WEATHERMART

by

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Abstract

Weathermart reinvents the supermarket by questioning the generic big-box typology, where produce is placed in the same way, in an hermetically sealed environment. Supermarkets now consume excess energy by heating and cooling in one giant open space. I am proposing a new typology of a supermarket that is organized thermodynamically into small chambers of different temperature zones to both mediate energy loss and enable external conditions to participate in the energy dynamics of food storage and consumption. Excess heat generated from cooling is used to heat cooked foods or warm up one of the adjacent spaces. The project utilizes 3 strategies: 1) creation of smaller active and passive chambers, 2) introduction of external chambers adjacent to the passive chambers, 3) the inhabitation of the poche spaces.

In this new thermally activated market, seasonal climates of the region participate in the energy exchanges between inside and outside. Gradational spectrum of heat and moisture begin to become part of a greater external spectrum of nature as it starts to expose its boundaries. Weathermart proposes a new environment between inside and outside, controlled and uncontrolled, permanent and temporal. During winter, it utilizes the chilled air from outside to keep the fresh fishes cold, and in summer, it keeps the moderate temperature for selling ripe fruits and vegetables. Relative locations from cold chambers to hot chambers will have different relation to its environment as it migrates across US. Weathermart acts like a sponge, breathing in and out the cycles of weathers.
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Sprinkler and Rain: conceptual image merging together artificial and natural weathers.
1 The Thesis

The challenge of this thesis is to rethink the notion of what’s inside and outside, and what is temporary and permanent, through air and mass. Architecture has ultimately been about defining what is inside or controlled, and I was very interested in how that boundary could change according to where on earth it’s placed, from summer to winter, and time of the day. “Supermarket” was an interesting material to think about such contradictory agendas.

A supermarket should be designed thermo-dynamically, reorganizing the climatic relationships between different atmospheres it houses. Such gradational spectrum of heat and moisture begin to become part of a greater external spectrum of nature as it starts to expose its boundaries.
1.1 Discourse

“How, you ask, does your air keep its temperature as it diffuses through the rooms, if it is forty degrees above or below zero outside? Reply, there are murs neutralisants (our invention) to stop the air at 18°C undergoing any external influence. These walls are envisaged in glass, stone, or mixed forms, consisting of a double membrane with a space of a few centimeters between them... a space that surrounds the building underneath, up the walls, over the roof terrace. ... In the narrow space between the membranes is blown scorching hot air, if in Moscow, iced air if in Dakar. Result, we control things so that the surface of the interior membrane holds 18°C. And there you are”

Le Corbusier c. 1931

“Climate,” which used to be designed to stabilize the human habitat since Modernism, is now becoming architects’ primary tool to free themselves from the static and homogeneous state of architecture. The discourse around “Climate” has been to follow specific body comfort. Modernism has led to a homogeneous, and generic space controlled in a stable state. Architecture was means to control the interior climate steady regardless of the external weather conditions. Through the design of a Salvation Army Hostel Cite de Refuge in Paris, Le Corbusier proposed to maintain a temperature of 18 degrees Celsius in buildings in all parts of the world irrespective of local need or preference. This idea still exists as thermal comfort zone, defined by ASHRAE as “the state of mind that expresses satisfaction with the surrounding environment. “

The thesis challenges the generic composition of contemporary architectures defined within six planes and “comfort zone.” What if the variety of climatic conditions out the comfort zone could be sensed more as an experience? When you

1 Le Corbusier, Precisions (Paris, 1930)
move through a space, your senses go beyond what is comfort. Transitioning from a humid place, to a hot place, to a chilly space becomes a climatic experience overall. The thesis proposes an architecture for climatic nomads. Instead of staying in one space at the most comfort, you migrate for different programs defined by its specific climate condition. The space is no longer a secondary element, but becomes the primary source, where the atmosphere directly shapes the space. The architecture is the sequence through such specific atmospheres. Weathermart investigates the relation between climate and human senses through time.

Creation of “Climate”

Since The Architecture of the Well-tempered Environment has been first published by Reynar Banham in 1969, the way in controlling the internal environment for human to inhabit has been discussed together with the building design. The internal climate control has developed for further stability of the indoor condition, regardless of the outdoor weather or climate.

Recently, the book -arium by Jurgen Mayer discusses the architecture’s current position in relationship to weather. Focusing on different typologies of existing “-ariums”, basically recreating natural phenomena in a hermetically sealed box, or a dome, the speculative projects challenge for a dynamic transformation of the architecture by imitating the behavior of a weather, or engaging the unstable state of weathers with architecture to allow change and growth. The technology to keep a stable environment inside the building has now become a tool for a dynamic intervention.

The idea of creating “climates” sometimes become office’s fundamental concept for practice. Philippe Rahm, on his website organizes his works in six typologies; radiation, conduction, convection, pressure, evaporation, and digestion. His architecture, which he calls meteorological architecture, are spatially zoned by these climatic features. Sean Lally, which he named his office
Weathers, seeks for how gradient boundaries newly inform and shape the spatial definition and organization, by shifting away from surfaces and lines. His architectures are organized by designing multiple micro-climates as a way to insert ‘nature’ as a conditioned space into the building.

