Converse's Breaking-Point Model Revised

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ABSTRACT

There are three basic types of trading area analysis models that can be used to assess new store location and trade areas potential: analog, regression, and gravity. Gravity models tend to be popular and primarily include Reilly's Law of Retail Gravitation, Converse's Breaking-Point Model, Huff's Model of Trade Area Attraction and Christaller's Central Place Theory. Arguably the most popular of theses gravity models and methods is Converse's Breaking-Point Model which was based on Reilly's Law of Retail Gravitation which first appeared in 1929 as a research monograph at the University of Texas, Austin and was subsequently widely distributed in book form in 1931.

Of primary research importance is the observation that a literature and textbook review of the application of the Converse Breaking-Point Model produces mixed results in terms of visually confirmable trade area calculations. This may be based on the further observation that the ratio in the formula's denominator should be reversed with corresponding inverse distance and trade area break-point applications. The authors' revision of the widely applied Converse Breaking-Point Model is therefore proposed on the basis of changed retail patterns from the original 1931 derivation of Reilly's Law due to the decentralization of retail shopping areas and greatly improved shopper mobility in more rural and suburban shopping areas. Reilly's original Law of Retail Gravitation is reviewed in addition to the Converse Breaking-Point Model with revised formulae logic and applications identified.

Keywords: Reilly's Law of Retail Gravitation, Converse's Breaking-Point Model, trade areas, gravity models, retail location

TRADE AREA DETEMINATION AND GRAVITY MODELS

A trading area is defined by Bennett (1995) as "a geographical area containing the customers of a particular firm or group of firms for specific goods or services". There are three primary types of trading area models that can be used to analyze store location potential and trading area: analog, regression, and gravity. An Analog Model uses revenues of similar stores in the market area, the competitors' position, the new store's expected market share, and the size and density of the trade area to approximate new store sales. A Regression Model employs a number of mathematical equations to relate potential store sales, as the dependent variable, with a number of independent variables to include population size, average income, the number of households, close competitors, traffic patterns, etc. A Gravity Model is based on the assumption that a certain radius or group of customers within a radius are drawn to stores in a particular area on the basis of variables such as distance to market, distance between markets, relative market population, store image, etc. Gravity Models are so called because they are loosely based on Newton's Law of Gravity and the premise that the probability that a given customer will shop at a particular store or market becomes greater as the size of the store or market increases and the distance or travel time to the store or market decreases.

Gravity Models have had an important place in retail location considerations and literature since the early 1930's. The most common and widely used Gravity Models include Reilly's Law of Retail Gravitation, Converse's revision and Breaking-Point Model, Huff's Model of Trade Area Attraction and Christaller's Central Place Theory. Each model has its own distinct characteristics and applications although these distinct characteristics and applications are not always understood or recognized by retail practitioners and educators. According to Jim Root of Thompson Associates, a leading retail consultant, (Francia, 2002) "I fully agree with David Huff that the terminology used in the industry with respect to the Huff model optimization and other forecasting jargon is incredibly sloppy and sometimes deliberately misleading". A brief discussion of the characteristics and applications of the identified primary gravity models follows.

Reilly's Law of Retail Gravitation (Reilly, 1931) defines the relative ability and probability of two cities to attract customers and therefore trade from a third trade area or intermediate place for non specialty goods. In particular, this ability to attract trade from the intermediate place or trade area is in direct proportion to the populations of the two cities and in inverse proportion to the square of the distances from these two cities to the intermediate town. This relationship is expressed as follows:

$$\left(\frac{Ba}{Bb}\right) = \left(\frac{Pa}{Pb}\right)\left(\frac{Db}{Da}\right)^2 \qquad \text{Where:}$$

Ba = the proportion of the trade from the intermediate city attracted by city a
Bb = the proportion of the trade from the intermediate city attracted by city b
Pa = the population of city a
Pb = the population of city b
Da = the distance from the intermediate town to city a
Db = the distance from the intermediate town to city b

