Determining Shelve Placement in a Chain Store for Optimal Customer Interaction

by

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Declaration

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Date: ....March 2017...........

Abstract

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Pedestrian interactions in any setting have a large impact on the pedestrians in this setting. The field of research behind these pedestrian interactions is rather young, with little research done on pedestrian interactions in a specific store. This study investigates two case studies in specific stores, in which the area covered by pedestrian foot traffic is attempted to be minimized. For each case study, there are three scenarios presented. The first scenario is the store as it currently is, the second scenario is how the pedestrian traffic would change if the amount of pedestrians that enter the store should double. The final scenario is how the pedestrian traffic would change if the layout of the shelves, and the placement of the products on the shelves should change from the layout in scenario one. The layout is changed by moving the shelves around the high pedestrian traffic areas in scenario one. The investigation of the case studies is done by gathering and analysing data, and placing all the pedestrians in different customer segments, to create a realistic simulation model in Pedestrian Dynamics. It is determined how many simulation runs are necessary to obtain statistically significant results, and the simulations are run for this number of runs. The area of high pedestrian densities is measured, and the average over all of the simulation runs is taken, to have a single value to compare to the other scenarios. All of the values for the three scenarios is then taken into comparison with one another, and the results of the simulations are discussed.

Uittreksel

Die Plasing van Rakke in 'n Kettingwinkel vir Optimale Kliënte Interaksie

("Determining Shelve Placement in a Chain Store for Optimal Customer Interaction")

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Die interaksie tussen voetgangers het 'n groot impak op die voetgangers in die omgewing. Die navorsingsveld agter die voetganger interaksies is 'n redelike jong veld, met min navorsing wat reeds gehandel het oor die voetganger interaksies in 'n spesifieke winkel. Hierdie studie ondersoek twee gevalle studies, elkeen in 'n spesifieke winkel, waar dit gepoog is om die area wat beïnvloed word deur die voetganger verkeer te minimeer. In elke gevallestudie is drie scenarios ondersoek. Die eerste scenario is die winkel soos dit tans is, die tweede scenario is om te ondersoek hoe die voetganger verkeer in die winkel sal verander indien die aantal voetgangers wat die winkel betree verdubbel. Die laaste scenario is die invloed op die voetgangerverkeer indien die uitleg van die rakke, sowel as die produkplasing op die rakke moet verander van die uitleg in scenario een. Die uitleg is verander deur die rakke in die hoë voetgangerverkeer gebiede in scenario een te verskuif. Die gevallestudies is ondersoek deur die insameling en ontleding van data, die om data te gebruik om die voetgangers in toepaslike kliëntesegmentasies te plaas, en gevolglik 'n realistiese simulasie te bou in Pedestrian Dynamics. Die aantal simulasielopies wat nodig is om betekenisse volle resultate te kry is bereken, en die simulasies is geloop vir hierdie aantal lopies. Die oppervlakte van die areas met hoë voetgangerdigthede is gemeet, en die gemiddelde van die areas oor die aantal lopies is geneem om 'n waarde te verkry wat vergelyk kan word met die ander scenarios. Al die waardes vir die drie scenarios word dan in vergelying geneem met mekaar, en die resultate van die simulasies word bespreek.

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Dedications

Hierdie tesis word opgedra aan my Pa en Ma, sonder wie se aanvaarding, ondersteuning, en onvoorwaardelike liefde ek nie die moed sou hê om hierdie tesis aan te pak nie.

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Nomenclature

Abbreviations

SDA	Spatial Data Analysis
GIS	Geographic Information System
ESDA	Exploratory Spatial Data Analysis
GRASS	Geographic Resource Analysis Support System
ECM	Explicit Corridor Map
IRM	Indicative Route Method
LSM	Living Standard Measure
MAC Id	Media Access Control Identifier

Chapter 1

Background

Spatial research has been focussed on shop layouts in cities, in residential areas, and shopping centre layouts. Shopping centres are being built to offer the same retail experience that is available in the city centre. Designs that are used for shopping centres are criticised for the reason that the natural laws of movement are restricted and opposed in artificially planned centres, as opposed to naturally evolving centres.

An effective design for shopping centres was found to be a dumb-bell shape (Fong, 2003). A magnet effect is created by placing two competing department stores at different ends of the shopping centre. This leads to pedestrian movement in the shopping centre, and force pedestrians to walk past smaller shops, which they might not have done otherwise.

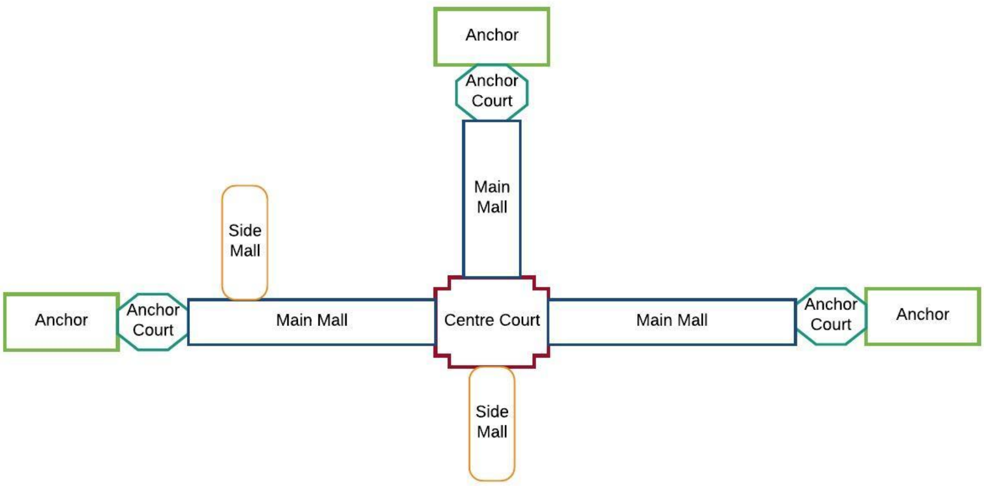

Figure 1.1: An example of a dumb-bell shopping centre layout

The dumb-bell layout of shopping centres attempts to create an artificial flow of the pedestrians in the shopping centre which replicates the natural flow that occur on the streets. There are several important factors in the dynamics of a shopping centre, such as the locations of entrances, where the stores that use the most floor space are located, and the overall layout of the centre. Most shopping centre developers are interested in the amount of rent that a certain space in the shopping mall can yield. Shopping centres are thus designed to ensure the rental return is optimised. The amount of rent that can be charged for a specific space in the shopping centre is often directly related to the amount of pedestrians walking past that space.

Ideally the layout should benefit all the shop tenants, by ensuring that the pedestrian traffic is distributed equally throughout the shopping centre. It is impossible for a space hierarchy not to form in any spatial area. A hierarchy of space is when the total spatial area is subdivided, and these sections are given a ranking from most to least important. The spatial hierarchy is in direct conflict with the optimal design of a shopping centre. As the hierarchy tries to separate the different spatial sections by a rating, the optimal design tries to balance the movement throughout the shopping mall (Fong, 2003).

One of the three questions that was asked by Fong (2003) is whether or not shopping centres obey the natural laws of movement, in such a way that it is possible to predict the distribution of the pedestrian movement. Fong (2003) attempted to answer this question by hypothesising the 'main mall' and the 'side mall' in a shopping centre display significantly different movement rates from the pedestrians. It was determined that the movement of the pedestrians within the shopping centre has a direct relation with the configuration of the shopping centre.

The research of shopping centre layouts is based on two relatively new fields of research, namely: Geographic Information Systems (GIS), and spatial statistics. GIS was established in the 1960s as a tool to handle spatial data, and perform statistical computations on spatial data. There are, however, several problems that can be solved using this tool. These problems are referred to as location problems. Location problems can be subdivided into many categories, of which the two most prominent problems are location measurement problems, and facility location problems. Facility location problems can be applied to a single facility, or to multiple facilities.

Most location models can be subdivided into four general classes, namely: the median model, covering models, capacitated facility models, and competition models. In median models the facilities are placed in a way that minimises the average distance from any user at any point in the total area. Covering models are used to locate the facilities in the area that have the highest demand for them. The capacitated facility models limits the production at each facility. Competition models are used when the capability to readjust location decisions lies with the competitor. The first three types of models are usually solved using classical optimisation, and the competition model is usually solved using simulations and game theory (Church, 1999).

The spatial relationship between the demand and facility is used to define a facility location problem. The 'demand'-area in a location problem is usually represented as a single point, although it is spread across the entire area. This assumption is used in most models. Facilities are represented as nodes in network models, although recent theory suggests that facilities can also be represented as arcs or links. Most solution algorithms are developed for when demand and facilities are represented as nodes.

Research in spatial statistics is based on the expectation that there is a relation between the units. Statistical analysis of areal distributions, spatial interactions, spatial correlation, and hypotheses about patterns in settlements, can be seen as the ancestors of modern spatial data statistical analysis. The nature of the problems that are being studied, as well as the availability of computers, play a part in the popularity of the types of statistical methods. Focusing on the geometry, rather than the topology, of buildings leads to one of the important shortcomings in space syntax (Reynoso and Reynoso, 2012).

Lu *et al.* (2009) showed that the visibility patterns have an influence on different kinds of behaviour in the pedestrians. The methodologies which are applied in visibility analysis can be extended to intensify the behavioural impacts of buildings by applying visibility analysis. It has been shown by Lu *et al.* (2009) that the way a pedestrian chooses a route is influenced by the visibility towards the important features in the area.

Customer segmentation can be described as the demonstration or expression of behavioural aspects of different customers towards a product Bijmolt *et al.* (2010). Inaccuracies in the customer segmentation can occur when working with a sample data set of a large data set. These inaccuracies can for instance be caused by the sampling variance of the sample data set.

Bijmolt *et al.* (2010) found that there are certain obstacles when it comes to the interpretation of the customer models. One of these obstacles is that the higher-level management often struggle with the interpretation of the results. A way to circumvent this is to be prepared with the analytics of the customer segmentation, and to take part in the actual decision-making. Before the analytic results can be integrated in the current processes, it needs to be tested in an experimental phase, usually through simulation. Customer analytics are not implemented in the current process as frequently as it should be in companies, because the people involved come from different disciplines.

The assumption that all units are in some way related is the basis for research in the field of spatial statistics Getis (2005). Distributions that mathematically describe areas were first consistently described by David S Neft. To have valid statistical association of spatial variables is still difficult. When spatial analysts work with pedestrian issues, a crucial part of the research is usually the interactions between the available activities.

Hillier and Hanson (1984), who did the first extensive research in the field of spatial statistics, is of the opinion that there is a moral science of design in the relationship between society and space. The moral part of the design is that the design must be for the greater good of the building. The other part of the design is described as science, because the space should be analytical. They are of the opinion that society places people in relation to one another, in various degrees of aggregation. This leads to different groups of pedestrians. The spatial order of pedestrians can be described as the way in which members of societies live with each other. Difference in spatial order might be when one society lives in subdivided and dispersed compounds, and another society lives in dense, open villages. It also arranges the components of space itself, for instance the buildings and roads, which forces the physical part of the society to take on a pattern. Cultural differences in societies can be recognised by the spatial order of that society, because culture has an influence on spatial order.

A building is, in the most rudimentary form, an arrangement of elements that give it its physical shape. It can be described as a physical, as well as spatial transformation of the previous space. By creating a building, you do not only create a physical building, but a categorical differentiation is also created. It is better to define a building by the function, rather than by the building shape. Although buildings are primarily about the movement inside and around it, it is viewed from a static point of view. It also creates a sociological distinction in the sense that the physical boundary of the building represents a certain function in society. Pedestrian events are not shaped by the physical space, but the physical space rather creates a possibility for events to take place. Buildings are significant in two ways in society. The first manner in which a building is significant is by creating working patterns in the space. The second manner is the aesthetics and the cultural significance that is influenced by the building. There are characteristics, which are commonly thought to be of pedestrians, but is rather a result of the physical building that house the pedestrians. These characteristics include: avoidance, interaction, encountering, and the congregation of pedestrians.

All pedestrians can be classified into two groups: inhabitants and visitors. Inhabitants are part of the layout of the space, and as a result have a certain degree of influence over the layout of the space (Hillier, 1997). Visitors have no control over the layout of the space inside the building, and are only temporarily in the building. When pedestrians enter a space, they can also be divided into two groups. The first group is ordinary pedestrians, which is pedestrians who use the space to perform everyday tasks. The second group is referred to as space explorers. These pedestrians are not focused on everyday tasks, but is rather focused on exploring the complete available space.

1.1 Problem Statement and Research Objectives

The aspects of GIS and spatial statistics explained in chapter 1 will be used to try to find a solution to a problem in a specific chain store in Southern Africa. One of the biggest problems with a store is the physical layout of the shelves, and the accompanying product placement on the shelves. It is difficult for store-owners to know what the effect of the store layout will have on the pedestrians who enter the store, as well as the ensuing pedestrian interactions. By not placing the products on ideal shelves, the store-owners will create unnecessary pedestrian foot traffic in the store, which might deter future pedestrians from entering the store.

In this research the shopping experience that a pedestrian experiences is inversely related to the amount of pedestrian foot traffic that is present in the store with a certain store layout. The objective of this research is thus to determine a way in which the change the layout of the store to ensure the least amount of pedestrian foot traffic congestion. Greater customer counts could be achieved by determining this shelve layout. The problem statement will be investigated by answering the following research questions:

- Question 1: Where is the current high pedestrian foot traffic areas in the two representative stores?
- Question 2: How can the shelve layout in the representative stores change in order to decrease the current foot traffic congestion in the two representative stores?

Chapter 2

Literature Review

In this chapter the different fields of research that were investigated for this research, and have an impact on the field of pedestrian dynamics will be discussed.

2.1 Space Syntax

Space syntax can be used to describe and analyse the relationship between the spaces of urban areas and buildings in urban areas. Spaces can be defined as the area between obstructions, e.g. buildings, which obstruct pedestrian flow or the visual field of the pedestrians. The spaces can be divided into four different groups: convex spaces, concave spaces, axial spaces, and isovist spaces (reference). In convex spaces there is no line that crosses the perimeter between any two chosen points. Concave spaces are spaces that can be divided into the least number of convex spaces. An axial space is a space with a straight line that a pedestrian can follow on foot. If an area can be viewed from a point, it is an isovist space. From these spaces different maps can be created, although the definitions change a bit. A convex map is when the least number of convex spaces cover the total area and all the connections between them. An isovist map is a map that depicts the areas that can be seen from a certain point. A map that shows the least number of axial lines that cover all of the convex spaces is called an axial map.

All of these maps can be transformed into graphs. A graph is made up of dots and links. The dots represent the spaces, where the links are used to represent the visibility relationship between the spaces (Klarqvist, 1993). The basic idea of space syntax is to create a network of the spatial configuration of the area that is to be studied. In this network the nodes will represent the spaces and the links between the nodes will represent the connections between the spaces (Wang and Liao, 2007). The first step to space syntax analysis is to break the study area down into spatial elements. A spatial element is defined as an open area that is generally enclosed in a way or have certain objects in the space, for instance a large room or open space that is surrounded by a wall with columns in the middle. The second step is to determine the connectivity of all the elements in the study area. This is done by either determining where two spaces overlap, or if the study area is a floor plan of a building, by finding the entrances and exits in the floor plan.

The relations between spaces, or the interaction between space and society, is referred to as 'syntax'. Hillier *et al.* (1987) defined space syntax as techniques, which can be used for the quantification, representations and the interpretation of spatial configuration in settlements and individual buildings. Space syntax is mainly focussed on the patterns of pedestrian movement in buildings and cities. The amount of space that you are aware of is the visibility structure. How spaces relate to their immediate neighbours and how one can get to where one wants to go, is referred to as the 'permeability structure'. The set of walled surfaces in an area is referred to as the 'built shape'. Combinatorial structures was used by Peponis *et al.* (1997) to define spatial syntaxes. These syntaxes enable analysts to describe the space that they are investigating.

Spatial techniques that are currently used are mostly static, which limits the interaction between the models, the data and the analyst. By creating a dynamic approach to statistical analysis the analyst can interact with the data, which allows the analyst to directly manipulate the data (Anselin, 1996). Peponis (1997) aimed to contribute a theory to complement space syntax. This theory is of the intelligibility of the spatial configuration and the shape. This, along with the proposed relationship between the social forces and form generators, was used to develop techniques that can be applied to settlements and individual buildings. There are many applications for space syntax, but it is commonly used for pedestrian modelling. The configuration of an area, be that an individual building or a settlement, is the relation between the spaces in a complex.

Spatial statistics is predominantly based on the assumption that all units that are close to each other are in some way connected. There has been a demand for net spatial analysis tools, which brought about GIS evolving quickly. This demand started when it was realised that traditional spatial analysis techniques could not address the questions that were being raised about spatial analysis. Spatial Data Analysis (SDA) can be described as a body of methods, which are used to analyse events in a certain space or area. To perform SDA it is necessary to have locational and attribute information about the area. Locational data can be described by the physical location of the space. The attribute information is information that makes that space unique. There are several significant outcomes of a SDA; for example, to detect patterns in spatial data, and to explore relationships between these patterns (Haining *et al.*, 1998).

Exploratory Spatial Data Analysis (ESDA) was developed to enhance the analytical capabilities of GIS. It is possible to extend exploratory data analysis to detect any spatial properties of a specific data set. This is used to detect any spatial patterns in the data, and to assess the spatial models (Haining *et al.*, 1998). The potential movement in an area is determined by the boundaries in the area, and the connections, which are created by the boundaries, between the areas. Hillier *et al.* (1987) performed an analysis to determine how syntactic representations and analyses could explain the relation between the patterns in a space, and how the spaces are used. The total depth of a system is the sum of all the depths in the system from a specific origin. This is usually interpreted as the distance that needs to be covered from the starting point to all other lines in the system.

Ratti (2004) investigated some irregularities in the space syntax field. Most of these irregularities deal with different features of axial maps, which are commonly used in space syntax. Jiang and Claramunt (2002) proposed a new way to model an urban structure. Most applications of space syntax include pedestrian modelling, or trying to understand complex built spaces. They proposed an alternative way to model an urban structure that has multiple advantages over models that are based on axial lines.Turner and Penn (1999) developed a method that is used to analyse isovists, which does not conflict with existing methods in space syntax. They focussed their method on the description of single isovists. This method takes isovists from the space which you want to study, and creates a graph of the physical space. The method that they developed proved to be quite tiresome, as it complicated the simplest plans of buildings.

Turner (2001) presented a new approach, which is about isovists and how they are applied in spatial systems. They used a visibility graph that is constructed using visibility relations between isovists and isovist-generating location. Their new approach resulted in the spatial system more responsive to analytical tools. Two further measurements were recommended for future research which might help in understanding the overall use and perception of architectural spaces. Fouss *et al.* (2007) developed a general procedure to compute similarities between certain elements of a database. The walk through the graph was based on a Markov-chain. They found one drawback with this method, in that the method does not work well with large databases. Another approach of space syntax is the research of Munro and Jordan (2013) They investigated the factors that influence an artists' decision for a performance space at the Edinburgh Fringe Festival. In the study they found that artists do not choose arbitrary performance spots, but that the artist's choice is influenced by socio-political factors, as well as the amount of sound at a certain space.

Hillier *et al.* (1987) defined urban space as the part of a town or settlement that consists largely of buildings. There are two features that seem to be the fundamental parts of a settlement. The first is closed elements, such as shops and houses; and the second part is the open system, such as roads and fields. The interaction between the open system and the closed elements, that form a spatial pattern, can be analysed. Factors that influence the thought process are crucial to build an accurate, as well as realistic, model of a non-work location choice. The choice of activity location, the time that the activity took place, demographic information about the pedestrians, and certain attributes of other locations are some of the only observable characteristics of the choices that the pedestrians make. To estimate a model that incorporates past choices of pedestrians, it is necessary to have data that stretches over a long period. The activity-travel patterns of pedestrians may be described by six attributes: the purpose of the activity, the location of the activity, the order in which different activities takes place, the duration of each activity, the mode of transport which the pedestrians used to reach the location of the activity, and whether or not the pedestrians perform the activity alone. Of the aforementioned attributes, the location where the activity takes place, has the largest influence on the activity-travel patterns of pedestrians (Sivakumar and Bhat, 2007).

Bafna *et al.* (2010) propose that the visual form of a building is a response to how humans organise information. The visual form of a building can be manipulated by the designer, by understanding how the human visual system naturally functions. There are two prevalent ways in which the visual function of a building can be manipulated. The first is in careful modifications to the visual form, and the second is in perceptual engagement between pedestrians and the building (Fischer, 1999). Penn and Turner (2003) found that there is little research done on how the optimal development of a space can be achieved, and subsequently maintained. One of the explanations for this is that the research that needs to be done is costly, and time-consuming. There are several events that are influenced by movement in, and the configuration of, urban spaces. For example, it has been shown that high movement rates are negatively related to crime in an area. Penn and Turner suggests to use agents with vision in the research space to understand the interaction between agents and the spaces; to determine how the development of a space can be achieved. Using agents with vision has two main advantages. The first is that agents can react to other agents in the space; and secondly, the agents can gather information about the boundaries of spaces, which influence their behaviour in the space. The point of this approach to the research is that urban space should not only be viewed as the physical space, but to integrate human behaviour in the research.

Psarra (2003) used local properties to create a two-step approach to measure the perimeter of a shape, by using local properties. The first is to determine the connectivity of each of the points, to get a categorisation of the shape, which is based on different syntactic properties. The second step is to plot a graph of the connectivity of each of the points. The four main measures that can be calculated using these graphs are: connectivity, integration, control value, and global choice. Global choice is the flow through the space from a particular point. The control value measures how a space controls the access to its immediate neighbours. The integration of the graph is the average depth from one space to all the other spaces in the area. Lastly, the number of neighbours of the space is the connectivity of the graph. Time is often used in SDA. Psarra (2003) defined time in two different ways. The first is as a succession of events. By defining time in this manner time can be seen as a gradual movement through different states. The second way to define time is as an order of events. This will lead to time being seen as an order that consists of a pattern which can be studied.

Most shopping centres and businesses are located in the centre of a city. These areas in the city centre can be emphasized as the trade axis of the centre. The trade axis show where the most retail activity takes place in the city centre. A store should be located in such a spot as to attract the most potential customers. Where a store is located can have an influence on the amount of sales which is directly related to whether a store is successful or not. There are certain criteria of the location of the store that helps to increase the amount of customers. These criteria include: the distance between the customers and the store, the amount of pedestrian traffic, the image of the building, and the convenience of nearby public transport. There is a trade-off in the spatial location of a store, called the agglomeration-differentiation trade-off. This trade-off has a significant impact on the choice of location for stores (Datta and Sudhir, 2011). In 2012 Szojnik *et al.* (2012) used retail stores in the centre of Cluj-Napoca in Romania, and analysed their locations in the city. This research was done to determine the guidelines with which central retail stores organize their spatial behaviour. For this research maps and detailed surveys of the buildings were used. Stores may locate close to each other for other reasons even if there is no strategic benefit. These reasons include the following: if a certain location has a high demand, or a low cost, and if there are zoning regulations that force stores to locate close to each other. When stores that offer the same products or services open close to one another it leads to spatial clustering. It has been recognised for a long time that opening a store close to a competitor could increase the stores profits(reference). This happens because the collective demand for the product or service is increased in that location.

Research has shown that the location of a store plays a significant role in the amount of rent that is expected to be paid. Des Rosiers *et al.* (2005) constructed a model to investigate how external and internal factors influenced the rent in a shopping centre . They found that neither external nor internal factors have an overall impact on the rent, but rather that the rent is influenced by a complex relationship between these factors. Sivakumar and Bhat (2007) focussed their model on non-maintenance shopping, and included several variable attributes in their study. These variable attributes include the: zonal size attributes, zonal impedance measures, demographic variables, and attributes of the choice occasion. Zonal size attributes are attributes that make the location of the store attractive, such as the area. The zonal impedance measures is the distance that each pedestrian has to travel to the different activity zones. Demographic variables include the income bracket of the pedestrian, the age, gender, and employment status. Lastly, the attributes of choice occasion is whether the activity took place as a singular activity, or in a chain of activities, on which day the activity took place, as well as the time of day which the activity took place. Each of these attributes had different outcomes with their model. The zonal size attributes indicated that larger zones result in a higher attraction to the store, namely, the larger the store, the more customers will find it attractive. For the zonal non-size attributes it was found that areas with a higher density are less desirable. With the impedance attributes it was clear that customers prefer to shop at locations that are close to their homes. Van Nierop *et al.* (2008) proposed a model to determine the effect on sales through shelf placement and shelf space. They investigated the effect, by monitoring the sales in a store with the current shelf placement, and then changed the shelves in the last week of the experiment. They found that by changing the layout, the shelve placement has an important impact on the sales.

2.2 Pedestrian Dynamics

There is currently very little research available on the spatial patterns of a store layout in centres, and almost no research available on the spatial patterns inside an independent store. However, research about pedestrian interactions and pedestrian dynamics have been done in other areas of application.

One of the methods that are used to simulate spatial areas is to set the area in a spatial lattice. The most common space used for this lattice is a rectangle with square cells. Birch (2006) suggested to use this method, which have been referred to as 'cellular automata', to show that the relative strength, orthogonal and diagonal, have a substantial effect on the results of a simulation. The Buffon-Laplace method was used to investigate this interaction, and it showed that the relative strength of orthogonal and diagonal interactions have indeed an effect on the results of a simulation. When there is a part of a settlement with a mix of land uses it is referred to as the 'centre' of the settlement. A spatial model to find the essential component of centrality was developed by (Hillier, 1999). 'Live centrality' is based on activities that thrives on pedestrian movement. Live centrality was used in this study, to find the essential component that is ever-present in 'live centres'. In this study Hillier found that the configuration and the attraction of a space are bound more in a spatial sense than was initially thought.

Pedestrian patterns are primarily developed by the configuration of an urban system. This was used by Hillier *et al.* (1993) to understand if the real urban system is described by the theory. Badland *et al.* (2013) applied GIS to existing spatial datasets to build a walkable network tool. This tool was used to determine the walkability of a neighbourhood. By determining the walkability of a neighbourhood, a standardised benchmark could be created that compared the different characteristics that would promote walking in a neighbourhood. Sugiyama et al. (2012) built a framework to organize environmental factors in neighbourhoods. This framework was primarily built for neighbourhoods in which pedestrians walk recreationally. They suggested certain research priorities for this framework. Firstly, there are certain relationships in environmental attributes, which are associated with walking that needs to be understood. Secondly, it is necessary to identify how the walking behaviour is affected by the quality of the destinations.

Owen *et al.* (2007) studied the walkability in neighbourhoods. The two essential elements that have an influence on the walkability of the pedestrians in the neighbourhood are the proximity of the attractors to which they want to walk, and the connectivity of the area. They found that in neighbourhoods that are considered to be more walkable, the distance that the pedestrians have to walk to reach their destinations is less than in neighbourhoods that are less-walkable. The pedestrians in more walkable neighbourhoods are also more likely to walk to the nearest grocer, than to take a vehicle. Gupta and Pundir (2015) derived model to investigate the different characteristics of pedestrian flow, to try and increase the amount of pedestrians who walk rather than take a vehicle. The main characteristics of a pedestrian flow study is the speed, flow, pedestrian density, area, and the relationships between them. They found with their model that there is mostly a linear relation between the speed and the pedestrian density in the area.

Individual decisions make up the basis of human behaviour. Pedestrian models are built on the assumption that the pedestrian decisions shows a certain predictability. There are four common reasons for fluctuations in pedestrian models, which lead to the model not being exactly valid. These reasons are, firstly, that pedestrians might find themselves in an unusual situation. The second reason is that pedestrians experience some emotional stress, which leads to suboptimal behaviour on their part. The third reason is that it might be the pedestrians first time in the shop, which means that the pedestrian might not know the optimal route to fulfil all of their activities. The last reason which might lead to fluctuations in the model is that all pedestrian behaviour have a certain degree of imperfection (Helbing, 1991). Helbing and Johansson (2009) compared crowd dynamics to gases and fluids. They stated that when the pedestrian density is low, the crowd behaves like a liquid. However, as the pedestrian density increases, the crowd moves more like granular media. Crowding is defined as a physical space with a high pedestrian density. Alawadhi and Yoon (2016) performed a study to investigate how pedestrian's different perceptions of crowding predict their shopping behaviour. From the statistical procedures that they performed, they found that the store layout plays an important role in the behaviour of the pedestrians. They found that pedestrians seem to perceive crowding less in a store layout with a linear layout.

Paris *et al.* (2007) investigated how pedestrians interacted with other pedestrians in a crowded environment. They used different steps to calculate the best direction in which a pedestrian need to walk, and at what speed to avoid a collision. When they ran the simulation model, there were no pedestrian collisions in the study area. Helbing *et al.* (2015) investigated how pedestrians self-organise in a crowded environment. Patterns of motion are formed when certain conditions is imposed on pedestrians. Some of these patterns of motion are lanes that form on opposite sides of a walking space, and the oscillatory flow of pedestrians that is found at bottlenecks. They performed their investigation by using experiments that are video-based, and submitted the pedestrians to normal and panic-like situations. They found that the boundaries not only limit the movement of the pedestrians, but also the gaps between the pedestrians. This result can be used in future design of facilities.

Pedestrian dynamics can also be used to investigate pedestrian interactions with attractors, for instance in an exhibition setting. Peponis *et al.* (2004) investigated these interactions in a science exhibition. A contact between the pedestrian and the exhibit was recorded when the pedestrian came sufficiently close to the exhibit. An engagement was recorded when the pedestrian interacted with an exhibit. The main purpose of this study was not only to investigate the interactions between the pedestrians and the exhibits, but how the visibility from the exhibition entrance affects the exploration pattern of the pedestrians. Newman and Foxall (2003) studied the behaviour of customers in fashion retailers. Reactions exhibited by the customer in response to the layout of the store and the aesthetic offering of the merchandise was used to investigate this behaviour. They found that, by analysing customers' behaviours, it is possible to plan the store layout corresponding to the customers' needs. Anic *et al.* (2010) studied the effect of the pedestrian traffic in the store, and the subsequent pedestrian flow on the customer's spending. They found that in a large shop, such as a hypermarket, the customer spending is increased when the pedestrian traffic in the store is increased.

By continuing the advertising and in-store promotions, the customers spending habits can be predicted by management. Cil (2012) used multidimensional scaling and rule mining to understand the store layout problem. The different products in the store were grouped together using multidimensional scaling. The primary objective of his study was to find a way to group products together in order to ensure that customers found all the products they are interested in, in the same place. There are a few advantages to his study. One advantage is that the association rules are applicable to the stores' management, because they are procured from the point of sale database. Since the rules are procured from the point of sale database, it is easy to change the rules, should it be necessary, and implement the changes. After the study, Cil (2012) found that the customer's time in the store was properly utilised, which led to high customer satisfaction.

2.3 Location Analysis

A geographic information system (GIS) is a tool that is used for the capturing, storing, manipulation, analysis, modelling, and graphic representation of spatial information Leslie *et al.* (2007). A GIS can be seen as multiple layers of spatial information. This spatial information that is contained in the GIS is used to reference certain locations on the Earth's surface. GIS can be used to show relationships and trends in locations, and to reveal hidden patterns that might not be discernible from the data. The spatial data in a GIS always contains three parts. Firstly, it contains the specific coordinate system that is used. The second part of a GIS is the standard unit of measurement, and the last part of a GIS is the map projection that is used. One of the major complications that arises from using GIS data for syntactic analysis is that GIS data is based on roads and their intersection nodes (Dalton *et al.*, 2003).The GIS representation also has some advantages, such as showing the changing conditions along a long piece of road.

Location analysis has also been used to analyse the layout of homes by Peponis and Bellal (2010) when they studied the Kaufmann Residence, better known as Fallingwater. This research was performed to investigate relationships in the space that can be recognised at the same time, without changing your position. Dalton *et al.* (2003) had two proposals for changes in depth. The first change is that the depth should be measured in fractions, rather than in a unit. The second change that was proposed is that changes between lines in GIS data should be treated as a change of direction, which would consequently be measured as a full depth value. It is apparent from using this two proposed changes that an approximation that is close to the results of traditional analysis, without the changes, can be achieved. Kasemsook (2003) stated that natural movement indicates that movement and attractors, such as buildings, are highly related to each other.

There is a theory of 'movement economy', which explains why there is a strong association between the attractors and movement, and the mechanism that creates this association. This theory states that the movement in a space is influenced by the grid, and it is the movement that in turn influences the placement of attractors. During Kasemsooks' study of eight spatial areas, it was found that the centrality process, which was first researched by Hillier, is linked to all forms of land use, whether it is residential or commercial, that benefits from pedestrian movement. Peponis *et al.* (2008) discussed relatedness, which is associated with street networks. Their study was based not on the land use, but rather on the street networks themselves. They suggested a framework with which to analyse the street networks. When the used the framework on the area that they studied, they found that it helps in two ways. The first is that it produces a way to measure how the grid becomes more easily accessible, and intelligible. Another advantage of this framework is that is produces a way to measure how the grid becomes sparser, and denser.

Aghazadeh (2006) performed a study to investigate whether the available floor space is utilised optimally. This study was done with the objective to maximise the profit of the store. He divided all of the shoppers into four groups: price seekers, affluent planners, convenience seekers, and passive purchasers. He also used several guidelines for the layout of the store. One of these guidelines are that the high draw items should be placed on the outside of the store and the power items should be placed at the back of the store, to force customers to walk past other items. There were many improvements found by implementing these guidelines, but there are still recommendations for further research. Hunneman (2011) investigated how the performances of different departments in a store are influenced by changes in the stores' assortments. Using their proposed model for a specific store, it was found that the different locational variables affect each department separately. For example, the distance that a customer has to travel to the store has a greater influence on the men's and women's department than it has on the children's department.

Bezawada *et al.* (2009) found that 70% of pedestrians decide on groceries in the store. This leads to store management that needs to place products that get bought together in the same aisle. A model was developed to study the effect of where different products were placed in the aisles. Their model showed that certain effects are extremely important when management has to choose which two product categories to place next to each other. Fong (2005) did a study on the location patterns that are found inside a shopping centre. This study used several shopping centres to investigate the location patterns. All of the shops were divided into groups, and the interaction between the pedestrians and these shop-groups were investigated. There are certain protocols for stores that need to be followed. An example of such a protocol is that anchor stores or department stores, should be located at different sides of a shopping centre, because these types of stores are in direct competition with one another. He found that the manner in which a store engages with a pedestrian depends on the location of the store, as well as the visibility of the marketing that the store offers. Only one of the five hypotheses that was tested in this study was found to be true. This hypothesis states that record stores tend to be dispersed in a shopping centre.

2.4 Modelling Software

2.4.1 R

The R language was developed at Bell Laboratories as a GNU project. It is offered as an open-source language. The main use of R is for statistical computing and graphics. It offers a wide range of graphical, as well as statistical techniques. It can be used for modelling classical statistical tests, clustering and time-series analysis.

One of the qualities that R offer is that good quality plots can be created, incorporating formulae that contain mathematical symbols.

2.4.2 GRASS

Another program that was used is the geographic information system is called Geographic Resource Analysis Support System (GRASS). It was originally developed as a tool for land management and environmental planning by a branch of the US Army Corporation of Engineering. Since its inception, GRASS has evolved into a powerful utility with a wide range of applications in many different areas of applications and research, and is thus being used in a variety of academic and commercial settings around the world. It is still being used by governmental agencies, including NASA.

GRASS is an open source program that has multiple purposes (Neteler *et al.*, 2012). Some of these purposes include the management, processing, modelling, and the visualisation of spatial data. Environmental modelling can be done in GRASS. There are over 350 available modules in GRASS that can be used to manipulate raster and vector data, including vector networks, and image rendering. It can also handle two-dimensional, as well as three-dimensional data. GRASS can link directly with other software applications, such as CRAN R. It is possible to perform statistical as well as geostatistical analysis in R, by creating an interface between GRASS and R.

2.4.3 PD

Pedestrian Dynamics (PD) [1] is a simulation program that is used to model, analyse, and visualise large crowds of virtual agents. These models are built by importing the infrastructure of the area in which you want to simulate the flow of the pedestrians, and setting the parameters for the pedestrians. The performance of the model can be evaluated using for instance density flows, walking times, as well as waiting times. All of this is achieved by using crowd simulation algorithms and software, which was

[1] http://www.pedestrian-dynamics.com/

developed as a collaboration between Pedestrian Dynamics and the University of Utrecht in the Netherlands.

Pedestrians in the simulation model should be able to find an efficient path from their current location, to the point they are trying to reach. There exists a data structure, called a navigation mesh, which divide the walk-able area into polygonal areas. The explicit corridor map (ECM) is an example of such a navigation mesh, and can also be used for areas, which is composed of more than one layer. The ECM can be described as a network, which consists of nodes and vertices. Each of these edges can be described as the centre of the allowable walkable space, and the nodes as the closest points. Pedestrians in the simulation use the $A*$ algorithm to plan the route that will be taken to reach the goal destination. Pedestrians in the models are able to move freely, and use the remaining part of the corridor to avoid other pedestrians. It can be time-consuming to avoid collisions, but this adds to the realism of the simulation. The ECM holds ample advantages, which include the small memory footprint, multi-layered environments are supported, it is constructed automatically, and paths can be determined for different types of agents by using only a single data structure.

The Indicative Route Method (IRM) is a framework that guides the pedestrians through the corridor to the goal location. Pedestrians compute a desired walking speed in each simulation step. The pedestrians may deviate from the desired walking speed, but are not allowed to deviate from the chosen corridor. Each of the walking speeds is a parameter, which is set by the user as a distribution, and these speeds can be set unique to each pedestrian group.

For the vision of the pedestrians field of view is illustrated using a cone shape. This vision is used by the pedestrians to detect if there are any obstacles in the way. By using the collision-avoidance algorithm in the ECM the pedestrians can prevent walking into other pedestrians by choosing a walking speeds that is close to the desired walking speed. Pedestrians also use their view to determine the local perceived stream. The local flow of the surrounding pedestrians is represented by this stream. The stream direction of the surrounding pedestrians will be an interpolation between the current location relative to the pedestrian and the direction of movement.

In PD the crowd density is set to a value between 0 and 1 by the user. The ECM uses this value to calculate the route. The crowd density value is converted to the expected walking speed, and the expected travel time. This travel time is used by the pedestrian to avoid the crowded areas in the simulation when planning the route Bijsterbosch *et al.* (2012).

Chapter 3

Methodology

This chapter discusses the experimental methodology which was followed. The data, customer segmentation, and the procedure for the dynamic analysis is discussed.

3.1 Research Design

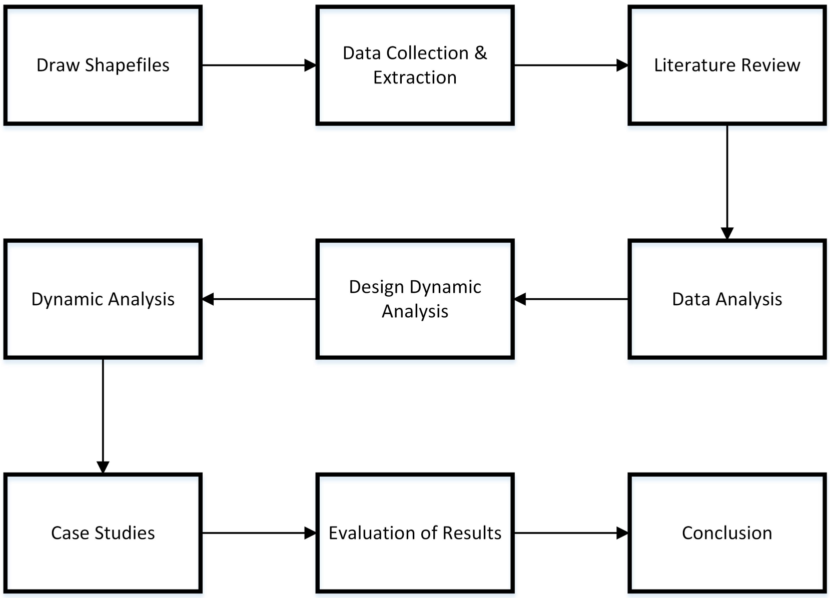

Figure 3.1: A diagram of the methodology that was followed

As mentioned in the research aim (1.1), the objective of this research is to determine the shelve layout of the store, in combination with the product placement, in order to ensure that the customers have a satisfying shopping experience. The literature review was conducted using targeted concepts, such as: customer segmentation, pedestrian dynamics, spatial models, space syntax, location patterns, spatial statistics, neighbourhood walk-ability, geographic information systems, spatial data, spatial locations, shopping centres, syntax analysis, crowd simulations, customer engagement, and pedestrian movement. These topics can be narrowed down to a few core keywords such as space, shape, analysis, space syntax, GIS, spatial, segmentation, customers, data, and pedestrian.

The quantitative part of the research is the research that was done on the software that was used during the simulation and analysis parts of the research process.

The research procedure was started by drawing the shape-files of the stores that is used in these case studies. The second step was to collect and extract the pedestrian data. A literature review was performed, and mainly consisted of the terms stated previously. Data analysis was done on the extracted data after the literature review. The dynamic analysis was designed, again starting by researching the software that would be used. In this part two different programs were used. First, MATLAB was used to determine the distributions of each of the customer segments. The second program that was used to create a dynamic simulation models is Pedestrian Dynamics [1]. The dynamic analysis was applied to the two stores that were used as case studies. The last step in the research procedure was to analyse the simulation results of the case studies. These results were used to draw a conclusion about where the shelves should be placed in the respective stores.

3.2 Study Area and Data

The study areas for the case studies consists of two stores that specialise in tile and bathroom ware in Southern Africa. Each store is categorised into eight departments, namely: entry exit, bath, browse, tile, decorate, do it yourself, shower, and buy. The departments and the information from the sensors in the stores were used to determine the different shopping patterns for each of the customer segmentation groups. Data was collected from 1 October 2014 until 9 October 2015. There is a total of 124 121 data points that were used to perform the data analysis that was used to perform the simulations.

The data that was used in the case studies was gathered by installing sensors, or Wi-Fi devices, in the display areas. These sensors picked up the signals from the customers cellular phones when the cellular phones ping the network for signal. The signal were used to obtain all the media access control identifier (MAC Id) of the different customer's cellular phones. The MAC Id's were then used to place each of the customers in a living standard measure (LSM) group.

The signals from the cellular phones were also used to determine certain aspects of the customers. The first aspect is in which department the customer currently was. Another aspect that can be determined from the cellular phone's signal is how long a customer spent in a department in the store.

[1] http://www.pedestrian-dynamics.com/

3.3 Customer Segmentation

The data that was gathered from the MAC Id's for the two stores were used to create five segments of the pedestrians. These segments are: contractors, browsers, buyers, staff, and unknown. Store 1 had a total of 76341 pedestrians throughout the data collection period, and Store 2 has 47780 pedestrians.

The first segment, called contractors, are usually contract workers who enter the stores to buy building supplies. They are mainly in the stores between 7 am and 12 pm. They represent 9% of the total pedestrians (6870 in Store 1, and 4300 in Store 2).

The next segment is called browsers. This is when the pedestrians enter the store, to shop for products that they might need later. These pedestrians are mainly in the store between 9 am and 4 pm. 77% of the total pedestrians are represented by this segment, which totals to 58782 pedestrians in Store 1, and 36790 in Store 2.

The third segment is called buyers. These pedestrians have usually already visited the stores, but were previously categorised as browsers. After they decided which products the need, the return to the store and only visit the departments with the products that they are interested in. The pedestrians in this segment usually visit the stores between 8 am and 3 pm, and also represent 9% of all the pedestrians.

The second last segment is the staff. These pedestrians enter the stores at opening time, 7 am, and leave the store again at closing time, 6 pm. These are usually two shifts for the staff, which can be seen in the arrival graph of the pedestrians. The staff represent 4% of the total distribution of pedestrians, which amounts to 3035 pedestrians in Store 1, and 1911 in Store 2. The staff segment has an impact on the amount of pedestrian foot traffic and pedestrian interactions, although they do not for part of the customers in the stores.

The last segment is called unknown. This encompasses all the other pedestrians that does not fit into any of the previous segments. These pedestrians represent 1% of the total pedestrian population. That is 763 pedestrians in Store 1, and 477 in Store 2.

3.4 Dynamic Analysis

There are a few steps that were necessary before the dynamic analysis could be completed. The first step was to analyse the data for the simulations. The data was first exported from Tableau to Excel for each of the segments for every day. This data still contained invalid entries, for instance entries of security guards who patrol the stores when it is closed.

Once the raw data was exported to Excel it was cleaned and sorted. This was done by determining which of the data entries are on what days. To get the data

						New Customer			Recurring Customers			Grand Total		
						Avg Time Spend	Customer Counts	GSH	Avg Time Spend	Customer Counts	GSH	Avg Time Spend	Customer Counts	GSH
2014	October	23	13	16	36	274	1	274				274	1	274
		24	13	42	14	254	1	254				254	1	254
		29	0	0	3				274	1	274	274	1	274
			10	6	1	343	1	343				343	1	343
		30	9	53	16	410	1	410				410	1	410
		31	13	9	14				258	1	258	258	1	258
			16	40	42	392	1	392				392	1	392
	November	1	6	32	10				334	1	334	334	1	334
			7	30	12	322	1	322				322	1	322
			8	1	55	273	1	273				273	1	273
				51	5	351	1	351				351	1	351
		4	0	0	47				274	1	274	274	1	274
			8	50	59				414	1	414	414	1	414
			10	16	24				360	1	360	360	1	360
				18	37	416	1	416	450	1	450	433	2	866
				19	46				317	2	633	317	2	633

Figure 3.2: A screen shot of the raw data

Date	Day	Time Calculations			Time
23 October 2014	Thursday	13:16:36	01:16:37 PM	01:16:36 PM	01:16:36 PM
24 October 2014	Friday	13:42:14	01:42:15 PM	01:42:14 PM	01:42:14 PM
29 October 2014	Wednesday	0:0:3	12:00:04 AM	12:00:03 AM	12:00:03 AM
29 October 2014	Wednesday	10:6:1	10:06:02 AM	10:06:01 AM	10:06:01 AM
30 October 2014	Thursday	9:53:16	09:53:17 AM	09:53:16 AM	09:53:16 AM
31 October 2014	Friday	13:9:14	01:09:15 PM	01:09:14 PM	01:09:14 PM
31 October 2014	Friday	16:40:42	04:40:43 PM	04:40:42 PM	04:40:42 PM
1 November 2014	Saturday	6:32:10	06:32:11 AM	06:32:10 AM	06:32:10 AM
1 November 2014	Saturday	7:30:12	07:30:13 AM	07:30:12 AM	07:30:12 AM
1 November 2014	Saturday	8:1:55	08:01:56 AM	08:01:55 AM	08:01:55 AM
1 November 2014	Saturday	8:51:5	08:51:06 AM	08:51:05 AM	08:51:05 AM
4 November 2014	Tuesday	0:0:47	12:00:48 AM	12:00:47 AM	12:00:47 AM
4 November 2014	Tuesday	8:50:59	08:51:00 AM	08:50:59 AM	08:50:59 AM
4 November 2014	Tuesday	10:16:24	10:16:25 AM	10:16:24 AM	10:16:24 AM
4 November 2014	Tuesday	10:18:37	10:18:38 AM	10:18:37 AM	10:18:37 AM
4 November 2014	Tuesday	10:19:46	10:19:47 AM	10:19:46 AM	10:19:46 AM
4 November 2014	Tuesday	10:20:50	10:20:51 AM	10:20:50 AM	10:20:50 AM
4 November 2014	Tuesday	11:13:22	11:13:23 AM	11:13:22 AM	11:13:22 AM
4 November 2014	Tuesday	11:24:35	11:24:36 AM	11:24:35 AM	11:24:35 AM
4 November 2014	Tuesday	11:25:35	11:25:36 AM	11:25:35 AM	11:25:35 AM

Figure 3.3: A screen shot of the processed data

in the right format it was sorted twice. Firstly the data was sorted according to the day. After that the data was sorted according to the time that the pedestrian entered the store. By doing this the data could be cleaned, by removing all entries before 7 am, as well as all entries after 6 pm. The data was then categorised into in eleven time groups, each signifying an hour interval.

