Gravity models and casino gaming: A review, critique, and modification

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Abstract

Gravity models have been widely used in expanded gaming debates to persuade investors that proposed casinos will be financially successful and to persuade state and local government officials, as well as a skeptical public, of the economic and fiscal benefits of casino gaming. However, most people involved in the decision-making process understand very little about the internal mechanics of these models and how they generate financial forecasts, estimates of customer visits, and projections of new job creation. In fact, the gravity models used in market feasibility studies for the casino industry are proprietary models that remain closely guarded secrets of the industry and its consultants. The purpose of this article is to open the use of gravity models to critical scrutiny by reviewing their origins, development, and limitations. A second purpose is to illustrate our main thesis by analyzing gravity models deployed in the New England expanded gaming debates. The authors offer a proposed modification to the calculation of gravity factors to account for the growing importance of non-gaming amenities.

Keywords: Gravity Model; Huff Model; Casino Industry

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The Basic Facts of Expanding Gaming

In the United States today, there are 492 commercial casinos and 448 Indian casinos hosted by 37 states as compared to less than half that number of casinos in two states in 1988 (AGA, 2013). However, after twenty-five years of expanded gaming legislation at both the state and federal levels, nearly half (46%) of all commercial casinos are now located in non-traditional jurisdictions (i.e., outside Nevada and New Jersey) and, if one includes Indian casinos, then seventy-two percent (72%) of all U.S. casinos are now located in non-traditional jurisdictions (AGA, 2012, pp. 12-22; Meister, 2012, pp. 15, 73). The percentage of adults who gambled at a casino at least once in the previous year climbed from 17 percent in

1990 to 32 percent in 2012, when 76.1 million Americans made more than 400 million visits to casinos (Harrah's, 2006; AGA, 2013, p. 3). Moreover, since the early 1990s, when new casinos began opening in non-traditional jurisdictions, nearly 82 percent of the increase in casino visitations has occurred in non-traditional casino jurisdictions, which now also account for 49 percent of casino gross gaming revenues (GGR) nationally. If Class III Indian casinos are factored into the equation, non-traditional venues now account for 69 percent of casino GGR nationally (AGA, 2012, pp. 12-22; Meister, 2012, pp. 15, 73).

During this time, the debates over expanded gaming from state to state have been remarkably similar because its proponents have offered the same two rationales for policy change in every jurisdiction: new tax revenues and economic development (i.e., jobs) (Evart, Treptow, and Zeitz, 1997, p. 425). The same two rationales structure debates about individual casino projects regardless of their type or location. Casino revenue and operating forecasts, as well as projections of new job creation, are normally based on market feasibility studies that depend on gravity models. Government officials want to know how much tax revenue proposed casinos will generate, while citizens want to know how many and what types of new jobs will be created by a casino. Chambers of commerce and restaurant associations are often concerned about the potential impact of casinos on the local lodging, food and beverage, and retail sectors. Tourism officials, and other segments of the hospitality industry, demand reliable estimates of the number of out-of-region visitors that can be generated by casinos and how many visits and what type of spending will occur each year as a result of those visits.

Thus, one purpose of gravity models has been to provide investors with an evaluation of specific sites for proposed business establishments and to determine the potential sales of the proposed establishments within a reasonable range of error, which allows investors to assess the probability that the proposed casino will be financially successful. A second practical use of gravity models has been to provide investors with empirically based research that allows them to identify the best location among alternative possible locations for particular casinos, with the "best" location being the one that "will produce for the firm an optimum share of the market potential, a minimum hazard for future sales erosion, and a maximum return on total investment over the long-run" (Applebaum, 1965, p. 235). A third use that is not unique to the casino industry is persuading state and local government officials, as well as a skeptical public, of the economic and fiscal benefits of expanded casino gaming.

However, John Williams (1997, p. 402) observes that outside of Nevada and New Jersey, where casinos have operated in fairly well-defined markets, any "feasibility study requires an intuitive leap from the known into the unknown," because "there is no magic formula by which you add A, B and C and reach X as a casino's performance." Yet, this is exactly the function of gravity models in market feasibility studies, even though most people involved in the decision-making process understand very little about the inputs to a gravity model and much less about the internal mechanics of these models and how they generate financial forecasts and estimates of customer visits (Hashimoto and Fenich, 2007, p. 47). In fact, scholars have often criticized gravity models as a black box (Bucklin, 1971, p. 490) – one can observe what goes in and what comes out – but not how inputs are converted into outputs. Despite this theoretical criticism, gravity models continue to be utilized and refined by private consultants and university scholars primarily on pragmatic grounds, i.e., because they seem to generate reasonably accurate revenue forecasts that public and private decision-makers find persuasive (Huff, 1963, p. 81; Evenett and Keller, 2002).

The gravity models used in most market feasibility studies for the casino industry are proprietary models that remain closely guarded secrets of the industry and its consultants. For instance, the International Gaming Institute (IGI, 1996) at the University of Nevada, Las Vegas (UNLV) published one of the first introductory overviews of the post-Las Vegas/Atlantic City casino industry in 1996 following the rapid expansion of riverboat and dockside gaming in the Mississippi River states and the introduction of racetrack casinos in the Northeast. This introduction to "the gaming industry" covered the historical background, economics, operations, and management of casinos, but without any mention of the role that market feasibility studies had played in each state's expanded gaming debates.

John Williams (1997, p. 402), who was one of the first to discuss this issue in the newly emerging gambling studies literature offered a generic discussion of the importance of market feasibility studies, but "without going into detail about all the methods of homing in on a market." Similarly, and more recently, Douglas Walker's (2007, pp. 5-34) highly respected *The Economics of Casino Gambling* examines the relationship between casino gaming and economic growth, including an extensive analysis of various methodological debates, but the book does not contain a single reference to gravity models and this omission is replicated in Walker's *Casinonomics: The Socioeconomic Impacts of the Casino Industry* (2013). Likewise, Kathryn Hashimoto's recent book on *Casino Marketing* (2010, pp. 16-21, 41) discusses the role of strategic planning and consumer behavior in casino marketing, but it does not discuss the role of gravity models in initial revenue forecasting or their importance to the industry's business *and* political practices.

In fact, a JSTOR search of journals in business, economics, finance, management, marketing, and transportation studies found exactly one published reference to the use of gravity models in gambling studies since 1931 (the origin of the gravity model) despite there being 367 total references in the academic literature to the use of gravity models in other industries. A Google.com key word search discovered one PowerPoint presentation delivered at the13th International Conference on Gambling and Risk Taking (Cummings, 2006). Nevertheless, during the last twenty-five years, gravity models have played a prominent role in persuading public officials to authorize expanded gaming in the United States, and elsewhere, and they have supported private decisions by casino operators, banks, and other financial institutions to invest in expanded gaming at various locations.

Thus, the purpose of this article is to open the use of gravity models to critical scrutiny by reviewing their origins, development, and limitations, particularly in light of recent changes in the casino industry. A second purpose is to point out the limitations of current gravity models in evaluating contemporary gaming markets and to propose a modification to the so-called gravity factor used in these models so they better account for the growing importance of non-gaming amenities.

