The Future of Warehouses

by
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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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ABSTRACT

The focus of this research is on the future of warehouses and how they could adapt to the needs and necessities of the 4th Industrial Revolution. The fact is that new technological achievements in digital and smart production, robotics, 3D printing, IoT, artificial intelligence (AI), deep learning and so on, are changing the world, and architecture is not an exception. Here the question is, how fourth industrial revolution is going to re-shape the future of warehouses, what is the scope of the changes and what are the repercussions. There are various references for automation and other technological advancements for warehouses, but spatial and operational impacts have not been addressed as much.

The Idea of Online shopping is getting more and more common all around the world, adding more convenience to people's lifestyles through the ease of access to goods via various platforms, a wide variety of products to choose from, easy payment and fast delivery, and so on. Companies providing such facilities need different types of buildings to operate, partly administrative for their offices and partly warehouse where they deal with actual products to store, process, and deliver to the costumers. This research intends to focus on the operational as well as the spatial qualities of warehouses and scenarios for their future developments. The standard "operations" that exist in the current warehouses include loading and unloading goods, storage, shelving and collecting products, labeling, packaging, and delivery, with some few administrative works needed to be done in parallel. This reflects an economic model in which goods are all produced somewhere else, imported and stored in the warehouse in bulks, packaged and delivered to costumers. What we expect in the near future, impacted by the fourth industrial revolution, would challenge this current model to shift from mass-production/ storage towards the on-demand production of goods. Various parallel technologies like IoT, 3D printing, digital fabrication, and so on, will help to accomplish that. In that scenario, operations in a warehouse could go beyond the current storage-only model and include actions such as on-demand printing and binding, on-demand 3D printing and preparing parts, partial to full assembly of products, and more. This future scenario will change the employees from low-skilled workers to the variety of professions needed to work together to run such facilities. In order to fulfill all those tasks and engage all different types of professionals, future warehouses should be redefined, include additional spaces for (at least partial) production and assembly, design, prototyping or brainstorming, and many more. Future warehouses should consider recycling materials and be responsible for the entire material cycle of their products. These are going to change the operational and functional aspects of future warehouses, being addressed, and experimented in this thesis.

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DEDICATION

... to all birds, to fly freely in the blue sky

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Chapter ONE

Introduction

1.1. Thesis Statement

The notion of Online shopping is getting more and more common all around the world, adding more convenience to people's lifestyles through the ease of access to goods via various platforms, a wide variety of products to choose from, easy payment and fast delivery, and so on. Companies are providing such facilities that are operating from a global scale (like Amazon) to local ones (like Carousel), some providing multiple categories of products, and others on a particular category like fashion and clothing. These companies need different types of buildings to operate, partly administrative for their offices and partly warehouse where they deal with actual products to store, process, and deliver to the costumers. As we have loads of research dedicated to residential and office buildings to improve their spatial qualities, warehouses need more research to improve and update their qualities based on modern needs and make them ready to face future changes. This research intends to focus on the operational as well as the spatial qualities of warehouses and scenarios for their future developments.

The term "warehouse" is defined as a place to store goods. These buildings are considered as industrial building types, and they are mostly located on the outskirts of cities. They are usually large flat buildings where goods can be stored for import and export, for packaging and delivery to costumers, and so on[1]. The standard "operations" that exist in the current warehouses include loading and unloading goods, storage, shelving and collecting products, labeling, packaging, and delivery, with some few administrative works needed to be done in parallel[2]. This reflects an economic model in which goods are all produced somewhere else, imported and stored in the warehouse in bulk, packaged, and delivered to costumers individually. Such operations should be done mainly by low-skilled workers who are just doing single actions like shelving. The model existed from the historical time of the trade, but more recently reflects the idea of mass-production of goods, storing and distributing them. This model was acceptable until now where we lived in the age of the third industrial revolution. However, what we expect in the near future, which is called the fourth industrial revolution, would challenge this currently accepted model[3]. The idea is to shift from mass-production towards the on-demand production of goods as much as possible, and various parallel technologies like IoT, 3D printing, digital fabrication, and so on, will help accomplish that. In that scenario, operations in a warehouse could go beyond the current storage-only model and include actions such as on-demand printing and binding, on-demand 3D printing and preparing parts, partial to full assembly, and more. This future scenario will change the employees from being only low-skilled workers to the variety of skills needed to work together to run such facilities that are no longer for storage-only, but production to some degrees. This is where we believe that the design scenarios of the future warehouses should be different.

In order to fulfill the operations discussed, future warehouses should include spaces for production and assembly. They may have spaces for some minor design, prototyping, or even brainstorming activities too. These types of spaces should be embedded in the program of such facilities. It should be noticed that the employees, who spend days and nights working in such facilities, are people with multiple skills and talents and this encourages us to put more energy and effort to understand the spatial qualities of such spaces and address them through design investigations. This should involve, but not be limited to, their social interactions, entertainment and refreshment, and even possibilities for training and personal improvements. Such spatial qualities are not just improving welfare for the employees, but also playing a role in this shift of operations.

One may argue that a warehouse may not necessarily serve as a production platform and the whole idea of the fourth industrial revolution still needs to be further developed. The answer is 'True, but isn't it better to be prepared?'. The purpose of the research is to investigate scenarios, address possibilities and shortcomings, and provide solutions as much as possible. The minimum outcome of this research

could be better spatial qualities for warehouses but at its best, it may offer new operational/functional scenarios for the future of warehouses, reflecting the changes happening in the near future economies and societies.

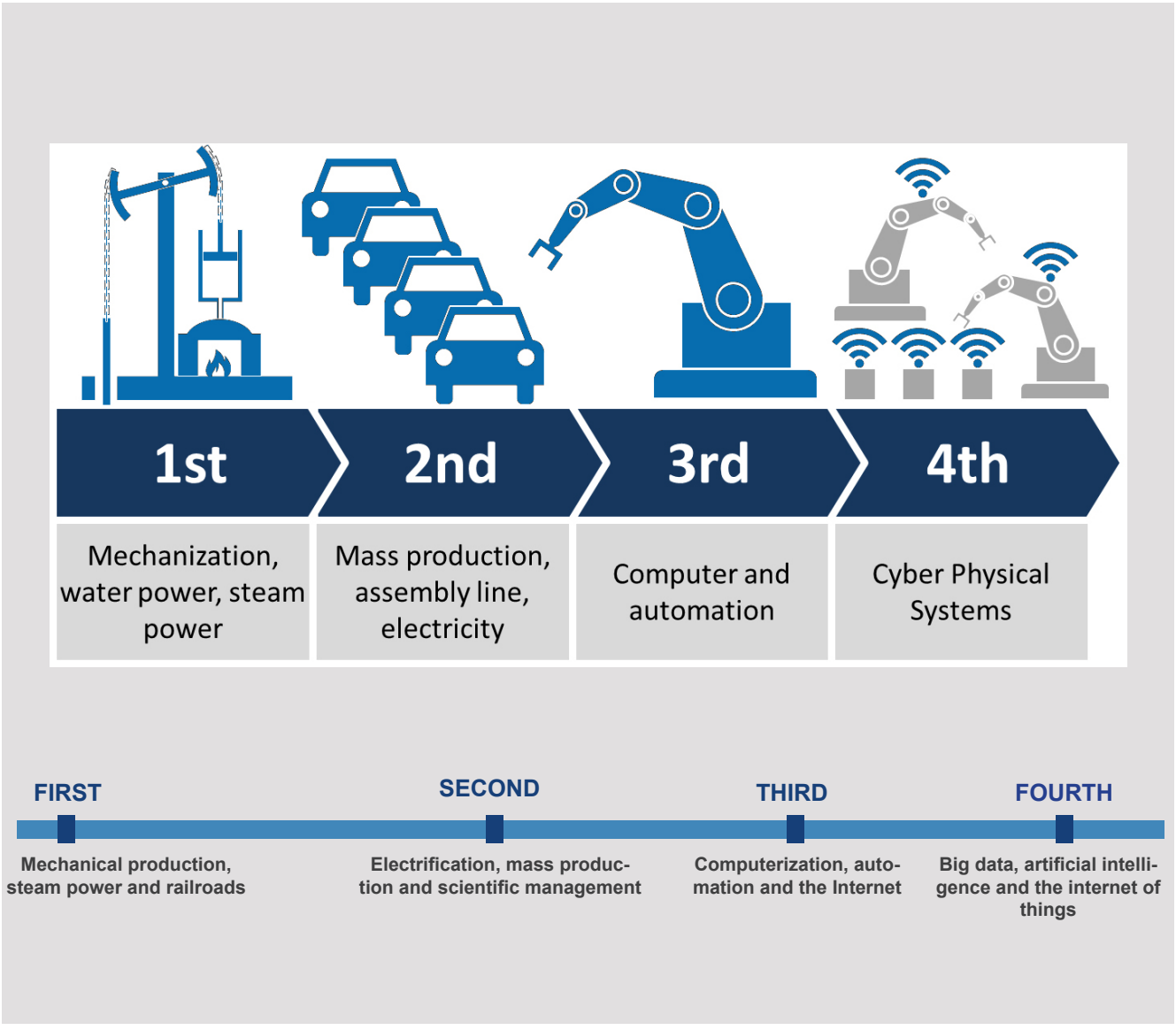

Fig. 1. Industrial revolutions

1.2. Why a Warehouse

Amazon established a new fulfillment center in Ottawa, ON, in 2019, with the surface area more than one million sq.ft[4]. They have another fulfillment center in Scarborough, to be completed by 2020, also more than one million sq.ft[5]. In Québec, IKEA is completing a 1.2 million sq.ft distribution center for 2020[6], while only a few years ago, in 2007, Canadian Tire opened a 1.6 million sq.ft distribution center[7]. These are just a few examples of very large warehouses which have been developed in Canada and the number is not limited to those. Looking at the quantity of new such spaces that are erecting, and the scale of each, ensures us that despite the fact that we do not have much studies and information about the architecture of warehouses, these are essential topics for exploration. Especially it becomes more important as we keep witnessing the global trend of using Online shopping which means less urban retail and more warehouse spaces to stock and prepares such orders. However, when we are looking at this expansion and growth in numbers, we are still undermining the importance of such spaces in architecture research and studies. Searching library catalog and Online databases, we find less information and written work about such spaces. The fact is that most of the industrial buildings are considered as prototypes, being copied and repeated here and there. Besides some standards and structural design of columns and roofs, we do not see enough studies compared to cultural, residential, and other types of buildings.

Fig. 2. Warehouse in a supply chain

The reason that warehouse spaces have not been a hot topic for architectural studies might be that these spaces used to be very simple. With the straightforward spatial arrangement and a simple program, their design should not be a complex one. Adding the fact that they are located outside urban areas, their formal repertoire and aesthetics are not very critical ones compared to other typologies of urban architecture. However, the story is not the same anymore. The scale of such buildings is growing, and the facilities and technologies incorporated in them are getting more extensive and complex. The operations are expanding from simple storage to multiple steps of automated storage and pick-up, order processing, packaging, delivery, and each, using various technologies, robotics, data structures, warehouse management systems, etc. All these new expansions prove that modern warehouse spaces should be more scrutinized in detail and from different aspects. This research aims to study warehouses from their operational point of view, though there are other different aspects to be studied in future researches.

1.3. Methodology

In order to address the research problem, some necessary information about warehouses should be gathered and concepts and ideas should be extracted from that information. The best way to collect information is a literature review and studies on precedents: studying different types of warehouses, their evolution through time, and their contemporary standards and technologies. A literature review will help to shape a body of information about the subject. It is essential to notice that this research is trying to investigate the impact of the fourth industrial revolution on the formation of future warehouses, so external sources of literature on this topic should also be encountered. In addition, some studies on the development of digital and communication technologies and their impact on everyday life and work, and the future of work are some of the main topics that should be covered.

While the information gathered, the next step is mainly analysis of the information, categorization of data, and connecting bits of non-related items in new forms of relations. This part will be done through tables, drawings, diagrams, and charts. The generation of these documents will help to convert the information gathered in the first part into concepts and ideas which can be later used as programs, operations, and other spatial standards that should be used for design purposes. Finally, this research will try to examine these concepts in a design scenario to showcase the outcome of the research in diagrams, drawings, and models for better communication of the ideas.

1.3.1. Selection of Precedents for Studies

Among different types of warehouses available worldwide, there are two types that are more relevant to the studies of this thesis. The first type of precedent we study is Amazon fulfillment centers. These are the best examples of logistics with high-speed operations in which seconds are matter. Some of the new spaces are very large, more than 1 million square feet, meaning that such fast operations are becoming even more complicated. Putting together so many orders on a daily basis and preparing them for delivery is a rigorous task that Amazon managed to achieve it in its fulfillment centers. Their warehouses are equipped with various storage and goods handling mechanisms that are very efficient, and robotic devices are adding more functionality to those facilities these days. The factor that puts Amazon in our first priority for studies is its integration with information technologies. In fact, Amazon represents a modern-day retail store in a different format. That is why Amazon warehouses are an interesting topic for our thesis.

Another type of warehouse which is interesting for us is IKEA. An IKEA warehouse is actually a combination of a showroom, a market-hall, a food-court, and a storage space, representing a megastore in the concept of a warehouse. We wanted to contrast this model with that of the Amazon to see how different each one of them work and what are the concepts behind each model. The fact that IKEA lets the costumers be involved in the warehouse spaces is the point that makes it a good catch for this study to be contrasted with the Amazon model.

All in all, with studies and analysis of these two types of warehouses, we try to understand some of the important concepts in the design and operation of modern-day warehouses. The understandings will inform the design section to reflect the design, programming, and spatial qualities of such successful models.

Fig. 3. Online shopping process

1.4. Defining the Literature for Review

The topic of this research, the future of warehouses, connects two different realms. The first important area to study is warehouses, their role in our cities, their typologies, operations, and programs, as well as their facilities, and other technical matters that relate to the topic. This field of study will inform the design of the qualities of such spaces and defines the ground on which the design should be set up. The other realm that this thesis needs to cover is about the future of work and the future of production, the fourth industrial revolution, and its effect on the way people will work and live. This part of the study will push the current study models of warehouses towards that of the future and will bring new ideas to be

incorporated into the design of future warehouses. To do this research we need to plan these studies carefully and address the literature that should be covered.

The study of warehouses is not similar to other architecture topics like residential or cultural spaces with the extensive literature. In fact, this topic lacks the available literature and references in the domain of architecture. The reason is that it is mainly covered in engineering domains and logistics. Looking at such domains, one of the good references is by Roy L. Harmon called “Reinventing the Warehouse, world-class distribution logistics” that covers how warehouses and logistics work. Another reference to cover in this section is “Warehouse Management” by Gwynne Richards in which the operations which are happening in a warehouse are described, layouts discussed, and equipment are sited. This is an informative source for the detailing of the programs and facilities for the design. There are other warehouse management and supply chain management references to study but in order to summarize, the “Warehouse Management and Inventory Control” by Philip M. Price and N. J. Harrison, and also “Warehouse management Handbook” by Jim Tompkins are good references to cover up. As the literature regarding the warehouses' architecture is limited, here there are various Online resources that are mainly coming from the companies that build and equip such spaces. There is also an extensive amount of data and criticism about major companies like Amazon, Walmart, Canadian Tire, etc. Their everyday operations need warehouses and as such, the related information is reflected in papers and articles across the web. All in all, related literature is going to be studied and covered in the second chapter, where the topic is about warehouses and their operations. Based on the topic, the resources mentioned above are going to be reviewed.

The next area of knowledge that this research needs to cover is about the future of work, future of production, history of industrial revolutions, and specifically, the fourth industrial revolution. This is where ideas about the changes that should happen to current architecture models like the architecture of the warehouse should be addressed. Studies about the future and how human lives could be affected are enormous, here some of the more relevant resources to the first section of the literature review, which is "warehouse", will be addressed. The first reference for the study in this section is “The Fourth Industrial Revolution” by Klaus Schwab. Klaus is the executive chairman of the World Economic Forum, an NGO where collects political and economic leaders and other global figures every year in order to think about the current and future states of global trade, governance, and more. He is the prominent figure who coined the term fourth industrial revolution and a key to be sited in this field. Ash Amin’s “Post-Fordism: A Reader” is a good reference to state the condition of the society after Fordism and gives an insight into the future as well. “Shaping the Future of the Fourth Industrial Revolution” by Klaus Schwab and Nicholas Davis gives more information about the changes that are going to happen in the future based on new computing technologies, artificial intelligence and robotics, the Internet of things, biotechnology, and more. A good reference to think about the future of work, energy, ecology and more is “Growth: from Microorganisms to Megacities” by Vaclav Smil with a critical view about the topic. Moreover, to summarize this chapter, covering “21 lessons for the 21st Century” by Yuval Noah Harari is an excellent reference to address what humans should be worried about and to consider about the future to come. These studies are going to be reflected in the third chapter of this thesis which is titled Cyber-Physical Societies.

It is clear that other parts of this research need a literature review as well. However, the main two areas to address the questions of this research that are addressed here are going to be shaped in chapters two and three. Alongside reviewing the written documents, there are projects, samples, and precedents that need to be studied and reviewed which are implemented between the two chapters as well. These are examples that are going to illustrate how ideas are being experimented in the real world and what could be learned from them in order to address the design of the project. This includes studies of Amazon Fulfillment centers, Ikea stores, and more. Reviewing literature and precedents, the next would be the design which is coming right afterward in chapter five.

1.5. Thesis Structure

This thesis is comprised of four chapters. The first chapter defines the thesis statement and what we are going to explore in the field of warehouse design and the future of Online retail in the age of the fourth industrial revolution. We are looking at the importance of the topic as well as reviewing some of the literature for understanding and development of the subject.

The second chapter is about warehouses, and basically what a warehouse is. In this chapter, we are looking at the definition of warehouses as well as a brief historical overview, followed by studies of its types. We are looking at warehouse operations to understand the activities happening in a warehouse plus technologies and facilities needed to support such operations. We finish our studies by reviewing two of the important types of warehouses for our study, one is IKEA, and the other is Amazon.

As this research tries to investigate how warehouse spaces should respond to the changes of the modern digital world and the fourth industrial revolution, the third chapter is about this phenomenon after a very brief review of other industrial revolutions. This section will help us to develop our ideas to be further solidified in our design section.

Chapter four is where our studies come together and we reflect our research into the design of a warehouse. This should be represented with proper design documents.

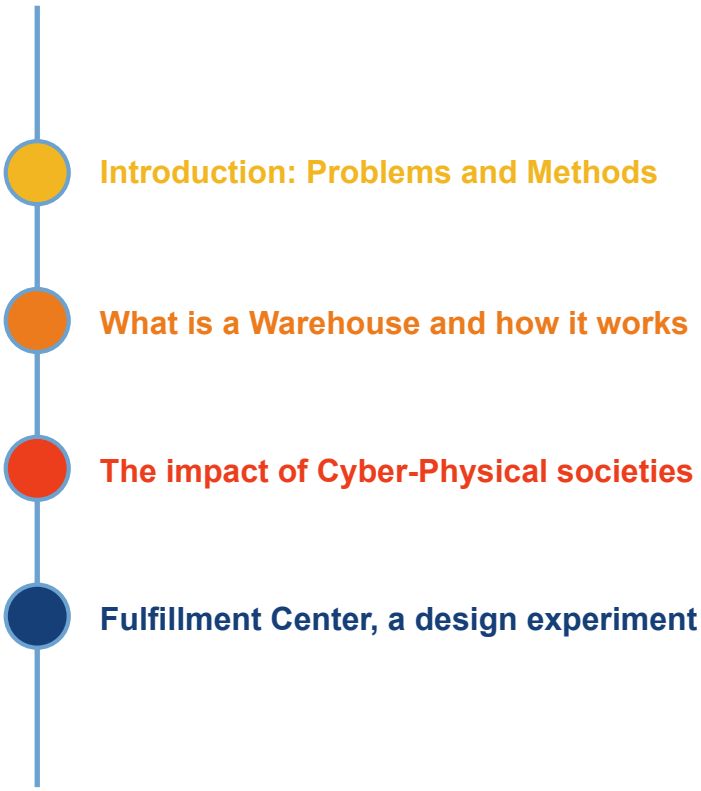

Fig. 4. Thesis structure

Endnotes:

1. “Warehousing and Warehouse Management .” . Published Sep 42020. Accessed Aug 15, 2020. https://www.encyclopedia.com/social-sciences-and-law/economics-business-and-labor/businesses-and-occupations/warehouse.
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Chapter TWO

Warehouse

2.1. What is a Warehouse?

The term ‘warehouse’ is defined as a place/building to store goods. They considered as industrial building types where mostly located in the outskirts of cities, as they should be connected to cities, but also industries and infrastructures, main transportation roots, agricultural lands, and so on[1]. They are usually large flat buildings in which goods can be stored for import and export, packaging and delivery to costumers and so on. The standard ‘operations’ in the current warehouses include loading and unloading goods, storage, shelving and collecting products, sorting, packaging, labeling, and delivery, with administrative and management works needed to be done in parallel[2]. There are various types of warehouses with some differences in their properties and their operations which are going to be addressed later in this chapter[3].

Traditional warehouses are usually large empty buildings for the bulk storage of goods while modern warehouses are equipped with shelves and other modern organization facilities to use the space in its most efficient way. Contemporary warehouses have automated facilities too, letting robots and machines pick and place goods and do other jobs.

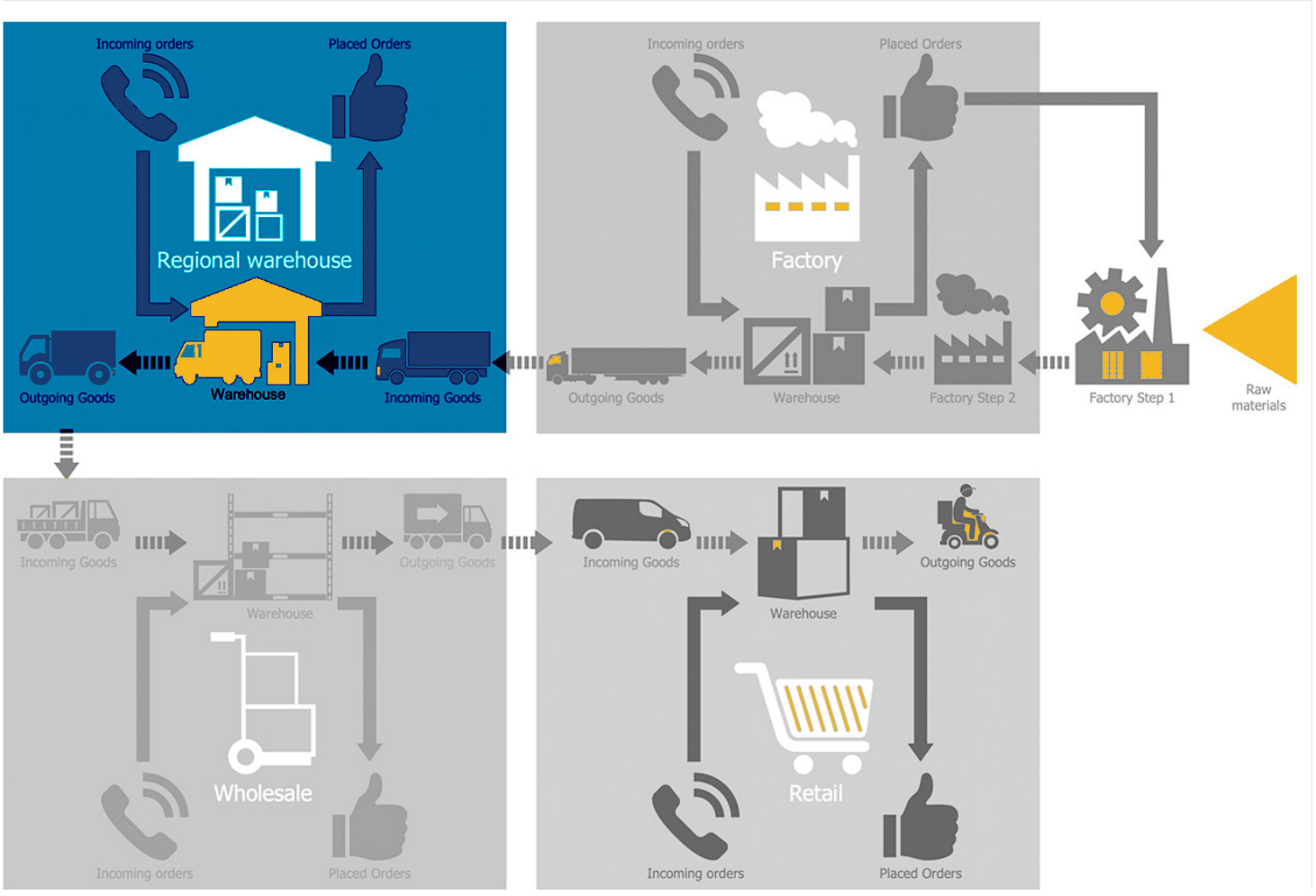


Fig. 5. What is a Warehouse

As warehouses are connected to products and goods, it is clear that they are indirectly connected to the economy as well. What we see in most of the warehouses is a reflection of an economic model in which goods are all produced somewhere else, imported and stored in a warehouse in bulk quantities, to be packaged and delivered to the next parties and customers. As industries are all following the Ford model of mass-production, the large quantities of the manufactured products should be stored somewhere to be further delivered. Any change in this economic model (which is the case happening now), will affect the operations and as such, the spatial qualities of warehouses as well. This would be one of the main areas of concentration in this research.

A traditional warehouse used to have simple operations and mainly by low-skilled workers who were doing single tasks like shelving. Even more contemporary ones are shaped around the idea of the division of the works between single-task workers. This could also be a point of challenge for the future of warehouses which is going to be addressed in this research.

While warehouses seem to be architecturally simple buildings that are mostly large and flat cubes, their internal operations, performances and storage technologies make them complicated topics for design and research. As the economy keeps shifting towards more Online modes, warehouses' use increases and makes them important topics for architectural research.

Fig. 6. Marshall Field Warehouse Store

2.2. A Brief History of Warehouses

Storing goods and especially food goes back to the early historical moments. There is evidence around the world that humans used to store food for the times they had problems finding it. But what we consider as a warehouse is more recent in history. The first evidence of warehouses in history goes back to the European traders and explorers with shipping goods across the world and as such, they started to build warehouses across the ports[4]. This is the first time that goods' transportation was happening on a large scale that needed warehouses to handle shipments. And as this happened by ships, that is why most of the warehouses are located in major ports especially in Europe5. During and after the 18th century and the development of rail transportation and car transportation afterward, more warehouses started to get shape close to the cities. There were terminals in the cities with train access that mainly reflected places with storage facilities for goods with access to wholesale markets.

While warehouses have been developed a lot during the middle ages, it was the second industrial revolution that introduced two important notions to the scene: one was the mass-production of goods and the immediate needs of industries to store goods after production and before distributing them in the market or sending them to the other locations. The second one was the introduction of trucks and then forklift trucks in addition to pallets which together they made it possible to handle and store goods

Fig. 7. 19th-century warehouses in Gloucester docks in the United Kingdom, originally used to store imported corn

on a scale and efficiency never experienced before[6]. This helped to increase the size of warehouses while enjoying the use of steel structures that made it possible to create larger spans for such facilities.

The contemporary warehouse is a combination of the previous version of warehouses with many technological advances for the storage of goods and the addition of data-driven systems to control the stock and even retrieve them automatically. There are various warehouse management systems, online tracking and monitoring systems, automated storage systems and so on which are making warehouses more complicated spaces that need many different partners to be involved in their design, making, and management. One of the more complicated examples could be distribution centers with many systems working simultaneously to provide goods to be delivered to individual customers instead of wholesale and retail stores. There are many more different types of warehouses based on the specific type of goods that they can store (like food) or based on their location (with connection to a specific type of transportation) or based on a special function (like a retail warehouse)[7]. All together, contemporary warehouses are very large facilities that are serving modern cities with millions of citizens with many different needs. Today, there are companies capable of making very large warehouse facilities and others that are producers of different facilities and systems to equip such complex spaces to fulfill the tasks required by our modern societies.

Fig. 8. A Sust, a Middle Ages type of warehouse, in Horgen, Switzerland

Fig. 9. Merchants' Warehouse, Castlefield, Bastin, 1825

Fig. 10. Seventeenth-century warehouses in Amsterdam, Netherlands

Fig. 11. The Pickles Building 101 Portland Street, Manchester

Time-line

This diagram represents a historical overview of warehouses and other related technologies such as transportation, the Internet and so on that are affecting the development of warehouses in history.

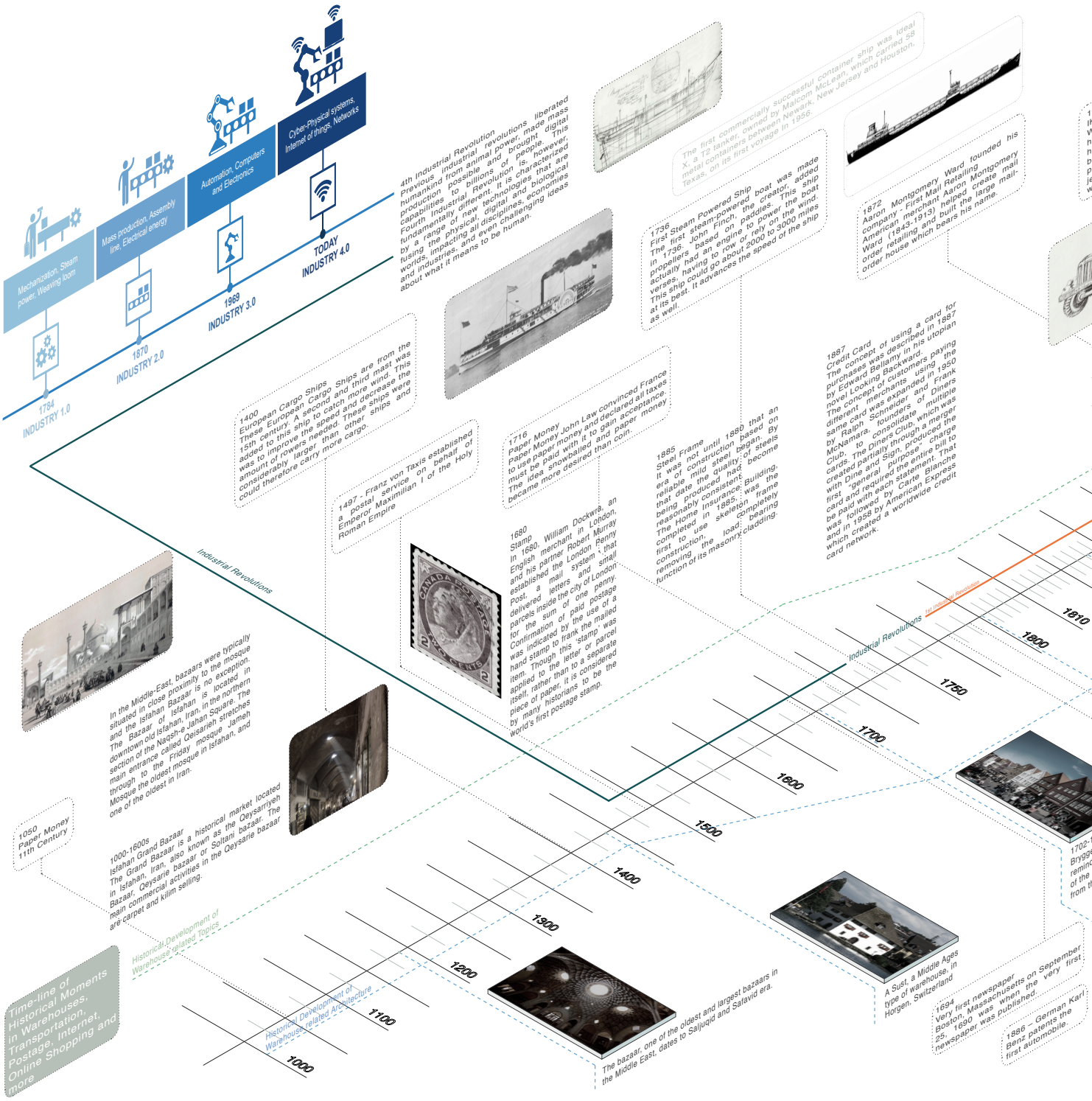
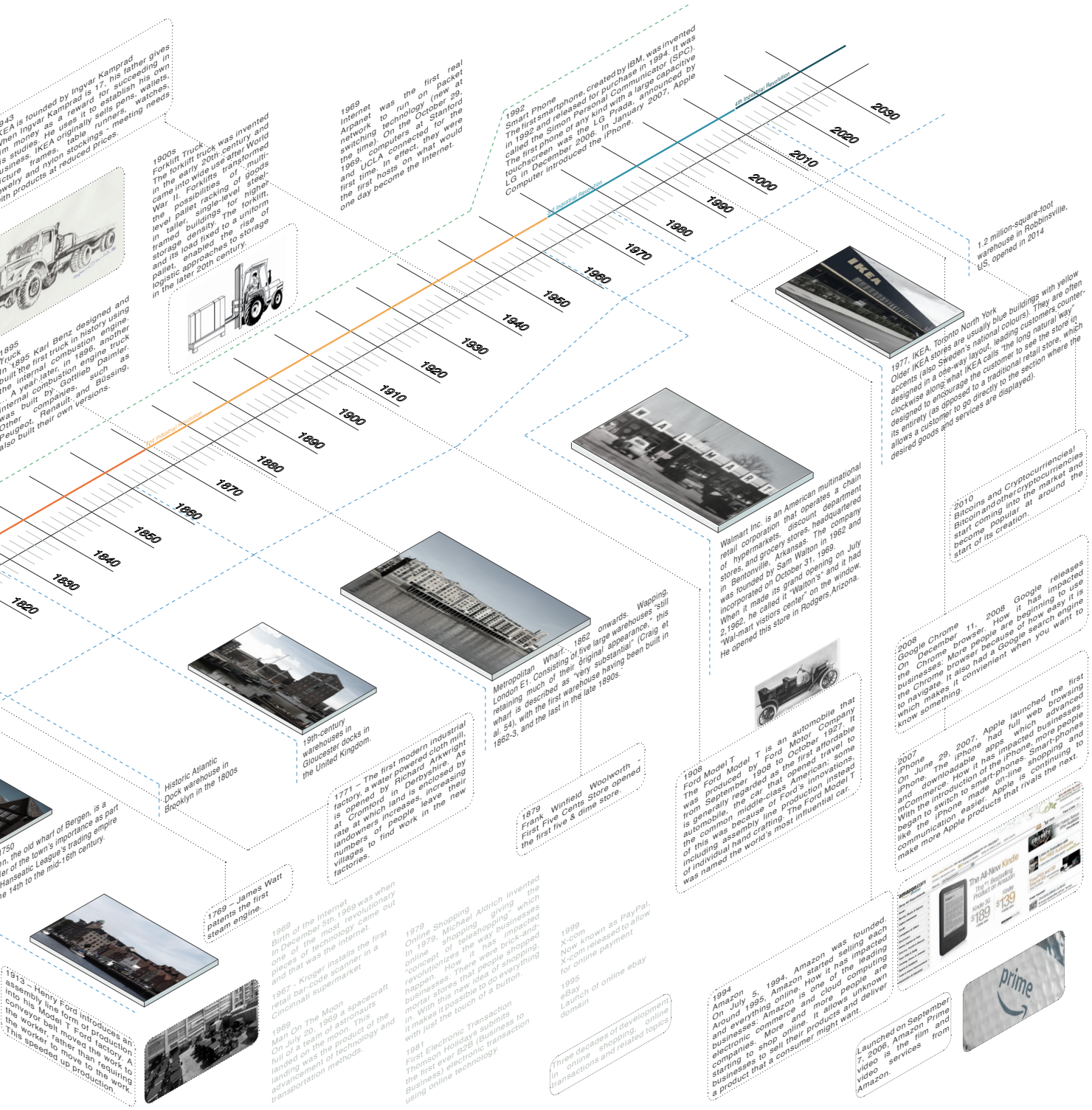


Fig. 12. Warehouse time-line


1820
1830
1840
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1870
1880
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1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2nd Industrial Revolution
3rd Industrial Revolution
4th Industrial Revolution
1943 - IKEA is founded by Ingvar Kamprad when Ingvar Kamprad is 17. his father gives him money as a reward for succeeding in his studies. IKEA originally sells pens, wallets, jewelry and nylon stockings - meeting needs with products at reduced prices.
1895 - Truck. In 1895 Karl Benz designed and built the first truck in history using the internal combustion engine. A year later, another internal combustion engine truck was built by Gottlieb Daimler. Other companies, such as Peugeot, Renault and Bussing, also built their own versions.
1900s - Forklift Truck. The forklift truck was invented in the early 20th century and came into wide use after World War II. Forklifts transformed the possibilities for multi-level pallet racking of goods in taller, single-level storage buildings. The forklift, and its load fixed to a uniform pallet, enabled the rise of logistic approaches to storage in the later 20th century.
1969 - Internet. The first real network to run on packet switching technology (new at the time) was the October 29, 1969 computers at Stanford and UCLA connected for the first time. In effect, they were on what would one day become the Internet.
1992 - Smart Phone. The first smartphone, created by IBM, was invented in 1992 and released for purchase in 1994. It was called the Simon Personal Communicator (SPC). The first phone of any kind with a large capacitive touchscreen was the LG Prada, announced by LG in December 2006. In January 2007, Apple Computer introduced the iPhone.
1977, IKEA: Toronto North York - Older IKEA stores are usually blue buildings with yellow accents (also Sweden's national colours). They are often designed in a one-way layout, leading customers counter-clockwise along; what IKEA calls "the long natural way". designed to encourage the customer to see the store in its entirety (as opposed to a traditional retail store, which allows a customer to go directly to the section where the desired goods and services are displayed).
1.2 million-square-foot warehouse in Robbinsville, US, opened in 2014
Walmart Inc. is an American multinational retail corporation that operates a chain of hypermarkets, discount department stores, and grocery stores, headquartered in Bentonville, Arkansas. The company was founded by Sam Walton in 1962 and incorporated on October 31, 1969. When it made its grand opening on July 2,1962, he called it "Walton's" and it had "Wal-mart visitors center" on the window. He opened this store in Rodgers,Arizona.
2010 - Bitcoins and Cryptocurrencies! Bitcoin and other cryptocurrencies start coming into the market and become popular at around the start of its creation.
2008 - Google Chrome. On December 11, 2008 Google releases the Chrome browser. How it has impacted businesses: More people are beginning to use the Chrome browser because of how easy it is to navigate. It also had a Google search engine which makes it convienient when you want to know something.
2007 - iPhone. On June 29, 2007, Apple launched the first iPhone. The iPhone had full web browsing and downloadable apps which advanced mCommerce. How it has impacted businesses: With the introduction of the iPhone, smart-phones began to switch to smart-phones. Smart-phones like the iPhone made on-line shopping and communication easier. Apple is continuing to make more Apple products that rivals the next.
Metropolitan Wharf - 1862 onwards: Wapping, London E1. Consisting of five large warehouses "still retaining much of their original appearance," this wharf is described as "very substantial" (Craig et al. 54), with the first warehouse having been built in 1862-3, and the last in the late 1890s.
19th-century warehouses in Gloucester docks in the United Kingdom.
Historic Atlantic Dock warehouse in Brooklyn in the 1800s
1771 - The first modern industrial factory, a water powered cloth mill, is opened by Richard Arkwright at Cromford. In Derbyshire. As rate at which land is enclosed by landowners increases, increasing numbers of people leave their villages to find work in the new factories.
1879 - Frank Winfield Woolworth - First Five Cents Store opened the first five & dime store.
1908 - Ford Model T. The Ford Model T is an automobile that was produced by Ford Motor Company from September 1908 to October 1927. It is generally regarded as the first affordable automobile, the car that opened travel to the common middle-class American people of this era. Ford's innovations, including assembly line production and the use of individual hand crafting. The Ford Model T was named the world's most influential car.
1750 - Bergen, the old wharf of Bergen, is a reminder of the town's importance as part of the Hanseatic League's trading empire in the 14th to the mid-16th century.
1769 - James Watt patents the first steam engine.
1913 - Henry Ford introduces an assembly line form of production into his Model T Ford factory. A conveyor belt moved the work to the worker, rather than requiring the worker to move to the work. This speeded up production.
1969 - Birth of the Internet. On December 5th, 1969 was when one of the most revolutionary pieces of technology came out and that was the internet.
1967 - Kroger installs the first retail bar-code scanner in a Cincinnati supermarket.
1969 - Man On The Moon. On July 20, 1969 a spacecraft full of a team of astronauts landed on the moon. This landing was the product of the advancement of technology and transportation methods.
1979 - Online Shopping. Michael Aldrich invented online shopping, giving the online revolutionizes the way businesses happen. How it has impacted businesses: There were brick-and-mortar stores that people shopped in. With this new idea of shopping, it makes it possible to do everything with just the touch of a button.
1981 - First Electronic Transaction. Thomson Holidays submits the first ever B2B (business to business) electronic transaction using online technology.
1999 - X-com. Now known as PayPal, X-com released to allow for online payment
1995 - Launch of online ebay. eBay domain
Three decades of development in online shopping, online transactions and related topics
1994 - Amazon. On July 5, 1994, Amazon was founded. Around 1995, Amazon started selling each and everything online. How it has impacted businesses: Amazon is one of the leading companies in e-commerce and cloud computing. More and more people are starting to shop online. It allows unknown businesses to sell their products and deliver a product that a consumer might want.
Launched on September 7, 2006, Amazon Prime video is the film and services from Amazon.

