Spatial Consumer Flow Analysis and Product Placement Intelligence: Machine Learning Approaches to Retail Store Layout Optimisation

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1. Introduction to Retail Store Layout Optimization

Retail store layout optimization promises strategic value in ensuring an effective shopping environment. Store layouts can account for patterns of human behavior that manifest in consumer purchasing behaviors. The field of retail store layout has traditionally been dominated by intuition-based decisions. However, new technologies are reshaping how retail is conducted. New technology is providing new avenues of approach to help businesses influence consumer behavior. Artificial intelligence, artificial neural networks, and convolutional neural networks are some of the tools that can aid in optimizing retail store layout. This essay will evaluate the methods for retail store layout optimization using artificial intelligence. For a concise study, the primary retail store layout interest is concerning grocery supermarkets.

The objective of this paper is to identify the impact of store layouts on operational efficiency in retail stores. This essay also aims to determine whether artificial intelligence in designing store layouts can strategically help retailers. Store layout optimization is an important operational process for many retailers, offering benefits for both the retailer and consumers. Store layouts can have various components, such as sensory space, diagonal dimension, vertical dimension, flooring, shelves, and other components affecting shopping behaviors. When consumers are unable to make use of a retail store's layout, it may cause confusion or frustration. The frustration may lead individual consumers to see the shopping experience as less satisfying or pleasurable. While working under the layout, if consumers do not know why or what part of the layout is causing ambiguities, it results in confusion or lower satisfaction. When 'effort' is required for shoppers to navigate around the retail floor, it will cause the shoppers to be

less satisfied with their shopping experience. Requirements for shoppers to maneuver around the store to search for departments or goods may also cause shoppers to feel fatigued, which can negatively affect their satisfaction with their shopping experience. The process of helping shoppers to more easily navigate around a retail store layout is store layout optimization. Do retailers make the best use of their layout? The implementation of store layout optimization is limited within the retail industry. The retail industry is a mature industry challenged by high competition and slim profit margins. Efforts that lead to cost savings without sacrificing performance are therefore attractive. The cost savings can then be concentrated and used on the enhancement of other retail operational components. Challenges faced when implementing layout optimization in supermarkets are cultural, legal, and policy barriers. An action plan for scaling up and expanding is formed to offer the next level layout optimization tool for retailers. Therefore, there are ample justifications to look into this area within the retail industry to better inform operational decisions at the top management and store level.

1.1. Importance of Store Layouts in Retail

Store layouts carry a large amount of significance in the retail world today. Creating an outstanding store design requires an understanding of how customers move through a new environment, what they buy, and how they interact with fellow customers. The customer decision process can be influenced by location, layout, placement of the display, and even the way products are grouped within a complete assortment. 3D store models play a crucial role in planning an effective merchandising strategy that will improve the overall sales performance of a retail location.

Several features of a store's layout can be used to influence the customer's experience. Visual merchandising can have a significant impact on store-brand associations, and it is predicted to continue carrying more importance as consumers are increasingly relying on a product's appearance and visual appeal to help inform a purchasing decision. A survey among design studios revealed that retailers can expect a rise in store traffic from a comprehensive layout overhaul. Stores have already successfully implemented innovative layout designs to increase conversion rates by emotional design or dimensional merchandising. Numerous mistakes pertaining to store layout design can be addressed. These include technical pitfalls such as the overuse of smells and noise, failing to use space efficiently, and misusing customer time. Dynamic elements of a store

can impact store reputation and the customer decision process. Some features are static and difficult to change often, such as the location of the store and the overall architecture of the store. Technological advancements change frequently and impact stores aesthetically.

2. Machine Learning Techniques for Retail Store Layout Optimization

In retail settings, we can use a few machine learning techniques to optimize store layouts. For example, customer buying behavior can include explorative and exploitative patterns and be represented using reinforcement learning algorithms. Instead of treating the layout plans as graphs, a Bayesian model can be used to analyze the sales space potential of an assortment of outlet shapes and sizes. The analytical results of these simulations present actionable insights for planners. Criteria developed by retailers can also be incorporated into traditional models; for example, there are extensive studies using genetic algorithms that can be applied to retail store formats.

Nowadays, a large amount of new and valuable data is generated daily in business establishments. We have more data than ever before and less certainty about the profound impact it will have on our business. There are numerous machine learning approaches used for retail layout optimization, such as negative binomial, Poisson, per store estimator, top-down machine learning, a neural network, and boost approach. It is very important that the outcomes of machine learning algorithms are aligned with the overall business objectives of an organization. One potential challenge of implementing these machine learning techniques in traditional retail environments is that they may need to be adapted for each new retail concept.