Reilly's Law of Retail Gravitation

The gravity model is a tool first developed by economists in the late 1920s and early 1930s for the purpose of estimating retail trade flows between various geographic areas, although private retail companies quickly recognized their utility for estimating the potential customer base and future annual sales of new stores. Gravity models are actually derived from Sir Isaac Newton's Law of Gravitation, which was first used to predict the movement of people, commodities, and sales by William J. Reilly, a professor of business at the University of Texas.[1] Reilly published *The Law of Retail Gravitation* in 1931 after he realized that Newton's Law of Gravitation seemed to loosely express the empirical regularities he observed while conducting several trading area investigations for chain grocery stores in Texas during the late 1920s (Reilly, 1929).[2]

Newton's Law of Gravitation, which was first articulated in his *Philosophiæ Naturalis Principia Mathematica* (1687) states that the gravitational force between two masses is proportional to the product of the two masses and inversely proportional to the square of the distance between them. Reilly argued that Newton's Law of Gravitation seemed to provide a good working hypothesis for defining the boundaries of competing retail trade areas if one translated the law into two behavioral concepts: (a) that the ability of a city to attract non-resident trade is a function of its population (mass) and (b) that the flow of nonresident trade to a city is an inverse function of distance (force) (Thompson, 1967, p. 37). If one adopted this hypothesis, then the law of retail gravitation could be used to calculate the "breaking point" between two places, where customers will be drawn to one or another of two competing commercial centers (Anas, 1987, pp. 45-54; Golledge and Timmermans, 1988). In this sense, Reilly argued that "two cities attract retail trade from an intermediate city or town in the vicinity of the breaking point approximately in direct proportion to the populations of the two cities and in inverse proportion to the square of the distances from the two cities to the intermediate town" (Huff, 1963, pp. 81-82), although notably, Reilly's formulation of the law presumes that the geography of an area is flat without any rivers, roads, or mountains to alter a consumer's decision about where to travel to purchase a particular good or service.

Reilly's Law remained an interesting hypothesis for more than a decade and, as late as 1944, the editor of *The Journal of Marketing*, which became a key academic testing ground for Reilly's Law, wrote that "there is a real need for inductive studies of consumer buying habits" (quoted in Bennett, 1944, p. 405). Professor Victor W. Bennett published one of the first studies of this type based on a survey of 240 families living in Laurel, Maryland. The families were questioned on their choice of shopping venues in Baltimore, Maryland and Washington, D.C. and, in one of the first empirical tests of Reilly's Law, Bennett (1944, p. 413) found that "there is more out-of-town buying by Laurel consumers in Baltimore than in Washington, [which] conforms roughly to the application of Reilly's Law."

Bennett's study was followed by the noteworthy work of P.D. Converse (1943; 1946; 1948), a professor of business at the University of Illinois, who examined retail customer movement between several communities in Illinois and established the usefulness of Reilly's Law for defining retail trade areas across a much larger geographic area. However, Converse (1949) made a significant addition to Reilly's Law that more precisely determined the breaking point between competing trading areas centered in two different cities. Converse defined the breaking point between two trading areas as an equilibrium boundary line where $B_a = B_b$, i.e., the point up to which one city exercises a dominant trading influence and beyond which another city dominates. The mathematical version of this adaptation is:

(Equation 1)

$$B_{ab} = \frac{D_{ab}}{1 + \sqrt{P_a / P_b}}$$

Where

B_{ab} = the breaking point between city A and city B in miles from B

D_{ab} = the distance separating city A from city B

P_a = the population of city A; and

P_b = the population of city B

This breakthrough was followed by the work of Frank Strohkarck and Katherine Phelps, who were working for the Curtis Publishing Company. They authored a 1948 article on the mechanics of constructing a trade area map that for the first time visually represented competing trade areas as a series of concentric and overlapping circles emanating from central places much like the three dimensional topographical or contour maps familiar to geographers. Thus, Strohkarck and Phelps added an important cartographic dimension to the gravity model as well as a mathematical refinement of the breaking point concept.

The pioneering work of Strohkarck and Phelps was further refined by Edna Douglas (1949a; 1949b), who employed three methods for identifying retail customer origins in Charlotte, North Carolina: (1) the records of the Credit Bureau of the Charlotte Merchants' Association to determine customer's addresses, (2) checks deposited during one week by a group of local retail stores to determine the location of the banks against which they were drawn and (3) an origin-destination study of passenger cars leaving Charlotte. Douglas's (1949b, p. 60) findings reinforced previous studies and again found that "Reilly's law of retail gravitation provides a remarkably accurate delineation of the Charlotte retail trading area." However, Douglas's empirical findings also suggested a slight modification to Strohkarck's and Phelps' concept of concentric market areas.

First, Douglas (1949b, pp. 59-60) found that the retail trading area was not a single concentric circle with one breaking point, but a series of circles within circles that comprised primary, secondary, and tertiary market areas, with customers in the tertiary market coming from otherwise significant trading areas that were in competition with Charlotte. This led Douglas to conclude that market breaking points were not hard boundaries, where all the potential customers on one side gravitated in one direction and all of those on the other side gravitated in the other direction, but porous boundaries that delineated points where an exponentially decreasing proportion of customers would be drawn to a trading area. In this formulation, the Strohkarck and Phelps breaking point formula defines the outer boundary of a primary market area at which point the proportion of customers attracted to a trading area begins to decline exponentially, while the tertiary market area marks another point of exponential decline in customer attraction (force), because the gravitational pull of a competing, but closer trading area begins to exert greater force on customers. Douglas also found that the primary market area was indeed nearly circular as hypothesized by Strohkarck and Phelps, but the secondary market area became somewhat elliptical, while the boundaries of the tertiary market area were quite erratic depending upon the level of competition from outlying areas with significant trading centers.

The next major advance in gravity modeling was stimulated by the emergence of regional shopping centers (i.e., malls). By the 1950s, the investors in costly real estate projects, such as banks, insurance companies, and other financial institutions, were no longer willing to rely on the intuition of business entrepreneurs for making decisions, but increasingly sought to base investment decisions on solid factual information as to the profitability of a proposed real estate investment. Similarly, prospective store tenants, often the large retail chains that were being asked to anchor the new shopping centers, conducted their own studies to evaluate proposed shopping center locations. This second generation of trade area studies incorporated concepts and research techniques from marketing, geography, statistics, economics and the behavioral science disciplines (e.g., psychology and sociology) (Applebaum, 1965, p. 234). By the mid-1950s, this type of gravity model was being applied to both inter-urban and intra-urban market areas for the purpose of determining the market feasibility of local malls, large chain stores, and regional shopping centers (Ellwood, 1954) and by the 1960s gravity models were being used to assist government officials with economic development and urban planning (Huff, 1963; Lakshmanan, 1964). Subsequently, gravity models were used to predict consumer preferences for a wide variety of competing retail and service industry outlets, such as hospitals (Bucklin, 1971), large chain stores (MacKay, 1973), banks (Ali and Greenbaum, 1977), and movie theatres (Davis, 2006). By the 1970s, gravity models were being extended to the leisure and social travel industries (Gilbert, Peterson, and Line 1972; Stutz 1973; Vickerman 1974).

However, during this period (1950-1970), there were two additional developments in the science of gravity modeling. First, as Louis P. Bucklin (1971, p. 489) observes: “In its original formulation, the retail gravity model was used to predict the point between two cities where trade between them would be divided. This ‘breaking point’ defined the geographical size of the market which each city controlled vis-à-vis the other.” However, Bucklin (1967a; 1967b) was among the first scholars to test the gravity model’s ability to predict *intra*-urban shopping patterns as opposed to inter-urban shopping patterns. For example, in one study, Bucklin conducted a survey of 500 female heads of household in Oakland, California. In this study, he (1967b, p. 42) concluded “that mass retains much influence in the selection of an intra-urban shopping center,” but this innovation also shifted the concept of mass from the size of an area’s population to the size and composition of the facility. This subtle shift built on the work of Professor George Schwartz’s (1963) University of Illinois marketing group, which had generated impressive statistical evidence to validate Reilly’s original hypothesis that one could use population *or retail square footage* as the sole proxy for measuring retail mass in gravity models.

The results of these studies were so consistent and so reliable that nearly three decades after the publication of Reilly’s *Law of Retail Gravity* (1931), Robert Ferber (1958, 302) was able to declare that: “The two variables included in Reilly’s Law and in subsequent formulations – *population* and *distance* – account for almost all the variations in sales between cities.”