Converse's revision of Reilly's Law (Converse, 1949), known as the Breaking-Point Model, extended Reilly's Law by defining the breaking-point of trade between two cities. A customer residing at the location of this trade breaking-point would be indifferent to trade area and have an equal or 50% probability of shopping at each of the two cities in question for non specialty goods. In particular, this ability to attract trade between the two cities or trade areas is in direct proportion to the square root of the populations of the two cities and in inverse proportion to the distance between these two cities. This relationship is expressed as follows:

$$Da{\rightarrow}b = \frac{d}{1+\sqrt{\dfrac{Pb}{Pa}}} \qquad \text{Where:}$$

$Da{\rightarrow}b$ = the breaking-point from city a measured in miles to city b
d = the distance between city a and city b. Travel time may be substituted for distance.
Pb = the Population of city b
Pa = the Population of city a

Huff's Model of Trade Area Attraction (Huff, 1964) is used to determine the probability that a customer residing in a particular trade area will shop at a particular store or shopping center. To forecast sales from a particular trade area, the trade area's population times an estimate of expenditures per customer is multiplied by this probability. Finally, all of the calculated trade areas sales forecasts are aggregated to estimate total sales from all of the areas. As with other gravity models, the ability of a shopping center to attract customers is in direct proportion to the size of the shopping center (relative to competing shopping centers) and in inverse proportion to the distance or travel time to the shopping center (relative to competing shopping centers). According to Francica (2002), "The Huff model is widely regarded as the industry standard for determining the probability of a retail location to attract customers". The relationship is expressed as follows:

$$Pij = \frac{Sj \div Tij^{b}}{\sum_{j=1}^{n} Sj \div Tij^{b}} \qquad \text{Where:}$$

Pij = the probability of a customer at a given point of origin i traveling to a particular shopping center j.
Sj = the size of shopping center j in square feet
Tij = the travel time or distance from the customer's point of origin to a particular shopping center
b = the exponent to Tij that reflects the effect of travel time on different kinds of shopping trips

Relative to the Huff Model calculation, the larger the value of *b*, the greater the effect of travel time or distance on the probability that a customer will shop at a given center. A larger value of b should therefore be assigned to a shopping center offering convenience goods than to a shopping center offering shopping or specialty goods. As such, the Huff Model is highly product specific and yields different trade areas and sales forecasts based on different product categories. When a product is of great value to a customer, all locations become equally attractive. This "inertia-distance factor" or *b* is usually determined through surveys of shopping patterns or from previous experience and generally ranges from four to one. The estimated nature of this "inertia-distance factor", which is also present in the Reilly and Converse models, is important as a subjective trade area model driver and will be further discussed in following sections.

Christaller's Central Place Theory (Christaller, 1935) was developed in Germany only a few years after Reilly's original formulae work with a "central place" being defined as a center of retailing activity such as a town or city. The theory identified a hierarchy of central places relative to the assortment of goods available. As such, a village would be at the bottom of the hierarchy based on a relatively small assortment of goods while a large city would be ranked at the top of the hierarchy due to its large assortment of goods and the greater opportunity for one stop shopping. Correspondingly, people were identified as traveling longer distances to shop in large cities with a large assortment of goods. Like all gravity models, the theory uses the size of retail business activity and distance from consumers in a non-formulae sense as the two critical metrics for determining retail locations and trade areas. Christaller identified the "natural" shape of trade areas, in the absence of natural boundaries, to approximate a hexagonal pattern to eliminate adjacent trade area "gaps" produced under circular trade area assumptions. Hexagonal trade areas also produced secondary trade areas identified at the "nodes" or conjunction of adjacent hexagonal trade area patterns. The related and equilibrating concepts of 'Threshold" as the minimum demand necessary to support a particular retail store type and "Range" as the maximum distance a customer will travel to a particular retail store type were additionally introduced by Christaller and are used extensively today in retail location terminology, analysis, and practice.

REILLY'S LAW AND THE CONVERSE REVISION

Reilly's seminal work and original publication in 1931of "The Law of Retail Gravitation" was an extension of a differently titled monograph, "Methods for the Study of Retail Relationships", produced at the University of Texas for the Bureau of Business Research in 1929 (Reilly, 1929), which was further based on unpublished work by Reilly beginning in 1927. The organization of the 1931 publication consists of two primary sections; the first section being data tables and applications of Reilly's Law and the second section as an appendix to include formulae derivation and explanation for the more mathematically inclined (or skeptical). A number of major principles gleaned from a review of the original 1931 published work can be summarized as follows:

