Synaptic City

Space Flexibility in the age of Big Data

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Abstract

"Flexibility" in architecture, refers to the ability of a building to continuously adapt its space layout and even its structure to evolving needs. Achieving such "architectural flexibility" has been over the past century a challenge a number of investigations have tried to take up. From the early stage of the Japanese Metabolist movement, to the formal flexibility of contemporary architecture, architects have progressively enshrined the principle of space plasticity. But, all in all, they have rather turned it into a style away from its initial ambition: make flexibility an actual functional principle.

Today however, independently of any disciplinarian consideration, the emergence of the Big Data powered by algorithmic and semi-automation, may put the promise of architectural flexibility within our reach. Data and analytics could simply enable the built environment to better understand and forecast space utilization. And semi-automation could help adapting space layout in near-to-real time while optimizing users' comfort and space efficiency.

Rooted in the Metabolist tradition, encouraged by the society's evolution, and the technology's disruptive potential, we propose a revived architectural answer: The Synaptic building, whose manifesto dedicates space flexibility as the corner-stone of the 21th century architectural practice.

Habitat 67 - Moshe Safdie

Introduction

Far from inventing from scratch the idea of space flexibility, we anchor our rational into a clear tradition: the Metabolist Movement. Understanding its outcomes, downturns, and translation in today's architecture is the first step towards defining the Synaptic Building.

The dream of buildings as living cells, breathing and adapting to stimulus, first took its essence at the turn of the 60s in modern Japan. Best expressed by Kiyonori Kikutake in his manifesto Metabolism 1960, the Metabolist movement stems from the urgency of post-war reconstruction. The vision offered by Kiyonori Kikutake is a mega structure, bearing interchangeable and connected units that would form the city of tomorrow.

From the Metabolists to Moshe Safie's Habitat 67, and even until today, in the architecture of contemporary architects such as SANAA, the idea of reconfigurable independent units has survived. This new impulse has forgotten the functional promise of the Japanese Metabolists, and offers a style more than a method. Units are freed from the constraint of the grid, or the authority of the structure, and rather "float" in the space, in an apparent serendipity.

From the early days of the Metabolists, to the formal aesthetic of the "floating" units, from Kurokawa's Nakagin Capsule Tower to SANAA's Rolex Learning Center, flexibility got crystalized into a style. How did functionality get lost on the way?


Clusters in the Air. Model, 1962 - Arata Isozaki

I - Space Flexibility: a Tradition coming from afar

The group manifesto's Metabolism- The Proposals for New Urbanism- opens with the following statement:

"Metabolism is the name of the group, in which each member proposes further designs of our coming world through his concrete designs and illustrations.[...] The reason why we use such a biological word, metabolism, is that we believe design and technology should be a denotation of human society. We are not going to accept metabolism as a natural process, but try to encourage active metabolic development of our society through our proposals." **(1)**

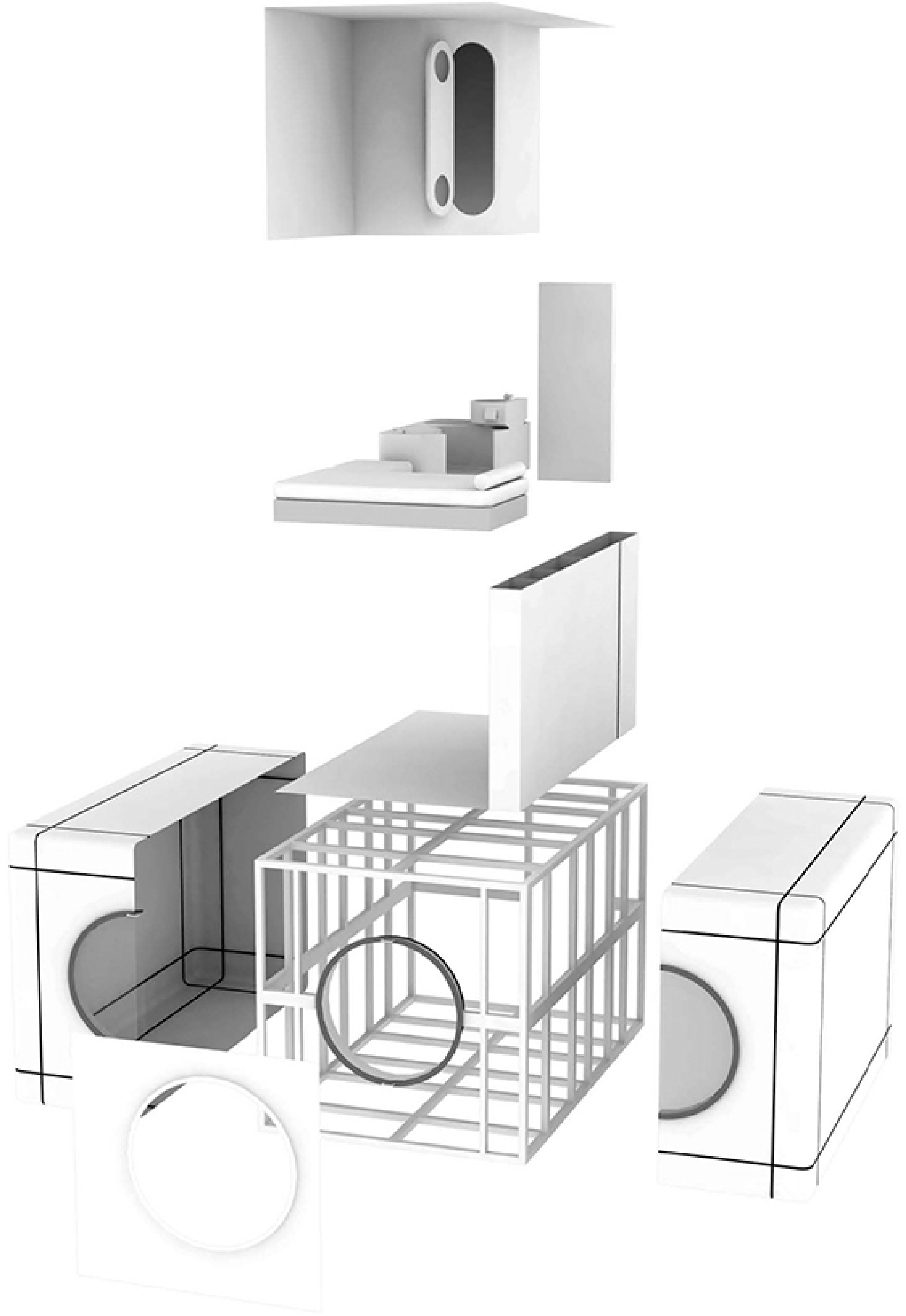
Metabolism in Architecture, p. 10. ▸

As Kikutake and Awazu write these lines, their intent is clear: the Metabolist Japanese movement in Tokyo takes its roots into a certain faith in technology and social welfare. Mainly, three facets define their vision:

· *A deep belief in Regeneration,* as a guiding principle. Inspired from traditional Japanese values, the Metabolists placed value in the ideal of a constant rebirth of the built environment.

· *The importance of society as the trigger of the built environment's metabolism.* Kikutake is in fact very specific, as he opposes the rigidity of the industrial planning in post-war Japan, to the organic nature of their ideal city. The organicity of the Metabolist's vision stems from their belief in social good. The constantly-morphing city should adapt to society's need, rather than constrain it.

· *Faith in technological advancement.* The Metabolists recognized in modular housing and new production technics a vector for their ideal. The growth of the metabolic city could not be sustained with traditional construction methods. Rather than relying on tradition, and wood-based construction, the Metabolists turned to concrete, steel and mass-production as the means to achieve their vision.



Nakagin Tower - Kisho Kurokawa

A- 1960s and the Metabolist Movement

The ideal scheme of the metabolic building derived also from an analogy with biology and nature: a tree. The core, the vertical circulation and the serving functions would be hosted in a "trunk"-like megastructure, onto which prefabricated-habitation capsules would be added, and ultimately replaced. Arata Isozaki, architect who worked with Kenzo Tange at the time, sums up the ideal scheme in Japan-ness in Architecture in the following terms:

"The image Metabolism deployed comprised a permanent core supplemented by a shorter-term growth module. The former was a mega-structure that may be likened to a tree trunk or spinal cord. The latter resembled branches of a tree or organs of the body, constantly renewing its cellular metabolism. Especially remarkable was a mass-produced, interchangeable capsule unit for living."

From the "trunk" (core) to the "branches" (units), concerns of function and lifespan are different: the core is long-lasting while the units are interchangeable. The core serves the units for access and structural support. The Nagakin Capsule Tower, by Kisho Kurokawa best exemplifies the application of such a scheme. Built in 1972, the "Capsule Hotel" was an attempt by Kurokawa to align the Metabolist vision with the reality of construction. U sing prefabricated units, that would fit on transportation trucks, Kurokawa erected in 30 days a residential tower, in the middle of the Shimbashi neighborhood, in Tokyo.

The square concrete core hosts an elevator and a stair case, that give access successively to each capsule. Each of them is self-contained and was entirely prefabricated before being brought on-site. Its design was aimed at being simple and industrial, in order to achieve mass-production in the long run. Structurally, each unit was individually attached as a cantilever to the core, so that individual-removal or replacement could still be achieved in the future. Also, as space usage might evolve, units could be merged together to allow for different activity, or larger communities.

Inside Nakagin Tower's Capsules

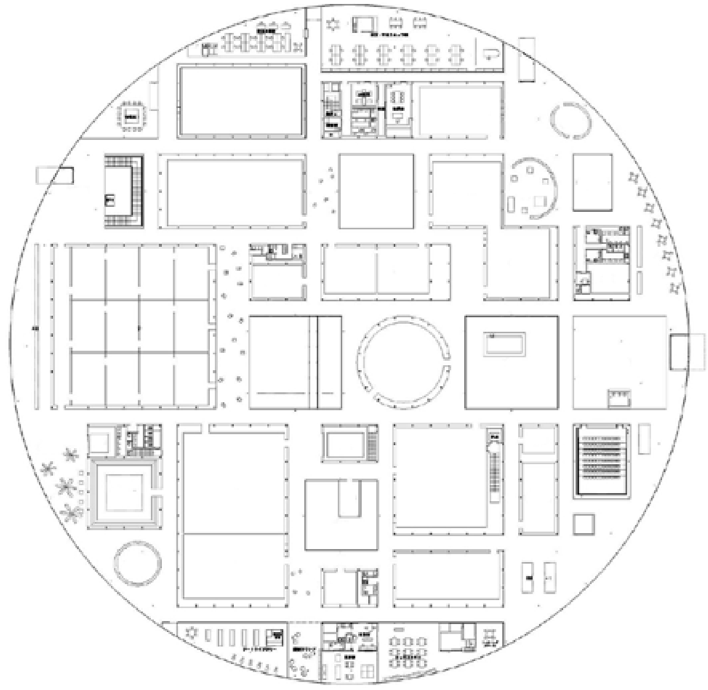
As a result, the building hosted at first a diversity of usage: 30 percent of single families, 30% of business men, and 40% of miscellaneous (small business, recreation rooms, merged units). Kurokawa's hope was that the tower usage would change throughout time, and the units would be renewed and replaced to adapt to this evolution. The architect even went on to design activity-related capsules such as the LC-30X leisure capsule, the tea room capsule, the culinary capsule, etc.