In each time group, the data was again sorted by date, in order to calculate the inter-arrival time. This was done by checking whether the time entry was the first time entry for a specific day by a pedestrian. If it is, the start time of that time interval is subtracted from the entry time to calculate the inter-arrival time. If there is an earlier time entry for the same date, then the first time entry is subtracted from the second time entry. Each of the inter-arrival time were converted to their equivalent number values. These number values were added in MATLAB, as a variable in order to fine the distribution of the number values. The distributions were the used

Monday	Date	Monday	Time	Amount
1	12 January 2015	1	05:35:13 PM	1
2	17 August 2015	2	05:30:17 PM	1
3	17 August 2015	3	05:23:50 PM	1
4	8 December 2014	4	05:13:47 PM	1
5	16 March 2015	5	04:43:15 PM	1
6	8 December 2014	6	04:42:15 PM	1
7	21 September 2015	7	04:41:50 PM	1
8	8 June 2015	8	03:11:47 PM	1
9	15 June 2015	9	02:45:56 PM	1
10	17 November 2014	10	02:40:03 PM	1
11	4 May 2015	11	02:27:31 PM	1
12	10 November 2014	12	01:17:57 PM	1
13	5 January 2015	13	12:54:36 PM	1
14	21 September 2015	14	12:49:45 PM	1
15	15 June 2015	15	12:49:11 PM	1
16	15 December 2014	16	12:40:20 PM	1
17	4 May 2015	17	12:38:01 PM	1
18	5 January 2015	18	12:35:25 PM	1
19	4 May 2015	19	12:29:02 PM	1
20	25 May 2015	20	12:28:28 PM	1
21	8 June 2015	21	12:28:16 PM	1
22	5 January 2015	22	12:25:40 PM	1

Figure 3.4: A screen shot of the half sorted data

	7-8		
Date	Time	IAT	Number Value
10 November 2014	07:09:42 AM	12:09:42 AM	0.006736111
10 November 2014	07:28:02 AM	12:18:20 AM	0.012731481
10 November 2014	07:57:46 AM	12:29:44 AM	0.020648148
10 November 2014	07:57:53 AM	12:00:07 AM	8.10185E-05
17 November 2014	07:32:25 AM	12:32:25 AM	0.022511574
17 November 2014	07:42:26 AM	12:10:01 AM	0.006956019
17 November 2014	07:56:51 AM	12:14:25 AM	0.010011574
24 November 2014	07:14:02 AM	12:14:02 AM	0.00974537
8 December 2014	07:02:24 AM	12:02:24 AM	0.001666667
8 December 2014	07:05:47 AM	12:03:23 AM	0.002349537
8 December 2014	07:06:08 AM	12:00:21 AM	0.000243056
8 December 2014	07:44:46 AM	12:38:38 AM	0.026828704
15 December 2014	07:00:12 AM	12:00:12 AM	0.000138889
15 December 2014	07:30:50 AM	12:30:38 AM	0.021273148
15 December 2014	07:59:12 AM	12:28:22 AM	0.019699074
22 December 2014	07:01:21 AM	12:01:21 AM	0.0009375

Figure 3.5: A screen shot of the sorted data

in Pedestrian Dynamics to simulate the agent's inter-arrival times.

The dynamic simulation was done for three scenarios: scenario one is each of the stores as it is at the moment, scenario two is if the pedestrian counts in each of the stores double, and scenario three is when the shelve layout changes in each of the stores. Images of the program settings that was used in Pedestrian Dynamics can be seen in Appendices A and B.

After all the distributions were determined, it was necessary to find out how many simulations runs are required to obtain statistically relevant results. To determine the amount of runs that need to be done, $n = 10$ was chosen. Each store's simulation for each day was run n times. In each simulation run the area representing the highest density for pedestrians was measured. In the simulation runs with more than one high density area, the areas were added up to get the total high density area in the store. The total high-density area was denoted as X_i. After n runs were completed for each day at each of the stores, the average high density was calculated.

$$\overline{X} = \frac{\sum_i X_i}{n} \tag{3.4.1}$$

The average density was used to calculate the standard deviation ${S_x}^2$. The half width confidence interval was also calculated. This was done using the following formulas:

$${S_x}^2 = \frac{\sum_n (X_i - \bar{X})^2}{n-1} \tag{3.4.2}$$

$$h = t_{n-1,1-\frac{\alpha}{2}} \times \frac{S_x}{\sqrt{n}} = 2.262 \times \frac{S_x}{\sqrt{n}}, n = 10, \alpha = 0.05 \tag{3.4.3}$$

Both the standard deviation and the half width confidence interval is used to calculate the required number of simulation runs. This is done by:

$$n^* = n\left(\frac{h}{h^*}\right)^2 \tag{3.4.4}$$

where n^* is the required amount of simulation runs. Each of the simulations were then run for the required number of runs

Table 3.1: Amount of simulation runs for Store 1

	Scenario One	Scenario Two	Scenario Three
Monday	13	13	13
Tuesday	13	13	13

Table 3.2: Amount of simulation runs for Store 2

	Scenario One	Scenario Two	Scenario Three
Wednesday	11	11	11

Chapter 4

Case Studies

In this chapter each of the three scenarios that were applied to the two case studies are discussed.

4.1 Scenario One: As Is

The first scenario which was done can be described as the base scenario. This scenario uses the store layouts as it is, and the customer data as it is. The layout of Store 1 and Store 2 are shown in figure 4.1 and figure 4.2. The turquoise lines in the figures represent the Explicit Corridor Map (ECM) of each store. The ECM is created automatically in Pedestrian Dynamics (PD). The ECM is a data structure that divides the walk-able space into connected polygons. Each of the lines form the medial axis in the layout. The medial axis is a set of lines that depict the centre of the available walk-able space between the shelves. The pedestrians in the simulations use the ECM to find an efficient path from the current location to another position in the defined environment.

4.1.1 Segmentation of Pedestrians

The segmentation of the pedestrians differ slightly from the overall pedestrian segmentation (table 4.1 on page 23). The amount of pedestrians for each store can be seen in table 4.1.

Table 4.1: Customer segmentation in percentages

Segment	Store 1	Store 2
Contractors	4.43	3.60
Browsers	87.18	86.71
Buyers	5.38	5.69
Staff	2.89	3.41
Unknown	0.12	0.59

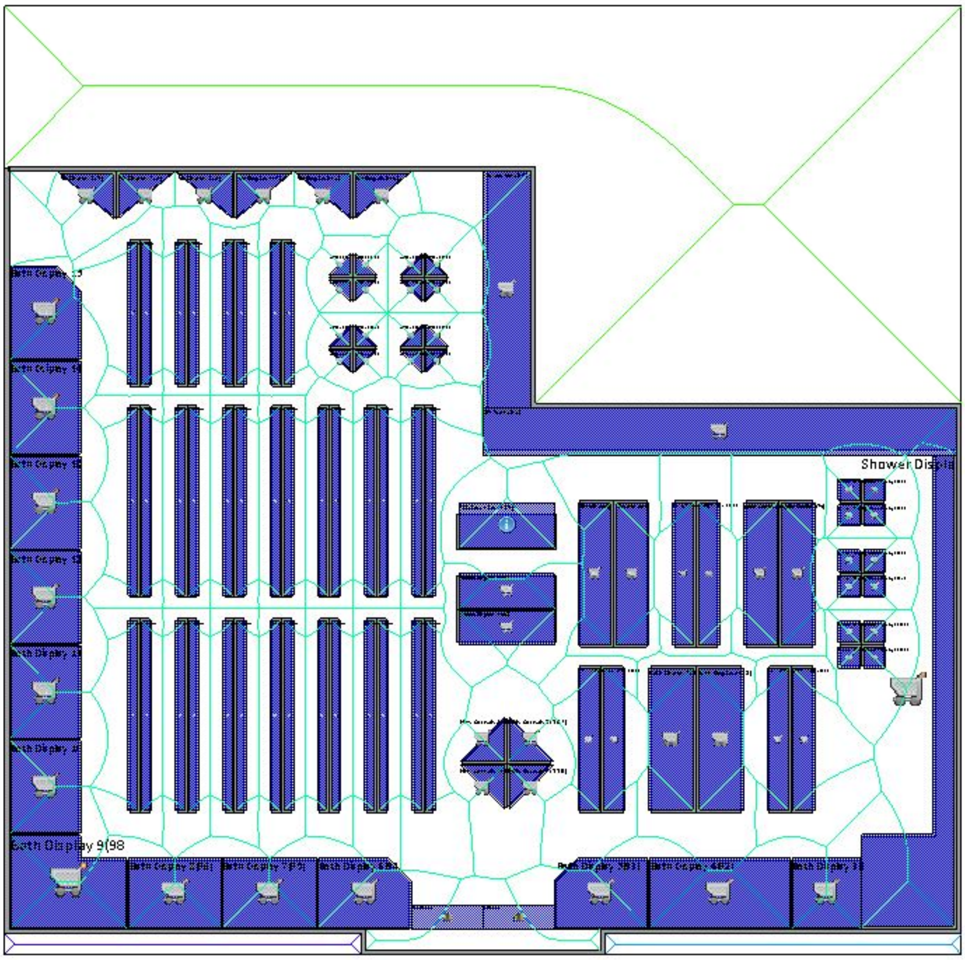

Figure 4.1: A diagram of the layout of Store 1 in scenario one

Each of the two stores have a total of nine different departments which the different segments of the pedestrians can visit to fulfill their shopping experience. The allocation of the floor space for each of the departments is shown in table 4.2 on page 26.

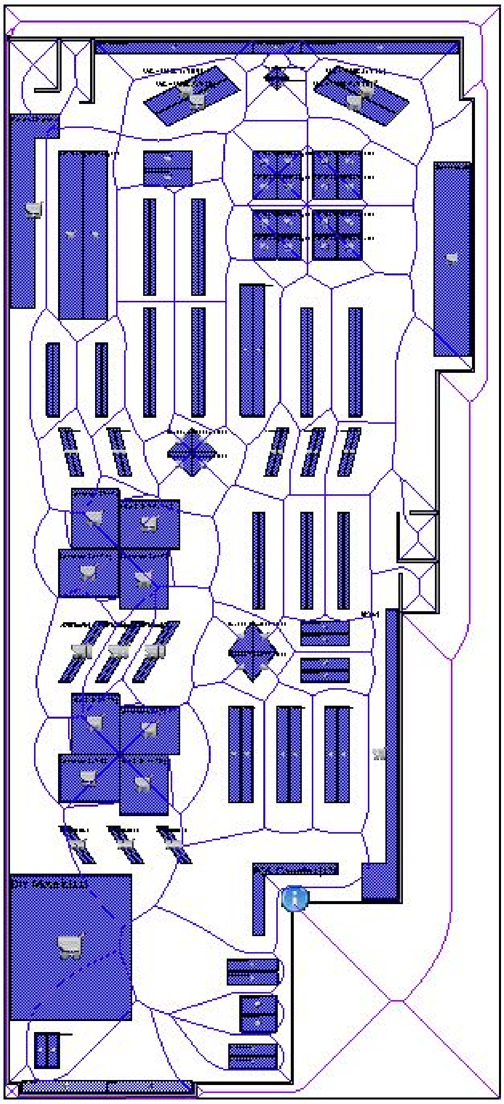

Figure 4.2: A diagram of the layout of Store 2 in scenario one

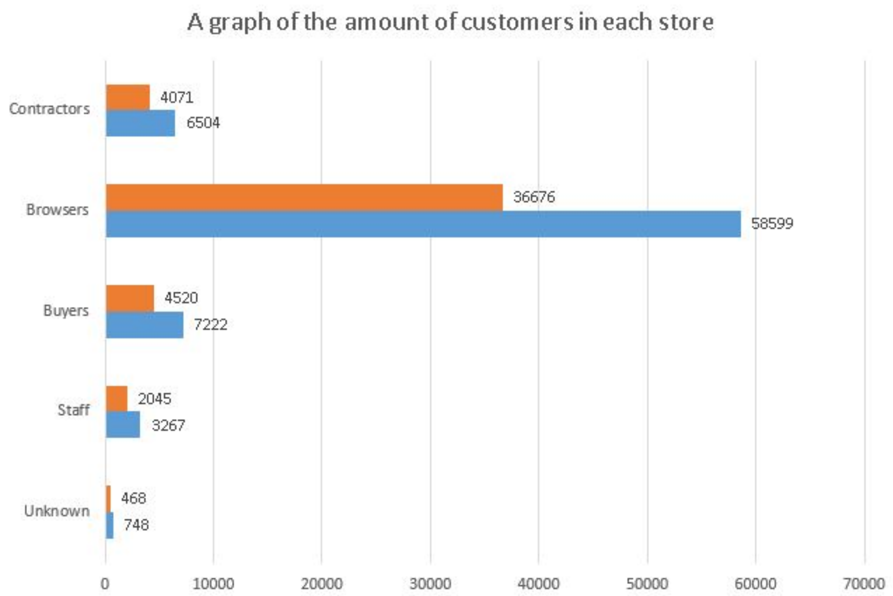

Figure 4.3: A graph of the amount of customers in each store for scenario one

Table 4.2: Floor space allocation in scenarios one and two for Store 1 and Store 2

	Store 1	
Department	Number of shelves	Floor space $[m^2]$
Entry Exit	2	6
Bath	15	266
Shower	13	44
Basin	8	54
DIY	1	40
Browse	6	20
Decorate	2	18
Tile	64	196
Buy	1	8
	Store 2	
Department	Number of shelves	Floor space $[m^2]$
Entry Exit	2	14
Bath	20	104
Shower	1	48
Basin	5	74
DIY	5	110
Browse	18	44
Decorate	116	180
Tile	51	135
Buy	1	12

4.2 Scenario Two: Customers Double

The second scenario that was done in this study is when the amount of pedestrians who enter the store are doubled. That is, each of the segments experience double the amount of pedestrians. In Scenario Two, the store layouts are the same as in Scenario One (refer to figures 4.1 on page 24 and 4.2 on page 25).

4.2.1 Segmentation of pedestrians

In this scenario the segmentation of the pedestrians is the same as in Scenario One, but the total number of pedestrians is more. The number of pedestrians can be seen in figure 4.4 on page 27.

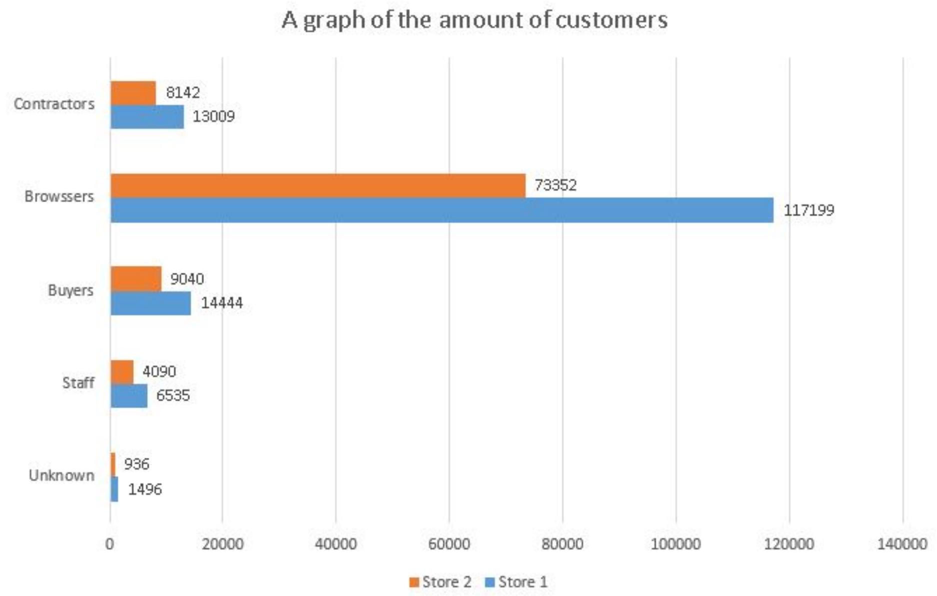

Figure 4.4: A graph of the amount of customers in each store for scenario two

The allocation of the floor space for each of the nine different departments is also exactly the same as in Scenario One (refer to table 4.2 on page 26).

4.3 Scenario Three: Layout Change

The third scenario was done to investigate the influence it will have on the pedestrian traffic in the store if the shelve layout is changed. The shelve layout was done by investigating where the high pedestrian foot traffic areas are in the store and moving the shelves around those areas.

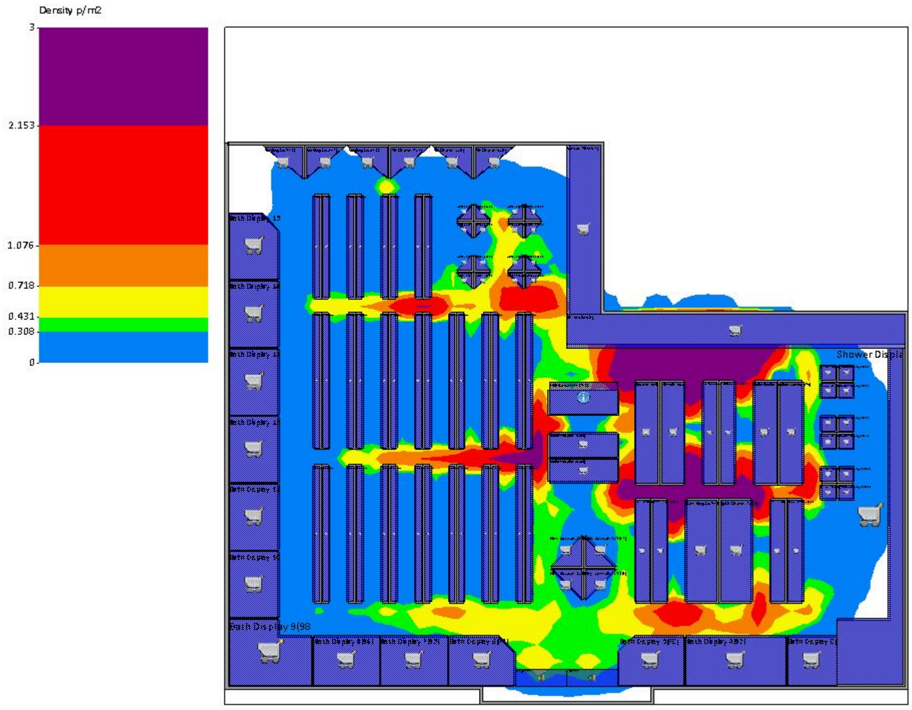

Figure 4.5: A screen shot of Monday's final simulation run, $n = 1$

In figure 4.5 the high pedestrian foot traffic areas are shown in purple. These areas were measured to determine where in the store the shelves needed to be moved. The shelves were moved to areas with low pedestrian foot traffic. Subsequently the shelves which were originally in low pedestrian foot traffic areas also had to be moved. The layouts of the stores are then showed in figure 4.6 on page 29 and figure 4.7 on page 30. In these figures the ECM network is also shown.

4.3.1 Segmentation of pedestrians

The segmentation of the pedestrians, as well as the total amount of pedestrians, is the same as in scenario one, as well as the data that was used to simulation this case.

However, the floor space allocation differs from Scenario One. When the layout was changed, it was aimed to keep the total amount of floor space of each the department the same as in Scenario One. The floor space allocation in this scenario is indicated in table 4.3.

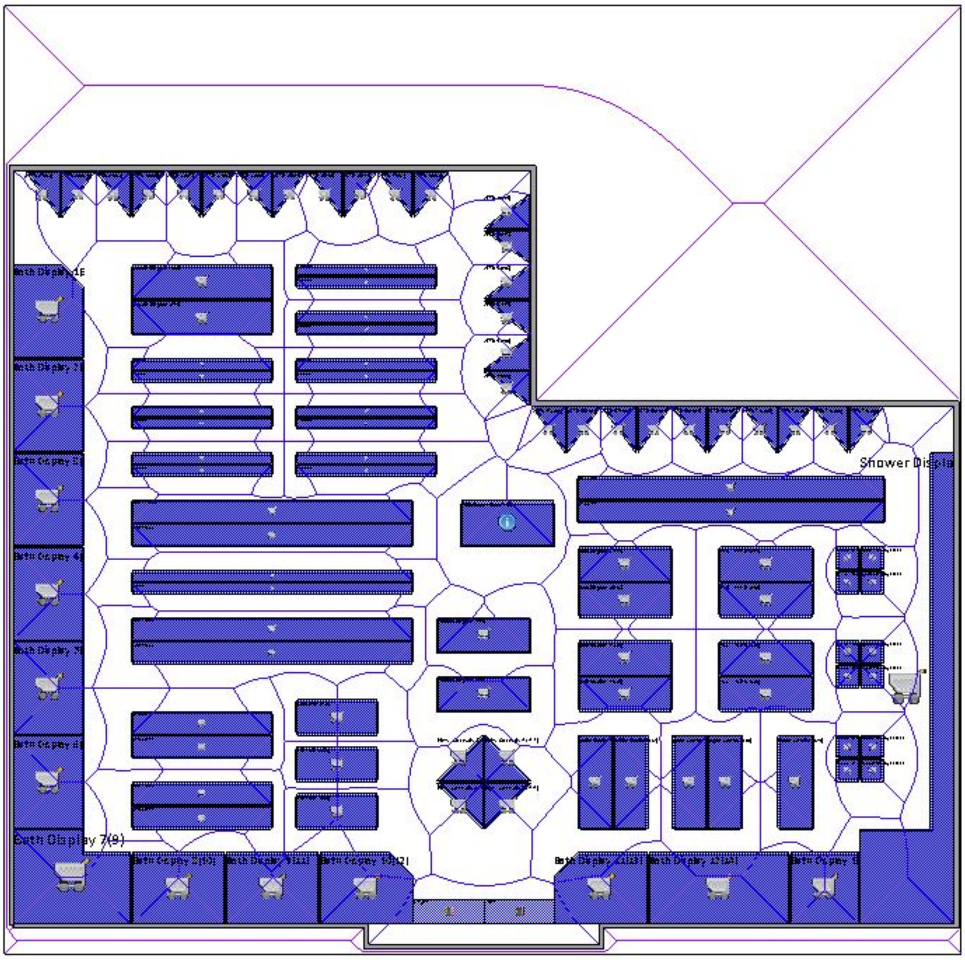

Figure 4.6: A diagram of the layout of Store 1 in scenario three

All of the data that is given in this chapter was used in the dynamic analysis described in section 3.4.

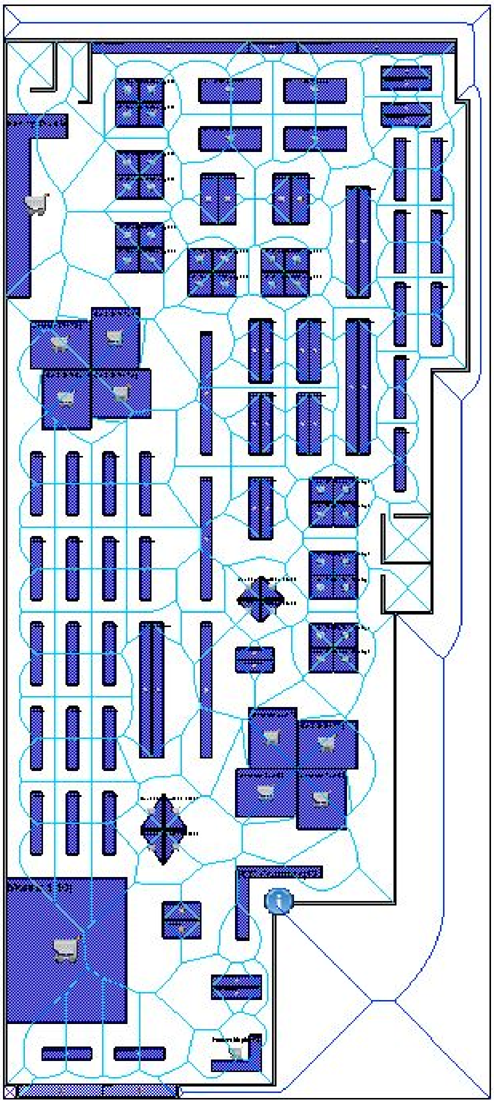

Figure 4.7: A diagram of the layout of Store 2 in scenario three

Table 4.3: Floor space allocation in scenario three for Store 1 and Store 2

	Store 1	
Department	Number of shelves	Floor space [m^2]
Entry Exit	2	6
Bath	13	44
Shower	13	44
Basin	9	54
DIY	2	26
Browse	6	20
Decorate	3	18
Tile	56	193
Buy	1	8
	Store 2	
Department	Number of shelves	Floor space [m^2]
Entry Exit	2	14
Bath	24	104
Shower	12	48
Basin	5	76
DIY	3	63
Browse	15	58
Decorate	16	207
Tile	40	246
Buy	1	12

Chapter 5

Results and Discussion

5.1 Scenario One Results

5.1.1 Store 1

Scenario One, which is the base case for the study, was done by running the simulation n times for each day. For the initial simulation runs, n was set to 10. These results are available in Appendix C.

For each simulation run the total area with the highest pedestrian frequency was measured. These measures were used to create comparison tables for each day. All of the comparison tables can be seen in Appendix D.

From the tables in Appendix D it can be seen that the confidence intervals for Monday and Tuesday have statistically higher values than the other days. The comparisons for Monday and Tuesday are shown in table 5.1 and table 5.2.

Table 5.1: Comparison table for Monday simulation results for Store 1

X_n	$\Delta_{Mon,Tue}$	$\Delta_{Mon,Wed}$	$\Delta_{Mon,Thur}$	$\Delta_{Mon,Fri}$	$\Delta_{Mon,Sat}$	$\Delta_{Mon,Sun}$
X_1	32.21315	42.85235	42.5987	43.3342	42.67435	43.3342
X_2	28.33595	40.11255	39.4163	40.11255	39.49795	40.11255
X_3	30.54064	38.65369	37.96494	37.81489	38.56924	38.653369
X_4	28.689275	42.582275	42.705825	43.050675	41.473975	43.050675
X_5	26.8507	39.5265	39.01835	39.5265	39.062	39.5265
X_6	29.89395	44.10275	43.754	44.10275	42.87645	44.10275
X_7	21.883	43.8612	44.9232	44.9232	44.11565	44.9232
X_8	29.73233	43.24758	43.71038	43.23168	42.88803	43.71038
X_9	29.10195	46.6183	45.69055	46.33665	46.79605	46.8607
X_{10}	26.31116	40.62986	40.79621	40.56076	40.13276	40.83406
CI	CI > 0	CI > 0	CI > 0	CI > 0	CI > 0	CI > 0

The number of simulation runs that are necessary to obtain statistically significant results was calculated using the formula 3.4.4 in section 3.4 on page 22. From

Table 5.2: Comparison table for Tuesday simulation results for Store 1

X_n	$\Delta_{Tue,Wed}$	$\Delta_{Tue,Thur}$	$\Delta_{Tue,Fri}$	$\Delta_{Tue,Sat}$	$\Delta_{Tue,Sun}$
X_1	10.6392	10.38555	11.12105	10.4612	11.12105
X_2	11.7766	11.08035	11.7766	11.162	11.7766
X_3	8.11305	7.4243	7.27425	8.0286	8.11305
X_4	13.893	14.01655	14.3614	12.7847	114.3614
X_5	12.6758	12.16765	12.6758	12.2113	12.6758
X_6	14.2088	13.86005	14.2088	12.9825	14.2088
X_7	21.9782	23.0402	23.0402	22.23265	23.0402
X_8	13.51525	13.97805	13.49935	13.1557	13.97805
X_9	17.51635	16.5886	17.2347	17.6941	17.75875
X_{10}	14.3187	14.48505	14.2496	13.8216	14.5229
CI	CI > 0	CI > 0	CI > 0	CI > 0	CI > 0

this calculation it can be seen that by choosing $h^* = 1.7$ for Monday and $h^* = 2.6$ for Tuesday, the amount of simulation runs which are necessary is $n^* = 13$. Monday's and Tuesday's simulations were run again, each for the recommended $n^* = 13$ simulation runs. The results for these simulations can be seen in Appendix E and Appendix F. Only the average of the high pedestrian frequencies were used to compare the three scenarios for Store 1.

The final results for the $n^* = 13$ simulation runs are shown in table 5.3 and table 5.4.

Table 5.3: Simulation results for Store 1 for Monday's final simulation runs

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	33.4062	0.1660	0.0276
X_2	36.1708	2.9305	8.5881
X_3	46.2311	12.9908	168.7615
X_4	34.2719	1.0317	1.0643
X_5	6.9323	-26.3080	692.1104
X_6	31.3393	-1.9010	3.6137
X_7	31.9172	-1.3231	1.7505
X_8	29.7235	-3.5168	12.3676
X_9	40.5856	7.3454	53.9543
X_{10}	37.6678	4.4275	19.6028
X_{11}	32.4201	-0.8201	0.6726
X_{12}	38.2173	4.9771	24.7712
X_{13}	31.7869	-1.4534	2.1123
		$\overline{X} = 33.2403$	$(S_x)^2 = 109.9330$
			$S_x = 10.48489$

Table 5.4: Simulation results for Store 1 for Tuesday's final simulation runs

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	19.0974	3.7817	14.3013
X_2	16.5986	1.2829	1.6460
X_3	11.4195	-3.8962	15.1804
X_4	13.3383	-1.9774	3.9100
X_5	23.3987	8.0830	65.3351
X_6	10.3941	-4.9215	24.2214
X_7	12.0137	-3.3019	10.9027
X_8	17.8583	2.5427	6.4652
X_9	15.0909	-0.2248	0.0505
X_{10}	18.5886	3.2729	10.7121
X_{11}	16.6323	1.3166	1.7336
X_{12}	9.3575	-5.9581	35.4995
X_{13}	11.7044	-3.6113	13.0412
		$\overline{X} = 15.3157$	$(S_x)^2 = 22.5554$
			$S_x = 4.7493$

The results show that the average high-density floor space for Monday is $33.4m^2$, and the average for Tuesday is $15.3m^2$. These are the results that will be used when comparing the results of the three scenarios.

5.1.2 Store 2

The initial n simulation runs was also set to $n = 10$ for Store 2. All of the results for the simulation runs is available in Appendix G. The areas with the highest pedestrian frequencies were measured, and comparison tables (Appendix H) were created using these results.

The confidence intervals indicate that Wednesday have more statistically relevant results compared to the other days. The comparison table for Wednesday is shown in table 5.5

The calculated confidence interval is larger than zero for each comparison. This indicated that it is only necessary to run the final simulation for Wednesday, as this is the only day on which there is a pedestrian flow issue. The number of simulation runs that are necessary to obtain statistically significant results was calculated using the formula 3.4.4 in 3.4.

From these calculations it was determined that by choosing $h^* = 141$ the necessary amount of simulation runs is $n^* = 11$. The simulation for Wednesday was run again for the calculated $n^* = 11$ simulation runs. The results for these simulation runs can be seen in I. The average of the areas with the highest pedestrian frequencies will be used in the comparison with scenario two and scenario three for Store 2.

The final results for the $n^* = 11$ simulation runs are shown in table 5.6.

Table 5.5: Comparison table for Wednesday's results for Store 2

X_n	$\Delta_{Tue,Wed}$	$\Delta_{Tue,Thur}$	$\Delta_{Tue,Fri}$	$\Delta_{Tue,Sat}$	$\Delta_{Tue,Sun}$	
X_1	27.1595	27.1595	27.1595	27.1595	27.1595	27.1595
X_2	200.3899	200.3899	200.3899	200.3899	200.3899	200.3899
X_3	322.7771	322.7771	322.7771	322.7771	322.7771	322.7771
X_4	352.3830	352.3830	352.3830	352.383	352.383	352.383
X_5	620.6862	620.6862	620.6862	620.6862	620.6862	620.6862
X_6	27.3979	27.3979	27.3979	27.3979	27.3979	27.3979
X_7	305.2921	305.2921	305.2921	305.2921	305.2921	305.2921
X_8	20.1852	20.1852	20.1852	20.18515	20.18515	20.18515
X_9	14.5785	14.5785	14.5785	14.57848	14.57848	14.57848
X_{10}	242.3368	242.3368	242.3368	242.3368	242.3368	242.3368
Δ_{avg}	213.3186	213.3186	213.3186	213.3186	213.3186	213.3186
σ_Δ	197.9777	197.9777	197.9777	197.9777	197.9777	197.9777
t	2.2622	2.2622	2.2622	2.2622	2.2622	2.2622
h	141.6247	141.6247	141.6247	141.6247	141.6247	141.6247

Table 5.6: Final simulation results for Store 2 for a Wednesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	249.3275	29.1286	848.4767
X_2	405.0762	184.8773	34179.6189
X_3	105.1783	-115.0206	13229.7312
X_4	31.2613	-188.9375	35697.3828
X_5	368.2254	148.0265	21911.8534
X_6	267.2357	47.0368	2212.4625
X_7	396.6375	176.4386	31130.5971
X_8	13.5912	-206.6077	42686.7340
X_9	202.3120	-17.8869	319.9397
X_{10}	163.1435	-57.0553	3255.3085
X_{11}	21.2290	-198.9698	39588.9794
		$\overline{X} = 220.1988$	$(S_x)^2 = 25006.7871$
			$S_x = 158.1353$

It can be seen from the results that the average high-density floor space is $220.5m^2$ for scenario Store 2.

5.2 Scenario Two Results

5.2.1 Store 1

In scenario two the amount of pedestrians that enter the store was doubled. This was done by doubling the number of pedestrians that enter the store in each hour-interval, for each day, and computing the new parameters of the distributions in MATLAB.

The initial simulation runs for each day was set to $n = 10$ to determine the amount of simulation runs that are necessary for the final runs. The results for these simulation runs are available in Appendix J.

The total area of the high-density pedestrian frequency was again measured to have a comparable value for the simulation. These areas were used to create comparison tables to find out which days had the most high-density areas of the pedestrians. The comparison tables for all of the days can be viewed in Appendix K.

From the results it is clear that, as in scenario one, the simulations for Monday and Tuesday have the most high-density areas, which pose a problem in the layout of the shelves. The comparisons are shown in tables 5.7 and 5.8.

Table 5.7: Comparison table for Monday's simulation results for Store 1

X_n	$\Delta Mon, Tue$	$\Delta Mon, Wed$	$\Delta Mon, Thur$	$\Delta Mon, Fri$	$\Delta Mon, Sat$	$\Delta Mon, Sun$
X_1	23.15815	36.023	35.387265	36.1931	35.579969	36.1931
X_2	28.8223	38.55445	37.9702695	38.59145	37.190018	38.59145
X_3	20.9794	33.34515	33.333248	33.5592	33.113698	33.5592
X_4	17.918	37.277941	37.422154	37.53731	37.104517	37.5589
X_5	27.75085	36.288861	35.4697735	36.785441	35.598156	36.81155
X_6	22.5815	33.877163	34.0079185	33.961776	32.2096615	34.3182
X_7	24.19605	40.46285	39.744035	40.316668	39.028068	40.46285
X_8	24.7571	34.000899	33.7196585	34.2512	33.379401	34.2512
X_9	8.82673	29.688458	29.6302235	30.09065	29.3521425	30.10578
X_{10}	16.06185	35.92355	35.20174	35.774202	35.620685	35.92335
CI	CI > 0	CI > 0	CI > 0	CI > 0	CI > 0	CI > 0

To calculate the amount of simulation runs that are necessary to obtain statistically significant results, the formula 3.4.4 in section 3.4 was used. From the calculations it can be seen that by choosing $h^* = 2$ for Monday, and $h^* = 3.3$ for Tuesday the amount of necessary simulation runs are $n^* = 13$. The simulations for Monday and Tuesday were run again for the calculated $n^* = 13$ runs. The results

Table 5.8: Comparison table for Tuesday's simulation results for Store 1

X_n	$\Delta Tue, Wed$	$\Delta Tue, Thur$	$\Delta Tue, Fri$	$\Delta Tue, Sat$	$\Delta Tue, Sun$
X_1	12.86485	12.229115	13.03495	12.421819	13.03495
X_2	9.73215	9.1479695	9.76915	8.367718	9.76915
X_3	12.36575	12.353848	12.5798	12.134298	12.5798
X_4	19.359941	19.504154	19.61931	19.186517	19.6409
X_5	8.538011	7.7189235	9.034591	7.847306	9.0607
X_6	11.295663	111.4264185	11.380276	9.6281615	11.7367
X_7	16.2668	15.547985	16.120618	14.832018	16.2668
X_8	9.243799	8.9625585	9.4941	8.622301	9.4941
X_9	20.861728	20.8034935	21.26392		21.27905
X_{10}	19.8617	19.13989	19.712352	19.558835	19.8617
CI	CI > 0	CI > 0	CI > 0	CI > 0	CI > 0

for these simulations can be seen in Appendix L and Appendix M. The average of these simulation runs will be used to compare scenario two with scenarios one and three. The final results for the $n^* = 13$ simulation runs can be seen in table 5.9 and table 5.10.

Table 5.9: Final simulation results for Store 1 for a Monday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	17.6446	4.9614	24.6159
X_2	11.1434	-1.5398	2.3708
X_3	14.5480	1.8649	3.4778
X_4	9.8921	-2.7910	7.7898
X_5	13.5752	0.8921	0.7958
X_6	14.0080	1.3249	1.7554
X_7	13.7858	1.1027	1.2159
X_8	8.6325	-4.0507	16.4078
X_9	13.5922	0.9091	0.8264
X_{10}	8.6325	-3.0645	9.3909
X_{11}	3.5398	-9.1434	83.6008
X_{12}	23.8185	11.1354	123.9971
X_{13}	11.0819	-1.6013	2.5641
		$\overline{X} = 12.6831$	$(S_x)^2 = 30.9787$
			$S_x = 5.5659$

The results show that the average high-density floor space for Monday is $34.2m^2$, and the average for Tuesday is $12.7m^2$. These are the results that will be used when comparing the results of the three scenarios.

Table 5.10: Final simulation results for Store 1 for a Tuesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	26.7709	-7.3796	54.4578
X_2	37.8005	3.6500	13.3227
X_3	34.5152	0.3648	0.1331
X_4	37.4907	3.3402	11.1569
X_5	20.6329	-13.5175	182.7238
X_6	36.5633	2.4129	5.8219
X_7	35.0113	0.8609	0.7411
X_8	25.8195	-8.3310	69.4056
X_9	38.3917	4.2412	17.9879
X_{10}	41.4750	7.3246	53.6491
X_{11}	38.0729	3.9225	15.3857
X_{12}	38.5799	4.4294	19.6198
X_{13}	32.8322	-1.3183	1.7379
		$\overline{X} = 34.1505$	$(S_x)^2 = 10.5715$
			$S_x = 7.0407$

5.2.2 Store 2

Each day's simulation was also run for the initial $n = 10$ simulation runs. All of the results are available in Appendix N. Once again, the areas with the highest pedestrian densities were measured and were used to determine the amount of simulation runs that are necessary to obtain statistically significant results.

Comparison tables were created with the results form the simulation runs. These comparison tables (Appendix O) were used to calculate the optimal amount of simulation runs that are necessary. The simulation runs for Wednesday are the only runs to produce high-pedestrian densities. The comparison table for Wednesday is shown below.

The confidence intervals for Wednesday, compared to all the other days, is larger than zero. This indicates that Wednesday is the only day that is necessary to run for the final simulation runs. To calculate the final number of simulation runs were calculated using the equation in section 3.4.

The necessary amount of simulation runs that are necessary is $n^* = 11$ is by choosing $h^* = 128$. The Wednesday simulation was run again for $n^* = 11$ runs, and these results can be seen in Appendix P. The areas with the highest pedestrian densities was averaged to use as a comparison with the other scenarios. The final results for the $n^* = 11$ simulation runs are shown in the table below.

It can be seen from the results that the average of thee high-density floor space is $246.3m^2$ for scenario two Store 2.

Table 5.11: Comparison table for Wednesday's results for Store 2

X_n	$\Delta_{Wed,Thur}$	$\Delta_{Wed,Fri}$	$\Delta_{Wed,Sat}$	$\Delta_{Wed,Sun}$
X_1	383.0771	383.0771	383.0771	383.0771
X_2	21.3704	21.3704	21.3704	21.3704
X_3	17.9851	17.9851	17.9851	17.9851
X_4	382.2835	382.2835	382.2835	382.2835
X_5	416.9726	416.9726	416.9726	416.9726
X_6	382.9246	382.9246	382.9246	382.9246
X_7	401.0823	401.0823	401.0823	401.0823
X_8	16.7027	16.7027	16.7027	16.7027
X_9	331.4264	331.4264	331.4264	331.4264
X_{10}	113.0653	113.0653	113.0653	113.0653
Δ_{avg}	246.6890	246.6890	246.6890	246.6890
σ_Δ	179.3150	179.3150	179.3150	179.3150
t	2.2622	2.2622	2.2622	2.2622
h	128.2742	128.2742	128.2742	128.2742

Table 5.12: Simulation results for Store 2 for Wednesday's final simulation runs

Xn	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	432.3656	186.0972	34632.1620
X_2	260.1692	13.9008	193.2321
X_3	22.1628	-224.1055	50223.2950
X_4	147.8710	-98.3974	9682.0502
X_5	365.7379	119.4695	14272.9635
X_6	154.2676	-92.0008	8464.1383
X_7	423.9917	177.7233	31585.5755
X_8	43.7385	-202.5299	41018.3591
X_9	241.9252	-4.3432	18.8635
X_10	246.9292	0.6608	0.4367
X_11	369.7936	123.5252	15258.4779
		$\overline{X} = 246.2684$	$(S_x)^2 = 22816.6171$
			$S_x = 151.0517$

5.3 Scenario Three Results

5.3.1 Store 1

In scenario three, the store layout was changed. The layout changes was done by looking at the high-density areas in the first two scenarios, and changing the layout around these high pedestrian density areas. The layout of Store 1 can be seen in figure 4.6 on page 29. The initial amount of simulations was again set to $n = 10$. The results for these 10 simulation runs can be seen in Appendix Q.

In each simulation, the areas with the highest pedestrian frequency was measured, and added to determine the total area. These measures were used to create comparison tables for the simulation of each day. All of the comparison tables can also be seen in Appendix R.

The results indicate that, unlike the first two scenarios, the simulation runs for Monday are the only results with confidence intervals higher than zero when comparing the results to that of the other days. This indicated that only Monday have statistically higher values than the other days. The comparison table for Monday's simulation runs is shown below.

Table 5.13: Comparison table for Monday's results for Store 1

X_n	$\Delta_{Mon,Tue}$	$\Delta_{Mon,Wed}$	$\Delta_{Mon,Thur}$	$\Delta_{Mon,Fri}$	$\Delta_{Mon,Sat}$	$\Delta_{Mon,Sun}$
X_1	49.7518	49.6875	45.7068	49.1953	49.0609	49.6323
X_2	48.8392	49.3461	49.0571	48.1693	47.3703	49.3116
X_3	40.1280	39.9792	40.7923	40.9754	40.5658	41.6757
X_4	43.8136	43.7408	43.1667	44.3494	43.2092	44.6950
X_5	44.2753	44.5636	44.6670	44.7873	44.4179	45.4163
X_6	44.6446	44.0386	44.5738	44.8180	43.5333	44.7055
X_7	54.3213	54.2862	54.8313	54.2701	54.5601	55.4400
X_8	43.9193	44.2107	44.5458	44.6761	43.5083	44.3197
X_9	49.3199	49.2716	48.9160	50.0292	48.4678	50.3758
X_{10}	56.9595	56.5902	56.7414	56.7314	57.8409	57.8409
Δ_{avg}	47.5972	47.5715	47.2998	47.80014	47.253442	48.3412785
σ_Δ	5.2218	5.1863	5.1151	4.886414	5.4489874	5.19673877
t	2.2622	2.2622	2.2621572	2.262157	2.2621572	2.26215716
h	3.7354	3.7101	3.6591548	3.49553	3.8979708	3.71752297

To determine the number of runs that is necessary to obtain statistically significant results equation 3.4.4 in section 3.4 was used. Using this equation it was determined that by choosing $h^* = 3.6$ the amount of simulation runs which are necessary is $n^* = 13$. Monday's simulations were run again for the calculated amount of n^* simulation runs. The results for this simulation runs can be seen below, as well as in Appendix S. The average of the $n^* = 13$ simulation runs is used to compare the results with the previous scenarios for Store 1.

Table 5.14: Final simulation results for Store 1 for a Monday

Xn	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	39.7942	-9.2469	85.5043
X_2	42.5570	-6.4841	42.0431
X_3	49.2902	0.2492	0.0621
X_4	46.6966	-2.3445	5.4965
X_5	43.7818	-5.2592	27.6591
X_6	48.0884	-0.9527	0.9076
X_7	46.9977	-2.0434	4.1753
X_8	46.4041	-2.6369	6.9534
X_9	46.9398	-2.1012	4.4150
X_{10}	45.8463	-3.1947	10.2063
X_{11}	46.2506	-2.7904	7.7865
X_{12}	44.9032	-4.1378	17.1213
X_{13}	89.9835	40.9425	1676.2857
		$\overline{X} = 49.0410$	$(S_x)^2 = 209.8462$
			$S_x = 14.4861$

The results indicate that the average high-density floor space for Monday is $49.04m^2$.

5.3.2 Store 2

The initial n simulation runs was also set to $n = 10$ for Store 2. All of the results for the different days are available in Appendix T. The high pedestrian density areas were measured to create a comparison table for the different days.

From the comparison tables in Appendix U it can be seen that the simulation runs for Wednesday are the only runs which yield confidence intervals that is larger than zero. This suggests that only Wednesday have statistically higher values than the other days, and it is only necessary to run the final amount of simulation runs for Wednesday. The comparison table for Wednesday is shown below.

The amount of simulation runs which are necessary to obtain statistically significant results was calculated by using equation 3.4.4 in 3.4. From these calculation it was determined that by choosing $h^* = 10.3$ the necessary amount of simulation runs is $n^* = 11$. The simulation for Wednesday was run again for the calculated $n^* = 11$ simulation runs. The results for these simulation runs can be seen in V. The average of the areas with the high pedestrian densities will be used for the result comparison with scenarios one and two. The final results for the $n^* = 11$ simulation results are

Table 5.15: Simulation results for Store 2 for a Wednesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	76.6861	-14.8730	221.2066
X_2	72.0067	-19.5524	382.2974
X_3	82.4810	-9.0782	82.4130
X_4	76.0663	-15.4928	240.0283
X_5	74.5423	-17.0168	289.5722
X_6	74.7502	-16.8089	282.5389
X_7	143.6341	52.0749	2711.8000
X_8	136.6037	45.0446	2029.0133
X_9	84.9641	-6.5950	43.4946
X_{10}	93.8568	2.2977	5.2794
		$\overline{X} = 91.5591$	$(S_x)^2 = 698.6271$
			$S_x = 26.4316$

shown below.

