24.4%	45.5%
16-30 Game Pack	59.8%	0	0
31+ Game Pack	20.7%	0	0

Table 1.5.3 is the pricing analysis across major and minor leagues for each sport. There are more ticket levels in major leagues, especially in baseball and basketball major leagues which have about 10 more levels than in minor leagues. Major league teams have much higher maximum prices than minor league teams, which is reasonable because major league games are much more popular and have higher demand. However, minimum price does not vary much across league levels. Hence, price range in major leagues also has much greater variance.

Table 1.5.3: Pricing Analysis across Leagues

	Baseball		Basketball		Soccer	
	Major League	*Minor League*	*NBA*	*D-league*	*Major League*	*Minor League*
Number of Price Level	15.8	4.7	13.6	4.3	7.4	5.8
Maximum Price	194.9	21.6	215.5	32.5	109.4	38.8
Minimum Price	9.6	6.5	16.8	9.1	21.1	9.5
Price Range	185.3	15.2	198.7	23.4	88.3	29.3
Percentage of Teams with GA	24.1%	51.7%	0	13.3%	31.3%	66.7%
Number of Teams with GA	7	30	0	2	5	4

Figure 1.5.1 and 1.5.2 show the number and percentage of teams with GA option. More teams in baseball minor leagues offer GA tickets than in major leagues. As for percentage, baseball and soccer minor leagues have twice as much as percentage of teams selling GA tickets than major leagues. In basketball league, however, only 2 teams in its minor league offer GA tickets.

Figure 1.5.1: Number of Teams with General Admission

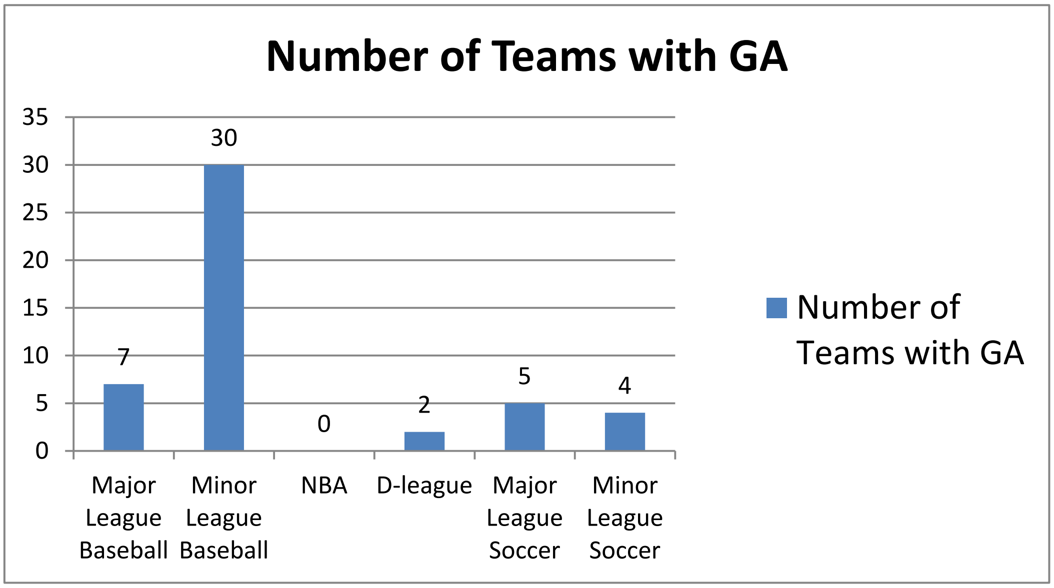
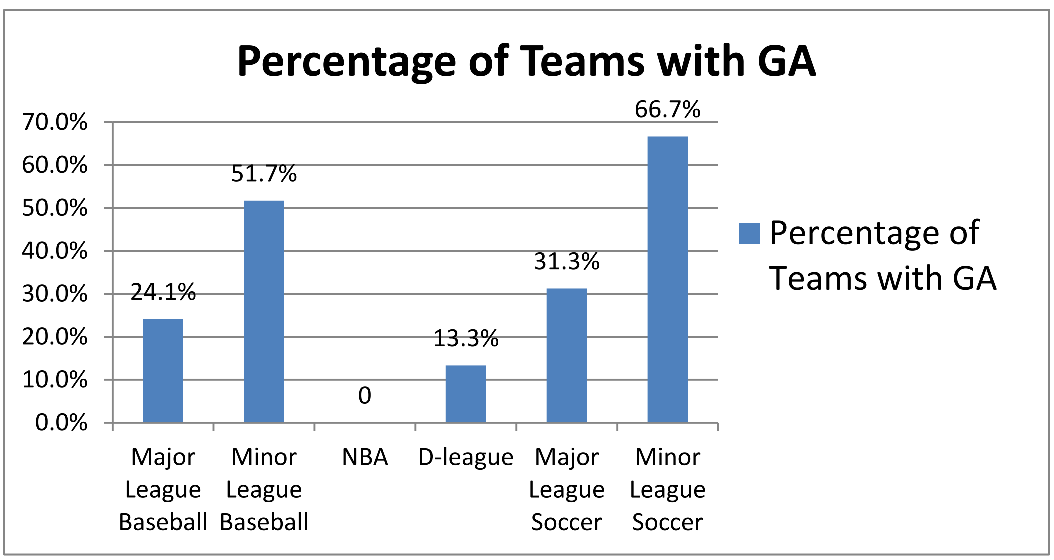


Figure 1.5.2: Percentage of Teams with General Admission



It is obviously presented by Table 1.5.4 that for game packages with any size, there are a higher percentage of teams in minor league baseball offering such packages than in major league. However, more teams in the soccer major league provide such packages and only 4.5% of soccer minor league teams sell packages. This is reasonable because low level soccer leagues have fewer teams and thus fewer games. For instance, there are only 10 games for each season in

NASL. Therefore these teams do not need to create many packages.