Indeed, after three decades of testing Reilly's Law, Allen F. Jung (1959, p. 62), a research associate at the University of Chicago suggested that "through the years little, if any, evidence has been presented which conflicts with this [Reilly's] law." These claims were reaffirmed by David L. Huff (1963, p. 81), who observed that "empirical evidence is available to indicate that in many cases the use of such [gravity] models has provided fairly good approximations of the limits of a number of retail trade areas."

The Huff Model:
Variety, Time, Income, and Probability

Scholars, retail executives, real estate investors, and urban planners enthusiastically embraced Reilly's Law of Retail Gravitation as an iron law of retail trade distribution, but at the same time a number of methodological amplifications were introduced in the 1960s and 1970s which culminated in the introduction of the "Huff model" (Applebaum, 1965, p. 234). It is actually David L. Huff, a former professor of business at the University of California, Los Angeles (UCLA), who pioneered the type of gravity model utilized most frequently by the casino industry and casino industry consultants. Huff (1963, 85) proposed four modifications to Reilly's Law that were critical to the development of the Huff model: (1) Merchandise Offerings (or the number of items of the kind a consumer desires that are carried by the retail outlet), (2) the travel *time* that is involved in getting from a consumer's travel base to alternative retail facilities, (3) the average household income of people living in the trading area, and (4) probability contours as opposed to breaking points. We might suggest by way of analogy that just as Newtonian mechanics was superseded – though not displaced – by Niels Bohrs' quantum mechanics a similar phenomenon occurred in the business and social sciences as the focus shifted from aggregate populations to individual consumer behavior – or from planetary bodies to sub-atomic particles.

First, Huff suggested that it is not just the square footage that measures the mass of a retail facility, but rather square footage is really a proxy indicator for the number of stores, types of stores, and range of merchandise offerings at a particular location, because it is this variety that justifies traveling longer distances by making more purchasing options available at a single location. In the gravity models used by the casino industry and its consultants, this concept of mass has typically been operationalized exclusively in terms of gaming positions, where one slot machine equals one gaming position and one table game equals five or six positions, because a table can accommodate multiple players.[3] These accumulated modifications to the concept of mass are often referred to today as "destination effects" (Black, 1983).

Second, and despite widespread recognition of this shortcoming, most gravity models, including those used in the casino industry are based on the assumption that customers patronize a facility according to some rule involving the comparative distance between two facilities, all other things being equal. A customer prefers facility A over facility B if the distance to facility A is shorter than some function of the distance to facility B (Drezner, Drezner, and Eiselt, 1996). However, Richard Nelson (1958, p. 149) was one of the first scholars to suggest that driving time, rather than distance was a more important determinant of customer preference for alternative shopping facilities (Nelson, 1958, p. 149). Similarly, by the late 1950s, Eugene J. Kelley (1958, p. 32) had commented that "convenience costs are assuming more importance as patronage determinants" compared to distance. Kelley observes by this time that marketers had actually identified "ten convenience forms" with "place convenience" being only one of the ten forms. Nevertheless, Kelley's work continued to emphasize the importance of place, or geographic area, as defined by the concentration or dispersion of population as did Reilly.

Yet, Kelley did introduce two new elements into the concept of place convenience. Kelley (1958, p. 35) challenged the equivalence of "the distance concept" with "convenience" by noting that distance involves "time-cost elements rather than a purely spatial one." Higher road speeds and the emergence of large planned retail centers were actually changing consumers' perceptions of distance, because one could travel further faster and obtain more goods and services at a single location. Kelley (1958, p. 35) also noted the importance of parking to retail structures as an element of time convenience, observing that "it is generally agreed that shoppers resist walking more than 600 feet from their parked cars to the nearest center store...this suggests a limit to the maximum parking distance" that can be used before a retail center loses its other advantages over competing centers and certainly anyone who operates, manages, or visits a casino will recognize the importance of parking, i.e., finding a space quickly, getting into the facility quickly, and avoiding inclement weather.

Kelley's observation was validated in subsequent research, including a study by Professors James A. Brunner and John L. Mason (1968), who studied consumer preferences for various shopping centers in Toledo, Ohio based on drive-times as opposed to distance. The findings confirmed the drive-time hypothesis as superior to the simple distance concept proposed by Reilly, but given the limited geographic sample, Brunner and Mason (1968, p. 61) called on other researchers "to ascertain the degree to which these observations are generally true for other shopping centers in other communities." A license plate survey of 93,500 passenger cars in 18 Greater Cleveland shopping centers by Cox and Cooke (1970, p. 13) in fact confirmed that "the driving time required to reach a center is highly influential in determining consumer shopping center preferences" (also see, McCarthy, 1964, p. 577; Cox and Erickson, 1967, p. 52; Berry, 1967).

However, Cox and Cooke also found that the "drawing power" (i.e., gravity factor) of a shopping center still had to be incorporated into the gravity model, because consumers were willing to drive farther to reach a shopping center depending upon "relative attractiveness" compared to other shopping centers. Cox and Cooke (1970, p. 14) suggested that a number of factors could be used to measure the attractiveness of a facility, such as the number of parking spaces, the size of the center, and the types of stores in the center," since these factors could partially overcome the "friction" or "inertia" of drive-time and distance. Furthermore, Gautschi (1981) points out that the first gravity models constructed to evaluate the potential trade areas of planned shopping centers assumed the automobile of the 1950s and the 1960s, as well as the transportation network in place at the time. Consequently, Gautschi (1981, p. 172) argues that the development of better, faster, and more comfortable automobiles, the construction of superior road systems (parkways, interstate highways), and urban mass transit means (at least theoretically) that "the travel time parameter has an inflated absolute value," which "serves to underestimate the expanse of a center's trading area."

However, even as late as 1978, Raymond Hubbard found that "the vast majority of the literature" on gravity modeling and retail trade areas still utilized "objective distance data," rather than drive times partly because distance data was easily available, but drive times were not available in any readily useable format. The use of distance, rather than drive-time, has been almost universal in the casino industry's gravity models, but the difference between distance and drive-time can be significant in various geographies that are not flat, where the width and quality of roads is not consistent, where weather can be a factor, and where urban congestion or other choke points can significantly alter the relationship between distance and drive-time. However, the lack of available data on drive-times is a technical problem that should largely have been eliminated by the introduction of computer and internet programs, such as MapPoint, Google Maps, Yahoo Maps, Map Quest, Free Mileage Calculator, and other programs that have made drive-time data easily accessible for incorporation into gravity models.

Third, while Reilly accounted for differences of population, he did not account for differences of income. Yet, as early as 1958, Ferber's (1958, p. 303) consumer behavior research, which was based on Reilly's Law had found that "income is a major factor influencing variations in per capita retail sales between cities for most categories of sales." Similarly, Bucklin (1967b, p. 42) found that consumer perceptions about the value mass imparts vary considerably" among consumers depending on the motivation of consumers. In particular, he found that mass had a higher attraction (force) for those with higher incomes, since these consumer cohorts were willing to travel farther to a primary retail center to obtain the benefits of retail mass, while secondary centers held a greater attraction for those seeking convenience, and tertiary centers (i.e., small out of the way stores) were more likely to attract price conscious consumers. Thus, subsequent research has found that mass and income are two factors that will interact to promote "excess travel behavior" (Hubbard, 1978, pp. 8-10). This is not only because a larger mass exerts more gravitational force on consumers, but because "those individuals showing evidence of higher income levels are more readily able to bear the costs involved in shopping around, and therefore tend to travel greater distances in the journey to consume" (Hubbard, 1978, p. 9; for example, McAnnally, 1965; Schiller, 1972). Thus, a larger and more attractive retail facility increases the likelihood that higher income consumers will travel distances in excess of those that are theoretically justified (Hubbard, 1978, p. 9). By the late 1960s, consumer behavior surveys were documenting that the nearest center postulate "provided an inadequate description of consumer movements" and that large numbers of consumers deviated from what was defined as "spatially lawful behavior" (Golledge et al., 1967; Rushton et al., 1967; Hubbard, 1978, pp. 3-4). This is particularly important to gravity modeling in the casino industry, where surveys have documented that the individuals who patronize destination resort casinos, in particular, have incomes higher than the median income of its host jurisdiction (AGA, 2013; Barrow and Borges, 2011).