Table 5.16: Comparison table for Wednesday's results for Store 2

X_n	$\Delta_{Mon,Thur}$	$\Delta_{Mon,Fri}$	$\Delta_{Mon,Sat}$	$\Delta_{Mon,Sun}$
X_1	76.6861	76.6861	76.6861	76.6861
X_2	72.0067	72.0067	72.0067	72.0067
X_3	82.4810	82.4810	82.4810	82.4810
X_4	76.0663	76.0663	76.0663	76.0663
X_5	74.5423	74.5423	74.5423	74.5423
X_6	74.7502	74.7502	74.7502	74.7502
X_7	143.6341	143.6341	143.6341	143.6341
X_8	136.6037	136.6037	136.6037	136.6037
X_9	84.9641	84.9641	84.9641	84.9641
X_{10}	93.8568	93.8568	93.8568	93.8568
Δ_{avg}	91.5591	91.5591	91.5591	91.5591
σ_Δ	26.4316	26.4316	26.4316	26.4316
t	2.2622	2.2622	2.2622	2.2622
h	18.9080	18.9080	18.9080	18.9080

It can be seen from the results that the average of high-density floor space is $106.2m^2$ for scenario three in Store 2.

5.4 Scenario Comparisons

5.4.1 Scenario One and Scenario Two

When comparing the results for the scenarios it is necessary to keep in mind what the differences between the scenarios are. In the comparison between scenario one and two, the only difference is the number of customer that enter the store. The customers were doubled for scenario two, as opposed to the normal amount of customers in scenario one.

The results for scenario one indicated that for Store 1 the average area of floor space with the highest pedestrian density is $33.2m^2$ for Monday's simulation runs and $15.3m^2$ for Tuesday's simulation runs. From this it is already clear that the pedestrian traffic is more than doubled on a Monday compared to a Tuesday. However, for the sake of completeness of scenarios one and two, both scenarios will be used for comparison of Store 1.

From the final simulation results for scenario two Store 1 the average high-density floor space is $34.2m^2$ for Monday's simulation runs, and $12.7m^2$ for Tuesday's simulation runs. The comparison of the results of Store 1 indicates that there is not much of a difference between the two scenarios for Store 1:

$$\Delta Monday_{Scenario1-Scenario2} = 33.2403 - 34.1505 = -0.9102m^2 \tag{5.4.1}$$

$$\Delta Tuesday_{Scenario1-Scenario2} = 15.3157 - 12.6831 = 2.6326m^2 \tag{5.4.2}$$

The results for Store 2 indicate that for scenario one the average floor space of the shop with the highest pedestrian density is $220.2m^2$. For both scenarios one and two it was only necessary to run the final simulations for Wednesday. After the changes were brought about regarding the amount of pedestrians that enter the store, the average amount of floor space with the highest amount of pedestrian traffic is $246.3m^2$.

$$\Delta Wednesday_{Scenario1-Scenario2} = 220.1988 - 246.2684 = -26.0696m^2 \tag{5.4.3}$$

This comparison indicate that the pedestrian traffic is not as negligible as with store 1, but the differences between scenarios one and two is not as large as what could be expected. This could be attributed to the fact that the segments would still enter the store at the same time that they would in scenario one, and thus not create more pedestrian traffic than under normal pedestrian densities.

5.4.2 Scenario One and Scenario Three

The main difference between these two scenarios is the layout between each of the stores, 5.17

Table 5.17: Floor space allocation comparison of Store 1

Description	Scenario One		Scenario Three	
	Amount	Floor space m^2	Amount	Floor space m^2
Entry	1	3	1	3
Exit	1	3	1	3
Point of sale	1	8	1	8
Product display	2	12	2	12
New arrivals	4	8	4	8
Lifestyle	2	18	3	18
DIY	1	40	2	26
Bath display	15	266	13	266
Wash cabinets	4	24	4	24
Vanity combo	4	30	5	30
Shower display	13	44	13	44
Mosaic display	1	20	2	18
Tile display	63	175	54	175
Total	115	651	105	635

The layout for both Store 1 and Store 2 was done by changing the shelve layout around the high pedestrian traffic areas found in scenario one. In the comparison table it is clear that the floor space which the shelves occupy are less than in the original scenario. This would lead to the expectation that the pedestrian traffic would be less in scenario three than in scenario one. It was only necessary to complete the final simulation runs for scenario three for a Monday, thus only Monday will be used in the comparison between scenarios one and three.

From the final simulation results it can be seen that for Store 1 the simulation runs have the following results. Monday's simulation runs indicate that there is an average area of $33.2m^2$ with high pedestrian traffic. When the layout is changed the results indicate that for Monday there is an average area of $49.04m^2$.

$$\Delta Monday_{Scenario1-Scenario3} = 33.2403 - 49.0410 = -15.8007m^2 \tag{5.4.4}$$

This calculation illustrates that although it was expected that the average areas of high pedestrian traffic would decrease with the layout change, the opposite occurred and the pedestrian traffic increased.

In the comparison of Store 2, the floor space that the shelves occupy in scenario three is $3m^2$ less that in scenario one. This would lead to the expectation that the

Table 5.18: Floor space allocation of Store 2

Description	Scenario One		Scenario Three	
Amount	Floor space m^2	Amount	Floor space m^2	
Entry	1	7	1	7
Exit	1	7	1	7
Point of sale	1	12	1	12
Product display	2	6	1	6
On promotion	6	10	4	14
What's hot	2	8	2	8
Department 38	4	12	4	12
Department 24	4	8	4	8
Lifestyle	16	180	16	207
DIY	2	80	3	33
Mosaic display	1	40	1	40
Tile display	50	195	39	206
Shower display	1	48	12	48
Bath display	20	104	24	104
Vanity display	1	36	1	36
Wash cabinets	4	38	4	40
Accessories	3	30	3	30
Total	119	821	121	818

pedestrian traffic should decrease for scenario three.

The final simulation results show that for scenario one the average area of high pedestrian traffic is $220.2m^2$ for scenario one. For Store 2 the average of the high pedestrian traffic area is $106.2m^2$.

$$\Delta Wednesday_{Scenario1-Scenario3} = 220.1988 - 106.1688 = 114.0311m^2 \qquad (5.4.5)$$

The difference between scenarios one and three is larger than zero, which indicates that the pedestrian traffic did in fact decrease. This was expected because the shelves around the high-density pedestrian traffic areas was moved.

Chapter 6

Conclusion and further Recommendations

In this chapter the limitations of the study are presented. Future research is also discussed.

6.1 Limitations of Study

With most research that is conducted in different fields, there are certain aspects which cannot necessarily be brought into consideration. This may be due to the fact that the information wasn't available, of that aspect was not considered to have a significant effect on the outcomes of the research. In this study, there are also limitations. The first limitation is the variables in the data that was provided. From the data provided is wasn't possible to calculate the speed at which the pedestrians travel for the different segmentations. To accommodate this, the average time that all of the customers spent in the store, and use that to calculate the speed at which they travelled. Another limitation is the time that each pedestrian spends in the different departments. This would have a significant influence on the pedestrian traffic occurrences in the stores.

The third limitation is the period over which the data was gathered. If the data was gathered over a longer period than a year, the customer segments could have been more detailed, and the customers in the Unknown segment could be placed in another segment. The information about the customer behaviour in each store would also have been more detailed, giving more information regarding the speed of the pedestrians, and the time spent at each department.

6.2 Recommendations for Further Research

If this research is taken further I would recommend the following two aspects. The first is that the data should be taken over a longer period of time, and should be more detailed. This would result in a more realistic simulation model. The results of this more realistic simulation model could be of greater significance to store management, who can use the results to change the store layouts to receive a greater revenue.

The other suggestion for future research is to explore different store layouts, in order to investigate the pedestrian traffic to a further extent.

An extension of this research could also be to apply this scenarios to a shopping centre, instead of a single store at a time.

6.3 Conclusion

In chapter 3 the objective was stated as the determining of a shelve layout in a store, as well as the accompanying product placement, to ensure that the customers experience a more enjoyable shopping experience. To determine the enjoyment which the customers experience, the amount of pedestrian traffic that is experienced in the store was addressed.

The data that was collected over a period of a year, was analysed using the MAC Id's to place the customers in different segments. These segments are contractors, browsers, buyers, staff, and unknown. More information about the customer segmentation can be found in section 3.3.

Two case studies were conducted, each representing a different store. In these case studies three scenarios were presented. Scenario one is the stores as it is. This scenario was used as the base case in the comparison with the other two scenarios. Scenario two is when the amount of customers who enter the store double. The last scenario is when the layout of the store is changed. The layout was changed by moving the shelves from where the highest pedestrian traffic was encountered in scenario one.

Two comparisons were made in each case study. The first is a comparison between scenarios one and two, and the other is made between scenario one and scenario three. The following results were found when the three scenarios were compared with each other. For the first case study (refer to section 5.4.1) it was determined that the pedestrian traffic does not differ much for scenarios one and two. For the Monday simulations the pedestrian traffic was $0.9102m^2$ less in scenario one, and for Tuesday the pedestrian traffic was $2.6326m^2$ less in scenario two. It can thus not be said that the doubling of the amount of customers would have a significant impact on the pedestrian traffic in the current layout.

In the comparison for scenarios one and two for the second case study, it was found that scenario two leads to $26.0696m^2$ more pedestrian traffic than scenario one. It is not recommended that the store invests in marketing campaigns to gather more customers with the current store layout.

The second comparison is between scenario one and scenario three. In this comparison for the first case study it was found that, although the layout is changed, scenario one has $15.8007m^2$ less pedestrian traffic than scenario three. The layout change that is proposed in scenario three for the first case study is consequently not a better alternative to the current layout.

For the second case study the comparison between scenario one and scenario three yields a different result. It was determined that the proposed layout in scenario three for the second case study has $114.0311m^2$ less pedestrian traffic than in scenario one. It is thus a better alternative to the current store layout in the second case study.

For future research in this topic it is proposed to investigate alternative layouts, to decrease the amount of pedestrian traffic as much as possible.

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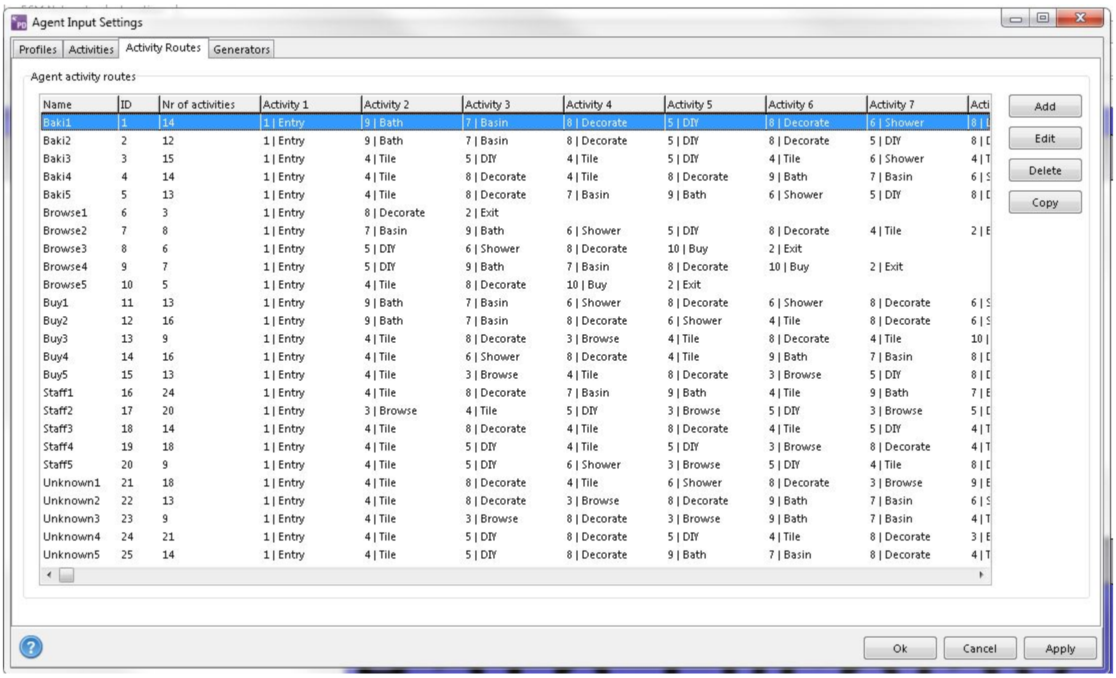
Appendices

Appendix A

Appendix A



Name	ID	Nr of activities	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 7	Acti
Baki1	1	14	1 | Entry	9 | Bath	7 | Basin	8 | Decorate	5 | DIY	8 | Decorate	6 | Shower	8 | D
Baki2	2	12	1 | Entry	9 | Bath	7 | Basin	8 | Decorate	5 | DIY	8 | Decorate	5 | DIY	8 | D
Baki3	3	15	1 | Entry	4 | Tile	5 | DIY	4 | Tile	5 | DIY	4 | Tile	6 | Shower	4 | T
Baki4	4	14	1 | Entry	4 | Tile	8 | Decorate	4 | Tile	8 | Decorate	9 | Bath	7 | Basin	6 | S
Baki5	5	13	1 | Entry	4 | Tile	8 | Decorate	7 | Basin	9 | Bath	6 | Shower	5 | DIY	8 | D
Browse1	6	3	1 | Entry	8 | Decorate	2 | Exit					
Browse2	7	8	1 | Entry	7 | Basin	9 | Bath	6 | Shower	5 | DIY	8 | Decorate	4 | Tile	2 | E
Browse3	8	6	1 | Entry	5 | DIY	6 | Shower	8 | Decorate	10 | Buy	2 | Exit		
Browse4	9	7	1 | Entry	5 | DIY	9 | Bath	7 | Basin	8 | Decorate	10 | Buy	2 | Exit	
Browse5	10	5	1 | Entry	4 | Tile	8 | Decorate	10 | Buy	2 | Exit			
Buy1	11	13	1 | Entry	9 | Bath	7 | Basin	6 | Shower	8 | Decorate	6 | Shower	8 | Decorate	6 | S
Buy2	12	16	1 | Entry	9 | Bath	7 | Basin	8 | Decorate	6 | Shower	4 | Tile	8 | Decorate	6 | S
Buy3	13	9	1 | Entry	4 | Tile	8 | Decorate	3 | Browse	4 | Tile	8 | Decorate	4 | Tile	10 |
Buy4	14	16	1 | Entry	4 | Tile	6 | Shower	8 | Decorate	4 | Tile	9 | Bath	7 | Basin	8 | D
Buy5	15	13	1 | Entry	4 | Tile	3 | Browse	4 | Tile	8 | Decorate	3 | Browse	5 | DIY	8 | D
Staff1	16	24	1 | Entry	4 | Tile	8 | Decorate	7 | Basin	9 | Bath	4 | Tile	9 | Bath	7 | E
Staff2	17	20	1 | Entry	3 | Browse	4 | Tile	5 | DIY	3 | Browse	5 | DIY	3 | Browse	5 | D
Staff3	18	14	1 | Entry	4 | Tile	8 | Decorate	4 | Tile	8 | Decorate	4 | Tile	5 | DIY	4 | T
Staff4	19	18	1 | Entry	4 | Tile	5 | DIY	4 | Tile	5 | DIY	3 | Browse	8 | Decorate	4 | T
Staff5	20	9	1 | Entry	4 | Tile	5 | DIY	6 | Shower	3 | Browse	5 | DIY	4 | Tile	8 | D
Unknown1	21	18	1 | Entry	4 | Tile	8 | Decorate	4 | Tile	6 | Shower	8 | Decorate	3 | Browse	9 | E
Unknown2	22	13	1 | Entry	4 | Tile	8 | Decorate	3 | Browse	8 | Decorate	9 | Bath	7 | Basin	6 | S
Unknown3	23	9	1 | Entry	4 | Tile	3 | Browse	8 | Decorate	3 | Browse	9 | Bath	7 | Basin	4 | T
Unknown4	24	21	1 | Entry	4 | Tile	5 | DIY	8 | Decorate	5 | DIY	4 | Tile	8 | Decorate	3 | E
Unknown5	25	14	1 | Entry	4 | Tile	5 | DIY	8 | Decorate	9 | Bath	7 | Basin	8 | Decorate	4 | T

Figure A.1: A screen shot of the different activity routes for store 1

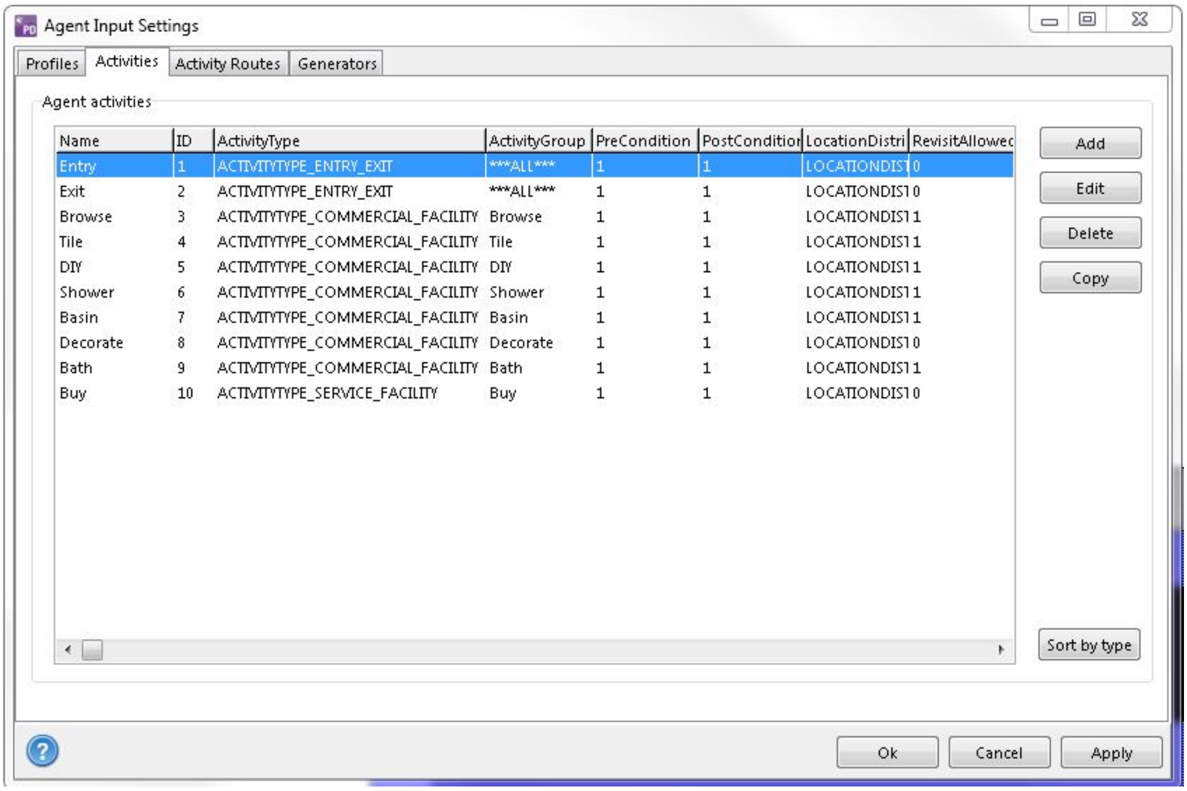


Figure A.2: A screen shot of the different departments that a pedestrian can visit in store 1

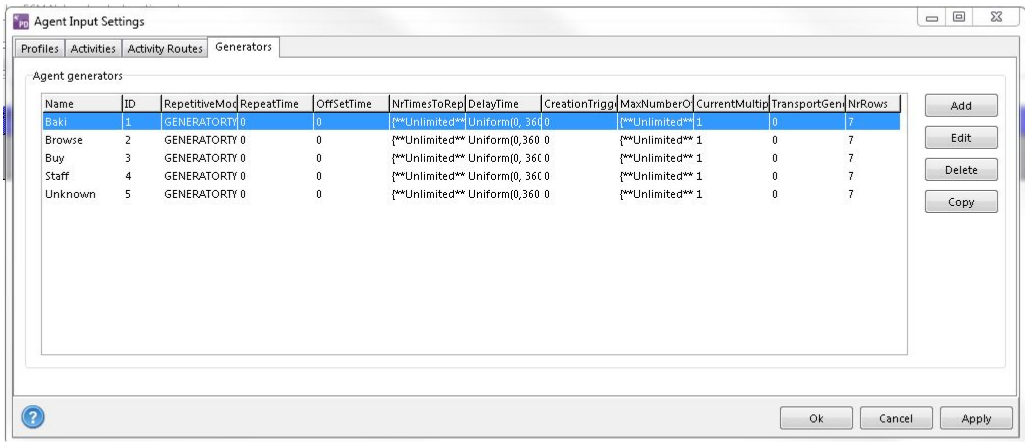


Figure A.3: A screen shot of how the agents were entered for store 1

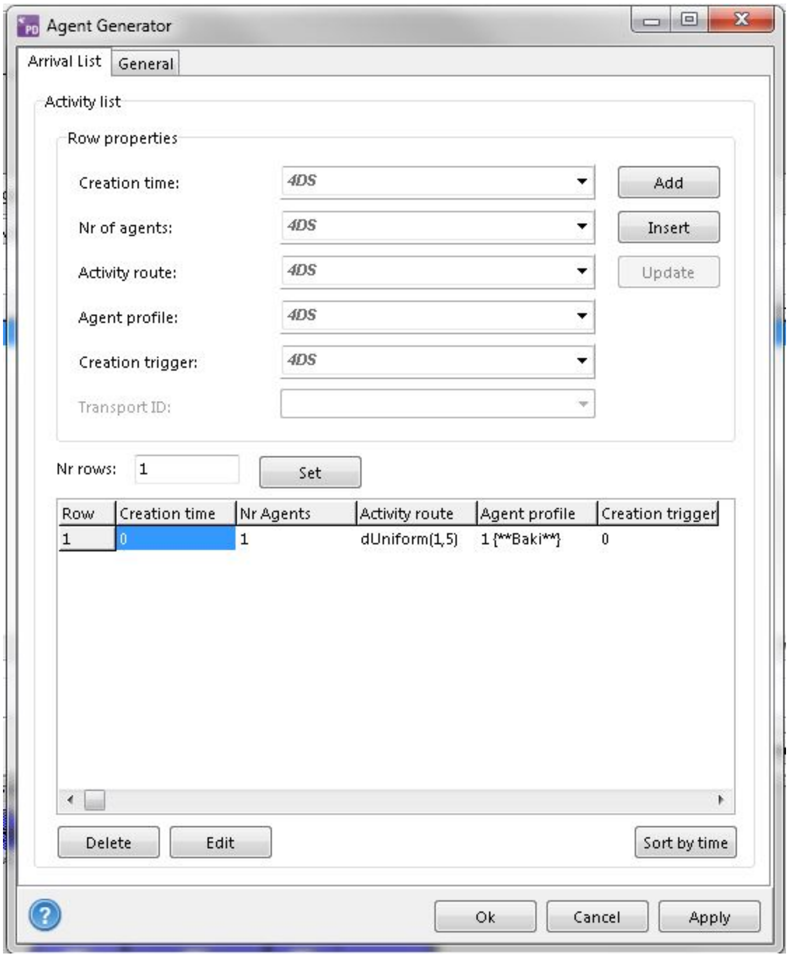


Figure A.4: A screen shot of how the arrivals of the pedestrians were added to the model for store 1

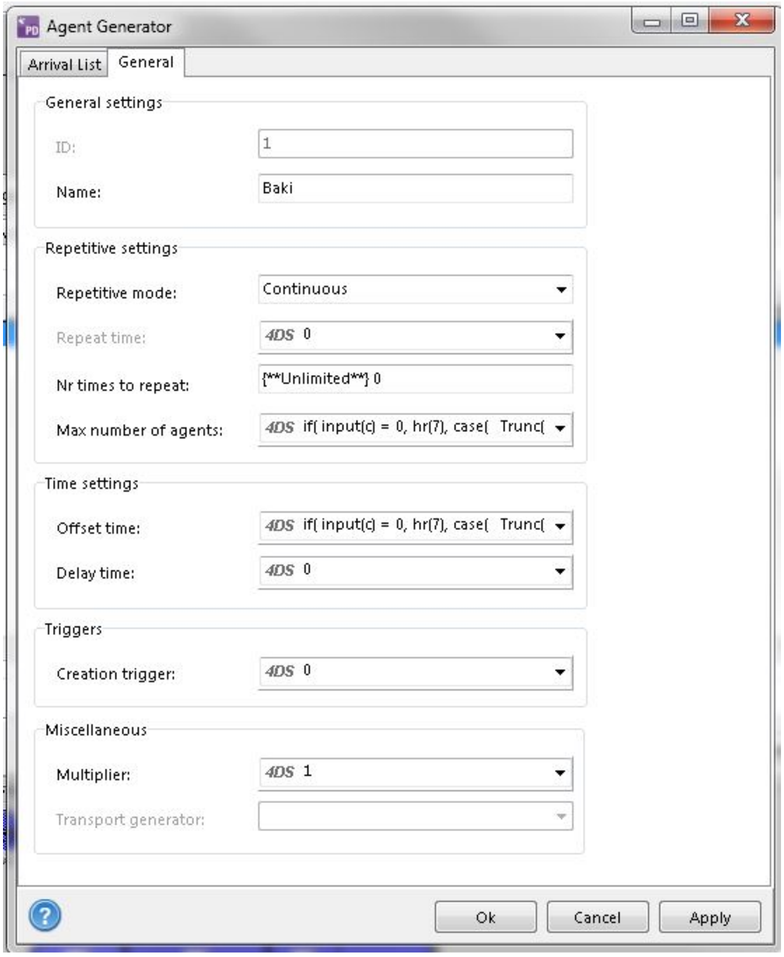
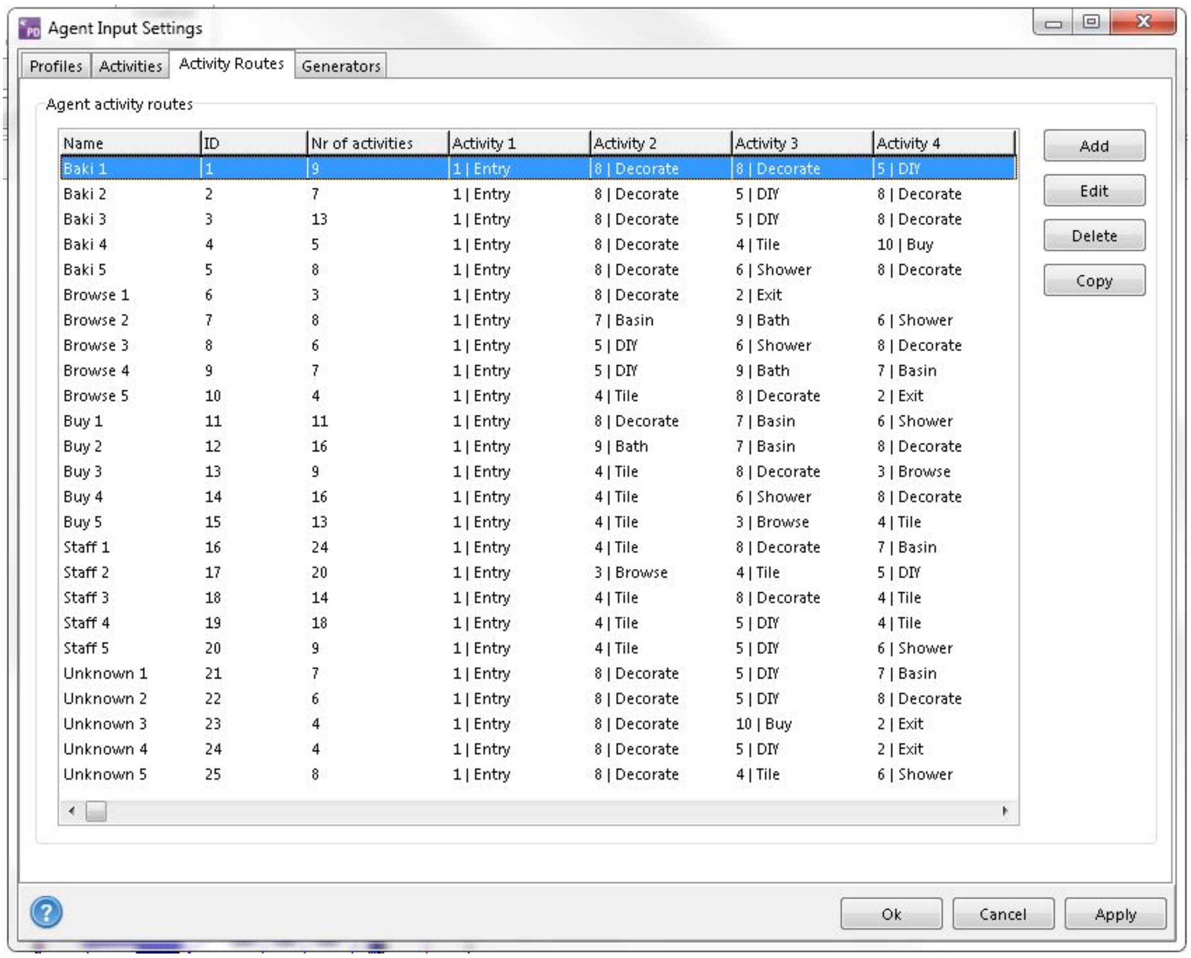


Figure A.5: A screen shot of where the details of the different pedestrians were entered for store 1

Appendix B

Appendix B



Name	ID	Nr of activities	Activity 1	Activity 2	Activity 3	Activity 4
Baki 1	1	9	1 | Entry	8 | Decorate	8 | Decorate	5 | DIY
Baki 2	2	7	1 | Entry	8 | Decorate	5 | DIY	8 | Decorate
Baki 3	3	13	1 | Entry	8 | Decorate	5 | DIY	8 | Decorate
Baki 4	4	5	1 | Entry	8 | Decorate	4 | Tile	10 | Buy
Baki 5	5	8	1 | Entry	8 | Decorate	6 | Shower	8 | Decorate
Browse 1	6	3	1 | Entry	8 | Decorate	2 | Exit	
Browse 2	7	8	1 | Entry	7 | Basin	9 | Bath	6 | Shower
Browse 3	8	6	1 | Entry	5 | DIY	6 | Shower	8 | Decorate
Browse 4	9	7	1 | Entry	5 | DIY	9 | Bath	7 | Basin
Browse 5	10	4	1 | Entry	4 | Tile	8 | Decorate	2 | Exit
Buy 1	11	11	1 | Entry	8 | Decorate	7 | Basin	6 | Shower
Buy 2	12	16	1 | Entry	9 | Bath	7 | Basin	8 | Decorate
Buy 3	13	9	1 | Entry	4 | Tile	8 | Decorate	3 | Browse
Buy 4	14	16	1 | Entry	4 | Tile	6 | Shower	8 | Decorate
Buy 5	15	13	1 | Entry	4 | Tile	3 | Browse	4 | Tile
Staff 1	16	24	1 | Entry	4 | Tile	8 | Decorate	7 | Basin
Staff 2	17	20	1 | Entry	3 | Browse	4 | Tile	5 | DIY
Staff 3	18	14	1 | Entry	4 | Tile	8 | Decorate	4 | Tile
Staff 4	19	18	1 | Entry	4 | Tile	5 | DIY	4 | Tile
Staff 5	20	9	1 | Entry	4 | Tile	5 | DIY	6 | Shower
Unknown 1	21	7	1 | Entry	8 | Decorate	5 | DIY	7 | Basin
Unknown 2	22	6	1 | Entry	8 | Decorate	5 | DIY	8 | Decorate
Unknown 3	23	4	1 | Entry	8 | Decorate	10 | Buy	2 | Exit
Unknown 4	24	4	1 | Entry	8 | Decorate	5 | DIY	2 | Exit
Unknown 5	25	8	1 | Entry	8 | Decorate	4 | Tile	6 | Shower

Figure B.1: A screen shot of the different activity routes for store 2

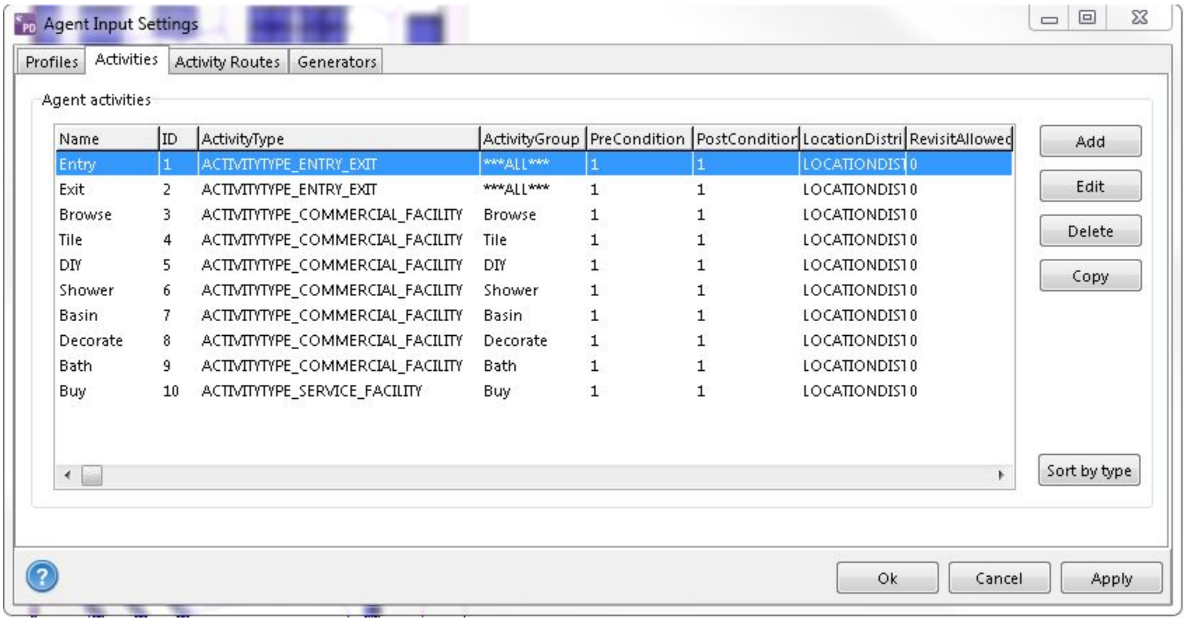


Figure B.2: A screen shot of the different departments that a pedestrian can visit in store 2

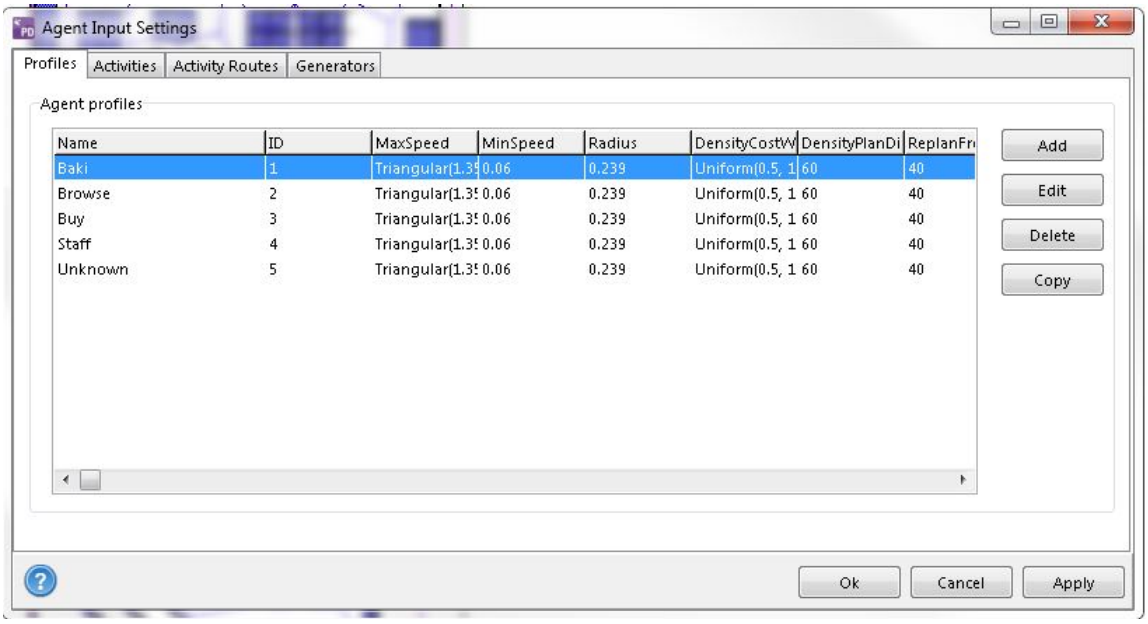


Figure B.3: A screen shot of how the agents were entered for store 2

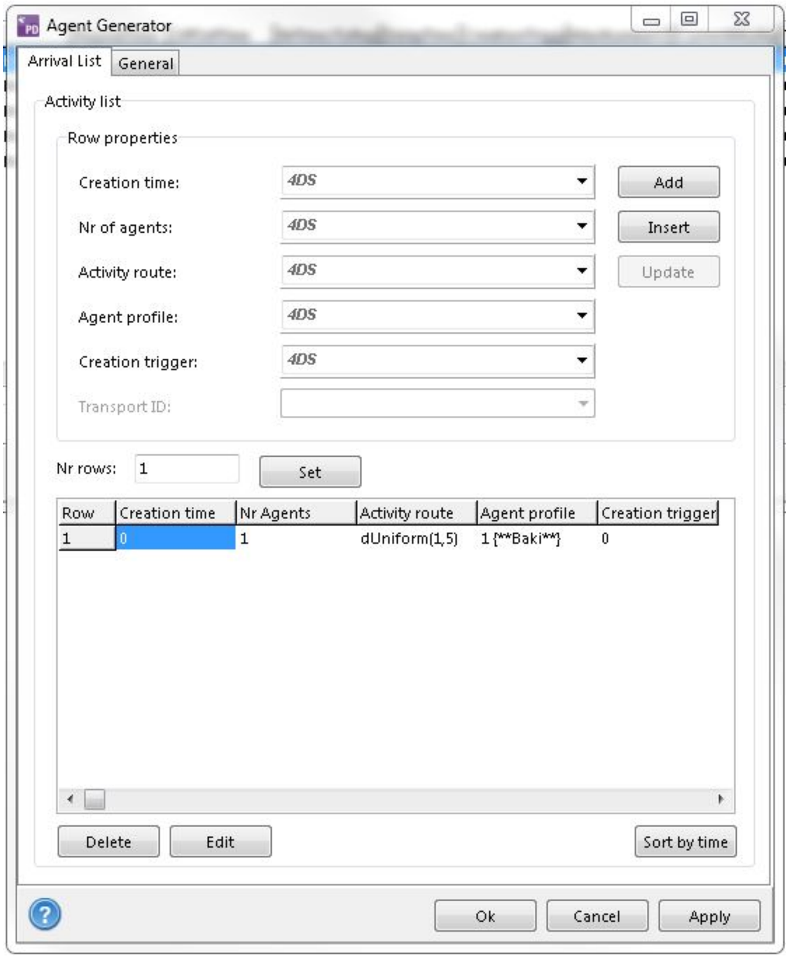


Figure B.4: A screen shot of how the arrivals of the pedestrians were added to the model for store 2

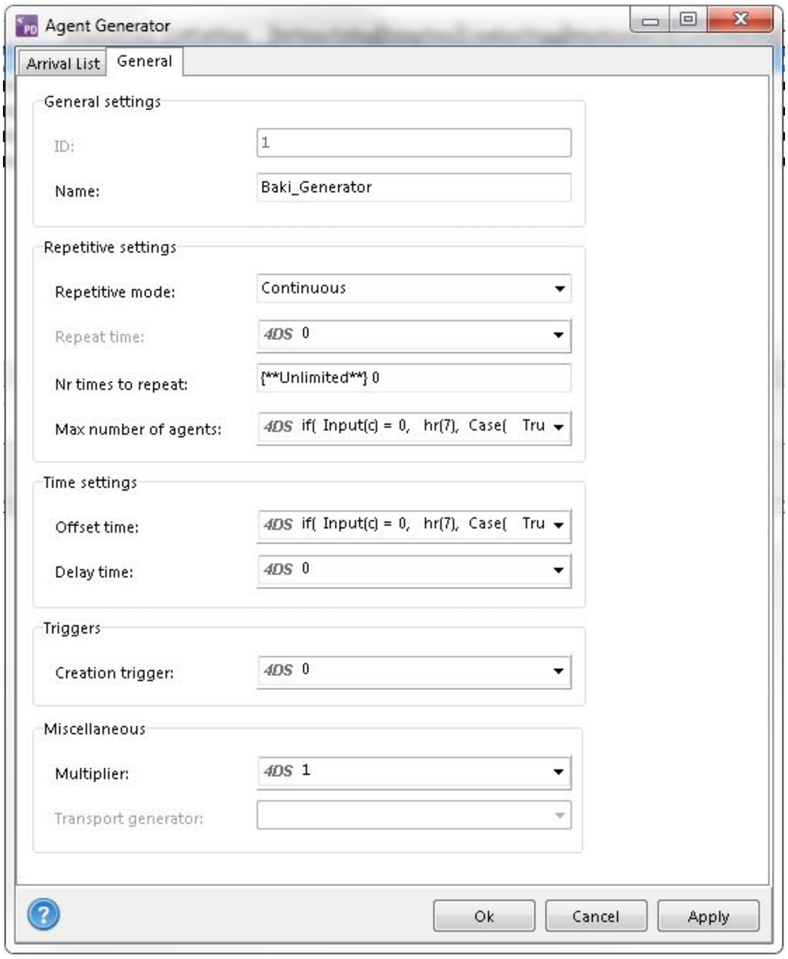


Figure B.5: A screen shot of where the details of the different pedestrians were entered for store 2

Appendix C

Appendix C

Table C.1: Simulation results for Store 1 for a Monday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	43.3342	0.8233295	0.677871466
X_2	40.11255	-2.398321	5.751961221
X_3	38.65369	-3.857181	14.87784141
X_4	43.050675	0.5398045	0.291388898
X_5	39.5265	-2.984371	8.906467281
X_6	44.10275	1.5918795	2.534080343
X_7	44.9232	2.4123295	5.819333617
X_8	1.1995095	1.1995095	1.438823041
X_9	46.8607	4.3498295	18.992101668
X_{10}	40.83406	-1.676811	2.811693453
		$\overline{X} = 42.510871$	$(S_x)^2 = 6.892273045$
			$S_x = 2.625313895$
			$CI = 1.877905949$
$t = 2.2621572$	$h = 1.8780364$	$h^* = 1.7$	$n^* = 13$

Table C.2: Simulation results for Store 1 for a Tuesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	11.12105	-3.03461	9.208858
X_2	11.7766	-2.37906	5.659926
X_3	8.11305	-6.04261	36.51314
X_4	14.3614	0.20574	0.042329
X_5	12.6758	-1.47986	2.18986
X_6	14.2088	0.05314	0.002824
X_7	23.0402	8.88454	78.93505
X_8	13.97805	-0.17761	0.031545
X_9	17.75875	3.60309	12.98226
X_{10}	14.5229	0.36724	0.134865
		$\overline{X} = 14.15566$	$(S_x)^2 = 16.18898$
			$S_x = 4.023553$
			$CI = 2.878076$
$t = 2.2621572$	$h = 2.878276$	$h^* = 2.6$	$n^* = 13$

Table C.3: Simulation results for Store 1 for a Wednesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0.48185	0.189685	0.035980399
X_2	0	-0.292165	0.085360387
X_3	0	-0.292165	0.085360387
X_4	0.4684	0.176235	0.031058775
X_5	0	-0.292165	0.085360387
X_6	0	-0.292165	0.085360387
X_7	1.062	0.769835	0.592645927
X_8	0.4628	0.170635	0.029116303
X_9	0.2424	-0.049765	0.002476555
X_{10}	0.2042	-0.087965	0.007737841
		$\overline{X} = 0.292165$	$(S_x)^2 = 0.115605$
			$S_x = 0.340009$
			$CI = 0.243211$

Table C.4: Simulation results for Store 1 for a Thursday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0.7355	0.282475	0.079792126
X_2	0.69625	0.243225	0.059158401
X_3	0.68875	0.235725	0.055566276
X_4	0.34485	-0.108175	0.011701831
X_5	0.50815	0.0551225	0.003038766
X_6	0.34875	-0.104275	0.010873276
X_7	0	-0.453025	0.205231651
X_8	0	-0.453025	0.205231651
X_9	1.17015	0.717125	0.514268266
X_{10}	0.03785	-0.415175	0.172370281
		$\overline{X} = 0.453025$	$(S_x)^2 = 0.146359$
			$S_x = 0.382569$
			$CI = 0.273654$

Table C.5: Simulation results for Store 1 for a Friday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	-0.211485	0.044725905
X_2	0	-0.211485	0.044725905
X_3	0.8388	0.627315	0.383524109
X_4	0	-0.211485	0.044725905
X_5	0	-0.211485	0.044725905
X_6	0	-0.211485	0.044725905
X_7	0	-0.2114855	0.044725905
X_8	0.4787	0.267215	0.071403856
X_9	0.52405	0.312565	0.097696879
X_{10}	0.2733	0.061815	0.003821094
		$\overline{X} = 0.211485$	$(S_x)^2 = 0.092756$
			$S_x = 0.304558$
			$CI = 0.217853$

Table C.6: Simulation results for Store 1 for a Saturday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0.65985	-0.042375	0.001795641
X_2	0.6146	-0.087625	0.007678141
X_3	0.08445	-0.617775	0.381645951
X_4	1.5767	0.874475	0.764706526
X_5	0.4645	-0.237725	0.056513176
X_6	1.2263	0.524075	0.274654606
X_7	0.80755	0.105325	0.011093356
X_8	0.82235	0.120125	0.014430016
X_9	0.06465	-0.637575	0.406501881
X_{10}	0.7013	-0.000925	0.0000008
		$\overline{X} = 0.70222$	$(S_x)^2 = 0.213224$
			$S_x = 0.461762$
			$CI = 0.330302$

Table C.7: Simulation results for Store 1 for a Sunday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$
			$CI = 0$

Appendix D

Appendix D

Table D.1: Comparison table for Monday's results for Store 1

X_n	$\Delta_{Mon,Tue}$	$\Delta_{Mon,Wed}$	$\Delta_{Mon,Thur}$	$\Delta_{Mon,Fri}$	$\Delta_{Mon,Sat}$	$\Delta_{Mon,Sun}$
X_1	32.2132	42.8524	42.5987	43.3342	42.6744	43.3342
X_2	28.3360	40.1126	39.4163	40.1126	39.4980	40.1126
X_3	30.5406	38.6537	37.9649	37.8149	38.5692	38.6537
X_4	28.6893	42.5823	42.7058	43.0507	41.4740	43.0507
X_5	26.8507	39.5265	37.0184	39.5265	39.0620	39.5265
X_6	29.8940	44.1028	43.7540	44.1028	42.8765	44.1028
X_7	21.883	43.8612	44.9232	44.9232	44.1157	44.9232
X_8	29.7323	43.2476	43.7104	43.2317	42.8880	43.7104
X_9	29.1020	46.6183	45.6906	46.3367	46.7961	46.8607
X_{10}	26.31121	40.6299	40.7962	40.5608	40.1328	40.8341
Δ_{avg}	28.3552	0.222	0.4530	0.2115	0.7022	0.0000
σ_Δ	2.8465	0.3400	0.3826	0.3046	0.4618	0.0000
t	2.2622	2.2622	2.2622	2.26222	2.2622	2.2622
h	2.0363	0.2432	0.2737	0.2179	0.3303	0.0000