Table 1.5.4: Percentage of Teams Selling Different Packages across Leagues

	Baseball		Basketball		Soccer	
	Major League	*Minor League*	*NBA*	*D-league*	*Major League*	*Minor League*
2-5 Game Pack	6.9%	10.3%	4.4%	4.4%	59.1%	4.5%
6-15 Game Pack	21.8%	54.0%	15.6%	8.9%	40.9%	4.5%
16-30 Game Pack	18.4%	41.4%	0	0	0	0
31+ Game Pack	8.0%	12.6%	0	0	0	0

5.2 General Admission Analysis Results

According to Table 1.5.5, MLB teams which do not sell GA tickets have 2.3 more ticket levels, 25.7% higher maximum price and 27.5% higher price range on average than teams which sell GA tickets. Minor league teams do not present such great difference probably because the variances of these factors are small. Teams without GA tend to have higher rank and percentage of wins in both major and minor baseball leagues. For both major and minor baseball leagues, teams without GA are also facing much larger population and household numbers, more civilian employees aged more than 16, and more people in other race (except white and black) in their home city.

Table 1.5.5: General Admission Analysis - Baseball

Baseball	Major team with GA	Major team without GA	Difference %	Minor team with GA	Minor team without GA	Difference %
Number of Price Level	14.7	17.0	15.6%	4.8	4.6	-3.3%
Maximum Price	163.1	205.0	25.7%	22.1	21.1	-4.8%
Minimum Price	9.86	9.55	-3.2%	6.07	6.89	13.6%
Price Range	153	196	27.5%	16	14	-11.8%
Rank	18.4	14.3	-22.6%	7.8	5.5	-29.9%
Percentage of Wins	47.4%	51.1%	7.8%	48.1%	52.2%	8.5%
Home Attendance Rate	74.1%	70.6%	-4.7%	56.8%	59.1%	3.9%
Stadium Capacity	42710	43722	2.4%	9631	9397	-2.4%
Population in the City	853185	1610045	88.7%	223120	303391	36.0%
Household Number in the City	384430	682932	77.6%	101197	130249	28.7%
Civilian Employees Aged 16+	394904	747504	89.3%	105242	136335	29.5%
Percentage of Females	51.3%	51.2%	-0.2%	51.6%	51.4%	-0.4%
Percentage of Males	48.7%	48.8%	0.2%	48.4%	48.6%	0.4%
High School Aged 25+ %	83.0%	81.3%	-2.1%	83.9%	83.1%	-1.0%
Bachelor Aged 25+ %	35.0%	32.0%	-8.4%	28.7%	25.5%	-11.2%
Median Age	32.6	34.6	6.2%	35.0	34.0	-2.9%
Percentage of Whites	48.2%	50.5%	4.8%	66.1%	60.4%	-8.6%
Percentage of Blacks	36.3%	27.6%	-23.9%	20.8%	23.7%	13.9%
Percentage of Other Races	15.6%	21.9%	40.8%	13.1%	15.9%	21.2%
Income Household	66237	68811	3.9%	63157	59689	-5.5%
Income per Capita	28247	28234	0.0%	25861	23843	-7.8%

Table 1.5.6: General Admission Analysis - Soccer

Soccer	Major team with GA	Major team without GA	Difference %	Minor team with GA	Minor team without GA	Difference %
Number of Price Level	7.1	8.4	18.3%	5.3	7.0	33.3%
Maximum Price	84.6	163.8	93.6%	33.0	50.5	53.0%
Minimum Price	20.20	21.55	6.7%	11.75	5.00	-57.4%
Price Range	63	144	128.6%	21	46	114.1%
Rank	4.8	4.9	2.3%	5.0	2.5	-50.0%
Percentage of Wins	39.4%	40.4%	2.4%	32.1%	41.1%	27.8%
Home Attendance Rate	17.2%	19.1%	11.1%	45.9%	76.8%	67.1%
Stadium Capacity	48407	27984	-42.2%	10294	9000	-12.6%
Population in the City	164412	490416	198.3%	221870	731321	229.6%
Household Number in the City	71166	212434	198.5%	117264	289775	147.1%
Civilian Employees Aged 16+	79973	242731	203.5%	108014	328523	204.1%
Percentage of Females	51.2%	50.5%	-1.2%	50.1%	51.3%	2.4%
Percentage of Males	48.8%	49.5%	1.3%	50.0%	48.8%	-2.4%
High School Aged 25+ %	84.5%	83.9%	-0.8%	88.4%	87.5%	-1.0%
Bachelor Aged 25+ %	34.6%	37.6%	8.5%	34.1%	42.8%	25.4%
Median Age	35.9	33.6	-6.5%	38.1	34.7	-9.0%
Percentage of Whites	59.7%	59.8%	0.2%	63.4%	74.7%	17.7%
Percentage of Blacks	15.1%	18.7%	24.2%	28.2%	5.5%	-80.6%
Percentage of Other Races	21.5%	25.3%	17.7%	8.4%	19.9%	136.2%
Income Household	84605	71576	-15.4%	76643	86786	13.2%
Income per Capita	30804	29289	-4.9%	32620	32339	-0.9%

Soccer teams show similar characteristics in Table 1.5.6, but with a larger variance. It might be affected by the limited number of observations, but the more price levels, higher maximum prices, larger price ranges and population bases still support the findings in baseball data. The average attendance of home games for soccer teams also presents a higher value for teams which do not sell GA tickets.