2.3. Warehouse Types

While any type of large industrial building that is being used for the storage of goods could be called a warehouse, there are various types of warehouse buildings for different purposes and functions. As most of the warehouses are sharing similar building types, it is not a useful practice to categorize them based on their building type or even structure. Warehouses could also be studied based on their location or their relation to infrastructures, like canal warehouses, railway warehouses. But even this type of categorization is not useful for this study. Here though, when we look at various types of functions and services that they provide, it becomes helpful to see the typologies based on functions that they perform[8]. This will help in the future design processes in order to define programs, spaces, and spatial qualities. In this regard, these are the main types of warehouses which is being studied in this section of the research[9]:

_ Storage Warehouses
_ Distribution Centers
_ Retail Warehouses
_ Cold-Storage Warehouses

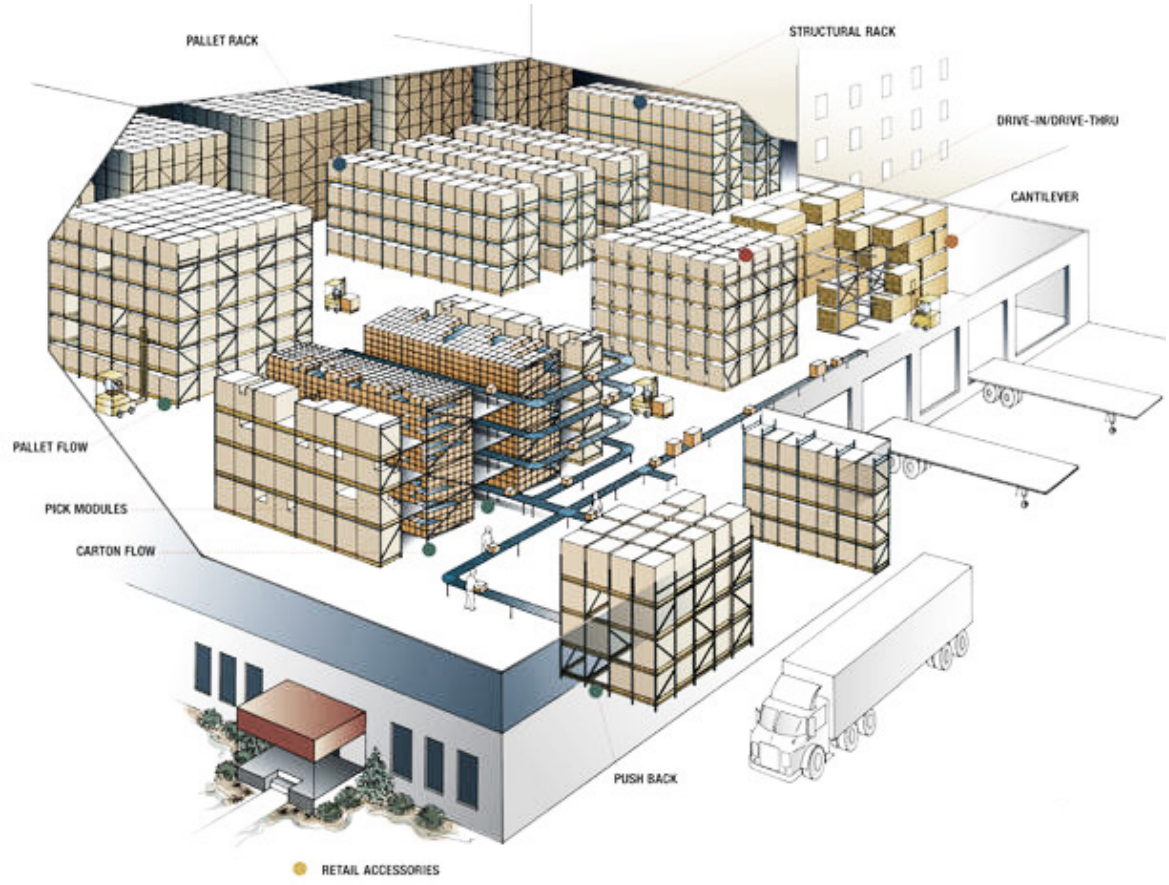


Fig. 13. Warehouse procedures
Warehouses are providing storage facilities, but based on additional features they can provide different services. It is very useful to classify their functionalities in order to address their design issues in later stages.

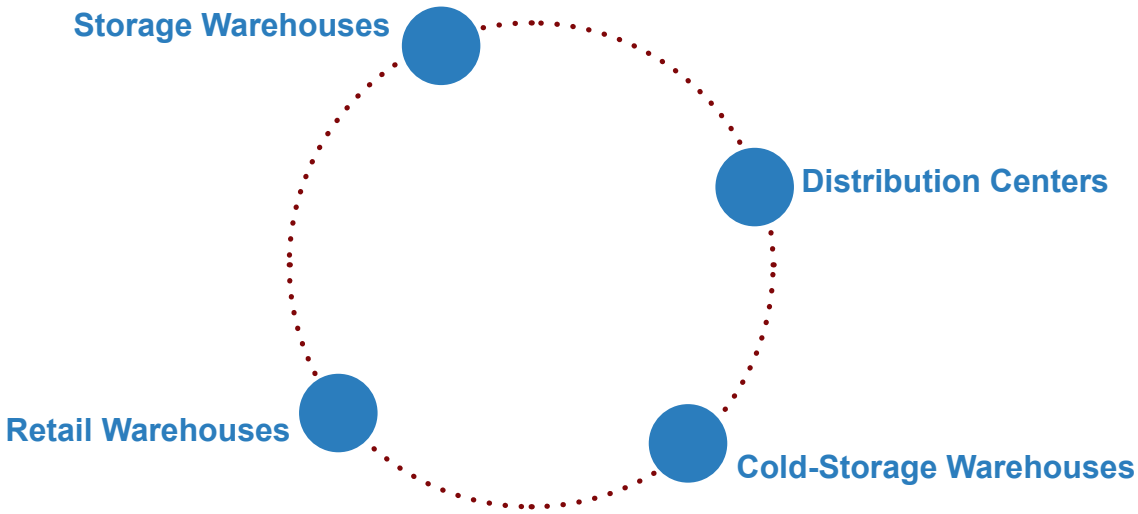


Fig. 14. Warehouse types

2.3.1. Storage Warehouses

A storage warehouse is a very basic type of warehouse designed to be used for storage purposes only. This might be the case of having shelves for better efficiency of the space, although we have non-shelved facilities, which are more traditional ones, usually dedicated to the storage of one type of goods[10]. In the case of shelves, there are many different types of them based on using pallets or not, using forklifts or not, and so on. One of the more recent types of shelving systems is those which are movable, meaning that the area needed for internal access between the aisles are minimized, although the access time is going to be more[11]. Most of the modern warehouses are directly connected to the docking area, where heavy trucks could stop and directly load/unload goods into/from the warehouse.

Fig. 15. Storage warehouse with loading/unloading area and the shelving area

Fig. 16. Storage warehouse with remote shelves

Fig. 17. Storage warehouse without shelving system for bulk storage of goods

Fig. 18. Typical exterior of a warehouse and its docking area

2.3.2. Fulfillment Centers (Distribution Centers)

A distribution center or a fulfillment center is a warehouse equipped with the facilities to process goods to be packaged individually for delivery, usually used for the Online shops and e-commerce[12]. These centers provide storage, but also facilities for order processing, pick-up and sorting, packaging and labeling, and consolidation for delivery[13]. Most of the modern Online retailers are using these systems to store and process their products, especially companies like Amazon, with a wide variety of goods and very large storage areas. Some of these processing facilities are automatic, using various types of machines and robots.

Fig. 19. Automated facilities inside a fulfillment center

Fig. 20. Sorting facilities of a distribution center

Fig. 21. Automated robots for carrying goods in a distribution facility

2.3.3. Retail Warehouses

The idea of a retail warehouse is a place where goods can be stored and sold at the same time. These warehouse types of stores are usually located in large pieces of land, in the areas far from the center, where they can present goods in larger quantities, and better prices[14]. Companies like Costco or Walmart, to some extent, are using this concept, combining the wholesale, large quantities of goods, and a combination of various goods to be purchased in one store as well as providing large parking facilities in some dining options too. The same concept has been used for the companies selling building and construction materials for consumers and so on. While the general concept of these spaces is not so different from the other warehouses, the main important feature to notice is the public's involvement in the spaces. This means that there should be more safety measurements and other considerations needed for public safety.

Fig. 22. Walmart; a typical distribution and display of goods without shelving


Fig. 23. Ikea; typical shelving units


Fig. 24. Walmart; Checkout area

Fig. 25. Costco; a typical view of the warehouse building

2.3.4. Cold-Storage Warehouses

Cold-storage warehouses are storage facilities for agricultural products. They are equipped with facilities to control the temperature and moisture content of the space in order to control the rotting and sprouting of agricultural products[15]. They are also controlling insects or any other damages that might come from other animals, bacteria, and so on. There are various types of refrigerator systems for these facilities, where the details are beyond the scope of this research. These technologies are keeping the desired temperature for the specific type of products stored in the warehouse. Basically, cold-storage warehouses are used to control the distribution of agricultural products during the year. Like other warehouses, they are also using bulk storage as well as shelved ones.

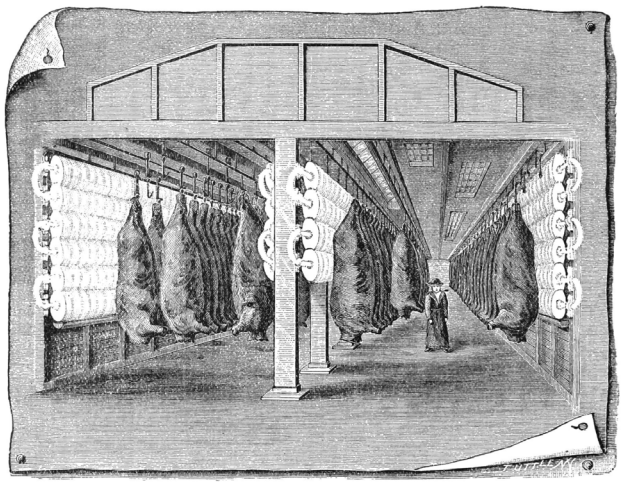


Fig. 26. Example of an old cold storage

Fig. 27. A typical shelved cold-storage

Fig. 28. Stacking food in a cold storage

Fig. 29. Cold-storage with especial basket-type storage

2.4. Warehouse Operations

There are various operations that could happen in a warehouse that spends on the type of warehouse and the goods it deals with. As mentioned in the previous section, there are various types of warehouses, but here the fundamental focus is on the storage one in terms of its operations. Further investigations will cover the extra operations of a distribution center as well as a retail warehouse. These distinctions will help to understand better the dynamics of each type of them for further planning and design[16].

Basic operations in a storage warehouse:

The basic operations that happen inside a storage warehouse includes[17]:

- Loading and unloading goods in the loading docks area, where usually tricks could stop by the side of the warehouse and directly deliver items into the warehouse, where there is a large empty area for temporary stacking of them
- Shelving/Sorting is the act of distributing goods (mainly in large packages) into shelves or on the ground. This usually happens with the use of forklift-trucks, modern mechanical machinery or manually by workers
- Picking orders which means either picking individual items from large packages, or even taking the entire package. Each of these operations might need a different strategy and machineries.
- Sorting happens where items collected for delivery need to be sorted for each separate delivery/ customer
- Package formation, to put items inside packages, wrapping, and generating labels to of shipment
- Consolidation which is the final step of making the packages ready for delivery for each delivery service

Extra operations in special warehouses:

While having all of the operations listed above, other types of warehouses could feature additional operations. In the case of a fulfillment center, there are additional operations as follows[18]:

- Order processing, which includes the process of Online orders in order to prepare the pickup list for goods to be prepared
- Package formation and pre-consolidation for individual customer’s orders (order filling)

Looking at other types of warehouses, there are special operations for the preparation of food and agricultural products to be stored in a cold-storage warehouse. This becomes a combination of operations while looking at retail warehouses especially those working as supermarkets with food products. The operations include additional steps like[19]:

- Picking items by individuals in store, with specific entrances and routes for customers
- Checkout including the automated/self-checkouts for payments
- Food and beverage services for customers with all background and foreground facilities to prepare food and serve it
- Management of parking and shopping carts
- Daily food/pastry/fruit preparation for those offering fresh food
- Consultation for those offering home/furniture and other similar services

Perhaps this list could be modified and extended based on the type of warehouses, but it is informative to overview such additional procedures. It is clear that any modern warehouse's design and programming need a careful study of all the operations needed to run that facility and include them in the design process. The good point is that most of such companies have standard design and operation manuals

that should be followed in all their warehouses for the most efficient performances.

It is worth mentioning that there are operations that usually happen on a regular basis, which are more or less global to most of the warehouses. Operations like supervision, quality control, and asset and inventory management are among those. Human resources, housekeeping, equipment maintenance, and safety controls are also an essential part of the daily operations of warehouses. There might be research and development, or educational activities in combination with other activities too.

As the core operations remain on the storage and picking of items, it is worth having a more detailed overview of some of the main strategies and technologies used for such purposes. This will be an essential part of most modern warehouses.

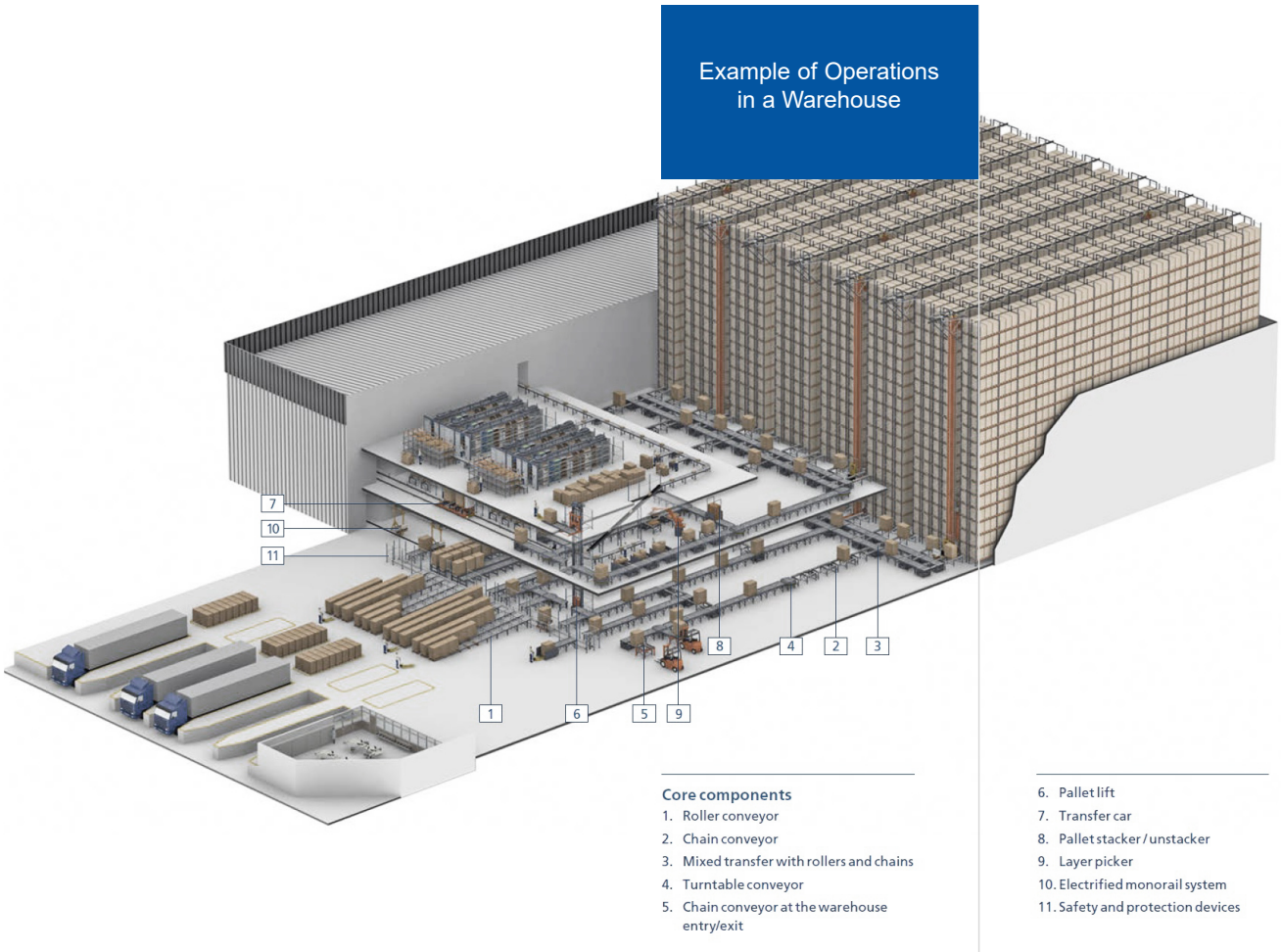
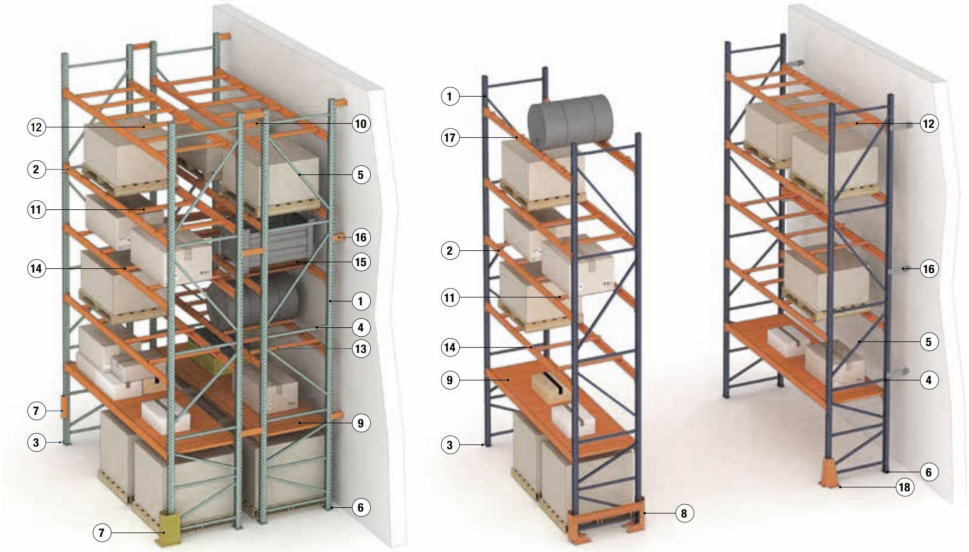


Fig. 30. The example of warehouses operations

2.5. Warehouse Storage Systems

2.5.1. Pallet Racking

Pallet racking reflects the idea of using pallet for storing goods as a material handling and storage system. Pallets have different sizes and materials but the main point is that they facilitate handling goods using a forklift-truck. They could be arranged horizontally or inside the racks of a storage facility.



1. Frames
2. Beams
3. Foot plate
4. Horizontal strut
5. Diagonal strut
6. Shim
7. Post protector
8. End aisle proctor
9. Shelf panel
10. Row spacer
11. Roll-in pallet support
12. Double flanged pallet support
13. Drum/coil bed
14. Fork clearance bar
15. Skid channel
16. Wall tie
17. Drum cradle
18. Corner protector

Fig. 31. Selective pallet racking of the Interlake Mecalux Inc

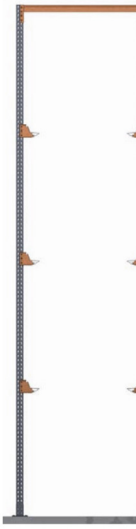


Fig. 32. Sam

2.5.2. Cantilever Racking

Cantilever racking is a storage system that uses arms to store products in rows while being cantilevered. This means that there is no limitation in the length of the items being stored. This is useful for storing long products like pipes, timber, and so on.

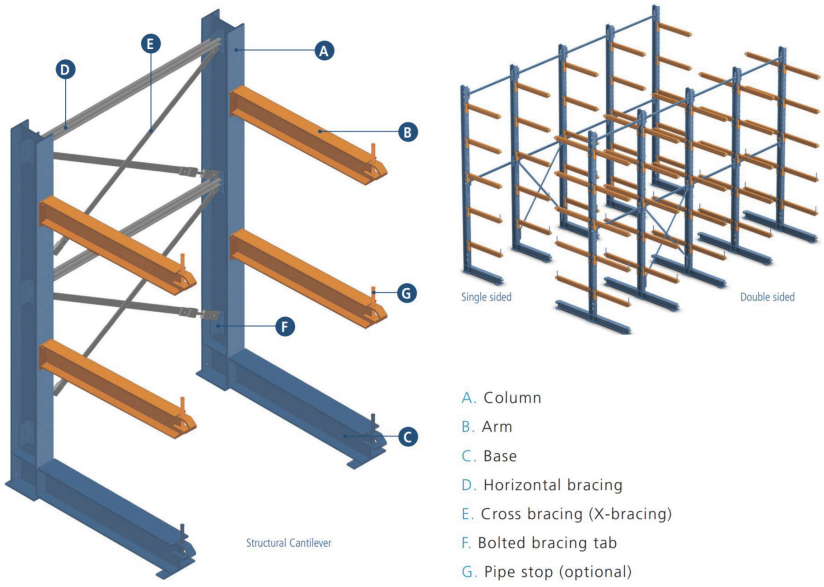
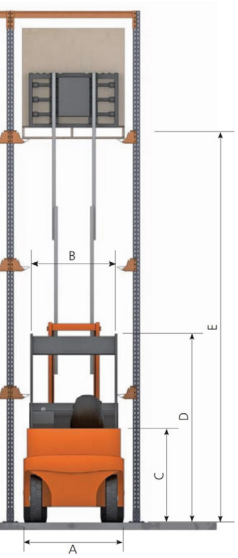


Fig. 33. Structure of cantilever racking system of the Interlake Mecalux Inc

Fig. 34. Cantilever racking system of the Interlake



nple of forklift scale

Fig. 35. Drive-in pallet racking of the Interlake Mecalux Inc

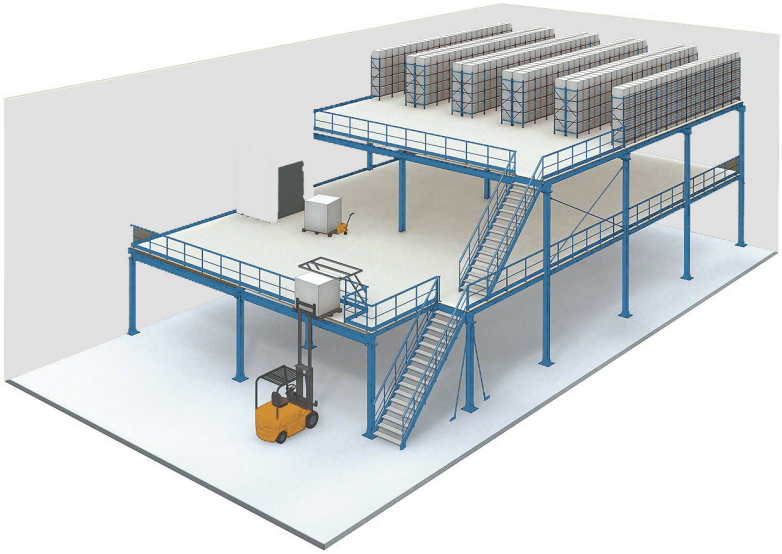
Fig. 36. Drive-Thru pallet racking of the Interlake Mecalux Inc

e Mecalux Inc

Fig. 37. Cantilever racking system of the Interlake Mecalux Inc

2.5.3. Mezzanine

As an intermediate floor in high-ceiling buildings, which adds semi-permanent storage to warehouses. This system is useful for items that should not be in direct access to forklift-trucks and could be easily managed in another level. This strategy is useful when there is not any full-height shelving system installed.



Basic component
1. Column
2. Main beams
3. Secondary beams
4. Floor
5. Floor support angle bracket
6. Floor attachment clamps
7. Column base plate
8. Base plate floor fixing
9. Staircase
10. Handrail
11. Up and over pallet gate

Fig. 38. Mezzanines system of the Interlake Mecalux Inc

Fig. 39. Mez

2.5.4. Vertical Lift Modules

These are automated systems where there are shelving systems inaccessible to the humans and an automated lift has access to different levels of the shelves to load and unload goods. These systems use trays that could usually service on two sides of the lift for better spatial efficiency.

Fig. 41. Sample of vertical lift modules

Fig. 42. Sructure of vertical lift modules

Fig. 43. Vertical lift of th
Interlake Mecalux Inc

zzanines in warehouses of the Interlake Mecalux Inc

Fig. 40. Using mezzanines in warehouses of the Interlake Mecalux Inc

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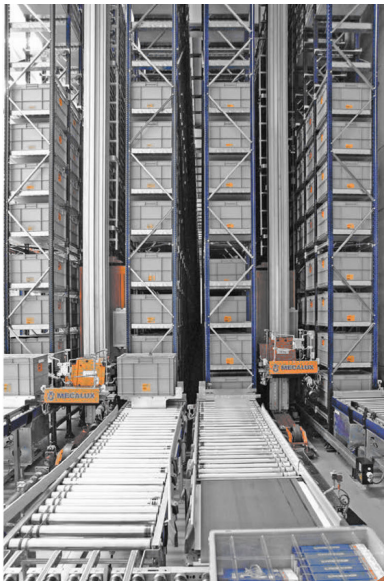


Fig. 44. Vertical lift of the Interlake Mecalux Inc

Fig. 45. Vertical lift of the Interlake Mecalux Inc

2.5.5. Horizontal Carousels

Horizontal Carousels are rotating bins, mounted on frames, together they create a path for goods that could move on the bins. These could help to transfer goods from one location to another, connecting different parts of the warehouse. Such systems reduce the use of forklift-trucks, especially for the transferring of smaller packages.

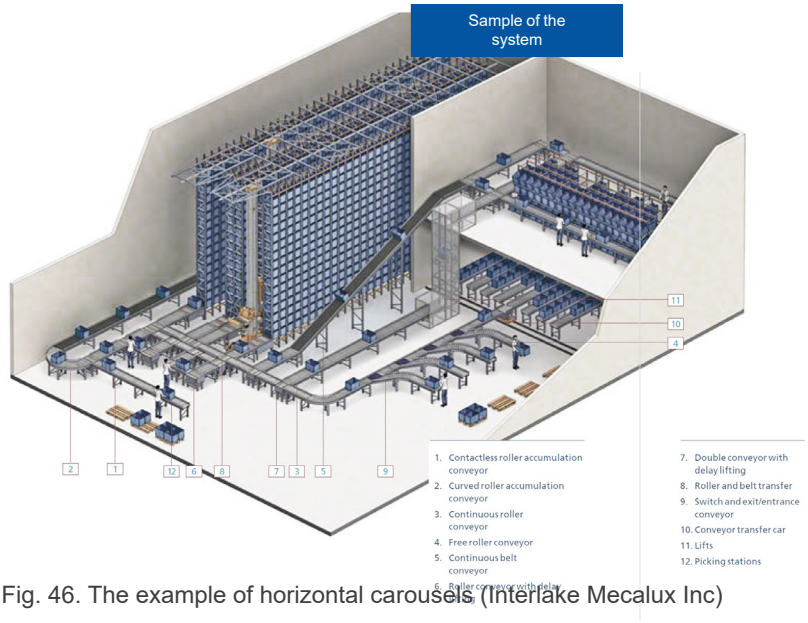


Fig. 46. The example of horizontal carousels (Interlake Mecalux Inc)

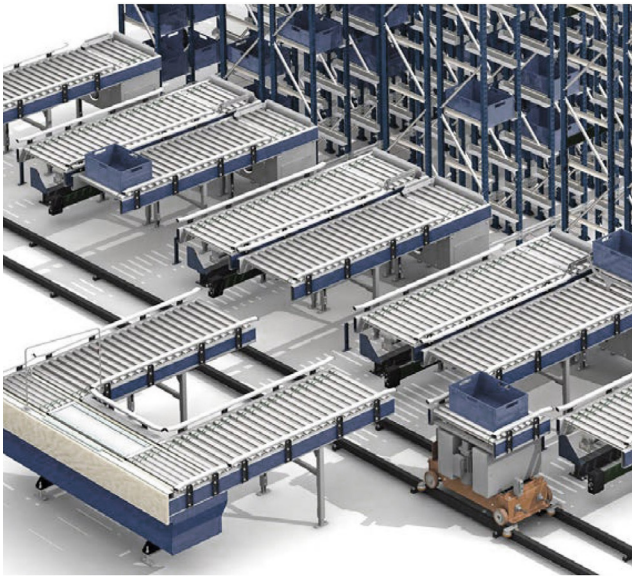


Fig. 47. Transfer cars on carousels (Interlake Mecalux Inc)

2.5.6. Vertical Carousels

Vertical Carousels are a series of trays, containers, or bins, together they create a continuous chain of storage spaces. While they are part of the automated storage systems, an operator would have access to levels of storage through a controller that would rotate the system to prepare the desired level in front of the access window.

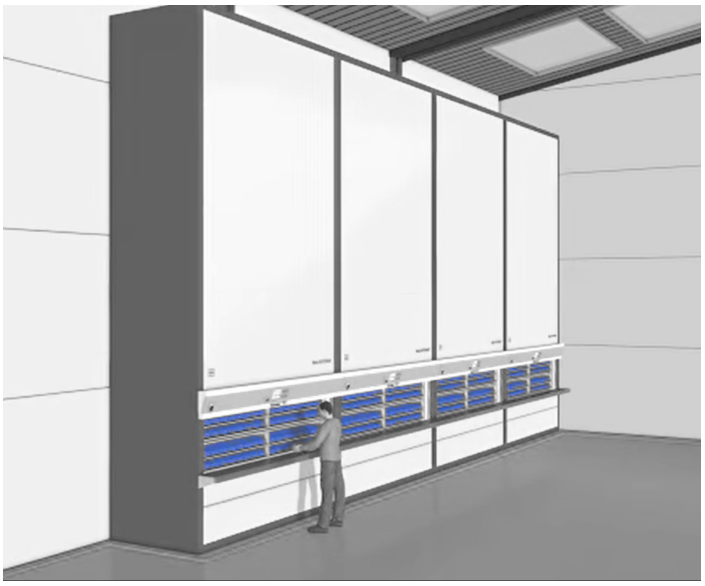


Fig. 50. Sample of vertical carousels

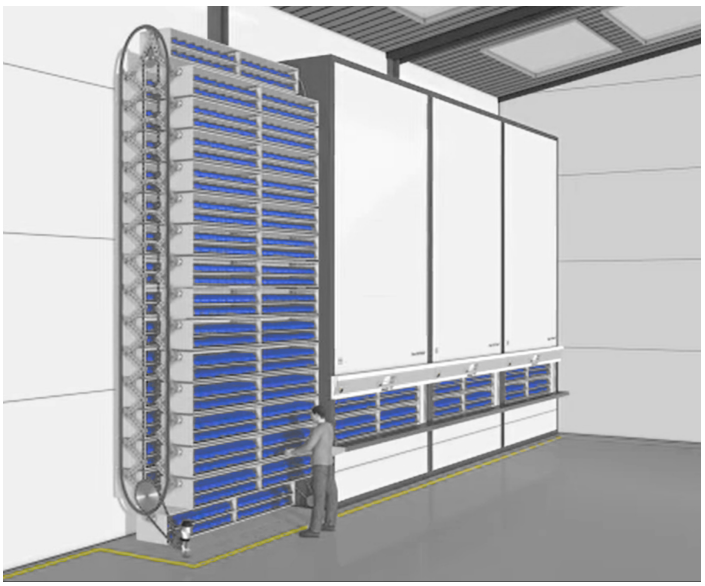
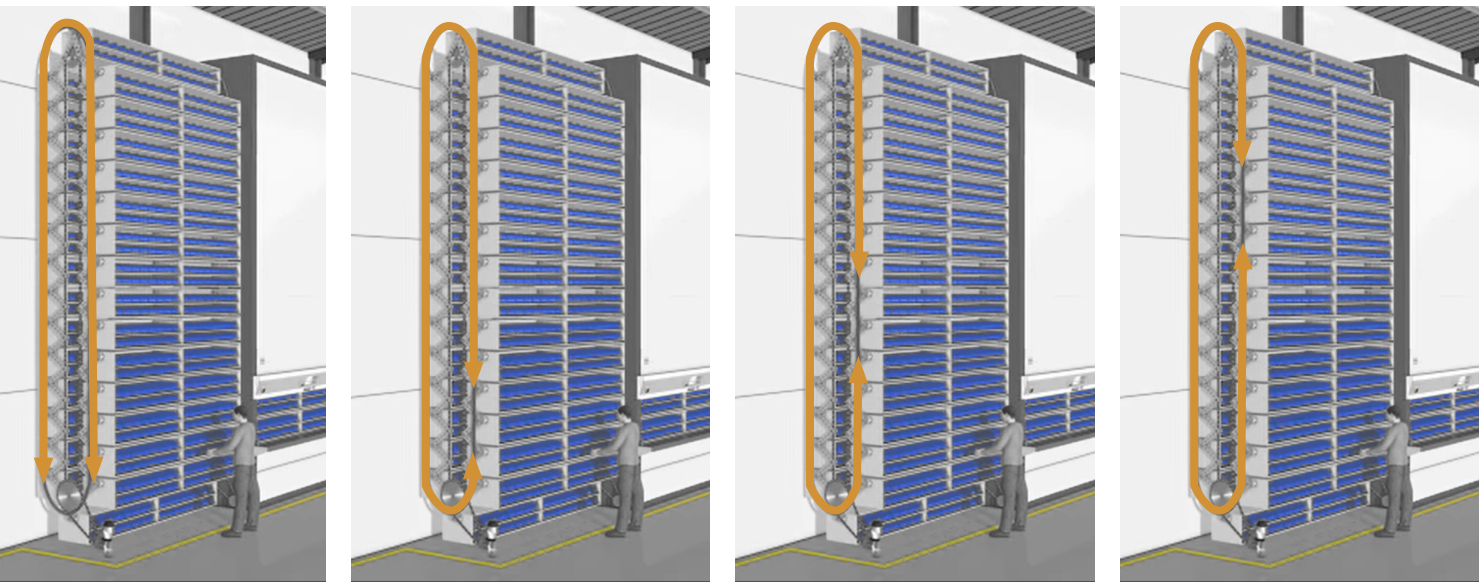


Fig. 51. Structure of vertical carousels

Fig. 48. Box of packages on horizontal carousels (Interlake Mecalux Inc)

Fig. 49. Packages movement on horizontal carousels (Interlake Mecalux Inc)



. 52. Vertical Carousel movement

2.6. Warehouse Precedents

2.6.1. IKEA Store

The idea behind Ikea was to bring good and stylish furniture to the life of the middle class as much as possible. Especially with the concept of providing flat-packed furniture to be home-assembled, they made it possible to purchase many items from their showrooms and assemble them at home[20]. In order to do that, they used this concept of combining a showroom with a warehouse. With this scenario, they get large pieces of land with a large warehouse facility and lots of parking, making an easy and to some extent fun experience of shopping. In these large warehouses, they have the chance to exhibit so many furniture and sample furnished spaces, and also a lot of retail products for domestic use, while being exhibited as bulk, to be picked by customers.

Fig. 53. IKEA's core idea of selling flat furniture for easy pick-up and transportation

Ikea stores have a strict, designed one-way visiting route through which customers will experience all the products and have access to the food-court and at the end, to the storage area where they can pick up their desired furniture inside small packages. All such strategies helped Ikea to reduce its prices as low as possible and to be able to present so many items in its showrooms, which eventually attracts so many people to their stores.

Fig. 54. IKEA enforces its costumers to follow a one way path during their visit

Warehouse/Showroom/Retail

Of course, a combination of a store/showroom with a warehouse is an important point in this research. It is clear that this strategy provided this showroom more spaces to exhibit items, which satisfy customers as they can find items they like. Also, getting flat-packed furniture means delivery with personal vehicles which is another encouraging point to shop more with less additional costs.

Fig. 55. A typical IKEA store


Fig. 56. A typical aisle in an IKEA warehouse

Fig. 57. Information section in the beginning of storage area


Fig. 58. A sample section of the furniture showroom

Layout

Ikea warehouses are following similar layouts and similar ways of presenting items that are the standard coming from the management that applied to all stores worldwide. This idea of having a one-way path to go through the entire store might be challenging for some people. In my opinion, it could be unnecessary for some customers to walk the entire showroom while they need access to one specific section. Another criticism is that the concept of warehouse/showroom puts Ikea in the outskirt of the city, in the areas not easily accessible by the public, where you need to use vehicles to reach and to deliver your items. This might limit the access of some groups of people who might prefer to have easier access to their store in closer proximity and minimize the number of stores in each city. All in all, Ikea keeps growing to be one of the most favorite stores for furniture and home decorations.

Fig. 59. A sample section of the retail in an IKEA store

Fig. 60. IKEA store checkout

Fig. 61. IKEA food, as part of the showroom

Fig. 62. IKEA food-court

Access / Circulation

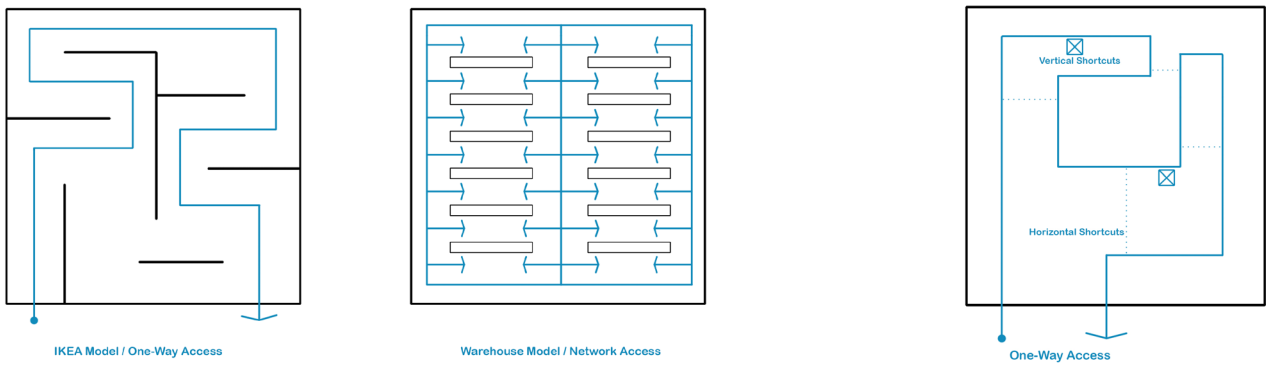


Fig. 63. IKEA circulation

IKEA provides one-way access throughout the store and guides everyone to follow a similar path. But it also provides shortcuts where these connect different spaces horizontally and vertically.

Fig. 64. Ikea lobby

Fig. 65. Ikea showroom

Inward / Outward

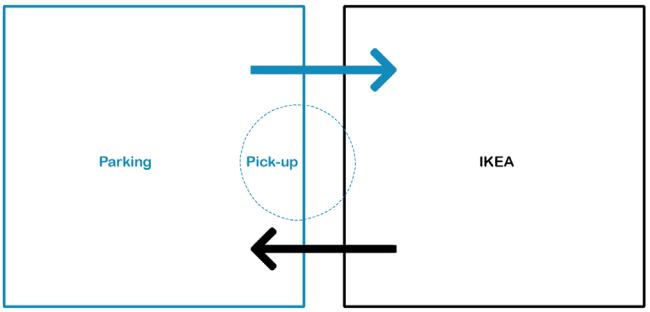


Fig. 66. IKEA access diagram

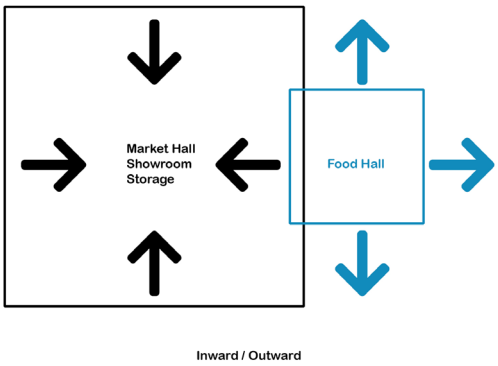


Fig. 67. IKEA access diagram

As large retail, IKEA connects its warehouses to parking spaces and provides easy access to vehicles for costumers to load and unload their goods. They provide easy access to return counters to make sure that the handling of goods is easy.