1. Reilly offers his law and previously stated equation as "…merely a summarized statement of existing conditions" (Reilly, 1931, p.6).
2. Reilly's Law was derived and based on the use of 1930 Census of Population data with the predictive value confirmed through the use of "personal investigation".
3. Reilly's Law recognizes the principle of "agglomeration" in which consumers often seek multipurpose and comparison-shopping opportunities and may travel farther to obtain a better price, better image, or better merchandise selection.
4. The observed rate at which outside trade is drawn by a city increases with the population of that city on a linear basis. As such, the exponent in the formulae population component (Pa/Pb) is one.
5. The observed rate at which business is drawn by a city in the surrounding territory decreases faster than the distance from the city increases by an exponential factor range of 1.5 to 2.5. As such, the exponent in the formulae distance component (Db/Da) is estimated as two, representing the closest whole number average.
6. At the breaking-point in trade between two cities, the business drawn by City A is equal to the business drawn by City B. As such, the formulae business component (Ba/Bb) is equal to one at any break-point in trade.
7. Through the use of Reilly's Law, a retailer or researcher "…can determine the breaking points between his city and competing cities on all sides and thereby construct his natural trade territory in which his store enjoys an advantageous position in competition with similar competing stores in adjacent cities" (Reilly, 1931, p.36).
8. Through the use of Reilly's Law, a retailer can compare the calculated trade area with known media geographic circulation or coverage to provide improved trade area and media usage congruence.
9. Each trade area represents an individual case with characteristic differences. As such the primary trade area factors of population and distance may be mitigated by secondary trade area factors to include transportation, communication, social class, population density, proximity to larger markets, selection and quality of retail structure, trade area amusements, parking, the nature of competition, topography and climate, etc.

The Converse revision of Reilly's Law of Retail Gravitation is initially credited to a formula derived at the University of Illinois with "author" unknown (Converse, 1949). As per Reilly's observation in above item number five (5), setting the business component (Ba/Bb) equal to one and algebraically solving for distance was used to derive the revised formula. Review of the prior stated Converse Breaking-Point formulae mathematically illustrates an equidistant trade area and breaking-point calculation when the population of adjacent cities are equal. The concept of an "inertia-distance factor" was popularized by Converse to reflect "…the inertia that must be overcome to visit a store even a block away" (Converse, 1949, pp. 381-382) and further established these trading area models as "gravity models". The majority of the classic Converse paper was dedicated to the calculation of four additional formulae by revising inertia-distance factors associated with significantly different sized and compared trade areas based on central Illinois shopping survey data. A number of major principles from a review of

Converse's original 1949 published work can also be gleaned and summarized as follows:

1. Reilly's Law of Retail Gravitation and the Converse Breaking-Point Model were formulated to apply to fashion and shopping goods but may be applied to other types of products within limits.
2. Reilly's Law of Retail Gravitation and the Converse Breaking-Point Model were derived to determine a town's "normal" trade area and how trade "should" be divided between two trading centers. Actual trade areas may then differ on the basis of varying market and trade area factors as identified in above item number nine (9).
3. Reilly's Law of Retail Gravitation and the Converse Breaking-Point Model predict the normal allocation of trade with a relatively high degree of accuracy when one city is no more than twenty (20) times the population of the other city. When the largest city has a population fifty (50) times or more than the small city, the formulae gives too much weight to population and are therefore unreliable.
4. Reilly's Law of Retail Gravitation and the Converse Breaking-Point Model predict larger trading areas for larger cities, which may not necessarily be the case. Decentralization of urban trading areas, new retail models and increased mobility in rural areas may serve to reverse traditional and actual trade area dominance based on population.

CONVERSE'S BREAKING-POINT MODEL APPLICATION REVIEW

A review of current and past popular retailing textbook inclusion of Reilly's Law of Retail Gravitation and Converse's Breaking-Point Model revealed wide variance in formulae presentation, understanding, and success in application.