Table 1.5.7 shows the average attendance rate of home games across sport leagues. Minor league soccer's unusually higher attendance rate may be due to the small sample, while the major leagues of baseball and basketball both present higher attendance than minor leagues. NBA games are the most attractive with the highest attendance rate, 90.4%.

Table 1.5.7: Home Attendance Rate across Leagues

	Baseball	Basketball	Soccer
Home Attendance Rate	*Major League*	*NBA*	*Major League*
	71.5%	90.4%	18.6%
	Minor League	*D-league*	*Minor League*
	57.9%	53.9%	56.2%

5.3 Overbooking Model Results

Values for parameters were assumed as: N = 200 seats, P_1 = 10 dollars, P_2 = 8 dollars, α% = 70%, A_1 = 5 dollars, A_2 = 10 dollars, A_3 = 10 dollars and C = 30 dollars. The overbooking level, n, is considered as the determination factor to maximize the revenue. Results showed that the revenue under normal pricing is 5,500 dollars, while 7,302 dollars will be gained when 84 more GA tickets than the 200 capacity are sold. Thus the revenue is increased by 32.76% with the implementation of overbooking.

SECTION6: CONCLUSIONS AND IMPLICATIONS

The thesis describes the regular pricing situation and presents how general admission has been applied in professional sport industry. Conclusions drawn from the analysis results and the feasibility of overbooking in sport games are discussed below.

The descriptive results provide evidence for the implementation of dynamic ticket pricing strategy and present the current pricing strategy applied by professional sport teams. It is presented that many professional teams are setting multiple seat levels with different prices to reach as many types of customers as they can. According to many of the team's online reservation system, dynamic pricing strategy has been popularized, showing a matrix of prices based on game day and seat location. The price range between the best and the worst seats is usually large, especially for teams in major leagues. As an effective way to ensure attendance and long term revenue stream, full season ticket and group price are applied by all teams, no matter it is in major or minor league. A number of teams are also applying smaller game packages with different sizes and discounts, supporting that professional teams are pricing based on customers' demand on how frequently they attend sport games. The package size is also based on demand, determined by the number of games in each season and the popularity of the games. For instance, soccer leagues with fewer games per season have less packages and also smaller package size; in baseball leagues with more games per season, less teams in major league offer packages to attract customers, probably because the demand is higher than minor league.

A number of baseball and soccer teams, and very few basketball teams are applying general admission tickets according to the analysis. The teams applying GA tend to such characteristics as: with fewer price levels, with lower rankings and percentage of wins, facing smaller population and with fewer customers in other race except white and black. In conclusion, GA tickets are more often sold in less popular teams and regarded as a low-price motivation to attract more customers. GA districts are often locations with relatively worse views to the game.

As one of the important technologies in revenue management, overbooking shares the same framework for determining whether it can be applied. Besides, three more requirements were concluded from former research: (1) the cancellation and no-show pattern has to be predictable; (2) the cost of oversales has to be predictable; (3) the demand has to be high enough for oversales. The first requirement is not a problem for professional sport industry since historical records of ticket selling and checking can provide this information. The cost of oversales can be predicted based on investigations and surveys on consumer behavior, and the team's policy to deal with dissatisfaction to overbooking (i.e., paying compensation). The last requirement can be analyzed in two different situations. For hot games such as the final round match of NBA and MLB, it is reasonable to expect that the stadium will be fully occupied. Then overbooking can be applied in the GA district to compensate the possible cancellations. For regular games, the attendance rate is expected to be lower. However, setting GA district in medium or even good seat levels for which demand is high with relatively lower prices can be an approach to apply overbooking and maximize the utility of the GA district. Customers may be willing to buy GA tickets either because of the lowered price or because of the better view if they come early. Therefore an over-booked GA district in a better location may create more revenue than the original one with assigned seats but only partial attendance, especially in some price-elastic games since each sport game can be regarded as a unique product as mentioned above (Rascher et al., 2007).

The results of overbooking model analysis also indicated the positive impact of this technology. Substantial revenue increase will be gained theoretically. However, the effect of GA and overbooking depends on factors such as the area of GA district, customers' price sensitivity and ticket prices. Managers have to tradeoff between the potential increase in revenue and possible loss due to over estimation of attendance increase. In addition, customer satisfaction should also be taken into consideration. Usually there is no employee especially responsible for dealing with customer disputes, customers who find the seat assigned to be occupied have to leave. The satisfaction will be hurt badly and the customers may even fight for a seat when the game is really attractive. Therefore, the overbooking level for hot games should be well controlled to avoid additional cost. Besides, overbooking should be applied to individual customers rather than season ticket and package holders since season tickets and packages contribute to a significant part of the ticket revenue. Based on research results, customers with lowered satisfaction may no longer buy season tickets or packages (Toh, 1985; Wangenheim and Bayón, 2007). Considering that the average attendance for sport games is not so high, a telephone hot line can be set to re-arrange seat or upgrade as compensation for those who do not get seats due to overbooking.

SECTION 7: LIMITATIONS AND FUTURE RESEARCH

Due to the lack of overbooking implementation in sport industry, this thesis does not test the revenue increasing effect of overbooking with quantitative data. The feasibility discussion is mostly based on qualitative analysis and past research. It does not consider the customers' attitude toward general admission and how the increase of GA ticket will affect their choices. For instance, some customers may not accept GA tickets since they are not confident to arrive early enough to get a better seat. Thus future research is expected to include the changed consumer behavior in regard of GA tickets. Future research is also expected to expand the sample to more sports such as hockey and football, with quantitative modeling which tests how much revenue will be gained by applying overbooking in GA district.