Fig. 68. Ikea parking

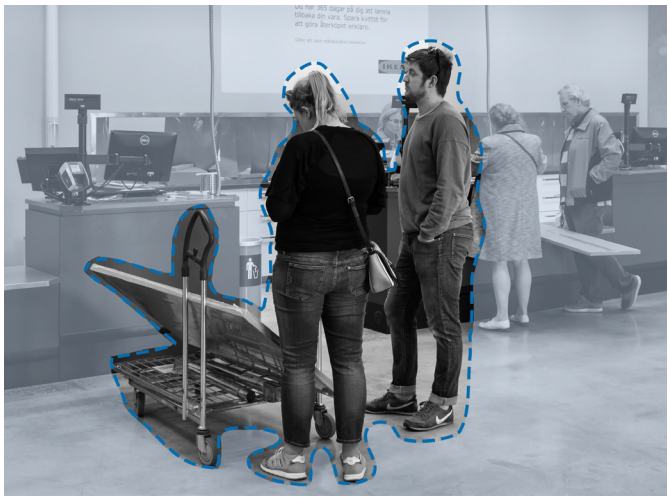


Fig. 69. Ikea return area

Spatial Organization

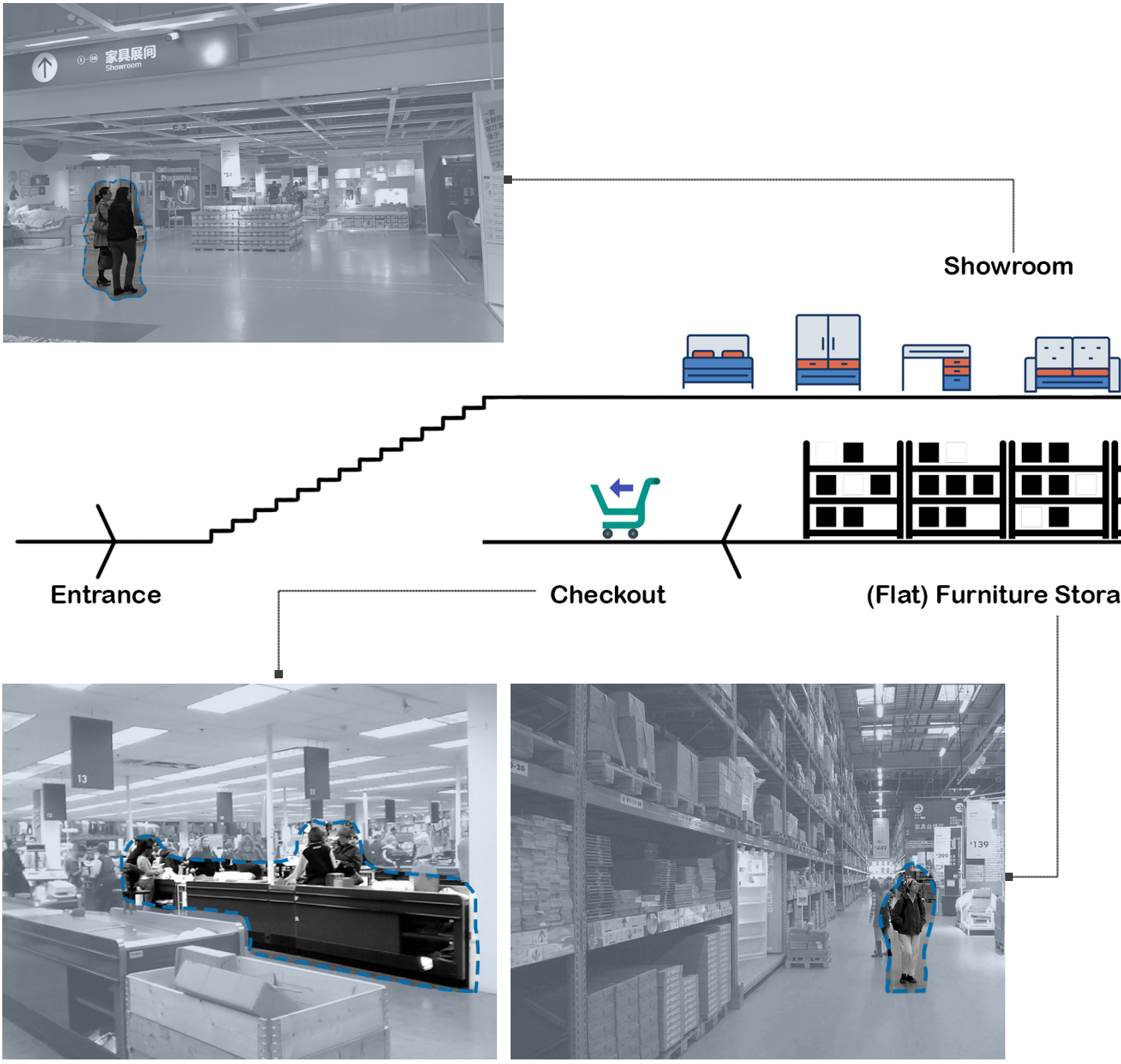
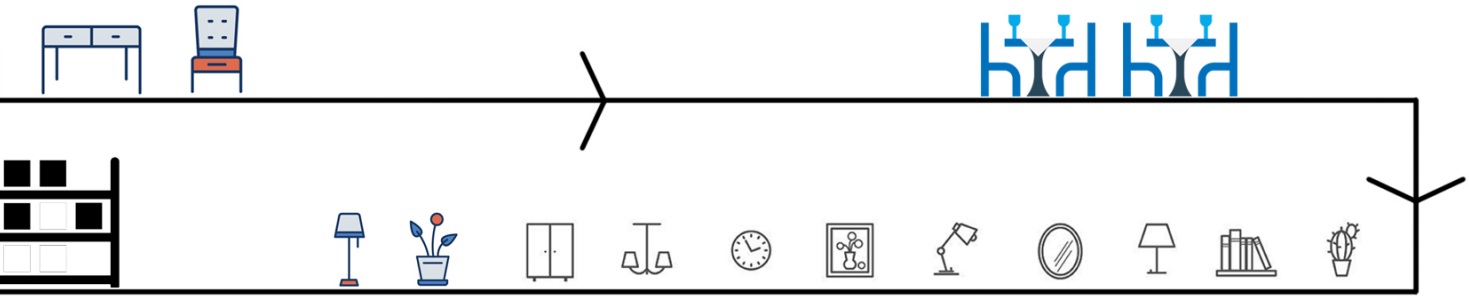


Fig. 70. IKEA spatial organization

While the first floor in an IKEA store is more for watching, spending time while imaging and depicting, and also having some food while resting, the ground floor is more of picking items, searching what is needed, and finally purchasing.

Food Hall



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Market Hall

The strategy that made IKEA such a giant player in the furniture market and home decor is its concept of flat pack and easy to transport furniture as well as being a mega player in the logistics of goods, providing a worldwide network of manufacturers and distribution warehouses, together they sell millions of items each year.

2.6.2. Amazon Fulfillment Center

Amazon fulfillment centers are very large facilities that are not only store goods like a warehouse but also process orders, sort and package them, send them out for delivery, and process returns as well. These extensive facilities are growing in the world, serving millions of citizens every day. Figures 71-74 present the massive scale and type of spaces and facilities that we can see in a modern Amazon warehouse these days. We shall look at some of the features in these centers in this section.

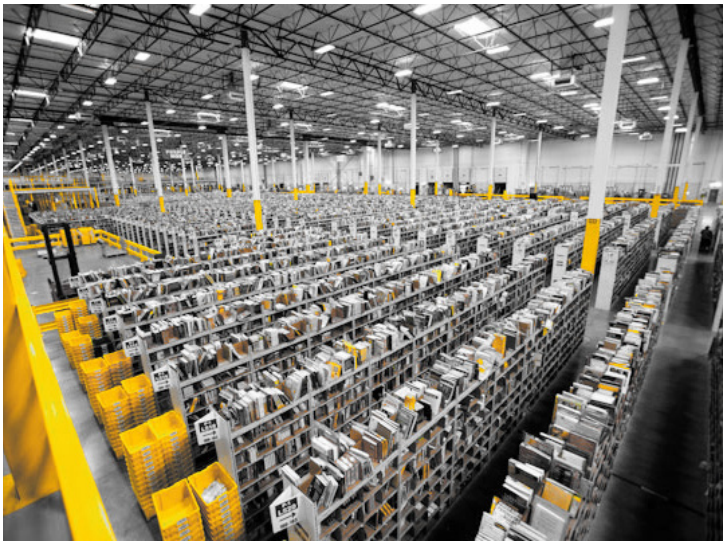

Fig. 71. Amazon fulfillment center / book section / manual pick and place

Fig. 72. Amazon fulfillment center, processing of packages

Fig. 75. Amazon fulfillment center, Troutdale Oregon

Fig. 76. Amazon fulfillment center, pano

Fig. 73. Amazon fulfillment center, robotic shelving system

Fig. 74. Amazon fulfillment center, sorting facilities

rama view

We shall start with the location of Amazon warehouses. Although warehouses are always located outside of the cities, Amazon facilities are usually located in very large lands as their initial occupation happens in a large footprint. More than 800,000 sqft of space, Amazon warehouses are one-story buildings requiring much land for their operations. These facilities should have parking and docking spaces.

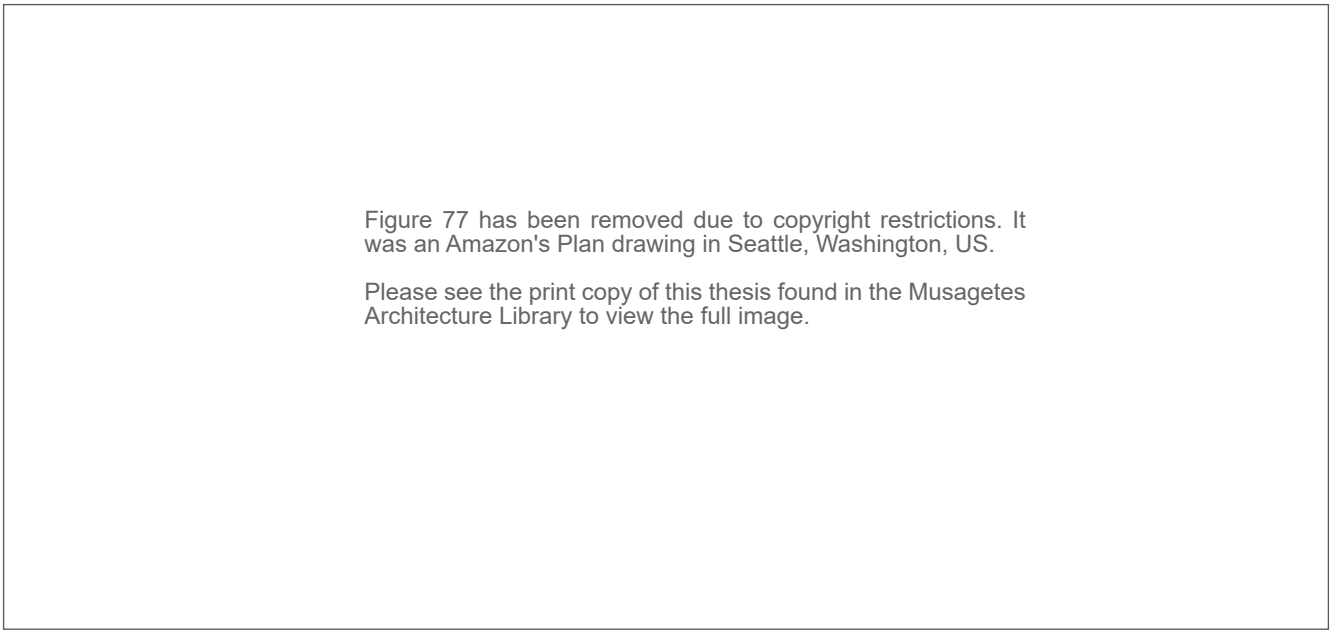

Fig. 77. Amazon Plan drawing, Seattle, Washington, US

Fig. 78. Amazon Facilities, Seattle, Washington, US

In a rectangular layout (cubic form), there is a systematic space subdivision in the fulfillment centers, dividing the area into three main sections: Storage and Shelving, Processing and Sorting, Packing and Loading. Although the terminology might slightly change in different samples, the function of those three spaces are clear: spaces for storage of goods with shelves, spaces for processing orders with tables and other sorting machinery, spaces for delivery which are empty, letting trucks and workers to handle goods[21].

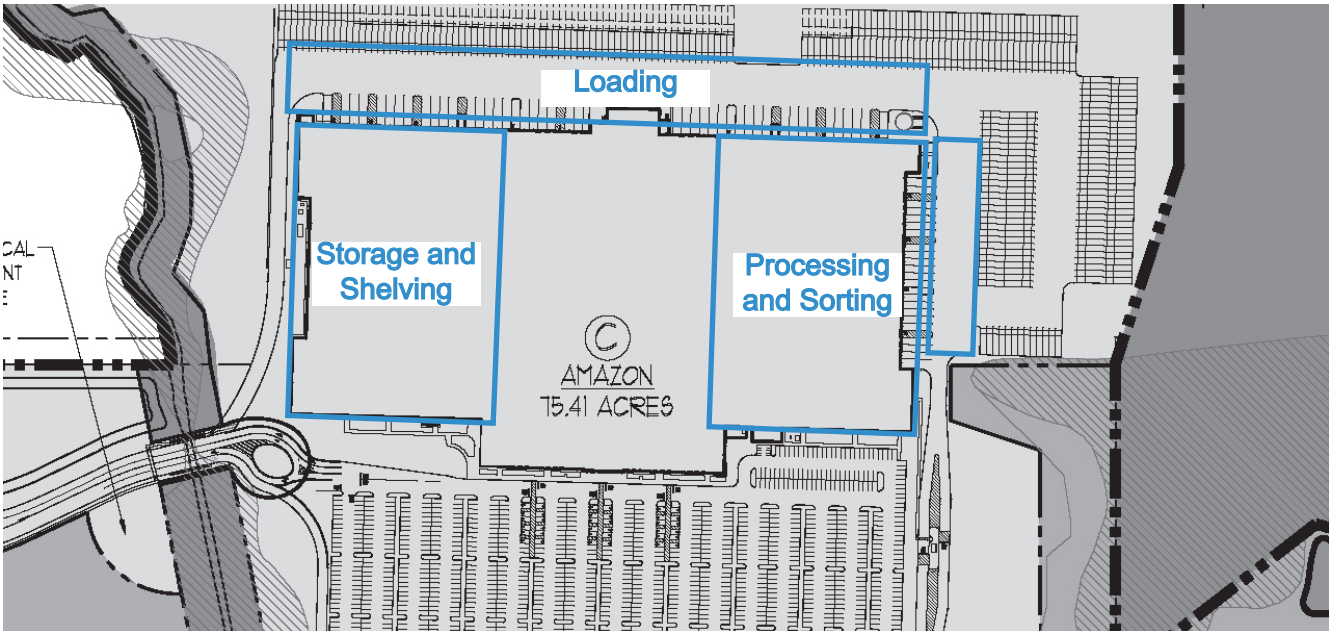

Fig. 79. Amazon Facilities, Milwaukee, US

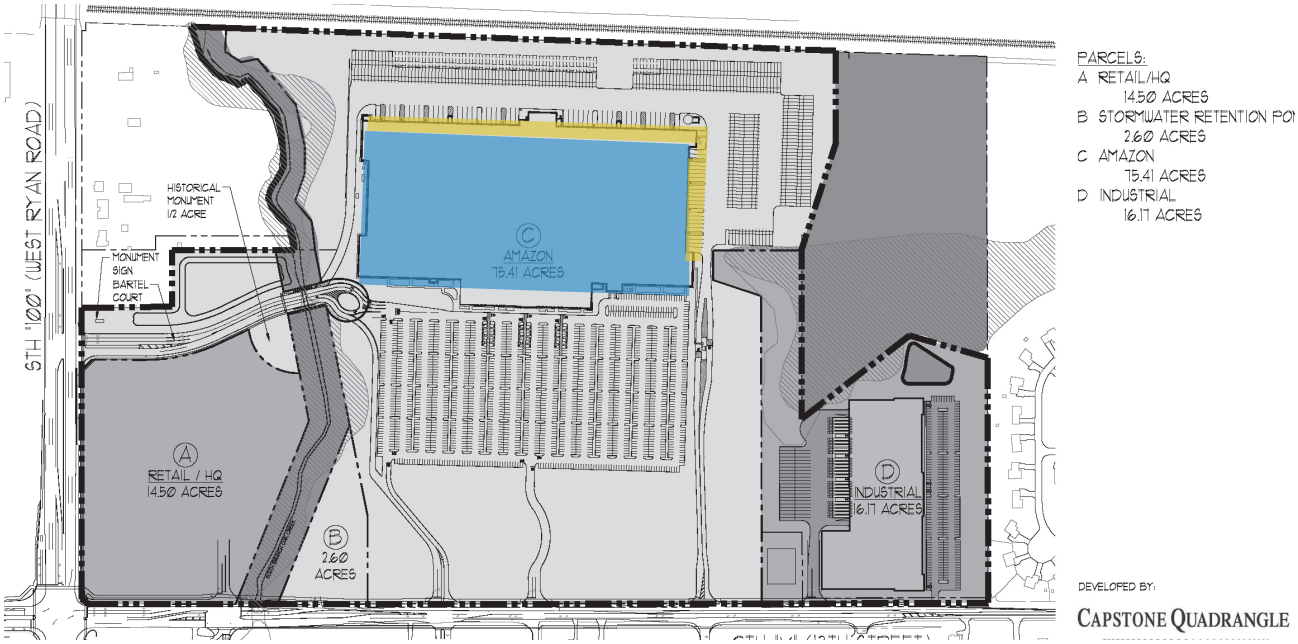

Fig. 80. Amazon Facilities, Milwaukee, US

As a pattern, docking spaces are alongside the warehouse, letting trucks directly connect to the interior spaces for faster and more efficient loading. There are small administrative, service, and other little spaces needed which are attached to the main spaces.

Exterior

In terms of architecture, while the interior of Amazon fulfillment centers is mostly like a vast cubic space made similar to most of the other industrial buildings with steel structures, the exterior is also simple, mostly cubic, sometimes with windows for lighting the administrative sections. The same typology could be seen more or less in all Amazon fulfillment centers.

Fig. 81. Amazon fulfillment center, Hillend, Great Britain

Storage / Shelving


Fig. 83. Amazon fulfillment center, storage system for packages


Fig. 84. Amazon fulfillment center, Convent

Fig. 82. Example of Amazon fulfillment center

ional storage system

Fig. 85. Amazon fulfillment center, new model for storage system

Robotic Shelving

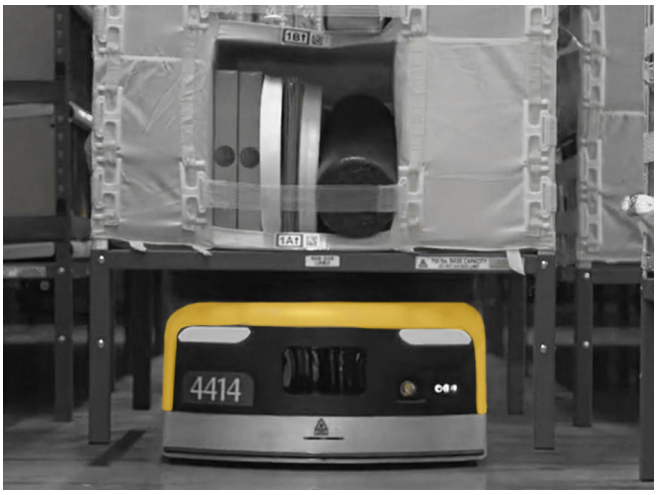

Fig. 86. Amazon robots for fulfillment centers

Fig. 87. Amazon robots, scale

Fig. 88. A line-up of Amazon robots in a fulfillment facility

In a robotic distribution system, like the above example in Brampton, Ontario, Canada, cubic-shaped robots are moving shelves with inventory to reach staff for picking up goods. In fact, robots bring shelves based on the orders they receive, so staff would reach products much faster[22]. When the item has been picked, the robot takes the shelf back. Not only this system is faster, but they also claimed that the space needed for them is less than that of operated by humans.

Shelving with Randomness

Fig. 89. Amazon “Picker” looking for goods to pick up for orders

One of the points that claimed to improve Amazon’s efficiency in its warehouses is its total random shelving strategy. They use empty spaces in their shelves to store goods randomly instead of sorting products in separate aisles and shelves and leaving behind so many empty spaces just because that specific product is not in stock or does have demand. This random sorting of products happens by using small hand-held devices to scan an empty location’s bar code and scan the products bar code to associate the location with a product. This will let the picker to find the closest item in the shelves and prepare it for packing. In modern systems, robots do the same job rather than humans, reducing the time and space needed for such operations[23].

Order Processing

Fig. 90. Amazon fulfillment center, order processing and sorting section

Fig. 91. Amazon fulfillment center, order processing and sorting section

Fig. 92. Amazon fulfillment center, order processing and sorting section

Activities in an order processing unit include receiving goods, sorting and packaging, labeling, and sorting for delivery. There are various belts, conveyors, slides, and other product-moving systems which help to ease the moving and sorting and basically handling of goods. These systems are installed in warehouses by specialized companies[24].

Docking / Delivery

Fig. 93. Docking area in an Amazon warehouse


Fig. 94. Amazon at Edison, preparing packages for delivery

Fig. 95. Packages ready for delivery

The final stage of procedures in a warehouse includes preparing packages for delivery. The conventional warehouses system has a large empty area to pile up packages, sorted for different delivery services. In modern mechanized systems, there are conveyors that connect the sorting facilities to the delivery section to load delivery cars as fast as possible. Both loading and unloading happen with vehicles directly connecting to the warehouse, called the loading dock[25].

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Chapter Three

Cyber-Physical Societies

3.1. Industrial Revolutions

There are many historical moments like the Renaissance, Enlightenment, Introduction of printing, and so on, which could be marked as the beginning of the modern era in the human history, yet nothing is more symbolic than the Industrial Revolution of the 18th century which is not just a period, but a phenomenon that still shapes our world today[1]. The important role of science in the human culture and the establishment of new production methods in the factories changed the way we live, produce and work, and the way we see the world around us. The industrial revolution converted humans to the only unrivaled power on the planet which can conquer all other forms of life and harvest nature as wanted. What started by this revolution, now called the First Industrial Revolution, continued to the second and third, and nowadays, the fourth one, fast-forwarding humans to a civilization never expected in the long history before. How we live and work, what we eat and wear, even what we see as entertainment or art, and what we buy and how we buy it, is extremely affected by these revolutions. When all aspects of human life have been touched upon in this scale, architecture is not an exception.

New building materials, mass-production of bricks, tiles, iron, steel, and so on, development of the science of buildings, and global needs to new typologies of buildings or change in the old ones, all together pushed architecture to face many changes in this period. From the 18th century onwards, different styles of architecture came to life and some of them rapidly gone, as the pace of change was much faster than previous centuries. There are many aspects of architecture to look at and observe how the industrial revolution affected those, but for this research, the focus is mainly on the development of building typologies. More specifically, on the development of an industrial building, perhaps as the house of this revolution itself, where most of the production and distribution of goods happened. This study will briefly study such buildings in those periods, to see how each industrial revolutions changed their characteristics. The objective of this study is to understand what would be the scale and scope of changes that might arise as a result of the 4th industrial revolution, where its dominance over our societies is just on the horizon.

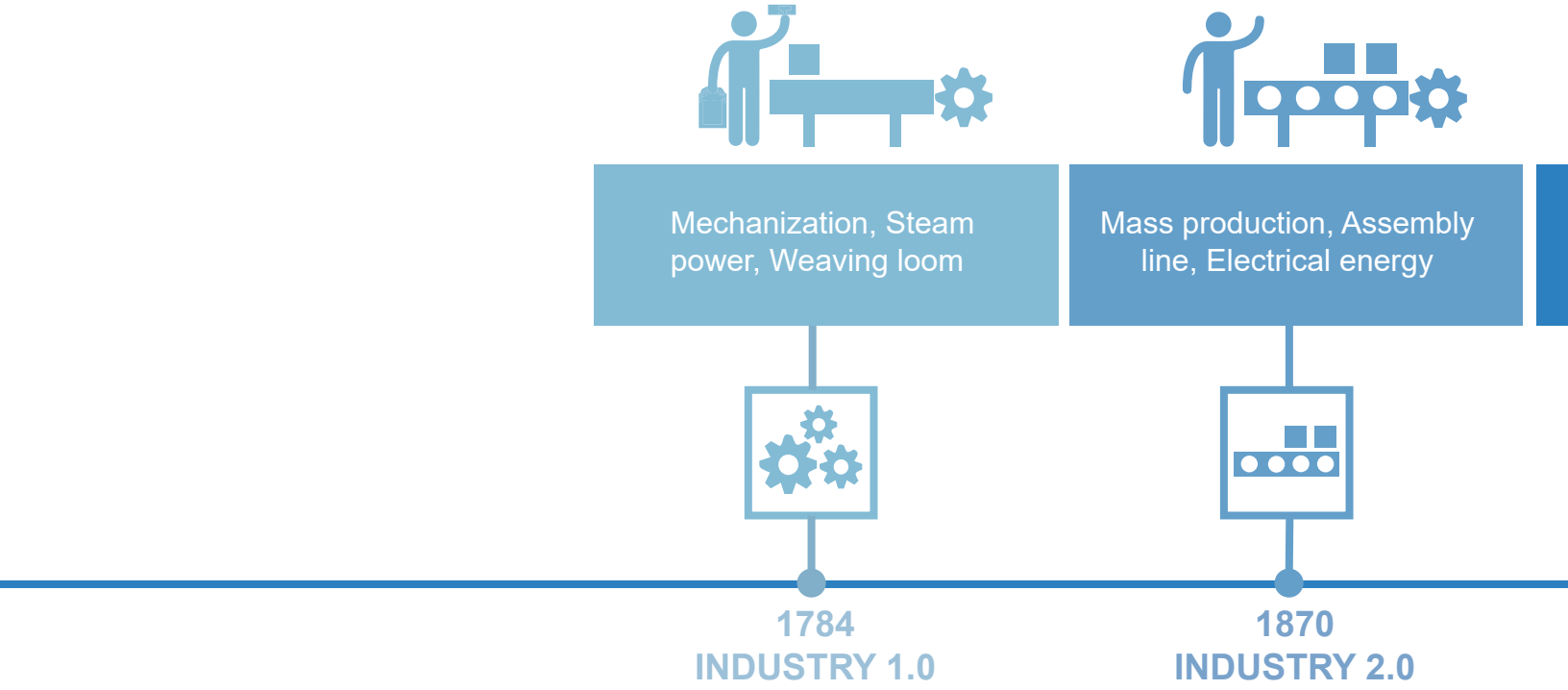
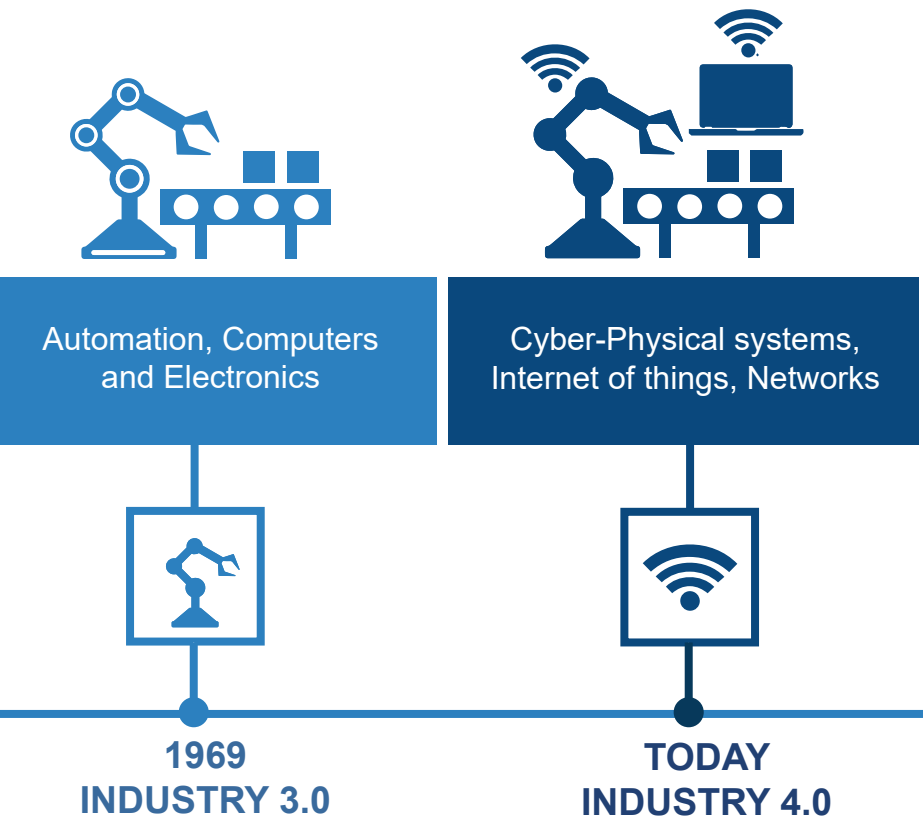
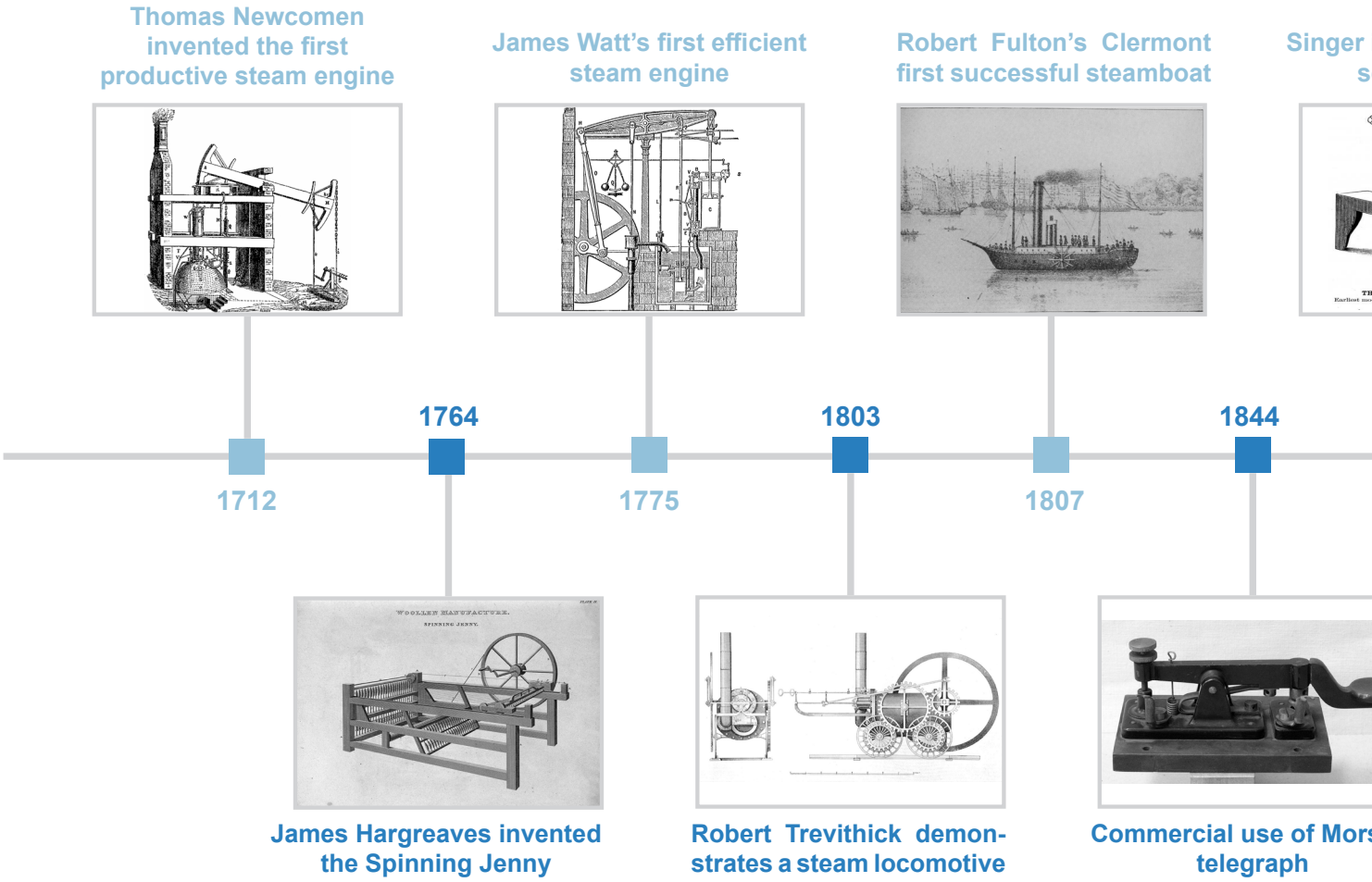


Fig. 96. Industrial Revolutions


Automation, Computers and Electronics
Cyber-Physical systems, Internet of things, Networks
1969
INDUSTRY 3.0
TODAY
INDUSTRY 4.0

3.2. The 1st Industrial Revolution

During the 18th century, the development of the steam engine, empowering factories to produce more, the introduction of powered rail transport, powered ships, and other similar technological improvements is what we know now as the 1st industrial revolution[2]. The impact of this revolution was on every aspect of human civilization, including architecture. As a result of growth in the size and production scale of factories, larger buildings needed to house facilities to spin cotton thread on spindles and weave fabric on mechanized looms[3]. The industrial revolution's major impact to help these large spaces happen was the introduction of mass-produced iron and later, steel, to the market, making such materials available choices for the building industry[4]. Steel allowed engineers to design larger spaces with slender columns, more light, less material, and let architecture detach from previous masonry techniques with classic styles. The height of this period's architecture could be observed in train stations, where new building technologies combined with new functions, but examples of industrial buildings are not so different (Figures 97 and 98).



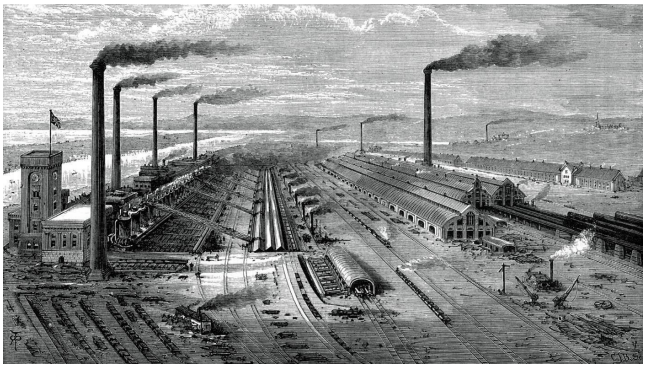


Fig. 97. The Barrow Hematite Iron and Steel Works, England, 1859-1963, an example of a large industrial building of the 1st industrial revolution

Fig. 98. Example of a warehouse built in 1867.
The Ducie Street warehouse was one of four that originally belonged to the Manchester, Sheffield, and Lincolnshire Railways (MS&LR) and is now the only surviving structure, Manchester, England. This sample shows how the introduction of steel structure enabled engineers to build multi-story warehouses.

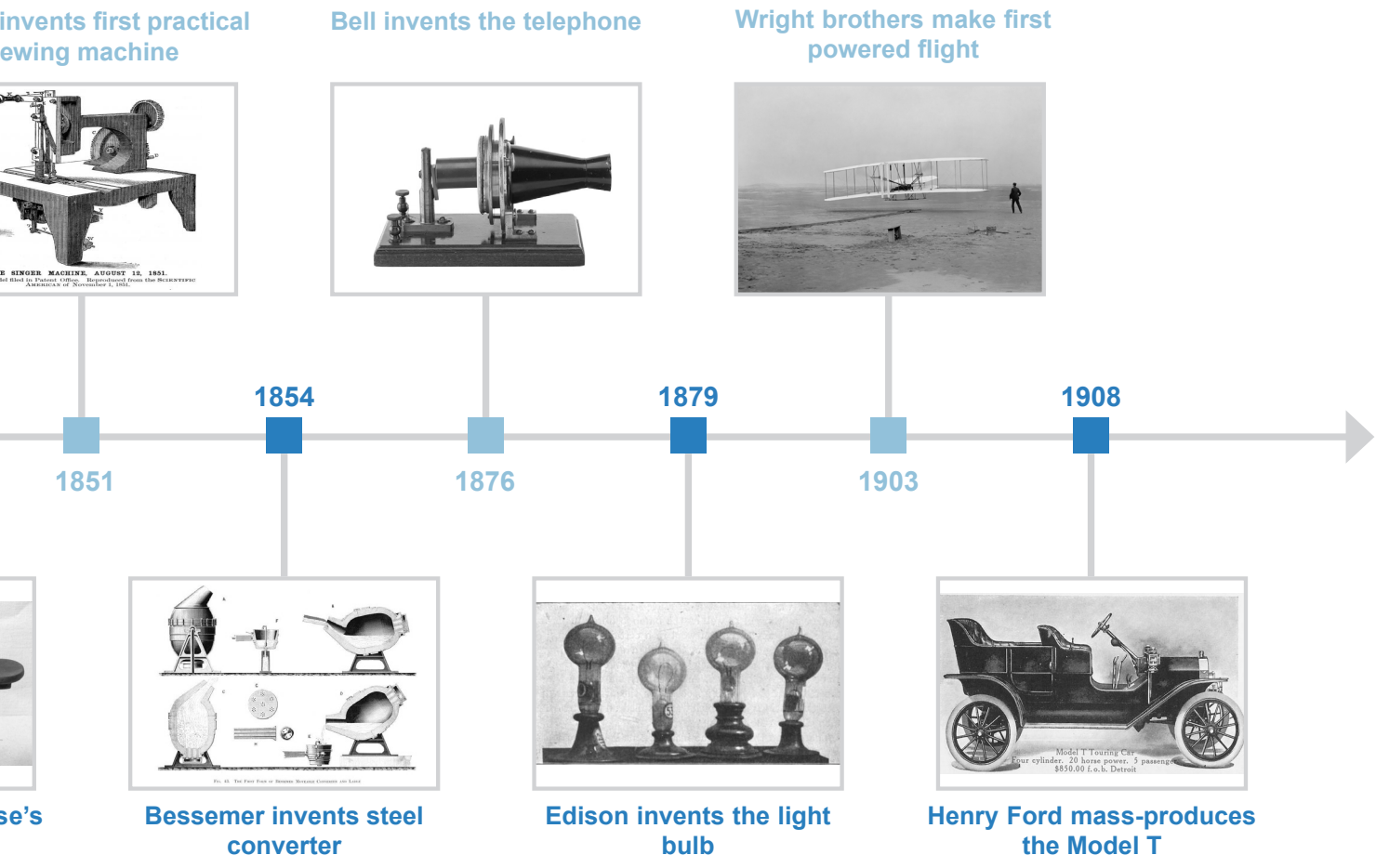


Fig. 99. First Industrial Revolution time-line

3.3. The 2nd and 3rd Industrial Revolutions

From the middle of the 19th towards the early 20th century, the technology scene started to face the development of electrical power, expansion of railroads, telegraph, and telephone, and other such advancements and ended at the most important systemic innovation for the industries: the production line[5]. This second wave of industrial development with the mass-production of goods, referred to as “Fordism”, changed the life and work of many people around the world, brought electricity, connectivity and comfort, and also wealth to their lives[6]. This also introduced new challenges to architecture: rapid urbanization and challenge of style. In terms of style, the main feature of the time is a battle between historical styles and modern ones, letting the revival of classical, Gothic, and other styles to be projected onto then steel-structure buildings[7]. But as known, this period of revival and engineering style did not last long. It is not surprising to see large industrial buildings, factories, and warehouses, to be covered with eclectic and classic styles (Figure 100). Towards the end of this period, there are samples of the architecture that are more towards modernism, which is going to be experienced extensively and dominantly later in the twentieth century (Figure 101).

Fig. 100. An example of a late 19th century industrial/warehouse architecture, Boston, US.
The essence of modern architecture being covered by a classical look is present in this project.

Fig. 101. The Turbine Factory of AEG by Peter Behrens, Germany from the early 20th century is an example of industrial buildings which are shifting towards modern architecture, leaving behind the classical styles and instead, providing large glass panels for better lighting of the spaces to provide better quality spaces for workers.

While the 1st and 2nd industrial revolutions are about mechanization and mass-production, the 3rd one is more about digitalization and automation of industries[8]. This is where new materials, automated systems, robots, and new processes and services are coming to life[9]. Automated production lines using robotics and digital systems, factories with fewer workers and more machines, and large warehouses with various storage and management systems are some of the products of this age. This period of time has been called post-Fordism[10], meaning that the idea of producing large quantities of identical items is over and it is time to alter products for the taste of customers[11]. This period happens through the 20th century and coincides with modernism, post-modernism, and movements after that. Looking at industrial buildings of modern architecture, they are becoming large scale buildings never seen before, made of space structures and steel trusses with large spans, covering very large surface areas. They are equipped with conveyor belts, automated storage, and transport systems, with forklifts and trucks supporting their material operations and many more features, all developed during this rapid modernization. Current fulfillment centers, distribution centers, and other large scale warehouses are the products of this period of time and model of the economy, especially in most of the western countries (Figure 102 and 103).

Fig. 102. The massive scale of T-600 Target warehouse, Washington, US. An example of large scale industrial buildings developed during the 20th century for storage and distribution of goods.

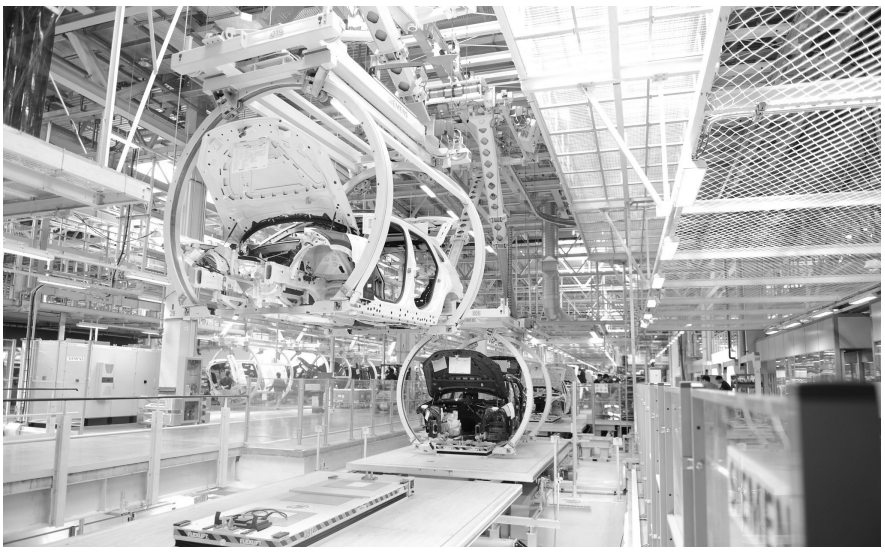


Fig. 103. BMW assembly line, one of the examples of automated, highly mechanized productions systems in which large number of tasks are done by robots and machines.

3.4. The 4th Industrial Revolution

As the first industrial revolution was about steam engine and mechanization of work, the second was about electricity and mass-production, and 3rd was mainly around digitization and automation, we are shifting towards a new era, which is mainly around connectivity, and blurring the lines between physical systems, digital technologies, and biological domains[12]. This new era, the 4th Industrial Revolution or the time of cyber-physical systems, is characterized by the dominance of the Internet, big data, connectivity, artificial intelligence, autonomous vehicles, 3D printing, and so on and so forth. The new revolution, similar to the previous ones, will bring challenges, but also opportunities too. There are going to be millions of people and loads of businesses to be affected by this new wave, both in a positive and a negative way: some gain more, some lose.

One of the important aspects of this new era is a technology which is driving the 4th industrial revolution in many ways. One of the examples is artificial intelligence (AI). AI could be seen as the mind of machines. Programs and systems which can recognize patterns and extract information and solutions for problems based on those patterns. They can be used in many ways, from driving autonomous cars to systems in websites proposing to us what to buy or pushing targeted advertisements to us[13]. Another important technology is virtual reality (VR) and augmented reality (AR), both helping us to see a mix of reality and imaginary objects together, and also seeing the world with extra information which is not really present physically, but could be added digitally through a device with which we are looking at the world[14]. Perhaps one of the most important areas of technologies these days is biotechnology, where there is this urge to understand what is going on inside human bodies or other living phenomena and to see how life could be sensed, monitored, and connected to this web of connectivity. Other applications include harnessing cellular and biomolecular processes to develop more efficient production procedures, fuels and so on[15]. Another interesting field of technology for the 4th industrial revolution is 3D printing. 3D printing or additive manufacturing is a process of making objects through a layer by layer addition of materials, representing very thin sections of the form through layers to be shaped by the deposition of material[16]. This technology is very important for manufacturers as it is believed to be a game-changer in the making of products in the future. While technological advancements are not limited to these, and we have not covered digital currencies, innovative materials, and so on, we should have a look at IoT devices and systems. These are simple devices that are connected to the Internet, meaning that they can send and receive information[17]. While initially, it was computers and then smartphones which were connected to the web, it is now extended to everything which has this possibility, either a fridge to send information about the stuff inside, or a plant to send a message when thirsty. IoT would be a pillar for a highly connected society in this new era.

