Leveraging Room Rates and Correlations for Effective Demand Variability Reduction in Hotel Inventory Pooling

Kuangnen Cheng*
School of Management, Marist College, Poughkeepsie, USA
*Corresponding Author: Kuangnen.cheng@marist.edu

Received 27 August 2024; received in revised form 23 October 2024; accepted 23 December 2024

Abstract

Risk pooling, a fundamental concept in supply chain management, posits that aggregating multiple sources of variability can lead to reduced overall variability. While existing literature predominantly examines risk pooling in the context of warehouses, this empirical study investigates how the hotel industry strategically employs room rates to optimize demand and supply alignment within a network of hotel locations. These locations, collectively referred to as a “pool,” are distributed around airport and downtown areas. We collected 11,470 real-time observations on room rates from a single hotel brand affiliated with the world’s largest hotel franchise. Our data spanned the period between July 23 and August 22, 2024, encompassing both airport and downtown properties across the 200 largest U.S. airports. Our findings reveal the following: (1) City without airport property: In cities lacking airport-affiliated hotels, downtown hotel room rates exhibit a strong negative correlation between weekdays and weekends, both within individual hotels and across the entire downtown portfolio; (2) City with one airport property: When a city has a single airport property, downtown hotel rates demonstrate a moderate negative correlation between weekdays and weekends within the downtown cluster. Simultaneously, a strong negative correlation exists within the hotel itself, as well as between the airport and downtown properties; and, (3) city with two airport properties: In cities boasting two airport-affiliated properties, downtown hotel rates exhibit a weak negative correlation between weekdays and weekends within the downtown subset and the hotel property. Additionally, a weak negative correlation exists between the airport and downtown properties, as well as between different airport properties. These findings shed light on the intricate dynamics of risk pooling within the hotel industry, emphasizing the importance of tailoring strategies to the specific context of perishable inventory and location-based demand patterns.

Keywords: Capacity adjustment, discrete demand, fixed capacity, perishable goods, risk pooling

1. Introductions

Inventory pooling, a strategy aligning supply with demand by managing a common inventory stock across multiple markets, involves spatial and temporal inventory sharing, crucial for capacity adjustment through pricing decisions and its relationship with discrete demand (Swinney, 2011; Cho et al., 2018). Despite its wide application in various industries, it is seldom considered transferable to the hotel market (Atcha et al., 2023). Literature suggests optimal results when demand is negatively correlated between locations within a pool, and effective pricing decisions complement capacity adjustment.

In the hotel industry, inventory pooling optimizes room availability, maximizing occupancy rates and revenue (Alptekinoglu et al., 2013). It balances supply and demand effectively, improving customer satisfaction. Hoteliers determine room pricing based on demand elasticity, contingent on the property’s location (Alrawabdeh, 2022; Singh & Corsun, 2023). Despite the perishability and limited supply of hotel inventory, hoteliers often oversell their capacity to counterbalance cancellations and no-shows (Cai & Du, 2009).

Historically, hotels have been strategically located near transportation hubs, leading to a proliferation of airport hotels primarily serving the weekday market (Carroll & Grimes, 1995). Conversely, leisure travelers often prefer downtown hotels for their proximity to local attractions, restaurants, and cultural sites. The decision to construct hotels near airports and downtown areas is driven by the distinct needs and preferences of different customer segments, risk mitigation, brand visibility, and pricing strategies (Cuomo et al., 2022). Premium prices can be charged for the convenience and unique location of airport hotels, while downtown hotels compete based on amenities, service, and proximity to attractions (Millar & Baloglu, 2009).

In metropolitan regions, prominent hotel chains commonly manage a multitude of establishments, strategically dispersed in proximity to airports, urban centers, and suburban areas. These establishments collectively constitute a network, catering to diverse customer demographics at distinct temporal intervals. For instance, clientele associated with business sectors predominantly patronize airport-adjacent locations during the workweek, whereas leisure-oriented customers exhibit a preference for urban and suburban locations during weekends. In the context of larger hospitality corporations, hotels in close geographical proximity often cater to a similar customer base and are consequently consolidated into clusters (Oliveira et al., 2017). As demand forecasting methodologies in revenue management mature (Fiig et al., 2014), it is anticipated that pricing strategies within the hospitality industry will align more closely with inventory allocation decisions.

Researching hotel inventory pooling presents challenges such as data availability, demand fluctuations, complex pricing strategies, customer behavior, and market competition. Implementing inventory pooling strategies often requires sophisticated technological infrastructure for managing reservations across different platforms and locations. This study accesses hotel pricing to analyze how hoteliers apply discreet pricing strategies to synchronize capacity adjustment, highlighting the interconnectedness of pricing and inventory movement as a fundamental aspect of inventory management and revenue optimization.

2. Literature Review

The operational benefits derived from the effective synchronization of supply and demand are fundamentally anchored in two seminal works. The first is the proposition of the ‘square root law’ related to locations by Maister (1976), and the second is the methodology proposed by Eppen (1979) for catering to aggregate demand by consolidating numerous similar markets into a single entity.

In practice, catering to two or more distinct markets using a shared inventory stock necessitates two unique methods, namely location pooling and product pooling (Swinney, 2011). For instance, research conducted by Saif Benjaafar et al. (2005) elucidates that an enterprise may choose between a segregated selling strategy (e.g., multiple physical stores catering to distinct geographic regions) and a pooled selling strategy (e.g., a singular internet channel catering to the entire country). The authors underscore that besides the operational advantages of pooling, the enterprise manipulates the volume of inventory accessible during the clearance sale, thereby inducing a shift in consumer purchase timing.

Product pooling is the practice of consolidating demands from analogous products or categories (e.g., amalgamating the inventory from diverse brands or lines). This method can be advantageous for products exhibiting low demand variability within a market segment, such as electronics or books. By centralizing the inventory in a single location, the enterprise can decrease the number of stock keeping units (SKUs) and streamline the inventory management process. However, product pooling also presents certain challenges, such as potential sales cannibalization among competing products or loss of differentiation among customers (Alfaro & Corbett, 2009).