Contemporary architects create micro-climate zones to define space. From a uniform and consistent interior to a diverse climate within the interior. Jurgen Mayer H’s Weather House, Philippe Rahm’s Interior Gulf Stream, Sean Lally’s Estonian Academy of Arts, and Toto Ito’s new Gifu Library. Others, such as Diller Scofidio + Renfro had created weather (fog) itself, especially interested in its effect. Rem Koolhaas for his Serpentine Gallery Pavilion has utilized the changing weather conditions to move the floating balloon up and down to open or seal the roof structure against the outdoor weather. William O’Brien has utilized the pooling and evaporating process of rain water to animate the territorial wood decking for PS.1 competition.

The use of climate now could be categorized into two, one side generating a specific kind of climate inside, and the other utilizing the weather to animate the space.

Creating Uncomfort Zones

The recent building technologies on intelligent facades and passive systems uniformly regulates the internal atmosphere in a climate called the “comfort zone.” Inside the climate zone, it is at a moderate temperature around 21 degrees celcius. The lightings are extremely bright day and night. The internal conditions are kept and stored equally. The facade may respond dynamically, but in this case, the interior is very static. What if the architecture is consisted of many different climate zones? The gradual weather changes outside will filter through the architecture and affect the program. The program follows the external climate which is reflected on
the interior. As weathers and natural processes animate the earth’s surfaces, weathers animate how people use the space and how they move through the building.

**Philippe Rahm and “Program follows Climate”**

“architecture must build sensual exchanges between body and space and invent there new aesthetical philosophies approaches capable of making long-term changes to the form and the way we will inhabit buildings tomorrow”

Philippe Rahm defines program according to its climatic conditions. By placing a radiator and using the principle that warmer heat stays at the top, colder in the bottom, he places objects which defines programs. Rather than the dividing walls zoning the uses, in his architecture, it is zoned by the difference in its climate. Bathroom 22C, living room 20C, kitchen 18C, bedroom 16C, hallways and toilets 15C. Unlike the black and white dichotomy of the Noli map, his map is in a gradient, changing its colors according to its temperature.

A new supermarket could be redesigned in his way, by relocating the foods by its ideal temperature and humidity. Then, we will first create different climate zones in a sealed environment, and place the products according to their “comfort zone." However, my criticism for his approach is that the environment must be sealed, and fully controlled from the inside. Could external gradient of heat and moisture participate in the internal gradient? In this case, the internal gradient from hot to cold changes according to the weather and climate conditions outside.

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1.2 Concept

Walking through a food market is an experience. You go through different atmospheres of different smell, temperature, humidity and scenes. WholeFoods in Cambridge is no exception. Inside a big box, under a giant shed, they are usually placed on a universal plane. Many climatic conditions are packed one next to each other.

In this new thermally activated market, seasonal climates of the region participate in the energy exchanges between inside and outside. During winter, it utilizes the chilled air from outside to keep the fresh fishes cold, and in summer, it keeps the moderate temperature for selling ripe fruits and vegetables. So relative locations from cold chambers to hot chambers will have different relation to its environment as it migrates across US. Weathermart acts like a sponge, breathing in and out the cycles of weather.
variety of products packed in one big box

supermarket is a sequence through different atmospheres
WeatherMart proposes a new typology of a food market, where different climates and atmospheres are contained in different environment chambers. Hot or cool, humid or dry, dark or bright, ventilated or sealed, each individual chamber will have unique combination of climate and weather according to the climate the foods produce and need. Shopping at a food market becomes a whole new experience, Your skin, your nose, your eyes will have a dramatic change of contact with the environment everytime you pass through a different chamber.

By isolating each food regions by semi-enclosed chambers, the super market could save a lot of annual energy consumption. The energy spent on controlling the ambient air temperature is not needed anymore, and will be able to control locally. The waste energy generated from one chamber could effectively be transferred to another chamber as a by-product.
Starting from a basic packing of spherical voids, the climatic chambers could begin to deform itself according to the spatial requirement of the housing products and atmospheric quality of humidity and temperature. Some chambers need to be completely hermetically sealed, some could be exposed for open air. We could start to imagine a mapping of external relationship.

Also, WeatherMart could begin to expand its program, like in the case of Roman Bath. Around the original circulation of shopping foods, there could be extensive program additions, such as lecture halls for cooking classes, farms, to grow your own food, kitchens to cook what you bought, and many other. WeatherMart centers around the culture of food, eating and health.
Since the chambers are locally controlled, the openings could also be seasonally controlled according to what kind of environment the products need. For example, during the cold winter in Boston, we could reduce the amount of energy used for cooling products inside a “well-tempered” environment for human comfort. We could even imagine a chamber where it rains inside to moist the vegetables, instead of spraying mist inside a sealed box in a rainy day. Some chambers could be turned inside out to become a greenhouse exposed to sunlight.
1.3 Methodology

The thesis operates in two folds. On one level, the thesis speculates a new organization and sequence of micro-climates in a continental scale, looking at how relative locations from hot chambers to cold chambers could have different relation to its environment. This phase is brought through siteless geometric study looking at how small chambers could have gradational exposure to the exterior.