All these new technologies would have multiple levels of impacts on societies, humans, and especially businesses, where they have effects on customers and their demands, effects on the products, and on the business models themselves, their production methods and facilities, and finally, on the innovation[18]. In each of the sections above, there are expectations for changes to happen, where the result will not remain in the circle of the business itself, but it will affect other related sectors too. So far, the most important point that has been talked about is the labor force and the future of the workforce[19]. For this research though, we will go back to architecture. For this study, the focus is to see how such changes are going to affect architecture.

In order to see the effect of new technologies on architecture, we should focus on two different sides. The first side that we will study is the physical aspects of architecture being influenced by the implementation of those technologies. But the other side of the impacts is programs and functions and how they will change our behavior, our way of living, or mode of working. Although both these sides are highly connected and affecting each other, we are trying to categorize them for better understanding and analysis.

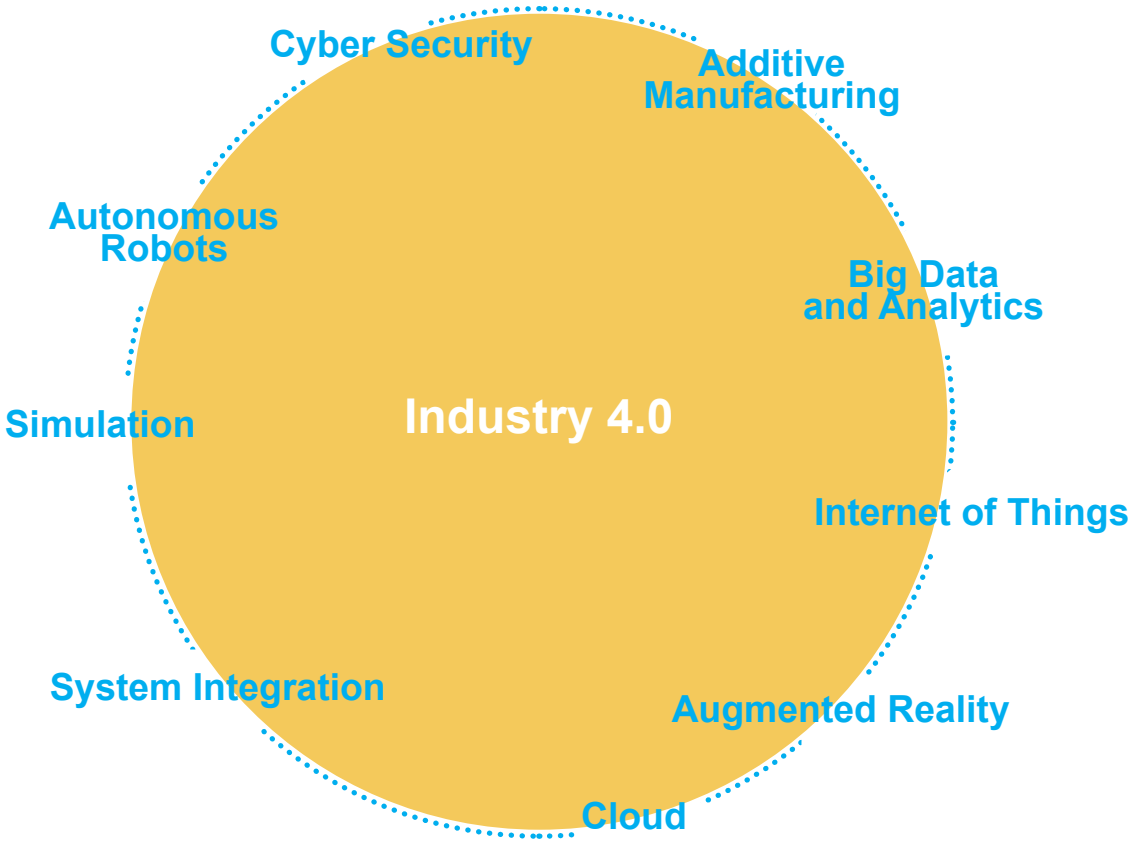


Fig. 104. 4th Industrial Revolution

3.5. Physical Implementations of New Technologies in Architecture

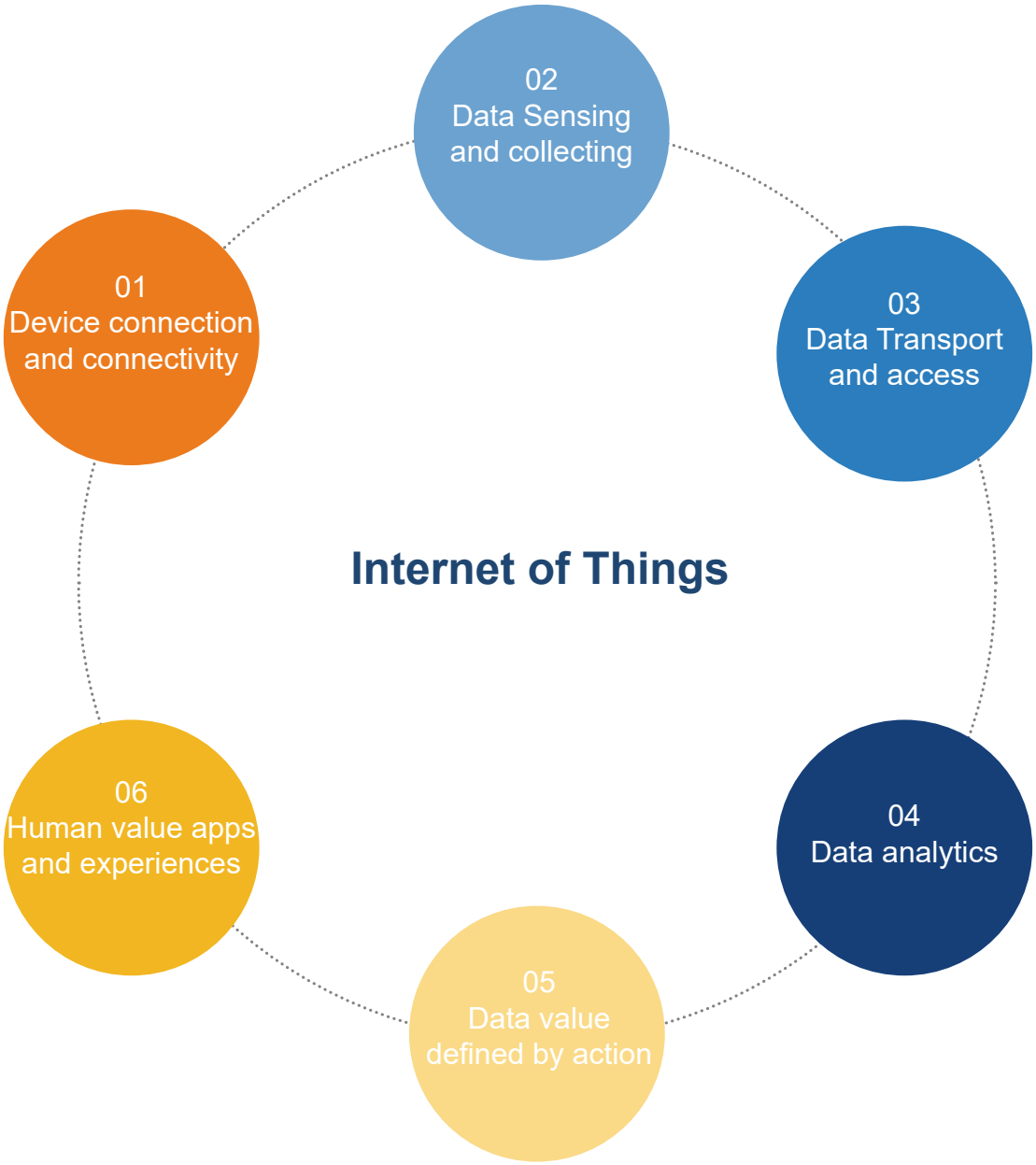
In the last few years, many different technologies have been developed and implemented in buildings, some of them controlling its environment, some of them making it “smart”. Here two of those important technologies are reviewed.

3.5.1. IoT and Smart Buildings

As mentioned earlier, IoT (Internet of Things), relates to the connectivity of almost anything to the web, letting objects, animals, and plants send and receive data. Nowadays, it is possible to connect an automated coffee machine to the web for sending instructions for brewing while you are not physically there. It is also possible to connect flower pots to the web to monitor their health and water them as needed. It is becoming possible to connect the fridge to the net as well, updating whatever inside it, to make sure that we are never running out of any essential food, we are not losing the expiry date of products, and we can get smart recipes based on the available ingredients[20]. This of course is happening by the developments of many sensors and detectors and also advancements in web and connectivity, big data, and many underlaying technologies and infrastructures which are keep growing to provide more services and facilities for our lives.

So far there have been so many scenarios for IoT in domestic scales. From the connection of appliances to the web, to control energy consumption and interior climate with smart sensors and connected air-conditioning systems, automated window blinds, connected lights, and so forth. The home environment could be set for work mode or relaxation and sleep mode, only by a command, and now this information is connected to the web, so the data is available to higher-level services and infrastructures. In this way, service providers, Online-retailers, and infrastructure providers could be aware of the demand and needs of the market that they are providing products and services for, so they could adapt themselves to the demands without the need for the production of extra goods and services to be wasted. For example, in terms of energy use, it is believed that IoT monitoring could provide more accurate data, for predictions, for monitoring patterns, so it would be much easier to see the real demand of the market. In factories, it becomes even more precise to see how much energy each part uses, to control and optimize it. So IoT could be a potentially powerful solution for issues like energy management[21]. It has been claimed that it is even easier to adopt green energy and store energy while we are using IoT devices with constant monitoring and live data and making decisions where to save electricity and when to have the maximum load based on the use[22].

In such an automated world, there are challenges too. We might be bounded to a certain product for a long time where your stock is kept updating automatically. One may receive more toothbrush than needed, as the old one which is expired, still perfectly works. These challenges should be observed and little by little solved. More complicated challenges like security issues are also important, bringing the example of a door that is not listening to the voice of its owner, not letting them in.



01 Device connection
IOT Devices
IOT Connectivity
Embedded Intelligence

02 Data Sensing
Capture Data
Sensors and Tags
Storage

03 Communication
Focus on Access
Networks, Cloud, Edge
Data Transport

04 Data Analytics
Big Data Analysis
AI and Cognitive
Analysis at the Edge

05 Data Values
Analysis to Action
APIs and Processes
Actionable Intelligence

06 Human Value
Smart Applications
Stakeholder Benefits
Tangible Benefits

Fig. 105. Internet of things

3.5.2. Automated Warehouse Storage

Automation was the outcome of the twentieth century, where robots worked instead of workers, to do hard jobs, repetitive tasks, highly precise actions in a fast and efficient way. But as a result of information-driven management systems and robotics, Amazon now utilizes robots that are moving inventory shelves in its warehouses, not in a repetitive pattern (Figure 7), but with actual demand coming from the Online retail store. The process has different stages[23]:

- The shelving personnel, place items in empty shelve slots. They do not need to place specific items into specific shelves. They just need to find empty ones, randomly. They will scan the barcode of the product and the shelf slot, so they associate a product with a location. This will result in a similar product being stored randomly on many shelves.
- As soon as an Online order is received, a robot goes and brings the closest shelve which includes the specific item of that order. At the front line, picking personnel will take that item off the shelf. The robot will take back the shelf to the storage area.
- Moving shelves keep going back and force with the autonomous robots which are finding inventory very fast. Shelves are being re-stock by shelving personnel and products are preparing for delivery on the other end.
- Amazon claimed that the time needed to prepare orders dropped down from 60-75 minutes to 15 minutes thought he uses this system.
- Amazon also claimed that they could stock 50% more products in their storage[24].

They said that in some cases, as soon as a customer clicks to place an order, a robot will start moving to bring the product forward for collection.

Once again, ideas and technologies of automation are not new, though these implementations are dependent on information technology, connectivity, digital order processing, and so on, which makes them relevant to the ideas of the fourth industrial revolution. Such systems are changing the way a warehouse should be designed. The storage area becomes the place where all these robots are moving back and forth, and no human is present. They are storing, moving, and restrain shelves and working constantly. They change the way humans are also working and interacting with machines. All in all, these new technologies will open up many new possibilities for architecture and the performance of spaces.

Fig. 106. A robot bringing a shelf for the pickup of items in an Amazon automated fulfillment center

3.6. New forms of Architectural Spaces

The effect of this new era is not just visible in terms of technologies, facilities, and devices, but also on the programs of buildings and functional aspects too. In fact, the introduction of these new tools started to change the architecture in its programming and functional level, which is studied in the next two examples.

3.6.1. Distribution and Fulfillment Centers

Distribution and fulfillment centers could be seen as the contemporary development of warehouses. In the conventional mode of production, there were factories to produce goods, warehouses to store them in bulks, and shops to display and distribute them. Shops should have a stock of products, so they could serve individual customers. With the expansion of online retail markets, the purpose of shops is shifting towards Online websites, so for such businesses, there is no shop to distribute the bulk of goods between individuals. That becomes a task to be done in a distribution center[25]. A distribution center is located in the outskirt of the city, non-accessible by customers, but it serves individual customers. It mainly receives goods in bulks but distributes them between individuals through Online orders (Figure 8). So the warehouse which supposed to receive and send bulk items and should receive mainly bulk items and distribute it and even handle individual returns too[26]. While a conventional warehouse is supposed to have large, bulk items, stored in large shelves and handled with forklift trucks, in a distribution center, we have stocks of small items, and handling and packing of multiple, irrelevant items at the same time to be delivered to a single customer. That is why the handling of goods is totally different from that of a conventional warehouse. A distribution center has conveyor belts and other transporting facilities to make goods handling easier. As there is no bulk item to be sent, a forklift truck is not useful to handle goods, though a “picker” should find and pick a product and send it for packaging and delivery. All in all, the whole process of storing, picking, handling, and finally packaging and delivery of the item are different from a conventional warehouse, though it is still happening in a physically similar space, just larger.

This shift of functions happened as a result of Online shopping and the advancement of technologies that support these procedures. As discussed in the previous section, the development of automated storage systems helped to have a more efficient working procedure in these spaces. As a result of these shifts, the number of people needed to work in a warehouse raises a lot, as there is much staff needed to handle individual orders. Because of the relatively fast process of handling goods, items store for fewer times in a distribution center, and the shelving and picking happens constantly and rapidly[27].

3.6.2. Dark Factories

Dark factories or light-out production is a mode of production where there is no human presence in the production line, and there are robots that are fully controlling the production line. In fact, with the improvements in automated and robotic fabrication, the advent of artificial intelligence, machine learning, and the Internet of Things, what has been called Industry 4.0, machines are becoming better in doing complicated jobs and with cognitive capabilities and controlling and measuring sensors, they become more independent from humans[28]. Changing Precision Technology Company in Dongguan, in China, is an example of a shift towards less staff production where they reduced their 650 workers to 60, substituted the staff with robots, where they increased their productivity by 250% and reduced their defects by 80%. But it should be understood that 90% of their staff lost their jobs[29].

Although there are many discussions about the social and economic changes that come from this shift of production, this research would focus on the architecture with the understanding that such changes will affect it eventually as well. While such production modes will not require humans to be present, the standards of design in such buildings are mainly around machines, movement of robots with tags, conveyor belts and other automated material handling facilities, and so on. There is a web of connectivity between production, monitoring, material handling, feedback, and control which all together support the production to happen fast and precise. These tasks will need fewer workers, but those who are good in controlling, making decisions, with good computational skills, also with coordinating, supervising, and management capabilities[30].

Fig. 107. Sample of dark factory; robots in Tesla's factory

3.7. The Future of Work

Any potential re-shaping of the working environments, including warehouses, is related to the changes to the ways people would work and interact. These days, looking at the title of “Future of Work” or “Future of Jobs”, we see that the notion of the 4th Industrial Revolution and the impact of digitalization and artificial intelligence is a dominant paradigm with which everyone is trying to define how the future of work may look like. It is, of course, clear that the world is changing, but we should understand that the scope and speed of change are not yet like a sharp decline. The very first point that experts are trying to say is that the scene is changing, some jobs are eliminated, but at the same time, new jobs are emerging[31]. Here, the main concern is that the elimination of jobs is not happening evenly, but the loss of jobs would affect some groups of people or some regions of the world more effectively than others, which may disrupt the work and life of large groups of people[32]. On the other hand, there will be jobs which will remain open, as there are not enough experts in the newly emerging fields that companies are looking for. This means that the shortage of workers would be another issue that will hit the market as well[33].

What are the suggestions for the current situation? Paul Wellener, Ben Dollar, and Heather Ashton Manolian from Deloitte have suggestions from their own perspective in manufacturing jobs[34]:

- one important point is to keep retraining the workforce, while rearranging the organization to adapt new technologies. While it is good for reducing the cost of repetitive tasks, it is valuable to create meaningful jobs for employees as well.
- As automation freed workers from repetitive tasks, they now have time to show their “soft” skills that reflects their real “human” side. These may include creativity, critical thinking, people management and so on.
- Although works are being transferred to machines, workers need to have a good working knowledge of digital tools, as completion of tasks is highly related to the humans working with these machines and working together effectively. That is why even work-based social media is important now.

They finally suggest that success in this competitive market depends on the good integration of digital technologies and skilled humans, working hand in hand to produce valuable products. The prominent point, as James Manyika mentions in a conversation with Peter Gumbel at the McKinsey Global Institute[35], these new technologies are coming to businesses as we see the benefits, but at the same time, most of the parties involved are trying to facilitate this transition for workers and the society. The same point has been argued by Carl Benedikt Frey as the most important part is how we are going to manage the transitions in the short term[36]. All in all, the future labor market seems to need more skilled and mobilized workers[37] with less repetitive tasks, and this is a fact that will affect the future of workspaces too. If most of the ordinary tasks are done by robots, humans are on higher-level jobs which will happen in different spatial and functional organizations. It is worth finishing this section with a coat from Klaus Schwab that believes: “The Fourth Industrial Revolution represents a significant source of hope for continuing the climb in human development that has resulted in a dramatic increase in quality of life for billions of people since 1800”[38].

3.8. Outlines for the Future

Following the concepts of mass-customization and personalization, today the idea is to shift from mass-production (of most of products) towards on-demand production of goods as much as possible[39], and various parallel technologies like IoT, 3D printing, digital fabrication, and so on, will help to accomplish that. Following this trend, the scenario for operations in a fulfillment center, and some other types of warehouses which are dealing with retail, is a shift in operations to go beyond the current model of storage-only and include some types of productions too. This idea will push such facilities towards manufacturing warehouses[40]. This may encompass actions such as on-demand printing and binding of books and magazines, on-demand 3D printing and preparing products and parts, partial to full assembly of projects, and more. This scenario will affect the warehouses in two different aspects: first of all they will need additional spaces to house those new activities. The second would be a change in the staff and a shift from low-skilled only, to the variety of skills needed to work together to run such facilities. This will affect the design scenarios of the future warehouses.

In order to fulfill the acts discussed, future warehouses should expand their programs to include various types of operations. These operations include previous storage and distribution works but might include some level of design procedures (like the combination of online designs to be completed in the house), preparation of customized products for fabrication, on-site fabrication of different products, using different types of high-end types of machinery, instructed and not-so-complex assembly of parts to make some of the ordered products, printing customized instruction booklets, printing, and bindings some books and magazines, all the way down to the packaging of products for final delivery. These are the example of operations that could become part of the daily routine of such warehouses, and each of these operations could be broken down into various sub-operations to be done by different teams. Fulfillment of such operations needs a new arrangement of spaces to house different types of machinery and staff, none of which is addressed in the current scenarios of warehouses.

These new arrangements should include spaces for production and assembly, also spaces for some minor design, prototyping, or even brainstorming activities too. These types of spaces and their related services should be embedded in the program of such facilities. It should be noticed that the employees, who spend days and nights working in such facilities, are people with multiple skills and talents, and this encourages us to put more energy and effort to understand the spatial qualities of such facilities and address them through design investigations as well. This should involve, but not be limited to, their social interactions, entertainment and refreshment, and even possibilities for training and personal improvements. Such spatial qualities are not just providing welfare for the employees, but also playing a role in this shift of operations.

One may argue that a warehouse may not necessarily need to serve as a production platform regarding the idea of the fourth industrial revolution, and such scenarios still need to be further developed. The answer is ‘True, but isn’t research like this act as a vehicle to carry such scenarios?’. The purpose of the research is to investigate scenarios, address possibilities and shortcomings, and provide solutions as much as possible. The minimum outcome of this research could be better spatial qualities for warehouses, but at its best, it may offer new operational/functional scenarios for the future of warehouses. In fact, this will open up opportunities for new spatial programming and design investigations about this topic which may result in better capabilities of such spaces for the future.

The last, yet the biggest challenge in front of this research with a topic regarding the future, is the model with which we are analyzing warehouse spaces and their future. This model is based on a common understanding of economic demands and growth. In contrast to the common belief, we see arguments like Vaclav Smil’s “Growth, From Microorganism to Megacities” in which the idea is “growth is finite”.

Whether microbes, animals or humans and as such their other aspects of life including economy is limited to resources and those are finite. And more than that, Smil argues that the ultimate constrain is sustainability and the environment. He mentions “Continues material growth, based on ever greater extraction of the Earth’s inorganic and organic resources and increased degradation of the biosphere’s finite stocks and services, is impossible”[41]. This very critical argument should lead us towards a point-of-view in which we should not promote more consumption in our scenarios. What we should put forwards is to make our processes (like making and distributing goods) smarter, avoid using more material and energy to mass-produce goods which might never be used and going to be stocked for long times, and focus on a very selective market, design responsibly and manufacture only when needed. With environmental responsibilities in mind, new scenarios for warehouses could function even better than the conventional ones, yet there are many more researches and investigations needed to embed such responsibilities into our design endeavor.

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Chapter FOUR

Design Studies

4.1. Design Statement

People's modern lifestyle, especially in highly urbanized areas, has been combined with many different needs for which people are buying goods, gadgets, and many different types of materials and products. To provide enough products for urban citizens, there are extensive supply chains that connect every single customer to manufacturers and producers of those goods. Warehouses and fulfillment centers are part of that supply chain. They are located in the middle, between the manufacturer and the customer, where bulk supplies could be broken down into individual items to be distributed. On the planning side, warehouses again stay in the middle, where we have large industrial facilities outside of cities and residential dwellers inside the city, and in the middle, it comes to a warehouse that locates itself in the outskirts of the city to be a transition of these scales. Contemporary warehouses are large scale facilities with different applications that are essential for storing and preparing goods that people are using in their everyday life. As such, they are interesting and important topics for design investigations. As we humans are facing various changes in the way we work and live and also shop, many things around us, including warehouses are going to be affected and perhaps see some changes too. Since such changes have been investigated in this research, a design project would be a good testbed to see how new ideas could be combined with the existing ones and produce better spaces for the future.

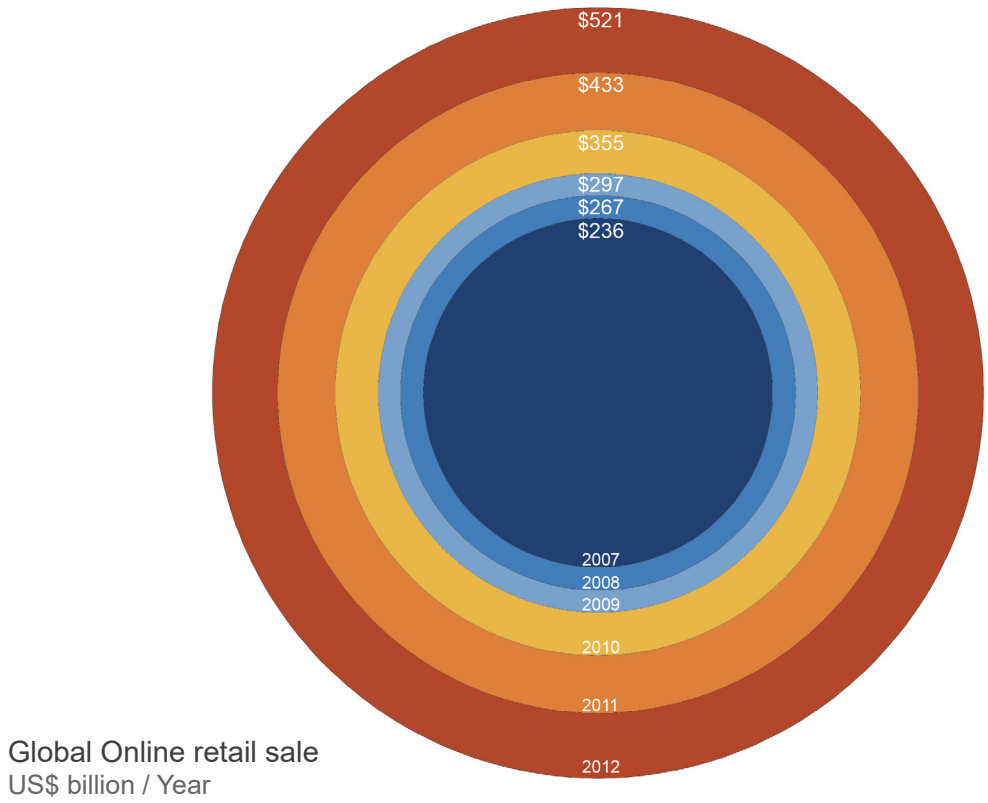
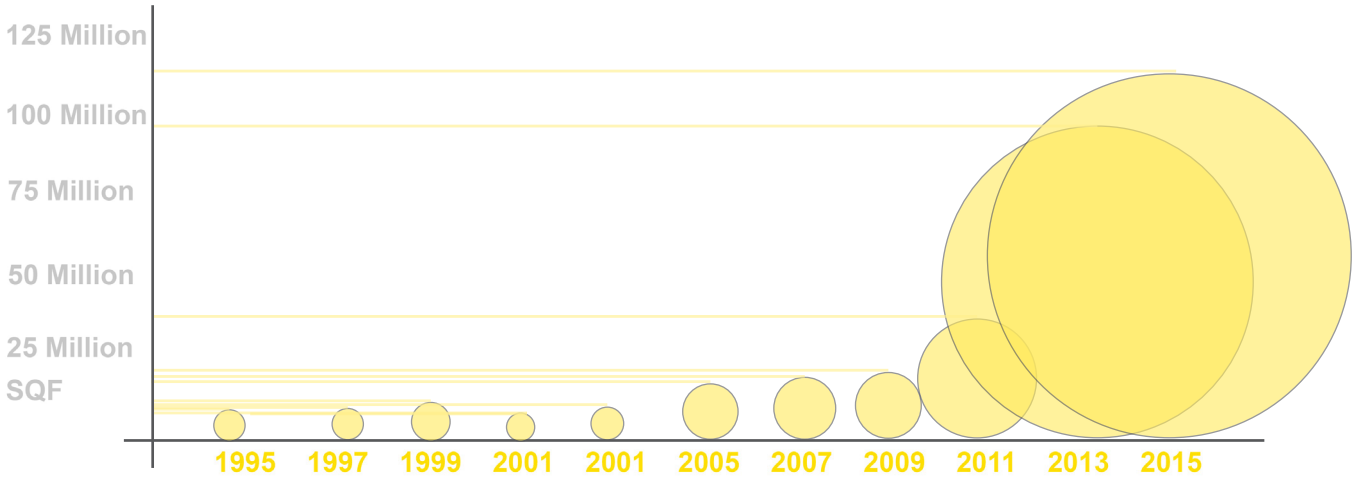


Fig. 108. Growth of global Online retail sale

Amazon Fulfillment Center

Why is an Amazon fulfillment center a good option for design experimentation in this thesis? The topic of retail and commercial spaces have been studied more than Online retail as they have been with us for a much longer time. It seems that we need more studies on the spaces related to Online retail. Among various types of spaces that an Online retailer needs to operate, fulfillment centers are for sure the most complicated ones where the most important parts of the operations, storage, and package consolidation up to delivery happen. Moreover, in this context, Amazon is the largest company in the world that operates in different continents, with many facilities and employers with many positive and negative feedback. Amazon started the business in 1994, and soon after three years in 1997, the second distribution facility in Delaware was opened[1], to be the beginning of a move that finally reaches all US states and later, many locations in the world. Having seven fulfillment centers in Ontario itself shows how vastly it operates, and the growth rates show how much more we should expect to see from Amazon in the future.



Amazon's Footprint
Square-feet / Year

Fig. 109. Growth of Amazon's footprint

Post-Fordism, Customization and Personalization

One of the issues studied in this thesis is that a warehouse represents a production-consumption model in which goods are being produced in large quantities and stored in warehouses to be distributed between the costumers. However, things are changing and demands are shifting. Today, we are facing societies with interests in customized products in order to fulfill certain needs[2]. Such needs might be limited to individuals or a very limited group of people, yet they want to have a solution for that. There is also this demand for personalized products to be unique to satisfy a customer's taste. All in all, these new trends are shifting the production of goods from mass-produced towards customized ones. This means that a fulfillment center could be a hub to consolidate orders that mix both types of goods. For that, such products could be produced elsewhere and shipped to the warehouse to be combined or produced in-house to reduce operations costs. Considering the potentials of in-house production of (certain) types of goods is a challenge that is going to be addressed in this design stage. This idea is built on the fact that production types of machinery are far more customizable and achievable in the age of digital fabrication.

New Modes of Production

Advancements in the fields of digital fabrication tools, 3D-printing machines, and robotic arms for production and assembly of complex goods is noticeable and has been marked as one of the most important factors that will shape the future of our lives. The fact that new digital types of machinery could produce objects on-demand, with a press of a button, is the base of a revolution which is already started to happen. With this production strategy, (at least some) goods could be produced outside of large industrial establishments and instead, in smaller production platforms using all these newly introduced technologies. This will facilitate the production of low-volume goods, customized ones, and even individual items. Coupling the production platform with the establishments in a fulfillment center would ease the access of customers to these types of products, connects designers almost directly to customers, and provide many potentials for the marketing and use of such products. In order to shift the idea of mass-production to customized production scenarios, we cannot think only of factories getting equipped with digital technologies of production, but we need to rethink the entire production procedure and supply chain to be able to embed these new procedures into practice[3]. This is what we are going to test in this design scenario.

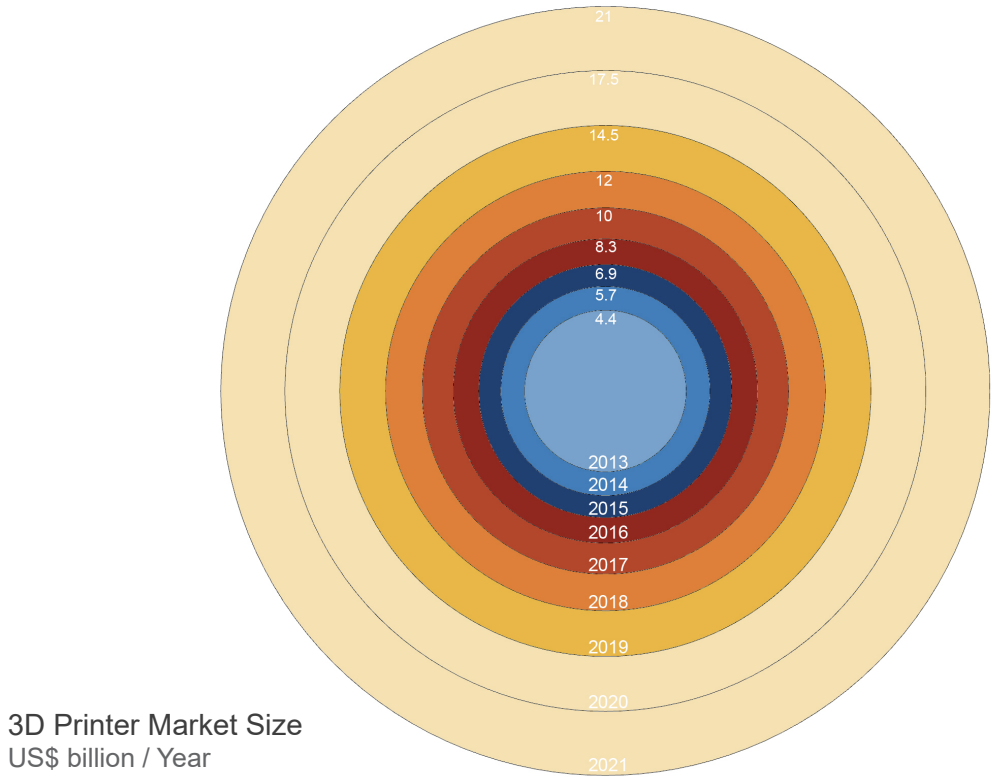


Fig. 110. Growth of 3D printer market size

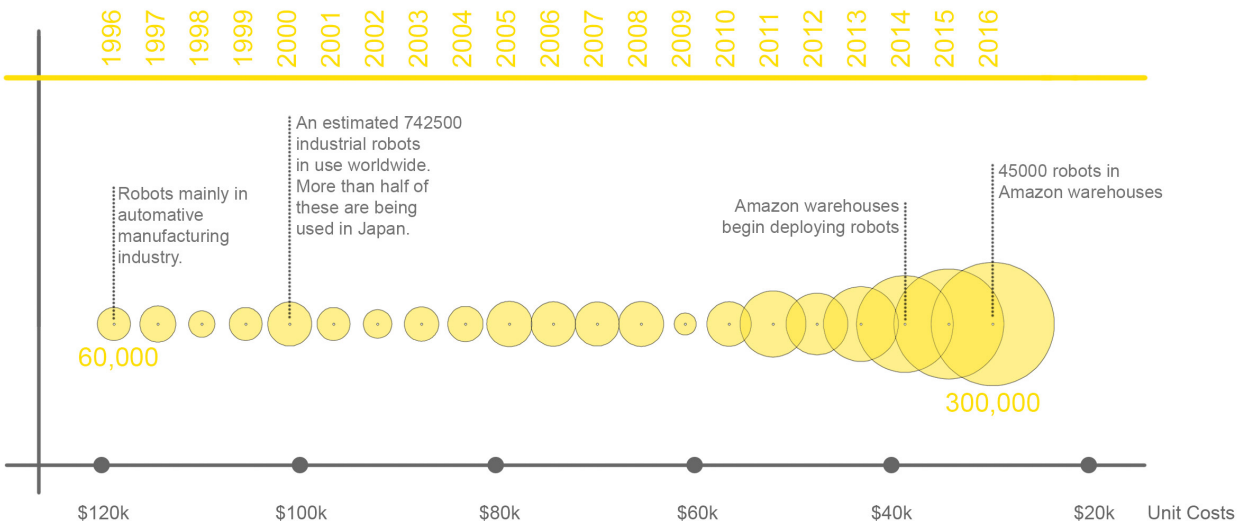


Fig. 111. Growth of industrial robots

Energy, Environment and Material Impacts

The last, yet the biggest challenge in front of this research with a topic regarding the future is the “model” with which we are analyzing warehouse spaces. This model is based on a common understanding of economic demands and growth. In contrast to the common belief, we see arguments like Vaclav Smil’s “Growth, From Microorganism to Megacities” in which the idea is “growth is finite”. Whether microbes, animals, or humans and as such their other aspects of life including the economy is limited to resources and those are finite. And more than that, Smil argues that the ultimate constrain is sustainability and the environment. He mentions “Continues material growth, based on ever greater extraction of the Earth’s inorganic and organic resources and on increased degradation of the biosphere’s finite stocks and services, is impossible”[4]. This very critical argument should lead us towards a point-of-view in which we should not promote more consumption in our scenarios. What we should put forwards is to make our processes (like making and distributing goods) smarter, avoid using more material and energy to mass-produce goods which might never be used and going to be stocked for long times, and focus on a very selective market, design responsibly and manufacture only when needed. With environmental responsibilities in mind, new scenarios for warehouses could function even better than the conventional ones, yet there are many more researches and investigations needed to embed such responsibilities into our design endeavor.

Returning for Reusing and Recycling

To address the challenges introduced above, an extensive program of returning, reusing, and recycling of products is needed. With this scheme (which already exists partly), items should be returned back to the warehouse, especially after being used and wasted. This could facilitate the process of disassembly and recycling of them. We can imagine that the products which are 3D-printed in the warehouse could be recycled back again, converted into filaments and powders that could be used in the production platform directly. This coupling of production and recycling needs many strategic plannings to be combined with the operations and logistics of the company. But still, part of it should be done in specific spaces that are going to be embedded into the program of the future warehouse, in this design experiment.

The Future of Warehouses

In order to summarize, the design stage of this thesis would incorporate a modern warehouse that is acting as a fulfillment center to work for Online retail (Amazon). This fulfillment center would be equipped with all modern technologies of automated storage and retrieval system and so on. In order to push productivity and environmental responsibility further, this warehouse is going to have a platform for recycling, especially for products that are made in-house. This reflects the fact that it is intended to have a production platform and a design and engineering platform to be coupled with all the scenarios of making customized goods. This warehouse is located in Scarborough, Ontario. More details about the design, program, and site of this project are going to be followed in this chapter.

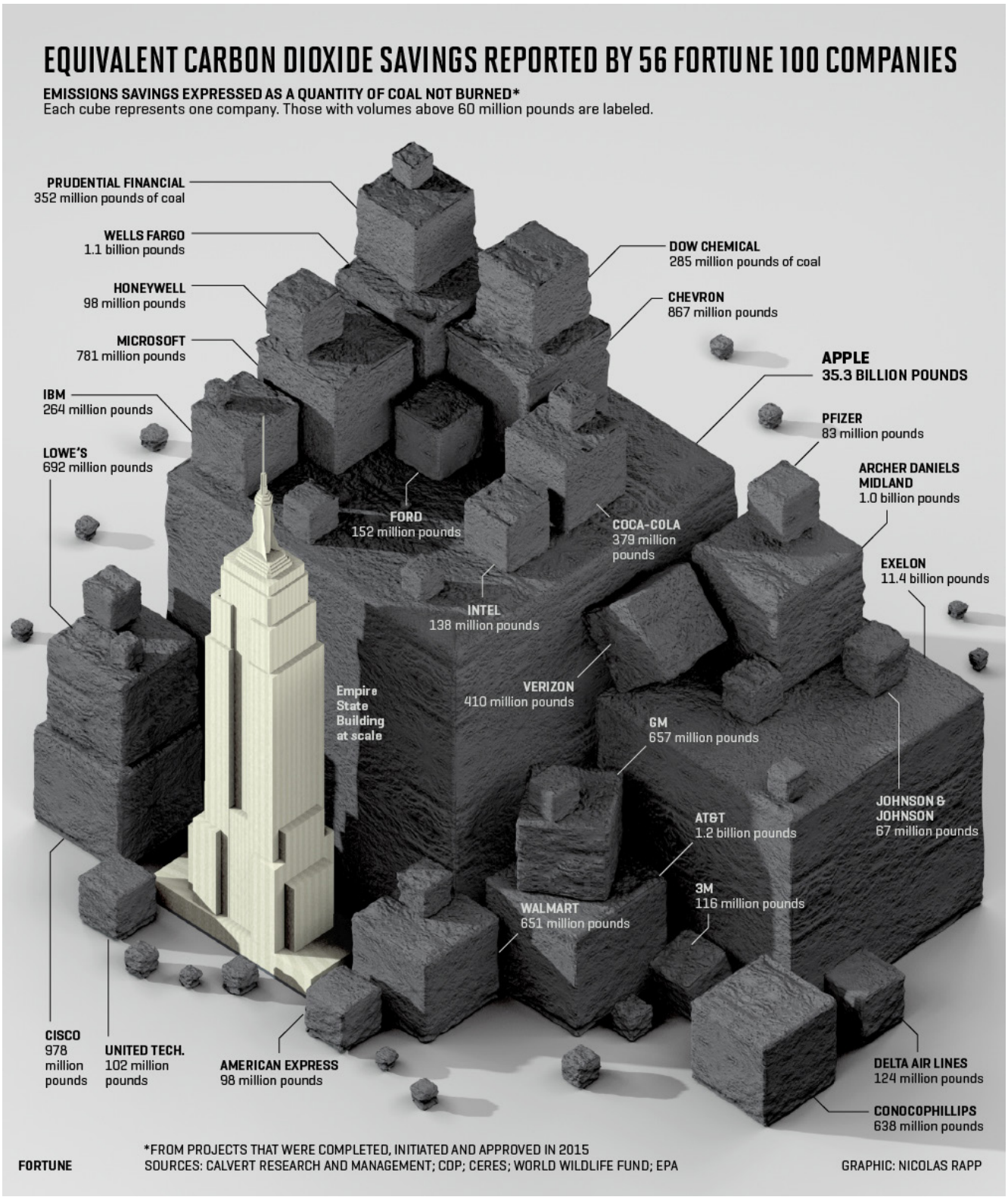


Fig. 112. Equivalent carbon dioxide saving reported by 56 fortune 100 companies

Amazon's Climate Pledge

Amazon itself works on the Sustainable Operations initiative to reduce the carbon emissions in its operations and is now committed itself to the Climate Pledge by which it agrees to reach net-zero carbon across its business operations by 2040[5].