The existing body of literature emphasizes the effectiveness of inventory pooling in achieving optimal results (Eruguz et al., 2016; Perez et al., 2021; Simchi-levi & Zhao, 2012), thereby stimulating a multitude of publications to assess the performance of pooling. Given that the critical elements encompass the efficient equilibrium of supply and demand, a specific school of thought has underscored the role of demand forecasting in enhancing inventory management. For instance, Lei et al. (2023) utilize aggregate sales data to forecast the demand for individual products, thereby facilitating the balance of supply with demand. Their methodology enhances the performance of forecasting, leading to substantial cost savings in the retail sector. Concurrently, Hu et al. (2019) ascertain that risk pooling significantly mitigates forecast errors and impacts the utilization of public and private information. This enhancement in forecast accuracy can assist firms in better aligning supply with demand.

On the supply side, two distinct lines of work are noticeable (Williams & Tokar, 2008). One focuses on how to integrate inventory control with other logistics activities such as transportation and warehousing, and the other on inter-firm collaborative inventory management. For example, Mosca et al., (2019) analyze various models and methodologies, highlighting the importance of coordinating transportation and inventory for efficient supply chain management. Their work serves as a valuable resource for researchers and practitioners interested in integrated transportation and inventory models. Aravindaraj and Chinna (2022) employ a systematic literature review (SLR) methodology on a sample of articles from multiple databases (Ali & Phan, 2022). Their analysis reveals a positive linkage between various industry 4.0 technologies and the three main pillars, economic, social, and environmental, of sustainable warehousing. The strength of the paper lies in its comprehensive review, identification of knowledge gaps, and practice implications for practitioners. Other similar investigations can be found in the work of Jagadeesan et al., (2023); Kmiecik (2022); Zhen and Li (2022).

Research on the impact of inventory pooling continues to attract significant interest, particularly within the marketing field, which is keen on understanding its implications for customer acquisition. A study conducted by Cho et al. (2018) considered two types of products and two outsourcing strategies, namely competitive bidding and consignment stock, under the (Q, R) (the order quantity vs. the reorder point) inventory policy with variable lead times. The paper makes substantial contributions to the field of Marketing. It enriches the existing literature by integrating demand switching into outsourcing practices, a development that holds benefits for both practitioners and scholars. The findings challenge the prevailing notion from previous research that demand switching invariably leads to increased costs or profit benefits.

Furthermore, research conducted by Kembro et al. (2018) provides a research agenda to further the theory on warehouse operations and design in omni-channels. This work can guide practitioners to comprehend forthcoming challenges and address pertinent issues in omni-channel warehousing, given its interdependence with value proposition, channel management, and network decisions.

Wang et al. (2022) examined the pricing and inventory decisions for a retailer operating in multiple markets with strategic customers. The study characterizes equilibrium decisions in pooled and non-pooled systems, underscoring the role of strategic customers in each market. The paper contributes to the Marketing field by offering insights into how strategic customer behavior influences inventory pooling and pricing decisions. It provides valuable guidance for retailers to optimize their inventory and pricing strategies, thereby enhancing their market performance.

Additional work by Zhong et al. (2018) and Kurata (2014) further elucidates this topic. Zhong et al. (2018) explained how integrating the heterogeneous service level requirements of different customers into the pooling model could expand the customer base. Kurata (2014) asserted that product availability naturally influences customers' purchasing decisions. When customers are product-availability-conscious, the design of a centralized inventory system needs to avoid a long delivery lead time.

In summary, findings from the aforementioned literature indicate that inventory pooling reduces costs by mitigating uncertainty and enhancing the alignment of supply with demand.

Thus far, inventory pooling literature predominantly focuses on sectors like retail (Swinney, 2011; Wang et al., 2022), e-commerce (Ovezmyradov, 2022), manufacturing (Hafner et al., 2021), healthcare (Rojas et al., 2021), and car rentals (Cheng & Jin, 2021) etc. Its application in the hotel industry, characterized by perishable commodities and unique demand patterns (Valentin & O'Neill, 2019; Alrawabdeh, 2022; Singh & Corsun, 2023), remains underexplored.

Dynamic pricing, a proven revenue booster (McAfee & te Velde, 2007; Sahay, 2007), requires understanding of key parameters like consumer response to incentives (Chen & Pearcy, 2010) and product capacity constraints. Such characteristics are common in travel and hospitality industries (Alderighi et al., 2011; Escobari, 2014; Kimes, 2011; Bayoumi et al., 2013; Drayer et al., 2012), and have been addressed by technologies enabling rapid data analysis (Chen et al., 2016; Elmaghraby & Keskinocak, 2003).

Fixed capacity industries employ "posted price" mechanisms (Einav et al., 2018), while "surge pricing" is used when demand exceeds supply (Hall et al., 2015; Riquelme et al., 2015). The shift from inventory to demand-side management (Elmaghraby & Keskinocak, 2003) has led to studies on dynamic pricing under flexible capacity (Ceryan, 2013; Yang & Zhang, 2014), suggesting periodic price changes and pre-determined inventory levels (Simchi-Levi et al., 2014). These approaches aim to optimize revenue and resource allocation in the face of varying demand and capacity constraints.

3. Data, Methods and Discussions

Dynamic pricing is a fundamental strategy employed by hotels, facilitating the optimization of occupancy rates and profits (Schamel, 2012). This results in a characteristic pattern of weekly cycles in hotel inventory, with a clear distinction between weekdays and weekends, the latter typically comprising Fridays and Saturdays. Demand fluctuates between these periods, effectively differentiating between business and leisure travelers due to their disparate motivations, price sensitivities, and travel patterns. It is widely recognized that business travelers predominantly undertake journeys during the week, while leisure travelers demonstrate a propensity for weekend travel.