Table D.2: Comparison table for Tuesday's results for Store 1

X_n	$\Delta_{Tue,Wed}$	$\Delta_{Tue,Thur}$	$\Delta_{Tue,Fri}$	$\Delta_{Tue,Sat}$	$\Delta_{Tue,Sun}$
X_1	10.6392	10.3856	11.1211	10.4612	11.1211
X_2	11.7766	11.0804	11.7766	11.1620	11.7766
X_3	8.1131	7.4243	7.2743	8.0286	8.1131
X_4	13.8930	14.0166	13.3614	12.7847	14.3614
X_5	12.66758	12.1677	12.6758	12.2113	12.6758
X_6	14.2088	13.8601	14.2088	12.9825	14.2088
X_7	21.9782	23.0402	23.0402	22.2327	23.0402
X_8	13.5153	13.9781	13.4994	13.1557	13.9781
X_9	17.5164	16.5886	17.2347	17.6941	17.7588
X_{10}	14.3187	14.4851	14.2496	13.8216	14.5229
Δ_{avg}	13.8635	13.7026	13.9442	13.4534	14.1557
σ_Δ	3.7840	4.1631	4.1213	3.9599	4.0236
t	2.2622	2.2622	2.2622	2.2622	2.2622
h	2.7069	2.9781	2.9482		

Table D.3: Comparison table for Wednesday's results for Store 1

X_n	$\Delta_{Wed,Thur}$	$\Delta_{Wed,Fri}$	$\Delta_{Wed,Sat}$	$\Delta_{Wed,Sun}$
X_1	-0.2537	0.4819	-0.1780	0.4819
X_2	-0.6963	0	0.6146	0
X_3	-0.6888	-0.8388	-0.0845	0
X_4	0.1236	0.4684	-1.1083	0.4684
X_5	-0.5082	0	-0.4645	0
X_6	-0.3488	0	-1.2263	0
X_7	1.0620	1.0620	0.2545	1.0620
X_8	0.4628	-0.0159	-0.3596	0.4628
X_9	-0.9276	-0.2817	0.1776	0.2424
X_{10}	0.1664	-0.0691	-0.4971	0.2042
Δ_{avg}	-0.16086	0.0807	-0.4101	0.2922
σ_Δ	0.6136	0.5058	0.4894	0.3400
t	2.2622	2.2622	2.2622	2.2622
h	0.4391	0.3618	0.3501	0.2432

Table D.4: Comparison table for Thursday's results for Store 1

X_n	$\Delta_{Thur,Fri}$	$\Delta_{Thur,Sat}$	$\Delta_{Thur,Sun}$
X_1	0.7355	0.0757	0.7355
X_2	0.6963	0.0817	0.6963
X_3	-0.1501	0.6043	0.6886
X_4	0.3449	-1.2319	0.3449
X_5	0.5082	0.0437	0.5082
X_6	0.3488	-0.8776	0.3488
X_7	0	-0.8076	0
X_8	-0.4787	-0.8224	0
X_9	0.6461	1.1055	1.1702
X_{10}	-0.2355	-0.6635	0.0379
Δ_{avg}	0.2415	-0.2492	0.4530
σ_Δ	0.4302	0.4781	0.3826
t	2.2622	2.2622	2.2622
h	0.3077	0.5351	0.2737

Table D.5: Comparison table for Friday's results for Store 1

X_n	$\Delta_{Fri,Sat}$	$\Delta_{Fri,Sun}$
X_1	-0.6599	0
X_2	-0.6146	0
X_3	0.7544	0.8388
X_4	-1.5767	0
X_5	-0.4645	0
X_6	-1.2263	0
X_7	-0.8076	0
X_8	-0.3437	0.4787
X_9	0.4594	0.5241
X_{10}	-0.4280	0.2733
Δ_{avg}	-0.4907	0.2115
σ_Δ	0.6947	0.3045
t	2.2622	2.2622
h	0.4969	0.2179

Table D.6: Comparison table for Saturday's results for Store 1

X_n	$\Delta_{Sat,Sun}$
X_1	0.6599
X_2	0.6416
X_3	0.0845
X_4	1.5767
X_5	0.4645
X_6	1.2263
X_7	0.8076
X_8	0.8224
X_9	0.0647
X_{10}	0.7013
Δ_{avg}	0.7022
σ_Δ	0.4617
t	2.2622
h	0.3303

Appendix E

Appendix E

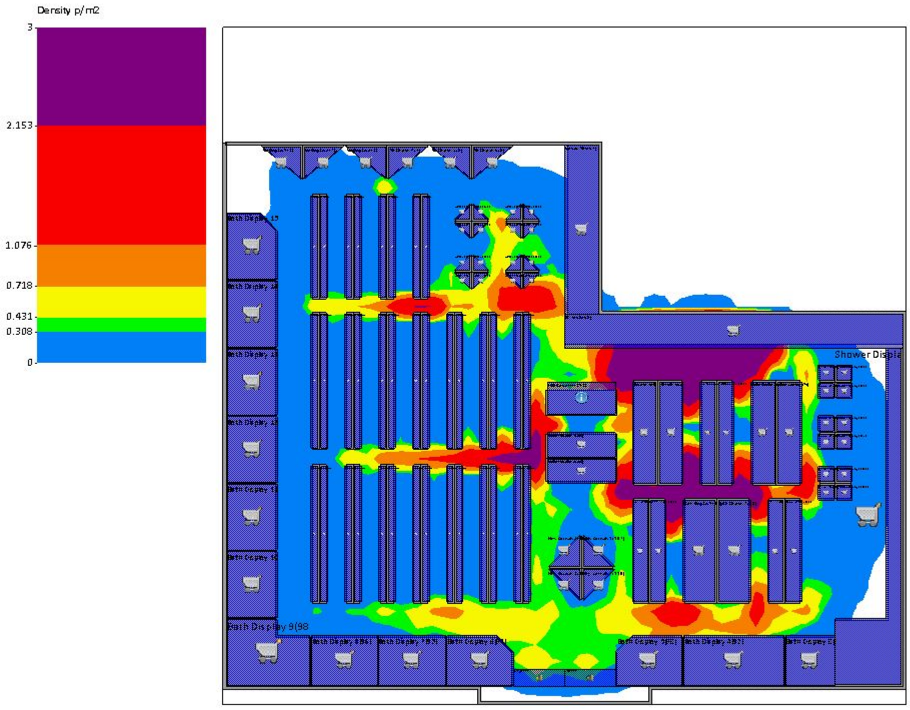


Figure E.1: A screen shot of Monday's final simulation run, $n = 1$

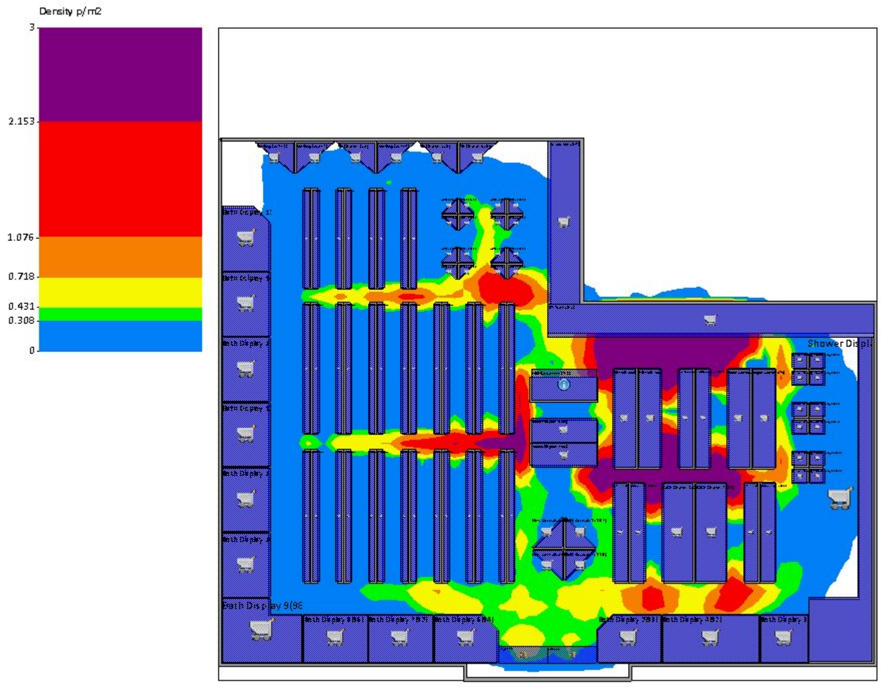


Figure E.2: A screen shot of Monday's final simulation run, $n = 2$

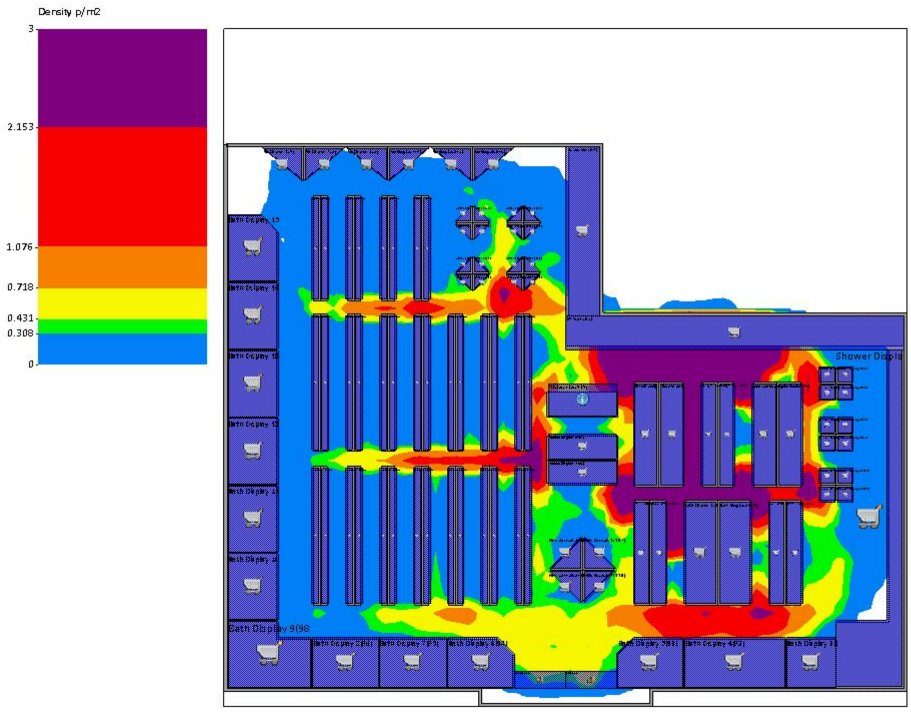


Figure E.3: A screen shot of Monday's final simulation run, $n = 3$

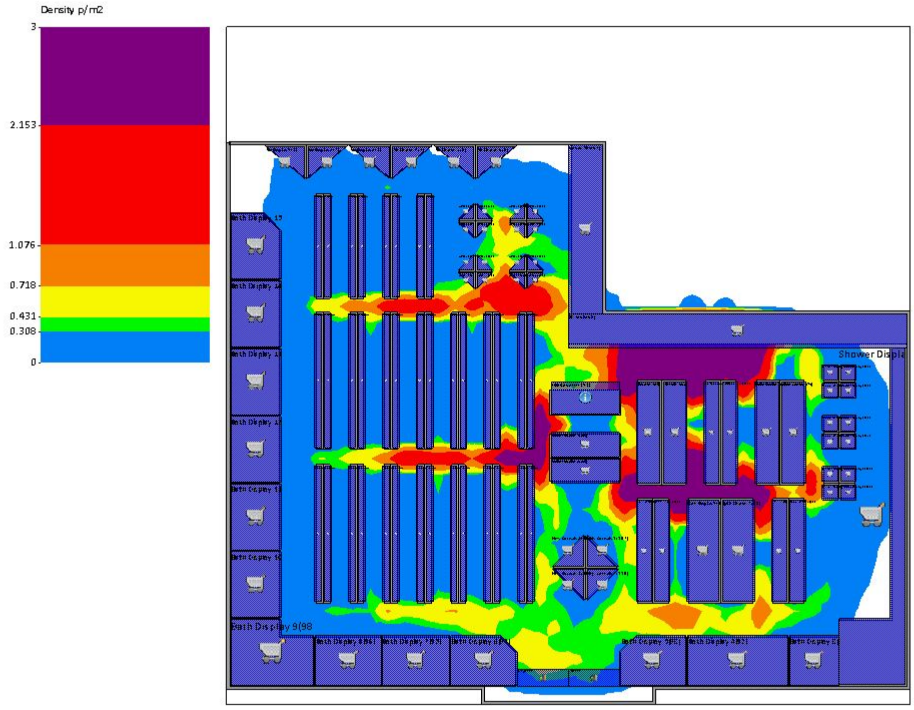


Figure E.4: A screen shot of Monday's final simulation run, $n = 4$

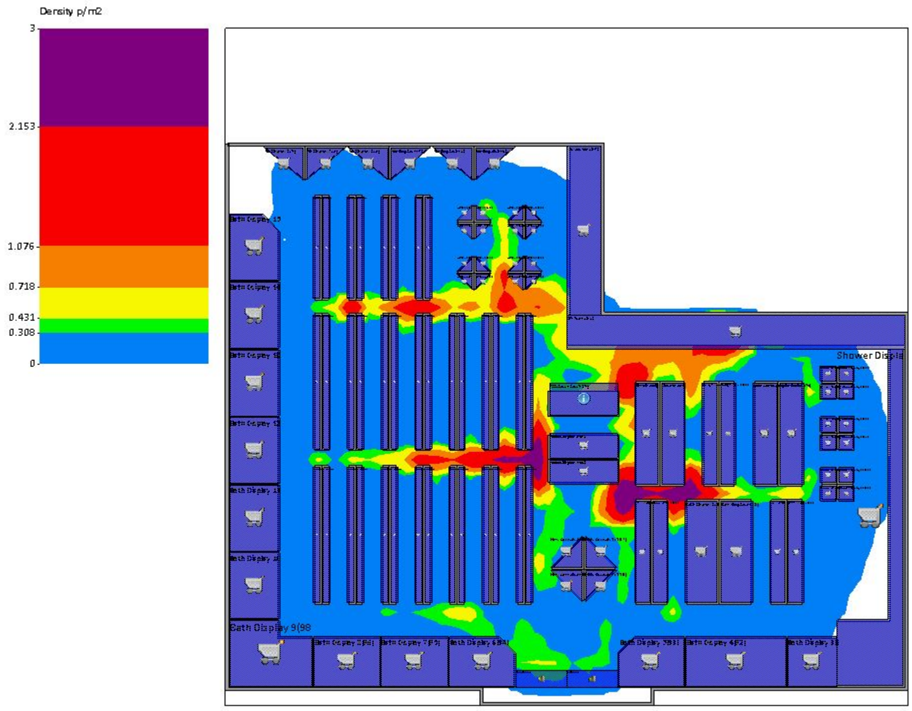


Figure E.5: A screen shot of Monday's final simulation run, $n = 5$

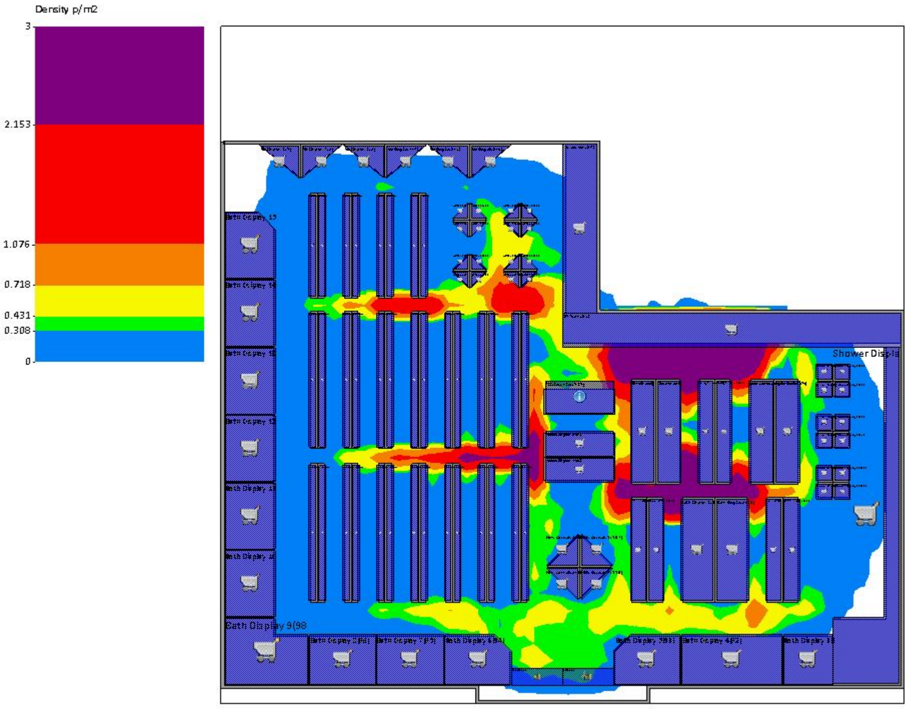


Figure E.6: A screen shot of Monday's final simulation run, $n = 6$

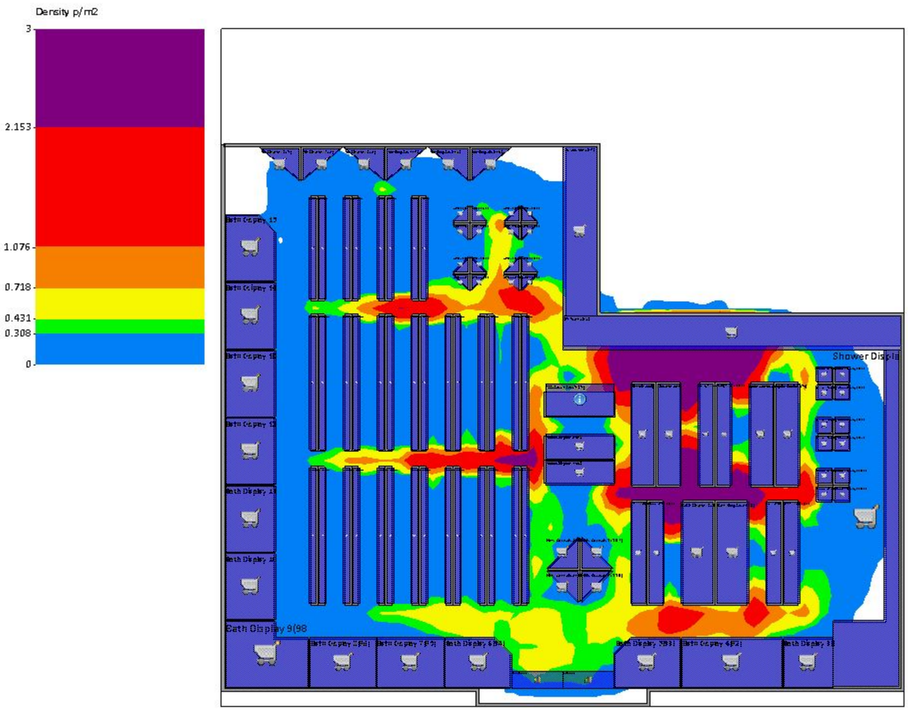


Figure E.7: A screen shot of Monday's final simulation run, $n = 7$

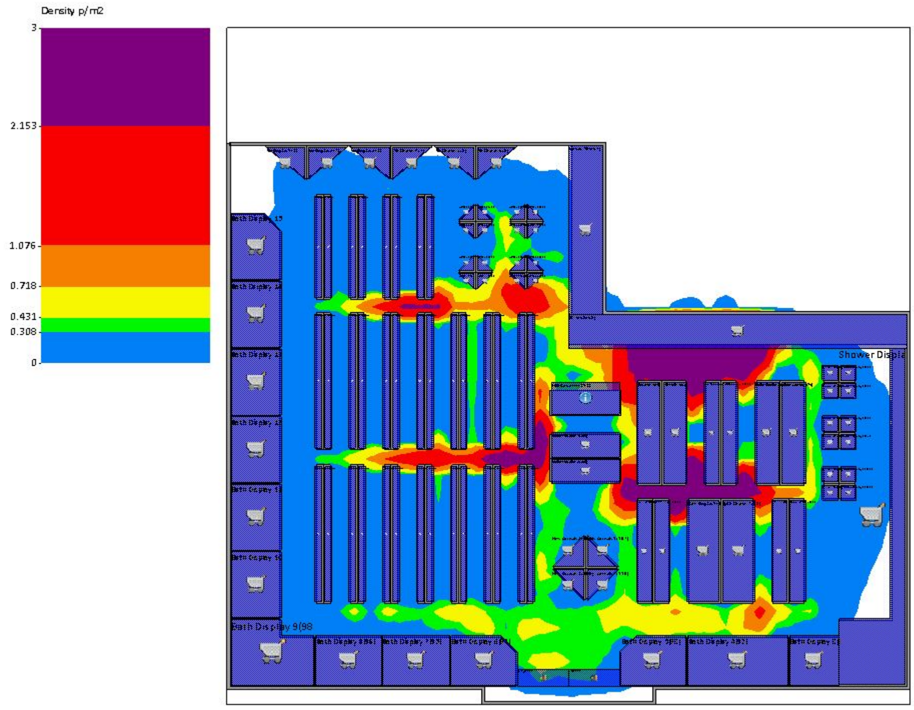


Figure E.8: A screen shot of Monday's final simulation run, $n = 8$

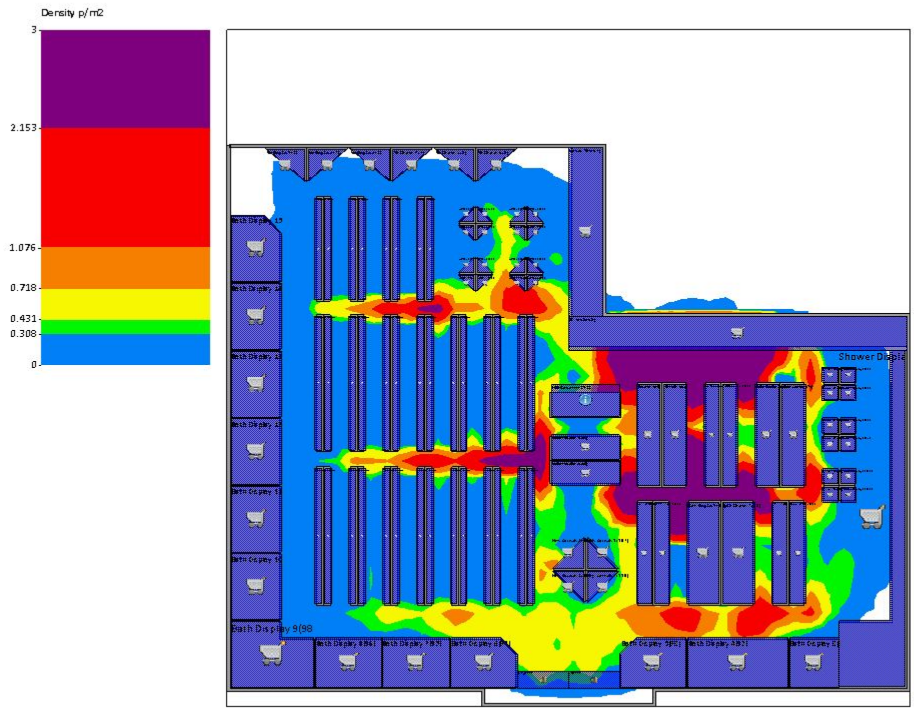


Figure E.9: A screen shot of Monday's final simulation run, $n = 9$

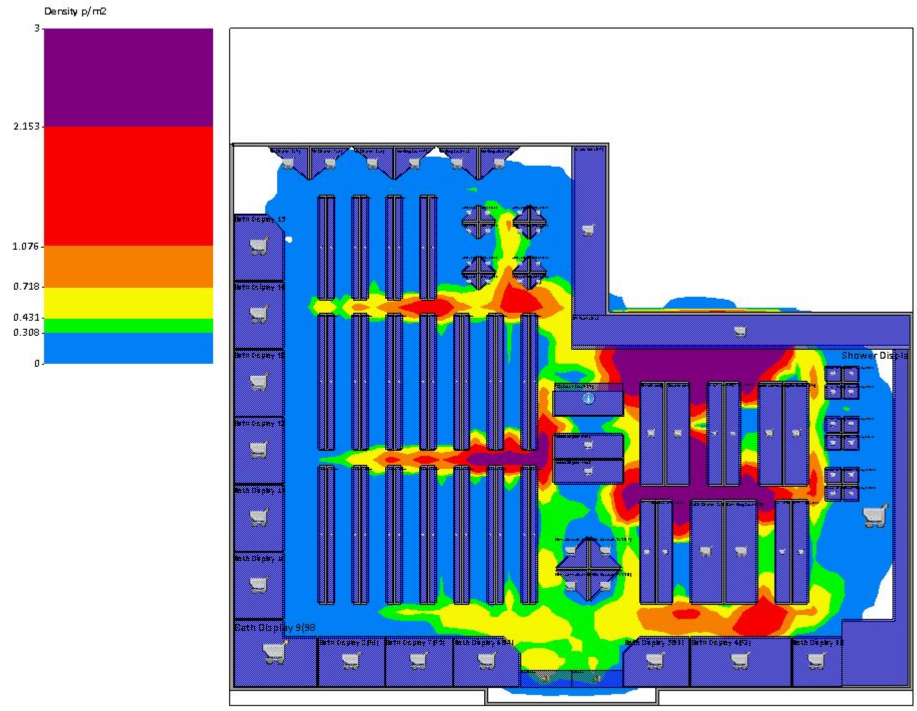


Figure E.10: A screen shot of Monday's final simulation run, $n = 10$

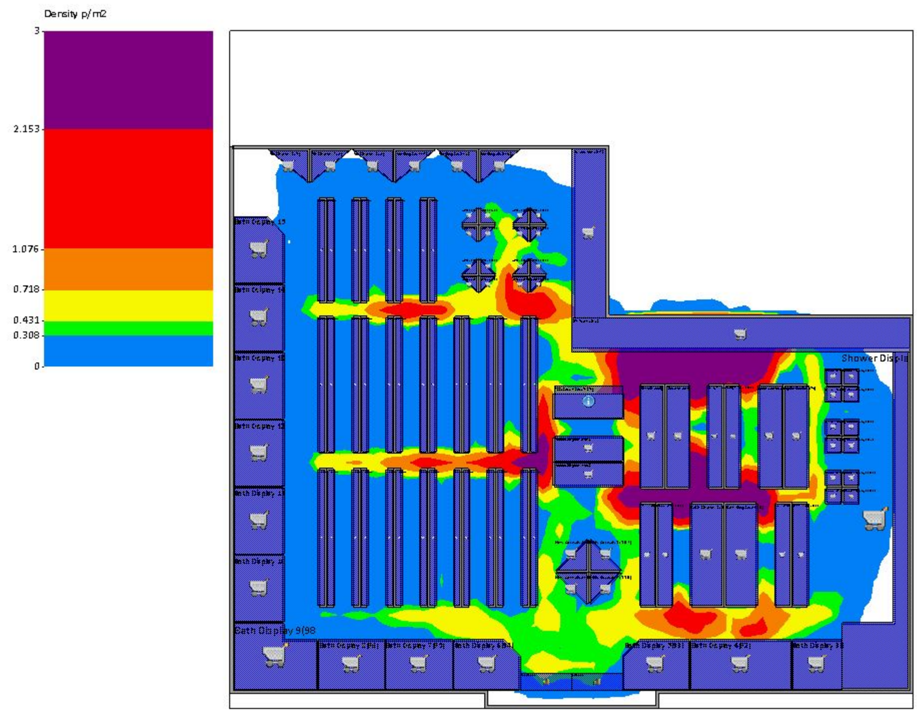


Figure E.11: A screen shot of Monday's final simulation run, $n = 11$

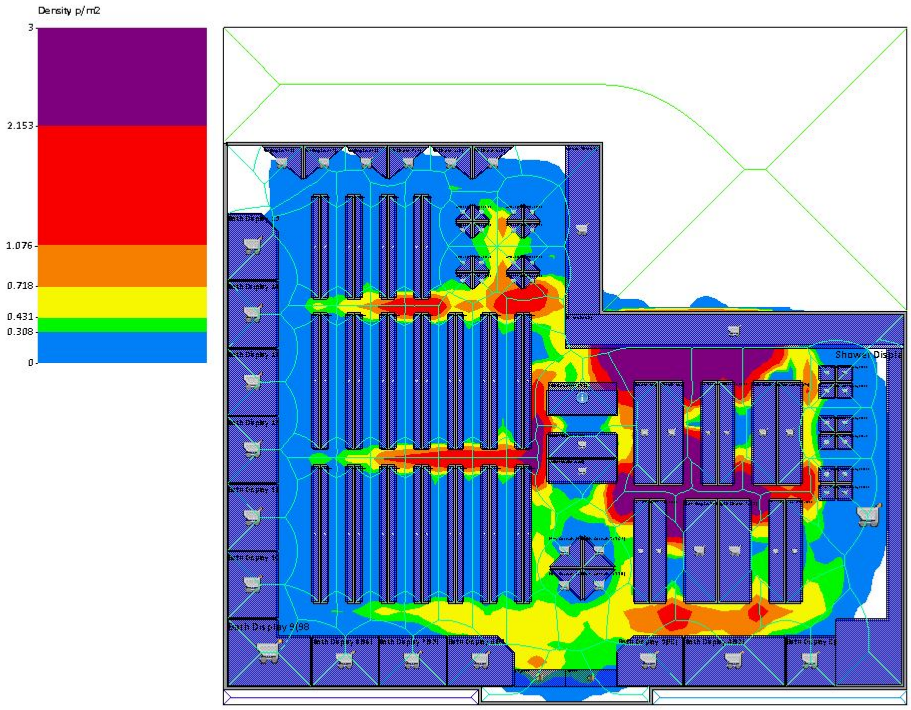


Figure E.12: A screen shot of Monday's final simulation run, $n = 12$

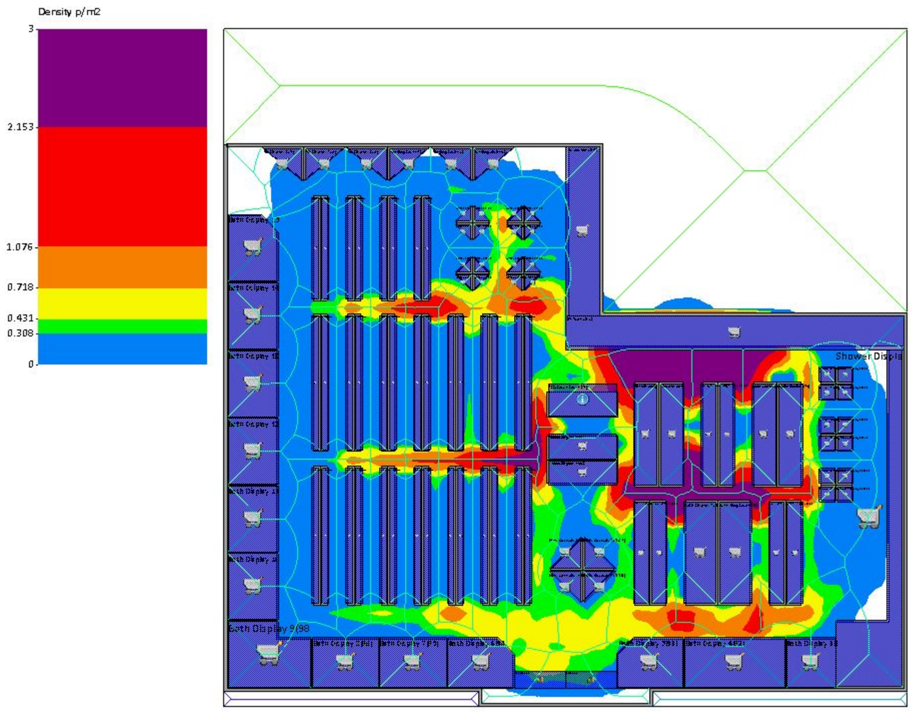


Figure E.13: A screen shot of Monday's final simulation run, $n = 13$

Table E.1: Simulation results for Store 1 for Monday's final simulation runs

Xn	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	33.4062	0.1660	0.0276
X_2	36.1708	2.9305	8.5881
X_3	46.2311	12.9908	168.7615
X_4	34.2719	1.0317	1.0643
X_5	6.9323	-26.3080	692.1104
X_6	31.3393	-1.9010	3.6137
X_7	31.9172	-1.3231	1.7505
X_8	29.7235	-3.5168	12.3676
X_9	40.5856	7.3454	53.9543
X_{10}	37.6678	4.4275	19.6028
X_{11}	32.4201	-0.8201	0.6726
X_{12}	38.2173	4.9771	24.7712
X_{13}	31.7869	-1.4534	2.1123
		$\overline{X}$ = 33.2403	$(S_x)^2$ = 109.9330
			S_x = 10.48489