Reconsideration of the Metabolist Model, p.1, http://slowmedia.net/archive_j/back.pdf ▸

Investigation in Collective Form, p 11-12 ▸

The economic downturn, along with the lack of proper technical conception, prevented the Metabolists' iconic landmarks from performing their intended objectives: no capsule was ever added to neither the Nagakin Tower nor to the Shizuoka Broadcasting Tower. Kurokawa's design turned out to prevent individual capsule replacement. Massive renovation was in fact needed to change a given unit **(2)**. At the same time Fumihiko Maki, one of the initial founder of the Metabolist movement, coined the main flaw of the Metabolist scheme: the independence between the functional parts of the system was never truly achieved **(3)**, in other words, the structure, supposed to act as an independent supporting matrix, was in fact technically linked to the units. Changing one unit necessitated an intervention on the structure, undermining the very ideal of the Metabolist scheme of a friction-less matrix-unit datum.

In clear, if the Metabolist aimed at space flexibility, the lack of technical conception along with a broader economic downturn undermined their project viability in the long run. But the echo of their radical ideal still resonates in contemporary architecture.

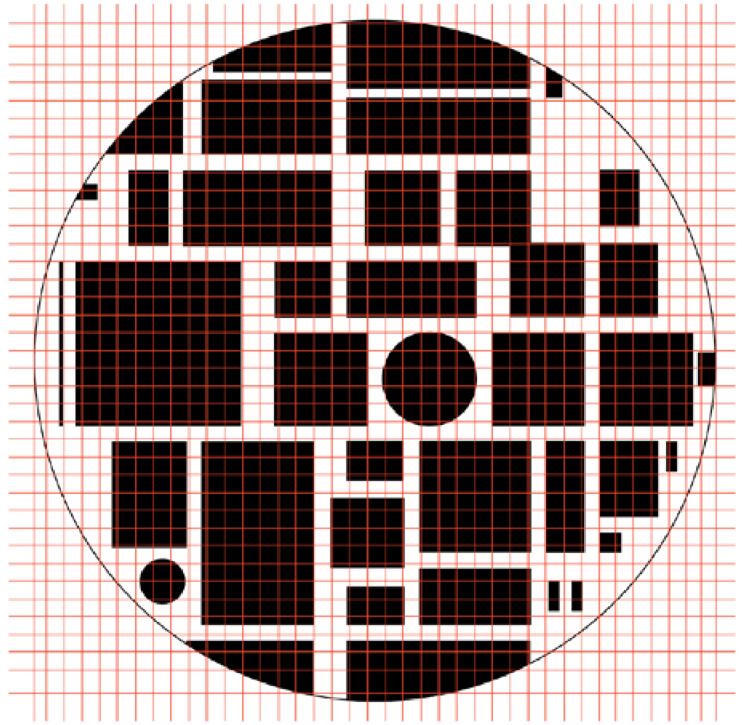


B- SANAA and the aesthetic of flexibility

Far from the verticality of the Nagakin tower, the horizontality of SANAA's projects seem at first to offer an entirely new perspective on Architecture. However, a closer look at the plans of SANAA's buildings reveals a parallel with Kikutake's manifesto: a revival of the unit as a free element in space. The matrix has vanished, leaving space for a continuous space into which the units are laid out. The focus is now on the "in-between" conditions that the neighboring of units creates. The system does not envision growth anymore, or reconfiguration, but the serendipity of the plan suggests a still-very organic organization of spaces.

At the Rolex Learning Center, the library, the information desk, the shops and working "bubbles" are purposely misaligned with the column grid, to suggest the organicity of the scheme. Also, the units' geometry is distinct. The space left for "in-between" conditions is vast, and leaves room for its appropriation by the users (the couch area, the café, etc).

The flexibility that SANAA offers at the Rolex Learning Center borrows significantly to the Metabolists' principles. As Eve Blau explains in his speech during SANAA's Pritzker Ceremony in 2010:

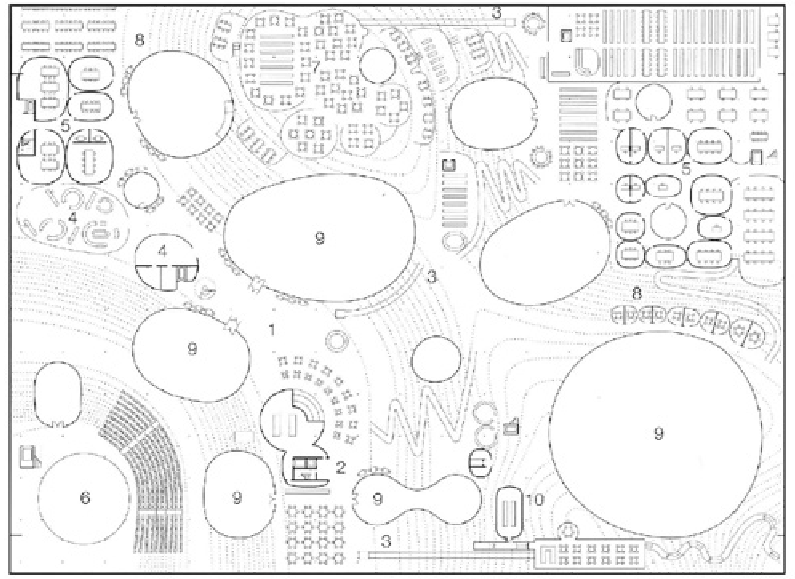


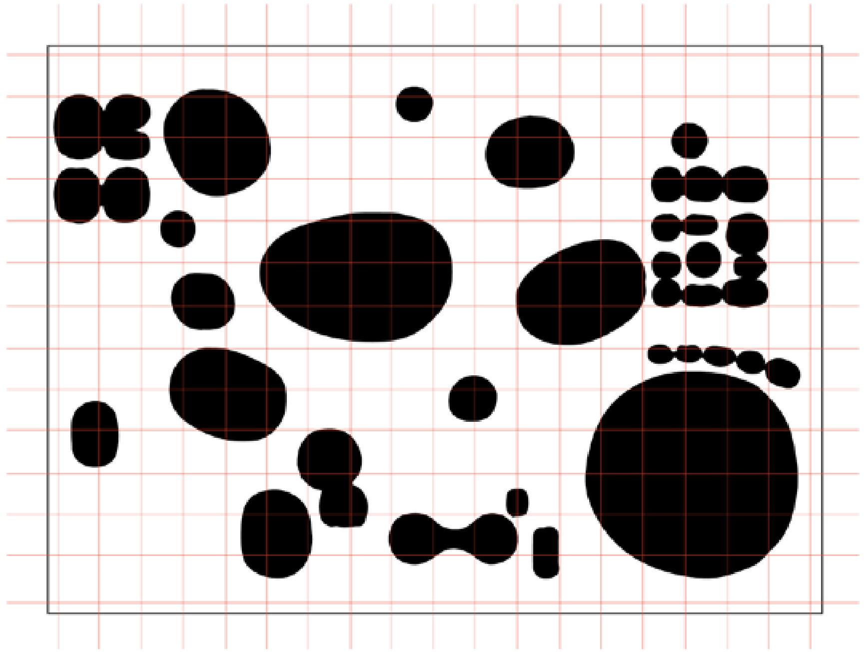
Inventing New Hierarchies, p. 5 ▸

> *"SANAA's plans, one could say, operate as abstract notational systems for the three-dimensional performance of the architecture. They constitute a system—much like the score of a musical composition—that is both carefully orchestrated and radically open to interpretation and variation. The result is typological indeterminacy of the spaces that allows for enormous flexibility of use. "* **(4)**

It is this flexibility that seems to tie back to Kikutake's ideal of flexible space. At the same time, the system is bounded, and not meant to grow: the Rolex Learning Center is closed by a permanent glass facade, while the units are fixed to the ground. The idea of organicity is translated in the style of the building, but not in its functionality.

Rolex Learning Center — SANAA





Kanazawa Museum — SANAA

A glance at SANAA's Kanazawa Museum comforts this idea. If we find again a similar pattern (misaligned units with specific geometries, "in-between" space for users' appropriation, horizontality), we also notice that the museum is bounded by a circular glass façade, while the units are fixed in the space. Flexibility of usage happens through the users' appreciation and usage of the space, rather than by an actual "regeneration" of the building throughout time.

The architectural grammar of SANAA is quite symptomatic of the current blend existing in contemporary architecture between the Metabolist intuition and the public's taste for open and flexible spaces. Although it is a clear step forward in terms of design it is functionally a step back from the Metabolist's ideal: the very idea of growth is ignored and no systems are embedded for facilitating future additions.

From functional flexibility to the aesthetic of space plasticity, the echo of the Metabolists still resonates today. The survival of Kikutake's ideal, even if partial, is a springboard to revive metabolism at the turn of the 21th century.

Typical WeWork Office

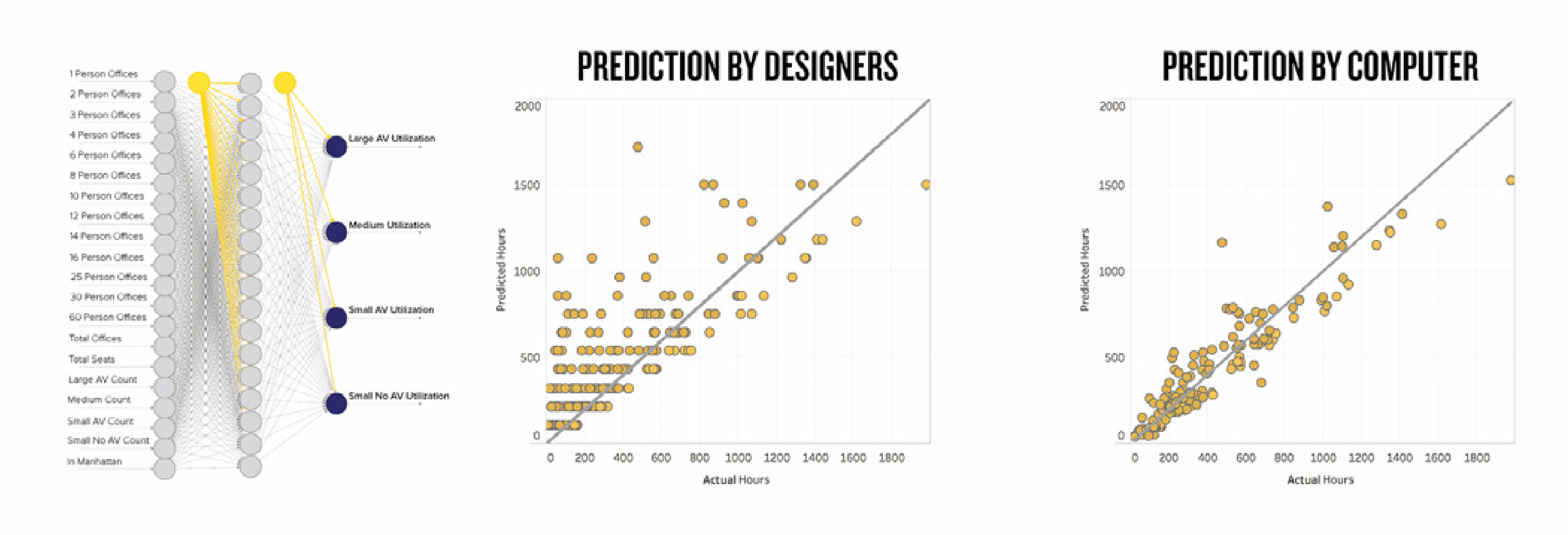
I - Space Flexibility: a Tradition coming from afar

At a time of deep societal change, and technological disruption, space flexibility might be an answer to reconcile society's need for increased space plasticity, and technology's ability to offer such spaces.