On the other level, it takes the studies from the first phase and apply scale, program and site borders. It attempts to propose a thermally active market in an architectural scale, looking specifically at the site and programmatic requirements.

This section is meant to fly through the strategies and thinking processes which lead into the final concepts and organizations of Weathermart. Details of each study models will be documented in the appendix in Chapter 4.
Excavation of Atmospheres

The first set of cnc milled blue foam models (facing page left side) examine the formal relation between internally excavated spaces and externally sliced off surfaces. If we were to assume that the architecture is a residual medium between internal and external activities, we would be able to gain different “controlled” spaces within the architecture from the variety of thickend wall. The excavation from underneath is organized programatically, resulting in its size and depth. The external slices would be a result of weather influence, such as rain drainage, solar direction, etc, and urban influence, such as public access and entry direction. This set of studies allowed us to realize a gradational shift from a extreme internalized chamber to open chamber. It was possible to fit variety of different market programs within the gradient from inside to outside. However, the gradient was always a global manipulation which resulted in a difficulty in controlling each programmatic requirement such as sizes and form.

The next blue foam model was a study in relationship to a imaginary landscape. From an ambition to relate the outside to inside, I attempted to make a systemized landscape on a grid which transforms into architectural columns, walls and ceilings. The carving of atmospheres generate columns and walls. Each cell size responds to specific program and needs which creates different thickness wall conditions between each cells.
2 points

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\begin{array}{c}
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\bullet \\
\end{array}
\]

\[d=2\]

3 points

\[
\begin{array}{c}
\bullet \\
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\bullet \\
\end{array}
\]

\[d=6\]

multiple points

\[
\begin{array}{c}
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\bullet \\
\bullet \\
\bullet \\
\end{array}
\]

\[d=10\]
Previous studies had started with setting up an orthogonal grid, which was transformed globally. Each individual cells had similar connection or relation to each other.

These studies start to look at relation between individual cells. The diagrams on the right shows how the temperature difference influences the wall thickness between which regulates and slows down the thermal transfer from one side to another. The calculations show (See appendix) that as the temperature difference gets larger, the wall gets thicker in proportion. Here, a grid no longer exists, but only relations exist. Could a supermarket “grow” just by local relations?

From this study, I began to use sphere as the initial form of each atmospheres, being the most rational state of air to be stable. The sphere gets influenced by neighboring atmospheres and create a wall in between. This system evolved to be a voronoi system to preserve equal thickness between neighboring cells.

The study models on the left side show some investigations in thinking about the local network of connections and buffers to move between each.
Climatic Organization Strategies

The four strategies here all indicate different methods of organizing the spectrum of heat and moisture. Tower, Mat, Linear, and Hybrid of Tower and Mat. Tower organizes the intensity of heat vertically by giving each temperature a floor, stacking up to 48 floors. The winding sequence of each room produces interesting vertical relation skipping several floors. Mat type pixilates the climates into a field conditions and forms a one story building, creating a radial gradation in plan. Linear type organizes the climates in a chain, allowing depth to become a factor to control temperature which forms an S shape with urban courtyards. The Hybrid combines the tower and the mat, which was interesting that it creates two different typology of sequence merging at the bottom. At this point, the hybrid had survived to the mid review with an interesting urban move.
Hierarchal Climate Zone Study

These studies are intended to create hierarchy between cells. As a strategy I grouped the micro climates into 10 segments. Theses series of models reflect the local wall thickness studies. By categorizing the spectrum of heat from -18 degrees celcius to 60 degrees celcius into 10 segments, Each 10 chambers have different wall thicknesses with its neighbors.
Site: Parcel 9, between the Blackstone District and the Big Dig
1.4 Site

Weathermart will be located at different places throughout United States. They will have different layout, with different cycles of produce. I am designing the first Weathermart in Boston which attempts to replace the Haymarket, together with a supermarket and farmers market. However, aside from the basic organization of Weathermart, each site will have idiosyncratic condition which will affect the generation of Weathermart.