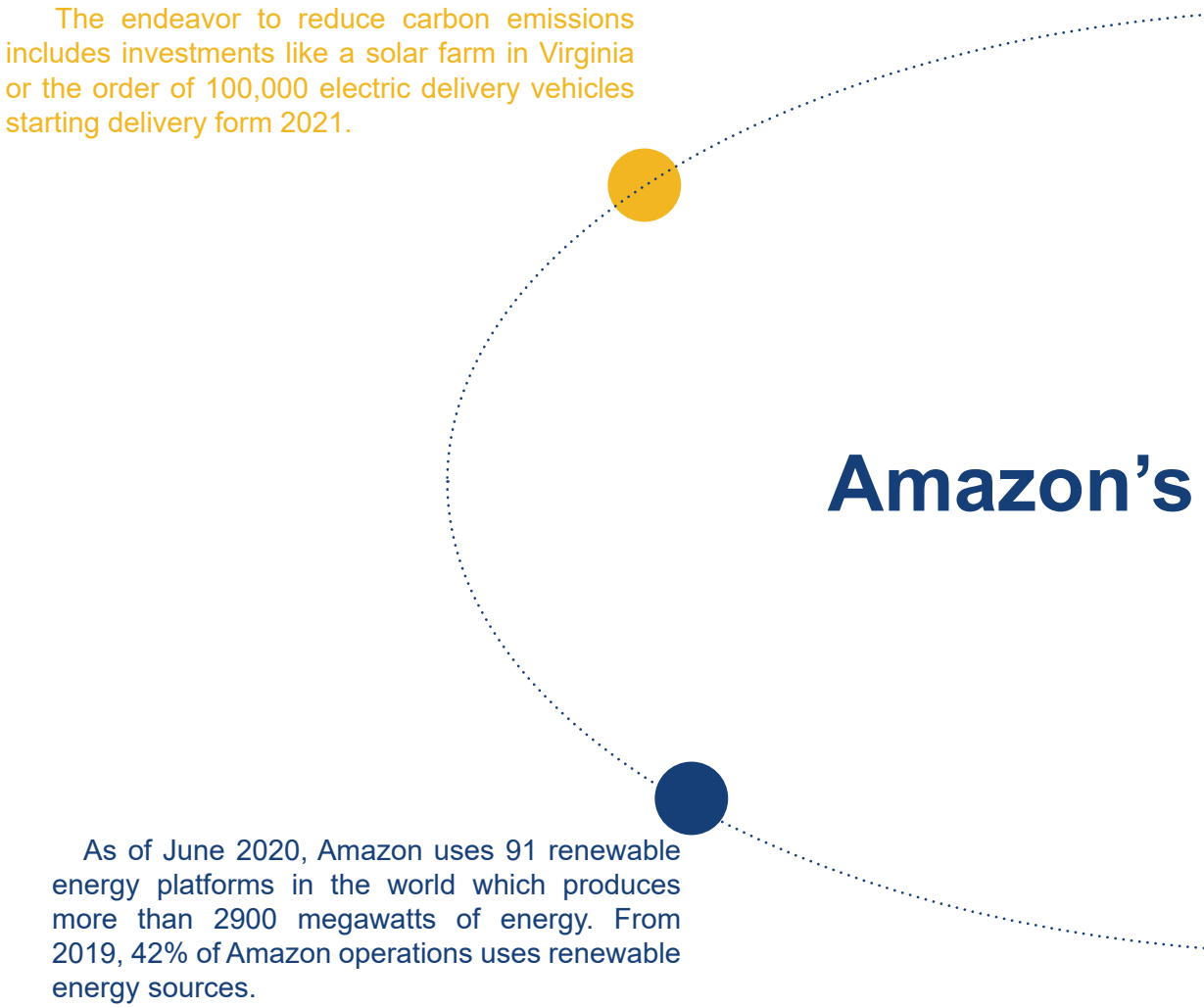


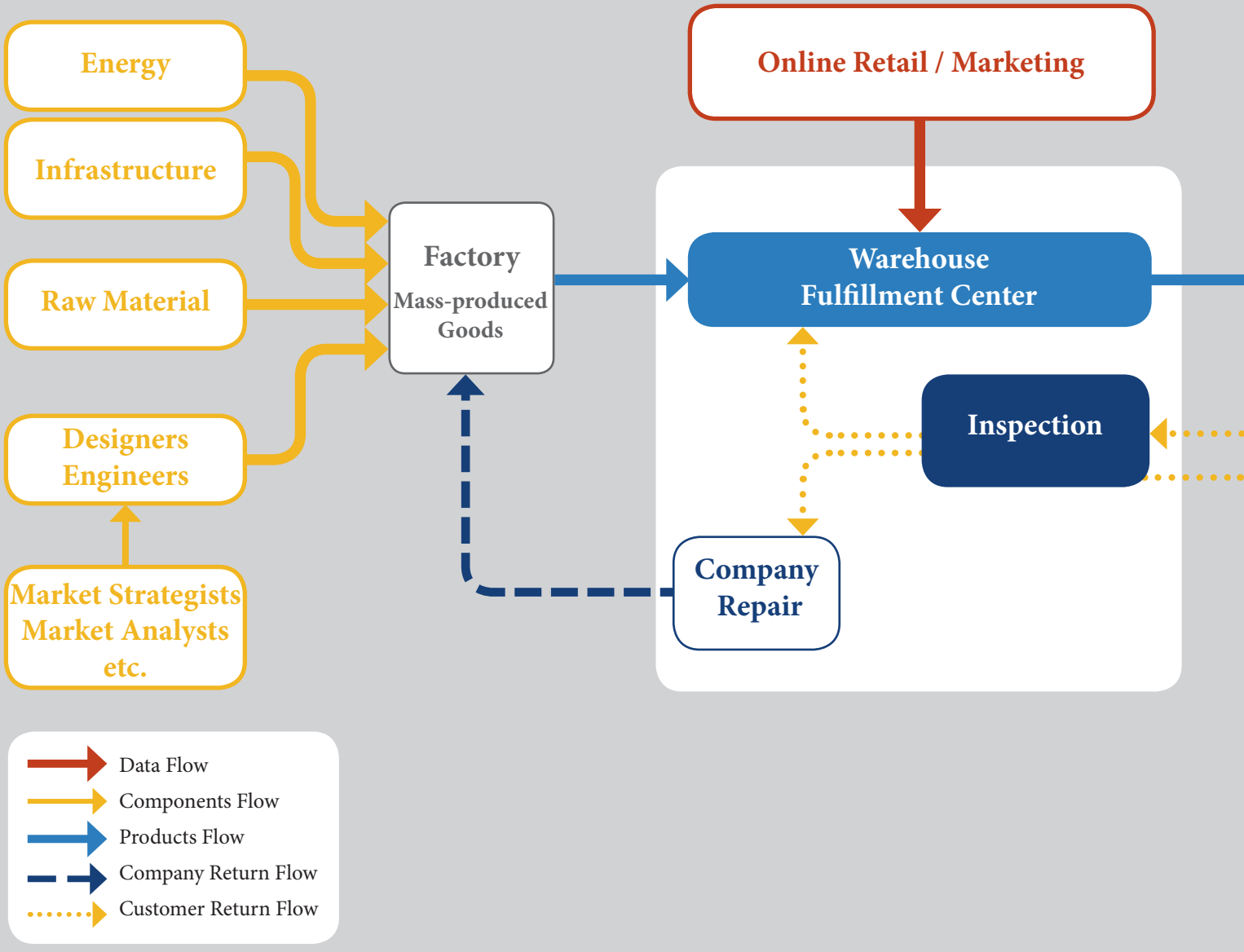
Fig. 113. Amazon's climate pledge

Sustainability

Amazon works on the Shipment Zero initiative to reach its 2040 goals. This means that all operations happen inside the fulfillment centers, materials for packing and deliveries are going to be net zero carbon.

Amazon also committed itself to reduce carbon footprints in its buildings in hope to reduce it to net zero by using solar panels, green building standard and using smart building control systems technologies to maximize the efficiency of energy and material.

Amazon works on the net zero delivery initiative to make sure that the fleet it uses to deliver products are operating on zero carbon. They are using electric cars and already waiting for 100000 electric cars from Rivian to operate in the US. They have other similar strategies in other countries, like using electric bikes.


Energy
Infrastructure
Raw Material
Designers
Engineers
Market Strategists
Market Analysts
etc.
Factory
Mass-produced
Goods
Online Retail / Marketing
Warehouse
Fulfillment Center
Inspection
Company
Repair
Data Flow
Components Flow
Products Flow
Company Return Flow
Customer Return Flow

Fulfillment Center (Current Model)

A conventional fulfillment center is a place to store manufactured goods and distribute them between individual customers with extensive logistics. The idea is that products are coming from manufacturers and customers have no say on the products unless through generic feedback programs.

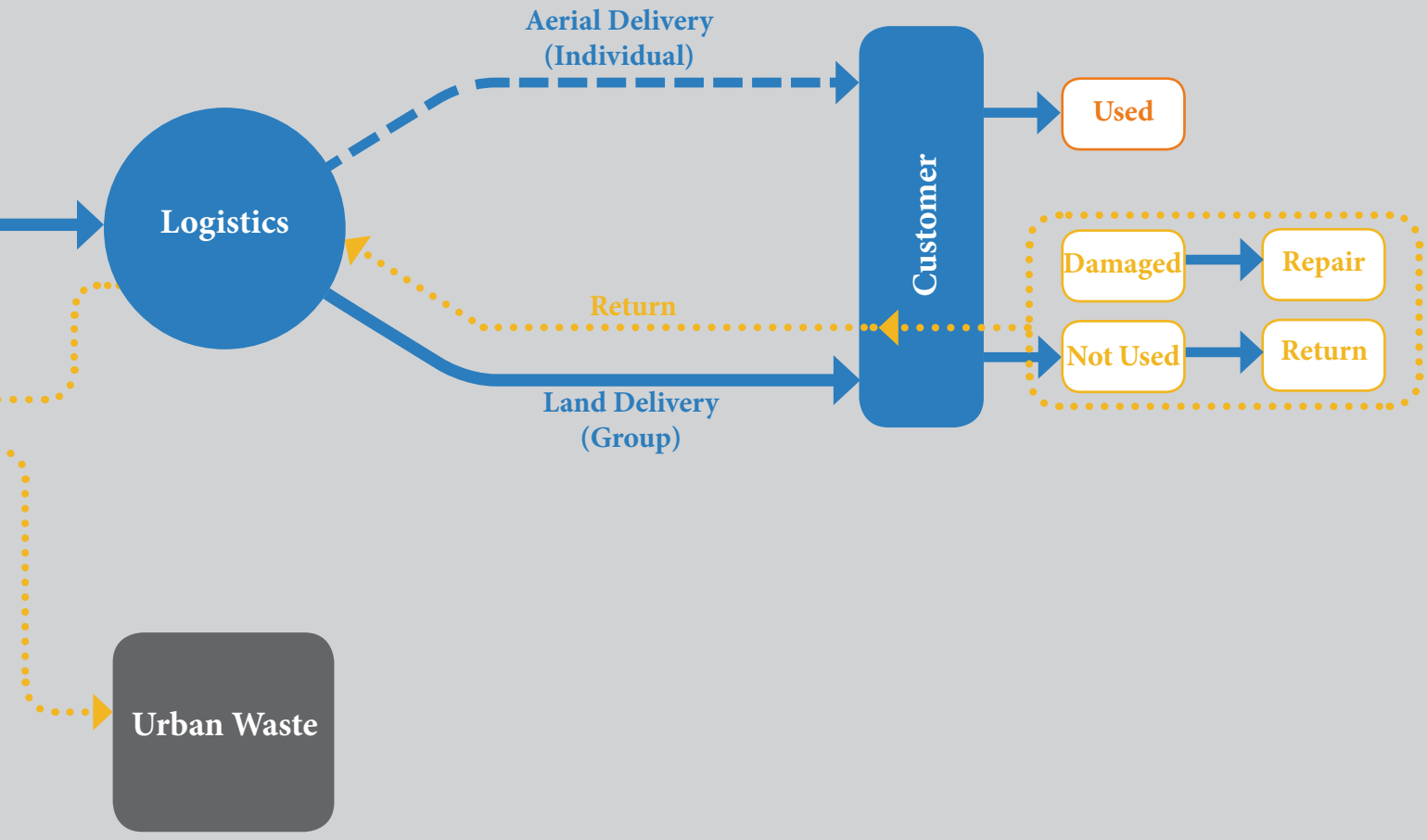
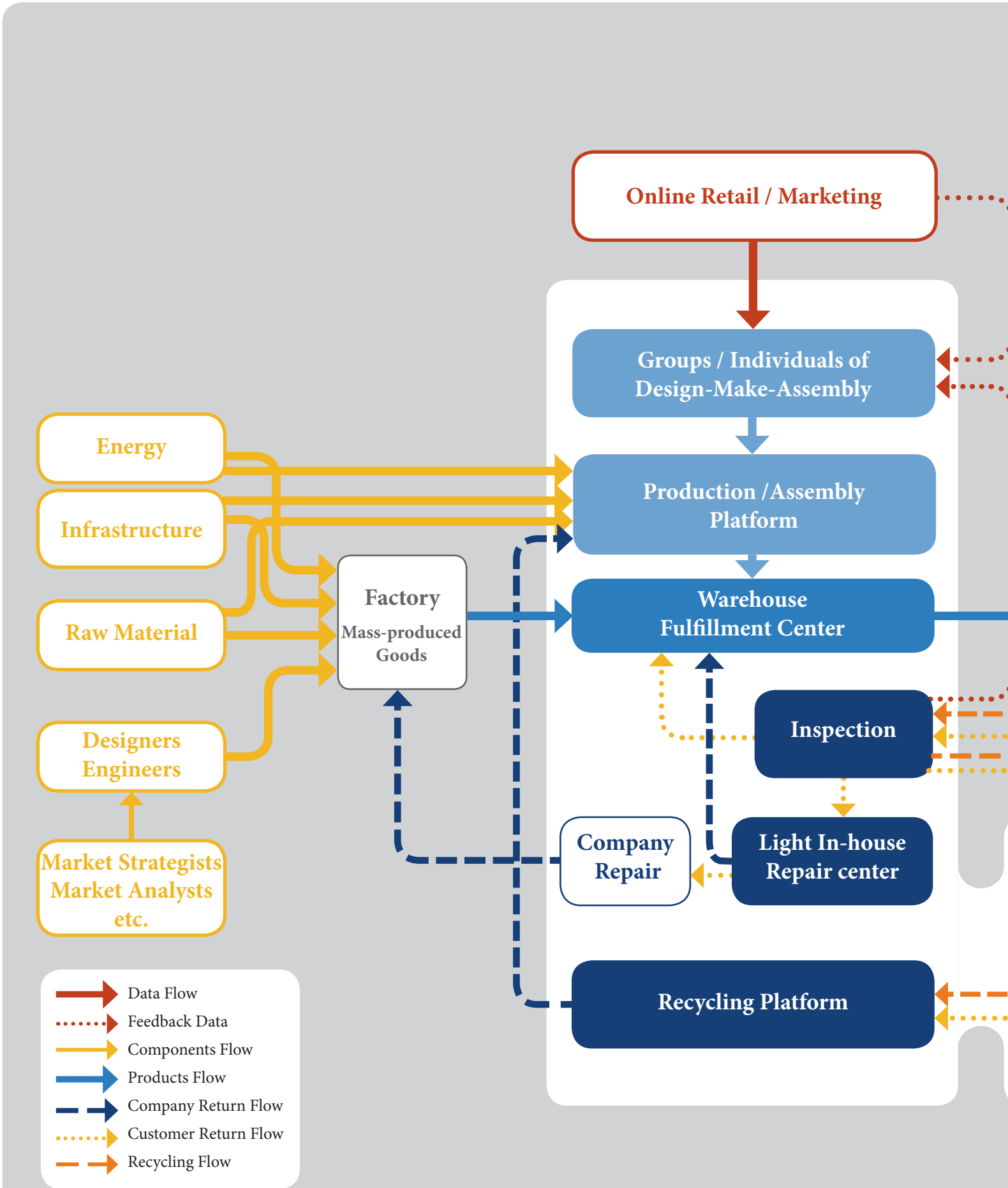


Fig. 114. Fulfillment center (Current model)


Online Retail / Marketing
Groups / Individuals of Design-Make-Assembly
Energy
Infrastructure
Raw Material
Designers Engineers
Market Strategists Market Analysts etc.
Factory
Mass-produced Goods
Production /Assembly Platform
Warehouse Fulfillment Center
Inspection
Company Repair
Light In-house Repair center
Recycling Platform
Data Flow
Feedback Data
Components Flow
Products Flow
Company Return Flow
Customer Return Flow
Recycling Flow

Fulfillment Center (Future Model)

The statement of this project is that fulfillment centers are no more acting as distribution centers only and they can act as a member of the production chain too. Products made in these facilities are highly customizable due to customers' needs and also highly recyclable due to the materials which are supposed to be used in their making process. These materials are aimed to be in usable in 3D printing platforms to be further recycled in these facilities too. Such a procedure would need a recycling platform, production platform as well as design and engineering platform to do the process from beginning to the end.

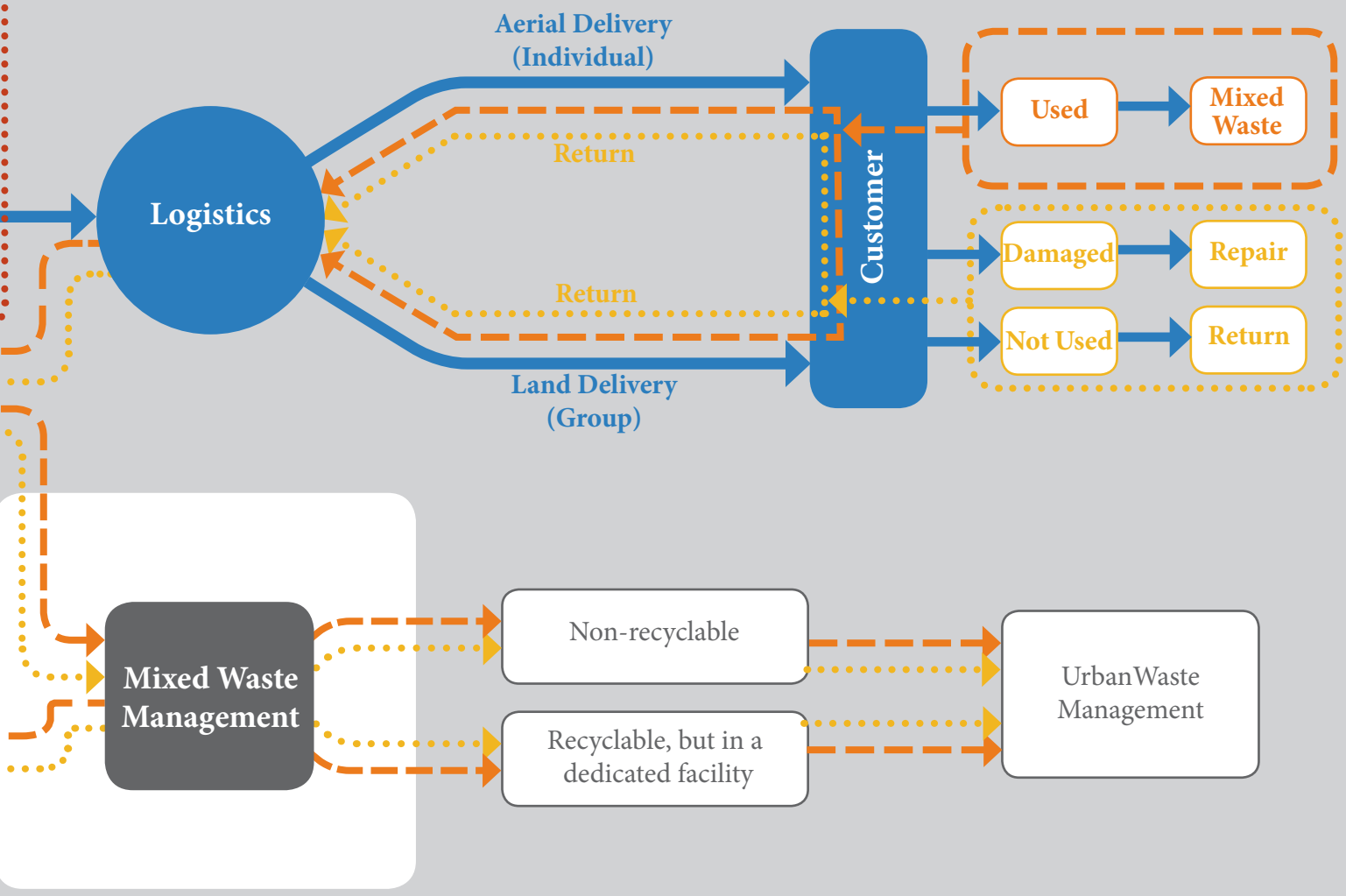


Fig. 115. Fulfillment center (Future model)

4.2. Material Procedures

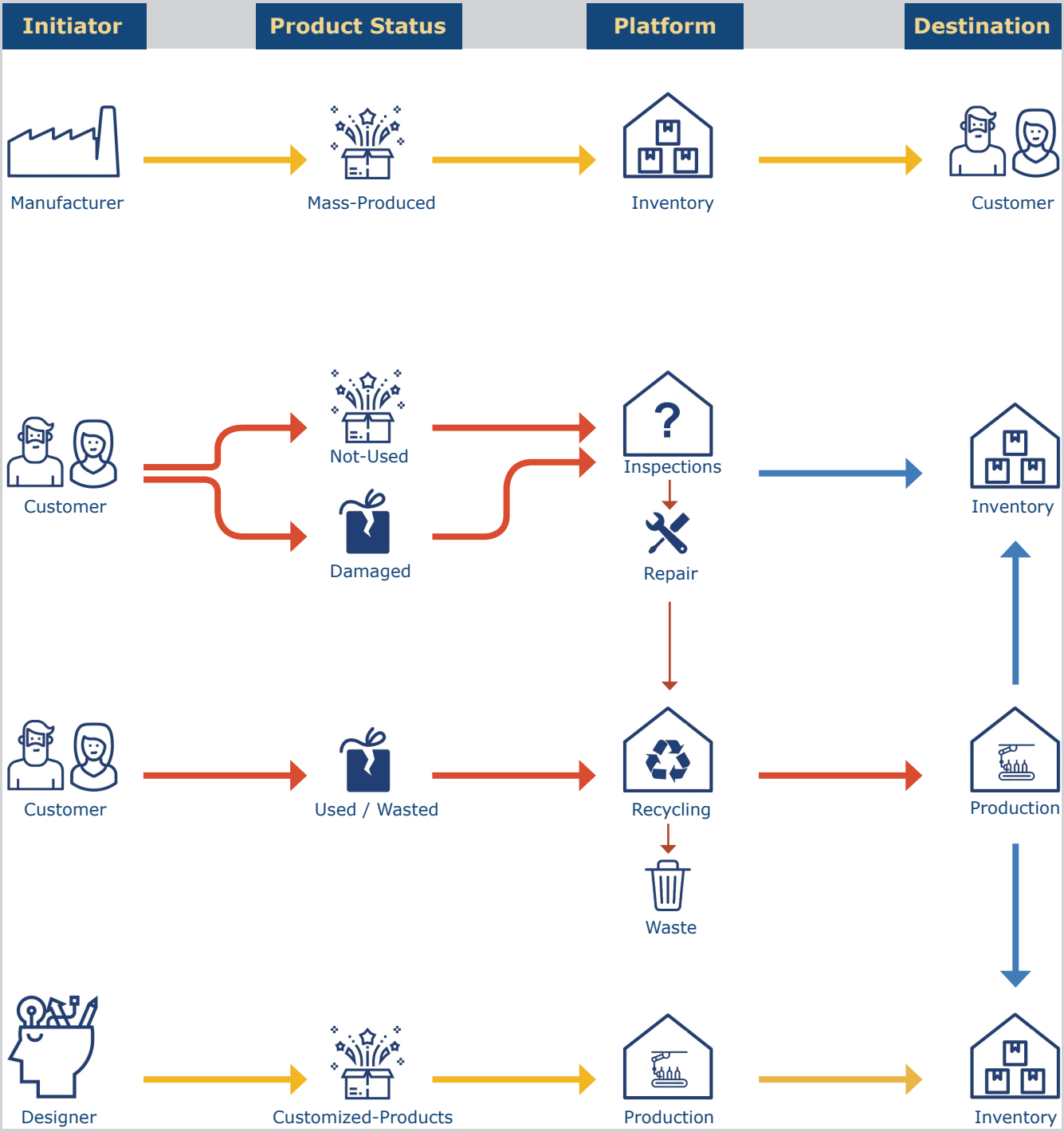


Fig. 116. Fulfillment center material procedures

Materials/Goods Procedures

One of the important aspects of the warehouse design is to map different materials/goods procedures and prepare the space and as such staff to handle them. In this way, the cycle of materials will inform the space and therefore the equipment will be prepared to provide a smooth operation for better performance. These are the four main procedures that in this specific fulfillment center should be noticed, of course, each would have sub-categories of actions:

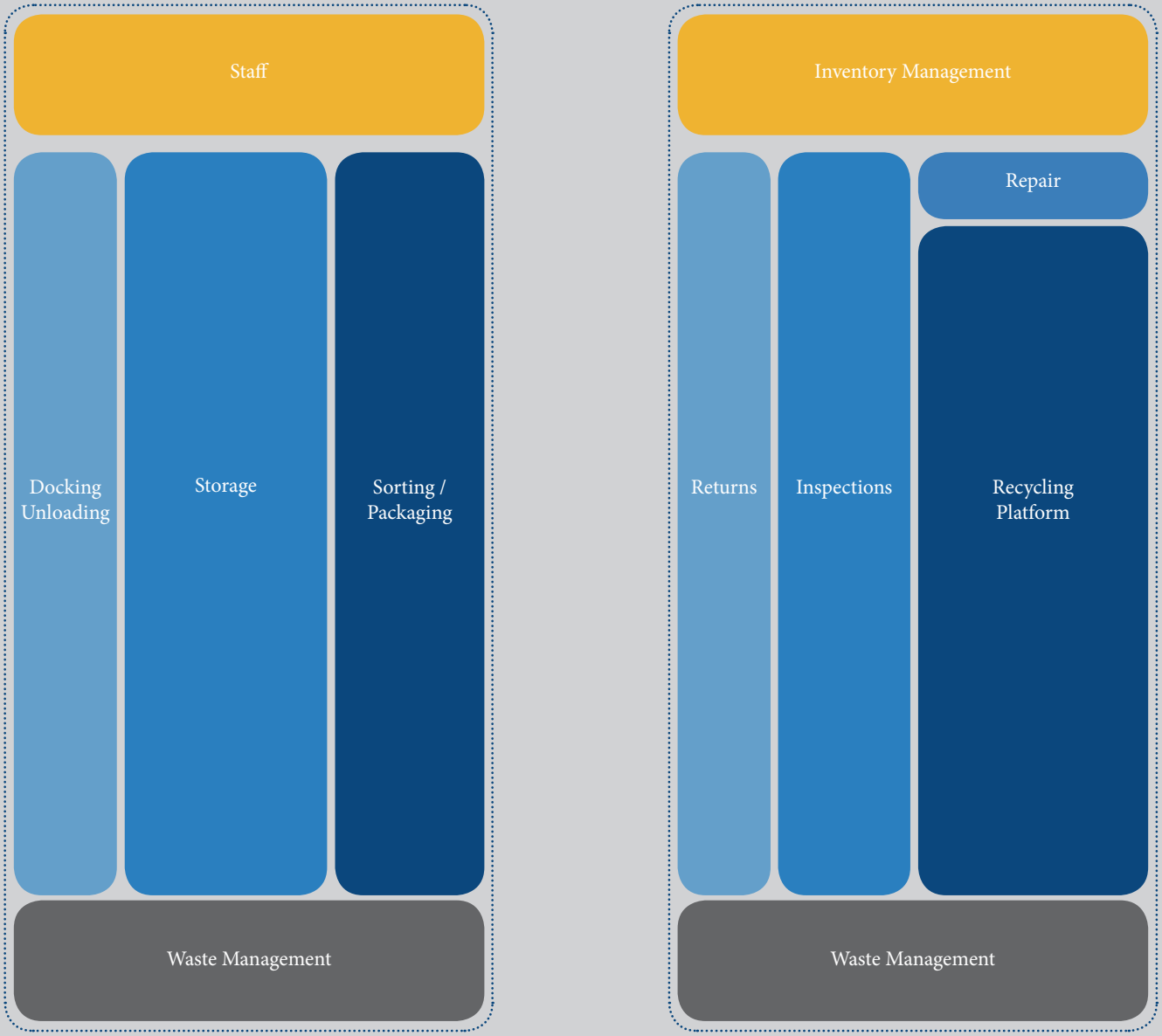
1. A cycle of bulk goods, manufactured outside in factories and shipped into the warehouse in bulks using trucks. These bulk items than would be shelved inside the warehouse by shelving personnel, to be further picked by picking staff to be sorted, packaged, and delivered.

2. A cycle of return items where they go to the inspection center to be decided about the product, whether it should be placed back into the inventory, directed towards the garbage, or most importantly, recycled in-house.

3. A Cycle of used/wasted items that are coming in special packages and going through inspections but for identification of the type of recycling.

4. A Cycle of production of customized products, starting from the designer/ engineering team, going through the production platform and assembly to be delivered to customers.

4.3. Program Studies



Fulfillment Center

Recycling Platform

There are four main platforms in the program of the proposed warehouse. The first one is the known fulfillment center with all the functionalities that a warehouse/fulfillment center should include. The second one is the recycling platform where it recycles the products made by Amazon itself. The third would be the production platform to manufacture and assemble customized products and finally, the design and engineering platform to design, make and assemble the products which are customized for individual customers.

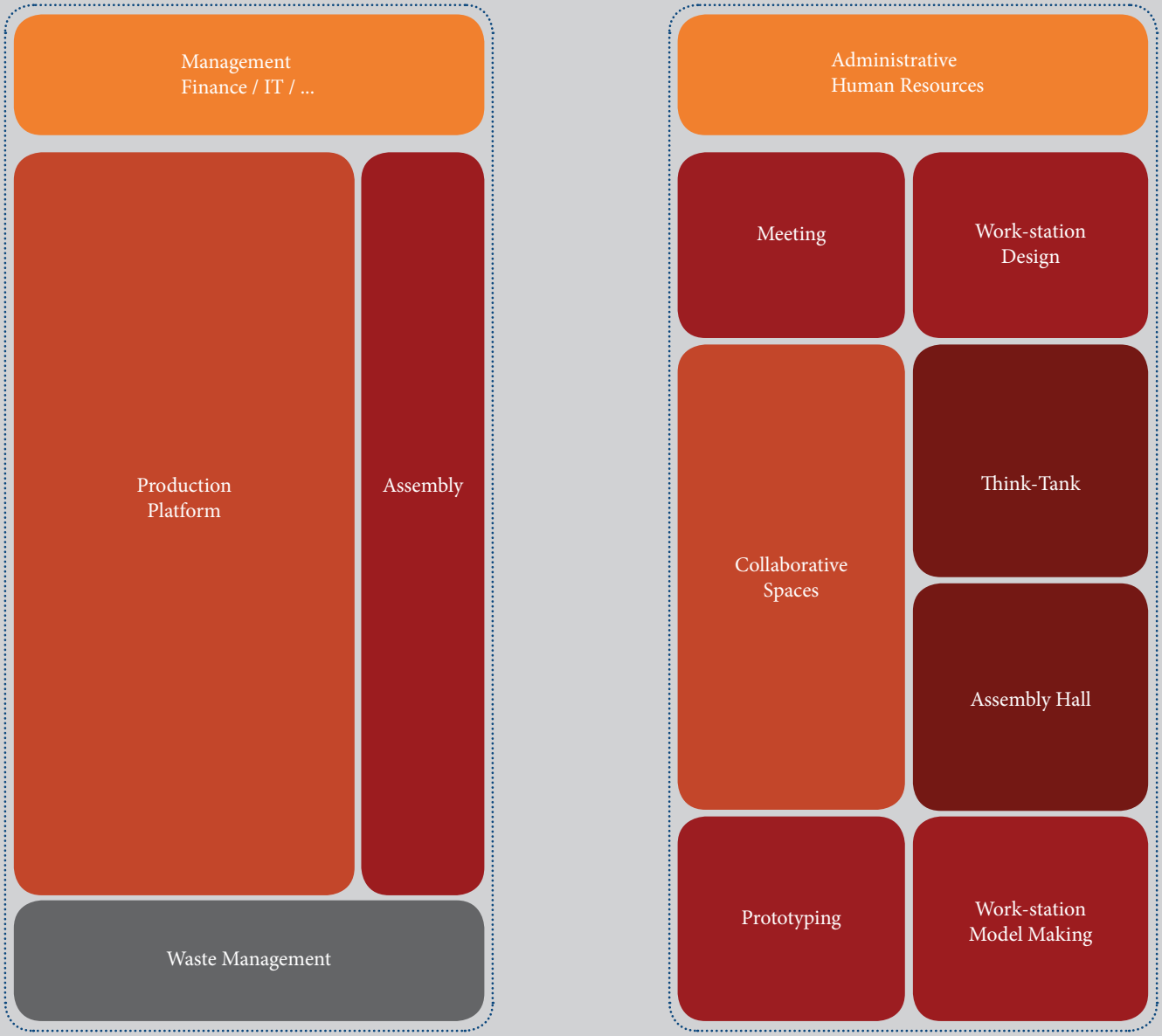


Fig. 117. Program studies

4.4. Form Studies

As described earlier, there are four main platforms that together, perform as the warehouse of the future. Each one of these platforms has different properties to be included in their programming and spatial configurations. To provide the best solution, such properties are listed and formulated into separate parts, each being studied in different layouts and formats to generate design options. After the initial generation of the spatial configurations, they are being combined to create sample solutions. These solutions are going to be evaluated and compared in order to choose the best working option for the design of the project.

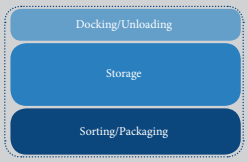
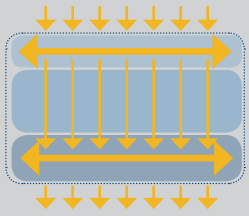
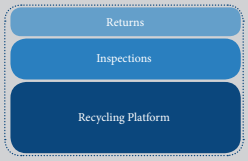
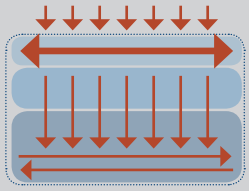
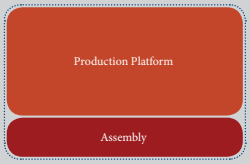
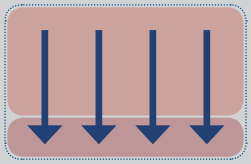
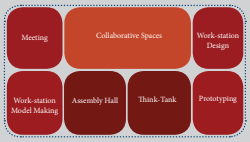
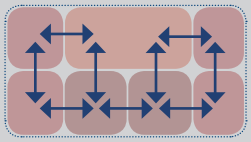
Platform	Program	Circulation	Points
Fulfillment Center			• One-way material procedure • Forklift-truck movement paths • Robotic shelves movement paths • Direct connection to docking/claiming platform
Recycling Platform			• One-way material procedure • Conveyors for material handling • Direct connection to return platform
Production Platform			• 3D-Printing farm and production facilities • Multiple-ways material handling • Assembly desks above sorting facilities
Design/ Engineering Platform			• Various types of work spaces • Multiple-level connectivity • No material handling in this level • Open, green and multifunctional spaces are necessary

Fig. 118. Program analysis and form studies

Platform | Program | Circulation | Points | Layout Options

This table work as above diagram, having different platforms with their program and access diagrams and being completed by their design points, and presented with more details in the following pages.

Layout Options

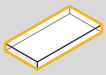
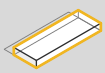
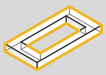
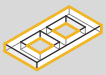
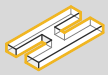
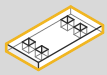
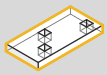
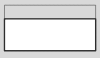
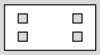
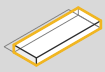
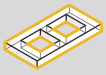
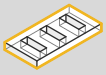
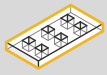
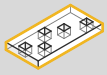
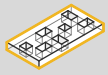
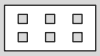
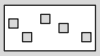
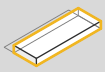
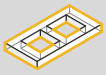
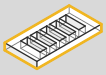
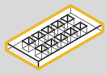
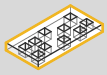
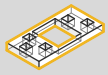
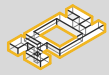
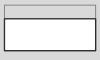
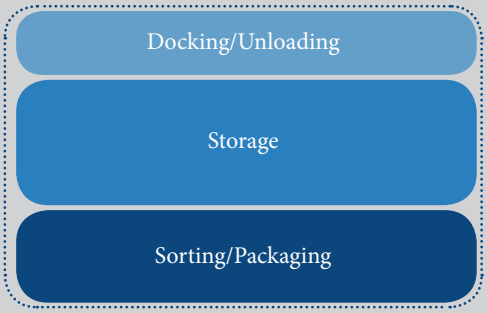
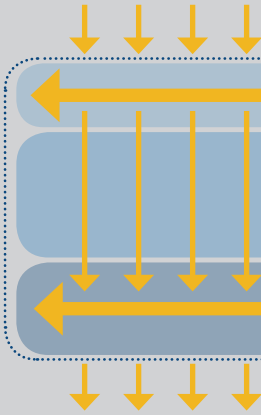
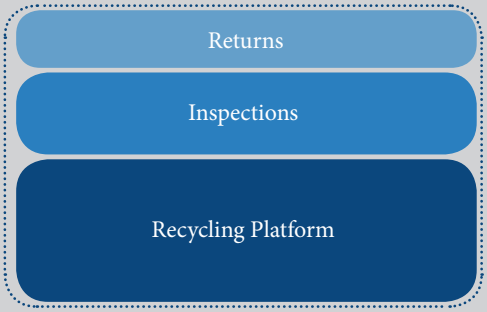
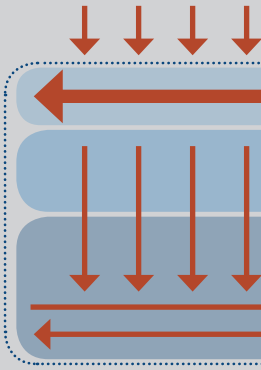
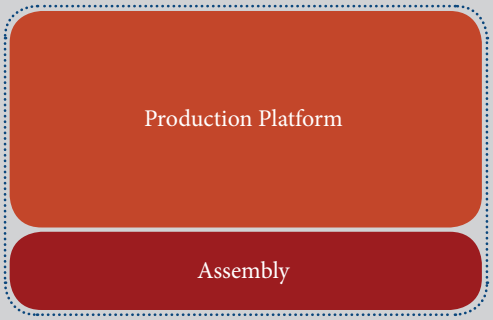
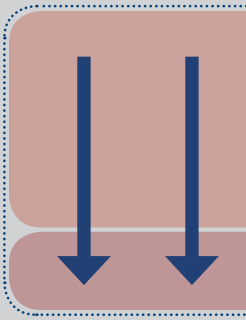
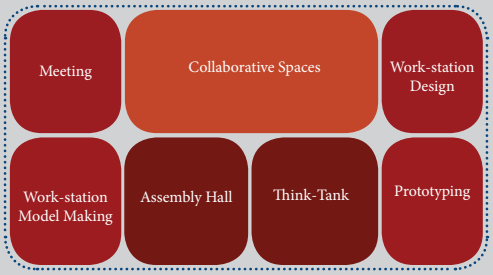
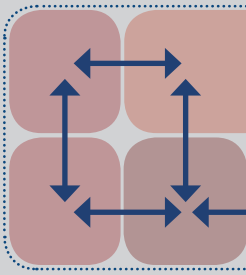
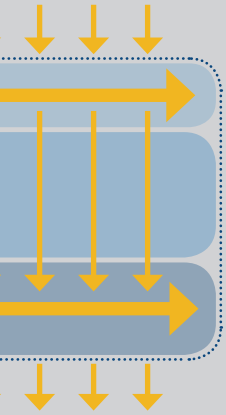
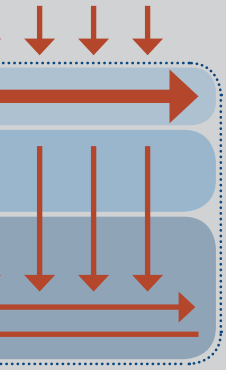
	Model									
	Layout									
	Model									
	Layout									
	Model									
	Layout									
	Model									
	Layout									

Fig. 119. Amazon fulfillment center, program analysis

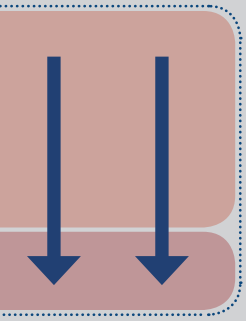
Fulfillment Center		
Recycling Platform		
Production Platform		
Design/ Engineering Platform		



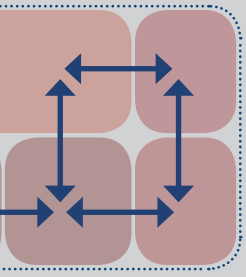
- One-way material procedure
- Forklift-truck movement paths
- Robotic shelves movement paths
- Direct connection to docking/claiming platform



- One-way material procedure
- Conveyors for material handling
- Direct connection to return platform

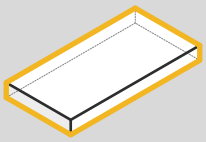
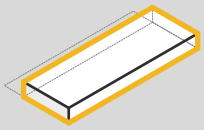
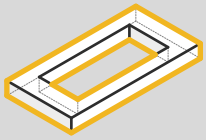
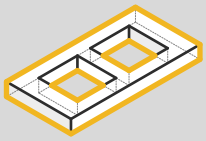
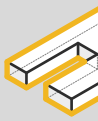
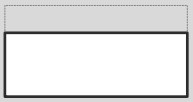
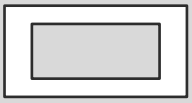
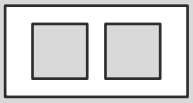
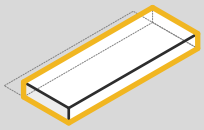
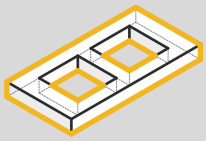
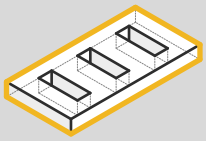
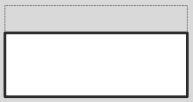
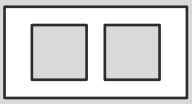
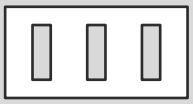
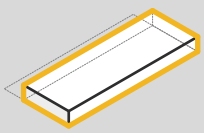
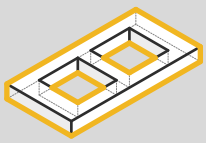
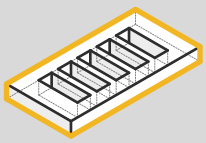
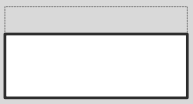
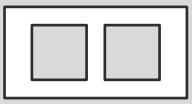
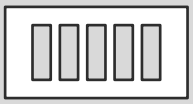


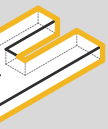
- 3D-Printing farm and production facilities
- Multiple-ways material handling
- Assembly desks above sorting facilities

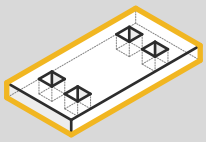


- Various types of work spaces
- Multiple-level connectivity
- No material handling in this level
- Open, green and multifunctional spaces are necessary

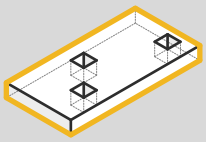
Fig. 120. Amazon fulfillment center, form studies