A - An Expectation from Society

If functional flexibility has faded out from contemporary architects' concerns, the public is expecting more space plasticity, as lifestyles evolve, at work or in consumption in American cities. Ownership structures themselves are being radically changed, to the point where the suitability of our current built environment might come into question. To answer such an imperative, understanding the deeper aspirations of society is more than crucial.

Work and consumption are on the verge of profound changes, more specifically in urban centers. The World Economic Forum as well as McKinsey Research are forecasting structural changes that will and are already affecting our built environment.



WeWork's Space Programming Optimization

Work

Our working environment is being vastly redefined today. Here is a breakdown of the main vectors of change in today's society:

- Companies' Hierarchical structures are being flattened Jobs are morphing into project-based activities, with shorter time frames.

- Remote workers enabled by communication technology, are off-loading the work place.

- Online platforms for job search enable seamless turnover and reemployment. **(5)**

Rethinking work in the digital age, McKinsey & Company, October 2016 ▸

- The community of workers is also now both a physical and virtual reality: online communities play a greater role in the work culture.

Those vectors are impacting the design of work spaces significantly:

- Dematerialization of the office and worker's mobility: the dematerialization of wires into WIFI and broadband connection suppresses the desk or personal office into more nomadic work habit. Porosity of spaces, less compartmentalization of activities, but constant re-adaptation of the space.

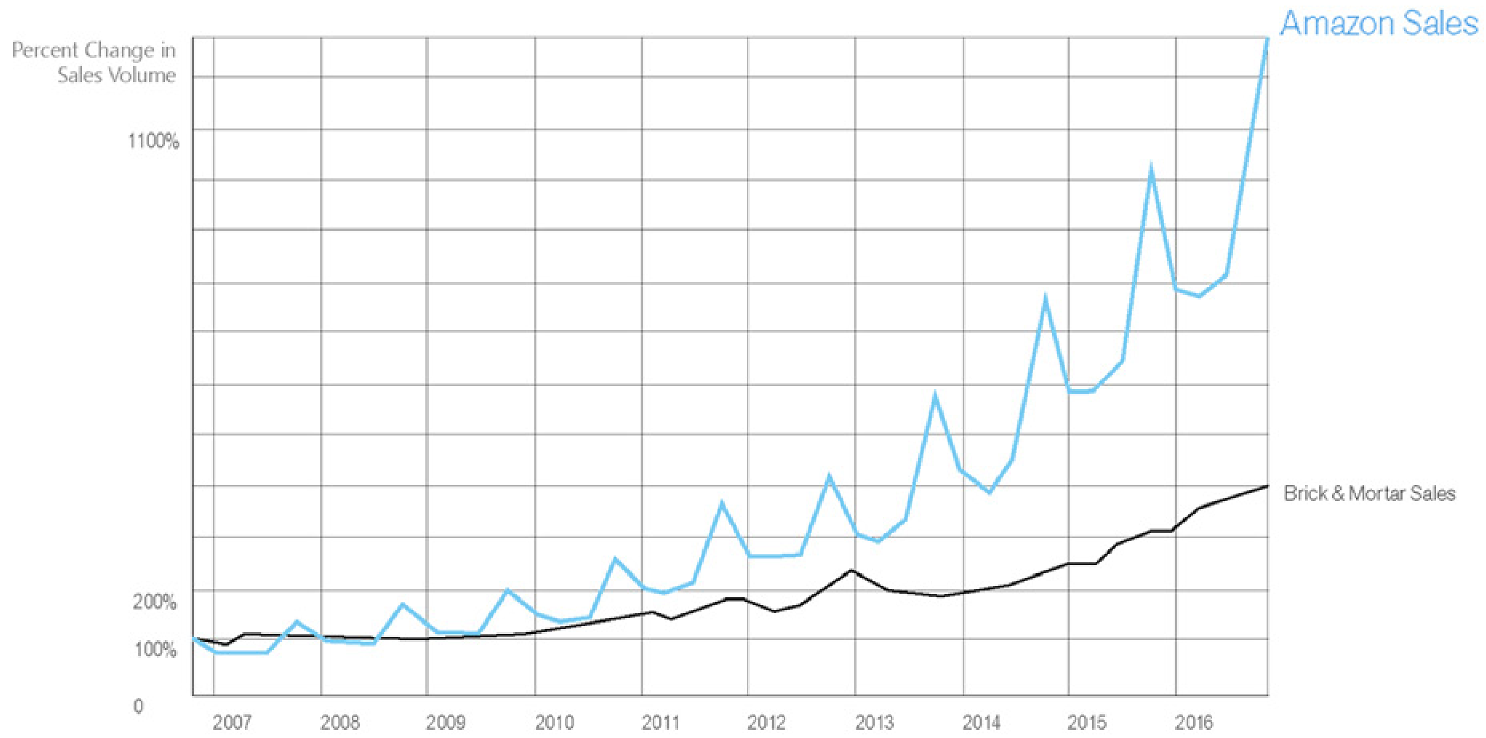
- Traditional functions are being aggregated into:
  - Open spaces for work
  - Transparent and continuous communal spaces
  - Enclosed meeting rooms

- Plasticity of space: space gets remodeled based on users' behavior and needs.

Case Study

This case study, realized by WeWork, offers a deep-dive into space remodeling based on users' behavior analysis. WeWork, to better adapt their open spaces to the demand and needs of their users, collects data about their office space usage, and predict future pattern of use, to then remodel the space monthly **(6)**. By the end, their approach (using Machine Learning) help their offer better match their clients' needs, by supplying the right mix of private offices and meeting room types.

Designing with Machine Learning https://www.wework.com/blog/posts/designing-with-machine-learning ▸



E–Commerce outpaces Brick & Mortar | Source: Bloomberg

Consumption

As a sign of the change happening in American cities today, the consumption patterns in urban centers are drastically evolving. A couple of key vectors are at play:

- A demographic shift, growth of baby boomers, Hispanics and millennials populations.
- Consumer used to highly personalized targeted marketing and experience
- Growing share of e Commerce purchasing **(7)** around 18% per year
- Growing share of smartphone-enabled consumers (around 60% today) **(8)**, with increasing share of mobile purchasing (15% in 2013!).

How Retailers can keep up with consumers, McKinsey & Company, October 2013

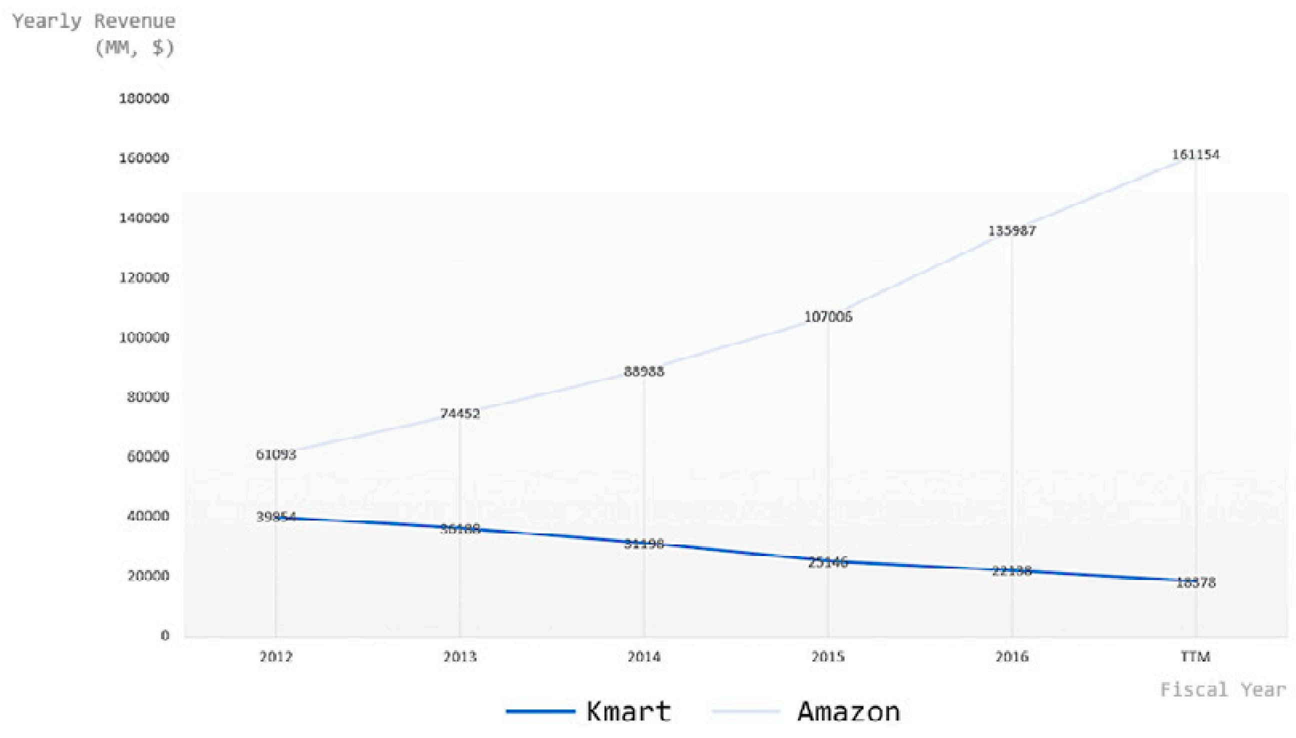
Rethinking work in the digital age, McKinsey & Company, October 2016

Disintermediation: consumer tend to buy online directly from the manufacturer, bypassing shops and retailers.
...resulting in drastic change in the retail industry:

- Less and smaller stores **(9)**: Dramatic decrease of retail surfaces, under the pressure of e Commerce platforms. McKinsey forecasts a reduction by half of retail surfaces in US cities. They also noticed that newly opened stores are in average 25% smaller than 10 years ago. The result is a fragmentation of the retail space , geared towards customer engagement.
- Store as extension of a website: for pick up and returns of online orders. For instance, 50% of Wal-Mart's sales were picked up in store in 2013.
- Customized store **(10)**: adapting to changing customer traffic patterns. Stores can analyze consumer behavioral data to adapt their store to usage patterns. For instance, Carrefour is using localization data of its customer in his shop to remodel monthly its shelves layout.
- Experiential stores: stores as a show-room for customer to engage with products, and interact with experts.
Stores within a Store: Retails as third-party marketplaces

Rethinking work in the digital age, McKinsey & Company, October 2016

Shaping the Future of Retail for Consumer Industries, World Economic Forum, January 2017

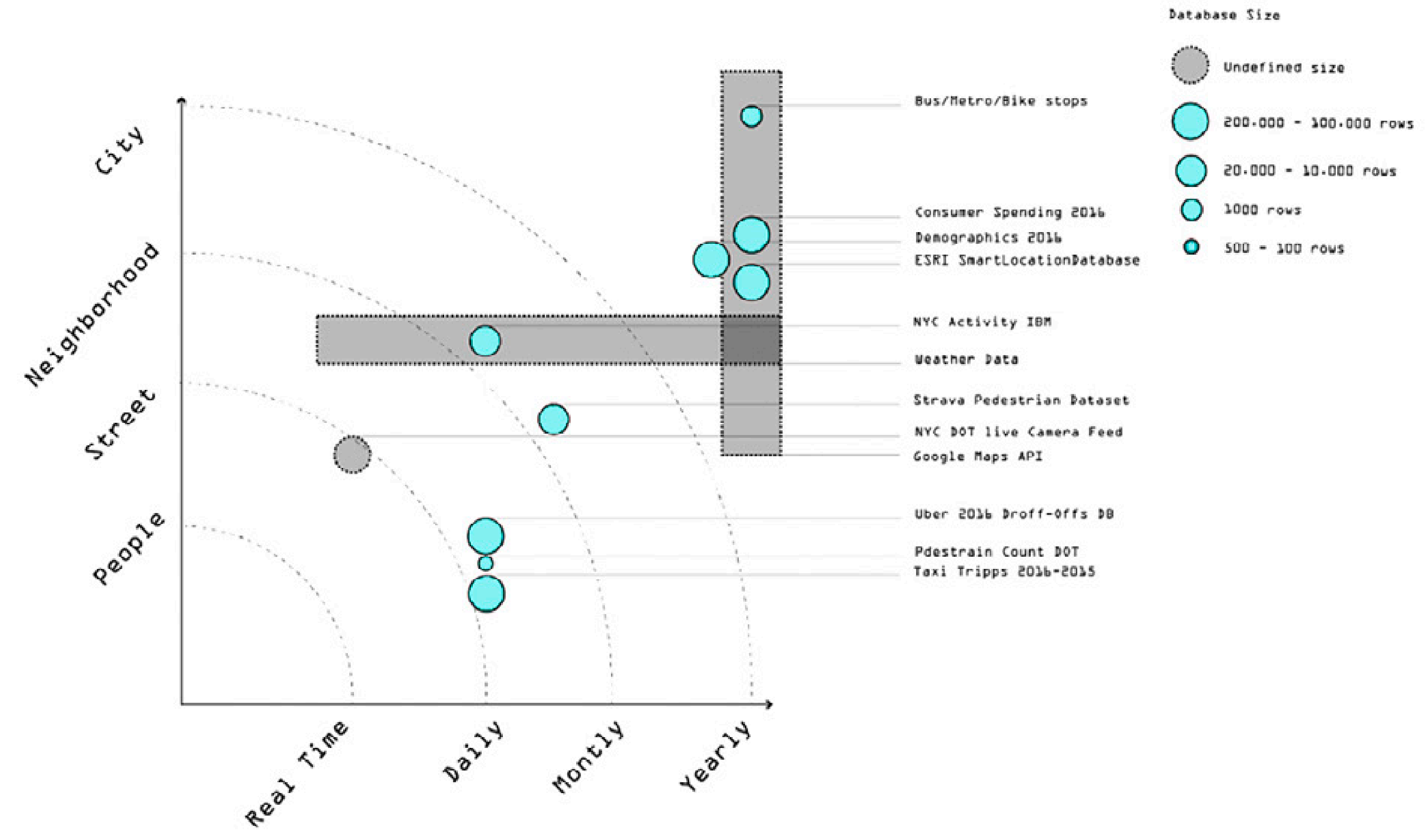


Kmart Revenue Vs. Amazon Revenue / 2012–Today

Case Study

Kmart was in 2000 the third US retailer, with 36 billion in sales. In 2014, revenue had declined by two third. Over the same period, Amazon went from 2,8 to 89 billion in sales, and announced in 2017 that it would buy Whole Food, one of the leader in the supermarket sector. The digital-based strategy of Amazon, and the too traditional approach of Kmart are exemplary of the current trend in the retail industry. **(11)**

The Consumer sector in 2030: Trends and questions to consider, McKinsey & Company, December 2015 ▸



Mapping Urban Data for Manhattan

B - Enabled by Technology

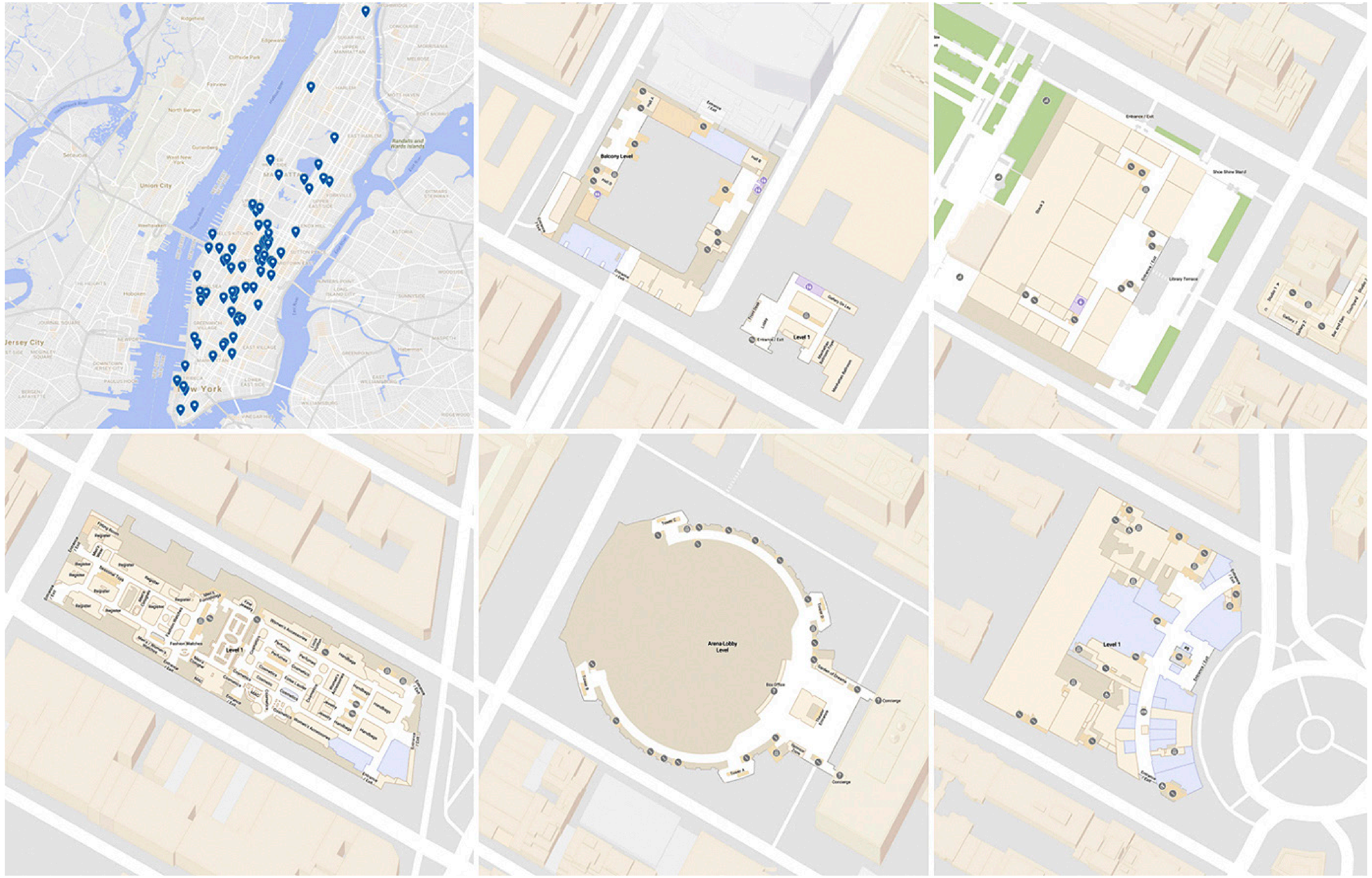
The same way the Metabolists believed in technology as a catalyzer for the Metabolic city, technology is today at a turning point, and could enable a profound shift in the way we build and live. Through the advent of urban analytics and semi-automation, our cities have today more insights and ability to react to the cities' pulse in a near-to-real time fashion.

The Rise of Urban Analytics

BigData has become a buzz word every single industry. It still has to land in the world of the built environment. As we witness the increase of data aware-cities ("Smart Cities"), and the ever-growing availability of spatial data over the web, we see the world of "urban analytics" structuring itself into useful and actionable tools.

If the construction industry is not showing the way to data usage, the quantity of available information has been exponentially growing over the past 15 years. From publicly available repository managed by cities (NYC Open Data for instance), to private company-datasets the amount of data gathered and analyzed on the built environment as never been bigger. Independently of the commonly used data, vast tanks of information are today available and could potentially inform our designs: user centered data, mobility data, space usage information, building maintenance logs, etc. Over the past 15 years, the amount of such data has increased from few megabytes gathered yearly, to terra-bytes aggregated daily.

For the city of Manhattan only, using open source data such as the NYC Open Data portal, and other open source websites, stakeholders are already able to collect in few clicks vast amount of granular and clean datasets, aggregated at different geographical scales (Building, Block, Neighborhood, City), and temporal timeframes (Real-Time, Day, Month, Year). The graph here on the left is an exhaustive attempt at mapping and classifying such data.