This section will look at the chosen site in Boston, between the Boston Government Center and the Big Dig. It is currently an open plot of land left over from the Big Dig Project. It has a great location but being underutilized now because of its numerous constraints. Following pages will flush out such constraints and basic geographical data of the site.
Blackstone District
Top
Plan of the District coloring the program, open spaces and facade condition

A New Boston Market District
Facing page
Axon of the site, showing access and neighboring landmarks

The site is located right behind the Blackstone and has good access from a subway T station on Green Line and Orange Line. The Freedom Trail marked red cuts through the site and has the potential of being Boston’s new tourist attraction showcasing local foods. The part marked green is the Big Dig adjacent to the site.
proposed Boston Market complex

proposed market place in Boston Museum

Hay Market

Fanueil Market Hall

Quincy Market
The parcel 9 of Big Dig used to be the entry/exit way to the interstate highway. Although the site does not lie under the highway, it has been transformed into a “grass field” together with the Greenway. However, the site still remains unprogrammed. A surface of turf lies without any use. One of the reason is because of the Big Dig running 2 meters under, making it hard for trees to grow and public access is shut off with many layers of roads around it. If you look at the plan on the right, you will see that half of the site is free from the Big Dig running underneath.
Bottom
Section cutting through the site and Big Dig

Facing page middle
images of the government proposed Boston Museum and Market place
The New Boston Museum and Market

The parcel 9 site has been assigned as a potential site for the New Boston Museum as a new epicenter for Boston’s tourism. On the first floor they plan to have Boston’s first indoor market. “Officials plan to have the 27,500-square-foot market open seven days a week, selling products consumers can now get only at farmers markets and other out-of-the-way venues. Construction could begin in early 2012, with the facility opening later next year.” writes the Boston Globe.

The thesis sees this as a potential for further investigation in the site and a new food market in Boston.


http://bostonmuseum.org/
Tulip Town Market, Grove Center
2 A New Supermarket

A supermarket organizes all different kinds of food and everyday needs in one big space. The sequence from taking the cart, circulating around the giant space and checking out is very systematic and efficient. However, “efficiency” has made all supermarkets and grocery stores around United States very similar. Existing typology of a supermarket is packaged inside a “Big Box” placing cold environments on the perimeter and dry goods in the middle under fully controlled environment.

The charts on the left show the percentage of different energy consumed in a supermarket in different climate zones in United States. The blue shows the cooling energy and orange shows the heating. You will realize that the energy consumption balance of cooling and heating is almost the same between supermarket in Massachusetts and Texas. This brings out the fact that supermarket environments are isolated from the regional climate of the place. I believe supermarkets should have more relationship with the outside.

1. Supermarkets could save more energy by utilizing the natural cycles of weathers from hot seasons to cold seasons.

2. Customers become more aware of seasonal and local produce from both farms and seas.

3. The act of shopping becomes more experiential navigating through the supermarket from hot to cold, wet to dry, dark to light.
2.1 WholeFoods and Farmers Market

Whole Foods Market

HayMarket

Farmer's Market
A new supermarket positions itself between Wholefoods Market and Farmer’s market. Wholefoods is a typical supermarket where the space is sealed inside and it is permanent. On the other hand, farmers markets are open to the outside under a temporary tent. Weathermart is a mix of the both.
Haymarket in Boston is a rare example where the two types of market exist together. One side of the Blackstone District facing the Big Dig has small supermarkets selling fishes and meats, mainly those that need specific temperature to preserve. On weekends, many tents line up along the side of the building selling many different kinds of produce for a very cheap price. The produce sold here are vegetables and fruits from the same week which had been left unsold. The Haymarket Pushcart association buys these left overs from supermarket vendors and sells them for very low price.
Haymarket is a mixed typology of permanent and temporary, inside and outside. From Sunday to Thursday, the site is just a row of Halal Markets and a big open space. On the weekends, the open space is filled with tents, creating another layer of street. The building unit usually has two entrances, one leading underground. Groceries, seafood, meat are sold in these underground stores.
This looks at Wholefoods Market in Cambridge River Street. The supermarket section is elevated 6 meters above ground for truck access. The above diagram of the plan shows a typical layout of Wholefoods market in United States, including the one in Cambridge.
The depth of each produce shelf is determined to be within one's reach, so it could be reconsidered as a strip, instead of calculating by area.
The chart on the facing page shows how produce sold in WholeFoods market categorizes its products. This measures how much space is dedicated for each category and in sum, it had 728 meters. Wehermart decomposes the existing categorization into one linear space thermodynamically. The diagram above shows how the strip of thermodynamic ribbon could be reconfigured spatially.
2.2 Spectrum of Heat and Moisture

This chart on the facing page is the program diagram of Weathermart. It reorganizes all the produce sold at wholefoods by its ideal preservation temperature from freezer temperature on the very left to cooked foods heating temperature on the right. Products which need specific environment such as sprinkler needed, icing preferred are extracted above the chart. The chart compares the range to the annual climate cycles in Boston. You can see that the range of sold produce fits within the natural climate range in Boston.

The vertical chart on the same page adds ideal humidity to the information. Y axis is the temperature and X axis is humidity. The ones with colors highlights the ethylene producing foods. The orange being the highest, yellow as medium, and green as low. The ones with red dot are ethylene sensitive products which needs extra attention for what it is being placed next to.
2.3 Network of Thermodynamic Relation

Instead of fitting linear passages in one big box, Weathermart will be a package of different atmospheres. It is a chain of different environmental chambers having its own climate to hold appropriate produce. That means the architecture is composed of many local relations between small rooms. Climatic difference defines the wall in between. The chain reaction between small chambers build up to be Weathermart as a whole.