Finally, David L. Huff (1961, p. 84) identified another significant limitation to the application of Reilly's Law, which is that "the calculation of breaking points to delimit a retail trade area conveys an impression that a trading area is a fixed boundary circumscribing the market potential of a retail facility, when in fact there is an exponential distance decay factor of declining retail attraction within the trade area, as well as interpenetration and overlap between designated market areas." This problem had been identified earlier in the development of gravity modeling by scholars, such as Edna Douglas, who had mapped trade areas based on actual consumer origins, rather than distance postulates. Huff (1961, p. 490) built on this work, but was more emphatic in stating that trading areas do not have hard boundaries, but shade off into one another and, therefore, "probabilistic models are appropriate measures of this process." Thus, Huff proposed that breaking points be replaced by "exponents," which are the statistical units that capture and measure the distance decay factor in terms of the probability that an individual consumer will choose to patronize a specified facility (Huff and Jencks, 1968). This does not mean that the breaking point formula is irrelevant, but that it defines the 0.50 probabilistic contour or the point up to which a customer has a greater or less than fifty percent (50%) probability of selecting one facility over another. The lines demarcating or connecting the geographical units with comparable decay factors on a map are called "probability contours" instead of market boundaries, because they delimit the statistical probability that individuals will select a particular trading area or facility.

The "most obvious deficiency" in the application of this principle at the time was "the lack of direct information on the actual spatial movements and expenditures of individuals" (Golledge et al., 1966, p. 261). This difficult has largely been removed in the casino industry where the annual Harrah's (2006) surveys of "propensity to gamble" – now conducted by the American Gaming Association (2007-2013) – has provided reliable data at the state level. The development of sophisticated players' club databases, hotel guest databases, and daily headcounts by casinos have perhaps made the industry a leader in this area, particularly as this proprietary information is often provided to consultants, who can then develop more elaborate models based on actual player origins and gaming behavior (e.g., spend per visit).

The Huff model, which was first articulated in two articles published in 1963 and 1964, incorporated these four modifications to Reilly's Law to construct an alternative model of retail gravitation based on consumer behavior theory and goods theory, rather than central place theory. In Huff's (1963, pp. 87-88) article, he walks the reader through a seven step process for constructing a gravity model that incorporates drive times and that maps trade areas based on exponential decay factors, the actual population residing within these probabilistic contours, and the average household income of the households residing within each contour of the map. The seven step process for constructing a Huff models is as follows:

1. "Divide the area surrounding any existing or proposed shopping center into small statistical units. These units could be Census enumeration districts.
2. Determine the square footage of retail selling space of all shopping centers included within the area of analysis.
3. Ascertain the travel time involved in getting from a particular statistical unit to each of the specified shopping centers.
4. Calculate the probability of consumers in each of the statistical units going to the particular shopping center under investigation for a given product purchase.
5. Map the trading area of the shopping center in question by drawing lines connecting all statistical units having like probabilities.
6. Calculate the number of households within each of the statistical units. The, multiply each of these figures by their appropriate probability values to determine the expected number of consumers (expressed in households) who will patronize the shopping center in question for a particular product purchase.
7. Determine the annual average per household incomes of each of the statistic units. Compare such figures to corresponding annual household budget expenditures in order to determine the average expected amounts spent by such families on various classes of products, e.g., clothing and furniture. Estimate *annual sales* for the shopping center under investigation by multiplying each of the product budget figures by expected number of consumers from each statistical unit who are expected to patronize the shopping

center in question. Then, sum these individual estimates to arrive at a total annual sales potential by product class for the selected shopping center" (Huff 1963, 87-88).

With respect to Step 6: Huff (1963, p. 87) notes that "in addition to the likelihood [propensity] of consumers from various statistical units patronizing a proposed shopping center, it is necessary to know the *expected number* of such consumers from each of the units. For example, it might be that a given contour possesses a high probability value but the consumers within its confines may be few in number" and, therefore, provide few customers and little revenue to the proposed facility. Similarly, with respect to Step 7, Huff (1963, p. 88) observes that "in terms of purchasing potential, another contour possessing a much smaller expected number of consumers may have a greater disposable income level and thus greater purchasing potential."

A formal expression of the Huff (1964, p. 36) model is:

(Equation 2)

$$P_{ij} = \frac{\dfrac{S_j}{T_{ij}^{\Delta}}}{\displaystyle\sum_{j=1}^{n} \frac{S_j}{T_{ij}^{\Delta}}}$$

- where P_{ij} = the probability of a consumer at a given point of origin traveling to a particular shopping center j;
- Sj = the size of a shopping center j (measured in terms of the square footage of selling area devoted to the sale of a particular class of goods);
- T_{ij} = the travel time involved in getting from a consumer's travel base I to a given shopping center j; and
- Δ = a parameter which is to be estimated empirically to reflect the effect of travel time on various kinds of shopping trips.

As Huff (1964, p. 36) described it, the *expected* number of consumers at a given place of origin *i* that shop at a particular shopping center j is equal to the number of consumers at *i* multiplied by the probability that a consumer at *i* will select j for shopping.

That is:

(Equation 3)

$$E_{ij} = P_{ij} * C_i$$

- where E_{ij} = the expected number of consumers at i that are likely to travel to shopping center j; and
- Ci = the number of consumers at i.

Huff (1964, p. 36) noted that his model "resembles the original model formulated by Reilly," but he argued that it differed from Reilly's Law of Retail Gravitation "in several important respects." The most important theoretical difference is that Huff's (1964, pp. 36-37) model was not a "contrived formulation" designed *post-hoc* to describe observed empirical regularities, but "a theoretical abstraction of consumer spatial behavior." As a result, real data including population, average household income, square footage, drive times, and propensity factors can be used in mathematical calculations to deduce probabilistic conclusions about the number of consumers and the spend per consumer that for a particular type and size of retail facility.

Gravity Models and Casino Gaming

The first likely use of gravity modeling as a means of forecasting casino revenues was by Economics Research Associates (ERA), an economics consulting firm, which produced a study in 1976 on the potential economic and fiscal impacts of legalized casino gaming in Atlantic City, New Jersey. The ERA study was released into a highly charged political atmosphere, since the forecasts from the study were incorporated into campaign literature developed by the Committee to Rebuild Atlantic City, which at the time was the state's leading pro-gaming coalition (Heneghan, 1999, p. 119). The model's forecasts evidently proved persuasive because the New Jersey referendum passed, but the ERA model immediately revealed both the promise and the shortcomings of gravity modeling in the casino industry.

As a model designed to forecast revenues from a regional base of commuter shoppers, it proved ill-equipped to accurately estimate visitations and revenues in a new industry, while comparisons to Las Vegas proved misleading for a new type of gaming market. On the one hand, as Dan Heneghan (1999, p. 120) points out: "the projections proved to be way off," because "the promises turned out to be extremely conservative." ERA's projections on annual visitations proved far too conservative with respect to the number of visitors, but far too optimistic on the length of stay by visitors, partly because Las Vegas was the only gaming jurisdiction at the time and it was not recognized that Atlantic City would be designed as a new type of regional commuter destination, rather than a site for integrated resort casinos. Atlantic City became a regional commuter destination, rather than a national or international destination, such as Las Vegas, but it was one that happened to be in the middle of one of the most densely populated areas of the United States. Similarly, the employment projections derived from the ERA model "were so conservative that the low end [of the employment projections] was passed by the end of 1980" (Heneghan 1999, p. 121). The same was true with respect to forecasts about tax revenues and capital investment (Heneghan 1999, pp. 123-27). However, the Atlantic City experience established a familiar pattern of critics claiming that the industry consultant's projections were exaggerated, while in fact they proved far too conservative.