CHAPTER TWO

EVALUATING THE IMPACT OF ENERGY MANAGEMENT SYSTEM IN THE STATLER HOTEL

SECTION 1: INTRODUCTION

The world's total primary energy supply has doubled in 35 years, and buildings account for 40% of this consumption (Accor, 2006). Ecological consciousness and concern for the environment have been increasing according to Laroche, Bergeron and Barbaro-Forleo (2001). In the hotel industry, over 1 billion dollar worth of energy was consumed every year and it is possible for most hotels to save their energy consumption by 20% to 40% while maintaining guest comfort (Dodds, 2005). Many customers are also starting to seek hotels that are taking steps to protect the environment (Han, Hsu and Sheu, 2010). With the awareness of the need to be environmentally friendly and control costs, hotels are implementing all kinds of sustainable technologies. There are a lot of companies providing various cutting-edge energy management solutions that aim to help hoteliers save as much as 30% to 50% on guest room utility expenses (M2 PressWIRE, 2011). Energy Management System (EMS) has become a potential alternative for many hotels pursuing cost saving and sustainability achievements.

With a nine-story structure and 153 guest rooms, Statler Hotel is located in the central area of Cornell University. Schneider Electric, a global energy management specialist company, was permitted to test Cassia™ in order to reduce energy cost and increase sustainability in Statler Hotel. Developed in late 2010 by Schneider Electric, Cassia™ is an in-room EMS based on motion sensors that detects room status and triggers temperature setbacks in heating and cooling units. When the motion sensor detects that a room is vacant, the system will initiate a temperature setback in order to reduce HVAC's runtime and save energy. At check-in, Cassia

Rooms are set at a default temperature of 70°F. Customers have complete control over temperature settings when they stay in the room. When the motions sensor detects the room as vacant, a 3 °F “simple” temperature setback will be operated by the system. When the room is unrented, a 6°F setback called “Deep Setback” will be implemented by the system. The company provided an estimation of energy saving effect of 25% - 44% for this system (Schneider Electric, 2010). A previous project has been conducted by Khadeejah Sani (2012), who is a student of Department of Biological and Environmental Engineering in Cornell University. Two control rooms and two test rooms with the installation of Cassia™ EMS were used to test and evaluate potential energy savings by Cassia™. According to Khadeejah’s (2012) report, an average 18% of the energy was saved by Cassia™ EMS during the 7 month test period. However, the previous study did not go deep into the impact of temperature setback, not did it succeed to make a technical estimation of the future savings in case that all 153 rooms are installed with the EMS.

This study is the extension and supplement of the previous study with a larger sample gathered from the same test and control rooms, comparing and verifying the results and conclusions of former analysis. A 12-month dataset was used to calculate the actual saving by Cassia™ EMS, showing that the system contributed to an average 20% energy saving on Statler’s HVAC units. A Multiple Linear Regression was also built to explore the impact of temperature setback, make more precise estimation of the system’s saving impact on the HVAC runtime as well as the energy cost saving of Statler Hotel.

SECTION 2: LITERATURE RIVIEW

2.1 Sustainability Development

Sustainability development has both environmental and economic benefits. Hotels have been implementing a number of practices and technological solutions to make the property environmentally friendly and reduce the demand of supplies, water and energy usage. According to Ruiz-Molina, Gil-Saura and Moliner-Velazquez (2012), hotels in higher classes tend to be more intensive to invest in sustainable technologies. H. Houdre (2008) also stated that hotels are seeking for competitive advantage by improving the sustainability of their operations because environmental friendliness will create an opportunity for hotels (Hendrie, 2006).

Hotels implement sustainable technologies for several reasons. Enz and Judy (1999) pointed out three motivations: first, some operators believe that operating in an environment-friendly manner is the right thing to do; second, the increasing governmental regulation encourages or forces hotels to be environmentally friendly; finally, a greater proportion of hotels' guests increasingly are demanding green operations and seeking for green hotels. Marketers in the hotel industry are making effort to gain recognition and increase customer retention through the application of sustainable technologies, thereby eventually enhancing their hotel profit (Manaktola and Jauhari, 2007).

Furthermore, sustainable technologies have been proved to be a way to cost saving and efficiency increasing. Porter and van der Linde (1991) stated that it pays to be green, since corporate performance will be improved by waste reduction and productivity increase when environmental performance is improved. King and Lenox (2001) then supported the benefit of sustainability but also extended the idea of "whether it pays to be green" to "when does it pay to be green", indicating that the effect of sustainability will be determined by specific attributes such as firm size, grow rate of the firm and research and development intensity. Strong evidence was found in Jie, Nitin and Rohit's (2012) study, suggesting that the operating units with a higher environmental sustainability level have significantly higher technical inefficiency, and thereby better operating performance. In their previous research (Jie, Nitin and Rohit's, 2010), two principal factors were identified to measure hotels' operational utility and supply expenses, providing a reasonable benchmark for efficient use of resources: the operating factor which indicates utility and maintenance expenses and the behavioral factor which indicates laundry and linen related expenses. According to the report of Sustainability in the Global Hotel Industry (2011), 41% of hotel industry suppliers expect that the implementation of sustainability will bring an increase in profitability over the next 12 months. The report also concluded that cost savings, operational efficiency and competitiveness strengthening are becoming the major drivers to implement sustainability in the hotel industry.

Walley and Bradley (1994) argued, however, managers should tradeoff between the sustainable benefit and value destruction, concentrating on how to enhance the efficiency and effectiveness of sustainable implementation costs. Besides, the simplicity and ease of adopting sustainable technologies will influence the managers' decision making. Smerecnik and Andersen (2011) found that the perceived simplicity of sustainability innovations and high levels of opinion leadership of hotels were strongly associated with the adoption of sustainability innovations.