Appendix F

Appendix F

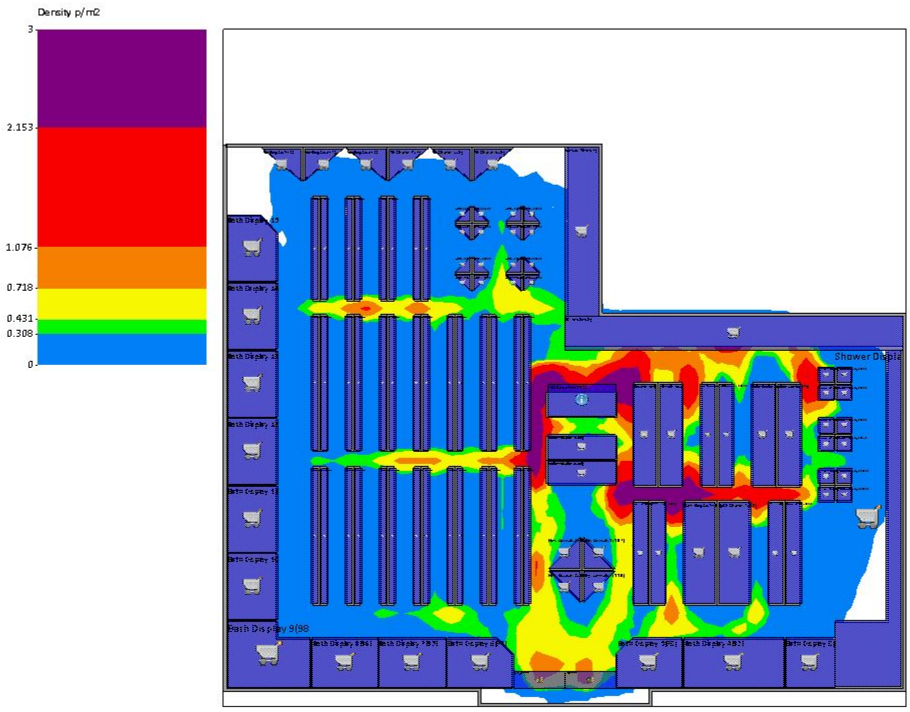


Figure F.1: A screen shot of Monday's final simulation run, $n = 1$

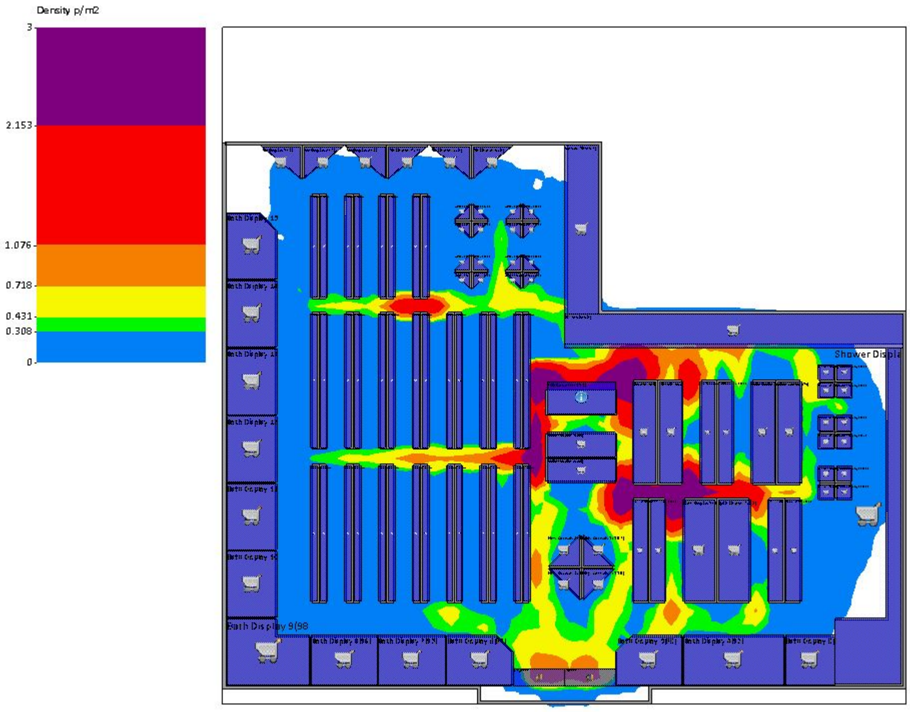


Figure F.2: A screen shot of Monday's final simulation run, $n = 2$

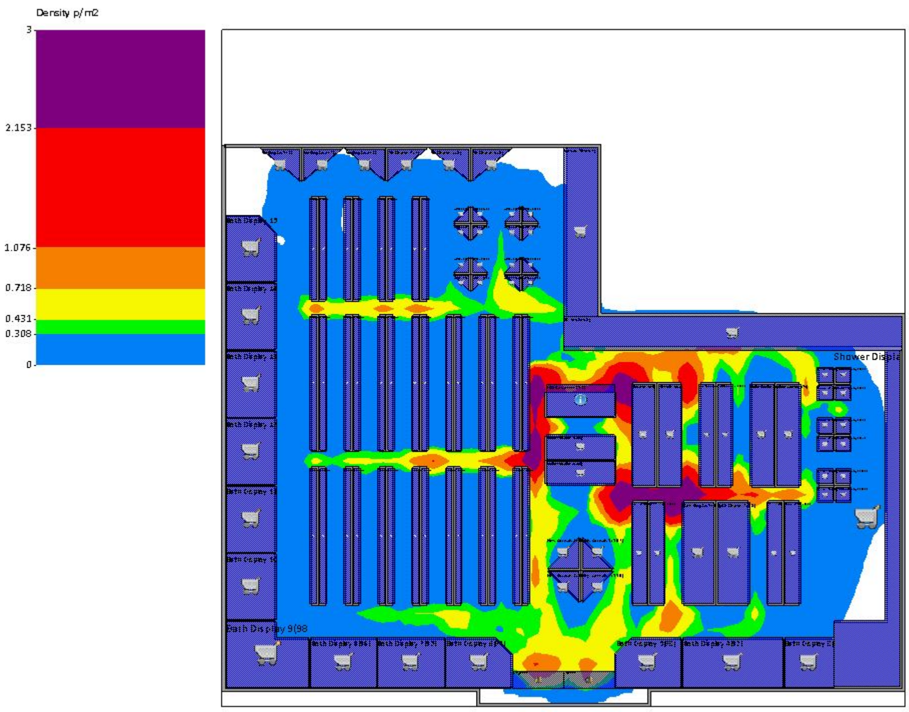


Figure F.3: A screen shot of Monday's final simulation run, $n = 3$

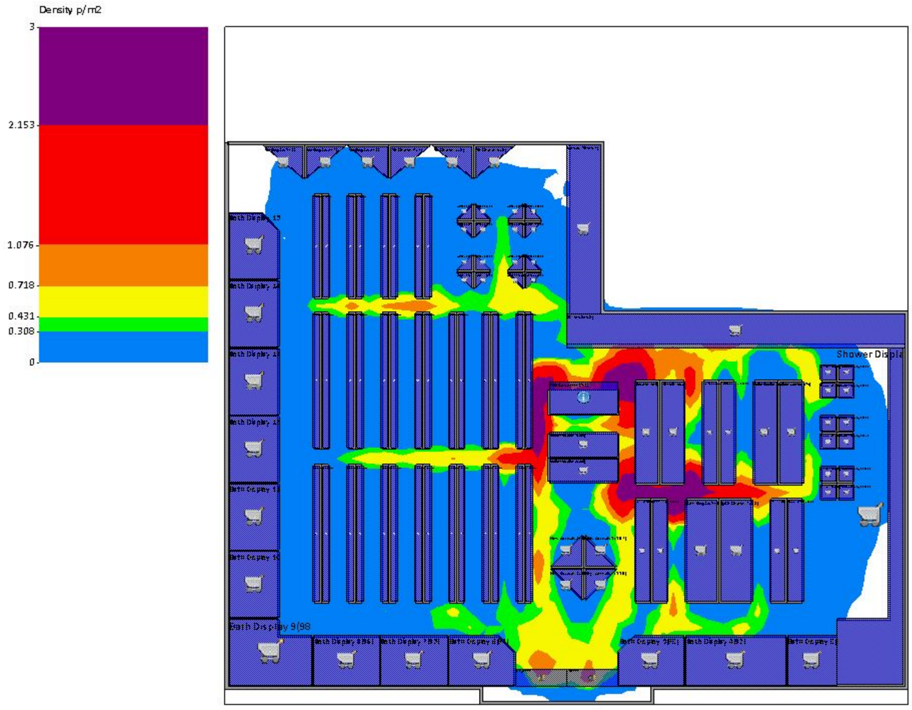


Figure F.4: A screen shot of Monday's final simulation run, $n = 4$

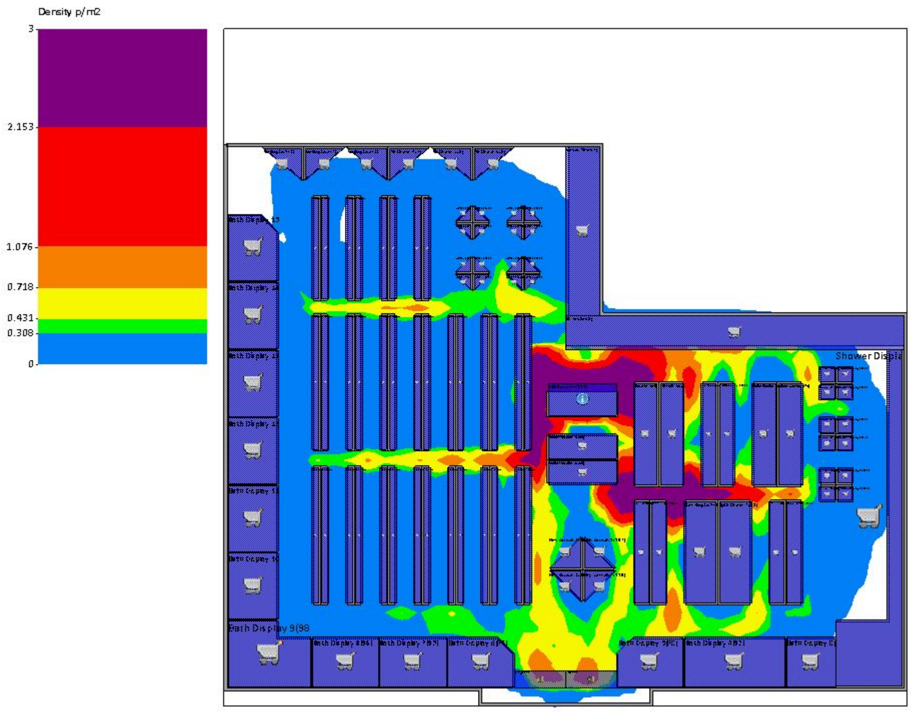


Figure F.5: A screen shot of Monday's final simulation run, $n = 5$

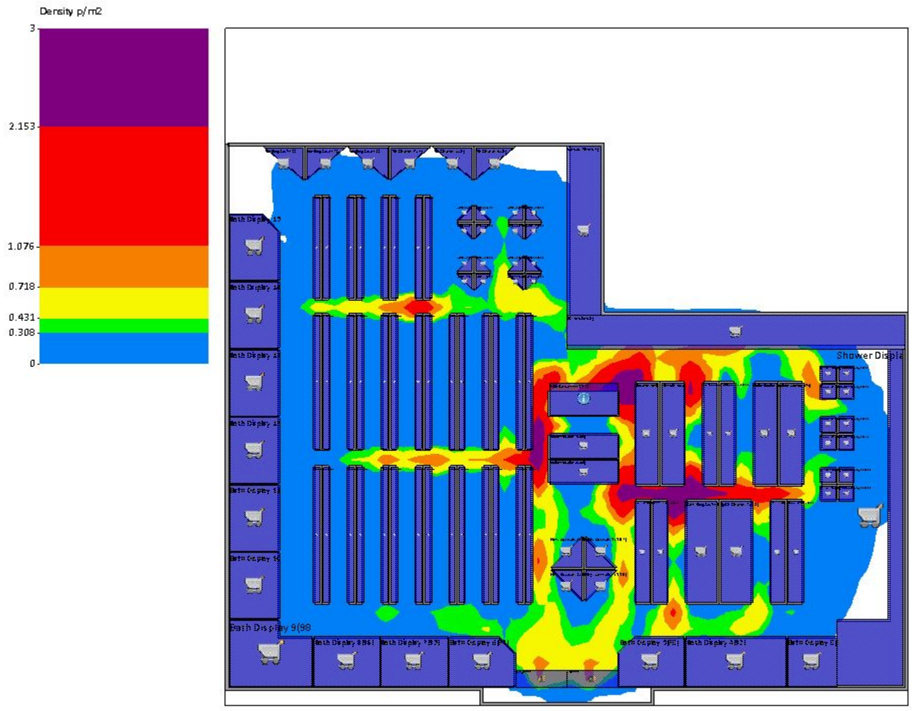


Figure F.6: A screen shot of Monday's final simulation run, $n = 6$

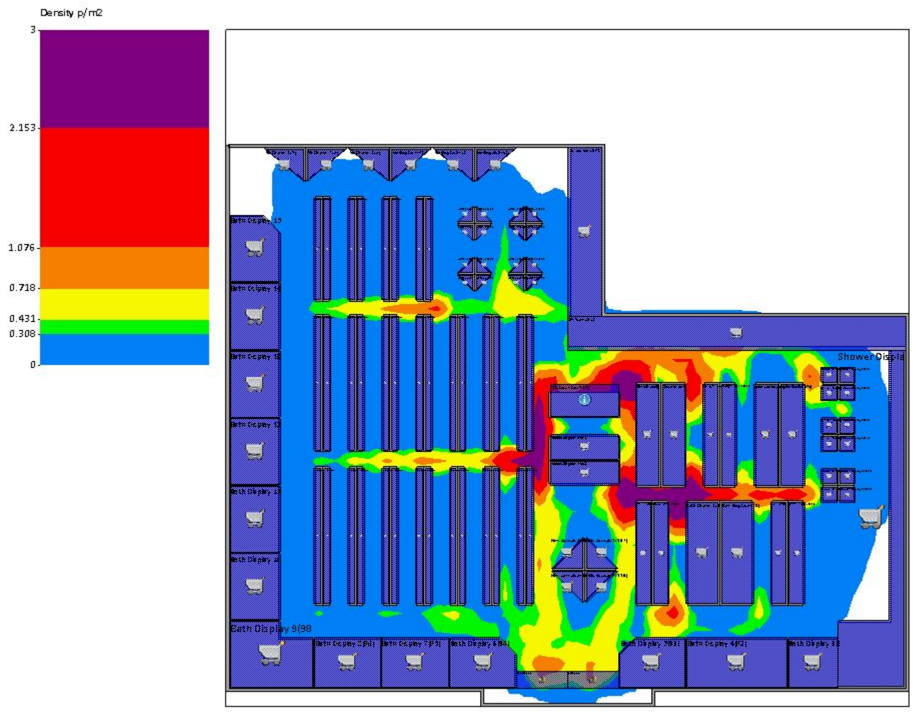


Figure F.7: A screen shot of Monday's final simulation run, $n = 7$

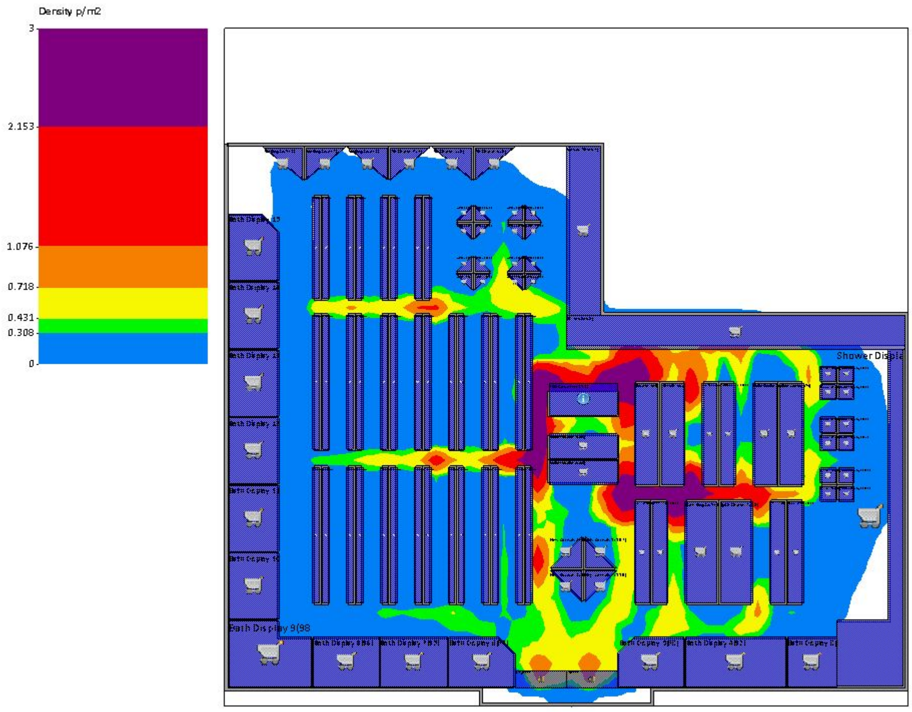


Figure F.8: A screen shot of Monday's final simulation run, $n = 8$

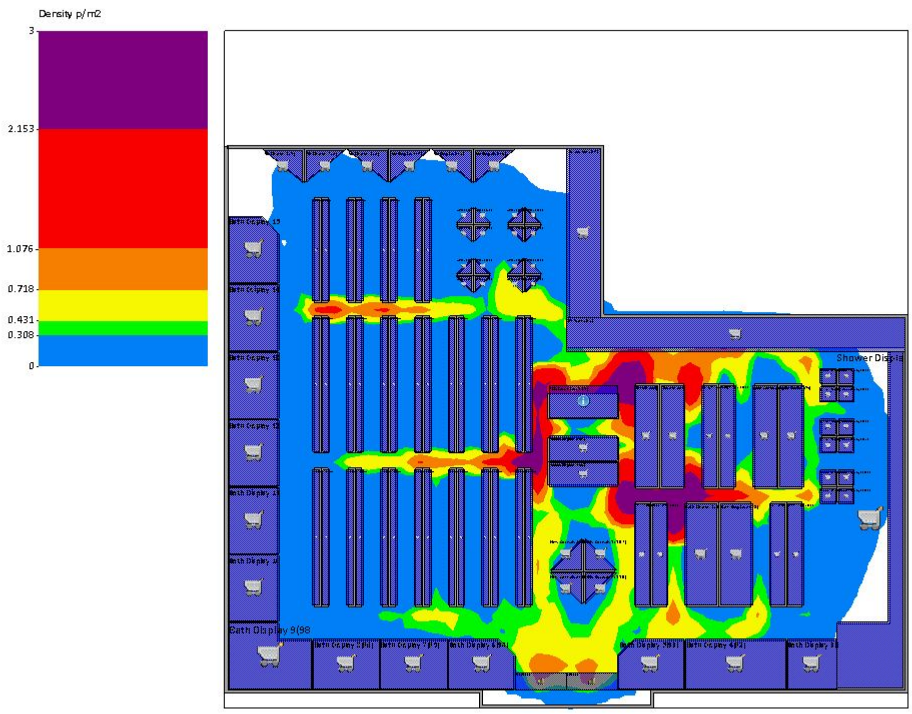


Figure F.9: A screen shot of Monday's final simulation run, $n = 9$

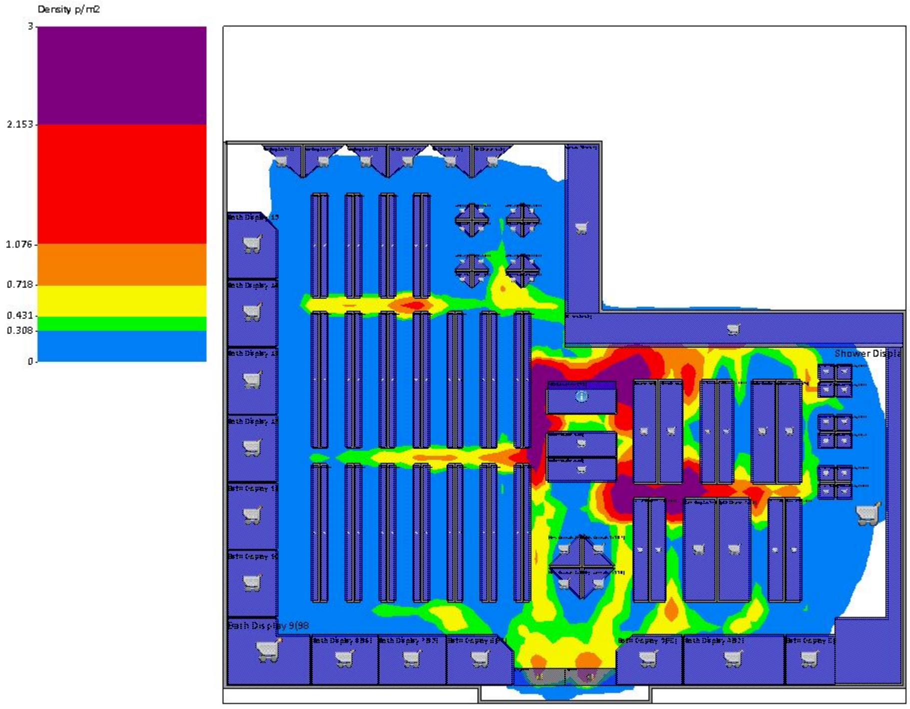


Figure F.10: A screen shot of Monday's final simulation run, $n = 10$

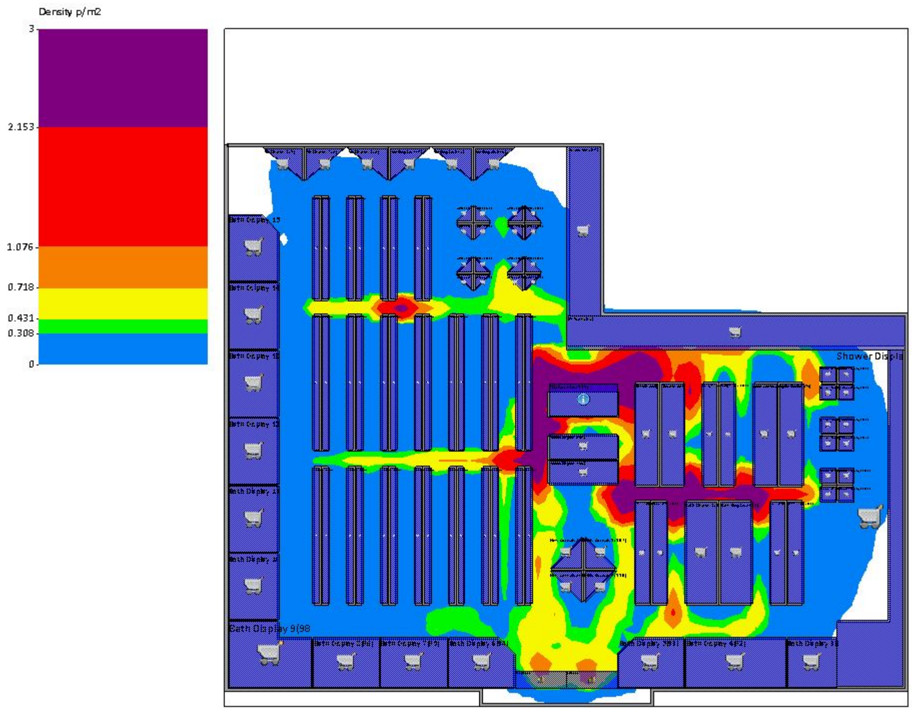


Figure F.11: A screen shot of Monday's final simulation run, $n = 11$

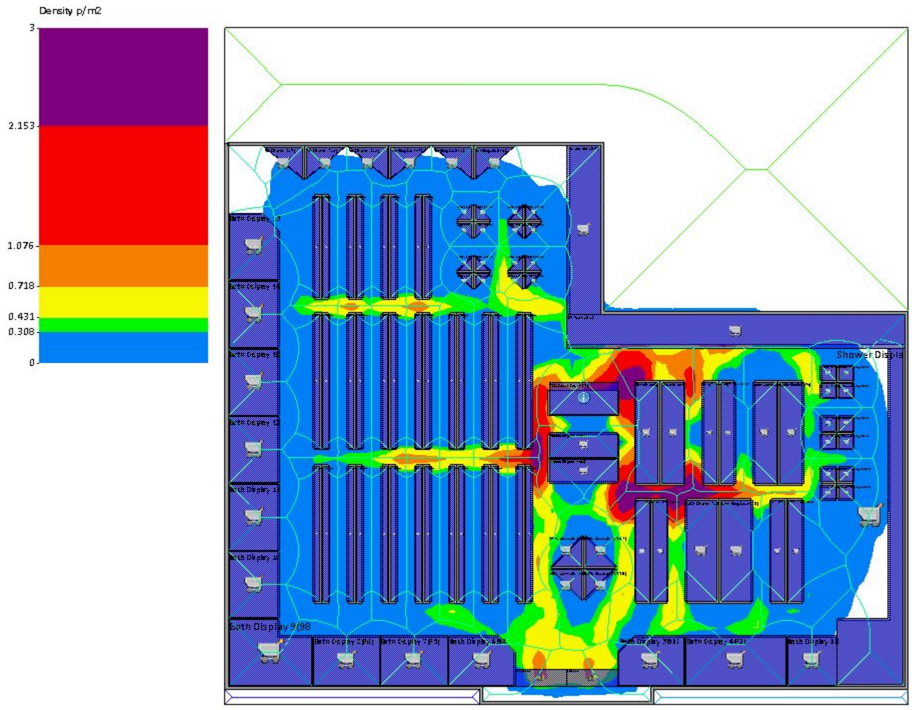


Figure F.12: A screen shot of Monday's final simulation run, $n = 12$

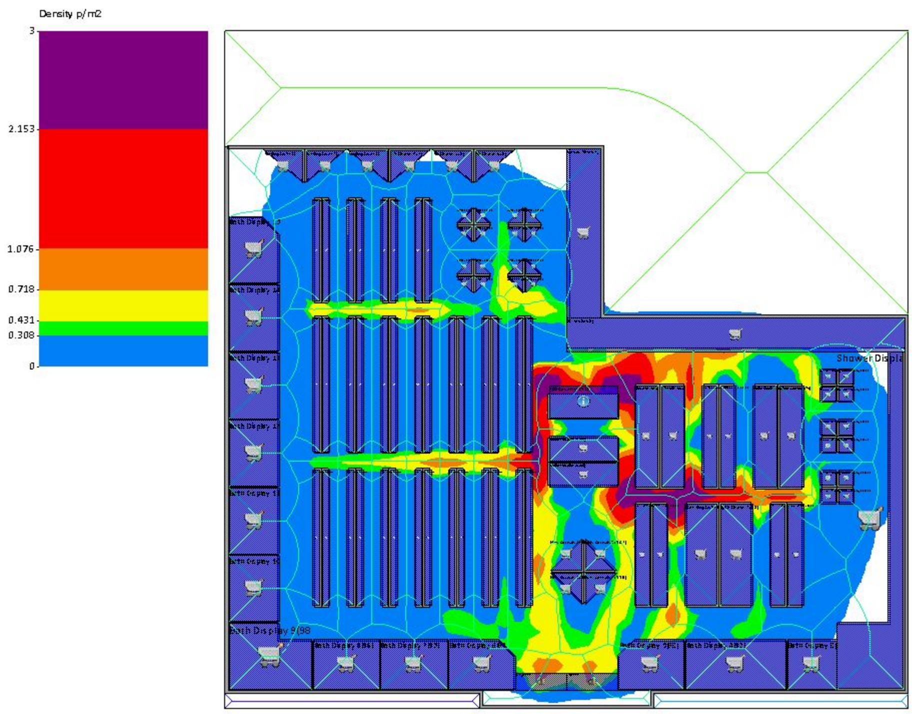


Figure F.13: A screen shot of Monday's final simulation run, $n = 13$

Table F.1: Simulation results for Store 1 for Tuesday's final simulation runs

Xn	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	19.0974	3.7817	14.3013
X_2	16.5986	1.2829	1.6460
X_3	11.4195	-3.8962	15.1804
X_4	13.3383	-1.9774	3.9100
X_5	23.3987	8.0830	65.3351
X_6	10.3941	-4.9215	24.2214
X_7	12.0137	-3.3019	10.9027
X_8	17.8583	2.5427	6.4652
X_9	15.0909	-0.2248	0.0505
X_{10}	18.5886	3.2729	10.7121
X_{11}	16.6323	1.3166	1.7336
X_{12}	9.3575	-5.9581	35.4995
X_{13}	11.7044	-3.6113	13.0412
		$\overline{X} = 15.3157$	$(S_x)^2 = 22.5554$
			$S_x = 4.7493$

Appendix G

Appendix G

Table G.1: Simulation results for Store 2 for a Monday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0

Table G.2: Simulation results for Store 2 for a Tuesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0

Table G.3: Simulation results for Store 2 for a Wednesday

Xn	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	27.1595	-186.1591	34655.2112
X_2	200.3899	-12.9287	167.1511
X_3	322.7771	109.4585	11981.1579
X_4	352.3830	139.0643	19338.8930
X_5	620.6862	407.3676	165948.3741
X_6	27.3979	-185.9207	34566.5073
X_7	205.2921	91.9735	8459.1175
X_8	20.1852	-193.1335	37300.5302
X_9	14.5785	-198.7401	39497.6380
X_{10}	242.3368	29.0182	842.0544
		$\overline{X} = 213.3186$	$(S_x)^2 = 39195.1800$
			$S_x = 197.9777$
			$CI = 141.6149$
$t = 2.2622$	$h = 141.6247$	$h^* = 136$	$n^* = 11$

Table G.4: Simulation results for Store 2 for a Thursday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0

Table G.5: Simulation results for Store 2 for a Friday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0

Table G.6: Simulation results for Store 2 for a Saturday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0

Table G.7: Simulation results for Store 2 for a Sunday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0

Appendix H

Appendix H

Table H.1: Comparison table for Wednesday's results for Store 2

X_n	$\Delta_{Tue,Wed}$	$\Delta_{Tue,Thur}$	$\Delta_{Tue,Fri}$	$\Delta_{Tue,Sat}$	$\Delta_{Tue,Sun}$	
X_1	27.1595	27.1595	27.1595	27.1595	27.1595	27.1595
X_2	200.3899	200.3899	200.3899	200.3899	200.3899	200.3899
X_3	322.7771	322.7771	322.7771	322.7771	322.7771	322.7771
X_4	352.3830	352.3830	352.3830	352.383	352.383	352.383
X_5	620.6862	620.6862	620.6862	620.6862	620.6862	620.6862
X_6	27.3979	27.3979	27.3979	27.3979	27.3979	27.3979
X_7	305.2921	305.2921	305.2921	305.2921	305.2921	305.2921
X_8	20.1852	20.1852	20.1852	20.18515	20.18515	20.18515
X_9	14.5785	14.5785	14.5785	14.57848	14.57848	14.57848
X_{10}	242.3368	242.3368	242.3368	242.3368	242.3368	242.3368
Δ_{avg}	213.3186	213.3186	213.3186	213.3186	213.3186	213.3186
σ_Δ	197.9777	197.9777	197.9777	197.9777	197.9777	197.9777
t	2.2622	2.2622	2.2622	2.2622	2.2622	2.2622
h	141.6247	141.6247	141.6247	141.6247	141.6247	141.6247

Appendix I

Appendix I

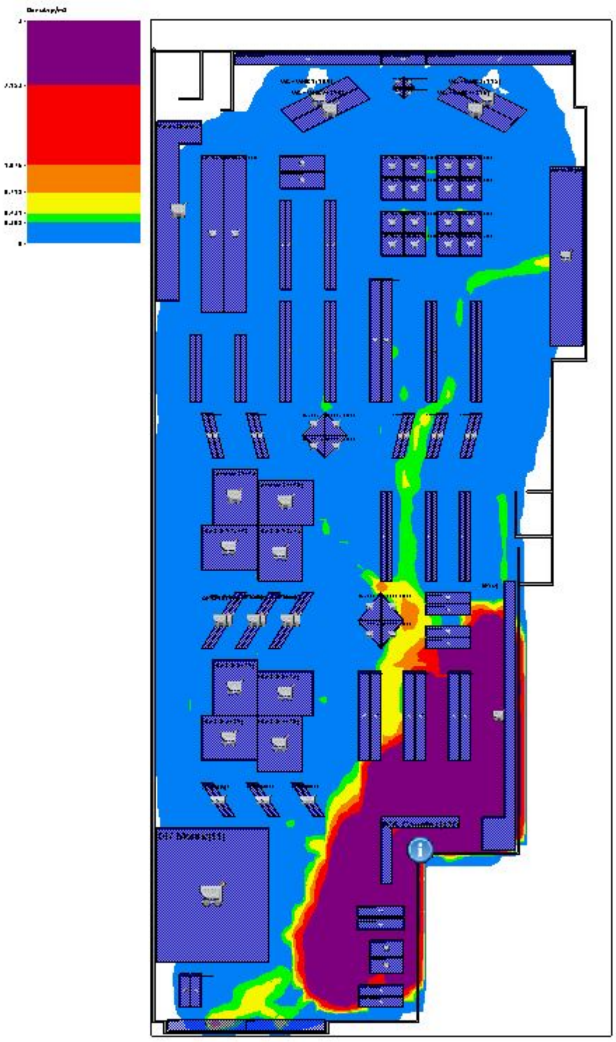


Figure I.1: A screen shot of Wednesday's final simulation run, $n = 1$

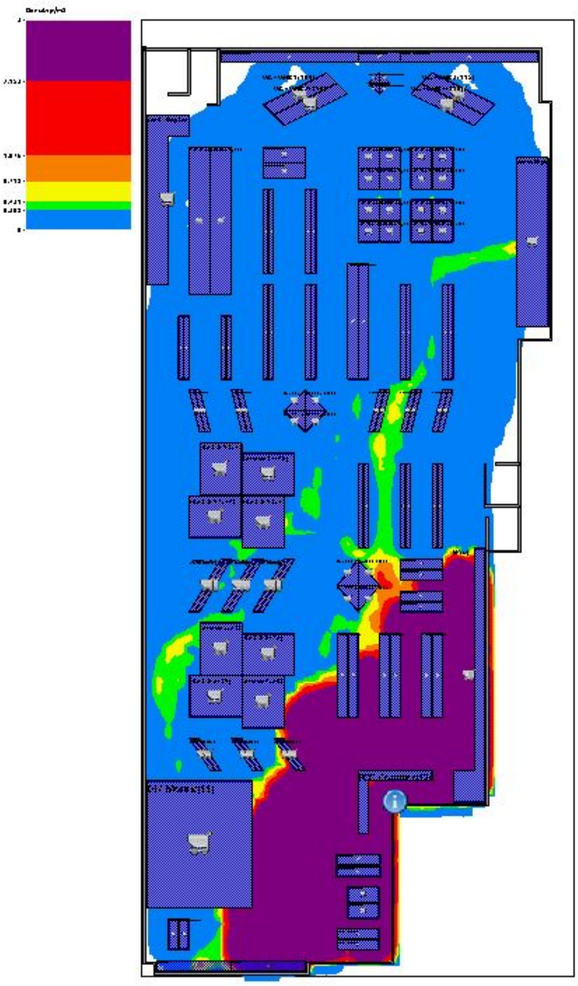


Figure I.2: A screen shot of Wednesday's final simulation run, $n = 2$

Figure I.3: A screen shot of Wednesday's final simulation run, $n = 3$

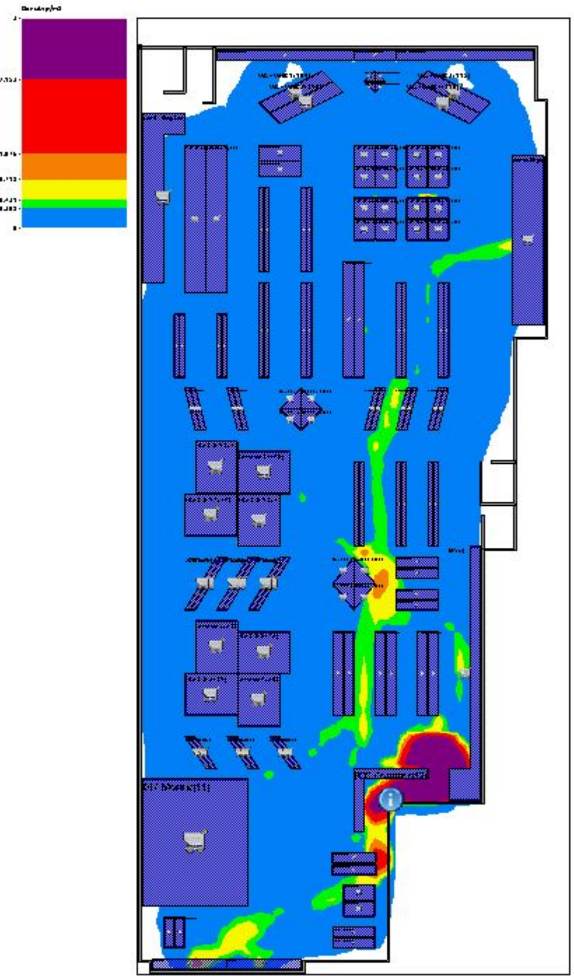


Figure I.4: A screen shot of Wednesday's final simulation run, $n = 4$

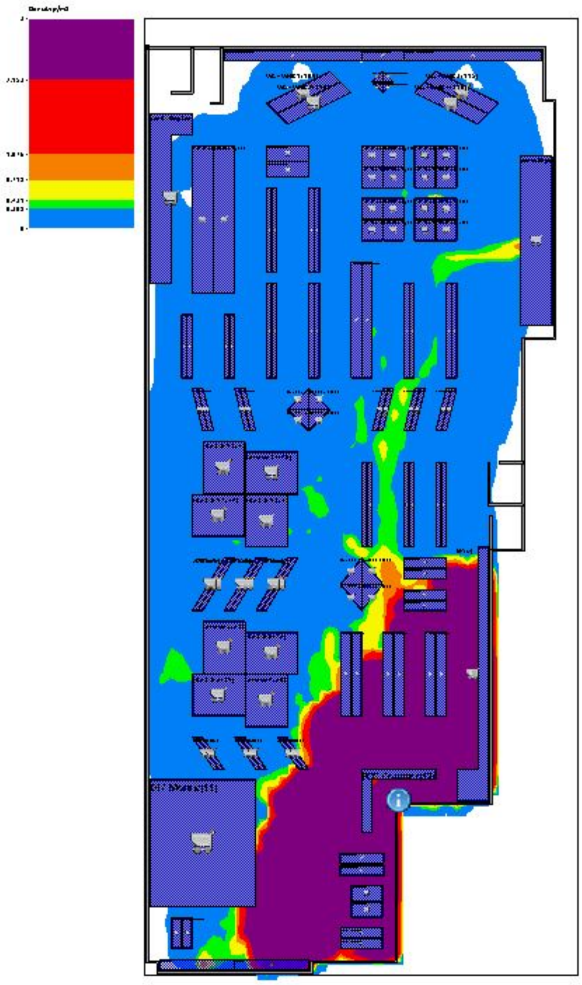


Figure I.5: A screen shot of Wednesday's final simulation run, $n = 5$

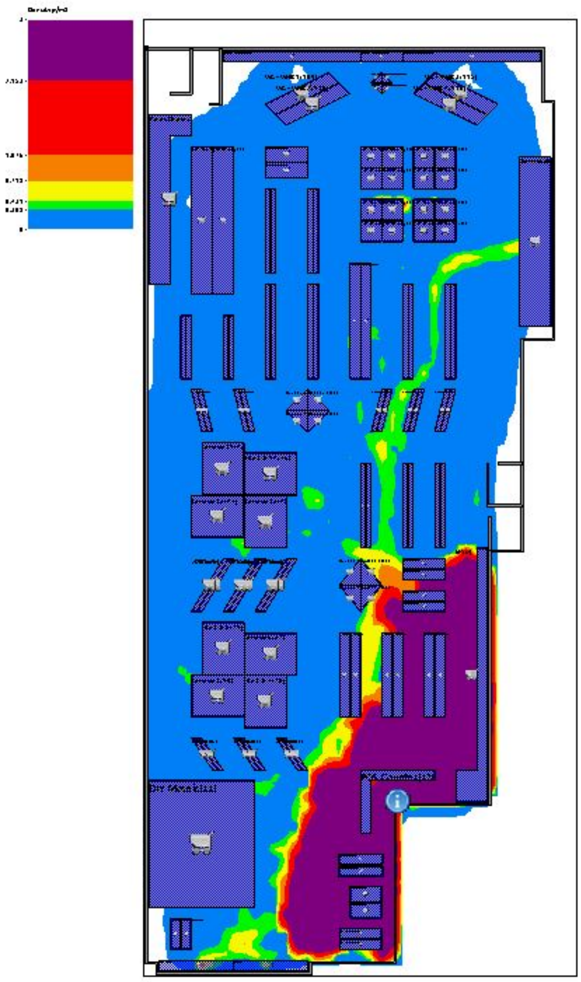


Figure I.6: A screen shot of Wednesday's final simulation run, $n = 6$

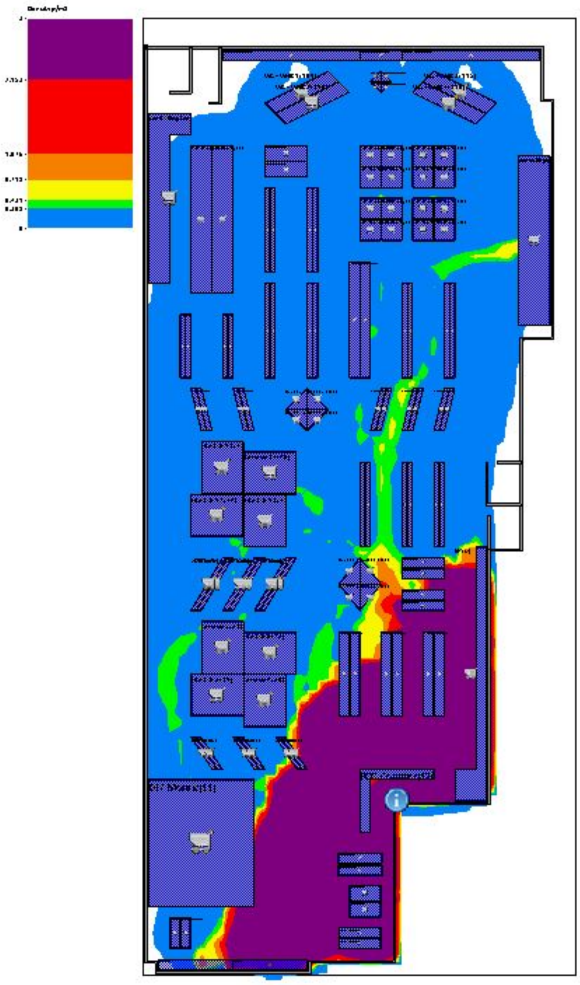


Figure I.7: A screen shot of Wednesday's final simulation run, $n = 7$

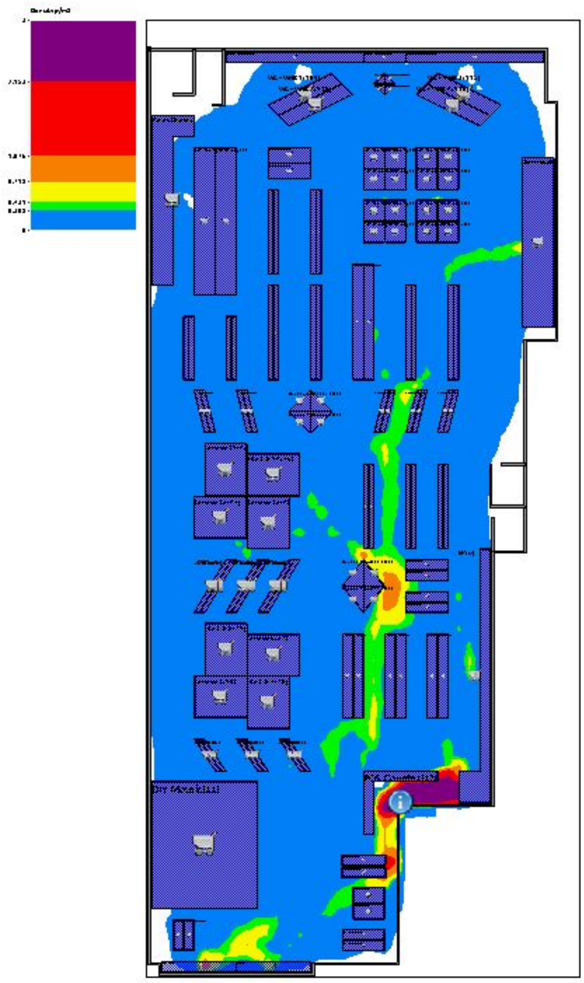


Figure I.8: A screen shot of Wednesday's final simulation run, $n = 8$

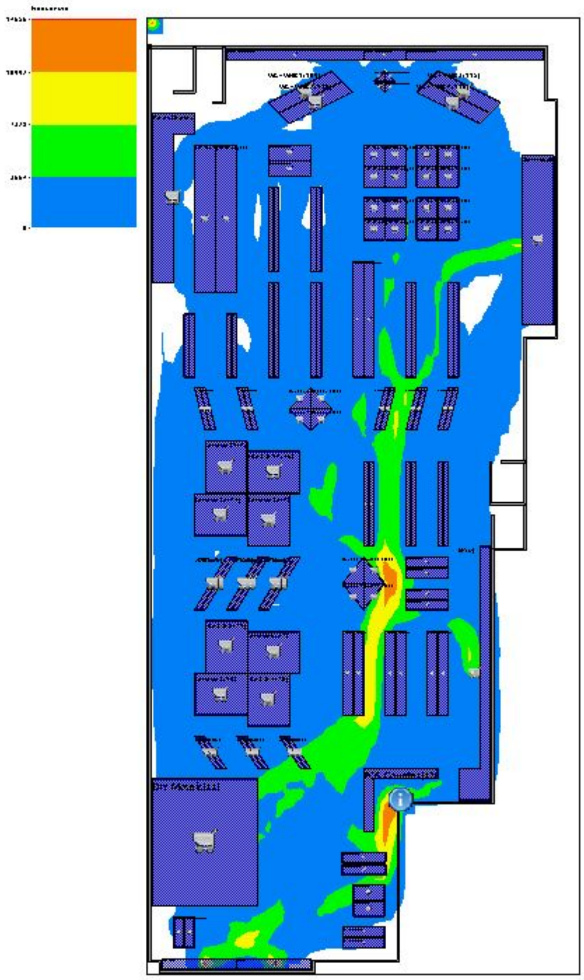


Figure I.9: A screen shot of Wednesday's final simulation run, $n = 9$

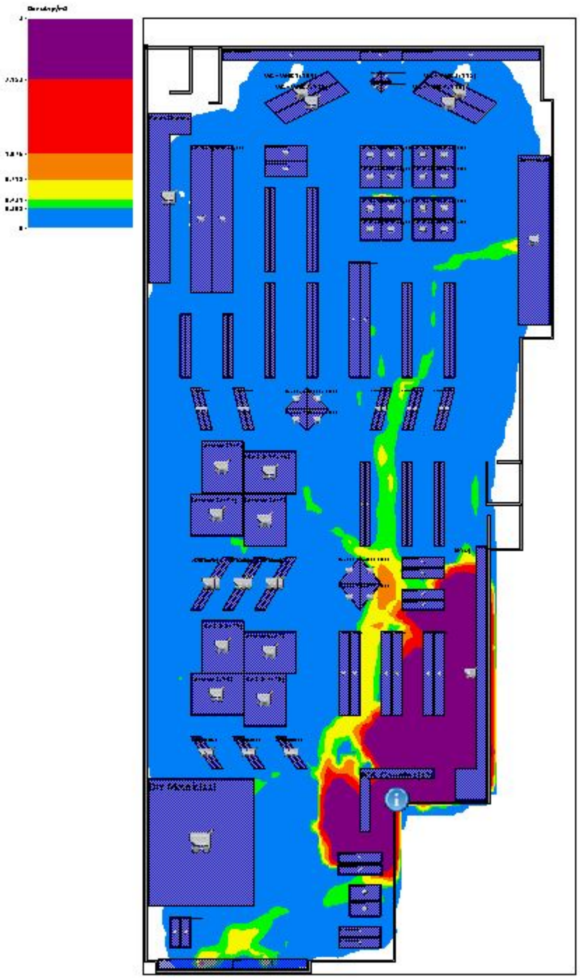


Figure I.10: A screen shot of Wednesday's final simulation run, $n = 10$

Figure I.11: A screen shot of Wednesday's final simulation run, $n = 11$

Table I.1: Final simulation results for Store 2 for a Wednesday

Xn	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	249.3275	29.1286	848.4767
X_2	405.0762	184.8773	34179.6189
X_3	105.1783	-115.0206	13229.7312
X_4	31.2613	-188.9375	35697.3828
X_5	368.2254	148.0265	21911.8534
X_6	267.2357	47.0368	2212.4625
X_7	396.6375	176.4386	31130.5971
X_8	13.5912	-206.6077	42686.7340
X_9	202.3120	-17.8869	319.9397
X_{10}	163.1435	-57.0553	3255.3085
X_{11}	21.2290	-198.9698	39588.9794
		$\overline{X} = 220.1988$	$(S_x)^2 = 25006.7871$
			$S_x = 158.1353$

Appendix J

Appendix J

Table J.1: Simulation results for Store 2 for a Monday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	36.1931	0.4155	0.1727
X_2	38.5915	2.8139	7.9179
X_3	33.5592	-2.2184	4.9212
X_4	37.5589	1.7813	3.1731
X_5	36.8116	1.0340	1.0691
X_6	34.3182	-1.4594	2.1298
X_7	40.4629	4.6853	21.9518
X_8	34.2512	-1.5264	2.3298
X_9	30.1058	-5.6718	32.1693
X_{10}	35.9236	0.1460	0.0213
		$\overline{X} = 35.7776$	$(S_x)^2 = 8.4284$
			$S_x = 2.9032$

Table J.2: Simulation results for Store 2 for a Tuesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	13.0350	-1.2374	1.5312
X_2	9.7692	-4.5032	20.2791
X_3	12.5798	-1.6926	2.8648
X_4	19.6409	5.3685	28.8210
X_5	9.0607	-5.2117	27.1617
X_6	11.7367	-2.5357	6.4297
X_7	16.2668	1.9944	3.9777
X_8	9.4941	-4.7783	22.8320
X_9	21.2791	7.0067	49.0934
X_{10}	19.8617	5.5893	31.2404
		$\overline{X} = 14.2724$	$(S_x)^2 = 21.5812$
			$S_x = 4.6456$

Table J.3: Simulation results for Store 2 for a Wednesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0.1701	-0.0632	0.0040
X_2	0.0370	-0.1963	0.0386
X_3	0.2141	-0.0193	0.0004
X_4	0.2810	0.0476	0.0023
X_5	0.5227	0.2893	0.0837
X_6	0.4410	0.2077	0.0431
X_7	0.0000	-0.2333	0.0545
X_8	0.2503	0.0170	0.0003
X_9	0.4173	0.1840	0.0338
X_{10}	0.0000	-0.2333	0.0545
		$\overline{X} = 0.2333$	$(S_x)^2 = 0.0350$
			$S_x = 0.1871$

Table J.4: Simulation results for Store 2 for a Thursday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0.8058	0.2169	0.0470
X_2	0.6212	0.0322	0.0010
X_3	0.2260	-0.3630	0.1318
X_4	0.1367	-0.4522	0.2045
X_5	1.3418	0.7528	0.5667
X_6	0.3103	-0.2787	0.0777
X_7	0.7188	0.1299	0.0169
X_8	0.5315	-0.0574	0.0033
X_9	0.4756	-0.1134	0.0129
X_{10}	0.7218	0.1329	0.0177
		$\overline{X} = 0.5889$	$(S_x)^2 = 0.1199$
			$S_x = 0.3463$

Table J.5: Simulation results for Store 2 for a Friday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	-0.0715	0.0051
X_2	0	-0.0715	0.0051
X_3	0	-0.0715	0.0051
X_4	0.0216	-0.0499	0.0025
X_5	0.0261	-0.0454	0.0021
X_6	0.3564	0.2849	0.0812
X_7	0.1462	0.0747	0.0056
X_8	0	-0.0715	0.0051
X_9	0.0151	-0.0563	0.0032
X_{10}	0.1493	0.0779	0.0061
		$\overline{X} = 0.0715$	$(S_x)^2 = 0.0134$
			$S_x = 0.1159$

Table J.6: Simulation results for Store 2 for a Saturday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0.6131	-0.3468	0.1203
X_2	1.4014	0.4415	0.1949
X_3	0.4455	-0.5144	0.2647
X_4	0.4544	-0.5056	0.2556
X_5	1.2134	0.2534	0.0642
X_6	2.1085	1.1486	1.3193
X_7	1.4348	0.4748	0.2255
X_8	0.8718	-0.0881	0.0078
X_9	0.7536	-0.2063	0.0426
X_{10}	0.3029	-0.6571	0.4318
		$\overline{X} = 0.9599$	$(S_x)^2 = 0.3252$
			$S_x = 0.5702$

Table J.7: Simulation results for Store 2 for a Sunday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$

Appendix K

Appendix K

Table K.1: Comparison table for Monday's results for Store 1

X_n	$\Delta_{Mon,Tue}$	$\Delta_{Mon,Wed}$	$\Delta_{Mon,Thur}$	$\Delta_{Mon,Fri}$	$\Delta_{Mon,Sat}$	$\Delta_{Mon,Sun}$
X_1	23.1582	36.0230	35.3873	36.1931	35.5800	36.1931
X_2	28.8223	38.5545	37.9703	38.5915	37.1900	38.5915
X_3	20.9794	33.3452	33.3332	33.5592	33.1137	33.5592
X_4	17.9180	37.2779	37.4222	37.5373	37.1045	37.5589
X_5	27.7509	36.2889	35.4698	36.7854	35.5982	36.8116
X_6	22.5815	33.8772	34.0079	33.9618	32.2097	34.3182
X_7	24.1961	40.4629	39.7440	40.3167	39.0281	40.4629
X_8	24.7571	34.0009	33.7197	34.2512	33.3794	34.2512
X_9	8.8267	29.6885	29.6302	30.0907	29.3521	30.1058
X_{10}	16.0619	35.9236	35.2017	35.7742	35.6207	35.9236
Δ_{avg}	21.5052	35.5442	35.1886	35.7061	34.8176	35.7776
σ_Δ	5.9421	3.0088	2.8183	2.8991	2.8297	2.9032
t	2.2622	2.2622	2.2622	2.2622	2.2622	2.2622
h	4.2507	2.1523	2.0161	2.0739	2.0243	2.0768

Table K.2: Comparison table for Tuesday's results for Store 1

X_n	$\Delta_{Tue,Wed}$	$\Delta_{Tue,Thur}$	$\Delta_{Tue,Fri}$	$\Delta_{Tue,Sat}$	$\Delta_{Tue,Sun}$
X_1	12.8649	12.2291	13.0350	12.4218	13.0350
X_2	9.7322	9.1480	9.7692	8.3677	9.7692
X_3	12.3658	12.3538	12.5798	12.1343	12.5798
X_4	19.3599	19.5042	19.6193	19.1865	19.6409
X_5	8.5380	7.7189	9.0346	7.8473	9.0607
X_6	11.2957	11.4264	11.3803	9.6282	11.7367
X_7	16.2668	15.5480	16.1206	14.8320	16.2668
X_8	9.2438	8.9626	9.4941	8.6223	9.4941
X_9	20.8617	20.8035	21.2639	20.5254	21.2791
X_{10}	19.8617	19.1399	19.7124	19.5588	19.8617
Δ_{avg}	14.0390	13.6834	14.2009	13.3124	14.2724
σ_Δ	4.6814	4.7753	4.6396	4.9433	4.6456
t	2.2622	2.2622	2.2622	2.2622	2.2622
h	3.3489	3.4161	3.3190	3.5362	3.3232

Table K.3: Comparison table for Wednesday's results for Store 1

X_n	$\Delta_{Wed,Thur}$	$\Delta_{Wed,Fri}$	$\Delta_{Wed,Sat}$	$\Delta_{Wed,Sun}$
X_1	-0.6357	0.1701	-0.4430	0.1701
X_2	-0.5842	0.0370	-1.3644	0.0370
X_3	-0.0119	0.2141	-0.2315	0.2141
X_4	0.1442	0.2594	-0.1734	0.2810
X_5	-0.8191	0.4966	-0.6907	0.5227
X_6	0.1308	0.0846	-1.6675	0.4410
X_7	-0.7188	-0.1462	-1.4348	0.0000
X_8	-0.2812	0.2503	-0.6215	0.2503
X_9	-0.0582	0.4022	-0.3363	0.4173
X_{10}	-0.7218	-0.1493	-0.3029	0.0000
Δ_{avg}	-0.3556	0.1619	-0.7266	0.2333
σ_Δ	0.3815	0.2117	0.5547	0.1871
t	2.2622	2.2622	2.2622	2.2622
h	0.2729	0.1514	0.3968	0.1338

Table K.4: Comparison table for Thursday's results for Store 1

X_n	$\Delta_{Thur,Fri}$	$\Delta_{Thur,Sat}$	$\Delta_{Thur,Sun}$
X_1	0.8058	0.1927	0.8058
X_2	0.6212	-0.7803	0.6212
X_3	0.2260	-0.2196	0.2260
X_4	0.1152	-0.3176	0.1367
X_5	1.3157	0.1284	1.3418
X_6	-0.0461	-1.7983	0.3103
X_7	0.5726	-0.7160	0.7188
X_8	0.5315	-0.3403	0.5315
X_9	0.4604	-0.2781	0.4756
X_{10}	0.5725	0.4189	0.7218
Δ_{avg}	0.5175	-0.3710	0.5889
σ_Δ	0.3808	0.6281	0.3463
t	2.2622	2.2622	2.2622
h	0.2724	0.4493	0.2477

Table K.5: Comparison table for Friday's results for Store 1

X_n	$\Delta_{Fri,Sat}$	$\Delta_{Fri,Sun}$
X_1	-0.6131	0.0000
X_2	-1.4014	0.0000
X_3	-0.4455	0.0000
X_4	-0.4328	0.0216
X_5	-1.1873	0.0261
X_6	-1.7521	0.3564
X_7	-1.2886	0.1462
X_8	-0.8718	0.0000
X_9	-0.7385	0.0151
X_{10}	-0.1535	0.1493
Δ_{avg}	-0.8885	0.0715
σ_Δ	0.5056	0.1159
t	2.2622	2.2622
h	0.3617	0.0829

Table K.6: Comparison table for Saturday's results for Store 1

X_n	$\Delta_{Sat,Sun}$
X_1	0.6131
X_2	1.4014
X_3	0.4455
X_4	0.4544
X_5	1.2134
X_6	2.1085
X_7	1.4348
X_8	0.8718
X_9	0.7536
X_{10}	0.3029
Δ_{avg}	0.9599
σ_Δ	0.5702
t	2.2622
h	0.4079