The difficulty of calibrating gravity models to a new industry, where reliable comparative data and primary behavioral data were in short supply, would be revisited many times over the next two decades, particularly after the federal government passed the Indian Gaming Regulatory Act (IGRA) in 1988 to provide a legal framework for the expansion of tribal gaming across the United States (Rand and Light, 2006). At the same time, several states legalized commercial casinos, including South Dakota (1989), Iowa (1989), Colorado (1990), Illinois (1990), Mississippi (1990), Louisiana (1991), Missouri (1993), Indiana (1993), and Michigan (1996). Thus, as expanded gambling took hold in the United States, John Williams (1997) correctly argued that one of the main areas of future research in gambling studies would be patronage and revenue forecasts. Williams (1997, pp. 402-403) did not elaborate how this research would be conducted, nor did he recognize that it would mainly be conducted by private consultants, rather than university-based scholars, but he did identify the specific data points and comparative factors that would have to be incorporated into future visitation and revenue models, including:

- population, demographics, and disposable income,
- existing visitors, both domestic and international,
- ease of access to the casino, domestically and internationally,
- regional propensity to gamble and outlets for it,
- residents who go to other countries to gamble,
- limitations on opening hours, types of gambling and credit, and,
- the performance of other casinos in the region, from which some parallels can be drawn.

Williams' recommendations might have provided the basis for a national research agenda for the growing number of scholars interested in the gaming industry, but at least the casino industry's leading economic consultants seem to have adopted variations of the framework established by Williams (and even earlier by Huff). One could multiply examples and case studies endlessly, but a few examples from the New England expanded gaming debate are examined here to illustrate our main thesis.

The first major wave of Indian and commercial gaming expansion into non-traditional jurisdictions (1988-1996) ignited expanded gaming debates in almost every region of the United States – the Mid-Atlantic states, the Mississippi River Valley, the Upper Mid-West, the Rocky

Mountains, the Southwest, the Northwest, and New England. In New England, the resounding success of Foxwoods Resort Casino in Ledyard, Connecticut immediately set off what became a perennial expanded gaming debate in almost every New England state with Massachusetts sitting at the epicenter of that debate, because of its regional population and wealth.

In Massachusetts, former Governor William Weld brokered a proposed gaming compact in 1995 with the Aquinnah Wampanoag Tribe of Gayhead to open a $200 million resort casino in New Bedford, Massachusetts (Halbfinger, 1996). The Weld compact would have granted the Aquinnah Wampanoag Tribe exclusive casino rights in eastern Massachusetts in exchange for 25% of the casino's gross gaming revenues, while allowing a limited number of slot machines at the state's four racetracks (Vaillancourt, 1994). A patron origin analysis released by the University of Massachusetts Dartmouth estimated that Massachusetts residents accounted for approximately 33% of Foxwoods' annual visitations and that Massachusetts residents were spending at least $300 million per year gambling at Connecticut's billion dollar casino in 1995 (Dense and Barrow, 2003). Nevertheless, the Weld compact was rejected by the state's House of Representatives.

In 1997, Governor Weld filed new casino legislation that would have allowed the Aquinnah Wampanoag Tribe to operate one casino in New Bedford, while authorizing a second casino in Hampden County (western Massachusetts), and authorizing 700 slot machines at each of the state's four racetracks. The governor's new bill died in committee without a vote. However, the expanded gambling issue was resurrected in 1999, when State Senator James P. Jajuga filed a bill known as the Massachusetts Casino Control Act that would have authorized the licensing of three resort casinos in Southeastern Massachusetts, Western Massachusetts, and Northeastern Massachusetts, where voters in each of the three regions had already passed non-binding referenda to host a casino.

For the first time, and to bolster proponents' claims about the potential economic impacts of the proposed casinos, a group of business people in the western Town of Palmer known as the Committee for Palmer Growth and Development hired Economics Research Associates to prepare a *Gaming Market Analysis for 3 Massachusetts Locations* (1999). Like each of the examples that follow, the ERA (1999, pp. 16-19) model is "semi-transparent" insofar as it identifies the types of data incorporated into the model (and often summarizes that data in tabular form). The model incorporates total population, adult population (aged 21+), number of households, average per capita income, and aggregate income in 30 minute drive time zones. The data is attributed to Claritas, although ERA (1999, p. 16) "developed population and income estimates for the resident population for drive times," and then relies on these estimates "for estimating the market shares between the casino locations." However, the equations and other assumptions used to derive final estimates of demand (i.e., gross gaming revenues), the weights assigned to various factors in the model (e.g., drive-time), and the internal mechanics of the model are never specified in the report. Moreover, the ERA (1999, pp. 3, 8-11) report never specifies a comparative gravity factor for any of the proposed casinos, but merely asserts that "the Massachusetts casinos would be of sufficient size to compete with other casino offerings in the northeast" in terms of slot machines, table games, and "appropriate amenities."

In this case, Economic Research Associates (1999, p. 12) operationalized a simple but standard gravity model. It uses "drive times as one means of estimating the potential numbers of adults 21 and over who live within varying drive times distances from the three locations. These [drive time bands] are broken into approximately half-hour increments…for purposes of approximating figures for attendance and revenue." For purposes of estimating the number of annual casino visits and forecasting revenues in a stabilized year, ERA (1999, 18) applies the national average (not locally specific) propensity to gamble, including the national average trips per year to casinos published in the *Harrah's Survey of Casino Entertainment* (1996), although as recommended by Walker, the report also makes comparisons to the Atlantic City and Connecticut casinos to further calibrate revenue and visitation estimates with purportedly comparable jurisdictions (ERA 1999, pp. 7-11). However, it does not appear that the model applies any type of distance decay factor as would be required in a more sophisticated Huff model. Finally, the ERA (1999, p. 18) report assumes a 20% "Tourism Factor" to account for non-regional casino visitors and revenues, based on Atlantic City bus arrivals, which is a typical approach when confronted with this problem, because standard gravity models cannot account for this type of visitor within their normal parameters. The tourism factor is, in effect, a shot in the dark – an educated guesstimate that could vary wildly from one jurisdiction to another depending on location and the amenities necessary to generate a destination effect.[4]

The ERA report concluded that three resort casinos distributed across Massachusetts would generate 13.7 million annual visits and $1.1 billion in annual gross gaming revenue, but the 1999 Massachusetts Casino Control Act was pigeonholed in a House committee and the expanded gaming debate shifted to Rhode Island. In Rhode Island, a proposal by Boyd Gaming Corporation and the Narragansett Indian Tribe to build a $500 million destination resort casino was rejected by the Rhode Island State Legislature in 2000 (Mello, 2000). However, soon thereafter, Harrah's Entertainment, Inc. (now Caesar's Entertainment, Inc.) and the Narragansett Indian Tribe proposed a $600 million destination resort casino in the Town of West Warwick, Rhode Island. Proponents of the casino retained Christiansen Capital Advisors (CCA), which prepared a report on the *Potential Impacts of a West Warwick Casino: Draft Report*

(2004). The CCA report (2004, 6) operationalizes a "supply side" model, in contrast to the demand side model exemplified by the ERA report, and states that "a convincing gauge of capacity constraints" is "gaming revenue and win/unit/day" for the facilities serving a gambling market." Based on comparative data for the New England gaming market, the report (2004, p. 6) concludes that "the observed distant adjusted spending per adult at the two Connecticut casinos [i.e., Foxwoods and Mohegan Sun] and at the two pari-mutuel facilities [i.e., Newport Grand and Lincoln], while certainly respectable at $586.50 and an average of around $514 respectively, is lower than the rate of spending for similar facilities in other more fully supplied jurisdictions." In the CCA (2004, p. 8) report, the "distant adjusted spending" at existing New England gaming facilities, compared to national averages, provides the basis for estimating "the demand for a casino to be located in West Warwick, Rhode Island."