2.2 Customer Perception on Sustainability

Manaktola and Jauhari (2007) found a significant relationship between customer attitude and their behavior towards environmental practices in the hotel industry. Besides, 22% of their respondents showed the tendency to look for and use environmental information in their hotel choosing process.

Nevertheless, customers perceive sustainability in different manners. Demographic factors such as gender, age and income level were found to significantly influence customer awareness and demand for environmentally friendly hotels (Yong, Radesh and Murat, 2012). For instance, some customers may regard green attributes as basic and integral part of the hotel service, rather than as differentiating criteria (Robinot and Giannelloni, 2010). For such customers, it is necessary to maintain a high level of sustainable performance. Other customers, however, perceive sustainability achievements as a value adding element. Han, Hsu,and Lee (2009) found that a hotel's overall image is a positively affected by its customers' attitude toward sustainable behaviors and that overall image will significantly influence customers' visit intension, word-of-mouth intention , and willingness to pay a higher price. Han and Kim (2010) added that service quality, customer satisfaction, and hotel overall image are positively associated with customers' revisit intention, indicating marketers should advertise the hotel's sustainable achievements to enhance a green image in customers' mind and eventually increase their intention to re-purchase.

2.3 Energy Management System

Energy use is a major part of operation cost in hotels. Space and water heating account for about 60% of all energy used within a hotel (Energy Efficiency Office, 1985). Aiming to monitor and improve energy savings, it is necessary to apply energy management programs which include temperature controls, motion-sensitive lighting systems, and Energy Star rated devices and appliances (Iwanowski & Rushmore, 1994). There are a number of benefits of implementing an energy-management program: reducing the cost of electricity as well as the demand for it; saving indirectly on water and fuel; reducing energy costs by 10% to 30%; and centralizing energy management (David, 1987).

Energy Management System (EMS) is a widely implemented technology in hotels to monitor and reduce energy use, thereby lowering the increased energy cost. A properly designed EMS is capable of achieving significant energy savings and enhancing guest comfort at the same time (Rick, 2008), with 7 possible objectives put forward by David (1987): (1) reducing heat loss to a minimum; (2) balancing heating and cooling loads to the duties required; (3) optimization of the operating periods of the system and equipment; (4) maintenance of equipment at optimum efficiency; (5) recovery of wasted heat; (6) monitoring and analysis of energy consumption; and (7) the education and training of staff towards the efficient use of energy. Saidel (1981) also listed three categories of centralized EMS: programmable controllers, sophisticated systems, and building-automation systems, each of which has significant effect in energy saving and applies to different situations.

Heating, ventilation, and air conditioning (HVAC) is a potential energy saving part focused by EMS. For instance, nearly 880,000 kilowatt hours and 141 kilowatt electric demand was saved from Boston Hotel's annual electricity consumption with the implementation of an EMS (Anonymous, 1995). According to David (1987), EMS usually has an HVAC section with three basic components: (1) central control processor which manages the program of heating and ventilation requirements of the building; (2) input modules which monitor environment such as air, humidity and outside temperatures; (3) output modules which regulate the supply of heat to the various zones of the building. The HVAC controller provides optimum levels of comfort to the users of the facility at the lowest possible cost. Anon (1980) stated that HVAC controllers have multiple functions: temperature control through set-back; time control to initiate start-up and shut-down cycles for HVAC systems; hot water control; frost protection; humidity control; duty cycling; enthalpy control; and chiller optimization.

SECTION 3: HYPOTHESES

The trial implementation of Cassia™ EMS in Statler Hotel provides a great opportunity to test and evaluate the saving effect of EMS in hotels. The thesis examined the percentage of saved runtime by the system and make estimation of future savings. As the extension of the previous study, this thesis expected to get close results of energy saving and positive evaluation for Cassia™ EMS. Below are the hypotheses:

Hypothesis 1: The percentage of saved runtime during the 12 months is close to that during the 7 months.

Hypothesis 2: The temperature setback of Cassia™ EMS has significant impact on energy saving for test rooms. As is explained in latter section, the variable Test? is negatively related to the response $\frac{\text{Rented Vacant Runtime}}{\text{Rented Duration}}$.

Hypothesis 3: The energy saving resulted from Cassia™ EMS provides Statler Hotel with substantial cost saving on energy use.

SECTION 4: METHODOLOGY

4.1 Sample

In order to evaluate how effectively Cassia™ EMS works, a 12-month sample of the energy consumption and room status information in two test rooms with the EMS and two control rooms without the EMS was gathered from the Statler Hotel Management and Schneider Electric. In Khadeejah's (2012) previous study, a dataset from August 1st, 2011 to February 29th, 2012 had been used while in this study, the dataset was expanded to July 31st, 2012. Both of the two control rooms and the two test rooms are exactly the same as the previous project. All the four rooms face west and are located on the same floor with a 315 square feet area. The Cassia rooms are room 612 and room 614; the control rooms are room 616 and room 618. The Cassia rooms have been installed with the full Cassia™ EMS, while Rooms 616 and 618 are referred to as the "Control Rooms," with only the motion sensors which detect the room status.