The subjects of this investigation are hotel brands with significant presence in the 200 largest U.S. airports. To render this research feasible, the ideal hotel rate is set within the mid-market properties, specifically within category three or four of the world's largest hotel franchise. Utilizing data from the world's largest hotel franchise ensures the highest probability of market presence at both airport and downtown locations among the 200 largest U.S. airports. Selecting hotel rates from the same brand mitigates the simultaneous presence of contradictory forces of cooperation and competition within the same market (Chiambaretto et al., 2022).

The data for our study was sourced from Travelport, one of the leading Global Distribution Systems (GDSs) in the travel industry. Known as the Apollo system in North America and Japan, Travelport plays a pivotal role in aggregating and disseminating information from hotel vendors. These vendors consistently update rates and inventory across major GDSs, providing valuable insights up to 330 days in advance of each travel date. Between 23 July 2024 and 22 August 2024, we meticulously collected 11,470 real-time observations from a single hotel brand. Our choice of 22 August 2024 as the study endpoint aligns with the project's initiation date of 27 September 2023, representing the farthest available data. This strategic decision aimed to mitigate rate fluctuations, which tend to intensify as the arrival date approaches. Hoteliers actively adjust rates during this critical period to optimize revenue. Our data collection spanned one month, specifically during the summer of 2023, from 27 September to 31 October. All statistical analyses were conducted using Microsoft Excel 2021 and SPSS version 29. Additionally, we referenced the Bureau of Transportation Statistics of the Department of Transportation (DOT) for the list of the 200 largest U.S. airports, ranked by 2022 systemwide scheduled enplanements passenger numbers.

There are numerous factors influencing how a hotel sets its pricing. This study focuses on inventory pooling, a strategy where a firm attempts to match supply with demand by managing a common inventory stock within a pool to serve multiple markets in a timely manner. Consequently, the hotel rates set within the same brand are exemplified by the hotel's autonomous decision-making and are independent of the demand environment.

In a study encompassing 200 cities, the maximum number of hotels from a particular franchise located within a single airport precinct was found to be two. Eight airports, including those in Newark, Dallas, Los Angeles, and Seattle, fall into this category. These airports are generally among the largest. Interestingly, 92 airports were found to have only one hotel property within their precincts, while 100 airports had no hotel properties within their airport precincts. The airports with a single hotel property are typically midsize. For instance, the airport in Pittsburgh, which ranks 49th in passenger numbers, is 19.20 miles away from downtown. Similarly, the airport in Greer, ranking 95th in passenger numbers, is 13.30 miles away from downtown. Airports with no hotel properties are usually smaller or closer to downtown. For example, the airport in Idaho Falls, which ranks 154th in passenger numbers, is only 3.20 miles away from downtown. The airport in Nantucket, MA, ranking 198th in passenger numbers, is even closer to downtown, at a distance of 3.00 miles.

In terms of downtown properties, 91 cities, including Atlanta, Boston, and Detroit, have one downtown hotel. There are 37 cities, such as Orlando, San Diego, and El Paso, with two downtown hotels. Fifteen cities, including Chicago, Austin, and Oklahoma City, have three downtown hotels. Four cities, namely Houston, San Antonio, and Columbus, OH, have four downtown hotels. Two cities (actually one metropolitan), Washington D.C., have five downtown hotels. Notably, downtown Manhattan, New York, stands out with ten downtown hotels.

Table 1 provides a detailed breakdown of the number of airports with varying numbers of properties between airport and downtown locations:

Table 1: Detailed Breakdown of the Number of Airports with Varying Numbers of Properties between Airport and Downtown Locations

# of property in each location		**Counts**
Airport	**Downtown**	**# of Airport**
0	0	31
0	1	47
0	2	18
0	3	3
0	10	1
1	0	16
1	1	42
1	2	16
1	3	12
1	4	3
1	5	2
1	10	1
2	0	1
2	1	2
2	2	3
2	4	1
2	10	1
Sum		200

The spatial dynamics of airports and their impact on nearby property distribution are evident from Table 2. As airport rank decreases, the distance between the airport and the city center tends to decrease. Lower-ranked airports exhibit fewer properties in their immediate vicinity, and similarly, downtown areas near these airports also have fewer properties. These findings may provide valuable insights into how hoteliers decide where to locate their properties.

Table 2: Correlation between Airport Rank, Distance, Number of Airport Properties, and Number of Downtown Properties

Correlations					
		Airport Rank	Distance to City	# of Airport Property	# of Downtown Property
Airport Rank	Pearson Correlation	1	-.355**	-.565**	-.444**
	Sig. (2-tailed)		.000	.000	.000
	N	200	200	200	200
Distance to City Center	Pearson Correlation	-.355**	1	.174*	.270**
	Sig. (2-tailed)	.000		.014	.000
	N	200	200	200	200
# of Airport Property	Pearson Correlation	-.565**	.174*	1	.247**
	Sig. (2-tailed)	.000	.014		.000
	N	200	200	200	200
# of Downtown Property	Pearson Correlation	-.444**	.270**	.247**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	200	200	200	200

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

We conducted an analysis to determine whether pricing strategies within a pool—comprising hotels in airport and downtown locations—exhibit correlated relationships. Our goal was to identify whether hoteliers apply risk pooling in business logistics to reduce the total variability of demand and lead time. From the top 200 airports in the U.S., we categorized pools based on the number of properties distributed in downtown or airport locations. For instance:

Some pools had one property at the airport and four in downtown locations (e.g., Houston, TX, and Columbus, OH). Others had two properties at the airport and two in downtown locations (e.g., Dallas, TX, Los Angeles, CA, and Seattle, WA). Since we collected data from 200 cities, we had a total of 200 pools. Within these pools, we analyzed pricing correlations for intra-downtown and inter-downtown, as well as intra-airport and inter-airport locations. Overall, there were 822 possible combinations. Notably, 29.22% of these combinations exhibited significant correlations. Please refer to the results summarized in Table 3.