A follow up analysis entitled, *Community Impacts of a Narragansett Casino in West Warwick* (2006, p. 1) "examined a scenario in which a casino resort facility with approximately 140,000 square feet of casino floor, 150 table games of the kind offered at Foxwoods and Mohegan Sun, 3,500 slot machines and other gaming devices of the kind offered at Foxwoods and Mohegan Sun, 500 hotel rooms, five restaurants, spa, premium lounge and 55,000 square feet of meeting space is constructed…in West Warwick, Rhode Island at an approximate total cost of $1 billion." This follow-up report (2006, pp. 1-7) contains a statement of estimated revenues and visitations for the proposed casino, but in this case there is absolutely no discussion of inputs and methodology in what appears to be a standard gravity model and thus decision-makers and the general public are left to take its findings on trust and good faith in what is inevitably a highly charged and politicized public debate. A referendum authorizing the proposed casino was defeated 63% to 37% on November 7, 2006.

Following the six year expanded gaming debate in Rhode Island, which resulted in three successive defeats for expanded gaming proponents, the debate shifted back to Massachusetts when on October 11, 2007, Governor Deval Patrick filed legislation to authorize up to three destination resort casinos in the Commonwealth of Massachusetts. In his message to the State Senate and House of Representatives, Governor Patrick indicated that the primary goal of his proposal was "to spur economic development and job growth throughout the Commonwealth" (Barrow, 2008). However, the governor's revenue and jobs projections were immediately dismissed by legislative critics, who began calling for an "independent study" to review the governor's projections. In response, the Secretary of Economic Development issued a competitive request for proposals that eventually led to the hiring of Spectrum Gaming on February 22, 2008 as "an independent third-party firm with specific expertise in the gaming industry." Spectrum Gaming was charged with examining the saturation point for gambling in New England, generating revenue projections based on the governor's proposal, and estimating the potential impact on the state lottery.

On August 1, 2008, Spectrum Gaming released its *Comprehensive Analysis: Projecting and Preparing for Potential Impact of Expanded Gaming on Commonwealth of Massachusetts*. The report (2008, p. 76) contains two forecasts of estimated gross gaming revenues and annual visitations:

> "First, we look at the basic demand for the type of planned destination casinos, absent any specific marketing programs that would rely on hotel rooms to target and reward gaming customers. This allows us to conservatively project the level of demand based on population within a reasonable driving distance. Second, we follow that with certain assumptions regarding the potential use of hotel rooms as marketing tools to develop our revenue estimates."

In the first phase of the demand analysis, Spectrum (2008, pp. 77-78) operationalizes a standard gravity model that incorporates "a variety of factors for each of these [three proposed] properties, which we assumed to be in the center of each of these [three] regions. These factors include, but are not limited to:

- Total population,
- Number of adults,
- The number and quality of competitors with in a two-hour drive,
- Number of slots and tables within that drive time,
- The type and quality of amenities of each competitor,
- Each competitor's distance from center of each region,
- The gaming value of each region adjusted for household income levels."

These factors are the typical inputs into a gravity model, but the report immediately moves to a forecast of gross gaming revenues without any further explanation of the model's internal mechanics, gravity factors, weights, or calculations. The initial model's gravity factor appears to be based exclusively on "the number of slots and tables," since the report (2008, p. 79) deploys a second gravity model that includes "the use of hotel rooms as marketing tools." Yet, how this factor gets incorporated into, or appended onto, the initial model is not explained in the report beyond the notion that by setting aside 50% of hotel rooms as "comps" for preferred players, it will add "incremental gaming revenue" above that normally expected for a regional commuter facility (Spectrum, 2008, p. 81). Moreover, there is no discussion of whether or how "the type and quality of amenities of each competitor" impacts revenues and visitation estimates so despite claiming that these factors are part of the model there is no explicit indication that these factors are actually incorporated into the model or, if so, in what way.

The Massachusetts House of Representatives rejected Governor

Patrick's casino proposal on March 20, 2008 by a vote of 108 to 46. However, following a change in legislative leadership, expanded gaming again returned to the top of the state's legislative agenda. While now generally supportive of the governor's previous gaming proposal, the State Senate decided to update the previous economic and fiscal analysis and commissioned a second report by the Innovation Group, entitled *Massachusetts Statewide Gaming Report* (2010). The Innovation Group (2010, pp. 86-87) tends to be more transparent than most in the description of its gravity model for Massachusetts, which is based on the identification of distinct market areas:

> "Using our GIS software and Claritas database, the gamer population [aged 21+], latitude and longitude, and average household income is collected for each postal code. Each of these market areas is assigned a unique set of propensity and frequency factors…both propensity and frequency are inversely related to travel time to a casino. In other words, as travel times increase, both the percentage of persons who gamble and the number of times they visit a casino tend to decrease. Gaming behavior also varies based on the availability and quality of the gaming experience. Alternative forms of entertainment are also a factor in determining gaming behavior. For this analysis, propensity and frequency rates for each market area are based on survey data presented earlier in this report and extrapolating information provided in public filings and published reports on gaming behavior in the region. Gamer visits are then generated from postal codes within each of the market areas based on these factors and distributed among the competitors based upon the size of each facility, its attractiveness, and the relative distance from the postal code in question. The gravity model then calculates the probabilistic distribution of gamer visits from each market area to each of the gaming locations in the market."

The Innovation Group's gravity model incorporates the standard factors, including adult population, average household income, drive time, average propensity to gamble, and the availability and quality of competing facilities. As with most such models, one can infer that some variation of the standard Huff equations are used to derive revenue and visitation estimates. Yet, the generic description of the model appears to incorporate "attractiveness" and "quality of the gaming experience," which suggests that factors other than gaming positions are being incorporated into the model as part of its gravity factor. However, when one examines a methodological section entitled Attraction Factors, which "measure the relative attraction of one casino in relation to others in the market," one finds that "attraction factors are applied to the size of the casino as measured by the number of positions it has in the market. Positions are defined as the number of gaming machines, plus the number of gaming seats at the tables" (Innovation, 2010, p. 89). In other words, slot machines and tables are the *only* measures of attractiveness (i.e., gravity).

One encounters a similar phenomenon in a response for proposals (RFP) submitted to the Town of Plainville, Massachusetts by Cummings Associates (2013), which includes examples of other gravity models operationalized by the consultant. Despite another misfire in 2010, Governor Deval Patrick finally signed a bill on November 22, 2011 that authorizes three destination resort casinos and one slot parlor in the state. Massachusetts is moving forward with the licensing process, which requires potential casino operators to negotiate host community agreements with local officials and to have that agreement ratified by voters in a local referendum. The Town of Plainville, Massachusetts already hosts a harness racing track, which is bidding on the one authorized slot parlor license. To assist it in negotiating the host community agreement, the Town of Plainville hired Cummings Associates through a competitive bid process to prepare an analysis that includes "a gravity-model analysis of the likely market for the proposed slot-machine facility at Plainridge" (Cummings, 2013, p. 2).

Cummings Associates (2013, p. 6) states that "this type of analysis is based on 'geography:' where do potential customers live, and how far (or more accurately, how long) do they have to travel to visit any existing or prospective casino that might be convenient for them?" The basic assumption of the gravity model is "that other things being equal, the surrounding population will tend to patronize each facility at rates sin1ilar to those elsewhere" (Ibid., p. 13). In their proposal to the Town of Plainville, Cummings notes that "a description of this methodology and assessment of some of its finer points may be found in several of the papers and PowerPoint presentations I have delivered to several of the International Conferences on Gambling and Risk-Taking," where the principal investigator (2006) has documented that a casino's gravity is "not always according to Reilly."