4.2 Variables in the Dataset

The detailed definition and measures of variables used are presented below in Table 2.4.1:

Table 2.4.1: Definition and Origin of Variables

Variable	**Definition and origin**
Total Runtime	The everyday total runtime of HVAC; provided by Schneider Electric
Runtime Vacant	Runtime of HVAC when the room is vacant; provided by Schneider Electric
Runtime Occupied	Runtime of HVAC when the room is occupied; provided by Schneider Electric
Runtime Occupied %	The percentage of runtime occupied; calculated by formula (2.4.3); provided by Schneider Electric
Estimated Runtime without EMS	The estimated runtime without EMS, calculated by

	formula (2.4.2); provided by Schneider Electric
Saved Runtime %	The percentage of runtime saved by EMS, calculated by formula (2.4.1); provided by Schneider Electric
Heating Degree Days	How much in degrees the outside air temperature is lower than a specific base temperature; gathered on Degree Days.net
Maximum Temperature	The everyday highest temperature; gathered from Northeast Regional Climate Center
Minimum Temperature	The everyday lowest temperature; gathered from Northeast Regional Climate Center
Average Temperature	The everyday average temperature; gathered from Northeast Regional Climate Center
Temperature Difference	The everyday temperature range: maximum temperature minus minimum temperature
Test?	Coded as “1” for Test Rooms and “0” for Control Rooms
Rented?	Coded as “1” for rented rooms and “0” for unrented rooms; a room is defined as “rented” if the rented duration is equal or longer than 12 hours
Rented Duration	How long a room is rented every day; calculated from room status data provided by Statler Hotel Management
Occupied Hours	How long a room is occupied; provided by Schneider Electric
Vacant Hours	How long a room is vacant; provided by Schneider Electric

According to Schneider Electric, the saving impact of Cassia™ EMS is shown by the percentage of runtime saved, which is defined as Saved Runtime %. The formula is presented as below:

$$\text{Saved Runtime \%} = \frac{\text{Estimated Total Runtime} - \text{Total Runtime}}{\text{Estimated Total Runtime}} \qquad \text{Formula (2.4.1)}$$

The Estimated Total Runtime is the estimated runtime when the Cassia rooms are not installed with EMS. Schneider Electric assumes the same percentage of runtime for a vacant room with an occupied room since no control will take place when the room is vacant. For instance, if the HVAC unit runs 20% of the time when the room is occupied, it will also run 20% of the time when the room is vacant. Hence, the Estimated Total Runtime can be calculated by the formula below:

$$\text{Estimated Total Runtime} =$$
$$\text{Runtime Occupied } + \text{Runtime Occupied \%} * \text{ Vacant Hours} \qquad \text{Formula (2.4.2)}$$

$$\text{Runtime Occupied \%} = \frac{\text{Runtime Occupied}}{\text{Occupied Hours}} \qquad \text{Formula (2.4.3)}$$

Heating Degree Days (HDD) is a measure of how much in degree the outside air temperature is lower than a specific base temperature. The data was extracted from Degree Days.net and utilized 70°F as the base temperature, as the previous project did. Temperature variables were drawn from Northeast Regional Climate Center (2012).

4.3 Saved Runtime Percentage Analysis

The Saved Runtime Percentage is used by Schneider Electric to evaluate the energy saving effect of Cassia™ EMS. Based on formula (2.4.1), the Saved Runtime Percentage of two Cassia Rooms (room 612 and 614) for each month was calculated to get the percentage of runtime saved by the implementation of Cassia™ EMS. Results were compared with the estimated energy saving provided by Schneider Electric as well as the tested saving impact given by the previous study (Khadeejah, 2012).

4.4 Multiple Regression Analysis

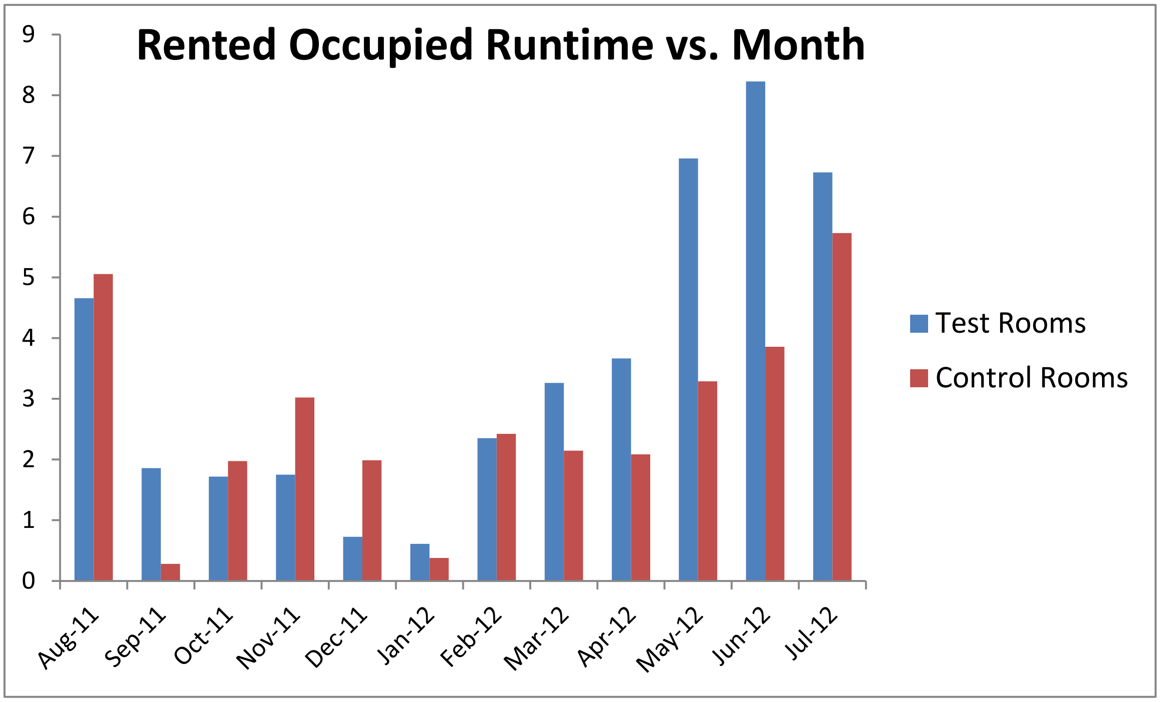
Descriptive statistics were conducted before the regression model was built. Average values for HVAC runtime were generated to see the energy usage difference between test and control rooms.