Google Indoor Maps in Lower Manhattan

Consequences for our built environment

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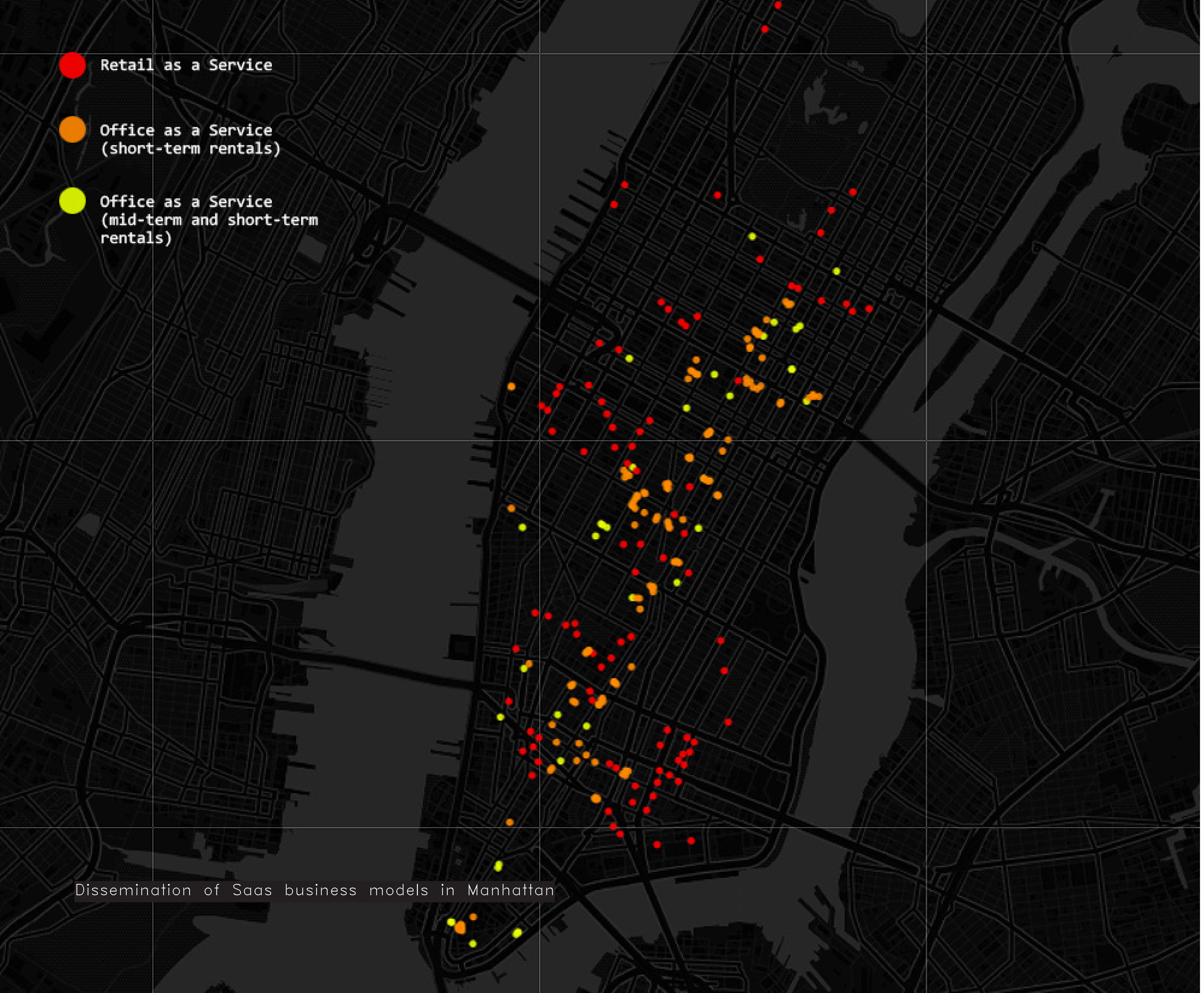
The Growth of the Built Environment Digital Footprint

The age of information first manifest itself in cities by the refinement of the cities' map: more granularly described, more discoverable, buildings are getting documented and fed back into the digital space: Google Indoor Map might best exemplify this current trend. In Manhattan only, more than 75 buildings already exist in the current version of Google Indoor Maps **(12)**.

Google Indoor Map in Manhattan, https://drive.google.com/open?id=1Mjo9gdH0tPwF-6FoKMbKDgZ1svk4&usp=sharing ▸

Such a simple example gives us a glimpse at the future of our built of environment. The same way Nolli drew a map of the continuity of the public space, as one single white area extending into buildings themselves, we can draw today the digital map of our cities, or in other words, a representation of the extent to which technology is reporting the built environment to the end user.



"Space as a Service"

Finally, data can empower new business models such as Space as a Service (SaaS), by connecting available spaces in city centers, with a real-time demand.

In clear, Space as a Service defines the rise of a new business model in both retail and office space rental. Large company such as WeWork or Breather lease large amount of space in city centers, and then sublet portions, from a single sit to an entire floor to individual or companies, from a day to an entire year of sublease. The reduced liability for the sub letter, and the flexibility of engagement for the user is a plus, and turned into premium built in the rental fee. Overall companies practicing SaaS are proved to be very profitable as their price per square foot is above market average, and their space usage efficiency is greater than standards in the industry. From a single month down to an hour, might it be a retail, an office, an apartment, or even a storage space, every program seems to fall under the umbrella of SaaS. New York has been the incubator for such business models, and hosts today the greatest variety and density of such SaaS businesses. Office spaces can be rented at WeWork, or Breather, flexible housing rental can be found at WeLive or AirBnB, storage spaces are offered by company like CubeSmart, and retail or exhibition spaces can be rented on Storefront's website. If few companies have been able to consolidate like WeWork, the overall growth in this sector remains bewildering.

The map here on the left exemplifies the dissemination of SaaS businesses across Manhattan. None of these were present 10 years ago!

Bitsense Dashboard — Operation Tracking

New infrastructures

More insights are simply more reasons for achieving flexibility, but they do not bring a functional answer to buildings' plasticity. Far from the failed attempt of the Japanese Metabolist movement, the construction industry is still after a system that could handle the stringent requirements of true space flexibility. Recent innovations and building technologies are forecasting new possibilities, and potentially could enable a real building metabolism.

Digital and Facility Management

The quantity and quality of insights that data aggregation and analyses can offer will benefit building operation and maintenance. Aside from the designer, further down the chain, facility managers (FM) will be able to leverage what technology is bringing today to building management. First in terms of hardware: thanks to cheaper and more accurate sensors, data collection will be much easier, and offer more in-depth insight for FM to use. Space utilization efficiency, head counts, traffic estimation, thermal comfort, peak hour analysis: all these are metrics occasionally measured by FM, that could be obtained more frequently and precisely thanks to sensor technologies. A company like Bitsense, specializes on the collection of such metrics, and offers us a deep dive in the world of utilization data collection. By placing a couple of sensors in a given building, Bitsense **(13)** is able to recreate a time-based map of the building's traffic throughout time. The screenshots here above display the resulting analytics produced.

Bitsense, https://www.bitsence.io/ ▶

Then in terms of software, the power of data analytics (machine learning, and predictive modeling) will help analyze current needs of the program, and even forecast future prospects or issues that could arise. The example of WeWork is striking: after having collected the space utilization log of their users, WeWork uses machine learning to predict future space usage, in order to provide the right mix of private offices versus meeting rooms across its open spaces. After using both a team of architects to determine the mix, and the algorithm, it turns out that the space utilization is 40% higher while using the algorithms prediction, rather than the architects' solution. Far from claiming to replace the architects by a software, WeWork claims to be able to enhance design solutions by serving their machine learning solution to their designer team, as an additional source of insight **(14)**.

Designing with Machine Learning, https://www.wework.com/blog/posts/designing-with-machine-learning ▶

Semi-Automation

To enable faster response time to such insights, FM will heavily benefit from semi-automation. Far from the dystopia of full-robotic automation, semi-automation offers to embed motors and robotic devices in building elements and appliances, to simplify and speed up space layout and modification. From automatic furniture trolleys, to moving units, and automatic foldable furniture, FM can remove the hurdle of physical work to ease up and speed-up space layout.

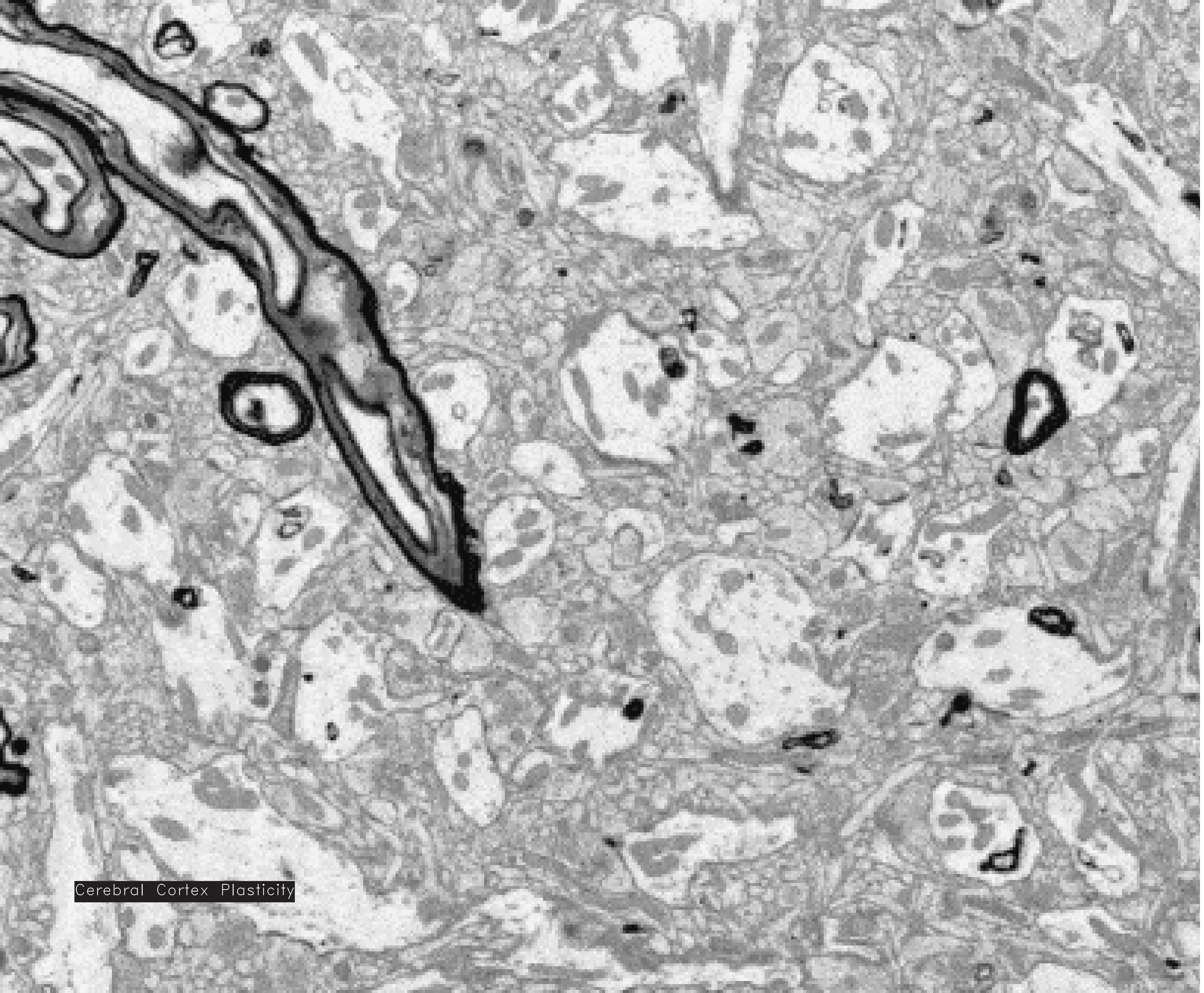
From space layout to warehouse storage, there might be just one step. Amazon recently announced their 45.000th robot across their entire warehouse infrastructure. The example is here striking: robots are used to move around shelves units, as workers check the inventory of each shelf, and track packages.