Of particular note and relatively early, the Mason and Mayer (1990) retailing textbook correctly identified the Converse Breaking-Point formulae as an extension of Reilly's Law of Retail Gravitation and formula although the population ratio in the denominator was represented as (Pa/Pb) and therefore inverted from the original Converse formula. This formula was used to determine the break-point between two fictitious cities with a resulting "inversion" of the historic break-point distance calculated between the two cities. As such, the larger city was expressed as having a smaller trade area and distance break-point. This formulae and interpretive inversion did not appear to be a typographical error in that significant justification for smaller trade areas for larger cities was offered as follows (Mason and Mayer, 1990, p. 681):

1. "Reilly's law works satisfactorily in rural areas where distance has a major impact on consumer choice".
2. "Breaking-points do not exist in metropolitan areas because consumers typically have a number of shopping choices available within the maximum distance which they are willing to travel".
3. "In essence then, Reilly's law states that the size of a trading area increases as population density decreases".

The argument was thus made that consumers may travel several miles to shop at a small rural village but would be willing or have to travel only a few blocks in a major metropolitan area due to urban concentration and higher retail land use.

A review of academic article discussion of Reilly's Law of Retail Gravitation and Converse's Breaking-Point Model also reveals limited current discussion and wide variance in formulae presentation, understanding and success in application as follows:

An early study by Douglas (1949) used Reilly's Law of Retail Gravitation compared with four other methods of trade area analysis (credit records, bank deposits, traffic flow, and population) to measure retail trading areas of Charlotte, North Carolina. Results indicated that Reilly's Law provided a "remarkably accurate delineation of the Charlotte retail trading area, as judged by other methods." (p. 487).

However, a later study by Jung (1959) of the breakpoint in trade between the cities of Kansas City, St. Louis, and Columbus, Missouri using the original Converse formulae produced contrary or inverted results relative to predicted trade area patterns and that reported by shopper survey. Differences in media habits by city were offered as a potential explanation for the unexpected trade area pattern inversion.

An additional study by Wagner (1974) of the breakpoint in trade between the cities of Springfield and Columbus, Missouri, also using the original Converse formulae, further produced mixed results in terms of accuracy and varied greatly by type of good studied and level or size of city studied.. According to Wagner (1974, p.31) "A breaking point is more easily determined in rural areas between large cities because distance is the most important factor affecting one's choice due to the increased cost and time required in traveling to a center. As the level of city increases, population density increases, and the accuracy of the breaking point diminishes". In particular, the original breaking-point formula derived from Reilly's Law was identified as inaccurate based on factors such as relative cost of travel, relative travel time, and travel convenience.

As a result of these conflicting research results, Rogers (2003) has necessarily indicated that some retailers are calling for modified gravity models based on changing retailing demands and uncertain results in formulae application.

INVERTED CONVERSE'S BREAKING-POINT MODEL APPLICATION

The identified Mason and Mayer (1990) inversion of the Converse Breaking-Point formula and agglomeration concept may provide an opportunity for gravity theory revision and improved Converse Model application. Given the identified retailing textbook variance in the presentation and application of Converse's Breaking-Point formulae and the mixed results of the applications of Converse's Breaking-Point formulae in the literature, a revised and inverted application of the Converse equation and Reilly's basic break-point assumptions may be in order.

Just as Reilly's original law and formulae were "…merely a summarized statement of existing conditions" (Reilly, 1931, p.6) and confirmed through the use of "personal investigation", some reinterpretation may be possible or even necessary for the current retailing environment. It can be argued that the "existing conditions" from which the Reilly and Converse formulae were derived have changed substantially and reflect consumer retailing, shopping, choice, and mobility factors peculiar to the late 1920's and early 1930's that no longer currently exist or apply. Although the Reilly and Converse assertion that "the ability to attract trade between two cities or trade areas is in direct proportion to the square root of the populations of two cities and in inverse proportion to the distance between these two cities" is pleasing and well accepted in retailing theory and texts, it may be equally intuitively pleasing to also assert that "the size of a trading area increases as population density decreases" reflecting urban concentration and reduced travel distance and time requirements.

According to Dunne and Lusch (1999), Reilly's Law and Converse's revision rest on two primary assumptions as follows (p.232):

1. The two competing cities are equally accessible from the major road.
2. Population is a good indicator of the differences in the goods and services available in different cities.