Fulfillment Center	Model	 FC1			
	Layout	 FC1			
Recycling Platform	Model	 RP1	 RP2	 RP3	 RP4
	Layout	 RP1	 RP2	 RP3	 RP4
Production Platform	Model	 PP1	 PP2	 PP3	 RP4
	Layout	 PP1	 PP2	 PP3	 RP4
Design/ Engineering Platform	Model	 DP1	 DP2	 DP3	 DP4
	Layout	 DP1	 DP2	 DP3	 DP4

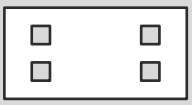




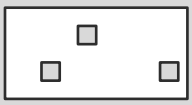
RP5



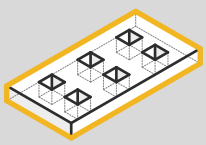
RP6



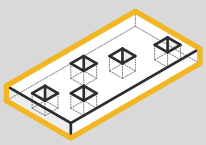
RP5



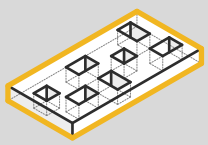
RP6



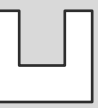
PP5

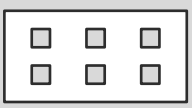


PP6

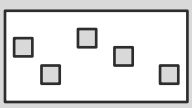


PP7

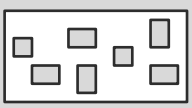




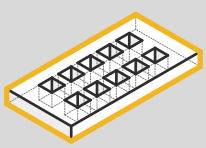
PP5



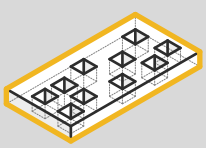
PP6



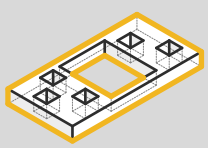
PP7



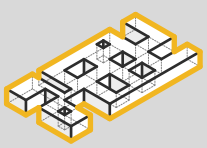
DP5



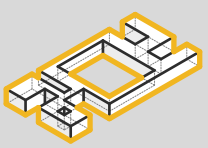
DP6



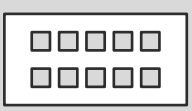
DP7



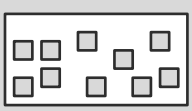
DP8



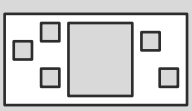
DP9



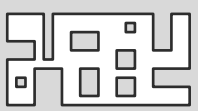
DP5



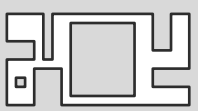
DP6



DP7

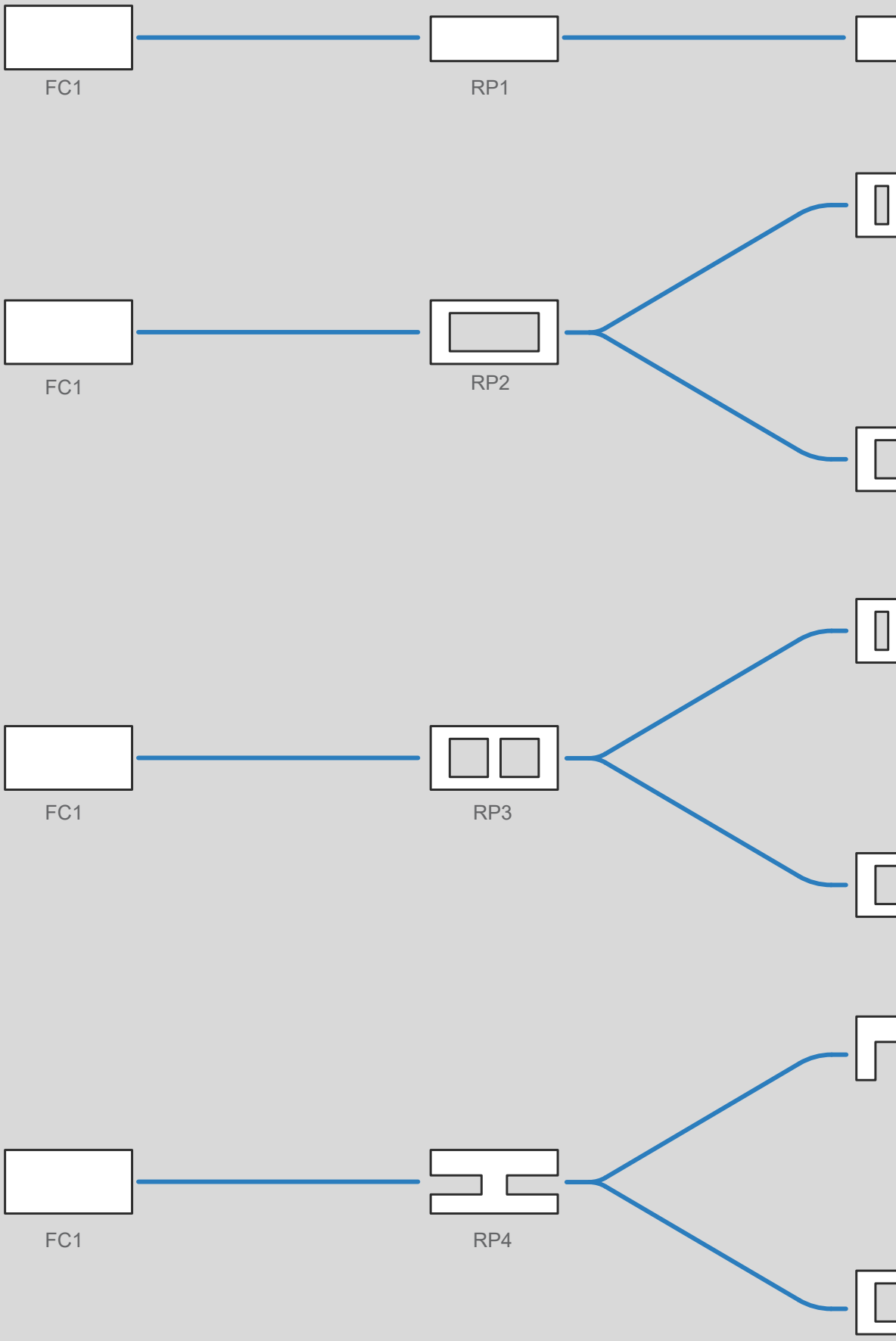


DP8



DP9

Fig. 121. Catalogue of forms



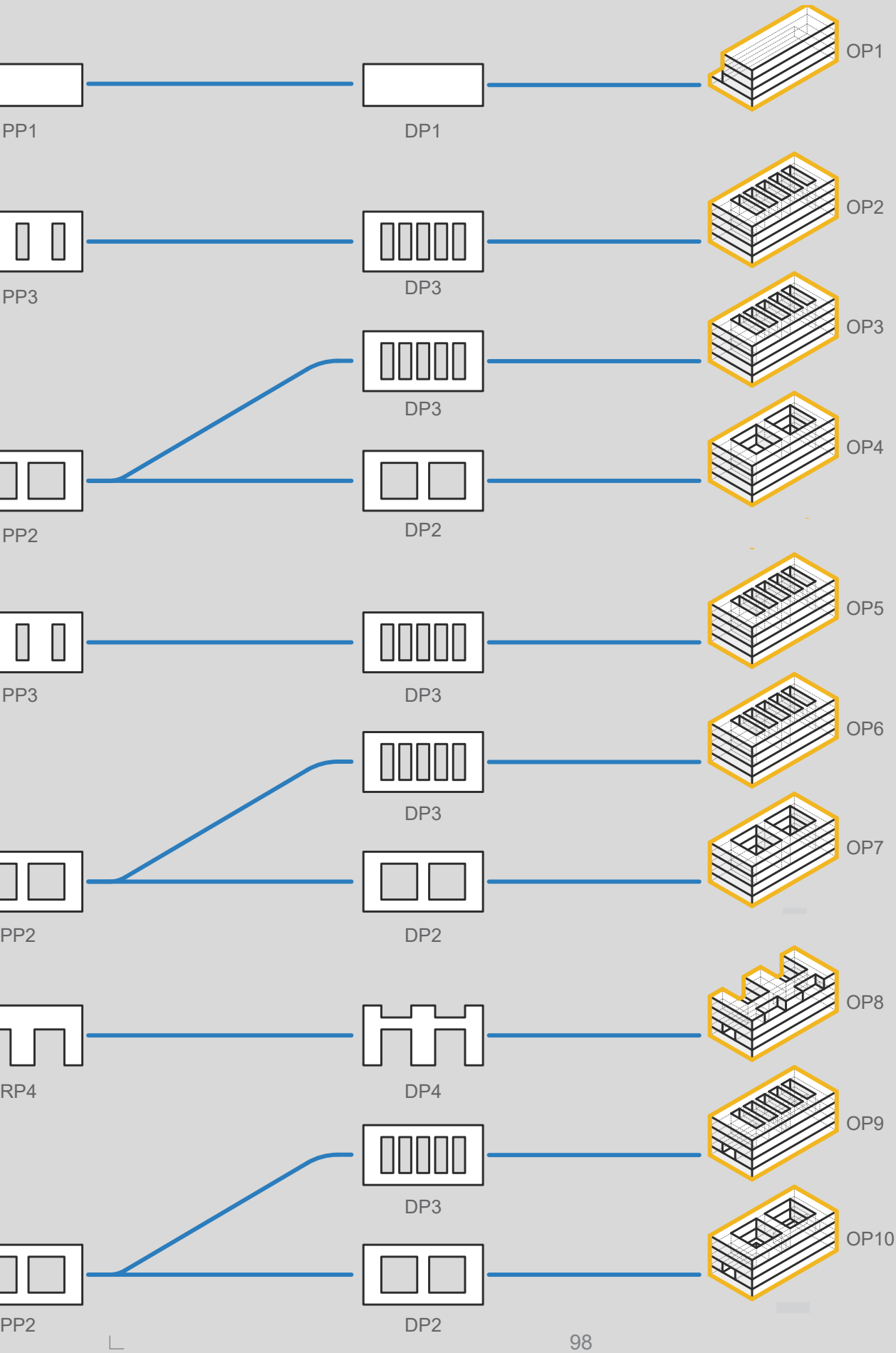
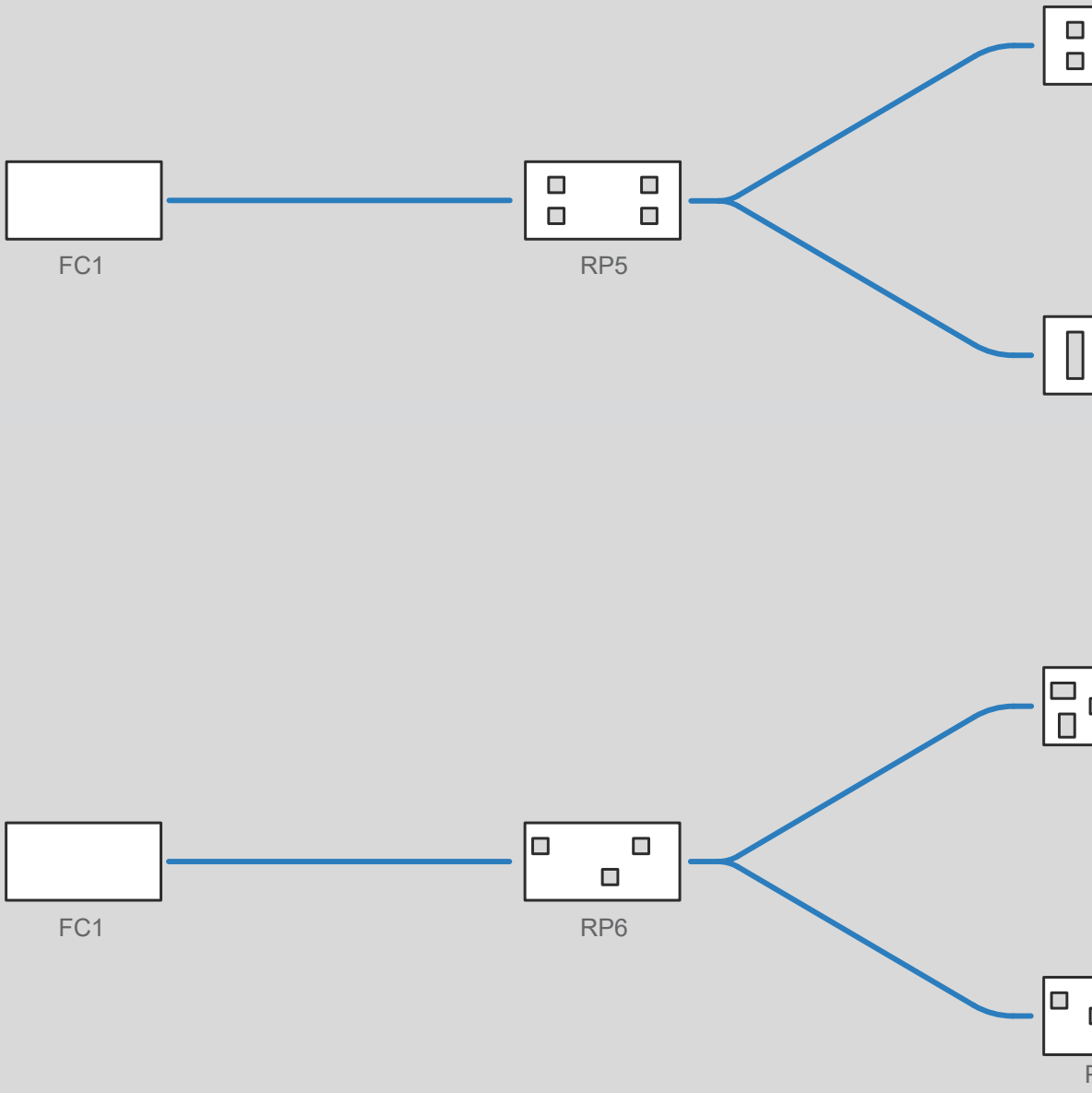
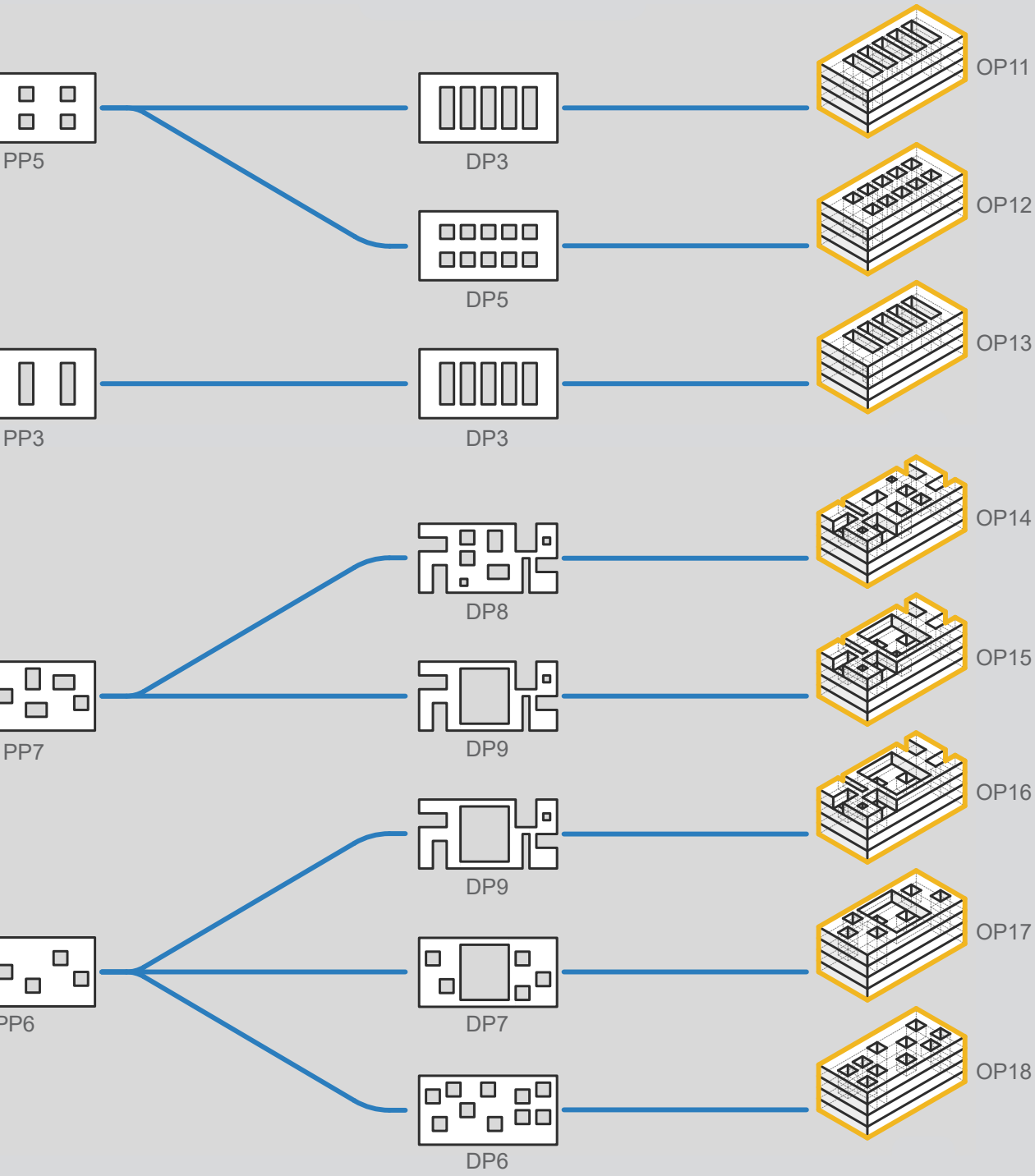

PP1
DP1
OP1
PP3
DP3
OP2
DP3
OP3
PP2
DP2
OP4
PP3
DP3
OP5
DP3
OP6
PP2
DP2
OP7
RP4
DP4
OP8
DP3
OP9
PP2
DP2
OP10

Fig. 122. Catalogue of forms




PP5
DP3
OP11
DP5
OP12
PP3
DP3
OP13
DP8
OP14
PP7
DP9
OP15
DP9
OP16
PP6
DP7
OP17
DP6
OP18

4.5. Evaluations

In order to evaluate various typologies that are possible to use for the design of the warehouse and select the best possible options, some points should be listed to be taken into account.

- Due to the many operations that require material handling, all floors must be flat.

- The inner areas of the first (warehouse) and the second (recycling platform) floors are mainly equipped with robots and machines and require minimum presence of humans.

- The first floor needs the entire area to be functional and accessible, though as we go up, less area per floor needed to be functional and more open/green spaces could be used.

- As the footprint of the project is large, having courtyards in upper floors is preferred to increase the chance of natural light penetration to the inner spaces of the floors, compared to the options that shrink the footprint of higher floors.

- Because of the need for smaller spaces in the third and forth floors (production and design platforms), having smaller and scattered courtyards are more preferable than having a large open space with large closed spaces around it.

- Although all the options are considering internal circulations, those options with less interruptions of main access lines are more preferred due to any changes that might happen in the future planning of the project.

- Level two needs to be connected to level one and level three for material circulation while level three and four are needed to be connected for human access.

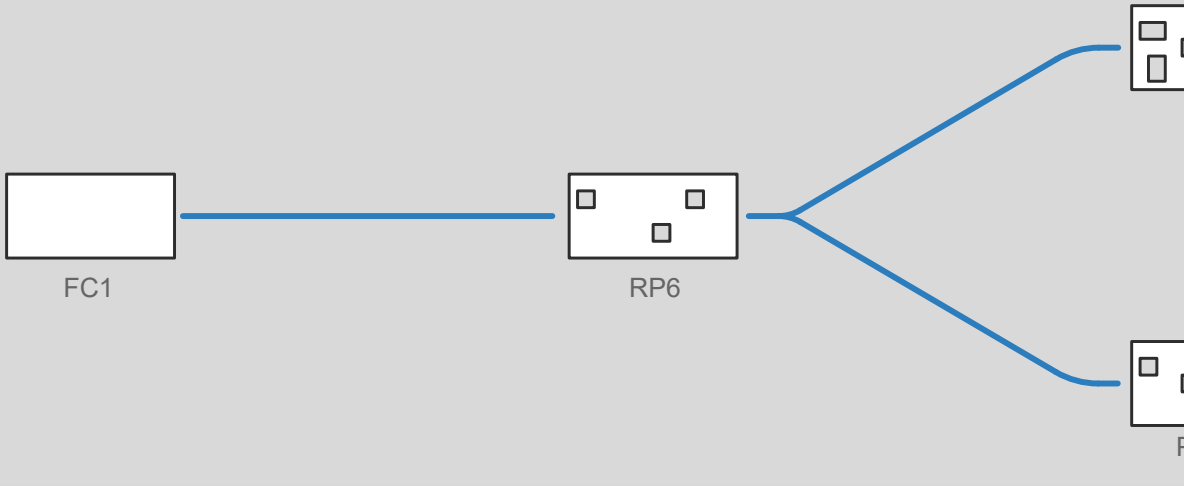
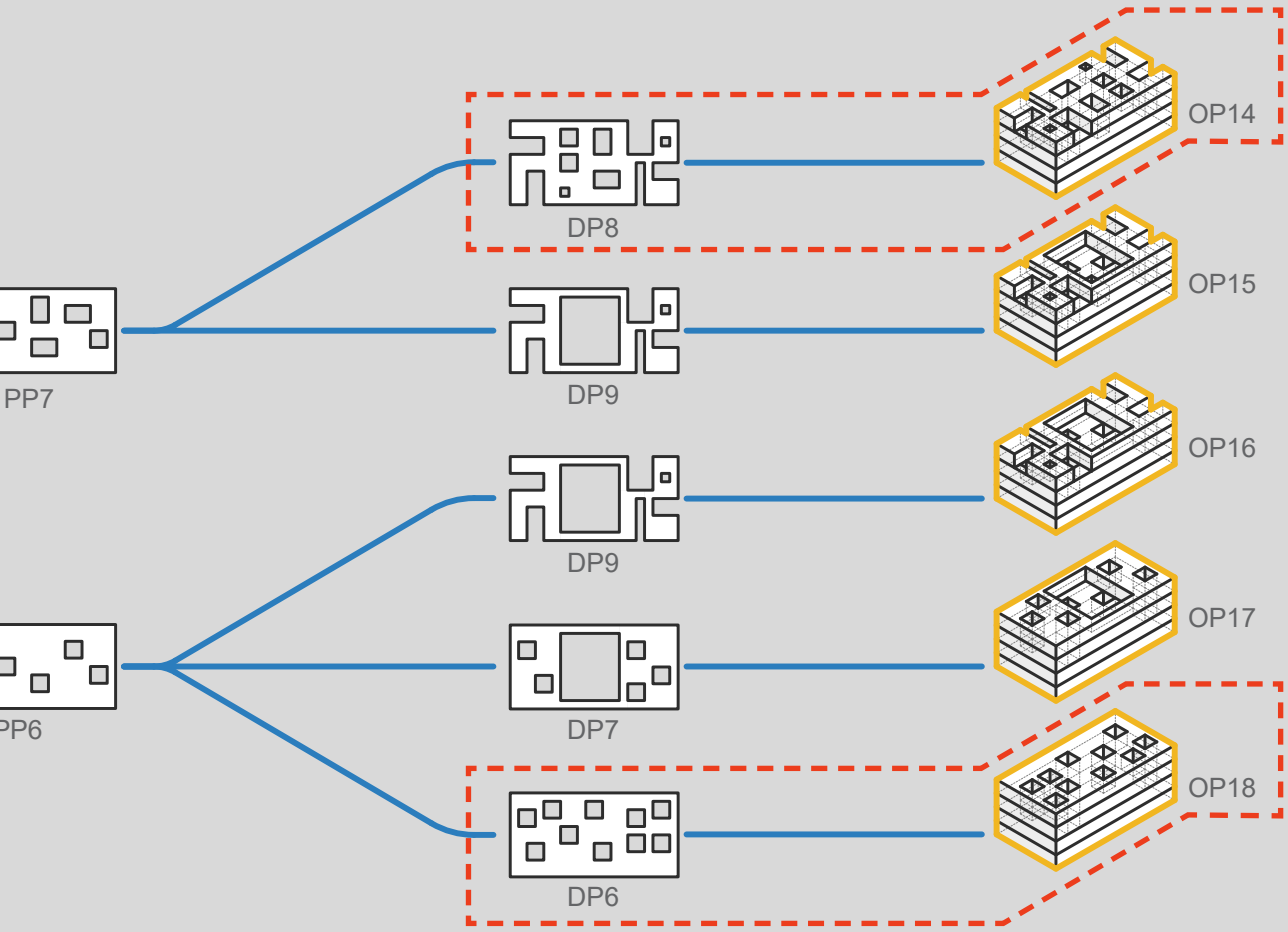


Fig. 123. Evaluations

Considering these points, OP14 and OP18 are the most relevant configurations that can be used as the main typology of design. This means that these options are going to address the design process, and develop further to incorporate the program while responding to the site.

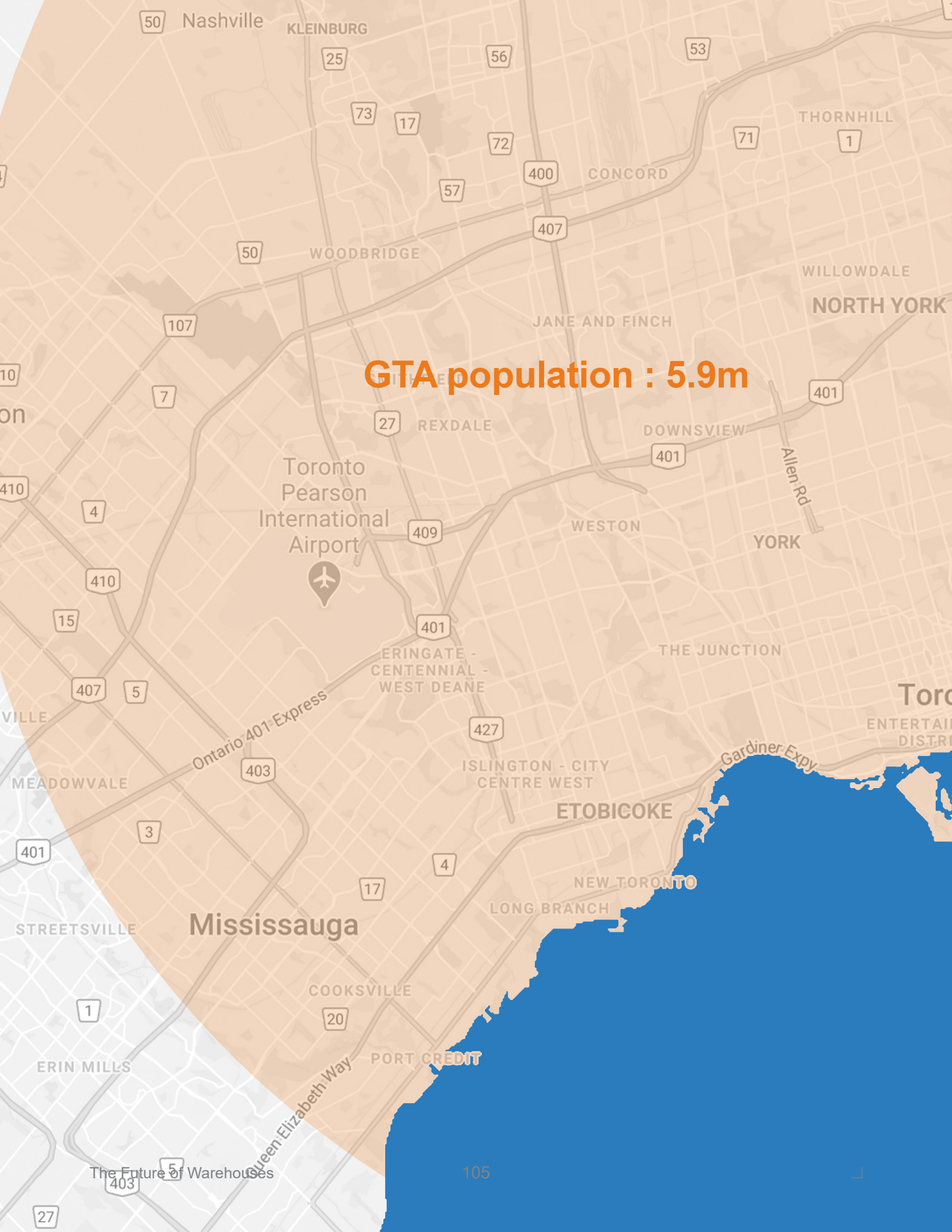


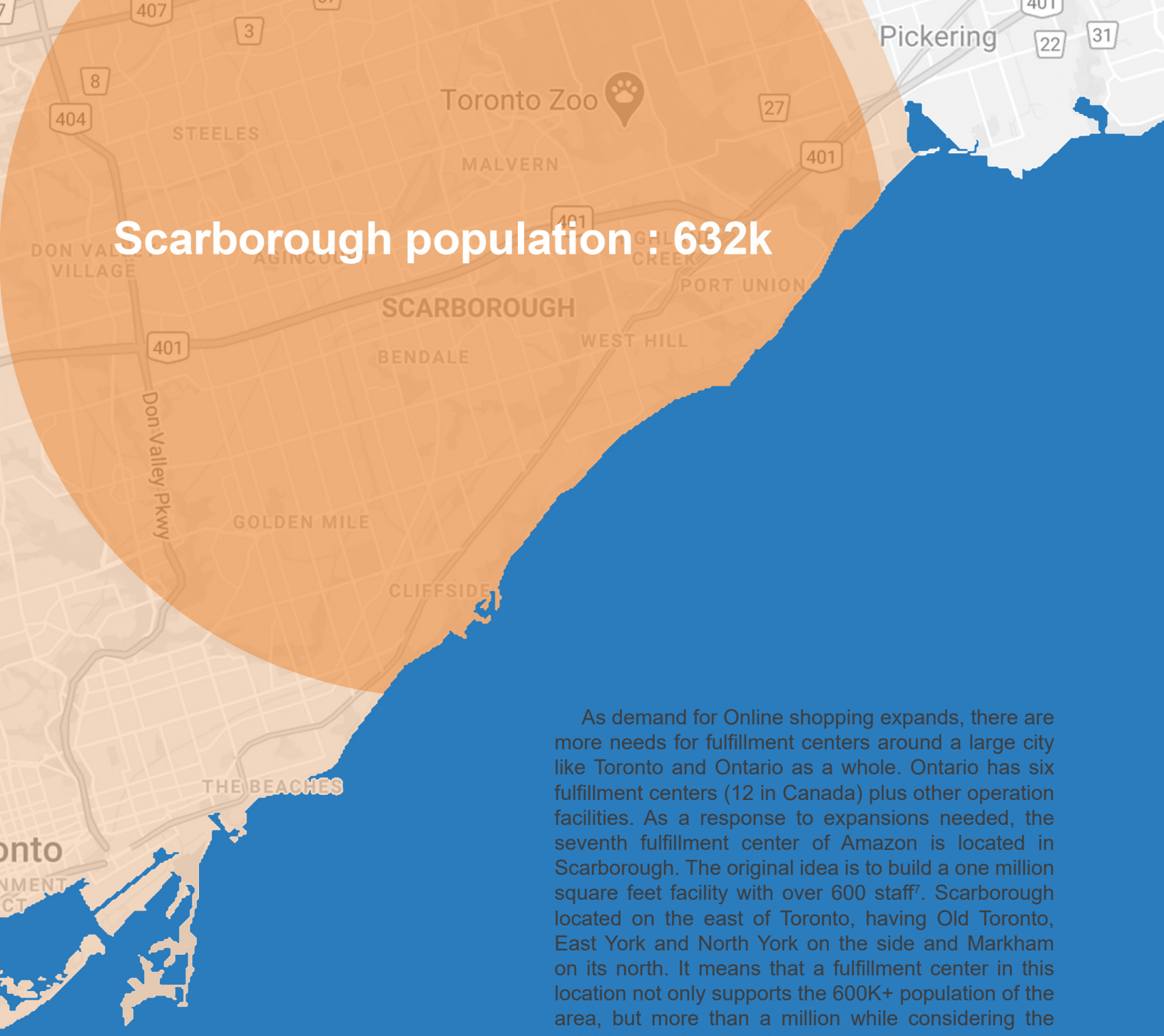
4.6. Amazon Fulfillment Center, Scarborough, ON

Toronto is the most populated city in Canada and works as a center of business, finance, culture, art, music, and sport. It is a multicultural city with residents from all around the world. This diverse population indicates that Toronto always works as an important hub for immigration to Canada and as such, houses people from different color, ethnicity, and culture. With a hight GDP[6] and such diversity, there is no doubt that Toronto is a huge market place and Online retail is not an exception.

Fig. 124. Amazon fulfillment center, Scarborough, ON


Population 2018 : 37m
Estimation 2030s: 40-47m
Quebec
542,298
Halifax
431,479
Monttreal
1.78 m
Ottawa
994,837
Toronto
2.93 m


GTA population : 5.9m
Nashville
KLEINBURG
THORNHILL
CONCORD
WOODBRIDGE
WILLOWDALE
NORTH YORK
JANE AND FINCH
REXDALE
DOWNSVIEW
Toronto Pearson International Airport
WESTON
YORK
Allen Rd
ERINGATE - CENTENNIAL - WEST DEANE
THE JUNCTION
Ontario 401 Express
Gardiner Expy
ISLINGTON - CITY CENTRE WEST
MEADOWVALE
ETOBICOKE
NEW TORONTO
LONG BRANCH
STREETSVILLE
Mississauga
COOKSVILLE
ERIN MILLS
PORT CREDIT
Queen Elizabeth Way



As demand for Online shopping expands, there are more needs for fulfillment centers around a large city like Toronto and Ontario as a whole. Ontario has six fulfillment centers (12 in Canada) plus other operation facilities. As a response to expansions needed, the seventh fulfillment center of Amazon is located in Scarborough. The original idea is to build a one million square feet facility with over 600 staff[7]. Scarborough located on the east of Toronto, having Old Toronto, East York and North York on the side and Markham on its north. It means that a fulfillment center in this location not only supports the 600K+ population of the area, but more than a million while considering the neighbors and connections.

There are various sources of information that helps to understand and analyze what types of products are being sold in stores and Online and what are the categories of different products that should be available as well. Perhaps one of the best sources to understand the trends and categories of products in order to plan for that is to see the expenses of families and trying to see which categories are absorbing most of the marginal budgets.

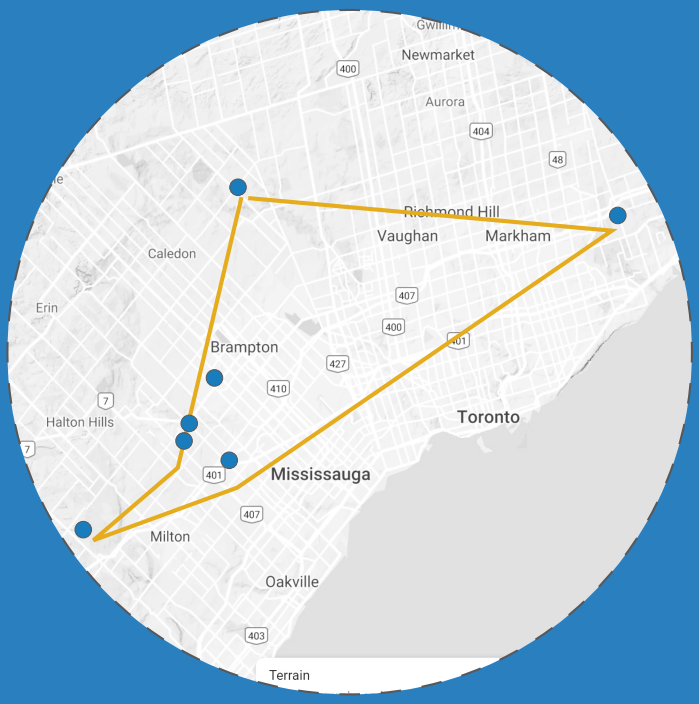
Fig. 125. Scarborough population

Amazon fulfillment centers in Ontario and Toronto

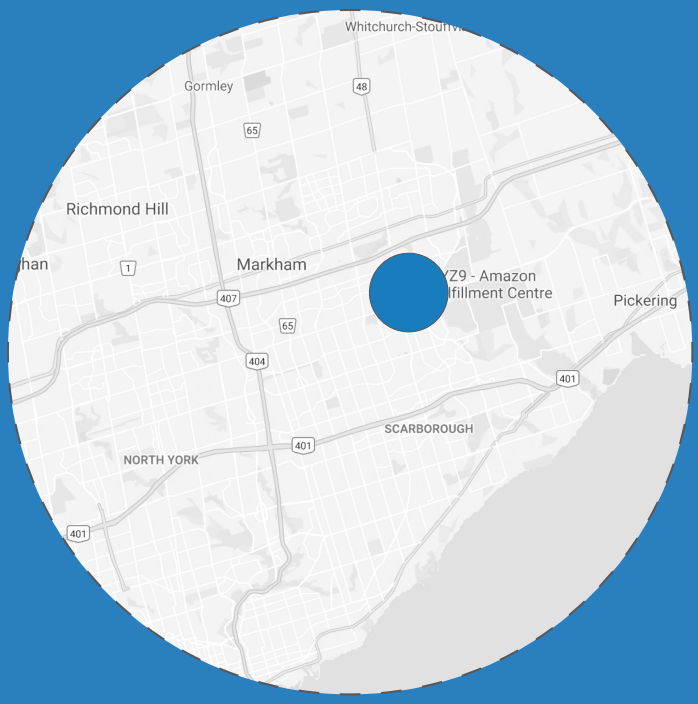
Amazon Warehouses in Ontario

Amazon Warehouses near Toronto

Fig. 126. Amazon fulfillment centers in Ontario and Toronto



Access of Amazon Warehouses

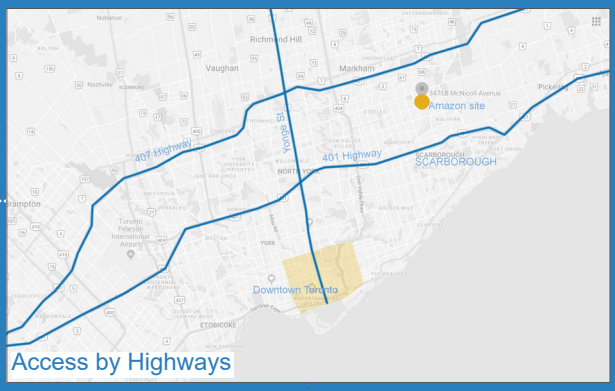


Scarborough Amazon Warehouse

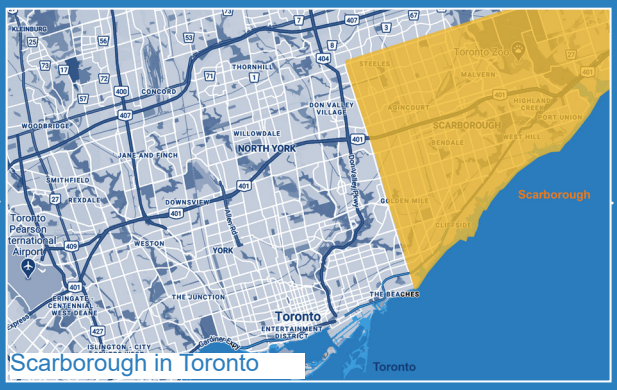
Scarborough Site Analysis

Fig. 127. Amazon fulfillment center in Scarborough

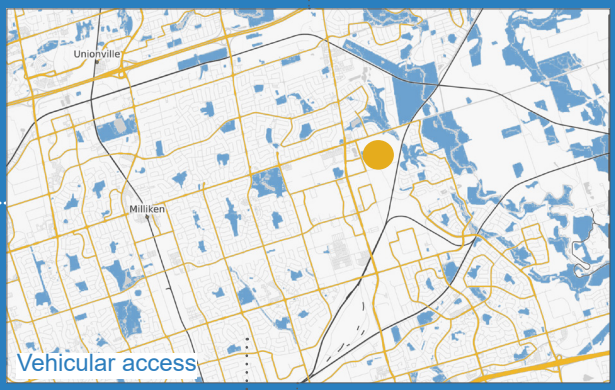
Scarborough in Toronto



Access by Highways

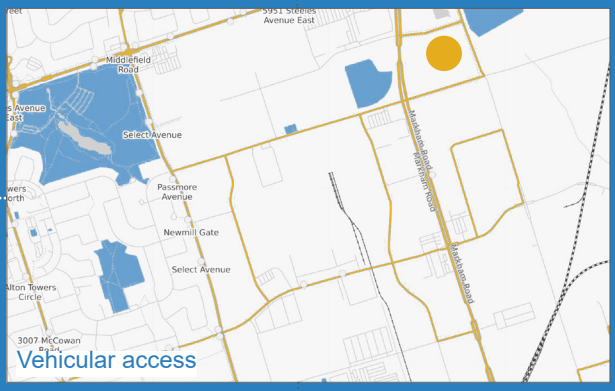


Scarborough in Toronto



Vehicular access

Scarborough Access



Vehicular access

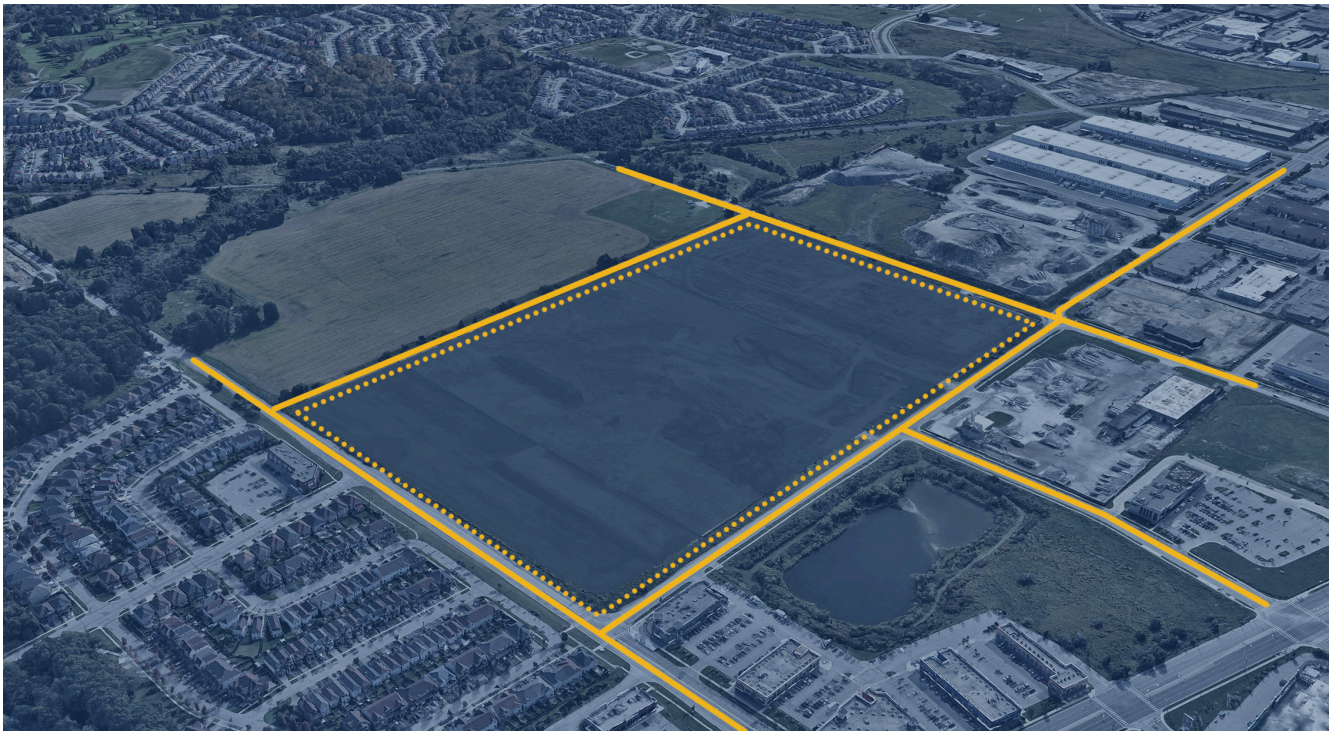


Fig. 128. Amazon fulfillment center; access

The site of the new fulfillment center has access from all its sides, makes it an ideal plot of land for multiple types of access/circulation scenarios.