As Marc Onetto, Amazon Senior Vice President of Worldwide Operations, explains the goal of their warehouse strategy is to automate the basics of the job:

"Autonomation helps human beings perform tasks in a defect-free and safe way by only automating the basic, repetitive, low-value steps in a process." **(15)**

When Toyota met e-Commerce, McKinsey Operations, https://www.mckinsey.com/business-functions/operations/our-insights/when-toyota-met-e-commerce-lean-at-amazon#0

And if FM is seen as a pure logistical challenge, then Amazon certainly could represent a best practice. As spaces are called to be more flexible and remodeled more often, the challenge for facility managers will be to deal with faster space layout cycles. Semi-automation could support such a challenge, and enable FM to deliver more value, at accessible prices.



Cerebral Cortex Plasticity

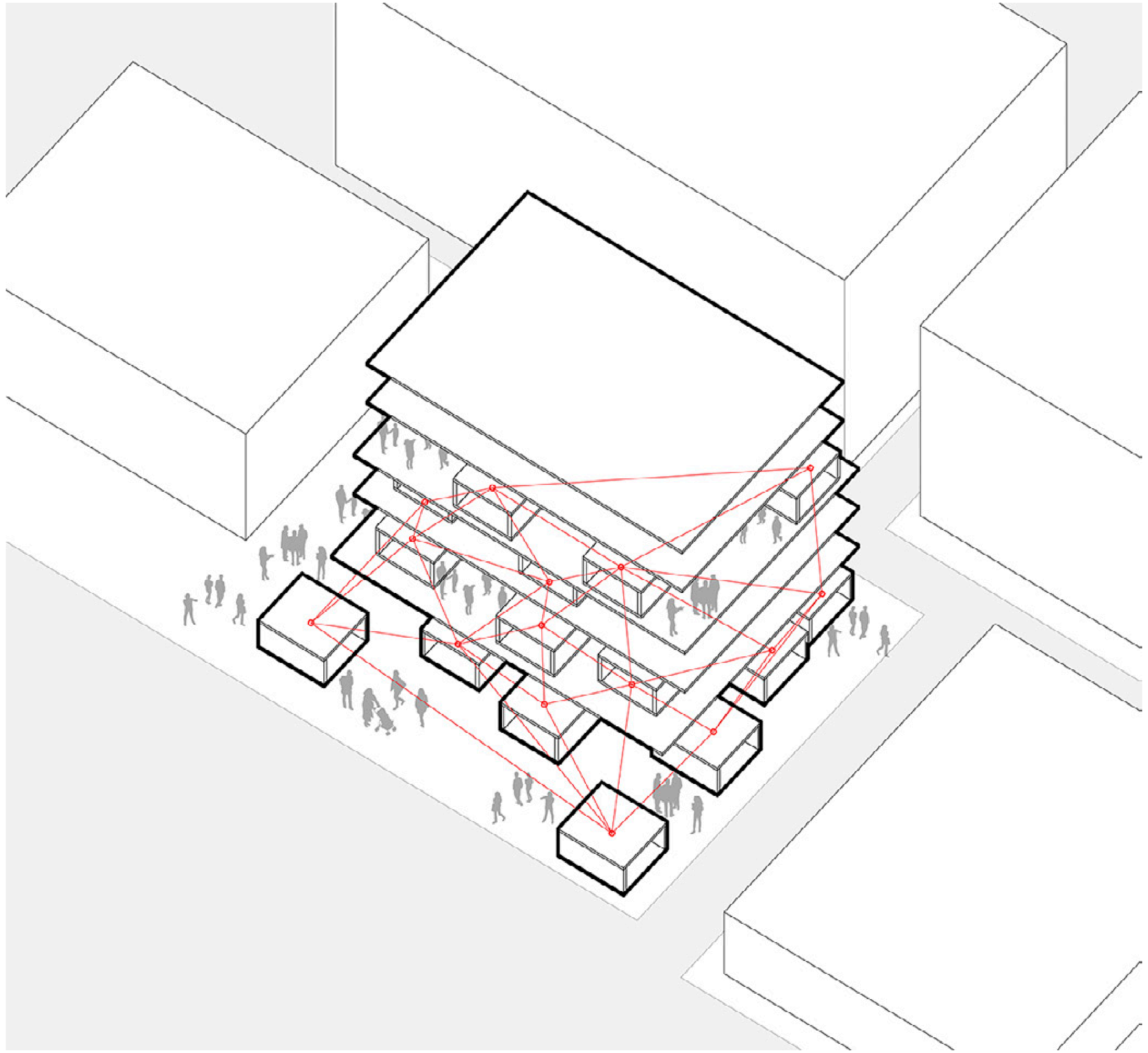
III - The Synaptic Building: Metabolism in the 21st Century

Our proposal is to offer a new prototype for a truly flexible building scheme, that embraces societies' expectations, and leverages technology's disruptive potential. More than a mere design exercise, it is a manifesto.

A- The Neural Network

The human neural network is at the center of current scientific explorations. Its structure, both flexible and malleable, fascinates the scientific community: encompassing the simple action/reaction paradigm, the neurons can adapt to short term stimulus and long-term memory to layout a network of complex interactions. At the center of this biological phenomenon is the rich architecture of each single neurons, its ability to process information, as well as its capacity to work in a system to shape our cortex, over time.

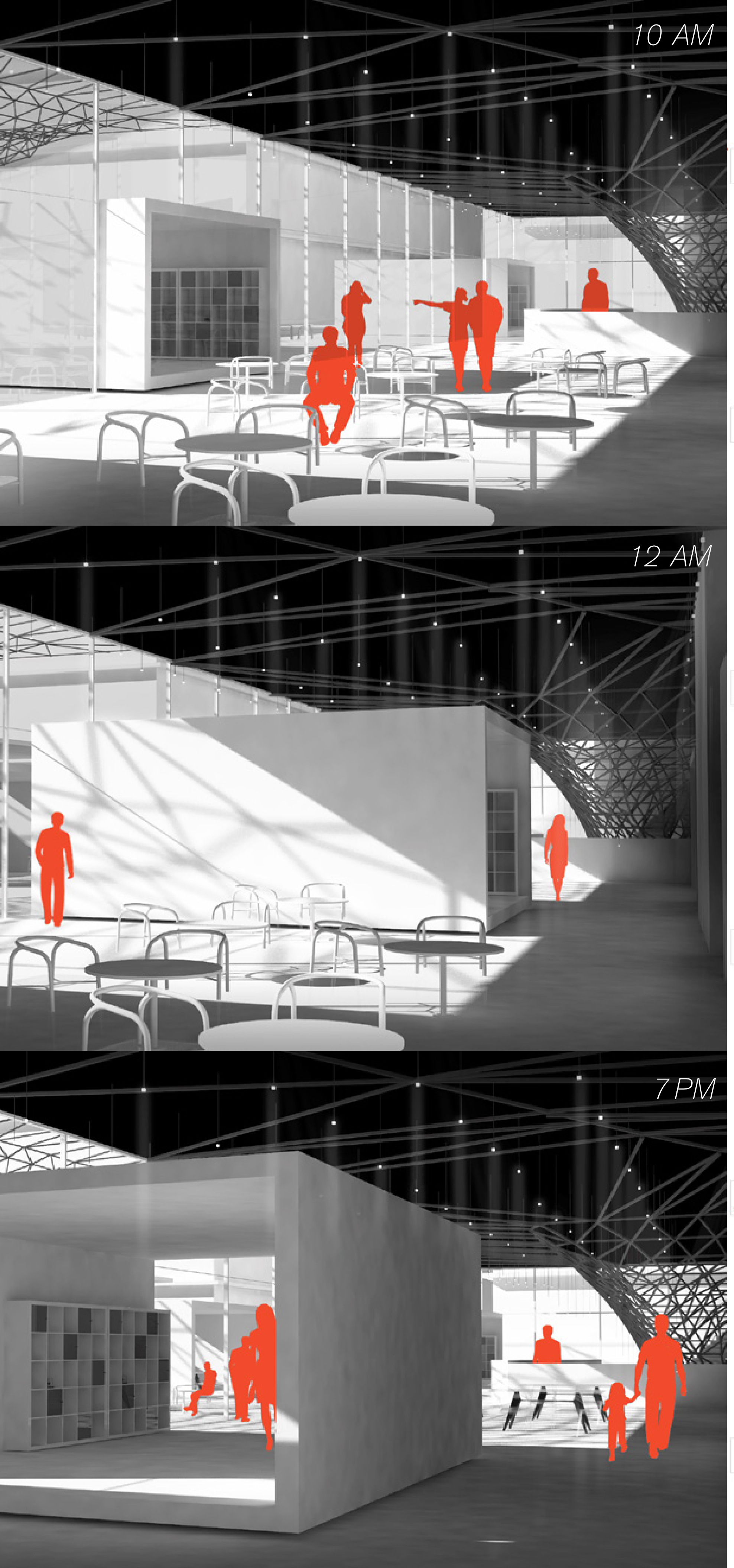
The Synaptic Building offers a new definition of our built environment, as a synaptic network, mirroring the principles the human neural network. The same way our cortex performs through the action of individual neurons, a building can be rationalized to a set of connected "units" (elementary cells of activity, ie a retail, an office, a kitchen), that migrate and evolve across the building floors. A new usage implies a new space layout, a new space layout triggers a new set of performance, new performances inform the space layout.