As discussed in the literature review section by Millar and Balogu (2009), location has a strong impact on demand. To effectively meet this demand while mitigating uncertainty and risk, hoteliers often employ risk pooling in business logistics (Oeser, 2015). However, further investigation is needed to understand the spatial dynamics of airports and their influence on nearby property distribution, particularly considering the effects of risk pooling in various supply chain settings (Cai & Du, 2009).

Our study examines how hoteliers strategically apply price discriminatory strategies to differentiate between weekday and weekend customers. By effectively utilizing pooling, hotels can reduce the total variability of demand. Here are our key findings:

Airport Presence and Downtown Pricing:

When no hotel is present at the airport location, downtown properties employ clear discriminatory pricing strategies. These strategies separate weekday business customers (who typically prefer airport locations) from weekend leisure customers (who value downtown locations). Among 100 airports without airport properties, 44.1% of downtown hotels apply distinct discriminatory pricing within their properties. Additionally, 23.60% of hotels coordinate with each other within the city pool to ensure demand is met effectively.

The intensity (defined as the percentage of pricing correlation between weekday and weekend cycles) of pricing correlation for downtown hotels decreases as the number of airport properties increases. In other words, discriminatory pricing strategies are less pronounced when more properties exist at the airport location.

Patterns Across Downtown and Airport Properties:

Similar patterns emerge among hotels within the downtown location and between airport and downtown hotels. However, when two airport properties exist, the correlation between the two airport properties is less distinct. These findings provide valuable insights for hoteliers seeking to optimize pricing strategies and manage demand effectively.

Table 4 summarizes the intensity of pricing correlation within and between hotels in different locations. Figure 2 illustrates the decreasing intensity as a higher number of hotels are present in airport locations.

Table 3: Summary of the Hotel Rate Correlations Among Airport and Downtown Hotels

Category	**0 Airport property, total 100 airports**				**1 Airport property, total 92 airports**							**2 Airport property, total 8 airports**				
# of Airport vs. downtown	0A1D*	0A2D	0A3D	0A10D	1A0D	1A1D	1A2D	1A3D	1A4D	1A5D	1A10D	2A0D	2A1D	2A2D	2A4D	2A10D
# of City out of 200	47	18	3	1	16	39	18	11	3	2	1	1	2	3	1	1
	Total # and # of combination				**Total # and # of combination**							**Total # and # of combination**				
Intra Downtown**	47	36	9	10		39	36	33	12	10	10		2	6	4	10
# of sig. corr.	21	17	4	3		16	15	8	3	0	3		0	0	4	3
Intensity	44.7%	47.2%	44.4%	30.0%		41.0%	41.7%	24.2%	25.0%	0.0%	30.0%		0.0%	0.0%	100.0%	30.0%
Inter Downtown***		18	9	45			18	33	18	20	45			3	6	45
# of sig. corr.		8	3	6			6	8	7	0	6			0	2	6
Intensity		44.4%	33.3%	13.3%			33.3%	24.2%	38.9%	0.0%	13.3%			0.0%	33.3%	13.3%
Intra Airport****					16	39	18	11	3	2	1	2	4	6	2	2
# of sig. corr.					7	16	9	5	3	0	1	0	1	2	1	1
Intensity					43.8%	41.0%	50.0%	45.5%	100.0%	0.0%	100.0%	0.0%	25.0%	33.3%	50.0%	50.0%
Airport vs. Downtown						39	36	33	12	10	10		4	12	8	20
# of sig. corr.						12	10	7	3	3	3		1	0	2	2
Intensity						30.8%	27.8%	21.2%	25.0%	30.0%	30.0%		25.0%	0.0%	25.0%	10.0%
Inter Airport												1	2	3	1	1
# of sig. corr.												0	1	0	0	0
Intensity												0.0%	50.0%	0.0%	0.0%	0.0%

*0A1D indicates 0 airport property but one downtown property; similarly, 2A0D means two airport properties but no downtown property etc.;

**Intra-hotel rate (downtown hotel): this refers to the rate variation within a specific hotel. It highlights the difference between weekday and weekend rates for the same hotel;

***Inter-hotel rate (among downtown hotels): the term describes the rate comparison between different hotels. It emphasizes the contrast in rates across weekdays and weekends for guests choosing among various downtown hotels;

****Same rule applied to Intra-airport hotel and Inter-airport hotels.

Table 4: The Percentage of the Pricing Correlation in Different Locations

# of Airport Property	0 Airport Property	1 Airport Property	2 Airport Property
# of Airport	100	92	8
Intra Downtown	44.1%	32.1%	31.8%
Inter Downtown	23.6%	20.1%	14.8%
Intra Airport		45.6%	31.3%
Airport vs. Downtown		27.1%	11.4%
Inter Airport			12.5%

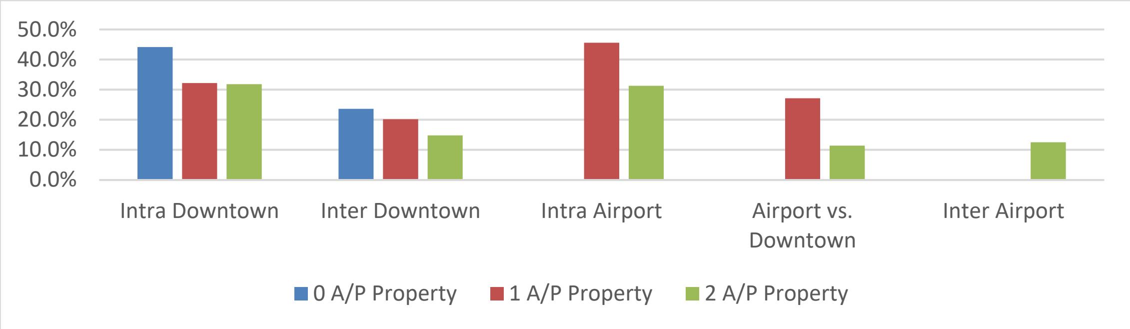

Figure 1: Airport Property and Its Impact on Hotel Pricing Correlations

Table 5 provides a comprehensive summary of the correlation intensity observed within the context of airport properties. Notably, we identify distinct patterns in pricing correlations based on the location category. Specifically, intra-airport correlations exhibit strong relationships, while inter-airport correlations demonstrate different dynamics. In this section, we delve into the details of these correlations and their implications for airport property pricing.