In an exemplary work submitted as part of the proposal, *Assessment of the Value of A License for a New Casino in Davenport, Iowa* (July 21, 2008), Cummings' (2008, p. 2) concurs with CCA that the "Slot Win/Unit/Day" figure is a common measure of performance in the casino industry, because slot machines typically provide 90%+ of the revenues (and even more of the profits) of most regional casinos." Thus, Cummings (2008, 2) argues that "slot performance is usually the single most revealing measure of such performance." However, Cummings adds another level of sophistication to this measure by developing what he calls a casino's "Power Rating" (i.e., a type of gravity factor), which measures a casino's ability to draw consumer spending from the surrounding population by comparing the number of slot machines at competing facilities and the win per unit per day at competing facilities

(Cummings 2008, Exhibits 6-13). The Cummings (2008, p. 2) Power Rating indicator takes:

> "the spending of the average adult who lives within the market of each casino at its slot machines, and compares it to a benchmark average of $700 per adult per year (who lives within ten miles of that casino, adjusted for distance and competition). A power rating of 100 therefore represents average spending of $700 per adult (again, adjusted for distance and competition)."

Cummings observes that a casino's Power Rating is similar to, but an extension of, the "Fair Share" concept pioneered by Larry Klatzkin and that is now used by many casino analysts. The Fair Share concept is that if a casino has 20% of the slots within a market, but attracts 22% of the slot revenues, it is attracting ll0% of its "fair share" of the market, although Cummings (2008, p. 2 fn. 3) "extends this element of comparison not just with other casinos in the area but also with the size and distribution of the surrounding population." However, despite being a model of transparency, when one examines the tables and exhibits where the Power Ratings are defined, the power ratings tables suggest that table games, hotel rooms, and even attractiveness are components of the power rating, but in fact the Cummings Power Rating is still based entirely on slot machines.

Analysis and Conclusion

There has been almost no academic literature on gravity modeling in the casino industry, although a number of well-established and reputable consulting firms have developed proprietary gravity models, including Economics Research Associates, Spectrum Gaming Group, The Innovation Group, Christiansen Capital Advisors, Wells Gaming Research, Cummings Associates, and many other management and financial consulting firms. In these gravity models, the problem of transparency is at least partially resolved by assuming that these models use some version of the Huff equations, including distance decay factors (i.e., drive times and propensity to gamble), although in some earlier models this was clearly not the case. Moreover, it is clear that greater sophistication has been introduced into these models over time as it became possible to use towns and cities, zip codes, census county divisions, or census blocks as the geographic units for population and income. The geographical units might vary depending on the political jurisdictions in different parts of the country or the availability of prepackaged commercial databases (e.g., Claritas, ESRI), but improvements in data availability, comparative jurisdictions, and access to players club data have no doubt improved the overall reliability of gravity models.

Likewise, official government data on disposable personal income, per capita income, and average household income for these units of analysis has become more easily available as a result of CD-ROMs, the internet, and the commercial repackaging of public data. Spreadsheet programs, a user-friendly Statistical Package for Social Sciences (SPSS), and other statistical software packages, coupled with rapid developments in personal computing power have made it possible to construct gravity models with tens of thousands of individual data points that can be linked together in mathematical formulas. Expectations about spend per visitor and the propensity to gamble are now based on behavioral surveys, proprietary data from comparable existing casinos, data from comparable casino jurisdictions, and proprietary consultant databases constructed through many years of access to casinos' players' clubs and other databases. Consequently, a casino's ability to attract visitations and spending can be reasonably estimated using gravity models, which incorporate data on the number of people living at different distances from an existing or proposed casino. However, we want to suggest that some important modifications to these models could improve their performance and may be necessary going forward in the industry. In this respect, the function and complexity of gravity models in the casino industry has already undergone at least three phases of development, with the most recent phase requiring that we reconsider how to measure the gravity factor – or mass – of casinos.

The first phase of gravity modeling in the casino industry was the period of its greatest expansion (1976-1999), beginning with the opening of casinos in Atlantic City and culminating with the opening of three commercial casinos in Detroit, Michigan. During this phase, casinos were opening in new jurisdictions, often with limited entry restrictions designed to protect new operators, so gravity models were comparatively simple efforts to measure the potential revenue that would be *captured* by casinos, including the percentage of revenues and visitors that would be captured from out-of-state or out-of-region visitors (Eadington, 1995; 1998; Hsu, 1999, Chaps. 5-8; Walker, 2007, Chap. 2-4; Meister, Rand, and Light, 2009).

The second phase of gravity modeling has revolved around later entrants to the expanded gaming movement, including new expansions, such as New York, Pennsylvania, Delaware, Maryland, Massachusetts, Maine, and Ohio (2005 -2012), where gravity modeling has focused more on the ability of local or regional facilities to *recapture* visitors and revenues from adjacent states (Barrow and Borges, 2010; Dense and Barrow, 2003; McGowan, 2009). This has meant that location (distance) and *mass* have become more important to estimating a casino's probability of success in the political terms that now structure expanded gaming debates. It also means that gravity models have become increasingly complex, or confronted with increasing difficulties in measuring the comparative impact of different facilities in increasingly congested market areas. Moreover, as expanded gaming debates have shifted from capturing revenues from adjacent states to recapturing revenues being lost to adjacent states, it has raised an additional question for gravity modelers: What types and size of gaming facilities (i.e., mass) are necessary to effectively compete with existing gaming facilities in adjacent states, particularly if the objective is to generate a new destination as opposed to merely recapturing local convenience gamblers. This has juxtaposed the question of using multiple small convenience facilities taxed at high rates to capture convenience gamblers (e.g., Pennsylvania) against the construction of resort casinos designed to generate new destinations and bolster the larger tourism and hospitality industry (e.g., Massachusetts).

Finally, it appears that gravity modeling is about to enter a third phase of development as expanded gaming reaches maturity, but new market entrants either seek to enter saturated or nearly saturated markets at lower operating margins or they seek to displace existing venues by constructing more elaborate facilities with a higher gravity factor. This debate is already surfacing in a number of U.S. jurisdictions and it means that the problem of measuring "mass" is becoming even more important in the construction of gravity models for the casino industry.

First, Huff models require investigators to have reliable survey data on the propensity to gamble at different distances from a casino, data from comparable facilities (e.g., players club databases), or it requires one to make reasonable assumptions about the distance decay factor, which theoretically declines exponentially at regular distances from a central place (e.g., 30 minutes). However, with the onset of the Great Recession in late 2007, the overall propensity to gamble declined in all of the New England states, as elsewhere in the country, which is directly related to rising unemployment, decreases in disposable personal income, increased savings rates, and declining home values. The general principle of distance decay remained intact during the Great Recession, but the propensity to gamble decreased across-the-board, which for the first time, has forced gravity modelers to recognize that propensity factors are not fixed by time or place, but can shift upwards or downwards significantly depending on the macro-level economy (Barrow and Borges 2007a; 2007b; 2009; 2011; 2013). These assumptions need to be recalibrated, at least for the time being, and in the future it must be recognized that the propensity to gamble will likely be cyclical in nature, especially once a gaming market reaches saturation.

Second, the mass of a retail shopping center was traditionally measured in square feet, but Huff offered persuasive arguments that square footage was really a proxy for the range of merchandise offerings and the range of choices available to consumers. The number and range of retail offerings in the case of casinos is a function of gaming space, gaming positions, and the range of non-gaming amenities. The size of a gaming facility can be measured in square feet of gaming space, or the number of gaming positions, but another significant determinant of mass is also the basis of the distinction between destination resort casinos and convenience gaming facilities, which have significantly different amounts of gravitational force.