By making small chambers, a path becomes a network of spaces, also gaining more surface area to sell or showcase foods. The open space in the middle of each chamber could be used for events such as cooking classes, cafes, and food labs.
2.4 Food Migration

Weathermart is affected by the seasonal climate changes. Typically, buildings regulate the internal temperature by facade system or HVAC systems. However, in Weathermart, the thermal properties of each chambers change month to month, season to season. So programs need to shift from one room to another according to seasons. In this case, the foods and produce migrate from chamber to chamber finding its ideal climate.

Produce placed in supermarkets are ever changing. They are sold and being replaced daily. If they are there for too long, they're also replaced. It continues the subtraction and addition one after another. When food needs to change its location, it can be moved in this manner. They will be replaced little by little and finally, changing its location.

During summer, a part of supermarket becomes more active with vegetables and fruits, like a farmers market. During winter, fishes and meat comes out of the enclosed active chambers to be more exposed to the main flow of people. Then it becomes a fisherman's market during winter.
-5.5<climate x<27

20 deg c

0 deg c
Top
seasonal temperature cycles
shifting along the climate zones of Weathermart

Facing page left
energy consumption comparison
between gas and electricity

Facing page right
Electricity substituting gas according to season

58
2.5 Breathing the Cycle of Weathers

Weathermart imagines a new access to food culture. Supermarkets pay an average of $36/sqm on natural gas consumption, which accounts for 42% of the energy bills. People usually go supermarket shopping with their jackets on. They don’t consider it as “inside.” We will demolish human comfort from supermarkets, where gas is mostly consumed on. Then we could substitute for the whole natural gas consumption by effectively harnessing the waste heat produced from cooling appliances. People will feel hot, people will feel cold, but the act of shopping becomes an experience through different chambers of climates.

“Breathing of weathers” does not mean wind blowing through the building. It is about the fluctuating raise and fall of atmospheric properties between spaces. When the heat rises outside, the inside rises in a delay, when it rains, the moisture level rises inside as well. The wall controls the atmospheric relation between inside and outside.
This chapter goes into the actual architecture design phase at the site in Boston. The invention of Active chambers and Passive chambers starts to organize the thermal gradient of produce and its degree of contact to the outside. By merging together two scales of loops, the first offseted inwards from the site boundary, and the second offseted outwards from the active chambers. The perimeter loop basically divides the inner wholefoods market and the outer farmers market. The internal loop offsets from active chambers creating a chain of passive chambers. The passive chambers bridges between the Wholefoods market and farmers market, stitching the two systems together.

The overlap of two loops creates three different boundary condition. The first between Active and Passive, second between Passive and Passive, the third between Passive and Exterior. This leads to three different envelope strategies which has different thermal transparency qualities.

The initial placement of the four Active chambers projects on to the roof surface generating a linear pathway for farm tractors to navigate. The overlapped relationship between the farm geometry and market geometry creates a sectional logic between the roof and the ground.
3.1 Organization: Passive & Active

Weathermart categorizes all the chambers into Active, Passive or External chambers. Active chambers use electricity to generate specific environment inside the chamber, such as freezer chamber, cooler chamber, greenhouse chamber and ventilation. The passive chambers use the exhaust waste heat generated from Active chambers. The overlapping of two loops (explained on p61) creates two types of Passive chambers, one on Wholefoods side, one on Farmers market side. They both utilize the waste heat from active chambers, but have different contact to the outside; one through a porous wall, the other conducting heat through different thickness of glass.
Wholefoods entrance are on both end of Weathermart. Instead of a typical loop circulation of supermarkets, Wholefoods in Weathermart is linear, starting on one end of the thermal gradient and ending on the other. You will weave through active and passive chambers experiencing the climatic shift from one space to another. Instead of looking across the supermarket for signs of where things are, your body and senses will navigate you through the Weathermart.

Wrapping the Wholefoods circulation is the Farmers and Haymarket circulation on the perimeter. During the weekdays, many local vendors of farmers market fill in the loop with seasonal produce. On weekends, Haymarket vendors take over the space.

There are 3 service entries on both sides of the long facade. Since Weathermart wants to be a “packing of atmospheres,” entries into the market does not happen conventionally. You will enter from a slit embedded in the thickness of the wall.
Facade of Weathermart during the day
North facade of Weathermart at night
3.2 Envelope: Three Layers of Boundary

Present architecture only allows for a binary condition. Inside or outside, controlled or uncontrolled, sealed or open. Once you open the window, the space becomes outside. You should turn off the AC. There is minimal opening to the interior, often called as an entrance, to minimize the gap between inside and outside. There are no mediation between open and closed. 0 or 100. However, by utilizing the wall thickness and its conductivity, the heat transfer slows down creating a time delay, instead of a binary relationship. The envelope will have degrees of “openness” all around, to breath in and out the cycles of weathers.