Table 5: Summary of the Correlation Intensity Based on Property Location

Type of Correlation	Correlation Intensity
Intra Airport	0.433962264
Intra Downtown	0.367424242
Airport vs. Downtown	0.233695652
Inter Downtown	0.20000000
Inter Airport	0.125

Intra-airport property pricing correlations:

The highest correlation intensity is observed within airport property locations. Specifically, airports with one or two airport properties exhibit strong pricing correlations. These 100 airports (92 with one property plus eight with two properties at the airport locations) are generally among the higher ranks based on yearly passenger enplanement and are normally located in larger metropolitan cities. However, these properties are often farther away from the city center. Airport hotels are arguably the most location-sensitive segment (Lee & Jang, 2010) and cater to business travelers who are less price-sensitive. Given that guest satisfaction with hotel location has been a rigid factor for customers to select their hotel (Latinopoulos, 2020; Rajaguru & Hassanli, 2018; Yang et al., 2017), pricing correlations within an airport property become essential to make weekend rates attractive for catering to leisure travelers.

Inter-airport properties pricing correlations:

Conversely, the lowest correlation intensity is observed between airport locations. Among the eight airports with two properties (e.g., Cincinnati, Dallas, Seattle, etc.), inter-airport pricing correlations are most pronounced at the 2A1D combination (two airport properties with one downtown property). Specifically, this occurs in Minneapolis, MN, and Orange County, CA. The rationale behind inventory pooling—to efficiently match supply and demand across multiple markets—applies here. However, the location premiums for airport hotels are influenced by their proximity to the central business district (CBD), as highlighted by Lee and Jang (2010). While both Minneapolis and Orange County have two airport properties and one CBD property, Orange County's airport properties are within two miles of SNA airport (Santa Ana airport in Orange County) and only 2.5 miles apart from each other. The differing needs of business and leisure travelers play a role: business travelers are less price-sensitive, whereas leisure travelers prioritize preferred locations. Consequently, inter-airport pricing correlations are inadequate in Orange County due to its association with Disneyland—a location customers are unwilling to substitute. Interestingly, despite the 5.7-mile separation between the two airport properties (one 4 miles southeast and the other 2 miles southwest of the airport) in Minneapolis, the distance to the downtown property remains within 10 miles. This airport property effectively serves as an intermittent point bridging airport and downtown areas, resulting in a strong Pearson correlation (r = 0.730, p = 0.0000) between the two airport properties in Minneapolis.

Intra-downtown property pricing correlations:

As previously discussed, the strength of intra-downtown pricing correlations is negatively associated with the number of airport properties. Instances with no intra-downtown property pricing correlations occurred at the following airports: 1A5D: National Airport and Dulles Airport (2 airports); 2A1D: Minneapolis and Orange County, CA (2 airports) and 2A2D: Dallas, Los Angeles, and Seattle (3 airports). A notable commonality among these airports is their affiliation with larger airports within the total 200 airports studied. Specifically: Dallas ranks #2; Los Angeles ranks #5; Seattle ranks #11; Minneapolis ranks #18; National ranks #23; Dallas ranks #28 and Santa Ana ranks #40.

Santa Ana, being home to Disneyland, caters to location-sensitive customers, resulting in minimal differentiation in pricing between weekdays and weekends. Similarly, larger metropolitan areas often have sufficient visitor demand to maintain high hotel occupancy rates. Figure 2 illustrates the location effect described in Table 5.

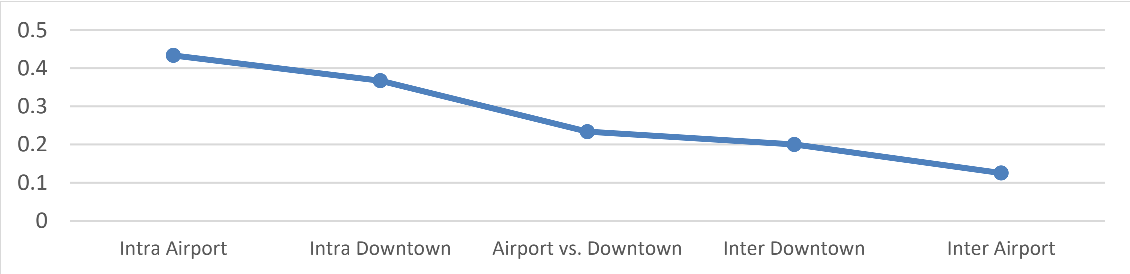

Figure 2: Location Effect of Pricing Correlation Intensity

Airport Rank and Distance to City: The correlation is -0.355 (a moderate negative correlation), and the p-value is 0.000, indicating the correlation is significant at the 0.01 level.

Airport Rank and # of A/P property: The correlation is -0.565 (a strong negative correlation), and the p-value is 0.000, indicating the correlation is significant at the 0.01 level.

Airport Rank and # of D/town property: The correlation is -0.444 (a moderate negative correlation), and the p-value is 0.000, indicating the correlation is significant at the 0.01 level.

Distance to City and # of A/P property: The correlation is 0.174 (a weak positive correlation), and the p-value is 0.014, indicating the correlation is significant at the 0.05 level.