Appendix L

Appendix L

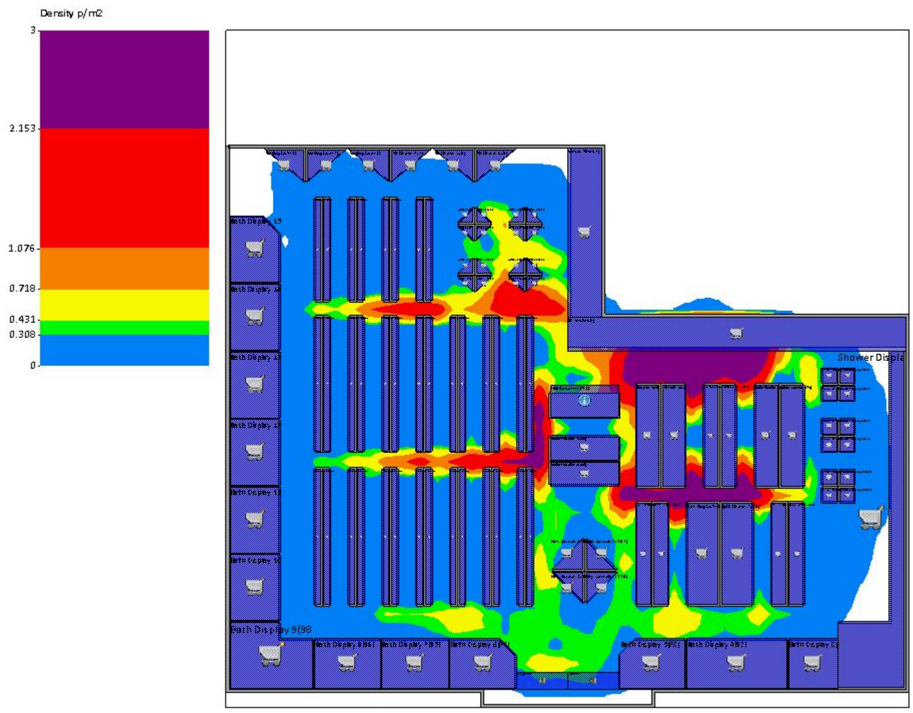


Figure L.1: A screen shot of Monday's final simulation run, $n = 1$

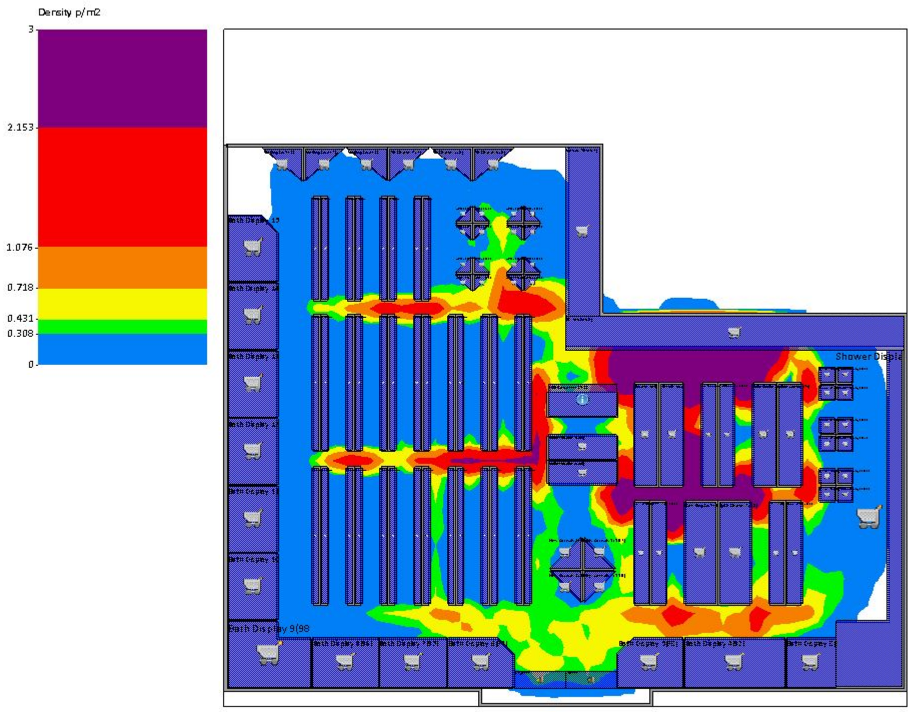


Figure L.2: A screen shot of Monday's final simulation run, $n = 2$

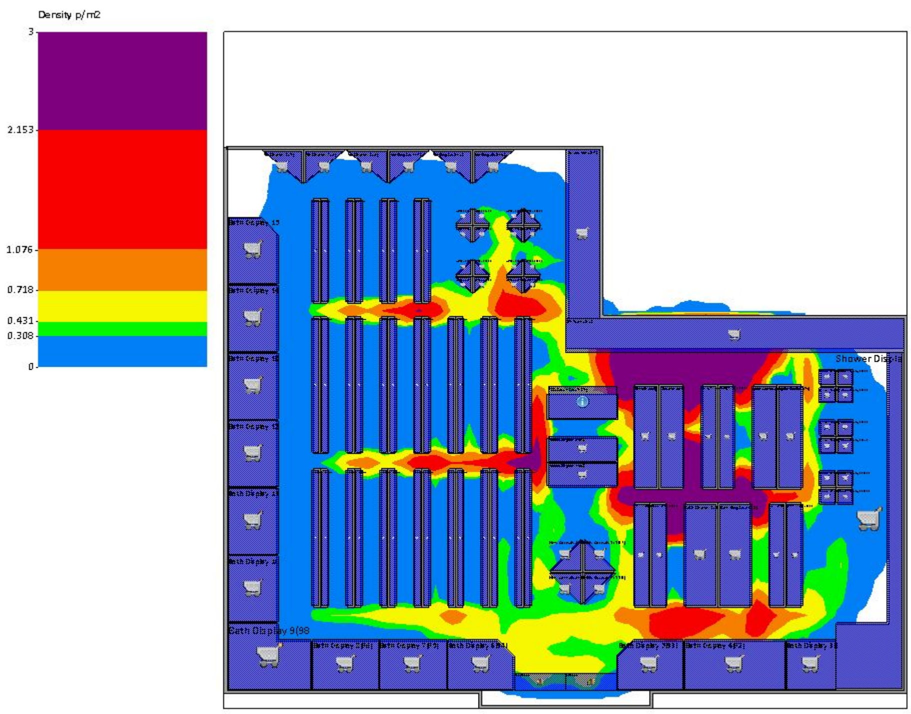


Figure L.3: A screen shot of Monday's final simulation run, $n = 3$

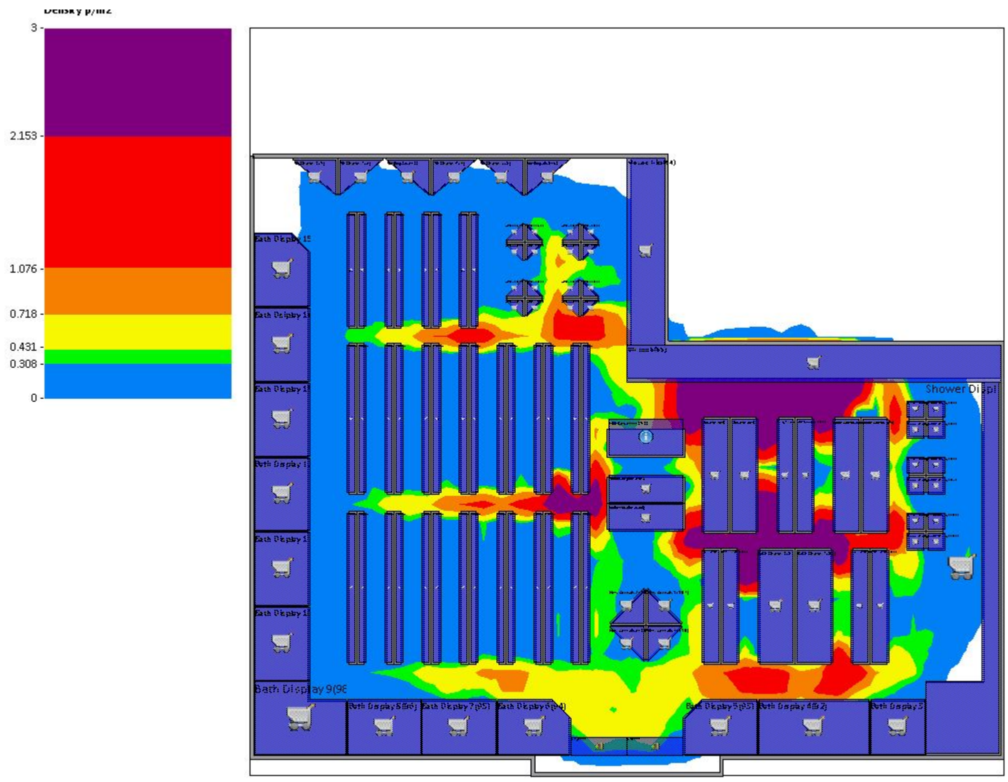


Figure L.4: A screen shot of Monday's final simulation run, $n = 4$

Table L.1: Simulation results for Store 1 for Monday's final simulation runs

Xn	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	26.7709	-7.3796	54.4578
X_2	37.8005	3.6500	13.3227
X_3	34.5152	0.3648	0.1331
X_4	37.4907	3.3402	11.1569
X_5	20.6329	-13.5175	182.7238
X_6	36.5633	2.4129	5.8219
X_7	35.0113	0.8609	0.7411
X_8	25.8195	-8.3310	69.4056
X_9	38.3917	4.2412	17.9879
X_{10}	41.4750	7.3246	53.6491
X_{11}	38.0729	3.9225	15.3857
X_{12}	38.5799	4.4294	19.6198
X_{13}	32.8322	-1.3183	1.7379
		$\overline{X} = 34.1505$	$(S_x)^2 = 10.5715$
			$S_x = 7.0407$

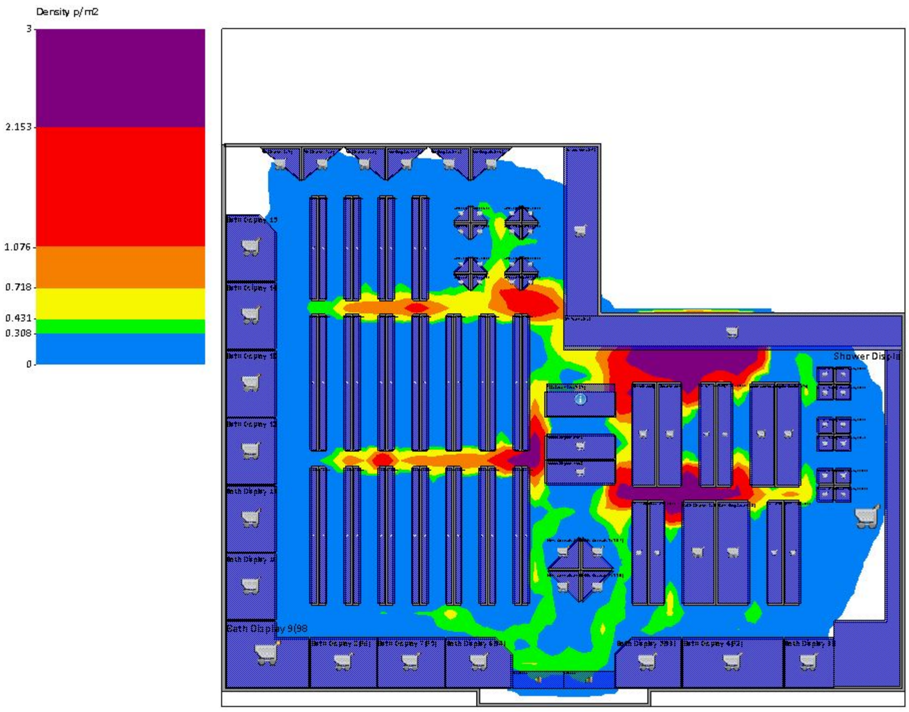


Figure L.5: A screen shot of Monday's final simulation run, $n = 5$

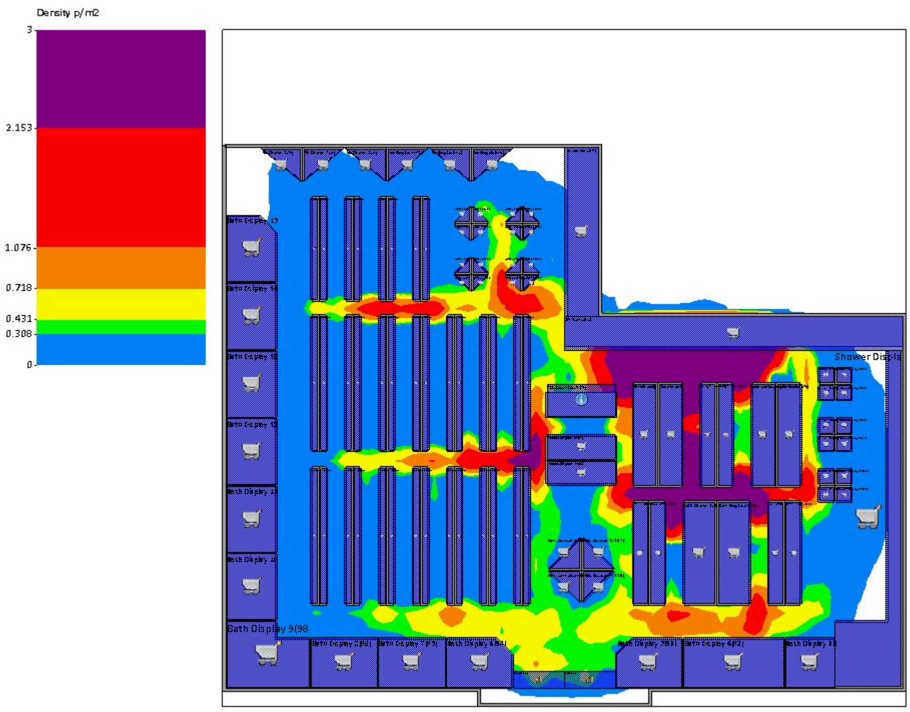


Figure L.6: A screen shot of Monday's final simulation run, $n = 6$

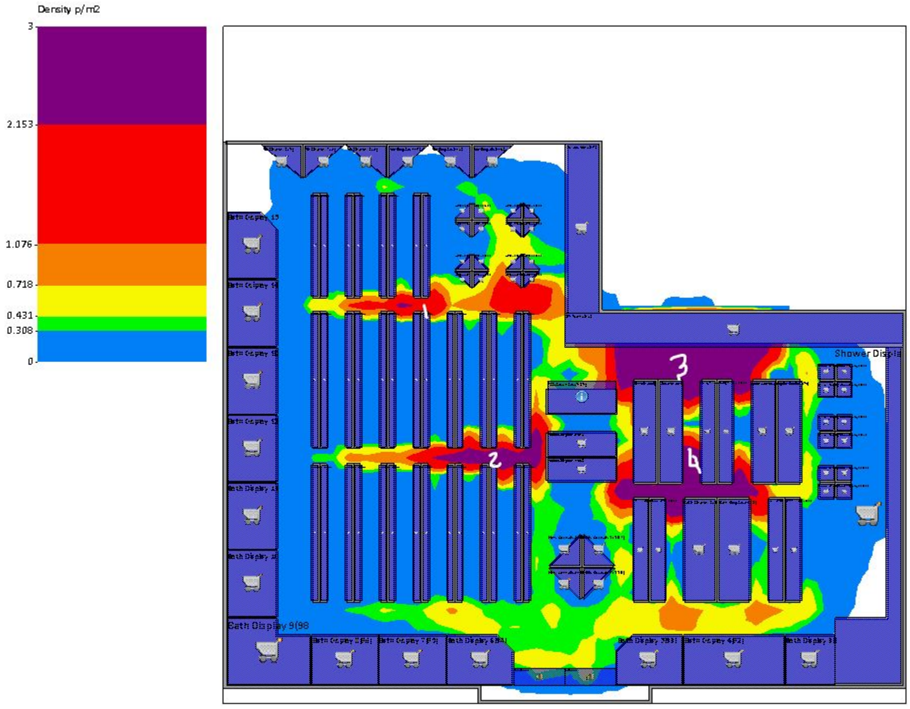


Figure L.7: A screen shot of Monday's final simulation run, $n = 7$

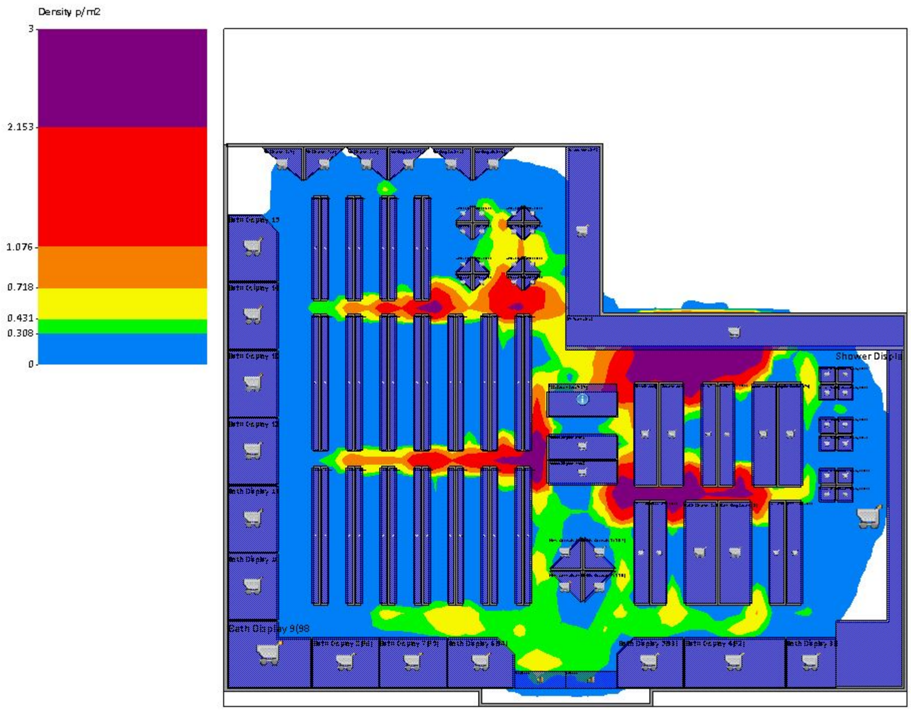


Figure L.8: A screen shot of Monday's final simulation run, $n = 8$

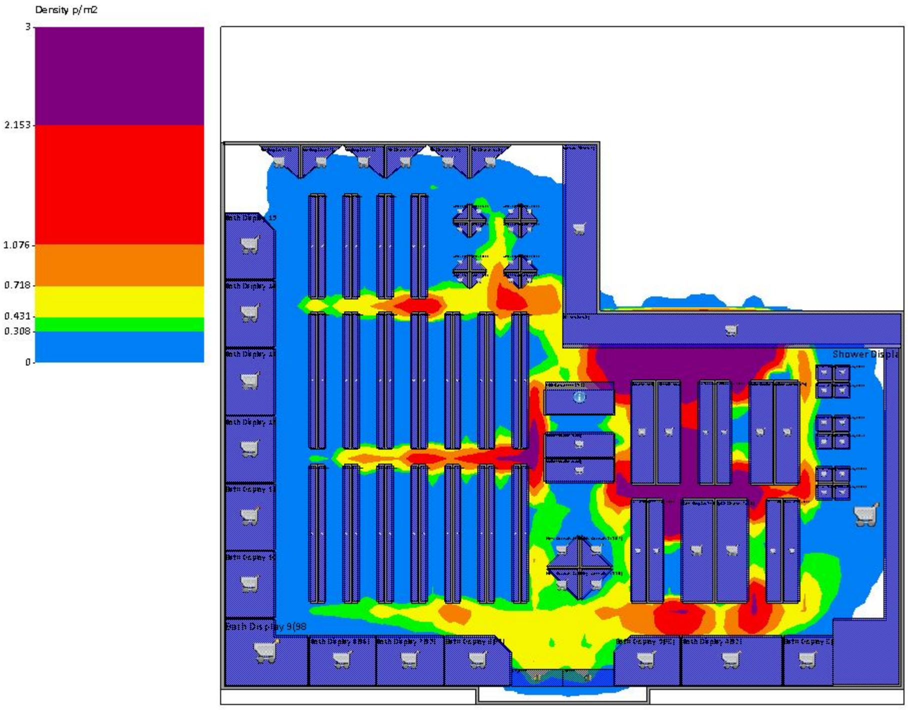


Figure L.9: A screen shot of Monday's final simulation run, $n = 9$

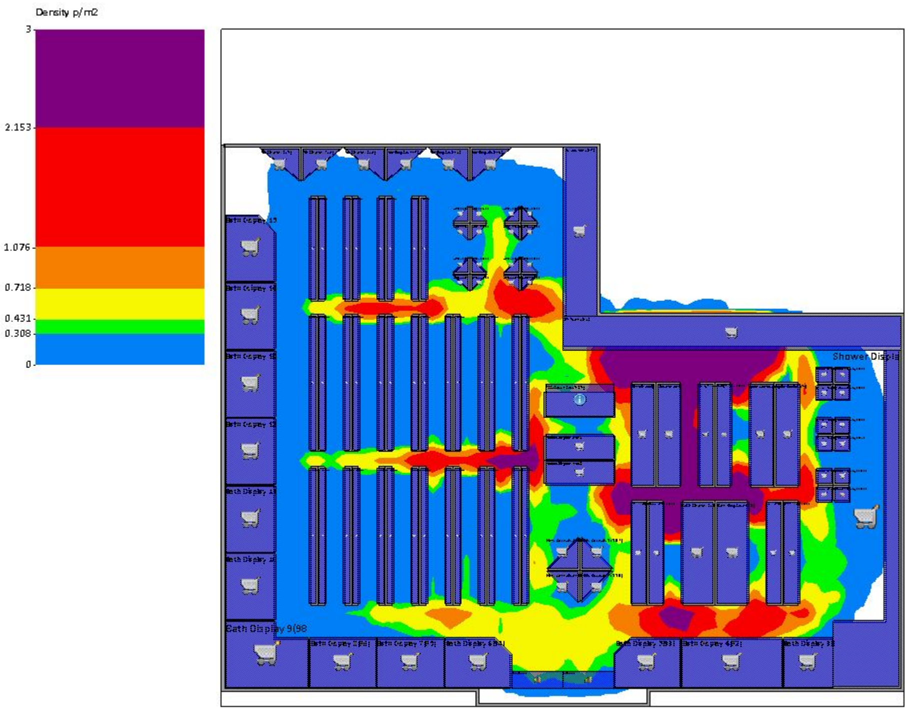


Figure L.10: A screen shot of Monday's final simulation run, $n = 10$

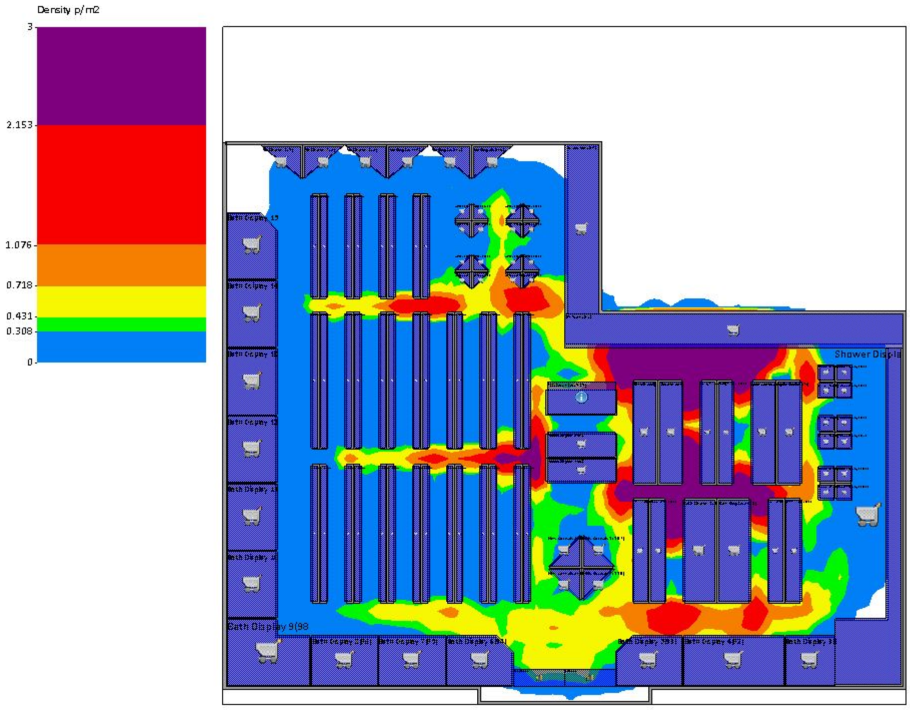


Figure L.11: A screen shot of Monday's final simulation run, $n = 11$

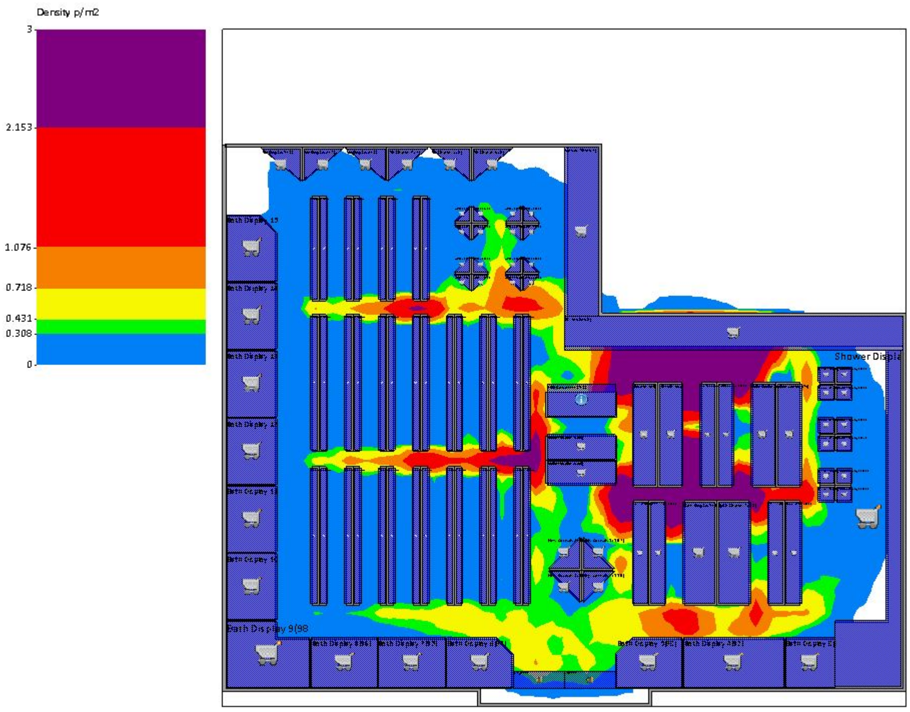


Figure L.12: A screen shot of Monday's final simulation run, $n = 12$

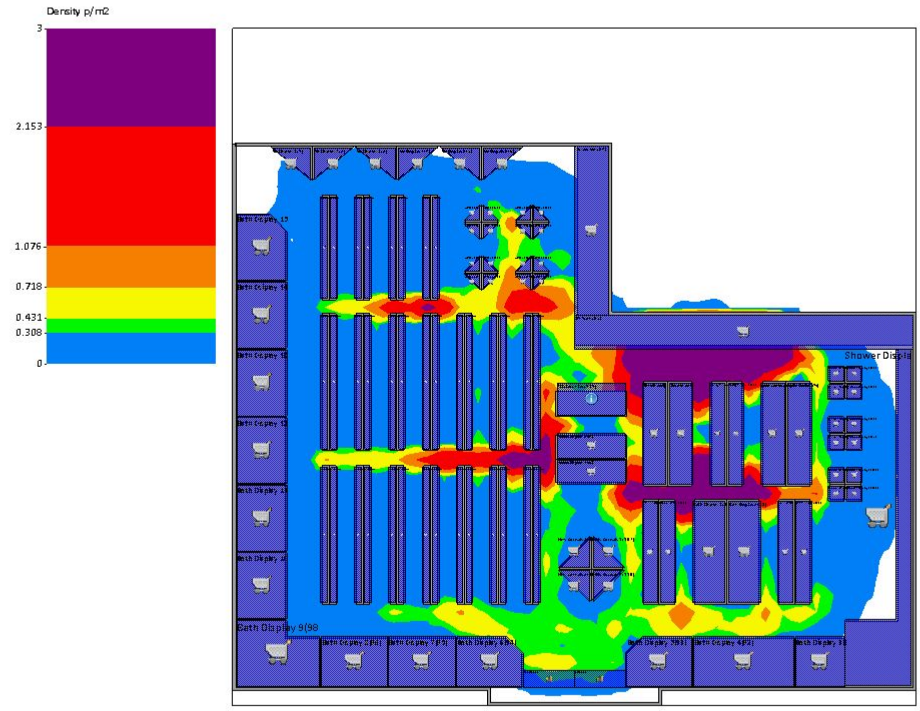


Figure L.13: A screen shot of Monday's final simulation run, $n = 13$

Appendix M

Appendix M

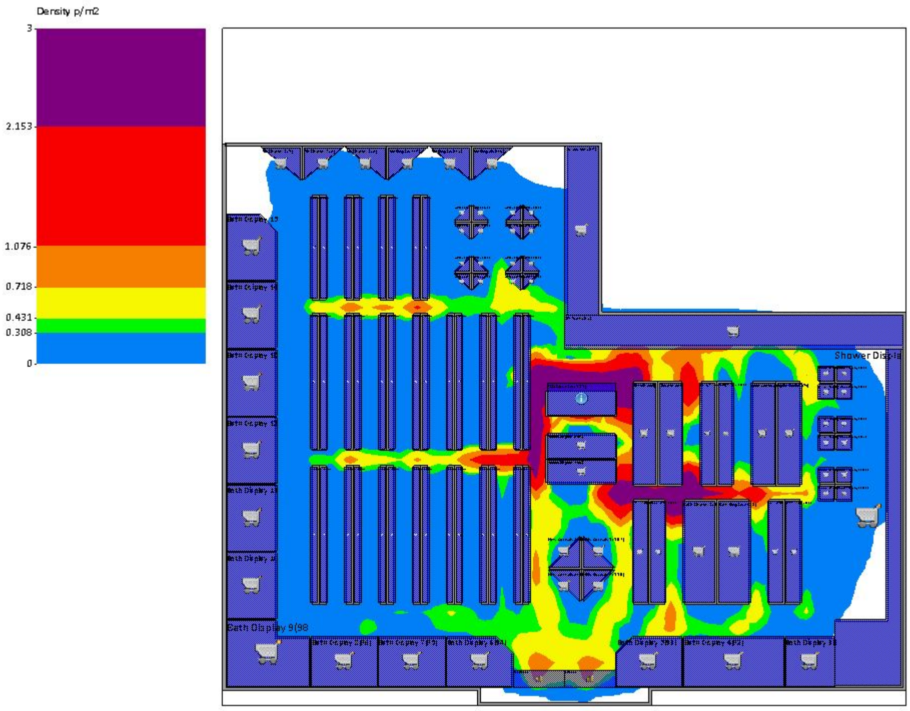


Figure M.1: A screen shot of Tuesday's final simulation run, $n = 1$

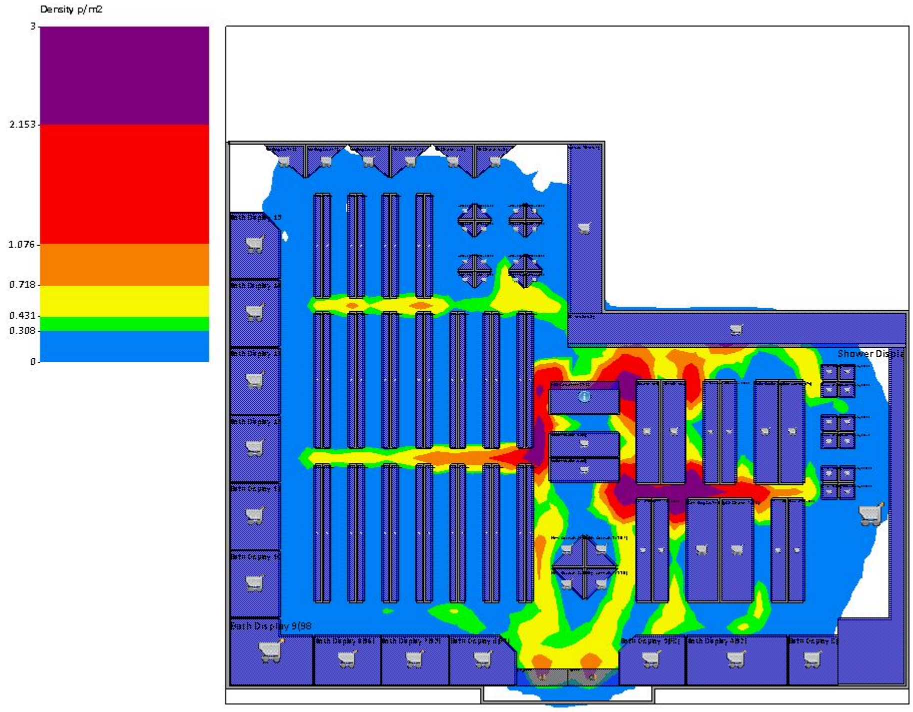


Figure M.2: A screen shot of Tuesday's final simulation run, $n = 2$

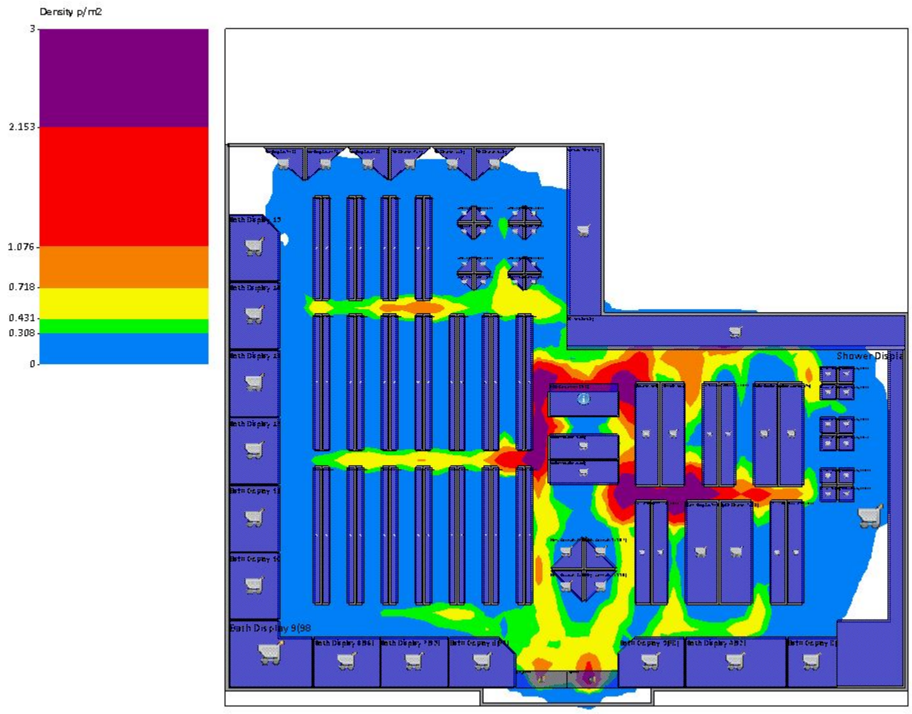


Figure M.3: A screen shot of Tuesday's final simulation run, $n = 3$

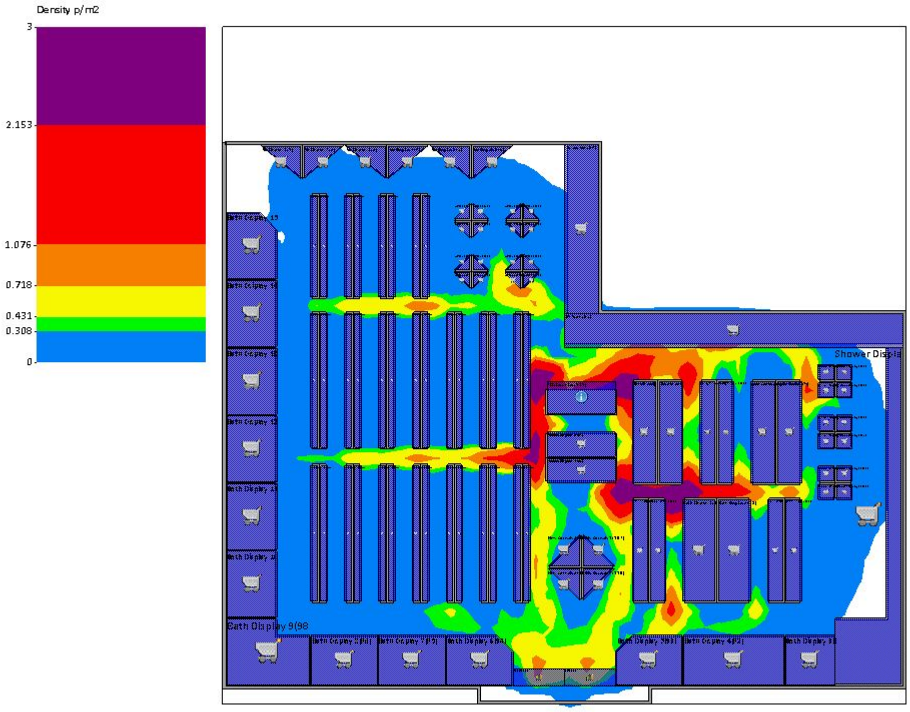


Figure M.4: A screen shot of Tuesday's final simulation run, $n = 4$

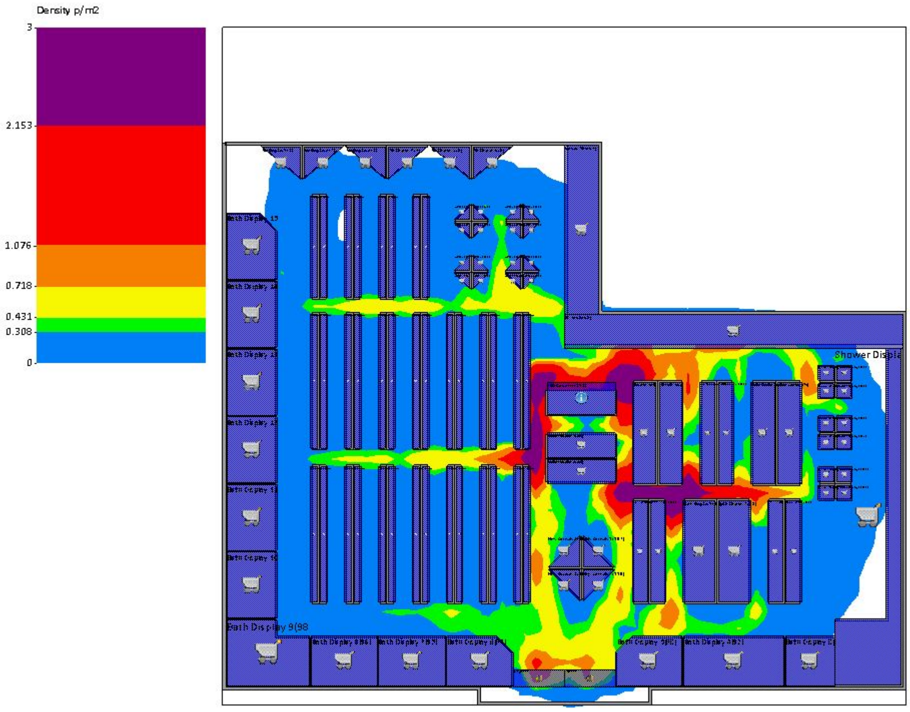


Figure M.5: A screen shot of Tuesday's final simulation run, $n = 5$

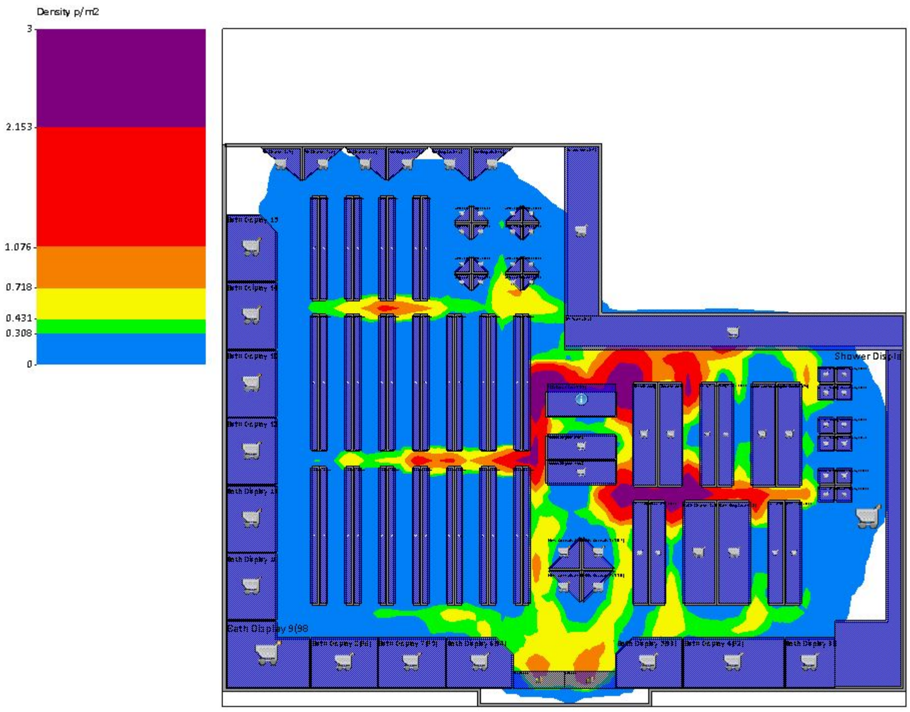


Figure M.6: A screen shot of Tuesday's final simulation run, $n = 6$

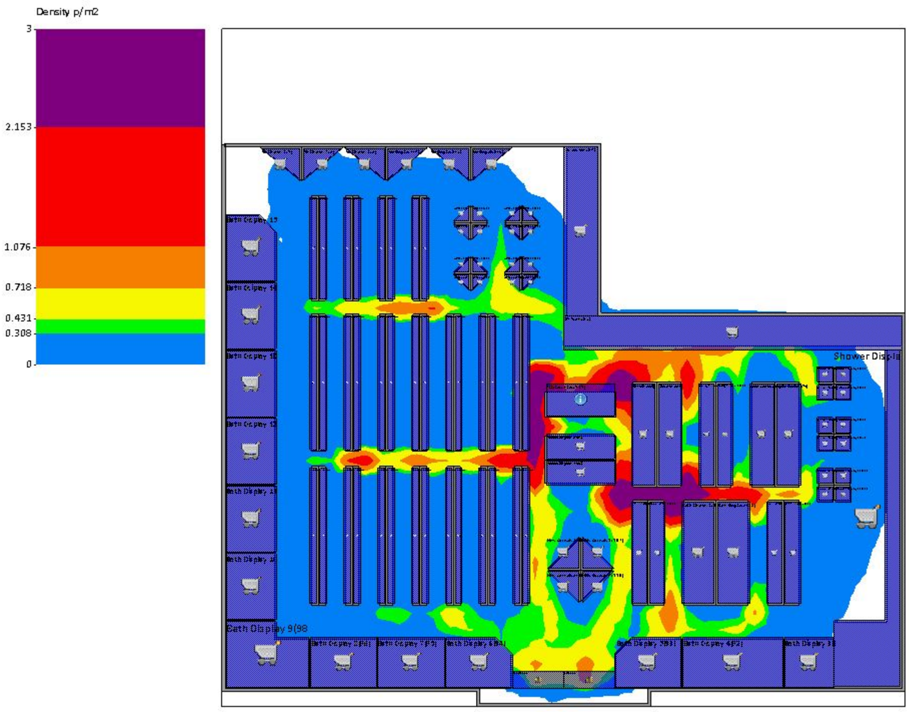


Figure M.7: A screen shot of Tuesday's final simulation run, $n = 7$

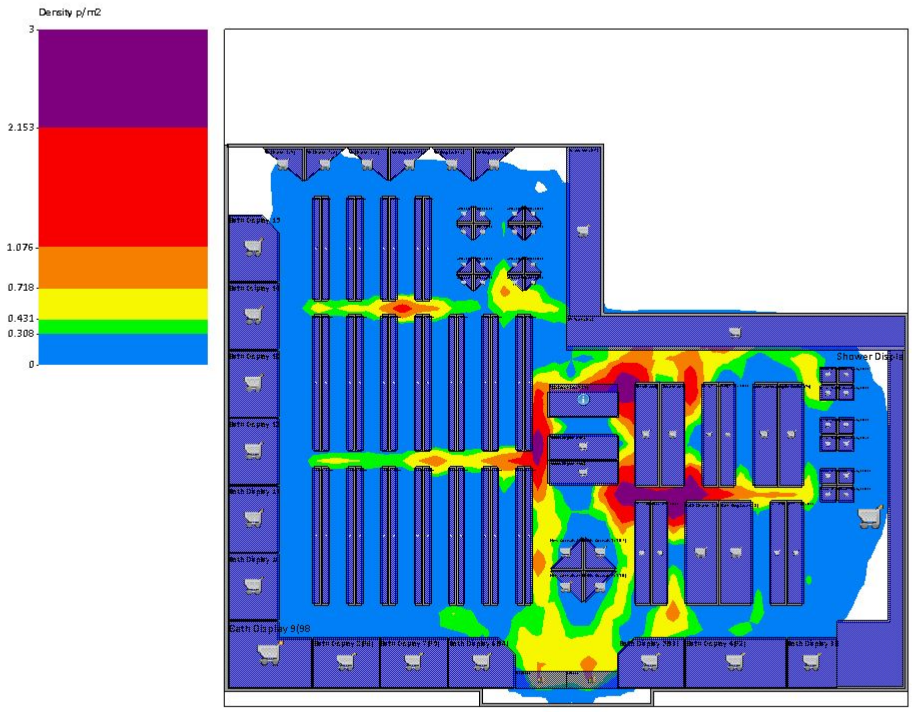


Figure M.8: A screen shot of Tuesday's final simulation run, $n = 8$

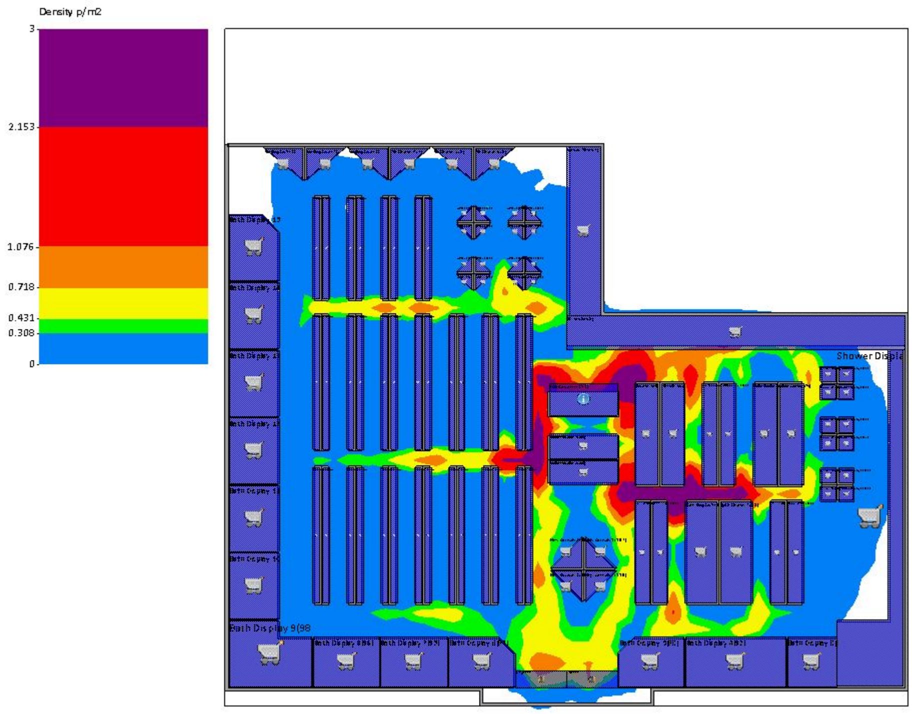


Figure M.9: A screen shot of Tuesday's final simulation run, $n = 9$

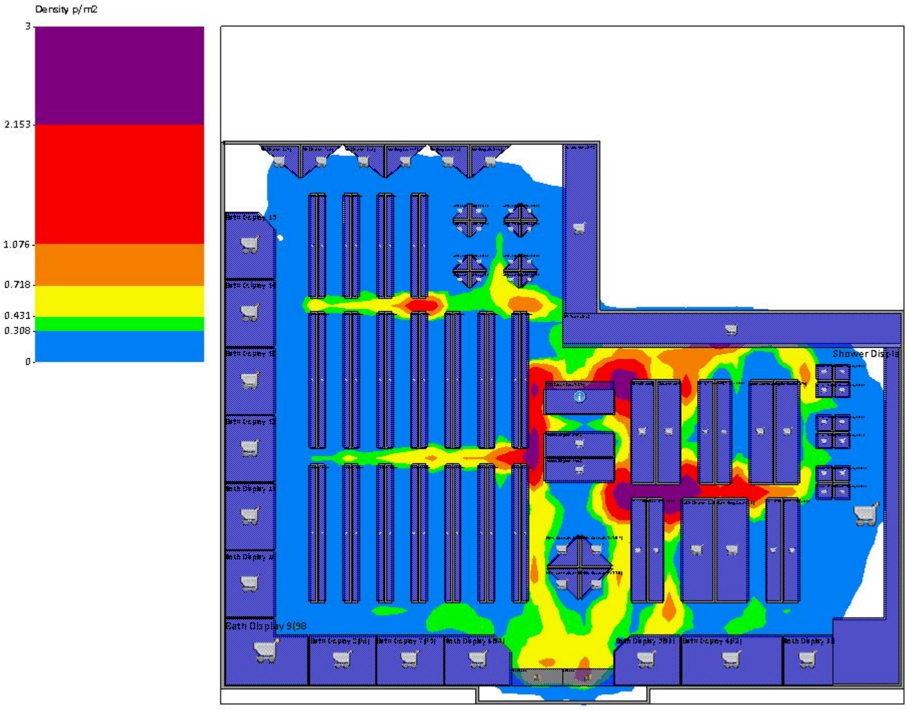


Figure M.10: A screen shot of Tuesday's final simulation run, $n = 10$

Table M.1: Simulation results for Store 1 for Tuesday's final simulation runs

Xn	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	26.7709	-7.3796	54.4578
X_2	37.8005	3.6500	13.3227
X_3	34.5152	0.3648	0.1331
X_4	37.4907	3.3402	11.1569
X_5	20.6329	-13.5175	182.7238
X_6	36.5633	2.4129	5.8219
X_7	35.0113	0.8609	0.7411
X_8	25.8195	-8.3310	69.4056
X_9	38.3917	4.2412	17.9879
X_{10}	41.4750	7.3246	53.6491
X_{11}	38.0729	3.9225	15.3857
X_{12}	38.5799	4.4294	19.6198
X_{13}	32.8322	-1.3183	1.7379
		$\overline{X} = 34.1505$	$(S_x)^2 = 10.5715$
			$S_x = 7.0407$