The fluctuating passive chambers are always paired with one Active chamber and one External chamber. The energy balance between the Active and External chambers define the climate of the Passives daily. The boundary condition is defined by this energy sequence. (diagram below)

The envelope now maximizes the visual transparency using glass façade, but thermally insulated. The envelope isolates the inside and outside atmospheres. The architecture is a transparent sealed box. I propose an opposite way of thinking about the transparency. The wall could be opaque and be visually isolated, however, the thick opaque wall mediates thermally between the two spaces. It is thermally transparent. The thermal transparency of the wall changes as the temperature difference fluctuates every day, every hour. It is controlled by the balance of energy exchange between the two atmospheres. It could also vary by human inhabitation. People radiate 75-100 watts, so during the day, when there are more people on one side, the energy exchange rises, as opposed to night time, when there are no people and lights, the walls become highly transparent thermally.
The diagram on the left shows the unitized system of the 3 envelopes. The middle envelope wrapping around the passive chambers have 7 levels of wall thickness allowing different thermal delays and conduction rate.
\[ f(x) = \frac{150}{x} \]

\[ Q = A \times T \div R \text{ Watt} = \text{Joule} \div \text{second} \]

\[ \text{Joule} = M \times c \times T \]

\[ R = \frac{W}{K} \]

\[ \text{mass} = \text{volume} \times \text{density} \]

\[ T = 0.05 \text{ degC} \div \text{hour} \]

\[ T = 1.2 \text{ degC} \div \text{day} \]

\[ T = 10 \text{ degC} \]

\[ \text{Heat} \]

\[ \text{wall width conductivity} \]

\[ \text{Area} \]

\[ \text{Temp difference} \]

\[ \text{Resistance} \]

\[ \text{c value for concrete} = 700 \text{J/kg*degC} \]

\[ \text{density of concrete} = 1500 \text{kg/cubicm} \]

\[ 10(\text{m}^3) \times 1500(\text{kg/m}^3) \times 700(\text{J/kg*degC}) \times T = 150(\text{watt}) \times 3600(\text{seconds}) \]

\[ \alpha T = 0.05 \text{ degC/hour} \]

\[ \alpha T = 1.2 \text{ degC/day} \]
Diagrams of facing page explains the relationship between temperature difference between two spaces and wall thickness. The thickness of the poche is inversely proportional to the temperature difference. We could start to define the wall thickness range when the temperature difference is given by looking at the curve break on the graph.

The exhaust heat produced to lower 1 degC in the colder chamber could raise 1.3 degC in the hotter chamber. (if the same volume)

EXHAUST HEAT IS PROPORTIONAL TO AND ALWAYS GREATER THAN COOLING ENERGY.

The bottom diagram shows the energy exchange within a refrigerator. This tells us the exhaust heat is always greater than the cooling energy, and making each room smaller to heat or cool can save great amount of energy.

The energy need to heat/cool a room is proportional to the volume of the room

MAKING SMALL CHAMBER FOR EACH CLIMATE CAN SAVE A LOT OF ENERGY!
ENERGY INTENSITY BETWEEN INSIDE AND OUTSIDE

CONDUCT DEGREE 1

CONDUCT DEGREE 7

PENETRATE
STORE

Left
Energy map

Facing page left
Winter energy map

Facing page right
Summer energy map
Facing page is a diagrammatic energy map of weathermart. You will recognize the 3 different boundary conditions. One type introduces the natural weathers to penetrate in to the market, and to be heated or cooled using internal thermal mass. The Conduct boundary is sealed in terms of physical air, but allows heat transfer to conduct through the varying mass of concrete and glass. The Exchange boundary isolates the two spaces using thick poche, allowing to exchange energy from cold to hot.

Below energy maps show how heat changes from winter to summer. During winter, the northern side of Weathermart is cooler, and as you meander down to the south side, it gets warmer. During summer, the north side of Weathermart is warmer, and as you move down to the south side, it gets cooler.
Winter fish market during winter in Passive chamber 2
Summer Green market during summer in Passive chamber 2
3.3 Roof: Farming and Welling

One of the main constraints the site has is the lack of depth in the ground for farming. Also, drainage in the soil is a major problem. Weathermart elevates the datum 7 meters above ground and creates a productive depth for growing crops. The shape of the planters funnels water through the roofscape of the market, feeding filtered clean water for hydroponic farming inside the market. The funnels are at places used for air ventilation from the Big Dig roadways.

The plannametric organization on ground plane is directly projected up on the roof surface. The linear organization on the roof is for effective tractor farming.
Overlaying the ground floor geometry and roof geometry extracts critical spots to poke up and poke down. The 7 Weatherwells are shared by 2 chambers; External and Passive, or 2 Passives. When External and Passive chambers share a well, it pokes upward. When 2 Passive chambers share a well, it pokes down.
I am designing the first Weathermart in United States here in Boston which attempts to replace the Haymarket, together with a supermarket and farmers market. However, big dig runs 2m under the surface of the site. Weathermart creates a new landscape 7meters above to have an efficient depth for food production and to also channel water into the hydroponic system of the market.