According to Table 2.4.2, test rooms had higher total runtime than control rooms. However, the saving impact of Cassia™ EMS was still supported since the runtime when the room is rented but vacant was lower for test rooms than control rooms. This is possible because the temperature setting of HVAC units can be completely controlled by guests. The higher value for runtime when the room is rented and occupied showed that the HVAC units in test rooms might be set at a higher operation level by guests during the test period. Figure 2.4.1 also presented the higher runtime for occupied test rooms in most of the months. Therefore, Rented Vacant Runtime was selected, rather than Total Runtime, as the measure of setback saving test to avoid errors caused by guest control.

Table 2.4.2: Descriptive Statistics for Runtime (Hours)

		Total Runtime	**Rented Occupied Runtime**	**Rented Vacant Runtime**
Average	**Test Rooms**	4.81	3.54	0.60
	Control Rooms	4.12	2.92	2.90
Standard Deviation	**Test Rooms**	5.86	4.58	2.73
	Control Rooms	7.59	3.78	7.65

Figure 2.4.1: Rented Occupied Runtime for Test and Control Rooms (Hours)



Besides, the length of Rented Duration determines the upper range of Rented Vacant Runtime. Consider the following situation with all other factors controlled: the Rented Duration is 20 hours and Rented Vacant Runtime is 5 hours for a test room; the Dented Duration is 10 hours and Rented Vacant Runtime is 4 hours for a control room. Even though the test room has a higher Rented Vacant Runtime, the EMS is still saving energy by operating the temperature setback since the HVAC runs only 20% of the Rented Duration in test room while 40% in control room. In order to make a precise estimation for the impact of Cassia™ EMS, the dependent variable of the Multiple Linear Regression was decided as Rented Vacant Runtime divided by Rented Duration ($\frac{\text{Rented Vacant Runtime}}{\text{Rented Duration}}$).

The variable “Test?”, coded as “1” for Test Rooms and “0” for Control Rooms, was used to test the impact of temperature setback function of Cassia™ EMS. In addition, HVAC runtime may also be affected by daily temperature. HDD and Temperature Difference were selected as independent variables to involve the effect of outside environment. Thus the regression model was determined as below:

$$\frac{\text{Rented Vacant Runtime}}{\text{Rented Duration}} = \beta_0 + \beta_1 * \text{Test?} + \beta_2 * \text{HDD} + \beta_3 * \text{Temperature Difference} \quad \text{Formula (2.4.4)}$$

Based on the multiple regression mode, the estimated percentage of Rented Vacant Runtime over Rented Duration was generated for both test and control rooms. The difference between the percentages was multiplied by the average Rented Duration to get the average daily saved runtime in rented and vacant period. Then the monthly and yearly total saved runtime was calculated assuming all the 153 rooms in Statler Hotel installed with Cassia™ EMS, shown as Formula (2.4.5) below:

Yearly Saved Runtime = Daily Saved Runtime per Room * 153 Rooms * 365 Days

Formula (2.4.5)

The General Electric HVAC unit applied by Statler Hotel runs with an average power rate of 7200 btu which is equal to 2.16 Kilowatt Hour (KWH). The average electricity price was determined as $ 0.192 per KWH based on report provided by U.S. Department of Labor (2012). Formula (2.4.6) shows the calculation of yearly saved energy cost with Cassia™ EMS in all rooms of Statler Hotel.

Yearly Saving =

Power Rate of HVAC * Yearly Saved Runtime * Average Electricity Price

Formula (2.4.6)

Therefore, both the runtime and cost saving impact of the 3°F temperature setback was estimated based on the Multiple Linear Regression to evaluate the saving effect of Cassia™ EMS.

SECTION 5: RESULTS

Results showed that all the 3 hypotheses were true. For the first hypothesis, Table 2.5.1 presents the monthly Percentage of Saved Runtime for test rooms. Room 614 was saving more energy than room 612, but the average Saved Runtime Percentage was 20%. This value is close to the average 18% saving effect, which had been concluded by Khadeejah's (2012) in the previous 7-month-data study.

Table 2.5.1: Calculated Results of the Saved Runtime Percentage Metric

	% Runtime Occupied		Estimated Total Runtime		Saved Runtime %	
	612	614	612	614	612	614
Aug-11	50%	26%	374.74	190.47	26%	33%
Sep-11	42%	13%	183.14	54.67	17%	28%
Oct-11	11%	7%	78.49	52.60	24%	0%
Nov-11	11%	11%	105.89	78.22	11%	11%
Dec-11	9%	8%	64.47	47.85	7%	9%
Jan-12	12%	8%	25.95	16.35	4%	4%
Feb-12	23%	16%	161.41	114.59	27%	41%
Mar-12	34%	28%	273.77	206.93	24%	46%
Apr-12	38%	16%	282.68	115.86	16%	36%
May-12	53%	37%	405.19	276.50	7%	28%
Jun-12	51%	36%	369.54	260.30	1%	33%
Jul-12	43%	31%	313.40	223.75	3%	34%
Monthly Average	32%	20%	219.89	136.51	14%	25%
Average	26%		178.20		20%	