A major lacuna in the standard gravity model, as applied to casinos, is that gaming positions are not the only measure of a casino's mass. A resort casino's mass and, therefore, its gravitational force is also a function of its range of games, which typically include table games and poker and it is not clear that one table equals six slot machines, because tables may attract a fundamentally different type of customer (Barrow and Borges, 2013). Thus, the availability of table games and the number of table games needs to be accounted for and weighted separately from slot machines. A casino with table games will necessarily attract a new cohort of players simply because slot parlors do not offer table games so it does not make sense to assume that 60 additional slot machines has the same weight as ten table games in calculating a gravity factor.

Furthermore, many gamblers are seeking an entertainment experience that includes more than just gambling or one that generates a different general atmosphere. Thus, a resort casino's gravity is also a function of its non-gaming amenities. In 2012, for example, the New England Gaming Behavior Survey (Barrow and Borges, 2013) found that 69% of the individuals from Rhode Island, Massachusetts, New Hampshire, and Maine who visited Foxwoods Resort or Mohegan Sun in the previous twelve months did not visit either Twin River or Newport Grand in Rhode Island, despite their closer functional distance to these population centers. Furthermore, the non-gaming component of casino entertainment complexes is becoming increasingly important to a casino's competitiveness. In New England, the percentage of visitors to Foxwoods Resort and Mohegan Sun, who report that they rarely or never gamble has increased from 8% in 2006 to 22% in 2012 (Barrow and Borges, 2007a, p. 15; 2013, p. 12). The American Gaming Association's (2013, pp. 3, 27-28) most recent survey of American gamblers finds that 26% of casino visitors nationwide report that they rarely or never gamble. Thus, it is clear that non-gaming amenities need to be incorporated into the calculation of gravity factors in some manner and to some significant extent. These amenities include parking spaces, hotel rooms, conference and meeting facilities, restaurants and bars, live entertainment venues, dance clubs, spas, RV parks, and golf courses. The authors agree that the exact weighting of non-gaming amenities is a matter for further discussion, but the magnitude of this difference could theoretically shift the breaking point and related probabilistic contours of a casino to a significant degree when assessing competitive impacts on existing facilities.

Finally, the evolution of casinos from gambling parlors to regional entertainment complexes and tourism attractions means that the problem of the tourist factor needs to be addressed in some explicit way. It appears that most gravity modelers, including the authors, when confronted with this problem simply choose a percentage add-on to the base gravity model, such as a 10% or 20% increment to gross gaming revenues. However, a more accurate tourism factor will require better local and regional tourism data (which is often quite sketchy), surveys of the gaming interests of tourists, and analysis of the increasing role of casinos in attracting tourists, conventions, and business travelers.[5]

The claim that gravity models need to incorporate non-gaming amenities when forecasting the potential revenues or competitive impact of new and existing casinos is also grounded in earlier critiques of gravity modeling, such as those by Cox (1959), Bucklin (1967), and Black (1983), who suggest that consumers make choices based on the aggregate utility or aggregate convenience of competing options. Louis P. Bucklin (1967, 37) notes that the earliest gravity models generally used a single variable such as population or retail square footage (or gaming positions) as a proxy for mass, although more recent research on consumer behavior confirms the importance of mass in shifting the consumer's ideal breaking point (DeSarbo, Choi, and Spaulding, 2002) and, therefore, the importance of defining it accurately. William Black (1983, pp. 18-19) has also called on scholars to more precisely specify and measure "the attractiveness component" of retail mass through the use of multiple attractiveness measures, which is what we propose by incorporating table games and non-gaming amenities into casino gravity models. For casinos, these factors may also include physical appearance, cleanliness, safety, luxury, the availability of different games, various types of food and beverage outlets, gaming floor service, employee friendliness, the surrounding vicinity, and brand name. However, a gravity model cannot specify or quantify these factors in any objective manner without additional locally specific research on gambling behavior and this continues to be a limitation of gravity models (Thompson, 1963).

More importantly, however, these limitations have three major implications for public and private decision-makers. First, as the casino market approaches maturity, and even saturation in some jurisdictions, there will continue to be proposals to move casinos closer to population and income centers. These new facilities will negatively impact existing casinos and traditional gravity models will likely understate that negative effect, particularly since the new trend is toward more and more elaborate non-gaming amenities. Thus, there is the potential to understate job losses and tax revenue losses at existing facilities and, thereby, overstate the net economic and fiscal benefits of new casinos in some jurisdictions. Furthermore, new operators entering saturated markets will have a vested interest in understanding their negative impacts on existing facilities to gain approval for their facilities and, hence, there may be pressure on the industry's consultants to retain the standard gravity model even when it is not the most accurate tool for evaluating economic and fiscal impacts.

Another diffculty in evaluating the impact of proposed new facilities in congested markets is that gravity models were originally designed to measure the comparative gravity of two competing regions or facilities. However, as the distance between casinos shrinks in congested and saturated markets, gravity modelers confront the di.culty of evaluating multiple overlapping market areas, which the traditional contour map has difficulty representing and which the standard gravity model has difficulty processing as new exponents overlap with already overlapping exponents. One can simply assign market share to a cluster of facilities based on gravity factors, but this requires more accurate gravity factors and it also evades the problem of the quality of travel networks and location (direction of travel) in selecting a casino.

Second, state gambling policies have been shifting from an emphasis on revenue generation to an emphasis on job creation and this further shifts the emphasis from slot machines to table games and to non-gaming amenities (Barrow, 2012). At the same time, as casino markets become more competitive, and slot machines become a widely available commodity, existing casinos are making the decision internally to add more non-gaming amenities, such as hotels, outlet malls, RV parks, convention centers and meeting space, golf courses, bowling alleys, concert halls, and sporting arenas to differentiate themselves from other gaming venues. These items increase the gravity of existing casinos and, thus, bring more visitors to an existing casino, including more employees. However, as local and state government officials have become more sophisticated in their economic development policies, they are seeking impact fees, infrastructure and public safety mitigation funds, revenue sharing, etc. Once again, casino operators have a vested interested in understanding these impacts by relying on existing gravity models that understate visitations and impacts.

Finally, these considerations could substantially affect policy-makers' decisions on whether to authorize new facilities (both commercial and Indian), the size and type of facilities, and the location of new facilities (i.e., distance and spacing requirements). These issues are already surfacing in many jurisdictions and, consequently, the theoretical limitations of gravity modeling present the industry and its regulators with a practical policy issue that is likely to intensify with time and that will put gravity models at the center of these debates.

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Endnotes

1 The earliest pre-Reilly "gravity models" were pioneered by chain tobacco shops attempting to identify the volume, composition, and quality of pedestrian traffic in different locations to scientifically identify the best and most profitable locations for opening tobacco stores. Oil companies later applied the same research technique to automobile traffic as the basis for identifying sites for gasoline stations (Applebaum 1965, p. 234).

2 For a critical analysis of the empirical evidence used in formulating the Law of Retail Gravitation, see (Schwartz, 1962).

3Mass factors into convenience, because if a slot machine player repeatedly finds that a local casino's gaming devices are occupied, and that there is a long wait time to find a position at their preferred device, they will often be willing to travel a longer distance to a larger facility to insure that a position is available, since the "time to position" (i.e., drive plus wait) is essentially the same or shorter, despite the longer initial drive-time.

4 In a more recent example, Spectrum Gaming Group prepared a 2011 market feasibility analysis which found that three destination resort casinos in South Florida would generate $1 billion in tax revenue for the State of Florida. However, in a more study prepared for the Florida Legislature (2013), it would find that "wide open" gaming – 33 casinos and six destination resorts – would cause the state to lose $22 million a year. When queried about the significant difference in results, the official response was "different assumptions" about tourist visits, with the former study's estimates assuming "a massive marketing plan aimed at Asians" and the promise that one of the casino operators "would hire private planes to ferry customers to the region" (quoted in Kam, 2013; see also, Spectrum Gaming Group, 2013).

5 For an excellent example of this type of work, see, Philadelphia Gaming Advisory Task Force (2005).