Left
Roof plan

Bottom
Planter depth map

Facing page
Dimension of different Vegetable roots
3.4 Sections: Architecture between Weather and Ground

The diagram on the left takes out a core sample from the lot. Weathermart is a filter. It absorbs influences from the weather, such as sunlight, rain, snow, filters through with the roof and sends it down into the ground. It also does in the opposite direction. It ventilates the interstate highway through the Weathermart and releases in the air. By harnessing the heat from ventilated air, Weathermat utilizes another source of heat.
3.5 1:50 Models Photos
4 Appendix

4.1 Food Charts

4.2 Precedent Research
   - Roman bath
   - bridgemarket
   - Grand Bazaar

4.3 Studies
   - initial studies
   - Mid Review
   - Mid Review 2

4.4 Pechakucha Night

4.5 Thesis Defense (12.16.2011)
4.1 Food Charts
4.2 Precedent Research

**THERMAE: Roman Baths**

Roman baths called Thermae have a specific relation between program and heat/moisture. The order in which the Romans took bath directly shaped and informed the architecture in a sequential manner. Starting from the undressing room called Apodyterium, people would enter the Tepidarium, where it encapsulates warm air. It is positioned as a transition zone between the Caldarium and the outside. After getting used to the heat in Tepidarium, people would proceed to the Caldarium, which is the hot bath. You could go in the bath made of copper, or you could do some excercises in the room. The section shows that each specific atmosphere carves out the space to retain heat. The thickness of the wall is informed by the relationship of the neighboring heat.
fortified palace with bath complex, Syria

woman's caldarium, Stabian Bath, Pompeii.
(wall heating entirely by tegulae mammatae)

bath of Pompeianus, Algeria.

South Precinct, Baiae

Ambulatio Villa, Baiae

Thermae of Mercury, Baiae
Roman baths develop with programmatic extension. Placing the main sequential functions of bath as a central axis, the circulation extends to make a loop, where many additional programs are attached, such as gymnasiums, library, lecture halls, and game rooms. The roman bath is not just a place to clean yourself, but becomes a cultural center for Romans to gather and communicate.
Roman baths begin to be more and more recreational complex. Basically, keeping the main sequence of cold bath, warm bath, and hot bath, many program are attached, expanding its circulation. There are gymnasiums called thermarium, game and sports room, lecture rooms and even libraries. Each room had its specific program according to heat which travels under the building in relation to the water supply.
A TYPICAL PLAN AND SECTION SEQUENCE OF ROMAN BATH

CALDARIUM  TEPIDARIUM  FRIGIDARIUM

ENTRANCE

1:200

Hypocaust - heating system

BATH AND ITS RELATION TO THE LANDSCAPE (WATER IRRIGATION AND DRAINAGE)

aqueduct  cistern  water pipe  bath complex  entrance
Grand Bazaar, Istanbul

Grand Bazaar in Istanbul consists of more than 58 covered shopping streets and 4,000 shops. Began its construction in 1455, it opened in 1461.
**Bedestens**

The bazaar contains two Bedestens, the two rectangular boxes above. Bedestens are domed masonry structures built for storage and safe keeping.
Flagship of Food Emporium lies underneath the Queensboro Bridge with Guastavino decorated tiles on the ceilings. It consists of Guastavino's restaurant, Food Emporium and Terence Conran Shop.

**Bridge Market**
1909 Queensboro Bridge completed
Terra-cotta tiles by Rafael Gustavino

1910 Flower market proposal by NYTimes
(not realized)

1914 NY severe market shortage
(Baltimore 5,000 NY 137)
"Free Market" open 40m x 90m market space
(farmers and fishermans could offer products without stall fee)

1920s Great Depression
Free Market close

1930 NY City Department of Transportation
used for sign painting shop, storage area, and parking garage.

1972 NY City Public Development Corporation advocates reuse.

1973 NYC Board of Estimate approves proposal to lease the space
to the American Cinematheque $1/year.
(terminated due to lack of funds)

1975 plans to transform the space into the International Fair, housing a mix of
food shops, restaurants, boutiques, movie theaters.

1977 Developer Harley Baldwin and architecture firm Hardy Holtzman Pfeiffer Associates
proposes a multilevel food market and restaurant complex, incorporating a plaza
with two gable-roofed market building and a greenhouse, plus an open area.

1986 project increase in size from 600sqm to 12200sqm by HHPA

1996 $42 million government funded restoration of the bridge and tiles.
replace exterior industrial sash with specially designed frames containing double pain glass panels

Bread and Circus (food store) leases 3,500 sqm occupying 6 vaults
Terence Conran (furniture) leases 3,200 sqm + 3,000 sqm below grade
Gustavino's Inc. leases 2,400 sqm beneath 3 tallest bays
4.3 Studies
Initial Studies
APPENDIX | STUDIES
2 points