Distance to City and # of D/town property: The correlation is 0.270 (a weak positive correlation), and the p-value is 0.000, indicating the correlation is significant at the 0.01 level.

# of A/P property and # of D/town property: The correlation is 0.247 (a weak positive correlation), and the p-value is 0.000, indicating the correlation is significant at the 0.01 level.

Airport vs. downtown property pricing correlations:

The number of airport property and the number of downtown properties has a weak positive correlation (r=0.247, p=0.001) which means the fewer the airport property (the larger the rank # the smaller the airport), the fewer downtown property. Almost all cities with at least one airport property have a moderate negative pricing correlation with downtown property. The only one combination with no pricing correlation happens in 2A2D (two airport properties and two downtown properties). Cities with 2A2D (see table 1) are Dallas (airport rank #2, distance between CBD and airport 17.60 miles), Los Angeles (airport rank #5, distance between CBD and airport 18.80) and Seattle (airport rank #11, distance between CBD and airport 13.40). Since these are all bigger city and the distance between airport and the CBD tend to be farther (airport rank and distance to city r=-0.355, p=0.001). Researchers found the effect of the property's spatial value predominately impacts the most when the property is within 10 miles of CBD (Valentin & O'Neill, 2019).

Inter-downtown properties pricing correlations:

Pricing correlations between downtown property has a weak intensity, the more downtown properties in a city, the less pricing correlations happened. For example, the intensity for 0A2D, 0A3D and 0A10D is 44.40%, 33.30% and 13.30% respectively. Only two type of location property have no correlation existed they are 1A5D and 2A2D. As mentioned above in the section of airport vs. downtown property pricing correlations, cities with 2A2D are those larger airports with a longer distance to CBD. In addition, the distance between two hotels is fairly small such as 0.9 miles in Seattle. Many scholarly research have documented the driver of CBD location's spatial variables impacts on travelers' selection. As such, when downtown hotels are within a shorter distance between each other, those spatial variables such as tourism attractions (Luo & Yang, 2016; Yang et al., 2018) or transportation systems (Roubi, 2004; Xiang & Krawczyk, 2016) do not differentiate each other. The other one type with no correlation is 1A5D which is the Washington D.C. All CBD properties are at least 25 miles away from Dulles airport.

4. Conclusions

The primary revenue stream for hotels is derived from their inventory, defined as the total number of rooms available for sale and distribution. Hotels operate as both real estate ventures and service companies. The perishable nature of hotel rooms and the location variable make managing a common inventory to meet demand from across multiple markets a complex task. Unlike industries such as car rental, where inventory shuttling can potentially balance supply and demand (Cheng & Jin, 2021) easier, hoteliers must employ dynamic pricing strategies (Talon-Ballestero et al., 2022) to prevent unsold rooms from becoming obsolete inventory. This study uncovers the existence of inventory pooling in the hotel industry. While the classification of hotels as heterogeneous or homogeneous firms is a matter of debate (Arbelo et al., 2020), a common inventory is feasible across multiple markets when demand is negatively correlated between locations within a pool.

Spatial variables distinct to airport and downtown properties influence traveler preferences. The presence of an airport property negatively impacts the pricing strategies of both downtown and airport properties. The correlation intensity of pricing within or between airport properties, downtown properties, and between airport and downtown properties decreases with an increased presence of airport properties. Among all pricing correlations, intra-airport has the highest density, followed by intra-downtown, airport versus downtown, and finally inter-downtown and inter-airport. These findings suggest that there is no distinct demand between airport locations or among downtown locations. Consequently, inventory pooling is less effective between properties in the same airport or downtown location within the same pool. However, it becomes more effective when both airport and downtown properties are present in a pool. These findings contribute to the understanding of how non-stockable and perishable inventory should be pooled.

This investigation has its limitations. We only examined the pricing records of one brand from the largest hotel franchise. Given more time and resources, we aim to compare multiple hotel brands within a pool to understand their dynamic relationships. Furthermore, this study utilized forecasted pricing data (prices from 11 months out). In future research, we plan to compare the pricing of the same property 11 months out versus 1 month out to determine whether the intensity of pricing correlation remains consistent.

References

Alderighi, M., Cento, A. and Piga, C.A. (2011). A case study of pricing strategies in European airline markets: The London – Amsterdam route. *Journal of Air Transport Management, 17(6),* 369-373.

Alfaro, J. A. and Corbett, C. J. (2009). The value of SKU rationalization in practice (the pooling effect under suboptimal inventory policies and nonnormal demand). *Production and Operations Management, 12(1),* 12-29.

Ali, I. and Phan, H. M. (2022). Industry 4.0 technologies and sustainable warehousing: A systematic literature review and future research agenda. *The International Journal of Logistics Management, 33(2),* 665-662.

Alptekinoglu, A., Banerjee, A., Paul, A. and Jain, N. (2013). Inventory pooling to deliver differentiated service. *Manufacturing and Service Operations Management, 15(1),* 33-44.

Alrawabdeh, W. (2022). Seasonal balancing of revenue and demand in hotel industry: The case of Dubai City. *Journal of Revenue and Pricing Management, 21*, 36-49: https://doi.org/10.1057/s41272-021-00290-6.

Aravindaraj, K. and Chinna, P. R. (2022). A systematic literature review of integration of industry 4.0 and warehouse management to achieve sustainable development goals (SDGs). *Cleaner Logistics and Supply Chain, 5.* https://doi.org/10.1016/j.clscn.2022.100072.

Arbelo, A., Arbelo-Perez, M. and Perez-Gomez, P. (2020). Heterogeneity of resources and performance in the hotel industry. *Journal of Hospitality & Tourism Research*, *45*(1). http://doi.org/10.1177/1096348020944450.