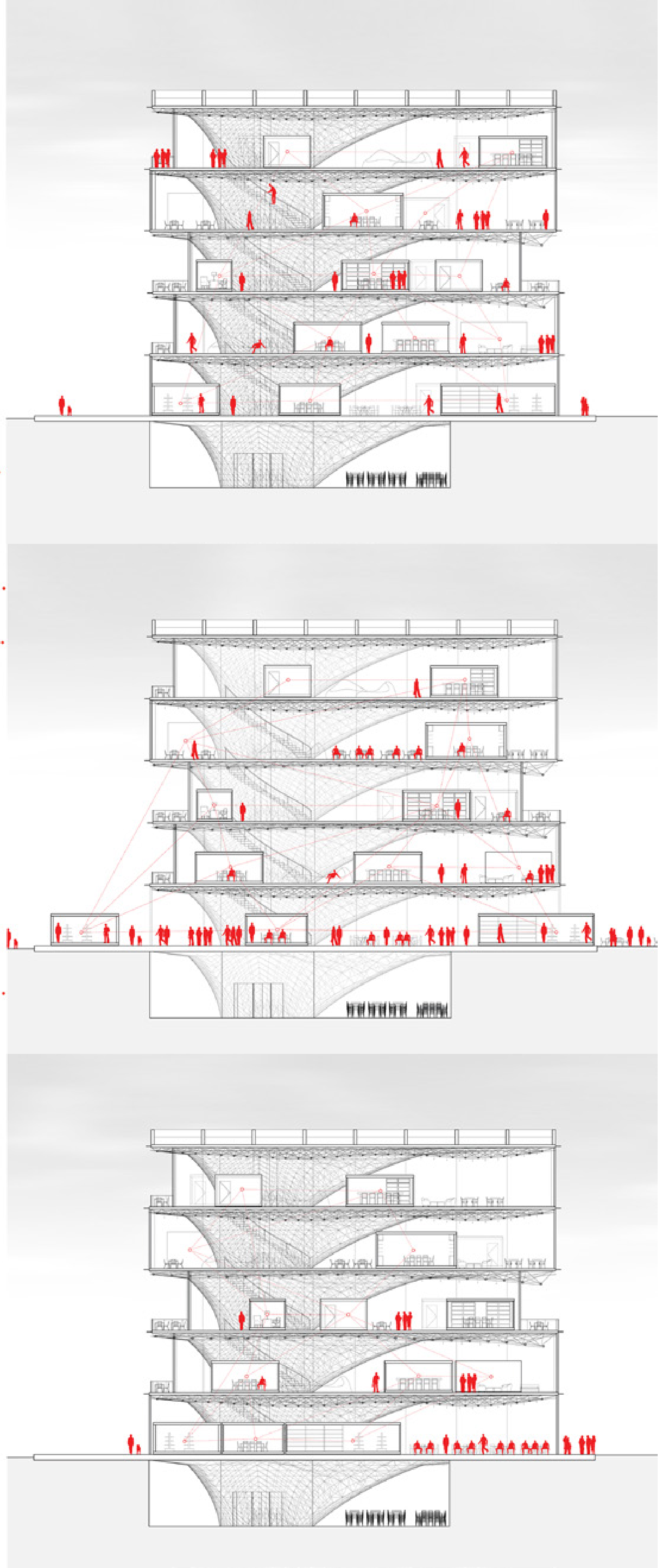


B- The Synaptic Building

The Synaptic Building typically would be at first 5 to 6 storey-high. Additional floors could be added later, allowing for vertical growth of the building. The structure, made of large steel vaults, is reduced to a minimal impact in the plan, and merged with the vertical circulation. A series of LED lightings are spread across the ceiling and offer entirely controllable lighting conditions across each floor.

From retail and restaurant at the ground floor to co-working spaces on the upper floors, each plate is radical free plan: few structural constraint, minimal impact of the vertical circulation, adaptable lighting. Within these conditions, the "units", or "cells" hosting the program are spread out in the space. Being either retails or restaurants on the ground floor, private offices or meeting spaces at the upper floor, these cells can move "semi-automatically" thanks to motors is their lower plate. During the day the units can be easily moved around, folded to be stored, while automatic trolleys help the FM layout furniture once the units are placed.





A Typical Day, lifecycle in the Synaptic Building, https://www.youtube.com/watch?v=iF3sos6KOXA&feature=you-tu.be ▶

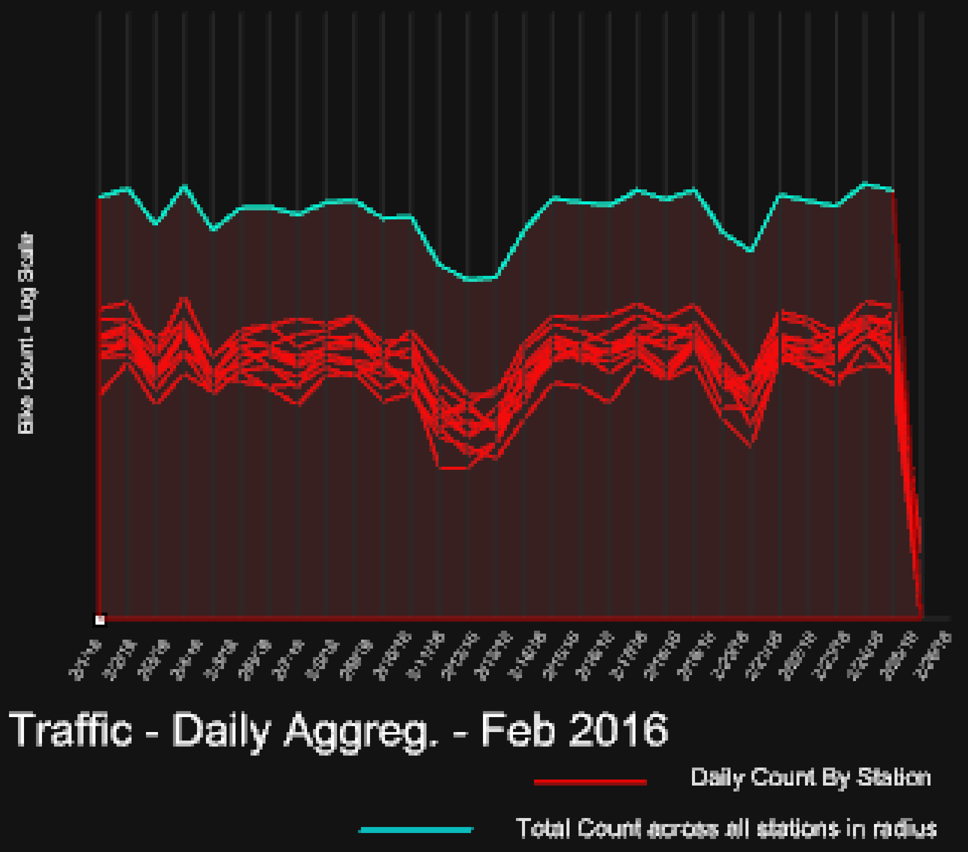
A Typical Day

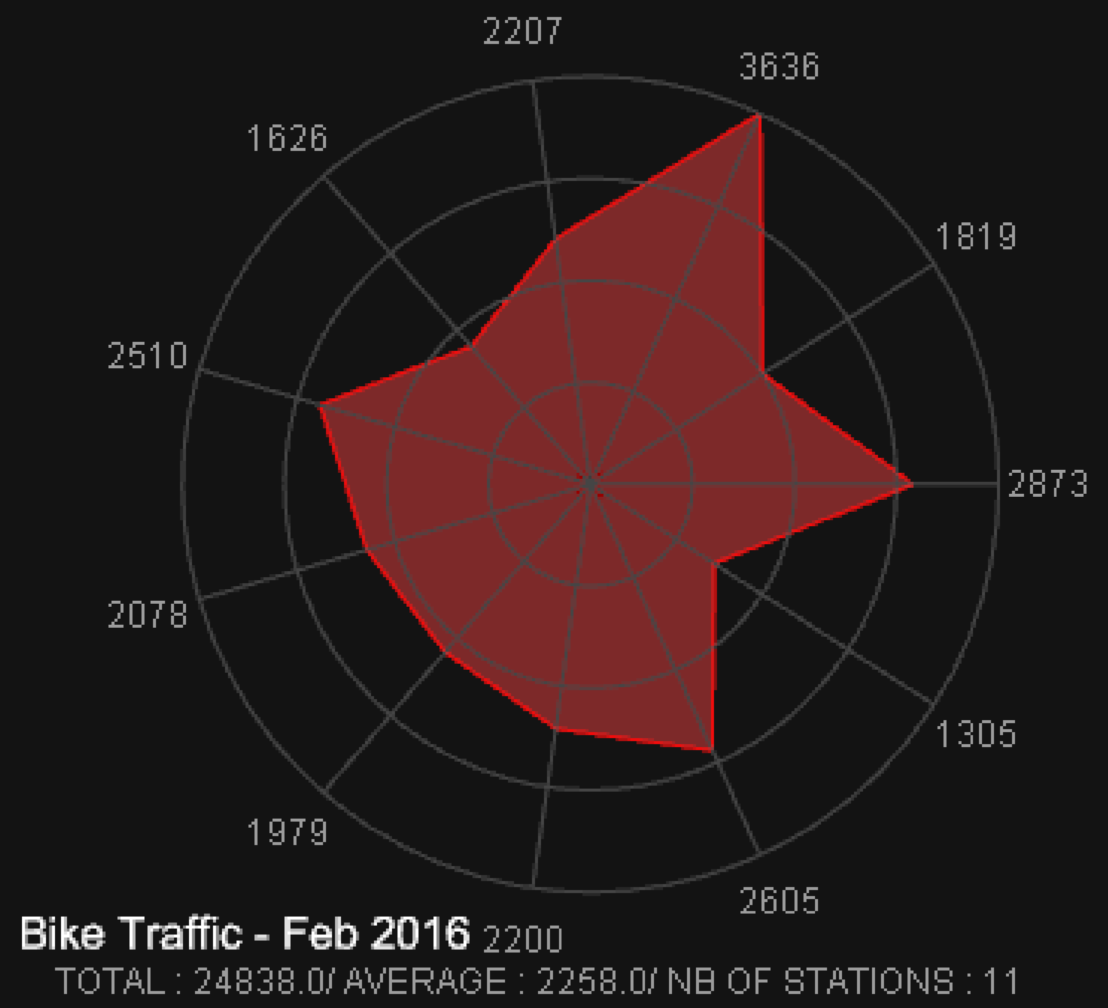
During a normal day, the building goes through a series of stages, each one corresponding to a certain layout in the space of both units and furniture, accompany by specific lighting conditions. This “choreography”, or metabolism is the daily activity of the building. **(16)**

10 AM As workers arrive and visitors come to the shops, the units are laid out in a grid like structure, to offer a simplicity of circulation, and optimize space usage. At the upper floors, in the co-working spaces: individual working spaces are located at the periphery, common working areas are pushed toward the center, while the kitchen and recreational spaces are secluded to the center of the plan, and under their most compact form.

12 AM As workers arrive and visitors come to the shops, the units are laid out in a grid like structure, to offer a simplicity of circulation, and optimize space usage. At the upper floors, in the co-working spaces: individual working spaces are located at the periphery, common working areas are pushed toward the center, while the kitchen and recreational spaces are secluded to the center of the plan, and under their most compact form.

7 PM Finally, at 7pm as the activity in the building decreases, and the retails close, the retail units are packed together, offering space for large restaurants. The deemed light of the LED ceiling offers a perfect atmosphere to welcome people throughout the evening.