3 points

multiple points

3 dimensional points

2.5 dimensional points

0  2
  d=2

-2  4
  d=6

-2  8
  d=10

block type

mat type
equally sized chambers, distributed unevenly

midpoint normal, offset degree 3

midpoint normal, offset degree 5

midpoint normal, offset degree 8

equally sized chambers, distanced evenly from each other

midpoint offset according to temp difference

offset according to temp difference

spherical relation \( z=0 \)

spherical relation, varying height

tangent sphere packing

tangent chambers

creates wall thickness
temp zones
temp differences
wall length

\[ k = \frac{t}{x} \times \text{length} \]
Mid review
Mid review 2
POCKETS OF ATMOSPHERES IN SPACE
DEFINE TERRITORY
SLICED OFF BY URBAN CONTEXT
PROGRAMMED
THERMO RELATION
4.4 Pechakucha Night
Weathermart. The challenge of this thesis is to rethink the notion of what's inside and outside, and what is temporary and permanent, through air and mass. Architecture has ultimately been about defining what is inside or controlled, and I was very interested in how that boundary could change according to where on earth it's placed, from summer to winter, and time of the day.

The thesis reinvents the supermarket by questioning the generic big-box typology where produce is placed in the same way in a hermetically sealed environment. A supermarket should be designed thermo-dynamically, reorganizing the climatic relationships between the different atmospheres it houses.

Such a gradational spectrum of heat and moisture begins to become part of a greater external spectrum of nature as Weathermart starts to expose its boundaries. The climatically engaged supermarket could save great amount of energy by effectively exchanging bi-products of waste heat. Furthermore, the act of shopping becomes a very sensorial experience through different chambers of weathers.
The Weathermart proposes that architecture nests in between the external and internal atmosphere. The continuous surface of landscape cuts through the two atmospheres, connecting the two. How could architecture act as something like a sponge, breathing in and out, the cycles of weathers?

The thesis operates in two scales. On one level, the thesis speculates a new organization and sequence of micro-climates in a continental scale, looking at how relative locations from hot chambers to cold chambers have different relationships to their environment.

On the other level, it proposes a thermally active market on an architectural scale, looking specifically at the site and programmatic requirements. Weathermart replaces the existing open air Haymarket in Boston by combining it with a new enclosed food market.
Weathermart positions itself between a temporal and external farmers market, and a permanent and internal market. Haymarket is a rare example where those two reside next to each other. Weathermart attempts to merge the farmers market and Whole Foods together to become a gradient.

This chart reorganizes all the produces by temperature and humidity, in relation to the range of external temperature in Boston. Iced, sprinkler needed, and ethylene sensitive products are extracted from the chart above.

The analysis of the existing Haymarket and Whole Foods Cambridge allows to determine the square footage needed, number of loading docks, parking and different kinds of produce to house in the new Weathermart.
Weathermart consists mainly of an open market that could be used for Haymarket and farmers markets, and an Internal Market, which houses the Whole Foods products. In addition, it has its own farms, kitchens, restaurant/cafes, and food labs, all residing in sequence from inside to outside with their own climatic character.

Instead of organizing the produce by aisles, the organization becomes a sequence through different chambers. The existing linear passage of produce, 728 meters in length, becomes a meandering ribbon that forms a chain of climatically different spaces, from outside to inside, uncontrolled to controlled.

Each chamber is placed in relation to the chambers next to it. The graph representing the relation between temperature difference and the wall thickness forms an exponential curve, which allows the chambers to determine the optimal wall thickness in between.
The network of climatic relationships among adjacent chambers makes up the Weathermart as a whole. Such composition, both in plan and in section, takes advantage of different adjacencies with its environment. The environmental factors, both natural and urban, and designated sequence from outside to inside forms the Weathermart.

The four strategies here all indicate different methods of organizing the spectrum of heat and moisture. One pixilates the climates into a field conditions and forms a mat building, one organizes each climate vertically, giving each temperature a floor forms a tower, one organizes in a linear fashion allowing depth to become a factor to control temperature forms an S shape with urban courtyards.

The hybrid of mat and tower organizes the Whole Foods produce into a mat building and open market into a tower that penetrates through from underneath creating a tension between controlled and uncontrolled. The tower becomes occupied with farmers markets on weekdays, and Haymarket on weekends. Other days become a vertical landscape tower to view across Boston.
The produce is largely zoned into seven segments, placing highly controlled chambers in the middle. The walls gain thickness according to the temperature difference and houses an atmosphere of different zones. The volume in the middle of each chambers act as thermal mass which controls each chambers.

Since the site is located right above the Big Dig, there is not enough depth for food production. The Weathermart provides depth for farming productivity on the roof and collects water to funnel into the market for hydroponics, moisture, and water based heating. Some funnels act as air vents from the highway underneath.

In the plan, you can see the seven climate zones, and the walls that surround them become carved for cafes and labs to nest within. The opened chambers to the street are for food storage and restaurants.
The upper section cuts across the open market which slides under and unfolds into a tower. The tower forms a double helix, one exposed and one internal. It becomes a chimney of different smells fuming up the tower. The section below shows the relationships between the food chambers and the hydro funnels.

The last slide will give you the sense of the Weathermart, where you experience transition from the hot chambers to cold chambers, through the act of shopping. thank you.
4.5 Thesis Defense
5 Bibliography


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