The second hypothesis was also supported by the regression results shown in Table 2.5.2 and Table 2.5.3. The model was significant with a degree freedom of 1069. Both Test? and HDD was significant predictors while Temperature Difference was not. The negative coefficient, which was -0.063, of Test? indicated that the HVAC unit in a test room would run 6.3% less proportion of Rented Duration than that in a control room. HDD was also a significant predictor and had positive relation, which was 0.002, with the response. Therefore the regression equation can be specified as below (Time Difference was not included because of its insignificance):

$$\frac{\text{Rented Vacant Runtime}}{\text{Rented Duration}} = 5.4\% - 6.3\%*\text{Test?} + 0.2\%*\text{HDD} \qquad \text{Formula (2.5.1)}$$

Table 2.5.2: Analysis of Variance Table for Multiple Regression Model

	Sum of Squares	Degree of Freedom	Mean Square	F Statistic	Significance
Regression	1.780	2	0.890	22.029	0.000
Residual	43.106	1067	0.040		
Total	44.886	1069			

Table 2.5.3: Coefficient Table for Multiple Regression Model

	Coefficients	Significance	Standard Error
(Constant)	0.052	0.000	0.012
Test?	-0.063	0.000	0.012
Heating Degree Days	0.002	0.000	0.000

Based on the specified equation, the estimated cost saving of Cassia™ EMS was generated. Table 2.5.4 presents the daily, monthly and yearly saving estimation of HVAC runtime, energy and dollar cost. According to the estimation, Cassia™ EMS's temperature setback during rented and vacant period is expected to contribute a yearly saving of 130.47 dollars per room. If all the 153 rooms in Statler Hotel are installed with the system, 103,967 KWH, or 19,962 dollars, will be saved each year. Therefore the third hypothesis was proved to be true.

Table 2.5.4: Estimated Energy Saving Results of Cassia™ EMS

	Saved Runtime (Hours)		Saved Energy (KWH)		Saved Cost ($)	
	Per Room	*153 Rooms*	*Per Room*	*153 Rooms*	*Per Room*	*153 Rooms*
Daily	0.86	132	1.86	285	$ 0.36	$ 55
Monthly	26.22	4011	56.63	8664	$ 10.87	$ 1,663
Yearly	314.59	48133	679.52	103967	$ 130.47	$ 19,962

SECTION 6: CONCLUSIONS AND IMPLICATIONS

Cassia™ EMS, which is developed by Schneider Electric, helps reduce the energy use of HVAC by detecting the room status via motion sensors. When the room is detected as vacant, the system operates a temperature setback to reduce the runtime of HVAC unit in the room. The thesis takes the trial implementation of Cassia™ EMS in Statler Hotel as an opportunity to test and evaluate the saving effect of EMS in hotels. With a 12-month dataset recoding the energy consumption and room status information, the percentage of saved runtime by the system was examined, the saving impact of Cassia™ EMS was tested and the future saving with full-scale implementation of the system was estimated. All the 3 hypotheses were proved to be true and results showed positive evaluation of the saving impact provided by Cassia™ EMS.

The result of Saved Runtime Percentage analysis did not vary much with the larger sample. The Cassia™ EMS was proved to have significant impact on reducing the Total Runtime of HVAC units in Statler Hotel. On average 20% of energy savings provides a good support for the 25% - 44% beneficial announcement by Schneider Electric, since energy saving in lighting and other aspects were not included in this study.

According to the Multiple Regression analysis, the temperature setback function of Cassia™ EMS was significantly effective on saving energy during the period when customers leave the rented room. The HVAC units in test rooms were proved to run less frequently than that in control rooms, based on the negative coefficient of variable Test? in the multiple regression model. The estimation of cost saving indicated a 19,962-dollar saving each year for all the 153 rooms with Cassia™ EMS. The estimated substantial saving amount proved Cassia™ EMS's positive impact on saving the energy use and thereby the energy cost of Statler Hotel.

Apart from the saving effect of EMS, other factors such as HDD and guest control also have significant impact on the runtime of HVAC units. According to the result of Multiple Regression, HDD was a significant predictor for the proportion of runtime in rented vacant period. Higher HDD tended to increase the runtime proportion. Guest control may also have great influence because both the total runtime and runtime when the room was occupied in the dataset had higher values for test rooms than control rooms. Even though the HVAC in a room with Cassia™ EMS runs less proportion of time during vacant hours, the total runtime may still be higher than that of a room without the system when the guest in the Cassia room set the temperature with a higher operation level. Another reason can be that, except temperature factors, other factors like the location of Cassia rooms also determined their higher runtime of HVAC. A better way which helps avoid such error can be transforming the room types. For instance, set room 612 and 614 as test rooms and room 616 and 618 as control rooms for the first year; then transform room 612 and 614 into control room while install Cassia™ EMS in room 616 and 618 for the next year.

It was proved to be promising to take the full-scale implementation of Cassia™ EMS in Statler Hotel because of significant the saving impact and substantial cost saving. However, the management team has to take into consideration of hotel's budget as well as the cost of purchasing Cassia™ EMS. Payback period and return of investment need to be evaluated with the offered price by Schneider Electric. Other benefits such as sustainability achievement and potential reputation among customers should also be considered. In conclusion, the research provides Statler Hotel management with detailed proofs and reference in deciding whether to install Cassia™ EMS. It also provides new support for the saving impact of EMS implemented in hotels with actual and practical data.

SECTION 7: LIMITATIONS AND FUTURE RESEARCH

As mentioned above, one limitation of the thesis is that influences by factors such as guest control and room location were not included in the estimation model. Future research is encouraged to transform test rooms into control rooms and vice versa to avoid such error. Besides, the thesis focuses on the system's saving impact of the simple temperature setback during period when the room is rented and vacant. The system's deep setback function during unrented period was not tested due to the lack of data.

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