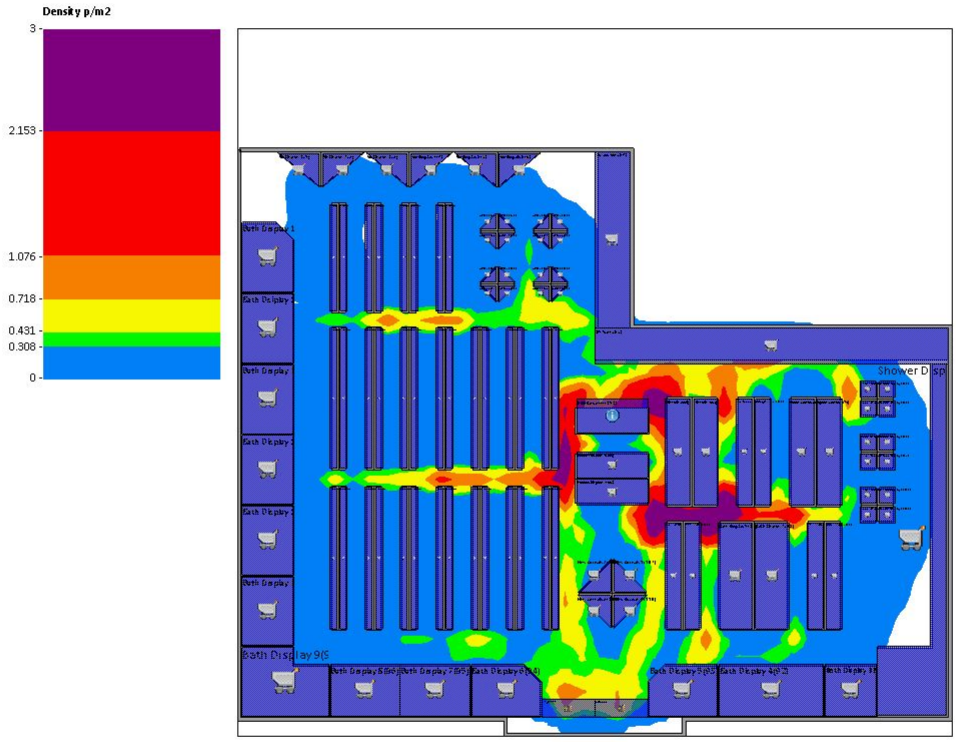


Figure M.11: A screen shot of Tuesday's final simulation run, $n = 11$

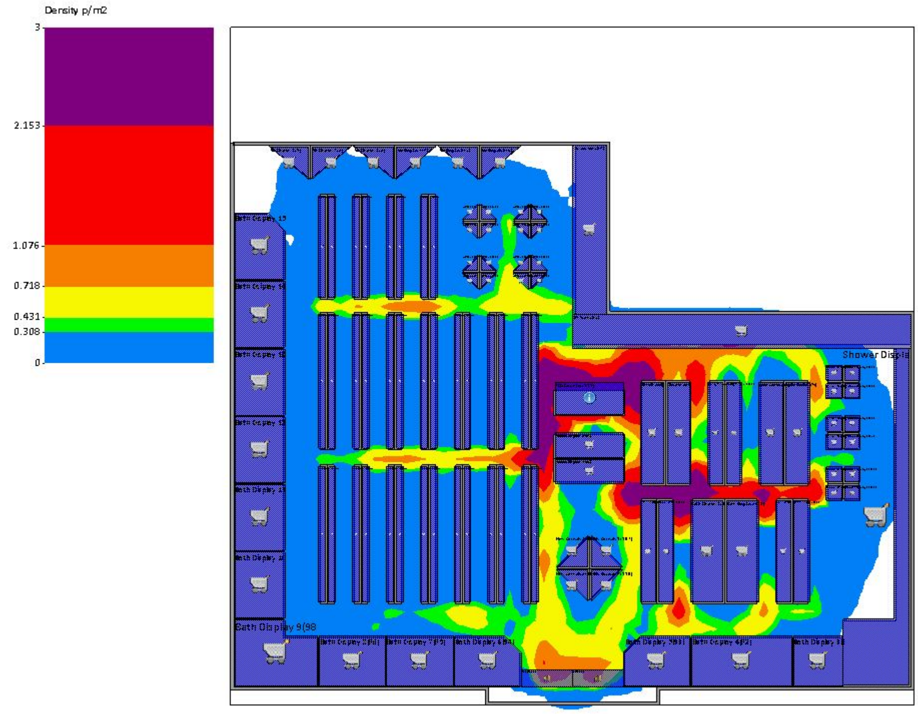


Figure M.12: A screen shot of Tuesday's final simulation run, $n = 12$

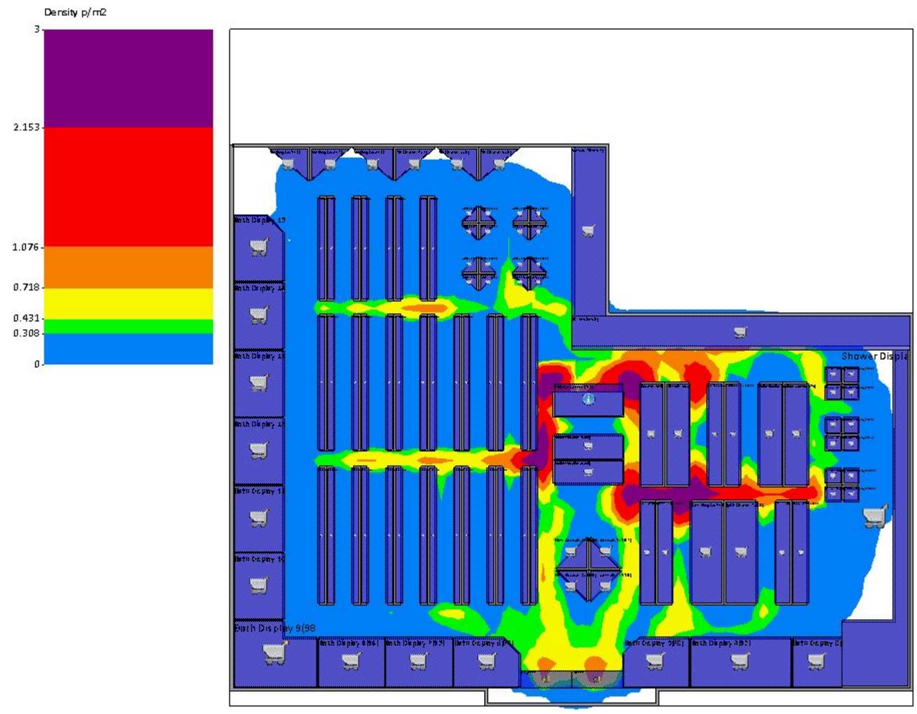


Figure M.13: A screen shot of Tuesday's final simulation run, $n = 13$

Appendix N

Appendix N

Table N.1: Simulation results for Store 1 for a Monday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$
			$CI = 0$

Table N.2: Simulation results for Store 1 for a Tuesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$
			$CI = 0$

Table N.3: Simulation results for Store 1 for a Wednesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	383.0771	136.3881	18601.7144
X_2	21.3704	-225.3186	50768.4932
X_3	17.9851	-228.7039	52305.4730
X_4	382.2835	135.5945	18385.8635
X_5	416.9726	170.2836	28996.5108
X_6	382.9246	136.2356	18560.1460
X_7	401.0823	154.3933	23837.3033
X_8	16.7027	-229.9863	52893.7102
X_9	331.4264	84.7374	7180.4192
X_{10}	113.0653	-133.6237	17855.2801
		$\overline{X} = 246.6890$	$(S_x)^2 = 32153.8793$
			$S_x = 179.3150$
			$CI = 128.2653$

Table N.4: Simulation results for Store 1 for a Thursday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$
			$CI = 0$

Table N.5: Simulation results for Store 1 for a Friday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$
			$CI = 0$

Table N.6: Simulation results for Store 1 for a Saturday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$
			$CI = 0$

Table N.7: Simulation results for Store 1 for a Sunday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$
			$CI = 0$

Appendix O

Appendix O

Table O.1: Comparison table for Monday's results for Store 2

X_n	$\Delta_{Mon,Tue}$	$\Delta_{Mon,Wed}$	$\Delta_{Mon,Thur}$	$\Delta_{Mon,Fri}$	$\Delta_{Mon,Sat}$	$\Delta_{Mon,Sun}$
X_1	0	-383.0771	0	0	0	0
X_2	0	-21.3704	0	0	0	0
X_3	0	-17.9851	0	0	0	0
X_4	0	-382.2835	0	0	0	0
X_5	0	-416.9726	0	0	0	0
X_6	0	-382.9246	0	0.	0	0
X_7	0	-401.0823	0	0	0	0
X_8	0	-16.7027	0	0	0	0
X_9	0	-331.4264	0	0	0	0
X_{10}	0	-113.0653	0	0	0	0
Δ_{avg}	0.0000	-246.6890	0.0000	0.0000	0.0000	0.0000
σ_Δ	0.0000	179.3150	0.0000	0.0000	0.0000	0.0000
t	2.2622	2.2622	2.2622	2.2622	2.2622	2.2622
h	0.0000	128.2742	0.0000	0.0000	0.0000	0.0000

Table O.2: Comparison table for Tuesday's results for Store 2

X_n	$\Delta_{Tue,Wed}$	$\Delta_{Tue,Thur}$	$\Delta_{Tue,Fri}$	$\Delta_{Tue,Sat}$	$\Delta_{Tue,Sun}$
X_1	-383.0771	0	0	0	0
X_2	-21.3704	0	0	0	0
X_3	-17.9851	0	0	0	0
X_4	-382.2835	0	0	0	0
X_5	-416.9726	0	0	0	0
X_6	-382.9246	0	0	0	0
X_7	-401.0823	0	0	0	0
X_8	-16.7027	0	0	0	0
X_9	-331.4264	0	0	0	0
X_{10}	-113.0653	0	0	0	0
Δ_{avg}	-246.6890	0	0	0	0
σ_Δ	179.3150	0	0	0	0
t	2.2622	2.2622	2.2622	2.2622	2.2622
h	128.2742	0	0	0	0

Table O.3: Comparison table for Wednesday's results for Store 2

X_n	$\Delta_{Wed,Thur}$	$\Delta_{Wed,Fri}$	$\Delta_{Wed,Sat}$	$\Delta_{Wed,Sun}$
X_1	383.0771	383.0771	383.0771	383.0771
X_2	21.3704	21.3704	21.3704	21.3704
X_3	17.9851	17.9851	17.9851	17.9851
X_4	382.2835	382.2835	382.2835	382.2835
X_5	416.9726	416.9726	416.9726	416.9726
X_6	382.9246	382.9246	382.9246	382.9246
X_7	401.0823	401.0823	401.0823	401.0823
X_8	16.7027	16.7027	16.7027	16.7027
X_9	331.4264	331.4264	331.4264	331.4264
X_{10}	113.0653	113.0653	113.0653	113.0653
Δ_{avg}	246.6890	246.6890	246.6890	246.6890
σ_Δ	179.3150	179.3150	179.3150	179.3150
t	2.2622	2.2622	2.2622	2.2622
h	128.2742	128.2742	128.2742	128.2742

Table O.4: Comparison table for Thursday's results for Store 2

X_n	$\Delta_{Thur,Fri}$	$\Delta_{Thur,Sat}$	$\Delta_{Thur,Sun}$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
Δ_{avg}	0	0	0
σ_Δ	0	0	0
t	2.2622	2.2622	2.2622
h	0	0	0

Table O.5: Comparison table for Friday's results for Store 2

X_n	$\Delta_{Fri,Sat}$	$\Delta_{Fri,Sun}$
X_1	0	0
X_2	0	0
X_3	0	0
X_4	0	0
X_5	0	0
X_6	0	0
X_7	0	0
X_8	0	0
X_9	0	0
X_{10}	0	0
Δ_{avg}	0	0
σ_Δ	0	0
t	2.2622	2.2622
h	0	0

Table O.6: Comparison table for Saturday's results for Store 2

X_n	$\Delta_{Sat,Sun}$
X_1	0
X_2	0
X_3	0
X_4	0
X_5	0
X_6	0
X_7	0
X_8	0
X_9	0
X_{10}	0
Δ_{avg}	0
σ_Δ	0
t	2.2622
h	0

Appendix P

Appendix P

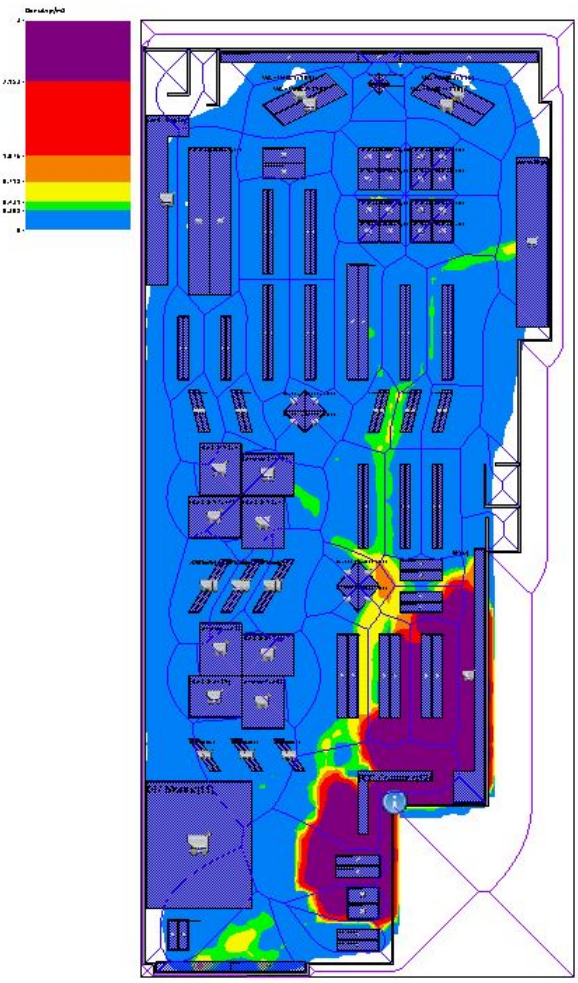


Figure P.1: A screen shot of Wednesday's final simulation run, $n = 1$

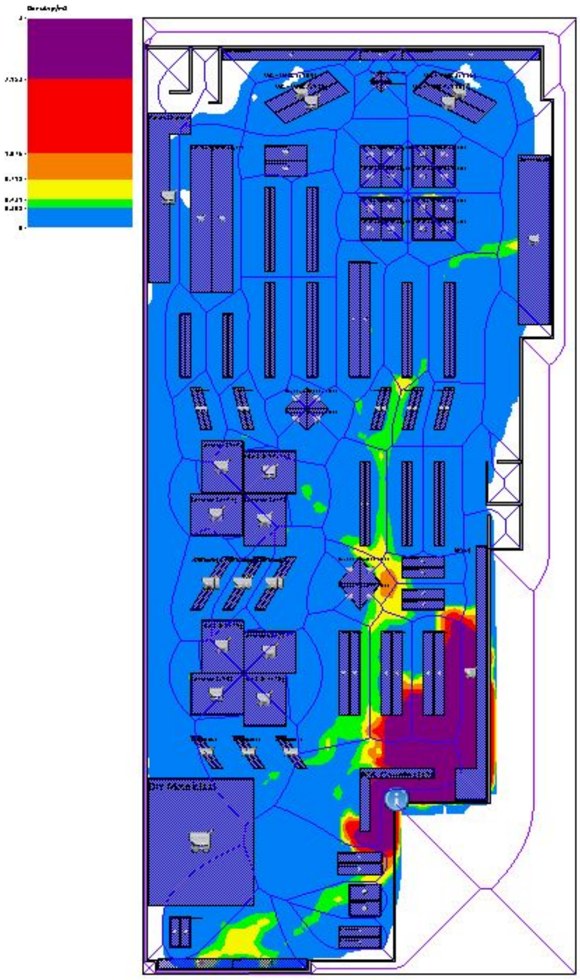


Figure P.2: A screen shot of Wednesday's final simulation run, $n = 2$

Figure P.3: A screen shot of Wednesday's final simulation run, $n = 3$

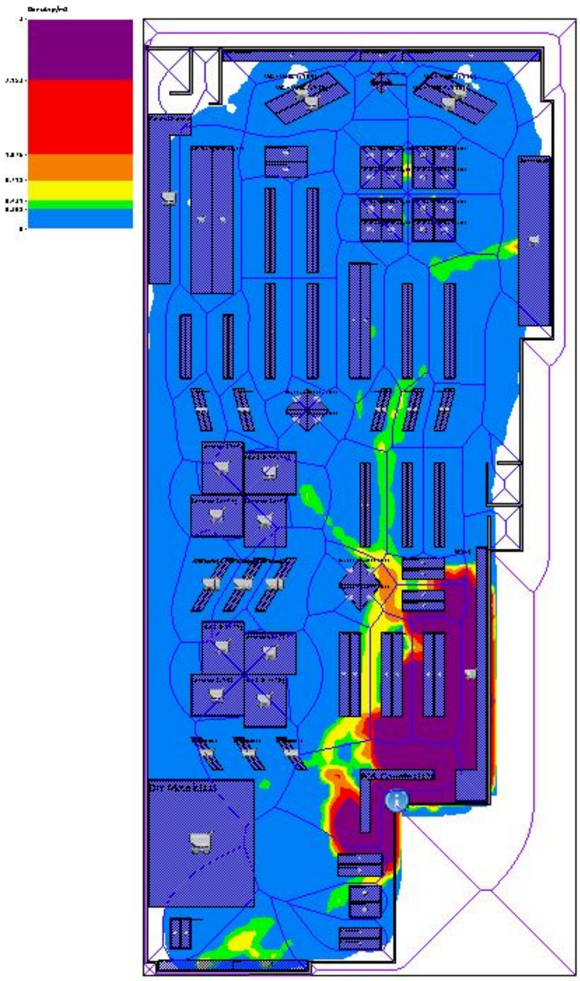


Figure P.4: A screen shot of Wednesday's final simulation run, $n = 4$

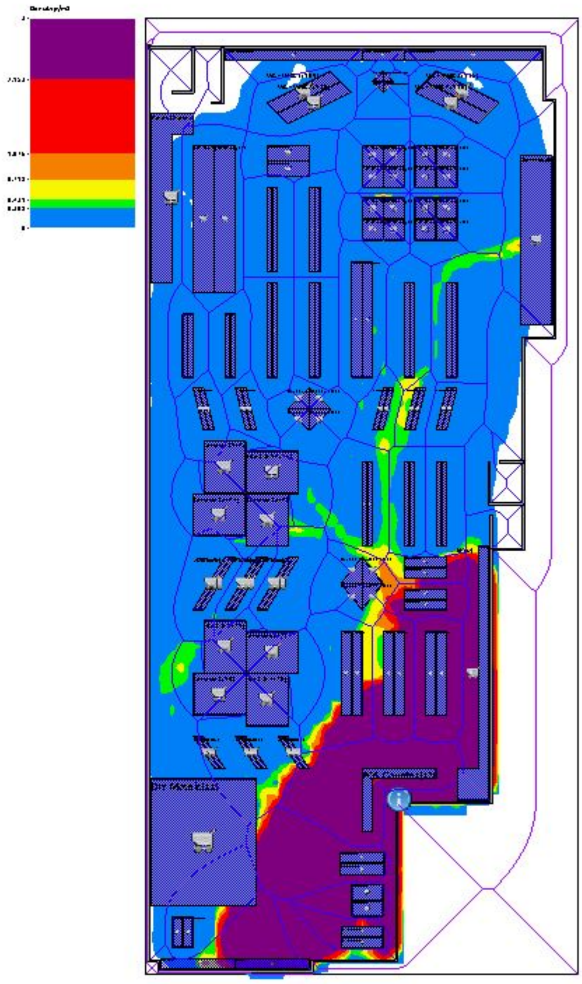


Figure P.5: A screen shot of Wednesday's final simulation run, $n = 5$

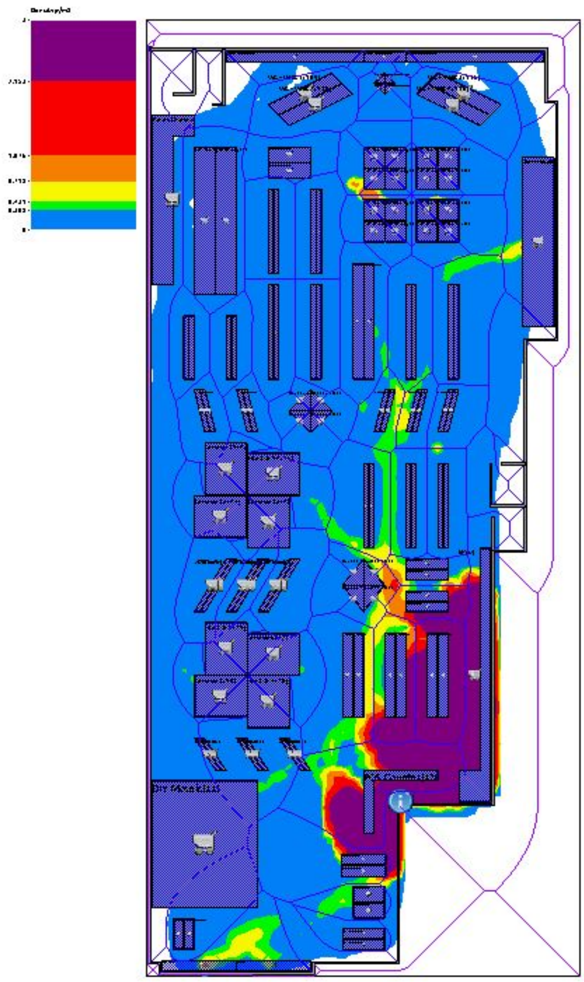


Figure P.6: A screen shot of Wednesday's final simulation run, $n = 6$

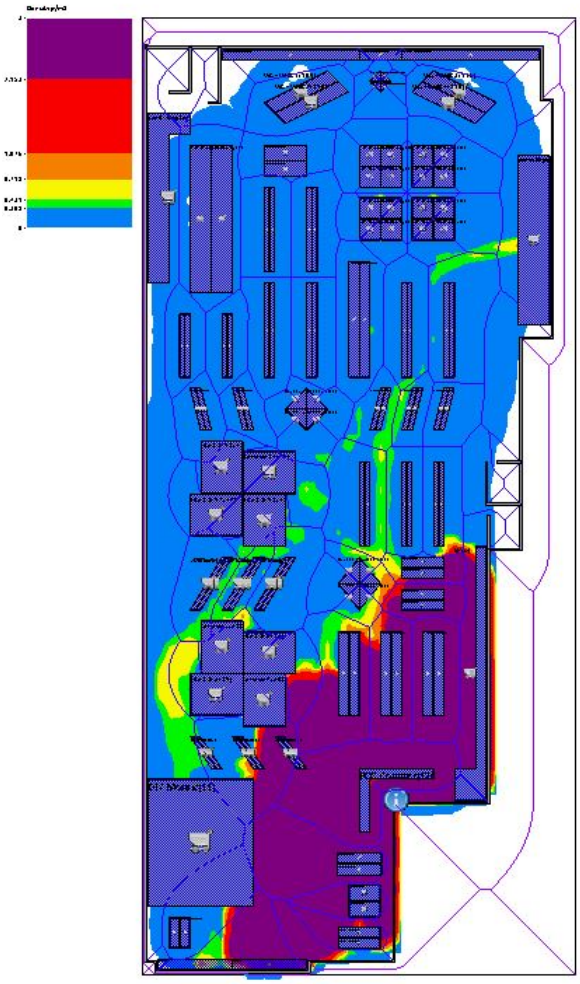


Figure P.7: A screen shot of Wednesday's final simulation run, $n = 7$

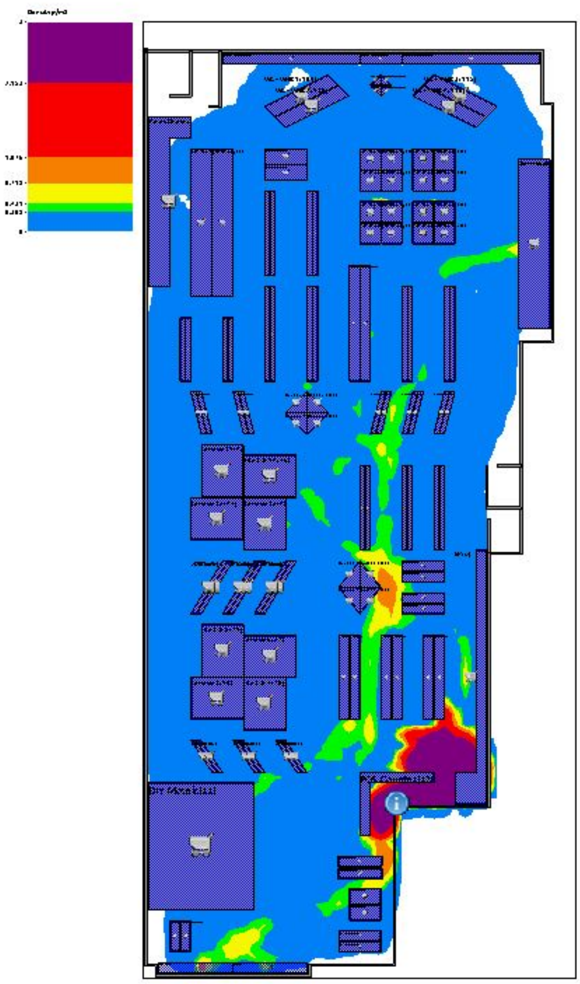


Figure P.8: A screen shot of Wednesday's final simulation run, $n = 8$

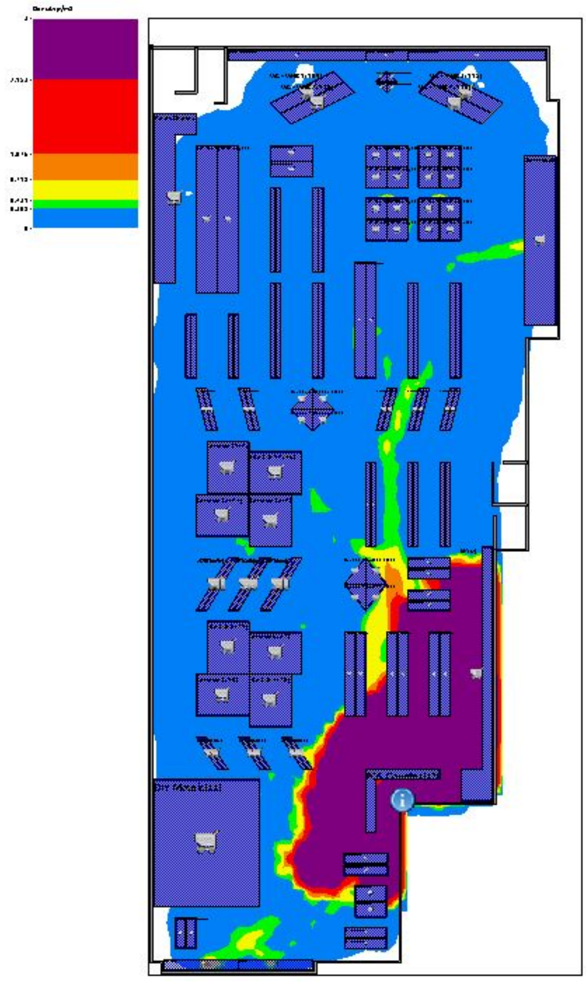


Figure P.9: A screen shot of Wednesday's final simulation run, $n = 9$

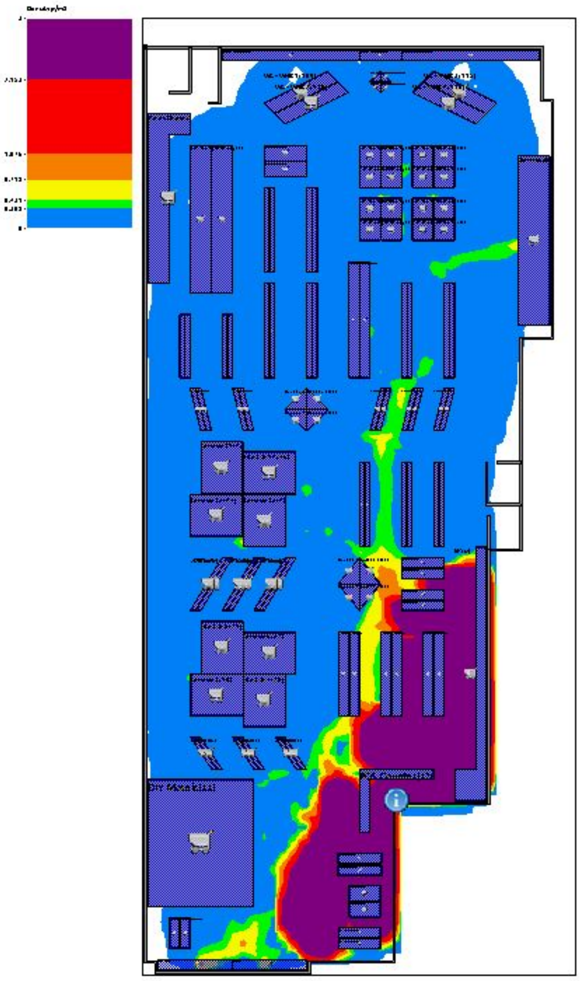


Figure P.10: A screen shot of Wednesday's final simulation run, $n = 10$

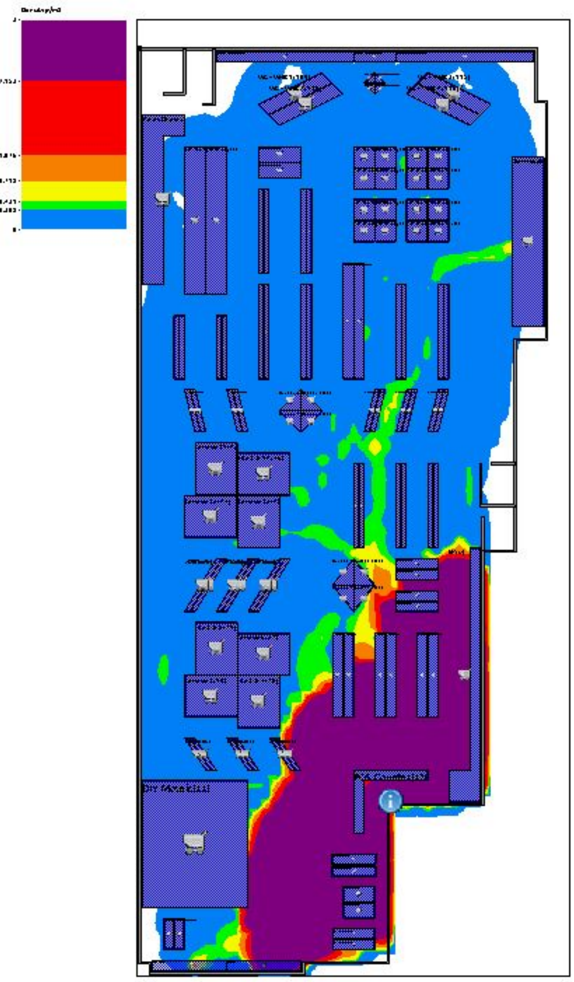


Figure P.11: A screen shot of Wednesday's final simulation run, $n = 11$

Table P.1: Simulation results for Store 2 for Wednesday's final simulation runs

Xn	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	432.3656	186.0972	34632.1620
X_2	260.1692	13.9008	193.2321
X_3	22.1628	-224.1055	50223.2950
X_4	147.8710	-98.3974	9682.0502
X_5	365.7379	119.4695	14272.9635
X_6	154.2676	-92.0008	8464.1383
X_7	423.9917	177.7233	31585.5755
X_8	43.7385	-202.5299	41018.3591
X_9	241.9252	-4.3432	18.8635
X_{10}	246.9292	0.6608	0.4367
X_{11}	369.7936	123.5252	15258.4779
		$\overline{X} = 246.2684$	$(S_x)^2 = 22816.6171$
			$S_x = 151.0517$

Appendix Q

Appendix Q

Table Q.1: Simulation results for Store 1 for a Monday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	50.4318	1.7594	3.0955
X_2	49.9411	1.2687	1.6097
X_3	41.6757	-6.9966	48.9529
X_4	45.0080	-3.6644	13.4278
X_5	45.4163	-3.2561	10.6024
X_6	45.4659	-3.2065	10.2814
X_7	55.4400	6.7676	45.8009
X_8	45.1283	-3.5441	12.5605
X_9	50.3758	1.7034	2.9015
X_{10}	57.8409	9.1685	84.0623
		$\overline{X} = 48.6724$	$(X_n - \overline{X})^2 = 25.9217$
			$S_x = 5.0913$
			$CI = 3.6419$

Table Q.2: Simulation results for Store 1 for a Tuesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0.6800	-0.3952	0.1562
X_2	1.1019	0.0268	0.0007
X_3	1.5477	0.4726	0.2233
X_4	1.1943	0.1192	0.0142
X_5	1.1410	0.0658	0.0043
X_6	0.8213	-0.2538	0.0644
X_7	1.1187	0.0436	0.0019
X_8	1.2090	0.1339	0.0179
X_9	1.0559	-0.0192	0.0004
X_{10}	0.8814	-0.1937	0.0375
		$\overline{X} = 1.0751$	$(X_n - \overline{X})^2 = 0.0579$
			$S_x = 0.2406$
			$CI = 0.1721$

Table Q.3: Simulation results for Store 1 for a Wednesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0.7442	-0.3567	0.1272
X_2	0.5950	-0.5059	0.2560
X_3	1.6965	0.5956	0.3548
X_4	1.2672	0.1663	0.0276
X_5	0.8526	-0.2483	0.0617
X_6	1.4273	0.3264	0.1065
X_7	1.1538	0.0529	0.0028
X_8	0.9176	-0.1833	0.0336
X_9	1.1041	0.0032	0.0000
X_{10}	1.2508	0.1498	0.0225
		$\overline{X} = 1.1009$	$(X_n - \overline{X})^2 = 0.1103$
			$S_X = 0.3321$
			$CI = 0.2376$

Table Q.4: Simulation results for Store 1 for a Thursday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	4.7249	3.3524	11.2385
X_2	0.8840	-0.4885	0.2386
X_3	0.8835	-0.4891	0.2392
X_4	1.8413	0.4687	0.2197
X_5	0.7493	-0.6233	0.3885
X_6	0.8921	-0.4805	0.2309
X_7	0.6087	-0.7639	0.5835
X_8	0.5825	-0.7901	0.6242
X_9	1.4597	0.0872	0.0076
X_{10}	1.0996	-0.2730	0.0745
		$\overline{X} = 1.3726$	$(X_n - \overline{X})^2 = 1.5384$
			$S_X = 1.2403$
			$CI = 0.8872$

Table Q.5: Simulation results for Store 1 for a Friday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	1.2364	0.3642	0.1326
X_2	1.7718	0.8996	0.8093
X_3	0.7004	-0.1719	0.0295
X_4	0.6585	-0.2137	0.0457
X_5	0.6290	-0.2433	0.0592
X_6	0.6479	-0.2243	0.0503
X_7	1.1699	0.2977	0.0886
X_8	0.4522	-0.4200	0.1764
X_9	0.3466	-0.5257	0.2763
X_{10}	1.1096	0.2373	0.0563
		$\overline{X} = 0.8722$	$(X_n - \overline{X})^2 = 0.1916$
			$S_X = 0.4377$
			$CI = 0.3131$

Table Q.6: Simulation results for Store 1 for a Saturday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0.3162	-1.1344	1.2868
X_2	1.3709	-0.0797	0.0063
X_3	2.5708	1.1203	1.2550
X_4	1.1100	-0.3406	0.1160
X_5	1.7987	0.3482	0.1212
X_6	0.9984	-0.4522	0.2045
X_7	1.9327	0.4821	0.2324
X_8	0.8800	-0.5706	0.3256
X_9	1.6200	0.1694	0.0287
X_{10}	1.9080	0.4574	0.2092
		$\overline{X} = 1.4506$	$(X_n - \overline{X})^2 = 0.4206$
			$S_X = 0.6486$
			$CI = 0.4639$

Table Q.7: Simulation results for Store 1 for a Sunday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0.7995	0.4684	0.2194
X_2	0.6295	0.6295	0.3963
X_3	0.0000	0.0000	0.0000
X_4	0.3130	0.3130	0.0980
X_5	0.0000	0.0000	0.0000
X_6	0.7604	0.7604	0.5782
X_7	0.0000	0.0000	0.0000
X_8	0.8086	0.8086	0.6538
X_9	0.0000	0.0000	0.0000
X_{10}	0.0000	0.0000	0.0000
		$\overline{X} = 0.3311$	$(X_n - \overline{X})^2 = 0.2162$
			$S_X = 0.4650$
			$CI = 0.3326$

Appendix R

Appendix R

Table R.1: Comparison table for Monday's results for Store 1

X_n	$\Delta_{Mon,Tue}$	$\Delta_{Mon,Wed}$	$\Delta_{Mon,Thur}$	$\Delta_{Mon,Fri}$	$\Delta_{Mon,Sat}$	$\Delta_{Mon,Sun}$
X_1	49.7518	49.6875	45.7068	49.1953	49.0609	49.6323
X_2	48.8392	49.3461	49.0571	48.1693	47.3703	49.3116
X_3	40.1280	39.9792	40.7923	40.9754	40.5658	41.6757
X_4	43.8136	43.7408	43.1667	44.3494	43.2092	44.6950
X_5	44.2753	44.5636	44.6670	44.7873	44.4179	45.4163
X_6	44.6446	44.0386	44.5738	44.8180	43.5333	44.7055
X_7	54.3213	54.2862	54.8313	54.2701	54.5601	55.4400
X_8	43.9193	44.2107	44.5458	44.6761	43.5083	44.3197
X_9	49.3199	49.2716	48.9160	50.0292	48.4678	50.3758
X_{10}	56.9595	56.5902	56.7414	56.7314	57.8409	57.8409
Δ_{avg}	47.5972	47.5715	47.2998	47.80014	47.253442	48.3412785
σ_{Δ}	5.2218	5.1863	5.1151	4.886414	5.4489874	5.19673877
t	2.2622	2.2622	2.2621572	2.262157	2.2621572	2.26215716
h	3.7354	3.7101	3.6591548	3.49553	3.8979708	3.71752297

Table R.2: Comparison table for Tuesday's results for Store 1

X_n	$\Delta_{Tue,Wed}$	$\Delta_{Tue,Thur}$	$\Delta_{Tue,Fri}$	$\Delta_{Tue,Sat}$	$\Delta_{Tue,Sun}$
X_1	-0.0643	-4.0450	-0.5565	-0.6909	-0.1196
X_2	0.5070	0.2179	-0.6699	-1.4689	0.4724
X_3	-0.1488	0.6642	0.8473	0.4377	1.5477
X_4	-0.0728	-0.6470	0.5358	-0.6044	0.8813
X_5	0.2884	0.3917	0.5120	0.1426	1.1410
X_6	-0.6060	-0.0707	0.1734	-1.1113	0.0609
X_7	-0.0351	0.5100	-0.0512	0.2388	1.1187
X_8	0.2914	0.6266	0.7568	-0.4109	0.4005
X_9	-0.0482	-0.4038	0.7093	-0.8521	1.0559
X_{10}	-0.3693	-0.2181	-0.2281	0.8814	0.8814
Δ_{avg}	-0.0258	-0.2974	0.2029	-0.3438	0.7440
σ_Δ	0.3261	1.3907	0.5552	0.7449	0.5253
t	2.2622	2.2622	2.2622	2.2622	2.2622
h	0.2333	0.9948	0.3972	0.5329	0.3757

Table R.3: Comparison table for Wednesday's results for Store 1

X_n	$\Delta_{Wed,Thur}$	$\Delta_{Wed,Fri}$	$\Delta_{Wed,Sat}$	$\Delta_{Wed,Sun}$
X_1	-3.9807	-0.4922	-0.6267	-0.0553
X_2	-0.2891	-1.1769	-1.9759	-0.0346
X_3	0.8131	0.9962	0.5866	1.6965
X_4	-0.5741	0.6086	-0.5316	0.9542
X_5	0.1033	0.2236	-0.1458	0.8526
X_6	0.5352	0.7794	-0.5054	0.6669
X_7	0.5451	-0.0162	0.2738	1.1538
X_8	0.3351	0.4654	-0.7023	0.1091
X_9	-0.3556	0.7576	-0.8038	1.1041
X_{10}	0.1512	0.1412	1.2508	1.2508
Δ_{avg}	-0.2716	0.2287	-0.3180	0.7698
σ_Δ	1.3759	0.6613	0.8799	0.5930
t	2.2622	2.2622	2.2622	2.2622
h	0.9843	0.4730	0.6294	0.4242

Table R.4: Comparison table for Thursday's results for Store 1

X_n	$\Delta_{Thur,Fri}$	$\Delta_{Thur,Sat}$	$\Delta_{Thur,Sun}$
X_1	3.4885	3.3540	3.9254
X_2	-0.8878	-1.6868	0.2545
X_3	0.1831	-0.2265	0.8835
X_4	1.1828	0.0426	1.5283
X_5	0.1203	-0.2491	0.7493
X_6	0.2441	-1.0406	0.1317
X_7	-0.5613	-0.2713	0.6087
X_8	0.1303	-1.0375	-0.2261
X_9	1.1132	-0.4482	1.4597
X_{10}	-0.0100	1.0996	1.0996
Δ_{avg}	0.5003	-0.0464	1.0415
σ_Δ	1.2262	1.4076	1.1587
t	2.2622	2.2622	2.2622
h	0.8772	1.0069	0.8289

Table R.5: Comparison table for Friday's results for Store 1

X_n	$\Delta_{Fri,Sat}$	$\Delta_{Fri,Sun}$
X_1	-0.1345	0.4369
X_2	-0.7990	1.1423
X_3	-0.4096	0.7004
X_4	-1.1402	0.3455
X_5	-0.3694	0.6290
X_6	-1.2847	-0.1125
X_7	0.2900	1.1699
X_8	-1.1678	-0.3564
X_9	-1.5614	0.3466
X_{10}	1.1096	1.1096
Δ_{avg}	-0.5467	0.5411
σ_Δ	0.8192	0.5199
t	2.2622	2.2622
h	0.5860	0.3719

Table R.6: Comparison table for Saturday's results for Store 1

X_n	$\Delta_{Sat,Sun}$
X_1	0.5714
X_2	1.9413
X_3	1.1100
X_4	1.4857
X_5	0.9984
X_6	1.1723
X_7	0.8800
X_8	0.8114
X_9	1.9080
X_{10}	0.0000
Δ_{avg}	1.0878
σ_Δ	0.5911
t	2.2622
h	0.4229