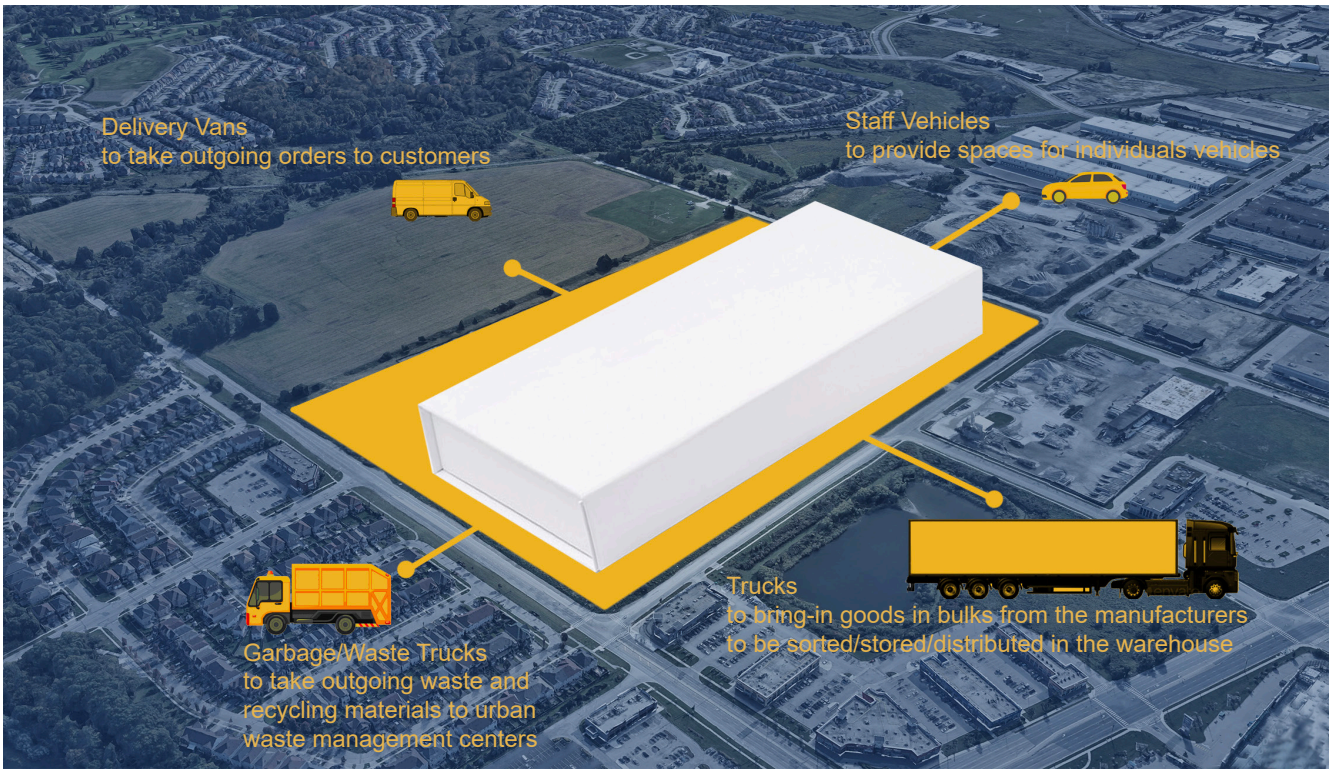


Fig. 129. Amazon fulfillment center; vehicles

Mainly there are four groups of vehicles in different formats to be involved with the project: Trucks, Delivery Vans, Garbage Trucks and Staff Vehicles.

Fig. 130. Amazon fulfillment center; scale

The site of this project with the area of more than 2.4 million sqft could be filled with 14 football pitches with running track, plus another one to fill the gap between them, meaning a total of 15+ football pitches inside this single plot of land.

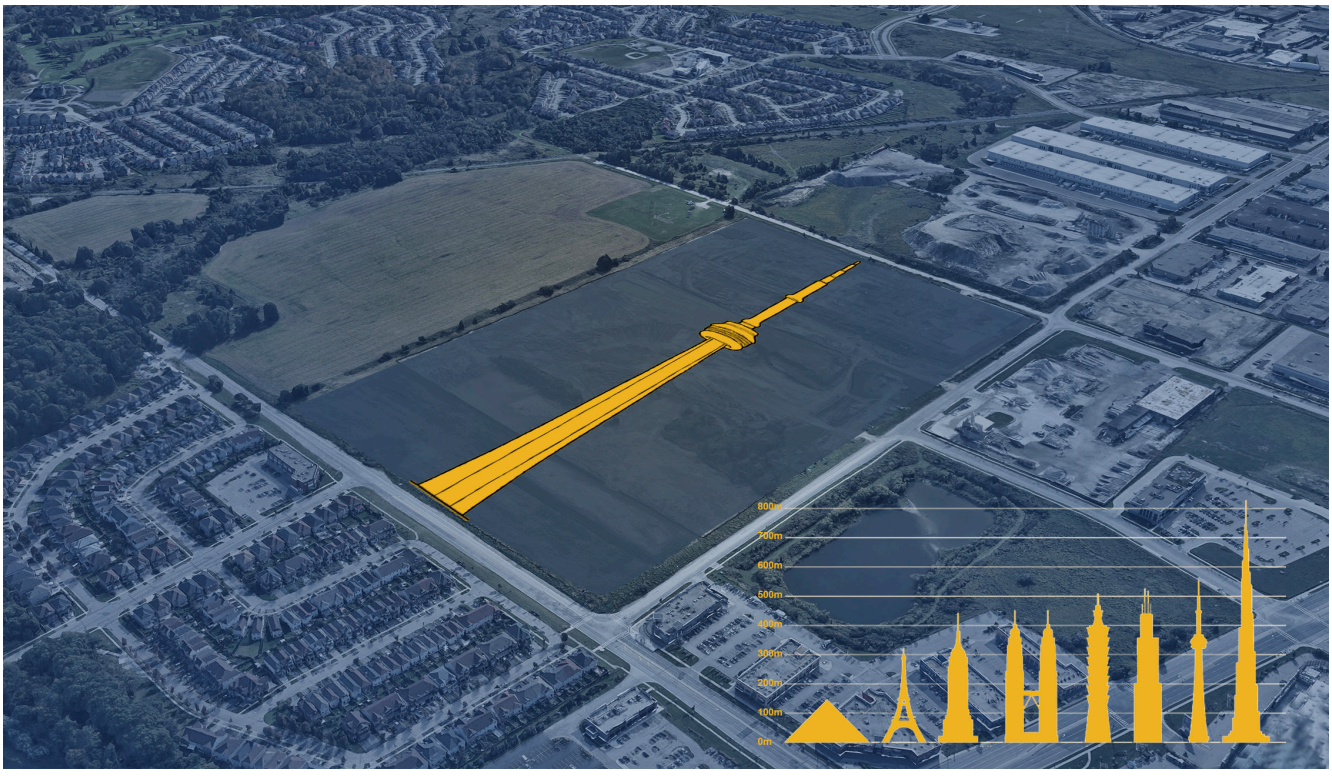


Fig. 131. Amazon fulfillment center; length

Looking at the dimensions of the site, it is insightful to map the iconic CN tower on it where the length of the site is almost equal to the height of CN tower at 553m.

Material Procedures Projection onto the Site

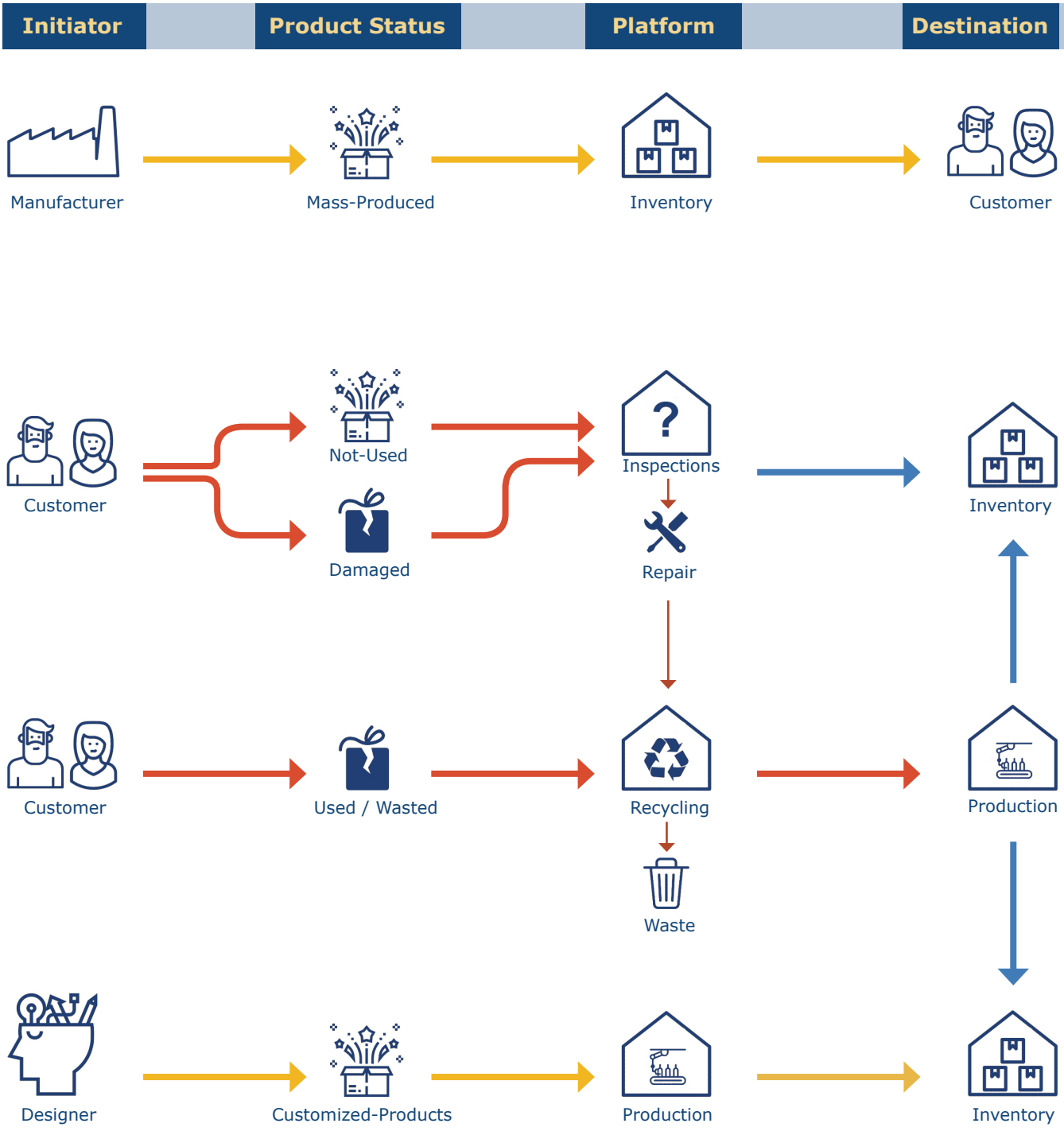
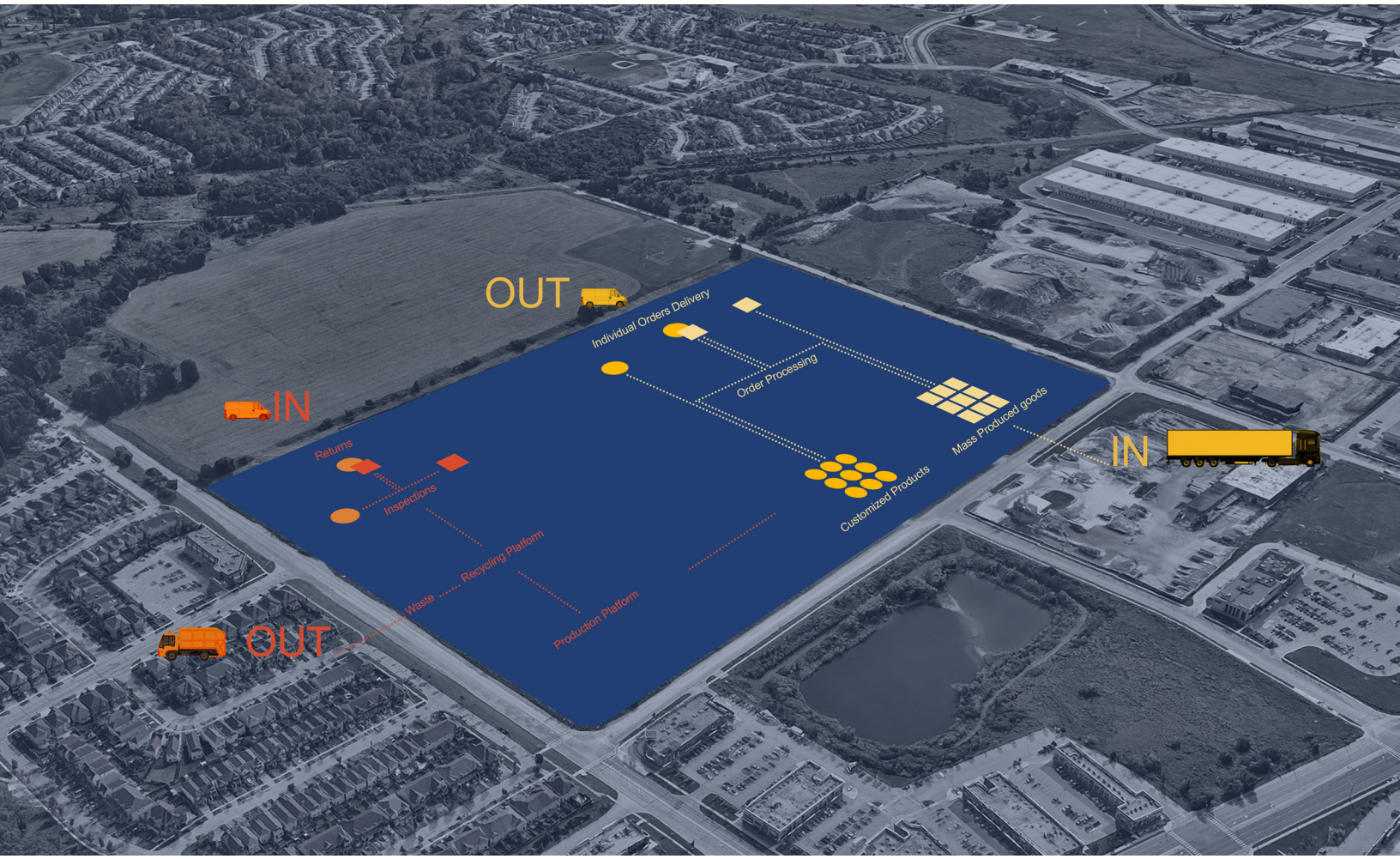


Fig. 132. Material Procedures Projection onto the Site

Procedures



Different cycles of the materials/goods are illustrated on-site in order to study how each main category of procedures could be organized in the project, considering size, access, position, and so on.

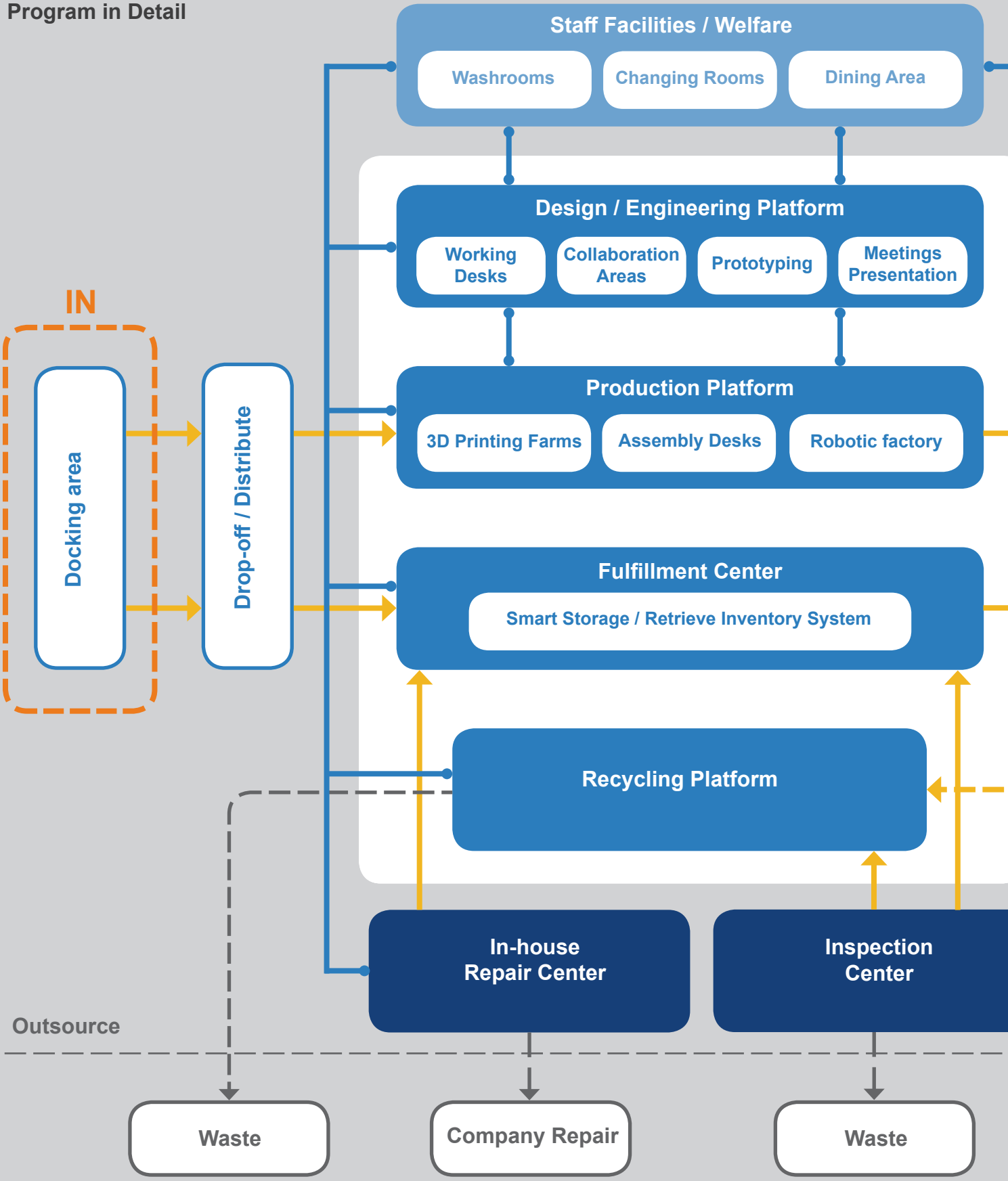
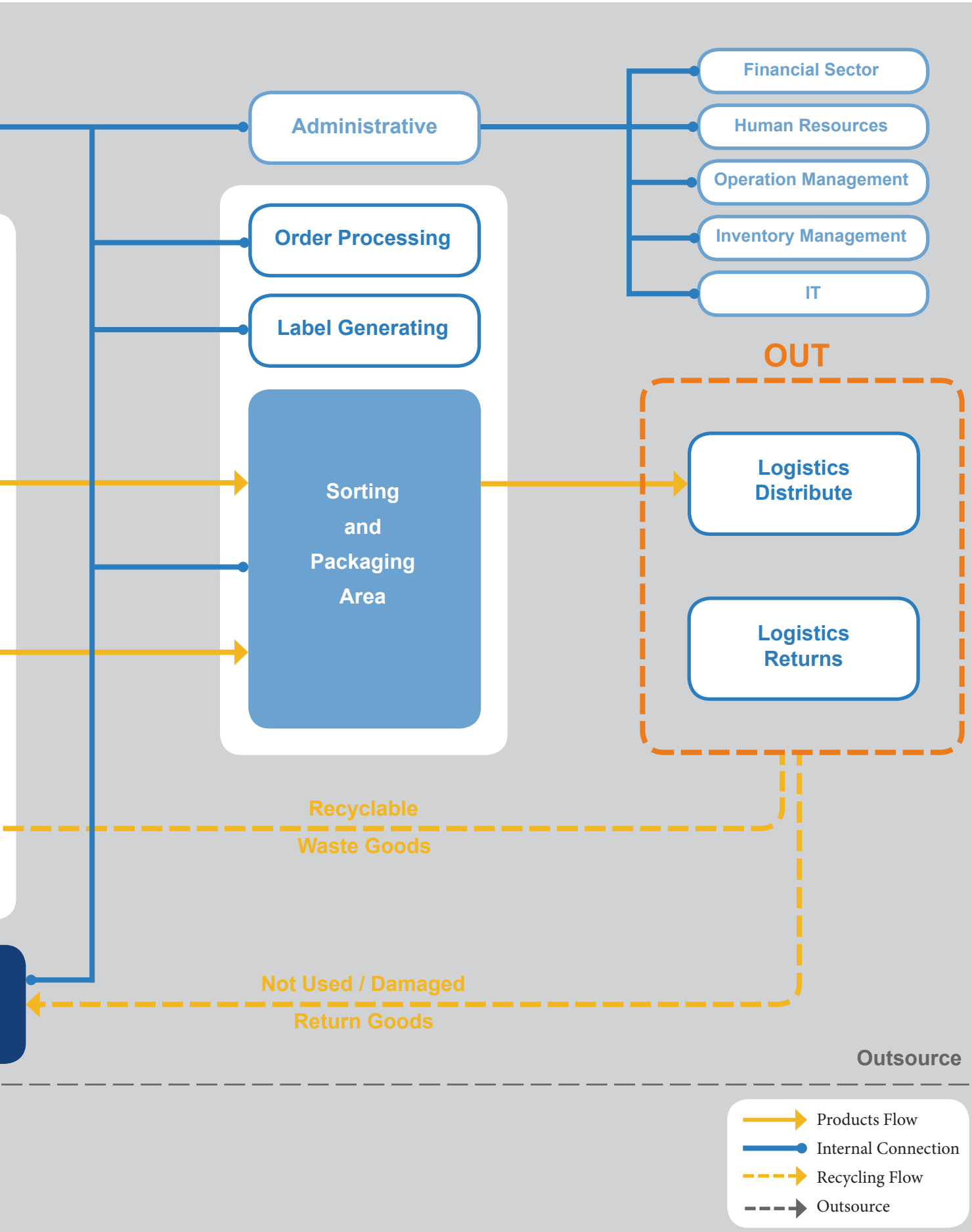
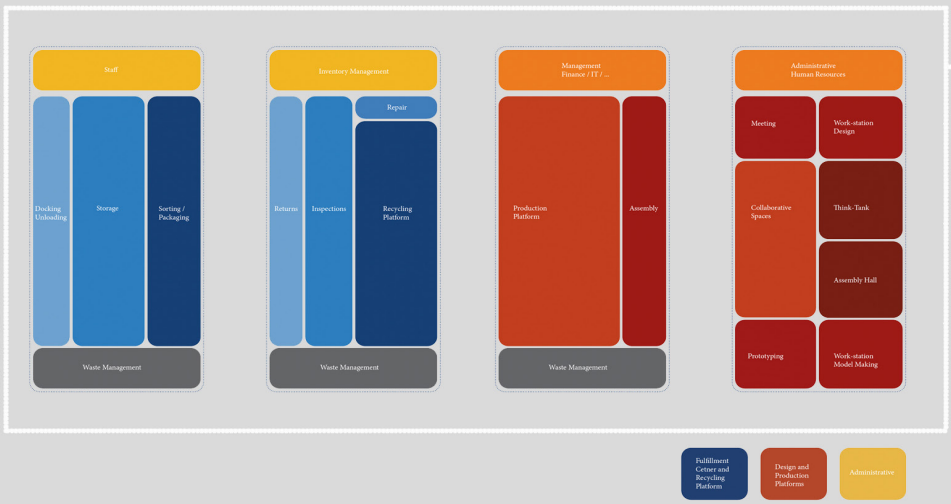
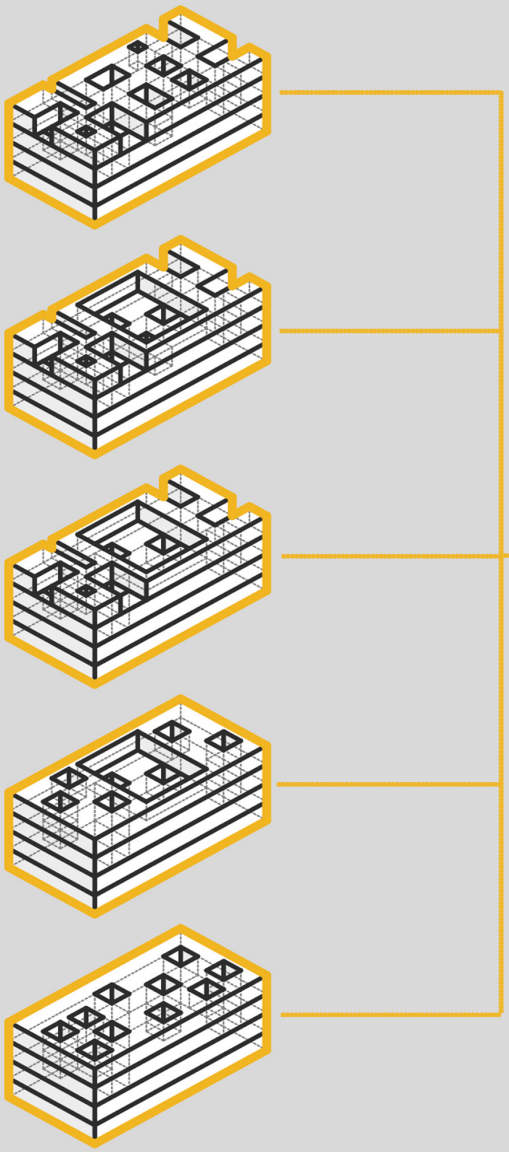


Fig. 133. Program in Detail


Financial Sector
Administrative
Human Resources
Operation Management
Order Processing
Inventory Management
IT
Label Generating
OUT
Sorting
and
Packaging
Area
Logistics
Distribute
Logistics
Returns
Recyclable
Waste Goods
Not Used / Damaged
Return Goods
Outsource
Products Flow
Internal Connection
Recycling Flow
Outsource

Program Projection onto the Site





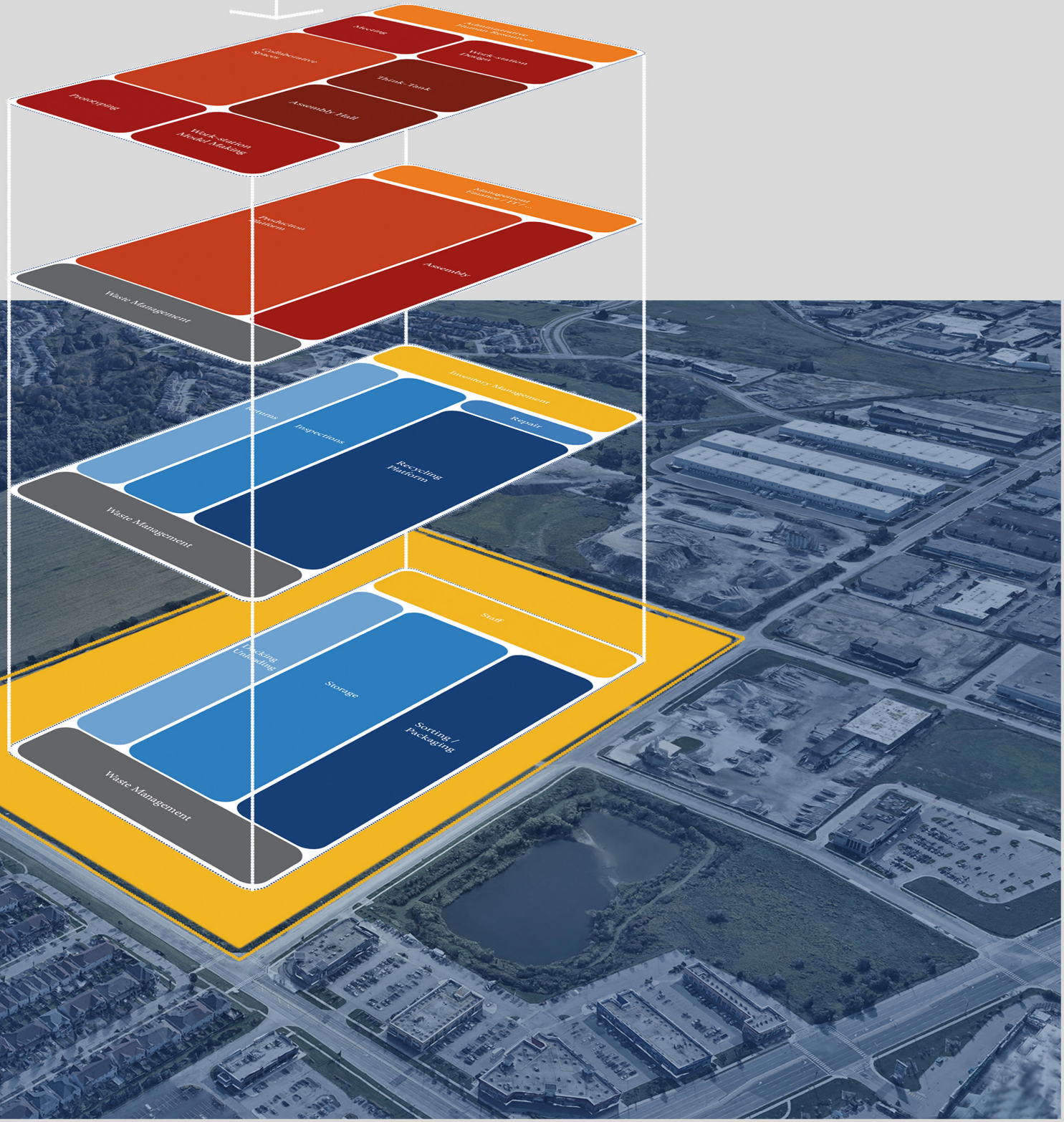
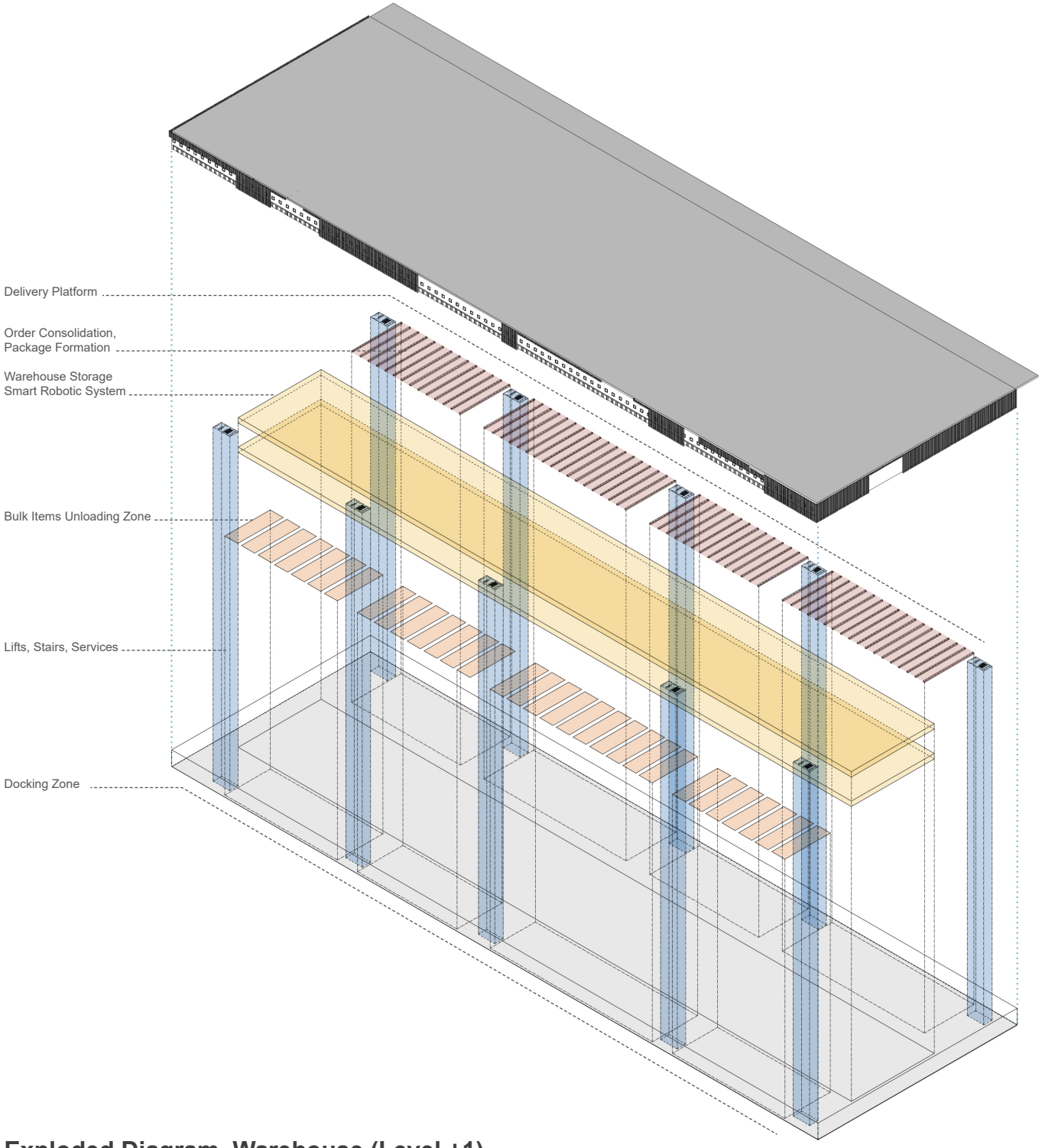
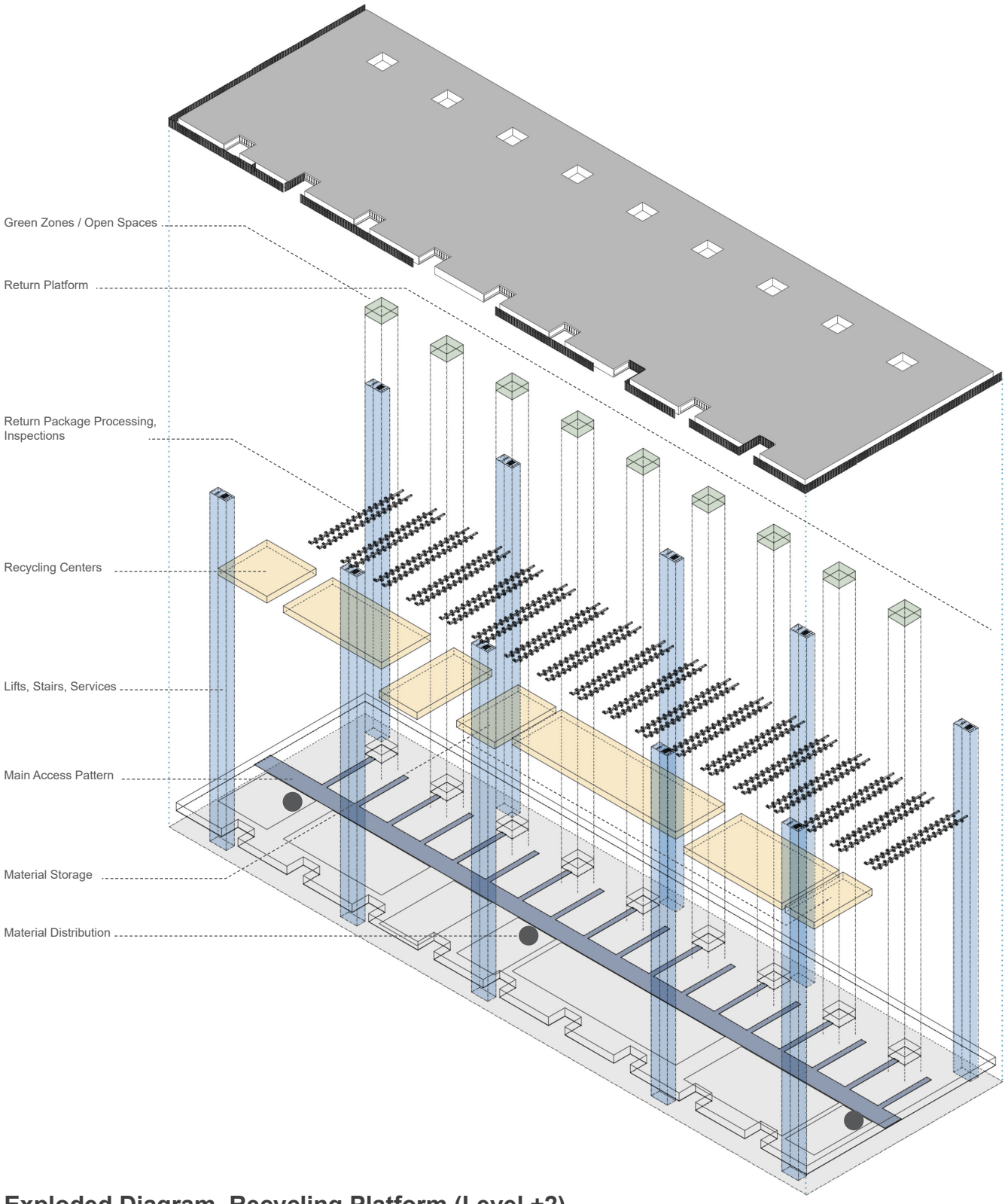


Fig. 134. Program Projection onto the Site



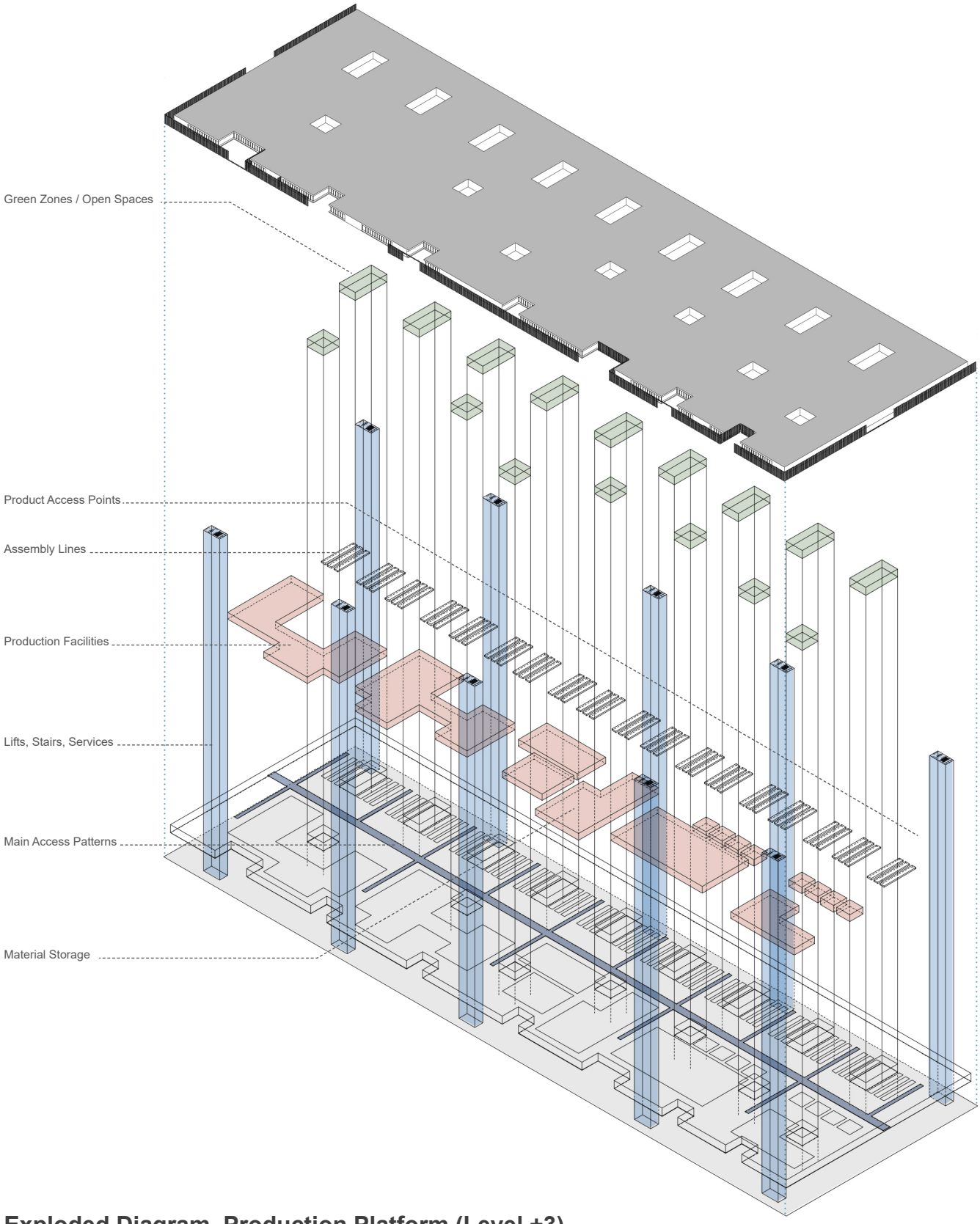
Exploded Diagram, Warehouse (Level +1)