As additionally stated relative to population, it is probably truer that "consumers are attracted to the larger population center, not because of the city's size, but because of the larger amount of store facilities and product assortment available, thereby making the increased travel time worthwhile". However, the increased availability of product assortment in more rural areas to include the expansion of Wal-Mart locations and superstores, rural factory outlet stores, increased cable television shopping channels, and increased broadband internet shopping activity may all serve to reduce the worthwhile nature of increased travel time to larger population centers. Revision of some of Reilly' Law of Retail Gravitation assumptions should also allow the revision of the Converse Breaking-Point Model equation to the revised or inverted Breaking-Point Model as follows:

$$D_{a \to b} = \frac{d}{1 + \sqrt{\frac{Pa}{Pb}}}$$ Where:

$D_{a \to b}$ = the breaking-point from city a measured in miles to city b
d = the distance between city a and city b
Pa = the Population of city a
Pb = the Population of city b

A simple inversion of the population ratio to (Pa/Pb) under the radical in the Converse formula denominator preserves the basic use function and non linear nature of the Converse Breaking-Point Model while inverting the relative population "gravity" or "agglomeration" effect to reflect the identified changed nature of more modern retailing methods and current shopping realities.

Initial empirical testing and application of the "Inverted" Converse Breaking-Point Model and formula has produced more useful and readily identifiable trade area delineations and break-points in numerous Tennessee city calculations. As a convenient and locally verifiable example, application of the "Inverted" Converse Breaking-Point Model produces the following break-point calculations between Clarksville and Nashville, Tennessee:

$$D_{a \to b} = 31 = \frac{45}{1 + \sqrt{\frac{130,000}{580,000}}} \qquad \text{Where:}$$

Da→b = the breaking-point from Clarksville measured in miles to Nashville = 31
d = the distance between downtown Clarksville and Nashville = 45 miles
Pa = the Population of Clarksville = 130,000
Pb = the Population of city Nashville = 580,000

The calculated 31 mile trade radius and break-point from Clarksville to Nashville along the I-24 “corridor” and Interstate is visually confirmed and identified as mile marker exit 31 and the beginning of Davidson County and Metro Nashville. Local application of the original Converse formulae on a non-inverted basis would estimate the trade radius and breakpoint from Clarksville to Nashville at 14 miles or between I-24 exit mile markers of 11 and 19 with no identifiable or logical basis in fact of existing retail trade patterns. Similar local trade area calculations between Clarksville and the adjacent Tennessee cities of Dover, Dickson, Springfield and Hopkinsville, KY using the “Inverted” Converse Breaking-Point Model formulae produce the same visually verifiable and logical trade area break-points in a basic hexagonal pattern as further predicted by Christaller. Further model application and data analysis on an expanded basis is identified as necessary to more fully establish the validity and usefulness of the proposed revised Converse Breaking-Point Model.

SUMMARY AND IMPLICATIONS

The initially identified four primary gravity models differ distinctly in textbooks and literature reviews in terms of interpretation and their intended application and use as follows:

1. Reilly’s Law of Retail Gravitation and formula defines the probability of two cities to attract retail trade from a third intermediate trade area.
2. Converse’s Breaking-Point Model and formula defines the 50% shopping probability or breaking-point in trade between two cities in miles or travel time.
3. Huff’s Model of Trade Area Attractiveness and formula defines the probability that a customer residing in a particular area will shop at a particular store or shopping center. The customer’s trade area population multiplied by an estimate of expenditures per customer further multiplied by Huff’s calculated probability can be used to estimate sales from this area.
4. Christaller’s Central Place Theory defines a hierarchy of “central places” and retail location theory relative to hexagonal trading areas, “Threshold” and “Range” in non-mathematical terms.

The suggested revision and denominator inversion of the Converse Breaking-Point Model formula is made with great sobriety. As with many discoveries, theories, and models, the proposed “Inverted” Converse Breaking-Point Model was identified quite by accident through multiple retailing textbook reviews and resulting limited and local application results over time. The identified assumptions and restrictions on the current use of the historic Reilly's Law and Converse's Breaking-Point Model are numerous. The proposed inversion of the Converse Breaking-Point Model and formula suggests that the classic primary trade area factors of population and distance are currently mitigated by emerging retail trade area factors to include transportation, communication, social class, population density, proximity to larger markets, selection and quality of retail structure, trade area amusements, parking, the nature of competition, topography and climate, as further initially recognized and stated by Reilly. As such, the proposed revision of the historic Converse Breaking-Point Model is considered by the authors' to be systematically integrated into the existing body of retail trade area knowledge and theory with an identified need for further and extensive empirical testing of the proposed model's revision and usefulness.

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