Appendix S

Appendix S

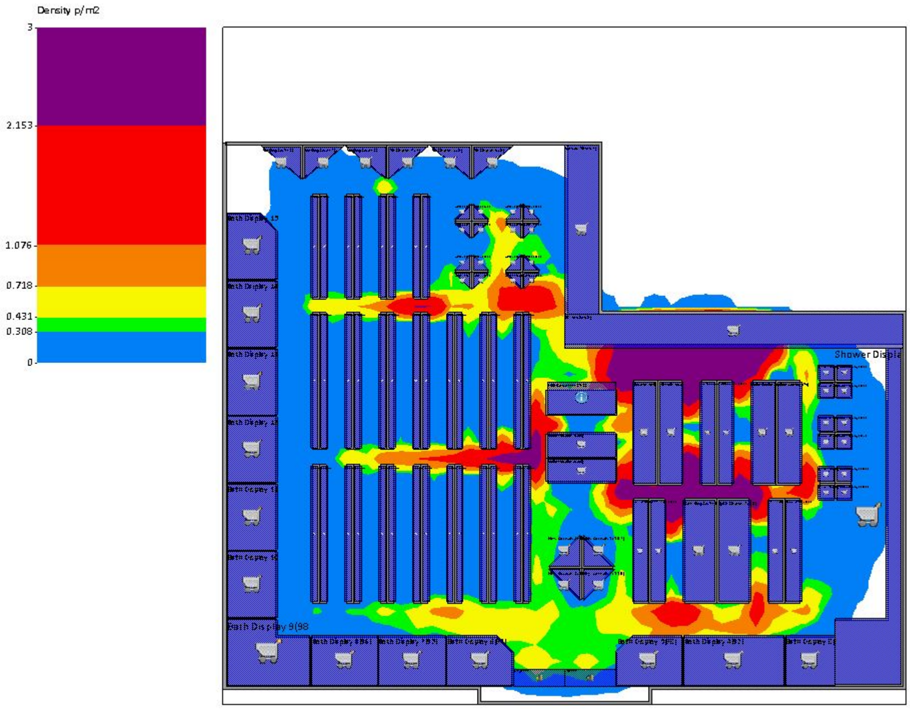


Figure S.1: A screen shot of Monday's final simulation run, $n = 1$

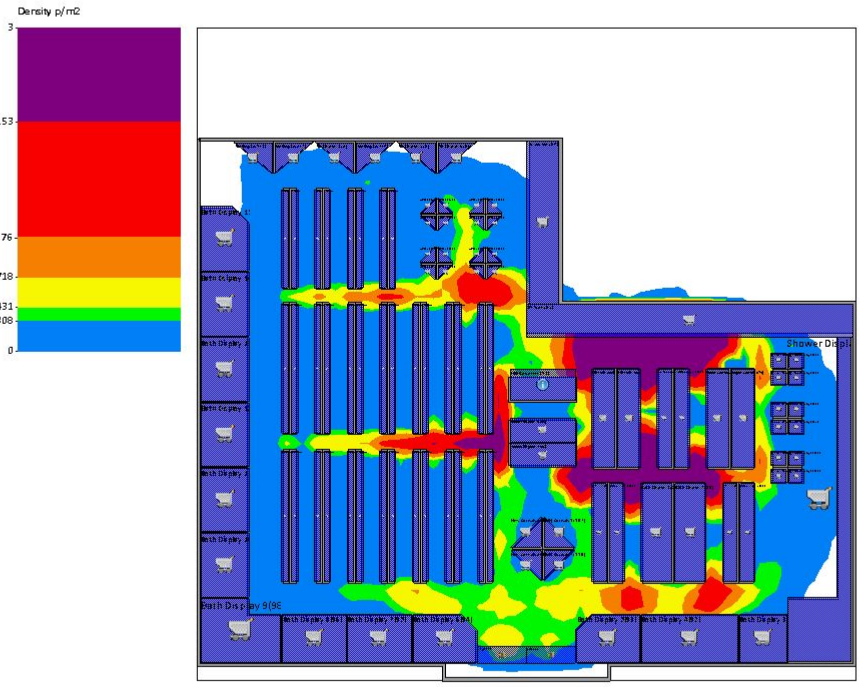


Figure S.2: A screen shot of Monday's final simulation run, $n = 2$

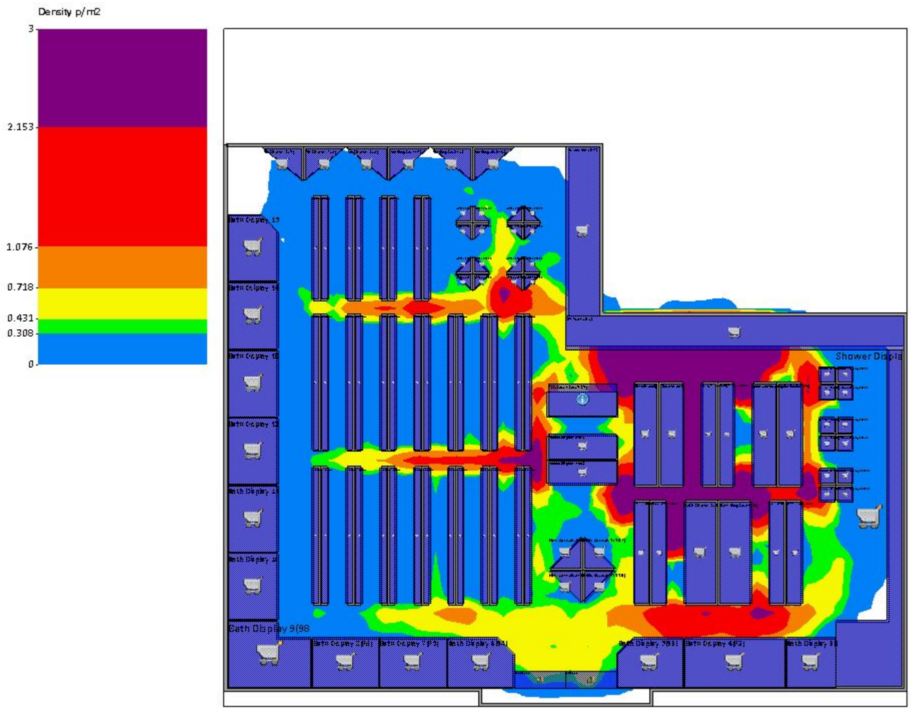


Figure S.3: A screen shot of Monday's final simulation run, $n = 3$

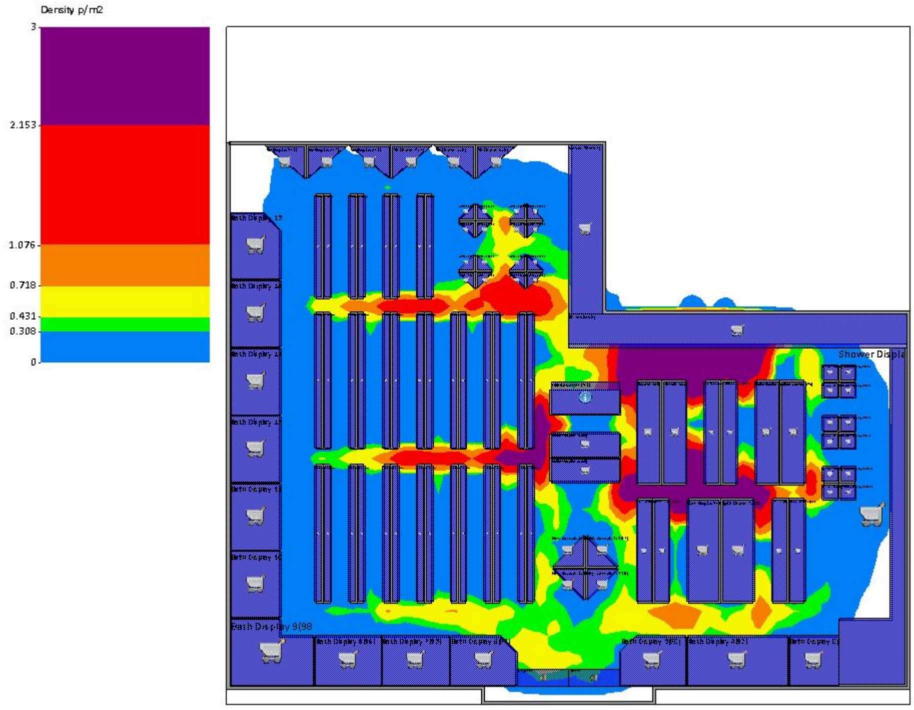


Figure S.4: A screen shot of Monday's final simulation run, $n = 4$

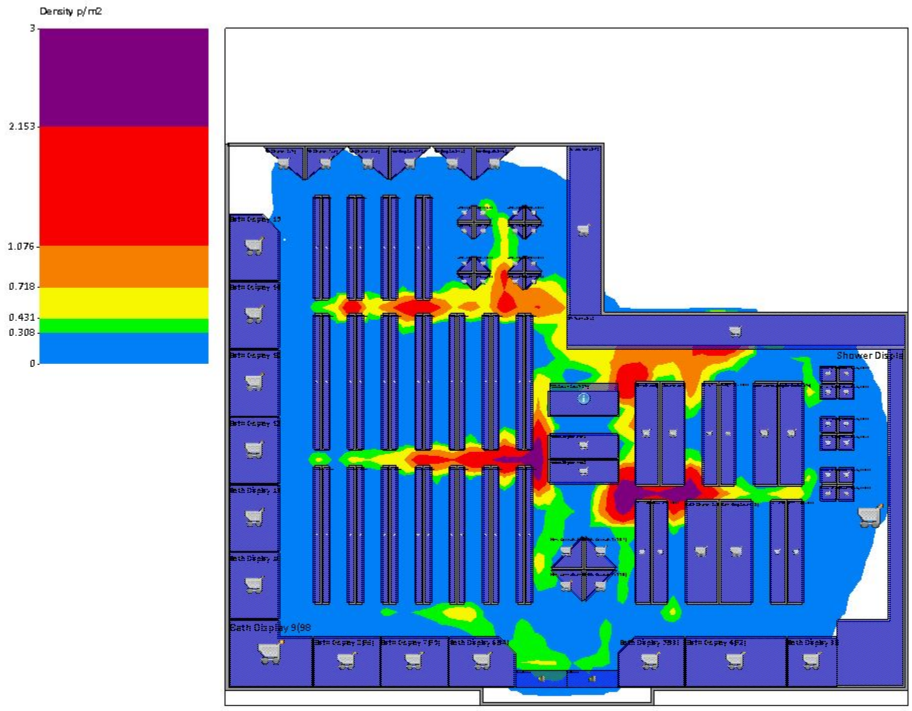


Figure S.5: A screen shot of Monday's final simulation run, $n = 5$

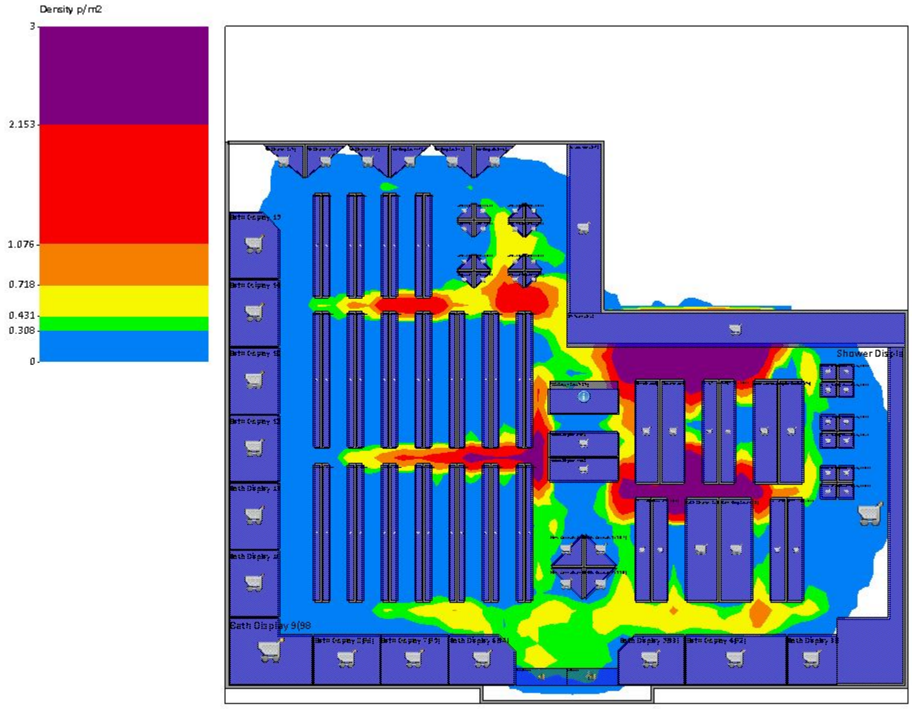


Figure S.6: A screen shot of Monday's final simulation run, $n = 6$

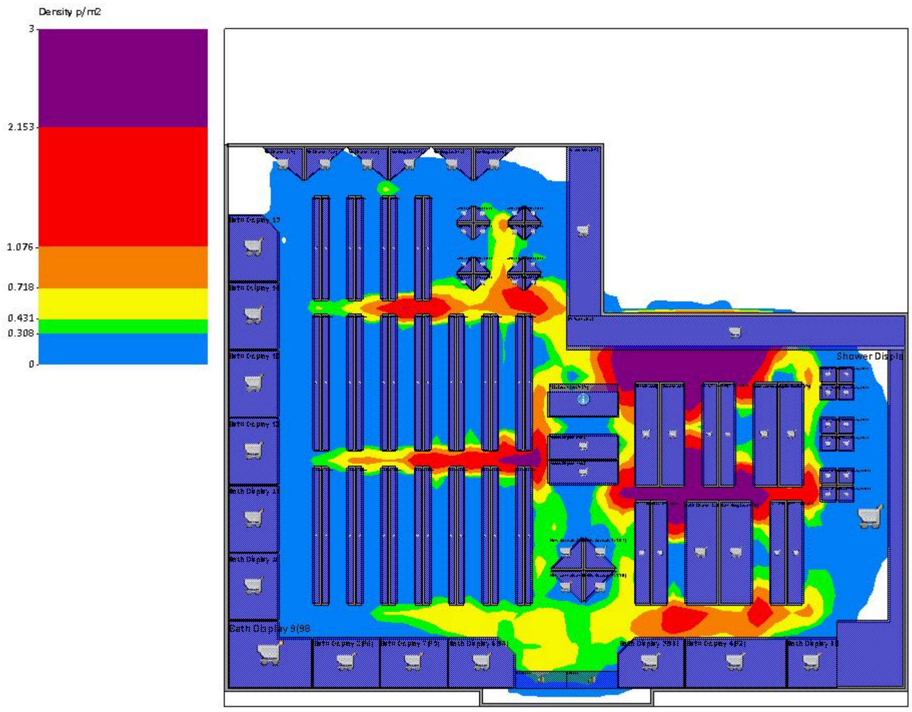


Figure S.7: A screen shot of Monday's final simulation run, $n = 7$

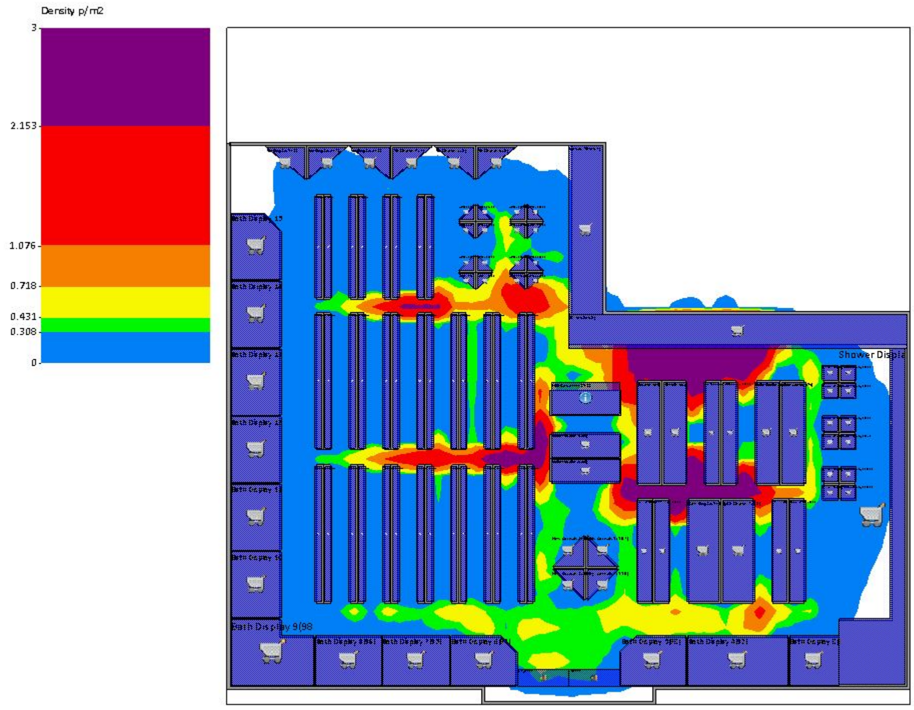


Figure S.8: A screen shot of Monday's final simulation run, $n = 8$

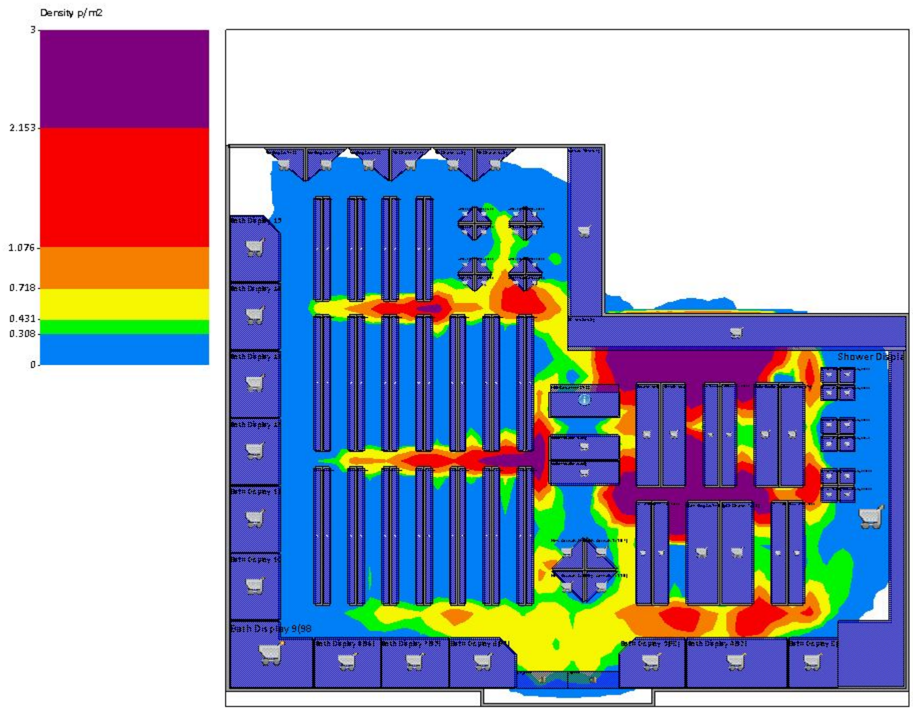


Figure S.9: A screen shot of Monday's final simulation run, $n = 9$

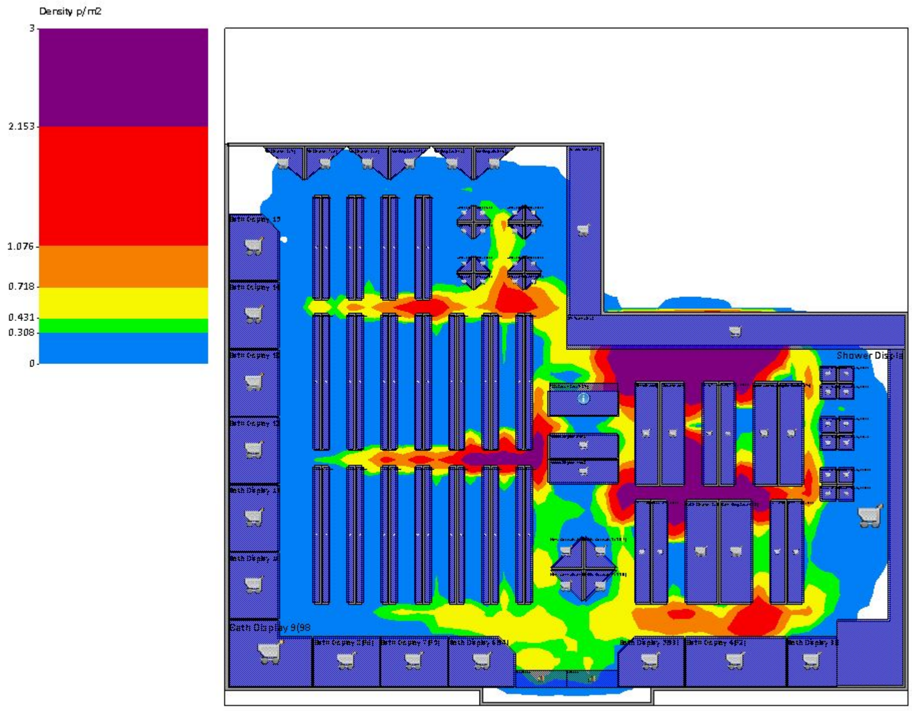


Figure S.10: A screen shot of Monday's final simulation run, $n = 10$

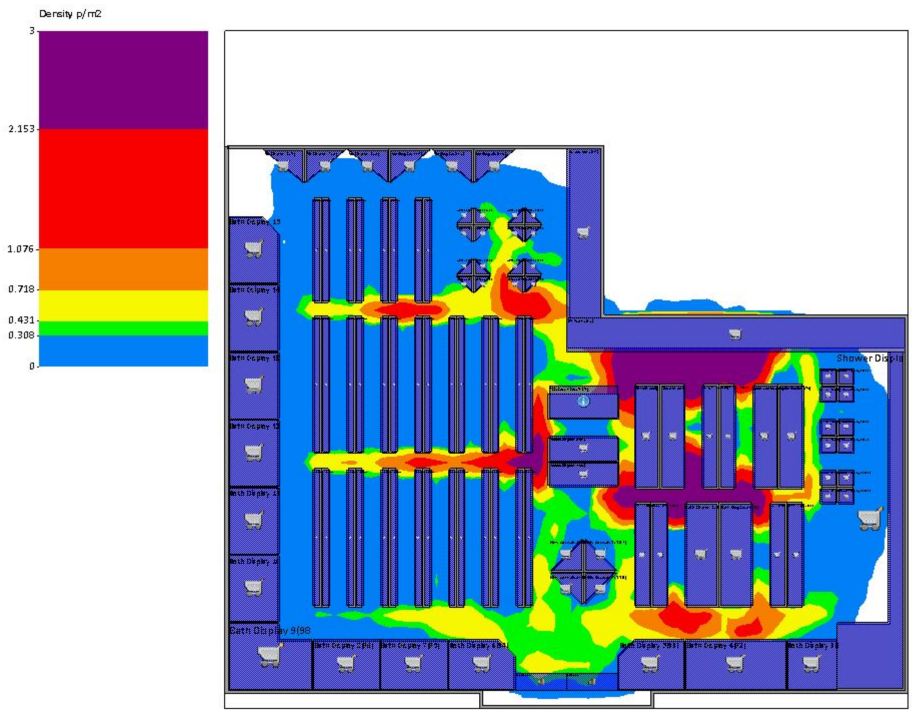


Figure S.11: A screen shot of Monday's final simulation run, $n = 11$

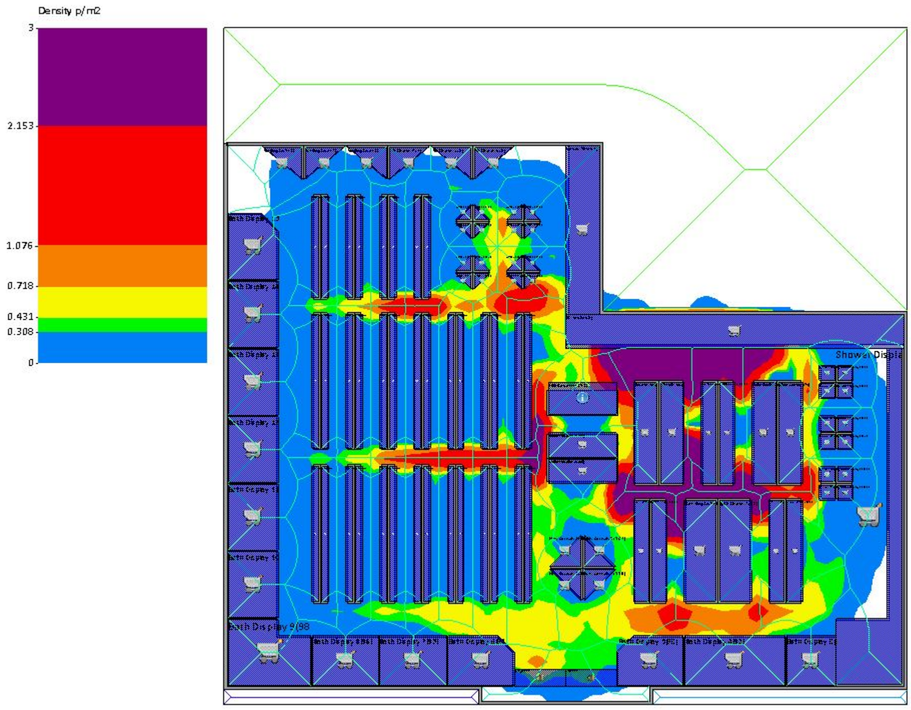


Figure S.12: A screen shot of Monday's final simulation run, $n = 12$

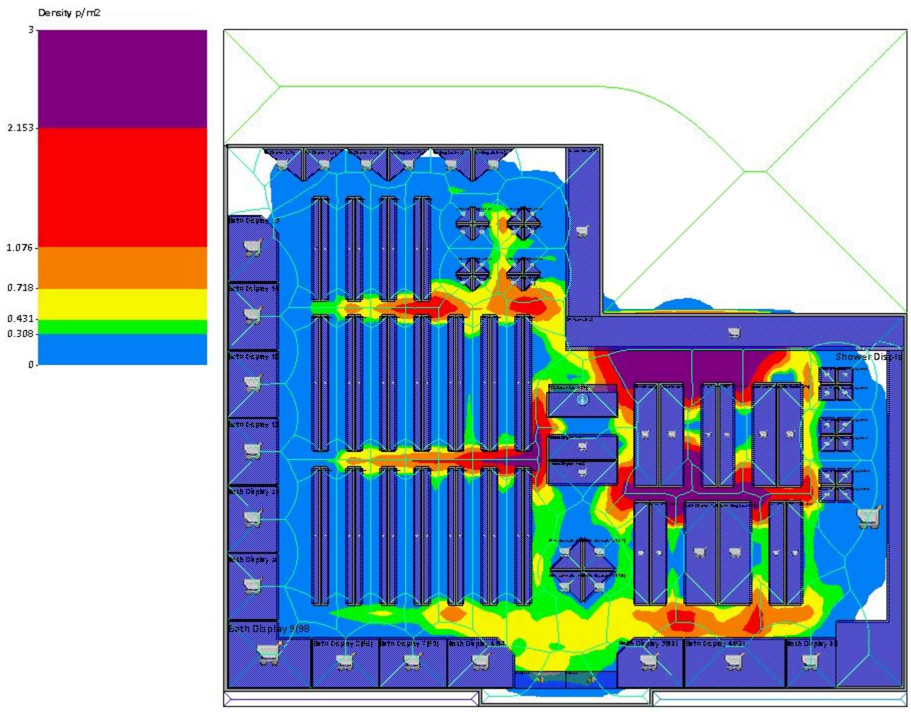


Figure S.13: A screen shot of Monday's final simulation run, $n = 13$

Table S.1: Simulation results for Store 1 for Monday's final simulation runs

Xn	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	39.7942	-9.2469	85.5043
X_2	42.5570	-6.4841	42.0431
X_3	49.2902	0.2492	0.0621
X_4	46.6966	-2.3445	5.4965
X_5	43.7818	-5.2592	27.6591
X_6	48.0884	-0.9527	0.9076
X_7	46.9977	-2.0434	4.1753
X_8	46.4041	-2.6369	6.9534
X_9	46.9398	-2.1012	4.4150
X_{10}	45.8463	-3.1947	10.2063
X_{11}	46.2506	-2.7904	7.7865
X_{12}	44.9032	-4.1378	17.1213
X_{13}	89.9835	40.9425	1676.2857
		$\overline{X} = 49.0410$	$(S_x)^2 = 209.8462$
			$S_x = 14.4861$

Appendix T

Appendix T

Table T.1: Simulation results for Store 1 for a Monday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	46.2084	39.8823	1590.6000
X_2	1.3966	-4.9295	24.2999
X_3	0.4987	-5.8274	33.9582
X_4	0.0000	-6.3261	40.0192
X_5	0.0000	-6.3261	40.0192
X_6	3.1532	-3.1729	10.0672
X_7	0	-6.3261	40.0192
X_8	0	-6.3261	40.0192
X_9	0	-6.3261	40.0192
X_{10}	12.0039	5.6778	32.2372
		$\overline{X} = 6.3261$	$(S_x)^2 = 210.1398$
			$S_x = 14.4962$

Table T.2: Simulation results for Store 1 for a Tuesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$

Table T.3: Simulation results for Store 1 for a Wednesday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	76.6861	-14.8730	221.2066
X_2	72.0067	-19.5524	382.2974
X_3	82.4810	-9.0782	82.4130
X_4	76.0663	-15.4928	240.0283
X_5	74.5423	-17.0168	289.5722
X_6	74.7502	-16.8089	282.5389
X_7	143.6341	52.0749	2711.8000
X_8	136.6037	45.0446	2029.0133
X_9	84.9641	-6.5950	43.4946
X_{10}	93.8568	2.2977	5.2794
		$\overline{X} = 91.5591$	$(S_x)^2 = 698.6271$
			$S_x = 26.4316$

Table T.4: Simulation results for Store 1 for a Thursday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$

Table T.5: Simulation results for Store 1 for a Friday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$

Table T.6: Simulation results for Store 1 for a Saturday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$

Table T.7: Simulation results for Store 1 for a Sunday

X_n	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
		$\overline{X} = 0$	$(S_x)^2 = 0$
			$S_x = 0$

Appendix U

Appendix U

Table U.1: Comparison table for Monday's results for Store 2

X_n	$\Delta_{Mon,Tue}$	$\Delta_{Mon,Wed}$	$\Delta_{Mon,Thur}$	$\Delta_{Mon,Fri}$	$\Delta_{Mon,Sat}$	$\Delta_{Mon,Sun}$
X_1	46.2084	-30.4777	46.2084	46.2084	46.2084	46.2084
X_2	1.3966	-70.6101	1.3966	1.3966	1.3966	1.3966
X_3	0.4987	-81.9823	0.4987	0.4987	0.4987	0.4987
X_4	0	-76.0663	0	0	0	0
X_5	0	-74.5423	0	0	0	0
X_6	3.1532	-71.5971	3.1532	3.1532	3.1532	3.1532
X_7	0	-143.6341	0	0	0	0
X_8	0	-136.6037	0	0	0	0
X_9	0	-84.9641	0	0	0	0
X_{10}	12.0039	-81.8530	12.0039	12.0039	12.0039	12.0039
Δ_{avg}	6.3261	91.5591	6.3261	6.3261	6.3261	6.3261
σ_Δ	14.4962	26.4316	14.4962	14.4962	14.4962	14.4962
t	2.2622	2.2622	2.2622	2.2622	2.2622	2.2622
h	10.3700	18.9080	10.3700	10.3700	10.3700	10.3700

Table U.2: Comparison table for Tuesday's results for Store 2

X_n	$\Delta_{Mon,Wed}$	$\Delta_{Mon,Thur}$	$\Delta_{Mon,Fri}$	$\Delta_{Mon,Sat}$	$\Delta_{Mon,Sun}$
X_1	-76.6861	0	0	0	0
X_2	-72.0067	0	0	0	0
X_3	-82.4810	0	0	0	0
X_4	-76.0663	0	0	0	0
X_5	-74.5423	0	0	0	0
X_6	-74.7502	0	0	0	0
X_7	-143.6341	0	0	0	0
X_8	-136.6037	0	0	0	0
X_9	-84.9641	0	0	0	0
X_{10}	-93.8568	0	0	0	0
Δ_{avg}	-91.5591	0	0	0	0
σ_Δ	26.4316	0	0	0	0
t	2.2622	2.2622	2.2622	2.2622	2.2622
h	18.9080	0	0	0	0

Table U.3: Comparison table for Wednesday's results for Store 2

X_n	$\Delta_{Mon,Thur}$	$\Delta_{Mon,Fri}$	$\Delta_{Mon,Sat}$	$\Delta_{Mon,Sun}$
X_1	76.6861	76.6861	76.6861	76.6861
X_2	72.0067	72.0067	72.0067	72.0067
X_3	82.4810	82.4810	82.4810	82.4810
X_4	76.0663	76.0663	76.0663	76.0663
X_5	74.5423	74.5423	74.5423	74.5423
X_6	74.7502	74.7502	74.7502	74.7502
X_7	143.6341	143.6341	143.6341	143.6341
X_8	136.6037	136.6037	136.6037	136.6037
X_9	84.9641	84.9641	84.9641	84.9641
X_{10}	93.8568	93.8568	93.8568	93.8568
Δ_{avg}	91.5591	91.5591	91.5591	91.5591
σ_Δ	26.4316	26.4316	26.4316	26.4316
t	2.2622	2.2622	2.2622	2.2622
h	18.9080	18.9080	18.9080	18.9080

Table U.4: Comparison table for Thursday's results for Store 2

X_n	$\Delta_{Mon,Fri}$	$\Delta_{Mon,Sat}$	$\Delta_{Mon,Sun}$
X_1	0	0	0
X_2	0	0	0
X_3	0	0	0
X_4	0	0	0
X_5	0	0	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
X_{10}	0	0	0
Δ_{avg}	0	0	0
σ_Δ	0	0	0
t	2.2622	2.2622	2.2622
h	0	0	0

Table U.5: Comparison table for Friday's results for Store 2

X_n	$\Delta_{Mon,Sat}$	$\Delta_{Mon,Sun}$
X_1	0	0
X_2	0	0
X_3	0	0
X_4	0	0
X_5	0	0
X_6	0	0
X_7	0	0
X_8	0	0
X_9	0	0
X_{10}	0	0
Δ_{avg}	0	0
σ_Δ	0	0
t	2.2622	2.2622
h	0	0

Table U.6: Comparison table for Saturday's results for Store 2

X_n	$\Delta_{Mon,Sun}$
X_1	0
X_2	0
X_3	0
X_4	0
X_5	0
X_6	0
X_7	0
X_8	0
X_9	0
X_{10}	0
Δ_{avg}	0
σ_Δ	0
t	2.2622
h	0

Appendix V

Appendix V

Figure V.1: A screen shot of Wednesday's final simulation run, $n = 1$

Figure V.2: A screen shot of Wednesday's final simulation run, $n = 2$

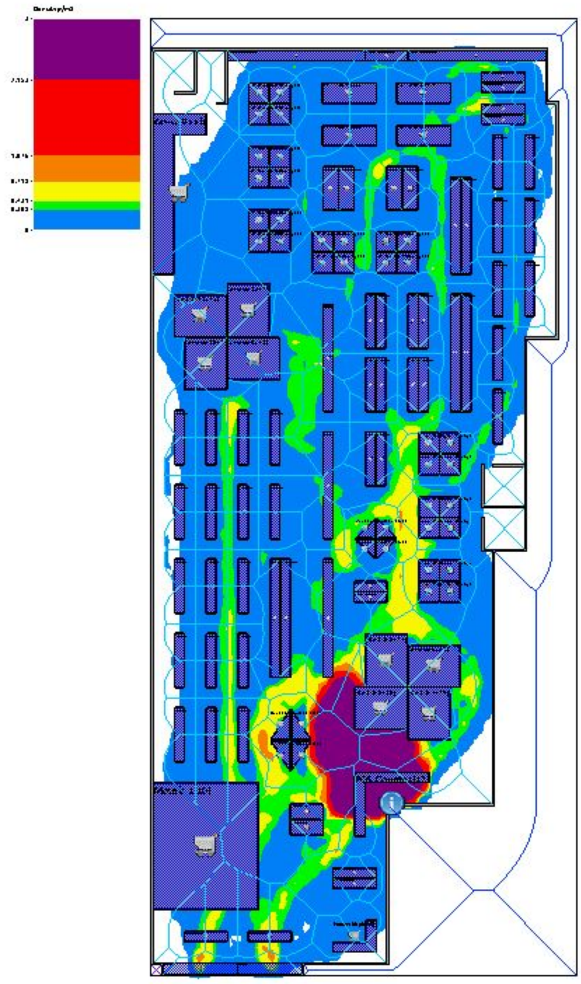


Figure V.3: A screen shot of Wednesday's final simulation run, $n = 3$

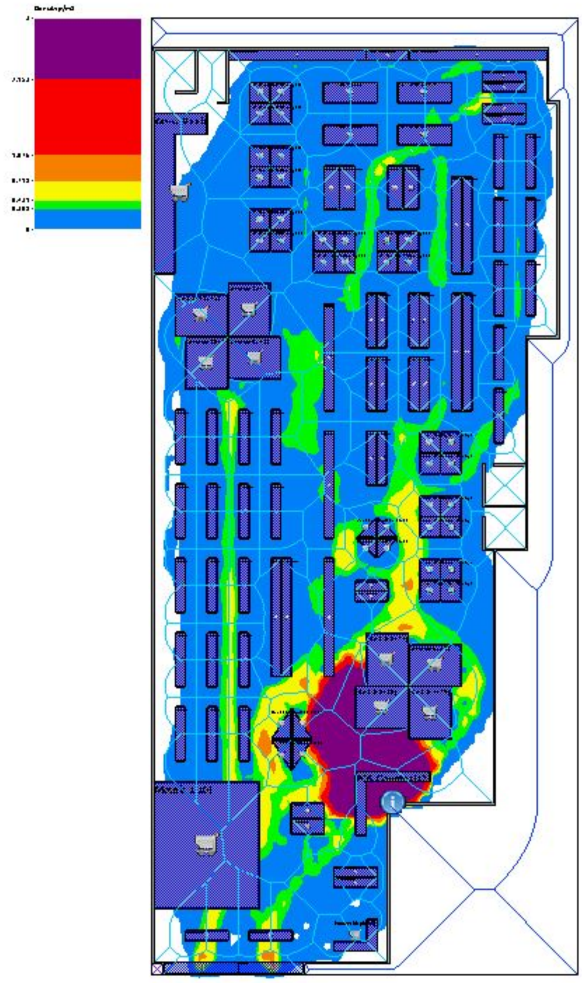


Figure V.4: A screen shot of Wednesday's final simulation run, $n = 4$

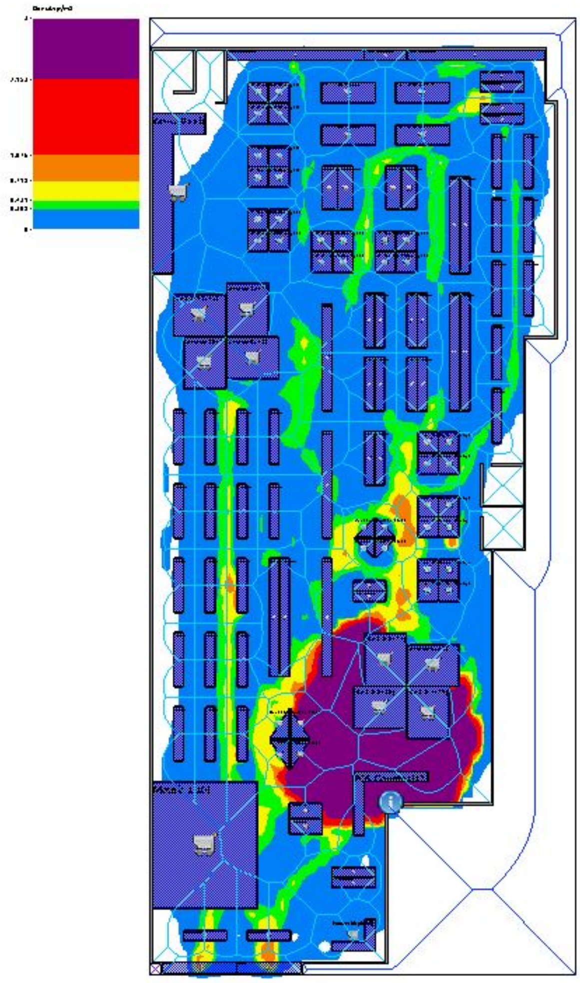


Figure V.5: A screen shot of Wednesday's final simulation run, $n = 5$

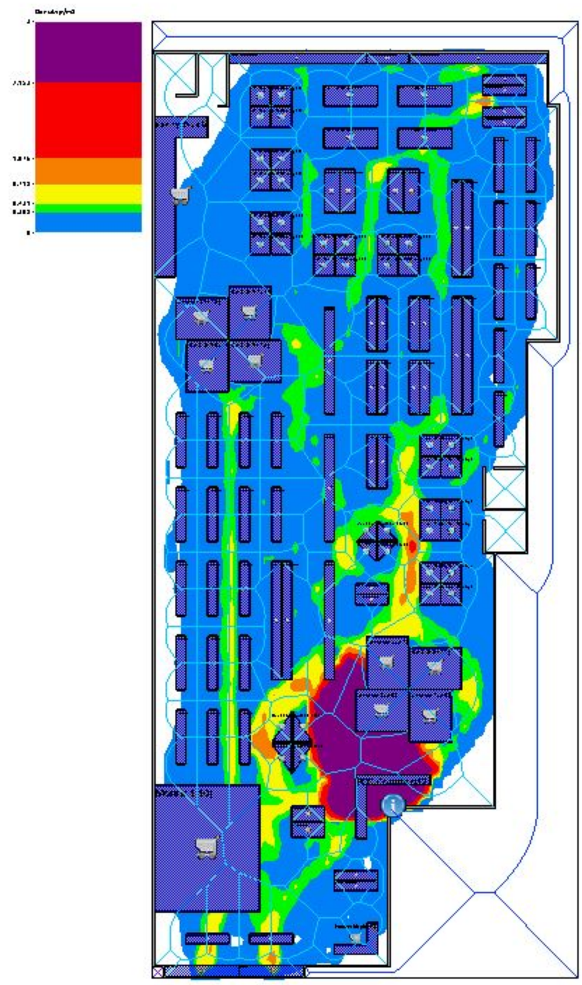


Figure V.6: A screen shot of Wednesday's final simulation run, $n = 6$

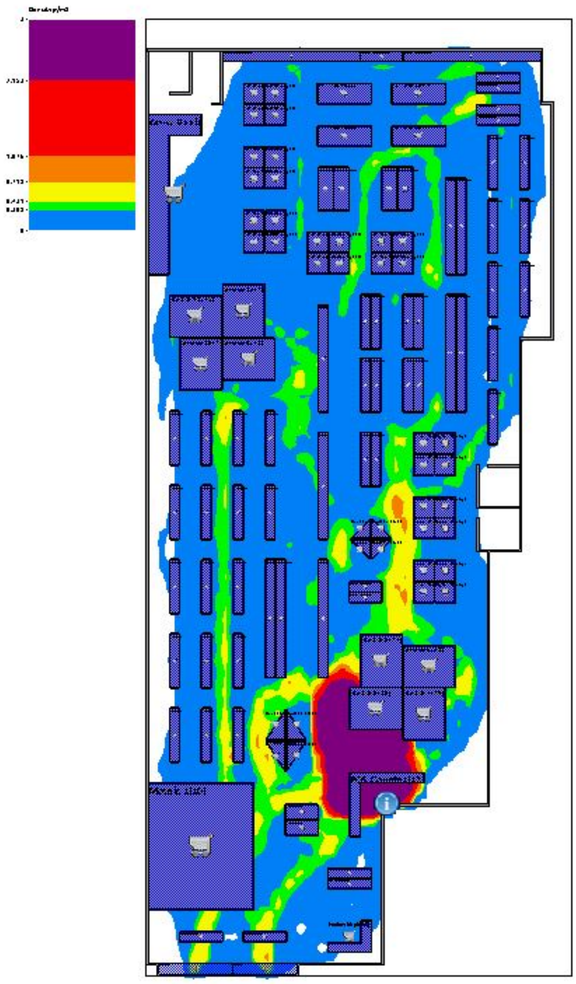


Figure V.7: A screen shot of Wednesday's final simulation run, $n = 7$

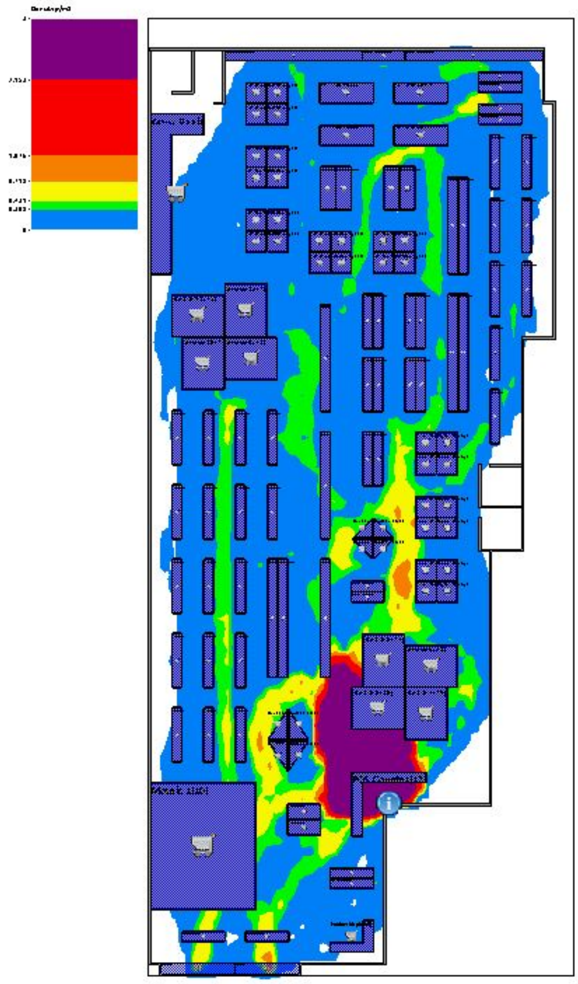


Figure V.8: A screen shot of Wednesday's final simulation run, $n = 8$

Figure V.9: A screen shot of Wednesday's final simulation run, $n = 9$

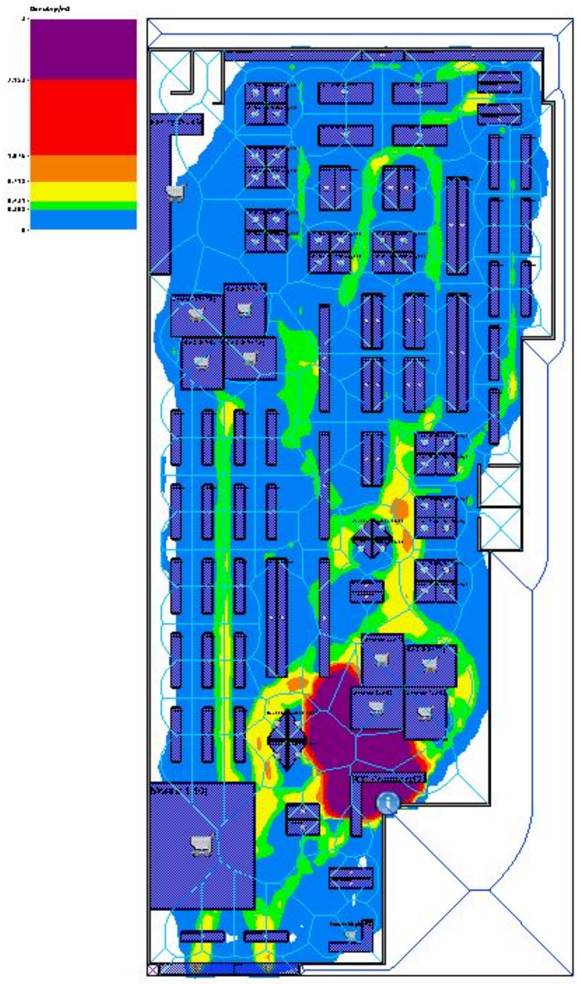


Figure V.10: A screen shot of Wednesday's final simulation run, $n = 10$

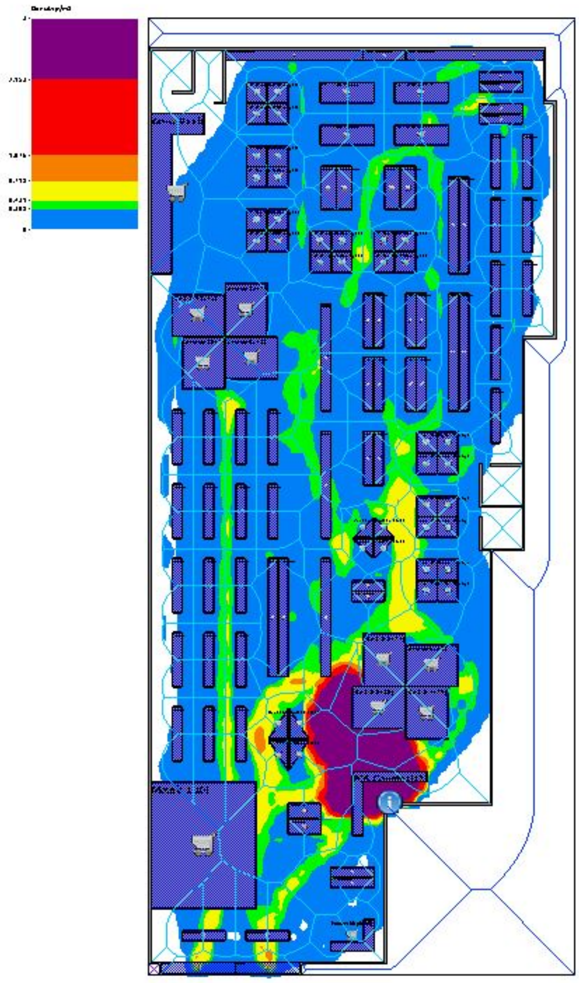


Figure V.11: A screen shot of Wednesday's final simulation run, $n = 11$

Table V.1: Simulation results for Store 2 for Wednesday's final simulation runs

Xn	Total Area	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
X_1	156.3873	50.2185	2521.8991
X_2	73.1154	-33.0534	1092.5294
X_3	72.1693	-33.9995	1155.9658
X_4	80.4936	-25.6752	659.2166
X_5	307.3352	201.1664	40467.9210
X_6	82.6779	-23.4909	551.8217
X_7	64.5867	-41.5821	1729.0698
X_8	70.4048	-35.7640	1279.0606
X_9	110.9124	4.7436	22.5016
X_{10}	76.2667	-29.9021	894.1347
X_{11}	73.5075	-32.6613	1066.7633
		$\overline{X} = 106.1688$	$(S_x)^2 = 5715.6537$
			$S_x = 75.6019$
			$CI = 54.0786$