The popularity of testing various retail layout strategies in offline environments is slowly declining relative to those that are dynamic. With the increasing challenge of efficient deep learning, physical retail real estate optimization analytics should become more common for retailers who are serious about using data to drive business decisions. In an increasingly competitive and dynamic market, retailers must wisely allocate their floor space because there can be limited flexibility to make changes in the future.

2.1. Data Collection and Preprocessing

Data Collection and Preprocessing. The success of any machine learning technique used in the application of retail layout analysis depends on the quality and integrity of the

relevant dataset to the retail environment. The actual data source for this application can be varied and consist of a mixture of different datasets. Retail layout analytics needs to output a layout that optimizes a certain thing or set of things that the adopting retailer is particularly interested in. These could be store sales, the sales floor space ratio, or net profit generated by every plot on the design. Thus, triangulating between different datasets is not only desirable but preferable: in the extensive diversity of possible data sources deployed in this kind of optimization, it is probable that some datasets will be more readily available in other settings, making improved performance a likely outcome.

Data Preprocessing. Regardless of the data source, there exist several stages in the data preprocessing pipeline that are common to almost all machine learning scenarios. Firstly, the raw data will need to be cleaned so that it is in a usable format for analysis. Secondly, data typically need to be transformed in a way that makes it amenable to a model, in terms of the data's dimensionality and data type. Lastly, visualization of data and patterns can both inform and validate the data preprocessing pipeline. Using machine learning approaches to optimize store layout is particularly challenging if retailers' data quality comprises duplicated data points, inconsistencies, and incorrect vocabulary. Data point resolution techniques will be used to clean data where such anomalies are observed. Data privacy and ethical implications are discussed to illustrate respect for customers' data and consider the reasons why retailers may only have partial data available. It is important to note that retailer accessibility to detailed data may be limited, and the best exact knowledge that the retailer has of its customer is the overall footfall and weekly sales data. This scenario and the teachings from retail literature underline that the model built must generalize in the absence of comprehensive customer purchase data. Data collection decisions are discussed.

3. Enhancing In-Store Customer Experience

In addition to maximizing profitability, many retailers are also concerned with making sure that the experience while in their store is a positive one for customers. One way to accomplish this is by optimizing store layouts, effectively leading customers through the store as they explore the various products. This process typically starts by modeling how a particular layout influences the way customers move around the store. How close are they willing to get to other people? Do they get hot or cold when they are inside? Do

they enjoy exploration and adventure in an environment, or would they be more comfortable on a set path? These models usually result in some type of metric that describes the predicted behavior of customers in the store, such as sales density. Changes to the layout are then made based on these metrics. The process of evaluating a new layout can be simplified by using a variety of different metrics to represent specific pieces of the customer experience. A few of the more common ones include sales, engagement with products, and path lengths.

Having an engaging shopping environment will make your store stand out in the customer's mind and help to promote customer loyalty. Depending on the business, there are a variety of customer experience metrics that can be used to gauge how well a store is fulfilling the customer experience of a particular layout. These metrics include customer traffic, path length, and engagement with products. Another way to increase the customer satisfaction potential of a layout recommendation is to ensure that employees are trained properly and can articulate a knowledge of the business and products. A well-informed employee can complement a well-optimized layout. In the next section, we discuss customer journey mapping as a new framework to evaluate every customer interaction from pre-transactional to post-transactional. Further, using the retail domain, we discuss how different elements related to transactional journeys can be characterized or evaluated. It is important to note that the layout of the store or the ambiance in the store is one of the influencing factors for a transactional customer journey. Intuitively, if a customer can easily locate the product category or the product itself in the store, they can have an engaging experience as a whole. In the future, the domain could incorporate more of the journey mapping area into the evaluation. However, a further step in this area could be to collaborate with enterprises that offer services combining the entire cycle. It is believed that a very strong correlation exists between the retail optimization process and customer satisfaction metrics based on the customer interaction evaluation.

3.1. Personalized Recommendations and Targeted Advertising

Recommender systems analyze a user's behavior and preferences to provide intuitive suggestions in real time. Similarly, an AI-based system in a retail store suggests products and services based on the shopper's buying behavior and choices. The apt suggestion of products creates a shopping experience, which are the things that customers find

relevant to them in a plethora of shopping arcs in an offline store, where digital touchpoints result in web users. When stores introduce deep consumer personalization, they observe a seven to ten percent increase in sales, double-digit increments in consumer valuation, and substantial savings in the retail industry supply chain. In brick-and-mortar shops, an AI marketing system might improve attention at the point of purchase, increase the popularity of the product, and produce a higher likelihood of conversion.