Atcha, P., Vlachos, I. and Kumar, S. (2023). Inventory sharing in healthcare supply chains: Systematic literature review and future research agenda. *The International Journal of Logistics Management, forth-*

coming, https://doi.org/10.1108/IJLM-12-2022-0497.

Bayoumi, A. E-M., Saleh, M., Atiya, A. and Habib, H. (2013). Dynamic pricing for hotel revenue management using price multipliers. *Journal of Revenue & Pricing Management, 12(3),* 271-285.

Benjaafar, S., Cooper, W. L and Kim, J. S. (2005). On the benefits of pooling in production-inventory systems. *Management Science, 51(4),* 548-565.

Cai, X. and Du, D. I. (2009). On the effects of risk pooling in supply chain management: Review and extensions. *Acta Mathematicae Applicate Sinica, English Series, 25,* 709-722. https://doi.org/10.1007/s10255-009-8830-x.

Carroll, W. J. and Grimes, R. C. (1995). Evolutionary change in product management: Experiences in the car rental industry. *Interfaces, 25(5*), 84-104.

Ceryan, O., Sahin, O. and Duenyas, I. (2013). Dynamic pricing of substitutable products in the presence of capacity flexibility. *Manufacturing and Service Operations Management, 15(1),* 86-101.

Chen, Y. M. and Pearcy, J. (2010). Dynamic pricing: When to entice brand switching and when to reward consumer loyalty. *The RAND Journal of Economics, 41(4),* 674-685.

Chen, L., Mislove, A. and Wilson, C. (2016). An empirical analysis of algorithmic pricing on Amazon marketplace. *In Proceedings of the 25th International World Wide Web Conference.*

Cheng, K.N. and Jin, B.H. (2021). Inventory pooling technique from the car rental industry: Now and in the autonomous future. *International Journal of Business Environment, 12(1),* 37-63.

Chiambaretto, P., Fernandez, A. S., and Le Roy, F. (2022). What coopetition is and what it is not: Defining the “hard core” and the “protective belt” of coopetition. *Strategic Management Review,* forthcoming.

Cho, H. S., Hsieh, Y. J and Huang, L. Y. (2018). Capturing the risk-pooling effect through inventory planning and demand switching. *Sustainability, 10(11),* 4104: https://doi.org/10.3390/su10114104.

Drayer, J., Shapiro, S. L. and Lee, S. K. (2012). Dynamic ticket pricing in sport: An agenda for research and practice. *Sport Marketing Quarterly, 21(3),* 184-194.

Elmaghraby, W. and Keskinocak, P. (2003). Dynamic pricing in the presence of inventory considerations: Research overview, current practices, and future directions. *Management Science, 49(10),* 1287-1309.

Eruguz, A.S., Sahin, E., Jemai, Z and Dallery, Y.A. (2016). Comprehensive survey of guaranteed-service models for multi-echelon inventory optimization. *International Journal of Production Economics. 172*, 110-125. https://doi.org/10.1016/j.ijpe.205.11.017.

Eppen, G. D. (1979). Effects of centralization on expected costs in a multi-location newsboy problem. *Management Science, 25(5),* 498-501.

Escobari, D. (2014). Estimating dynamic demand for airlines. *Economics Letters, 124(1),* 26-29.

Fiig, T., Haerdling, R., Poelt, S. and Hopperstad, C. (2014). Demand forecasting and measuring forecast accuracy in general fare structures. *Journal of Revenue and Pricing Management, 13(6),* 413-439.

Hafner, Y., Bock, J., Keppler, C. and Fottner, J. (2012). Evaluation model for cooperative inventory pooling-systems. *Procedia CIRP, 104*, 253-258: https://doi.org/10.1016/j.procir.2021.11.043.

Hall, J., Kendrick, C., and Nosko, C. (2015). The effects of Uber’s surge pricing: A case study. *Working Paper*, The University of Chicago Booth School of Business.

Hu, N., Ke, J. Y., Liu, L. and Zhhang, Y. (2019). Risk pooling, supply chain hierarchy, and analysts' forecasts. *Production and Operations Management. 28(2),* 276-291. Available at: https://ink.library.smu.edu.sg/sis_research/8011

Jagadeesan, V., Rajamanickam, T., Schindlerova, V., Subbarayan, S and Cep, R. (2023). A study on two-warehouse inventory systems with integrated multi-purpose production unit and partitioned rental warehouse. *Mathematics, 11(8),* 3986. https://doi.org/10.3390/math11183986.

Kembro, J. H., Norrman, A. and Eriksson, E. (2018). Adapting warehouse operations and design to omni-channel logistics: A literature review and research agenda. *International Journal of Physical Distribution & Logistics Management, 48(9),* 890-912.

Kimes, S. E. (2011). The future of hotel revenue management. *Journal of Revenue and Pricing Management, 10(1),* 62-72.

Kmiecik, M. (2022). Logistics coordination based on inventory management and transportation planning by third-party logistics (3PL). *Sustainability*, *14*(3), 8134; http://doi.org/10.3390/su14138134.

Kurata, H. (2014). How does inventory pooling work when product availability influences customers' purchasing decisions? *International Journal of Production Research, 52(22),* 6739-6759. doi:10.1080/00207543.2014.916825

Latinopoulos, D. (2020). Analyzing the role of urban hotel location in guests' satisfaction. *Anatolia*, *31*(4), 636–650. https://doi.org/10.1080/13032917.2020.1808489

Lee, S. K. and Jan, S. C. (2010). Room rates of U.S. airport hotels: Examining the dual effects of proximities. *Journal of Travel Research*, *49*(3). DOI:10.1177/0047287510362778

Lei, D., Qi, Y., Liu, S., Geng, D., Zhang, J., Hu, H. and Shen, Z. J. M. (2022). Pooling and boosting for demand prediction in retail: A transfer learning approach. *SSRN Electronic Journal,* available at SSRN: https://ssrn.com/abstract=4490516 or http://dx.doi.org/10.2139/ssrn.4490516

Luo H., Yang, Y. (2016). Intra-metropolitan location choice of star-rated and non-rated budget hotels: The role of agglomeration economies. *International Journal of Hospitality Management*, *59*, 72-83.