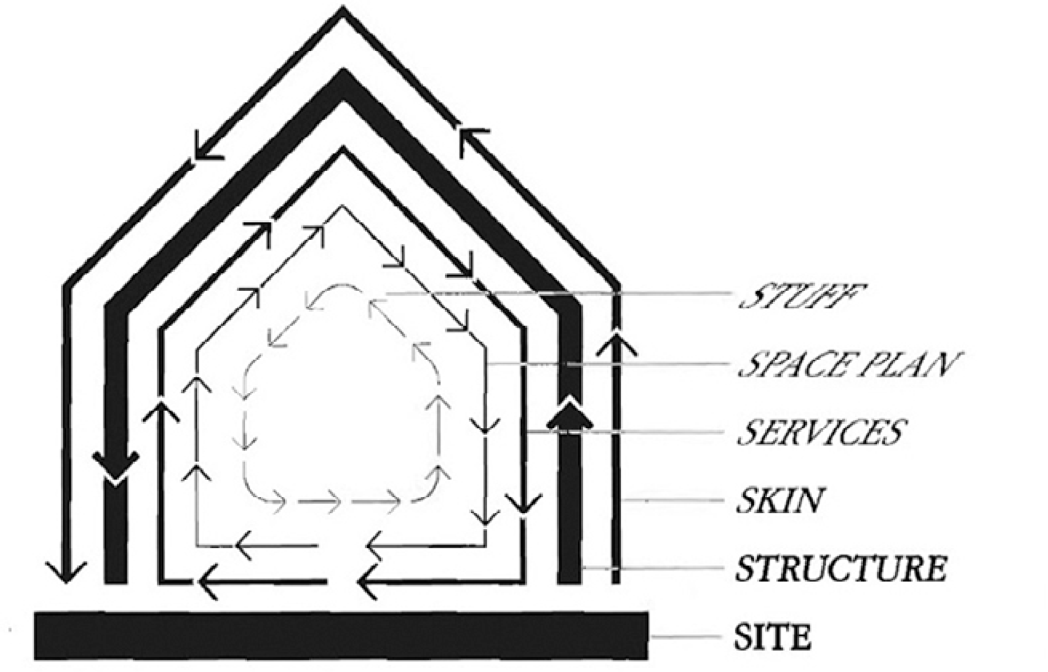


C- Informed Plasticity

As opposed to the Metabolists, who did not truly foresee what would trigger their buildings' evolution, the flexibility claimed here is informed, stemming from the collection and analysis of occupancy data collected all along the year.

At a short-term perspective, this choreography is controlled by the FM and the occupants. Every day, data on users is gathered by sensors and fed back to the system. Users can also give feedbacks online and control partially the building settings (local lightning condition, heating, furniture layout), to better fit their immediate needs. In the meantime, the FM runs the building thanks to a schedule than he can adapt based on short term efficiency metrics built with data collected daily, and users' feedbacks.

In the long run, a hybrid team of data scientists and designers work on optimizing the building's "choreography". Using monthly aggregated contextual and indoor data, they isolate usage trends, predict the future building's needs, and users' behavior. Using these outputs, future space layouts are defined, and turned into space management schedules.



SHEARING LAYERS OF CHANGE. Because of the different rates of change of its components, a building is always tearing itself apart.

Shearing Layers Diagram | Stewart Brand

D- Flexibility and Permanence

As Franck Duffy, a British architect and founder of the DEGW, rightly explains:

> *"Our basic argument is that there isn't any such thing as a building. A building properly conceived is several layers of longevity of built components."*

Stewart Brand in his book, How Buildings Learn: What Happens After They're Built, proposes a diagram to sum up Duffy's vision: Shearing Layers of Change.

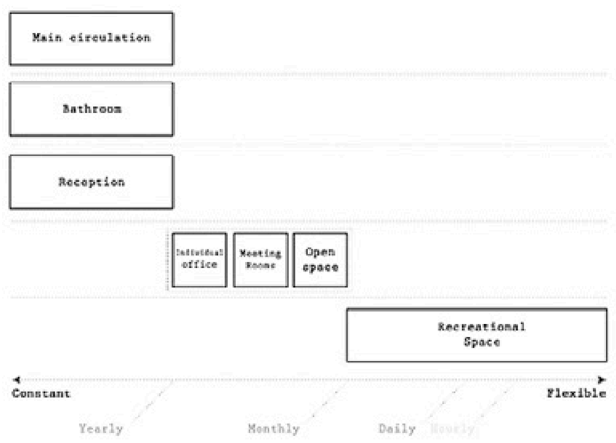
His vision is clear: buildings are living organism that adapt, evolve and change. More precisely, Brand isolates the "shearing layers", and groups them into batches of elements: Stuff, Space Plan, Services, Skin, Structure, Site. Each group has its own lifecycle, constraints, properties and should be treated as such. If the 21-st century might be the place and time for true space flexibility, achieving such a challenge translates into activating each layer of Brand's diagram. For any given type of program, understanding the extent of each layer's flexibility, while insuring the overall consistence of the building's metabolism is crucial.

Fixed Structure & Skin

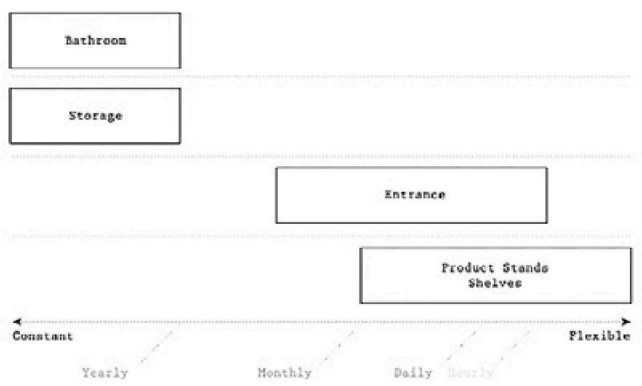
Overall the units are freed from the structure. No relationship of interdependence between the two systems exist, preventing the building from making the mistake of the Nagakin Tower: laying out the units, and moving them around is strictly independent from any structural concern.

Secondly, flexibility as understood here does not concern the structure or the skin of the building. If maintenance is required for these two layers, they are not concerned by the type of space plasticity we want to address. Services, as defined by Brand all the networks and wiring of the building. They support the program, and insurance its viability. For both reasons of costs, and practicality, Services should not be adapted constantly like the program, but rather should be disseminated evenly to be able to support any kind of space layout. Its flexibility is measured by its evenness of distribution across floors and ceilings (HVAC, outlets, lighting, etc).

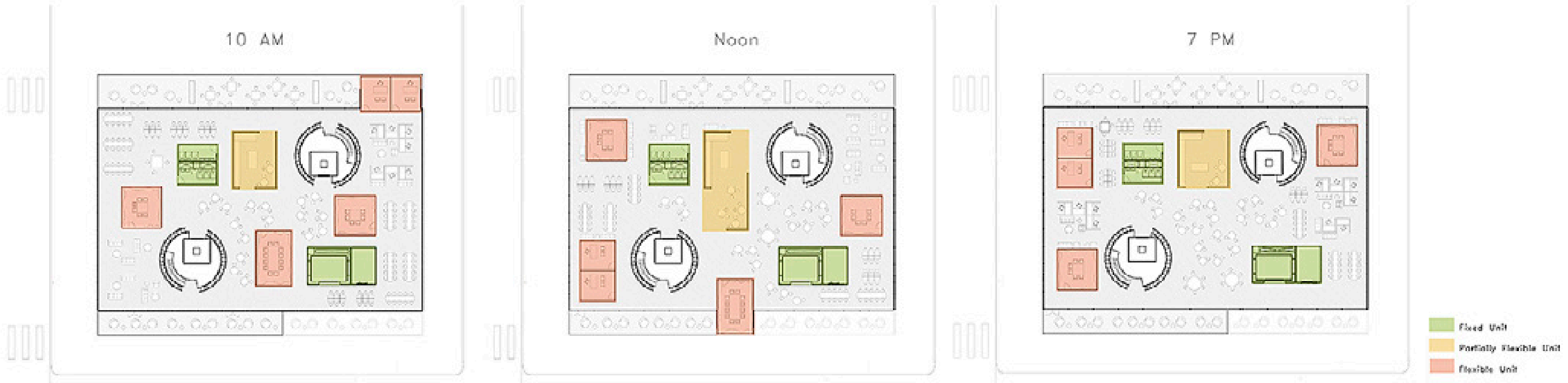
Space plan and Stuff are truly the two layers at stake in the Synaptic building.



Office Flexibility



Retail Flexibility



Flexibility Gradient

Space Plan

Space Plan would correspond to the layout of the units. Flexibility is here central, but should be modulated depending on the program, and the function being considered. Total space plasticity is limited both technically (Services-dependent units), in terms of users' comfort, and by programmatic needs.

Services-dependent units like bathrooms or kitchen that need constant access to water pipes, are necessarily fixed in space. As permanent element, they also represent common places, that act as landmarks for the community of users.

Similarly, certain spaces can be fixed in space to respect users' habits. Private offices for instances, are likely to be permanently assigned to an area, to keep users' familiar with their working environment.

Finally diving deeper into programmatic needs, we notice that retails or offices can allow for diverse levels of flexibility across their program. The graph here on the left, attempts at classifying common spaces in the retail and office world along a flexibility gradient.

Within the Synaptic Building, we therefore manage to curate different level of flexibility, to balance space plasticity and permanence across the building. The plans here on the left illustrate the variety of flexibility type across a given floor plate of office spaces.

Stuff and Semi Automation

As the unit move, so should the furniture. Chairs, desks, couches and arm chairs follow the cycle of the moving units, and are laid out to "fill" units and gaps between them, therefore defining space's functions. The increase cycle speed can be handled by the FM thanks to foldable furniture, and semi-automated furniture trolleys, that ease-up the physical work. All, as described before, units carry robotic motors in their lower plate, and can therefore be moved around faster and easier than traditional partitions.

IV - Conclusion

A synaptic built environment is not the mere reflection of current trends, but a radical proposal for the future of cities, grounded in long term societal and technological changes.

First of all, our proposal addresses the demographic shift of our century. The accelerating densification of urban centers is increasing real estate prices, putting pressure on rental markets. This reality, correlated to the space utilization inefficiency of current buildings, makes the synaptic definition more relevant than ever.

Then, the state of technological innovation enables us to achieve true flexibility. On the construction and operation side, modularity and semi-automation enable the production of low-cost mass-produced buildings, and their operation at always more competitive costs.

Also, from an information standpoint, the availability and aggregation of spatial-data allows stakeholders to understand and predict users' activity in buildings at more granular level; a brand-new opportunity to eventually inform space's design, and remodeling.

Finally, and maybe more fundamentally, the true disruption at stake in the Synaptic Building, is the birth of new field: time-based building design. Aside from the pure constructive reality of a building, the architect is today invited to understand, predict and eventually design the activities the program is expected to host. By working within a hybrid team of sociologists, anthropologists and data scientists, architects will soon have to surpass their current set of skills: they will have to understand the future users' behavioral patterns and cycles to finally adapt their building conception accordingly. In other words, rather than delivering a building as a finished product, the architect will have to define the ongoing choreography of each floor plate over time, and assist the owner to define the future of his building metabolism.

From the form to the function, it is a quantum leap for the profession of architecture that turns upside down the definition of space design, and redefine the very essence of the profession.

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