A lot has to do with creating experiences that reflect understanding preferences and what they expect from a retailer. However, the business-to-consumer digital sales sector traditionally leverages third-party targeting and digital marketing applications that gather data on our behaviors, from web analytics and publishing to purchasing a display, search, or social media ad. Between the ideal personal experience and ensuring confidentiality, retailers must also find the proper balance. In the retail store, careful visual arrangement can encourage customers to explore similar products and maybe add complimentary choices to their basket. It aids in rendering the layout of the store an integral feature of marketing and hence results in supply chain ripple impacts.

4. Maximizing Sales through AI

AI's transformative role in layout strategies and overall retail profitability is the focus of this section. In creating an optimal store layout that generates the highest sales, businesses are continually exploring new methods to revolutionize consumer buying habits. One sophisticated possibility for AI is to identify high-potential areas within the store to position a sale-pushing product, such as strategic eye-level placements or other strategic hot sales spots on the floor. Moreover, the integration of sales data with traffic data can help further analyze and explain purchasing habits. The potential value of integrating sales purchase data with traffic patterns in a retail store is crucial.

Beyond sales-maximizing strategies, AI can help identify successful health-promoting layout strategies. Some cautions arise as stores look into utilizing this technology. How much automation should be involved? Human intuition still plays an essential role in understanding retail operational needs, such as seasonal cycles and local preferences. Moreover, although the connection between store layout and spend is clear, any data is only as effective as its insights and solutions. At some point, it is prudent to revisit the connection to directly analyze store revenues. Consequently, it is clear that AI can aid in

store operations, particularly in improving the customer shopping experience, but it is not alone capable of increasing store revenue. Understanding the true relationship between store layout strategies and profitability is the correct next step.

4.1. Dynamic Pricing Strategies

4.1. Dynamic Pricing Strategies: AI Consumer and Pricing Models for Retail Optimization

Dynamic pricing is a method in which a retailer seeks to optimize the sale of products by artificially adjusting the price in real time based on different types of inputs, such as competition, stock levels, and historical data on consumer behavior. Adaptive pricing is thus often associated with consumer behavior studies, and it seeks to increase sales volume and profitability because it adjusts prices. As a tool for a company, a dynamic pricing strategy can lead to different customer perceptions of the brand and may also enable the adaptation of floor plans as a greater volume of sales occurs at different price markups. Responsive or dynamic pricing procedures produce a different effect on customer loyalty and spending levels, depending on whether a patient is informed about the pricing strategies. Certainly, dynamic pricing to create a personalized experience seeks to trace linkages from loyalty programs to pricing promotions by consumer segment.

Firms that employ adaptive flooring in response to reward programs will also resort to dynamic pricing schemes that are based on real-time statistics about busy floors in order to change the number of employees on duty when buyers are predicted to show. Different companies and industry retailers depend on pricing models for various reasons. For instance, some retailers employ dynamic pricing to adjust prices based on algorithms that understand demand and supply, and they can adapt prices based on costs, competitors' prices, demand, and sales. In other instances, online retailers set prices of e-books between certain price ranges, and the newest arrivals approach the top price.

5. Case Studies and Practical Applications

5.1. C&A

Retail chain C&A implemented ESL, cameras, and Wi-Fi tracking with an AI module to recommend outfit combinations and close clothing packages. They conducted a proof of

concept of the recommendation engine in the summer to winter clothes swap. The main challenge was related to the difference between the seasons in training data and evaluation data. They anticipated that they could use the same trained recommendation engine for sales but decided to pilot first. The results included data from the proof of concept, showing a sales lift of a factor of three for close sales. By mid-2019, the personalized recommendation engine was implemented in five stores. Results will be published after the pilot phase.

5.2. Carrefour

Carrefour has been conducting AI experiments on different company levels, geographies, and experimentation domains. One experiment took place in a convenience store format, Carrefour City, located in Paris and one of the Carrefour stores in the Paris region. The experiment took place over two months in 2018, and the overall goal was to improve customer insights and increase in-store conversion. By using the Wi-Fi infrastructure in their store, Carrefour tracked the movement of clients and collected interactions with the AI digital host to identify customers' real needs. Transforming these needs into simple and actionable tips, they tested the relevance of these messages in their daily customer journey and their real impact on their journey. The digital host was run on a device located at the entrance door, outside of the store. The tool, in addition to stopping the connections of passers-by to avoid Wi-Fi saturation, collected a lot of data. All data were anonymized and dated for GDPR purposes.