Maister, D. H. (1976). Centralization of inventories and the "Square Root Law". *International Journal of Physical Distribution, 6(3),* 124-134.

McAfee, R. P. and te Velde, V. (2007). Dynamic pricing in the airline industry. In: *Handbook on Economics and Information System.* (Ed): T. J. Hendershott, Elsevier Handbooks in Information Systems, Volume 1.

Millar, M. and Baloglu, S. (2009). A green room experience: A comparison of business & leisure travelers' preferences. *Hospitality Management. Paper 10.* http://repository.usfca.edu/hosp/10.

Mosca, A., Vidyarthi, N. and Satir, A. (2019). Integrated transportation – inventory models: A review. *Operations Research Perspectives, 6,* 100101. https://doi.org/10.1016/j.orp.2019.100101.

Oeser, G. (2015). Risk pooling in business logistics. In: Risk-pooling essentials. SpringerBriefs in Business. Springer, Cham, 5-23. https://doi.org/10.1007/978-3-319-14157-2_2

Oliveira, B. B., Carravilla, M. A. and Oliveira, J. F. (2017). Fleet and revenue management in car rental companies: A literature review and an integrated conceptual framework. *Omega, 71(C),* 11-26.

Ovezmyradov, B. (2022). Product availability and stockpiling in times of pandemic: Causes of supply chain disruptions and preventive measures in retailing. *Annals of Operations Research, 2022 Nov 30*: 1-33: https://doi.org/10.1007/s10479-022-05091-7.

Perez, H.D., Hubbs, C. D., Li, C and Grossmann, I.E. (2021). Algorithmic approaches to inventory management optimization. *Processes, 9*, 102. https://doi.org/10.3390/pr9010102.

Rajaguru, R. and Hassanli, N. (2018). The role of trip purpose and hotel star rating on guests' satisfaction and WOM. *International Journal of Contemporary Hospitality Management, 30(5),* 2268-2286.

Riquelme, C., Banerjee S, and Johari R. (2015). Pricing in ride-share platforms: A queueing-theoretic approach. *Working paper,* Stanford University, Stanford, CA.

Rojas, F., Wanke, P., Bravo, F. and Tan, Y. (2021). Inventory pooling decisions under demand scenarios in times of COVID-19. *Computer and Industrial Engineering, 161,* 107591.

Roubi, S. (2004). The valuation of intangibles for hotel investments. *Property Management, 22,* 410-423.

Sahay, A. (2007). How to reap higher profits with dynamic pricing. *MIT Sloan Management Review, 48(4)*, 53-60.

Schamel, G. (2012). Weekend vs. midweek stays: Modelling hotel room rates in a small market. *International Journal of Hospitality Management, 31,* 1113-1118.

Simchi-Levi, D and Zhao Y. (2012). Performance evaluation of stochastic multi-echelon inventory systems: A survey. *Advances in Operations Research, 2012*, https://doi.org/10.1155/2012/126254.

Singh, A. and Corsun, D. L. (2023). Price elasticity of demand and its impact on hotel revenue performance during the COVID-19 pandemic. *Cornell Hospitality Quarterly, 64(4),* 415-435: https://doi.org/10.1177/19389655231184475.

Talon-Ballestero, P, Nieto-Garcia, M. and Gonzalez-Serrano, L. (2022). The wheel of dynamic pricing: Towards open pricing and one to one pricing in hotel revenue management. *International Journal of Hospitality Management*, *102*, 103184. https://doi.org/10.1016/j.ijhm.2022.103184.

Swinney, R. (2011). Inventory pooling with strategic consumers: Operational and behavioral benefits. *Working Paper,* Stanford University, Stanford, CA.

Valentin, M., and O'Neill, J. W. (2019). The value of location for urban hotels. *Cornell Hospitality Quarterly, 60(1),* 5-24: https://doi.org/10.1177/1938965518777725.

Wang, X. T., Chen, Z. M., Zhou, S.R. Hu, M. F. and Ke, J. J. (2022). Inventory pooling and pricing decisions in multiple markets with strategic customers. *Rairo Operations Research, 56 (6),* 3941-3953: https//doi.org/10.1051/ro/2022163.

Williams, B, D. and Tokar, T. (2008). A review of inventory management research in major logistics journals. *The international journal of Logistics Management, 19(2),* 212-232.

Xiang Z. and Krawczyk, M. (2016) What does hotel location mean for the online consumer? Text analytics using online reviews. *Information and Communication Technologies in Tourism 2016,* 383-395. Springer.

Yang, N. and Zhang, R. Y. (2014). Dynamic pricing and inventory management under inventor-dependent demand. *Operations Research, 62(5),* 1077-1094.

Yang, Y., Mao, Z. X. and Tang, L. Y. (2017). Understanding Guest Satisfaction with Urban Hotel Location. *Journal of Travel Research, 57(2),* https://doi.org/10.1177/0047287517691153

Zhen, L. and Li, H. L. (2022). A literature review of smart warehouse operations management. *Frontiers of Engineering Management, 9,* 31-55. https://doi.org/10.1007/s42524-021-017809.

Zhong, Y. G., Zheng, Z. C., Chou, M. C. and Teo, C. P. (2018). Dynamic inventory pooling policies to deliver differentiate service. *Management Science, 64(4),* 1555-1573.

About Author

Dr. Kuangnen Cheng is an Associate Professor of Operations Management and Supply Chain at Marist College in Poughkeepsie, New York. With over thirty years of experience in the logistics industry, he brings a wealth of practical expertise to his academic work. His research primarily explores the complexities of supply chain management within service sectors, with a particular focus on optimizing operations and improving efficiency.