5.3. REWE

REWE is a business group based in Germany with a turnover of 61 billion euros. Acting as a large supermarket chain, REWE, one of the business group's supermarkets, conducted a study with customers in their Biallos store, located in Cologne. They implemented a study with approximately customers, presented through observations. This concept study compares the behavior of customers directly in front of the fruit and vegetable department. Motivated by a virtual store shelf that curves into the salesroom, the experiment makes use of two shelf lengths – one for fruits and one for potatoes – as well as the presence of a potato chip assortment. Evidence supports wider, rectangular, or bending shapes to optimize department sales floor utilization by rewarding longer visits. At the time of the data collection, the data from the experiment had been collected

and were being analyzed to take into account the environmental visits. Results will be published later.

5.4. Consumer Goods Manufacturing Company

A consumer goods manufacturing company asked an AI company how they could use AI to gain insight into opportunities to optimize customer interaction in their retail stores. The company was supplied with Wi-Fi tracking data from retail stores for a three-month period, with observation points on all the main aisles in the stores. The company was further given anonymized transactional data on the same stores, inventory levels, and product attribute characteristics for all the products in the stores. A multitude of studies and analyses have now taken place, focusing on different retail store key performance indicators. Optimal store layout studies include mapping customer journeys, facilitating in-store decision-making in product and store layout selection, and classifying which areas of the store are visited and which areas are not. Results will be published in the near future. Throughout the process, the amount of data being used was gradually reduced in order to increase the scalability of the final solution.

5.1. Successful Implementations in Major Retail Chains

It experienced several successful implementations by major retailers. Both retailers claimed an increase in foot traffic, but the technology itself was not considered a success and was dropped. Since then, the situation has changed dramatically. Both retailers did not have collaboration between departments, while the physical store department and the marketing unit tried to bring people from certain categories to others and implemented a similar strategy. Following the entry of a new specialist to lead these projects, both retailers changed their approach to providing this functionality as a service, instead of employing the retailer itself based on a highly efficient and adaptable algorithm to scan seasonal changes, returns, and the pound as they occur. Over time, a few more players adopted an insight-oriented, store-optimized page driving AI solution and gained a significant number of stores, units, and vertical assets, making them profitable in the space.

6. Future Direction

As more advanced technologies and different types of data become applicable, several trends are emerging that will have a large impact on the strategies of retailers and the implementation of AI in retail store layout optimization. 1. Human-centered technology A key future direction in retail layout optimization is the integration of incoming flows of customer behavior data and store design. Right now, this has already gained a foothold as customer queue management, but complete, automated feedback and an AI that learns and adapts will not only help optimize layouts; it is expected they will lead to setting up stores optimized for customers and their behavior. Products that need to be discovered will be placed in the back in such a manner that it creates a distinct and pleasurable walk through the store, optimizing for duplex interaction and some expected purchases. This may no longer be a walk in alphabetical or thematic order. 2. Automation Though most organizations are in a relatively early stage in the development of their customer behavior analytics, results show a lot of promise. As evidenced in retail management, this is typically a sign of what will come within the next decade. Some early implementation can already be seen with low-skilled and inexpensive employees executing model-driven, cognitive service automations, planting the seeds for future revenue streams utilizing these technologies.

7. Conclusion

For hundreds of years, strategic retail store layouts that lure shoppers in, encourage them to circulate through, and maneuver them to the register have been presented and scaled in published store optimization papers. Since sales in-store are dramatically affected by layout design, the integration of artificial intelligence is considered of greater importance than using an established sequenced layout from previous studies. AI optimizes layouts more effectively and efficiently than any retail human lead. The successful application of AI in the retail industry is showcased. The creation and management of strategic retail store layouts are pivotal to creating value. The continuous improvement of the design of these layouts is crucial for the retail industry. The first two studies skillfully implement machine learning technology in the retail industry to increase sales. The first study applies machine learning and neurophysiological measures to evaluate individuals' explicit and implicit responses to commercial goods exposed to varying interior pieces of design. The spatial layout has a huge impact on sales, considering a significant percentage of sales happen in the major

areas of the store. Research in sociology and psychology has shown that non-intrusive retail store environments contribute to increased customer satisfaction and, therefore, encourage positive behavioral implications that contribute to revenue progress. Later, machine learning was applied in the retail sector and a study on sales forecasting was written. The experimental test of this research performed in real stores demonstrates that employing non-intrusive AI for customer tracking improves sales forecasting, revenue planning, and store labor management.