Fig. 135. Future fulfillment center, exploded diagram, warehouse (Level +1)



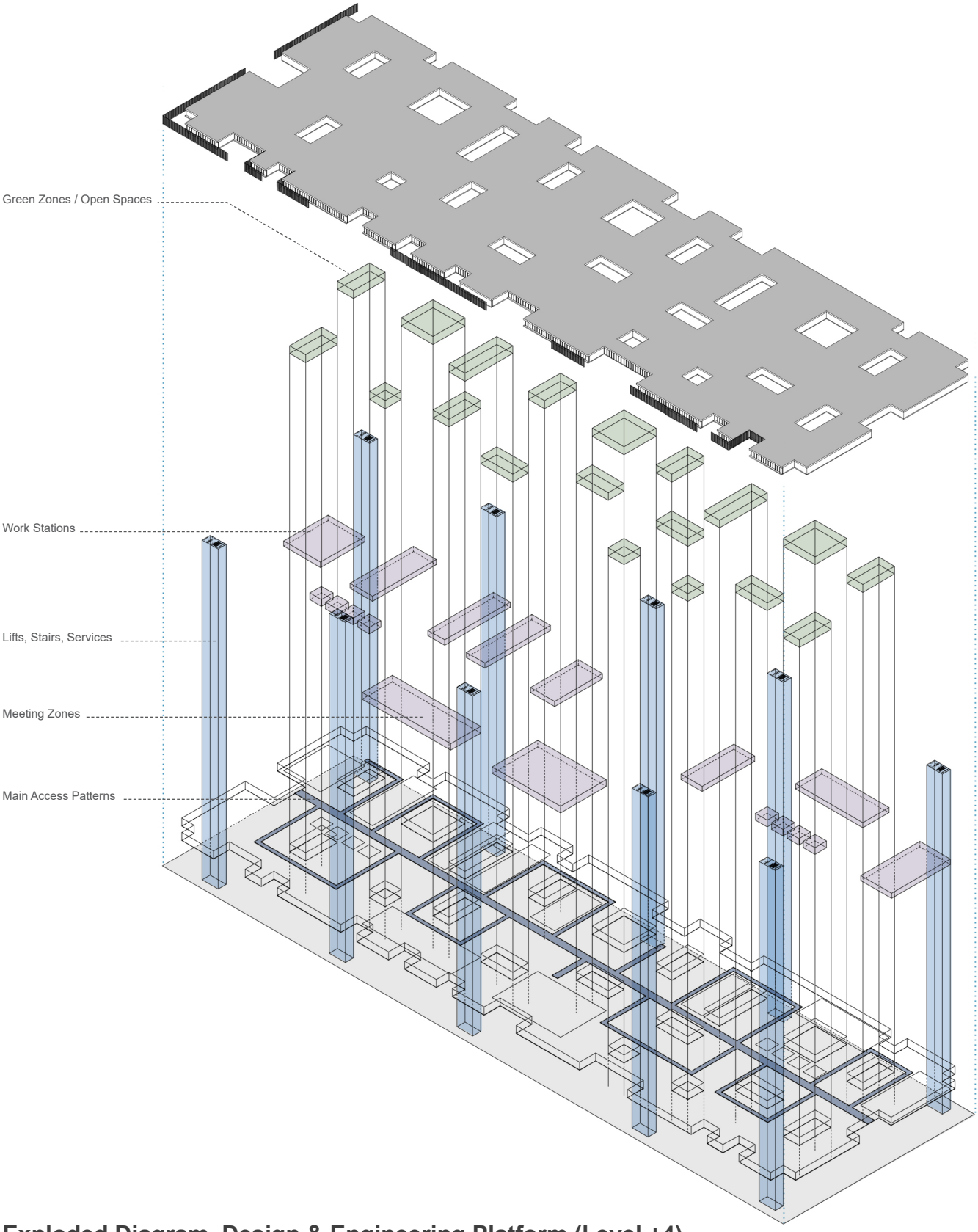
Exploded Diagram, Recycling Platform (Level +2)

Fig. 136. Future fulfillment center, recycling platform (Level +2)



Exploded Diagram, Production Platform (Level +3)

Fig. 137. Future fulfillment center, production platform (Level +3)



Exploded Diagram, Design & Engineering Platform (Level +4)

Fig. 138. Future fulfillment center, design & engineering platform (Level +4)

Building Section A-A

Scale: 1/500

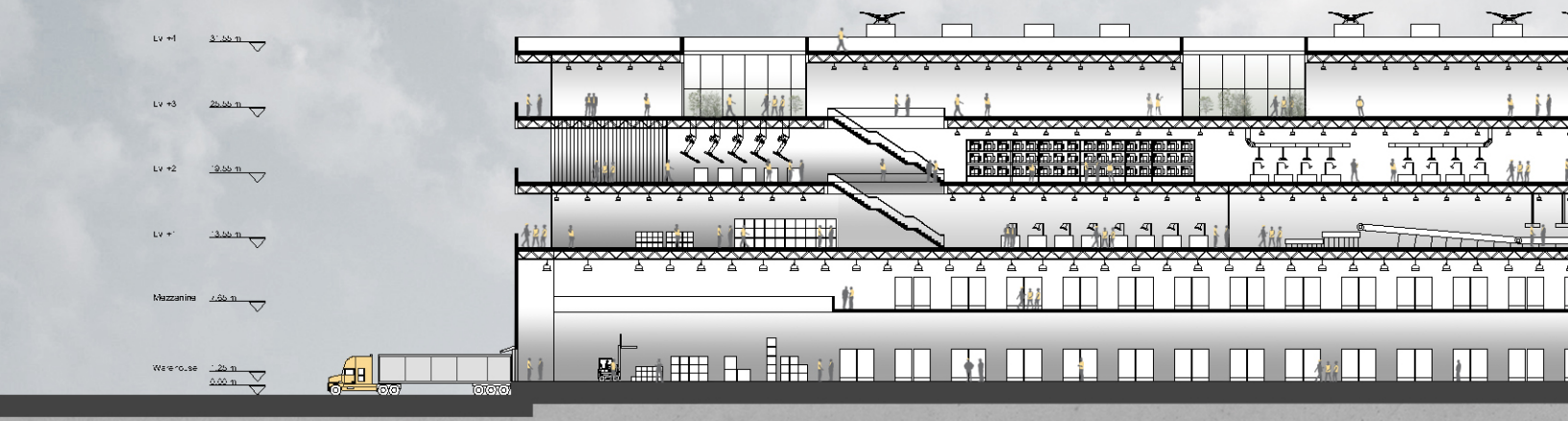


Fig. 139. Building Section A-A

Building Section B-B

Scale: 1/500

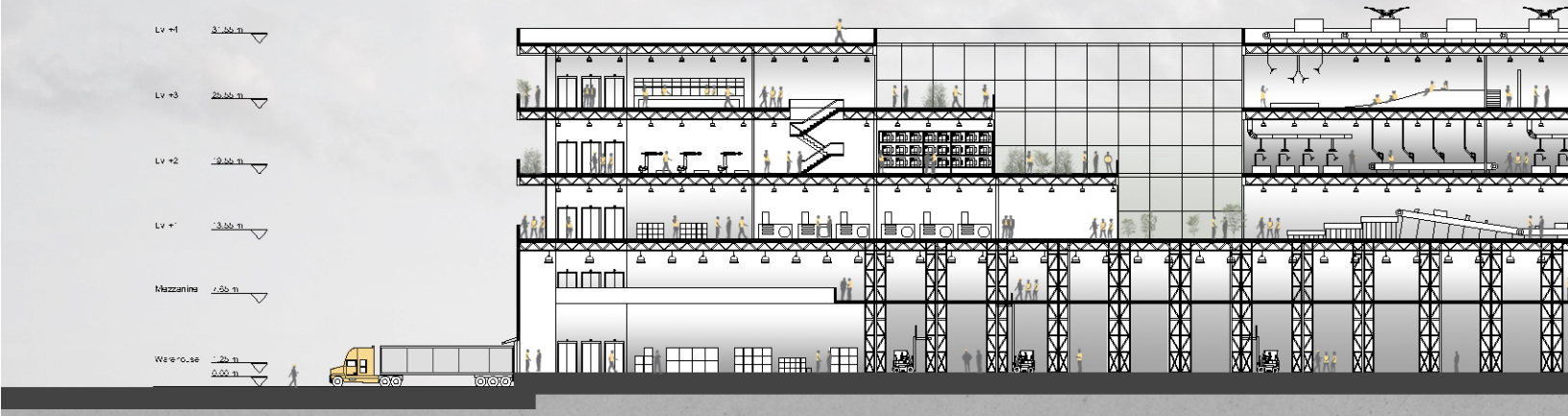
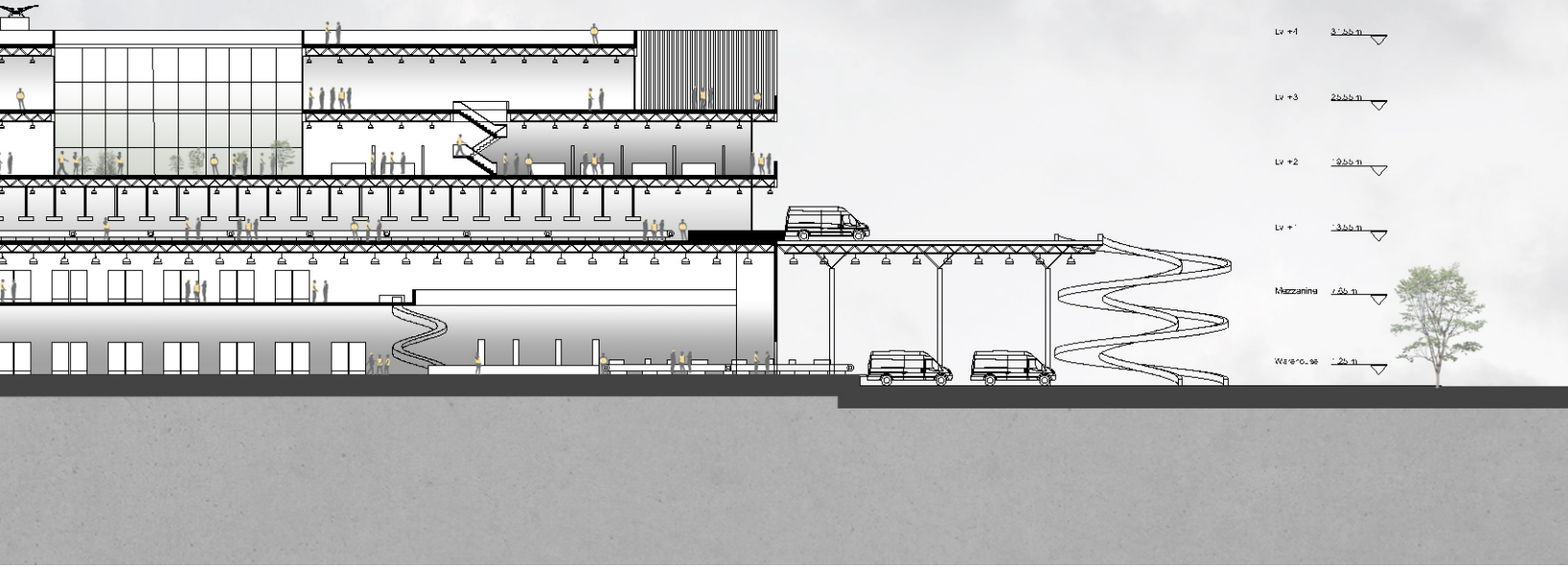
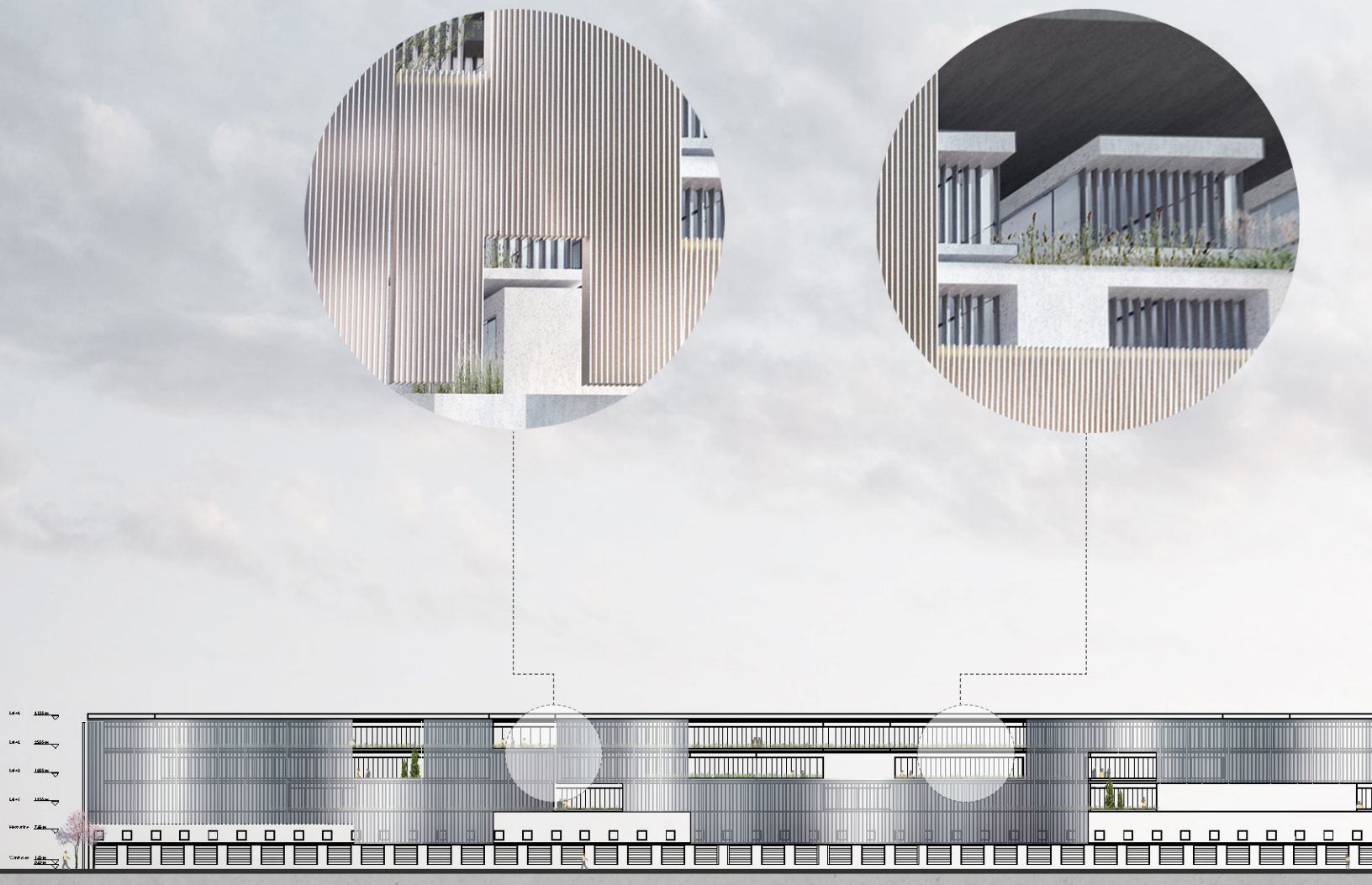


Fig. 140. Building Section B-B


Lv +4
Lv +3
Lv +2
Lv +1
Mezzanine
Warehouse


Lv +4
Lv +3
Lv +2
Lv +1
Mezzanine
Warehouse



West Elevation and Details

Fig. 141. Building west elevation and details

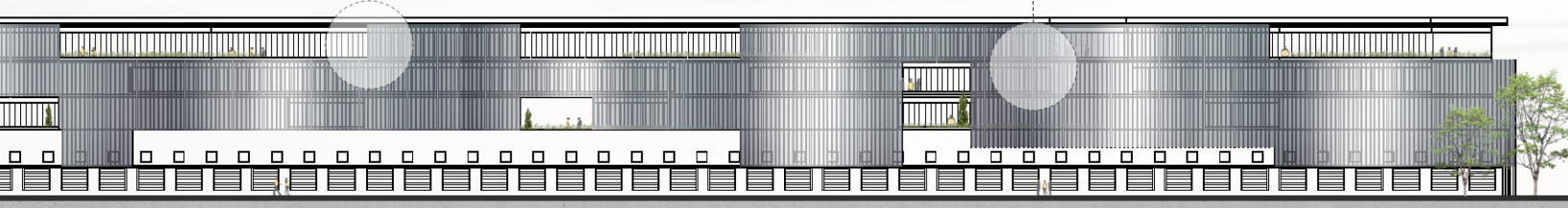


Fig. 142. Interior space of the production platform
Featuring one of the courtyards, a 3D-printing farm and a robotic fabrication lab.


ABRICATION LAB

Fig. 143. Interior spaces of the design and engineering platform with a courtyard and some of the office and meeting rooms

Fig. 145. Docking area with view of recycling, production and design platforms

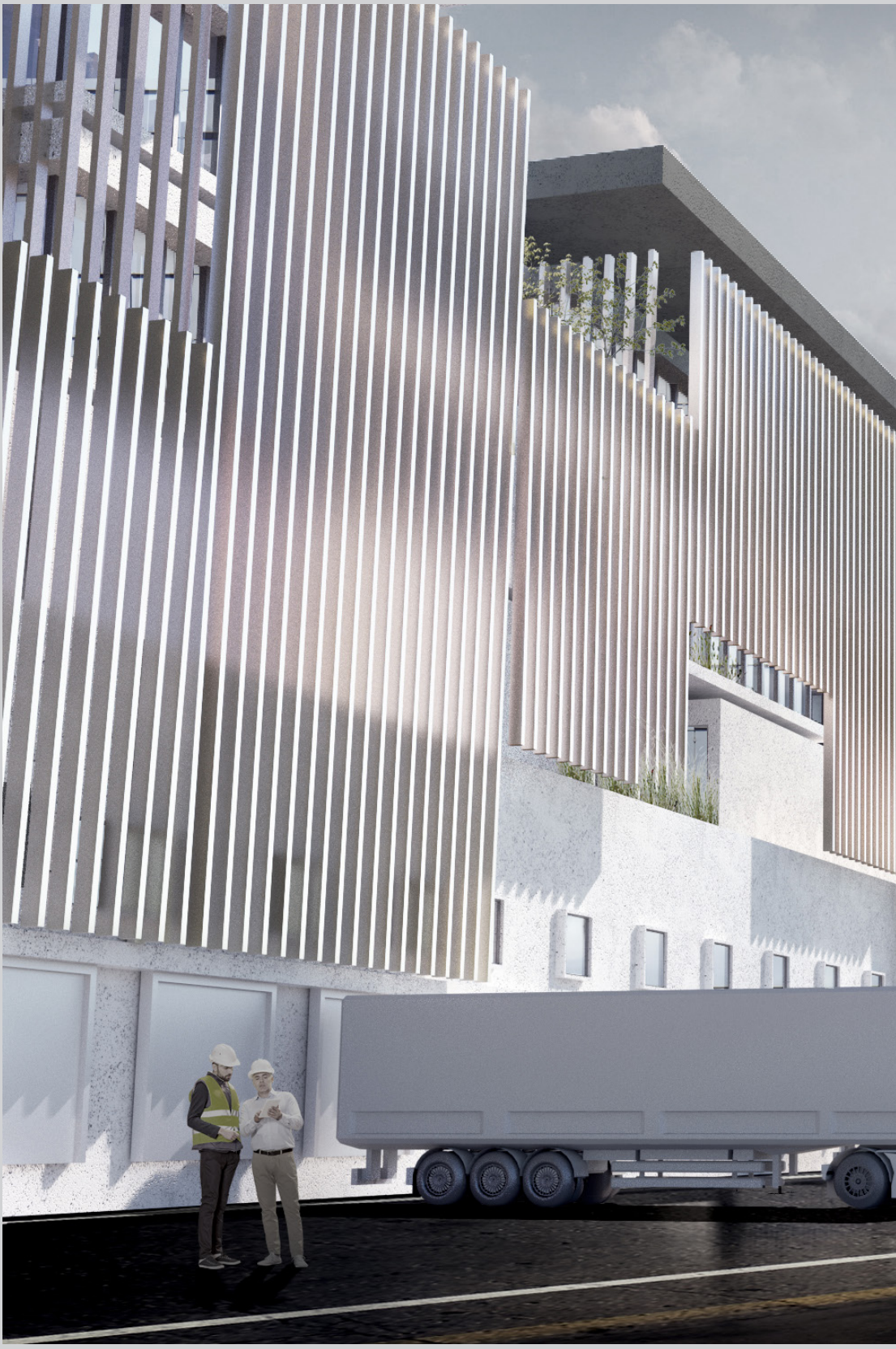


Fig. 146. Closer look at the docking area with some details of the facade

Level 1:

Procedures include docking and unloading goods from trucks, storing goods on shelves, picking items, order consolidation, packaging, labeling, and delivery to customers.

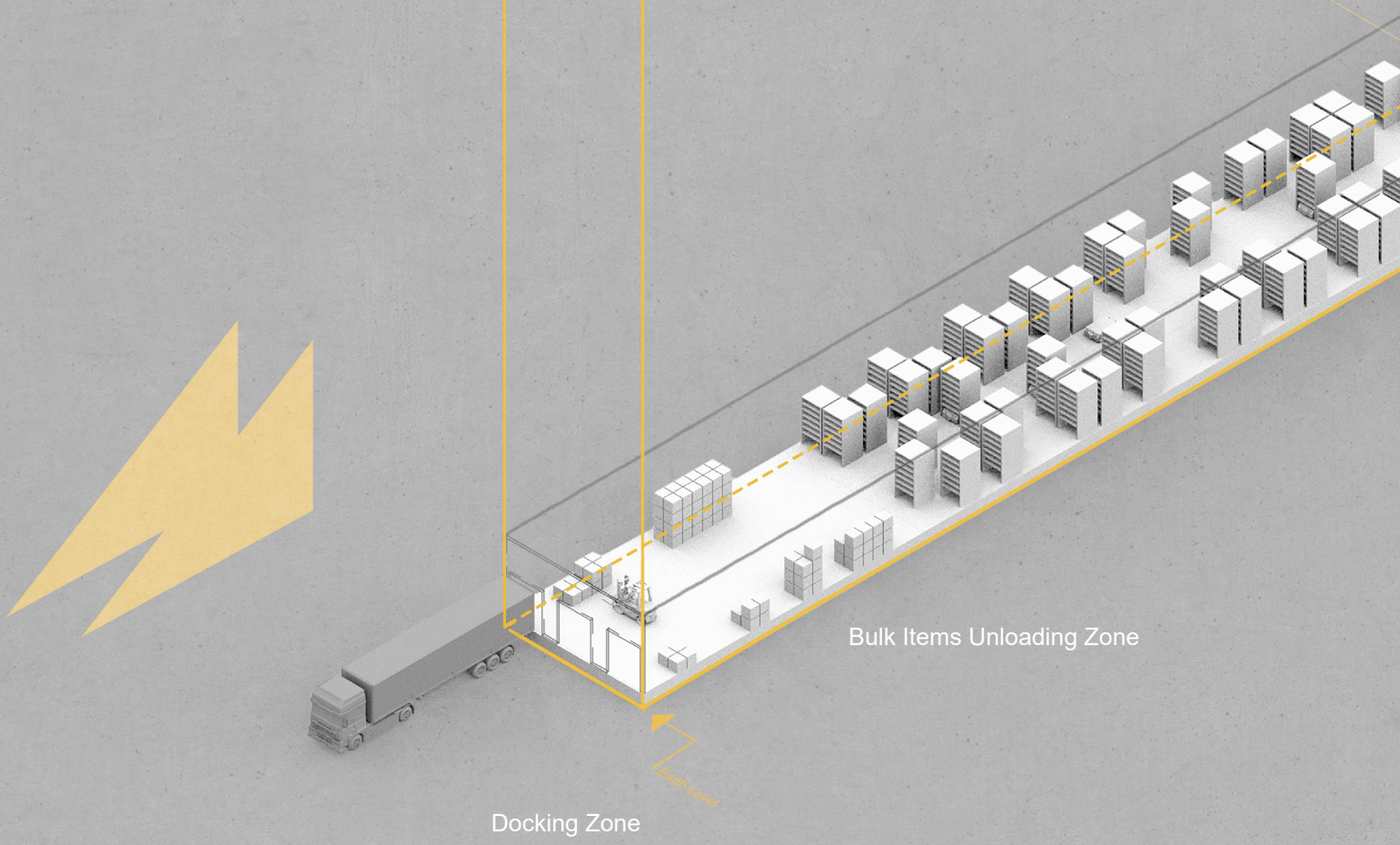
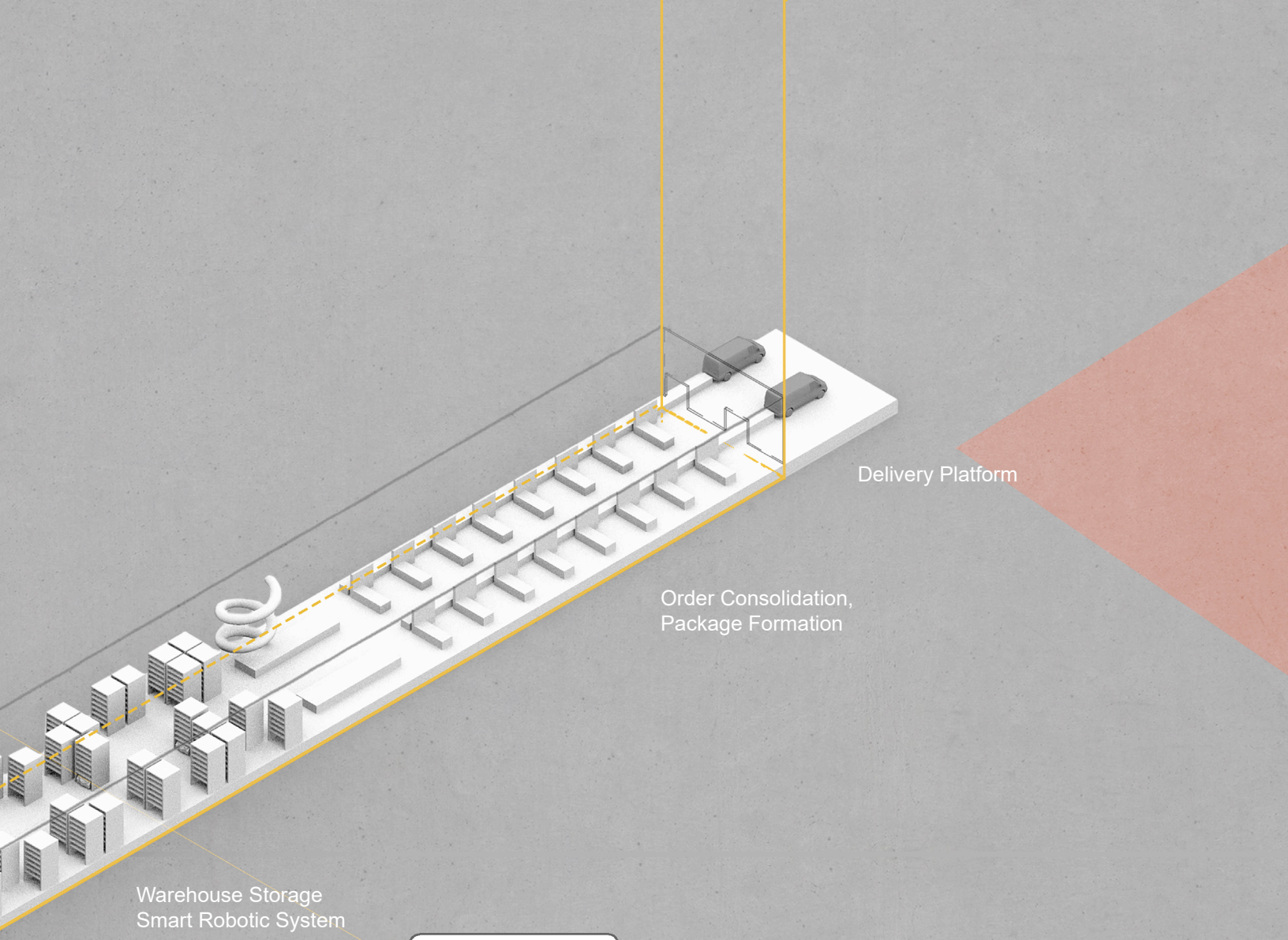
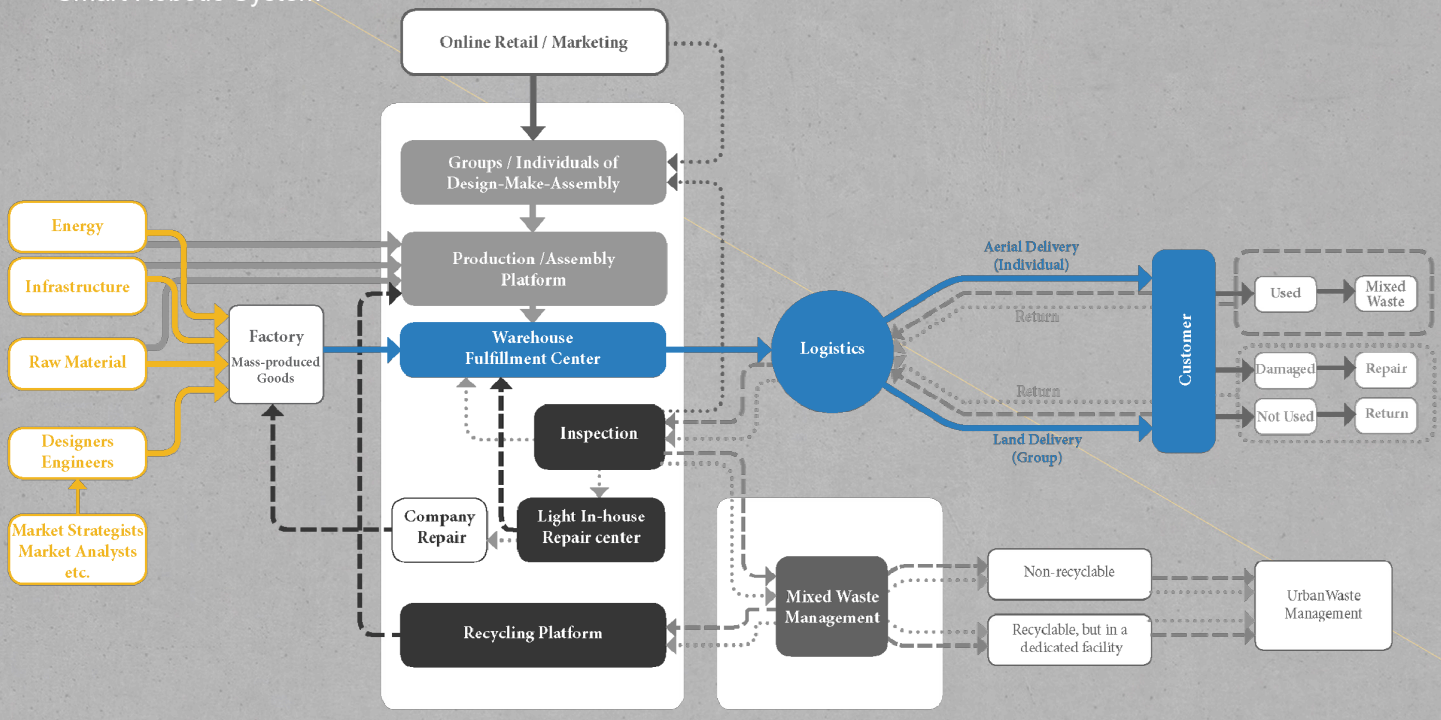


Fig. 147. Sectional 3D Plan, level 1


Delivery Platform
Order Consolidation,
Package Formation
Warehouse Storage
Smart Robotic System


Online Retail / Marketing
Groups / Individuals of Design-Make-Assembly
Production /Assembly Platform
Warehouse Fulfillment Center
Inspection
Light In-house Repair center
Company Repair
Recycling Platform
Energy
Infrastructure
Raw Material
Designers Engineers
Market Strategists Market Analysts etc.
Factory
Mass-produced Goods
Logistics
Aerial Delivery (Individual)
Return
Return
Land Delivery (Group)
Customer
Used
Mixed Waste
Damaged
Repair
Not Used
Return
Mixed Waste Management
Non-recyclable
Recyclable, but in a dedicated facility
UrbanWaste Management

Level 2:

Procedures include unloading return items and materials from delivery vans, unpacking and distribution of items, inspections, sorting materials, recycling of different materials, waste management, and related processes.

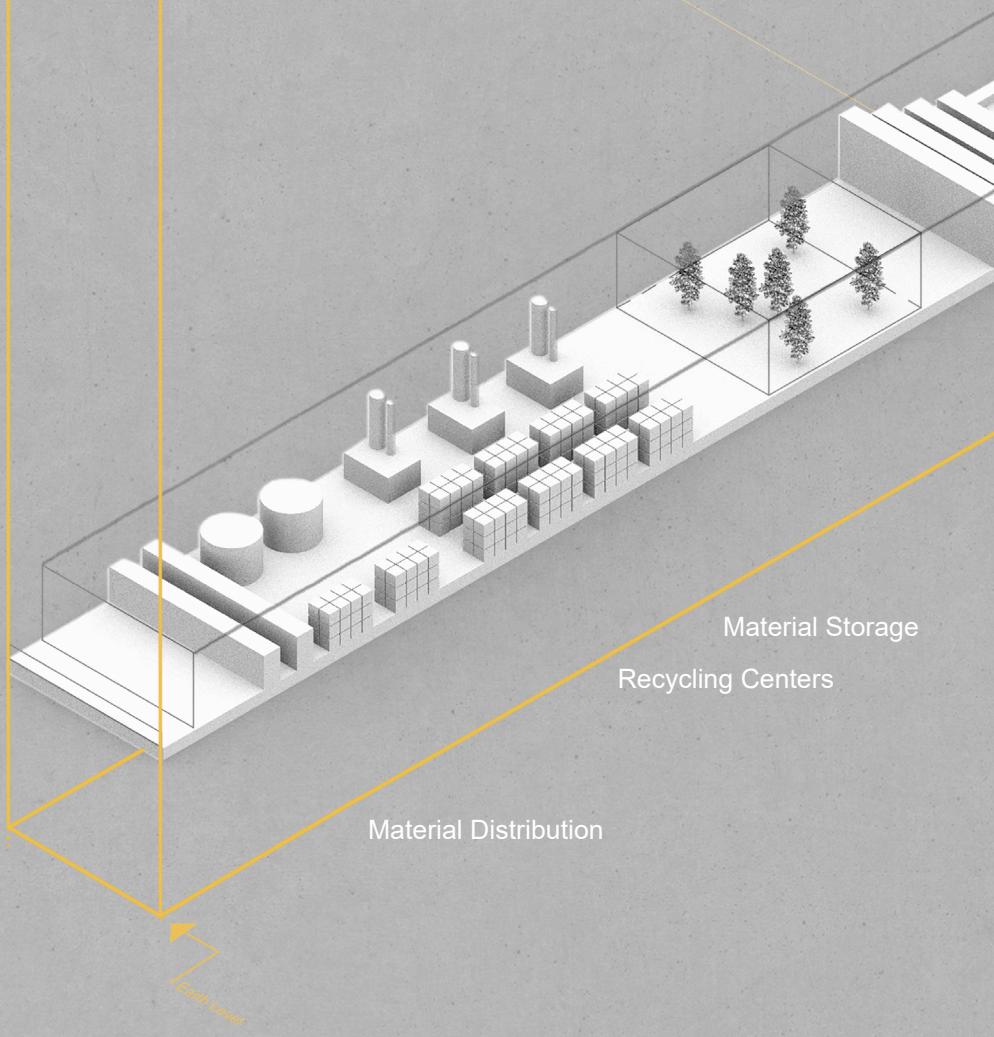
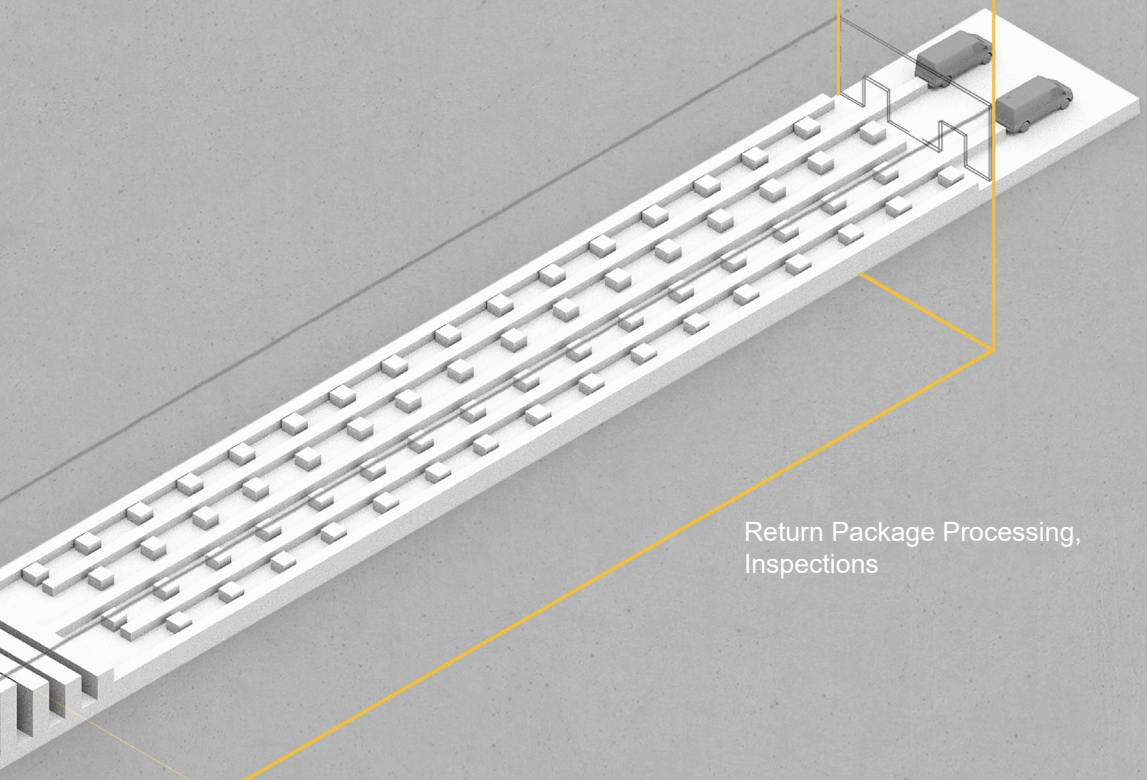


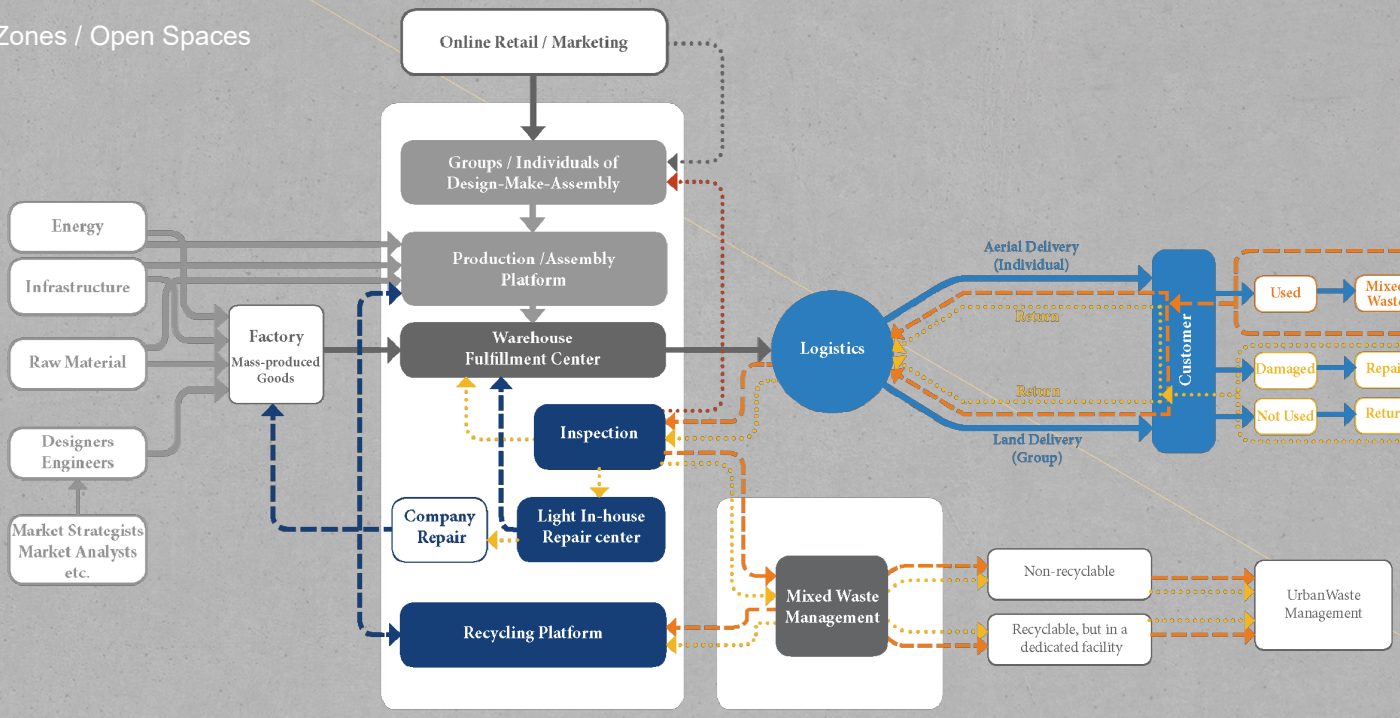
Fig. 148. Sectional 3D Plan, level 2



Return Platform

Return Package Processing,
Inspections

Green Zones / Open Spaces



Level 3:

Procedures include the production of special goods in various production platforms, assembly of items and products, storage of materials and products, and related processes.

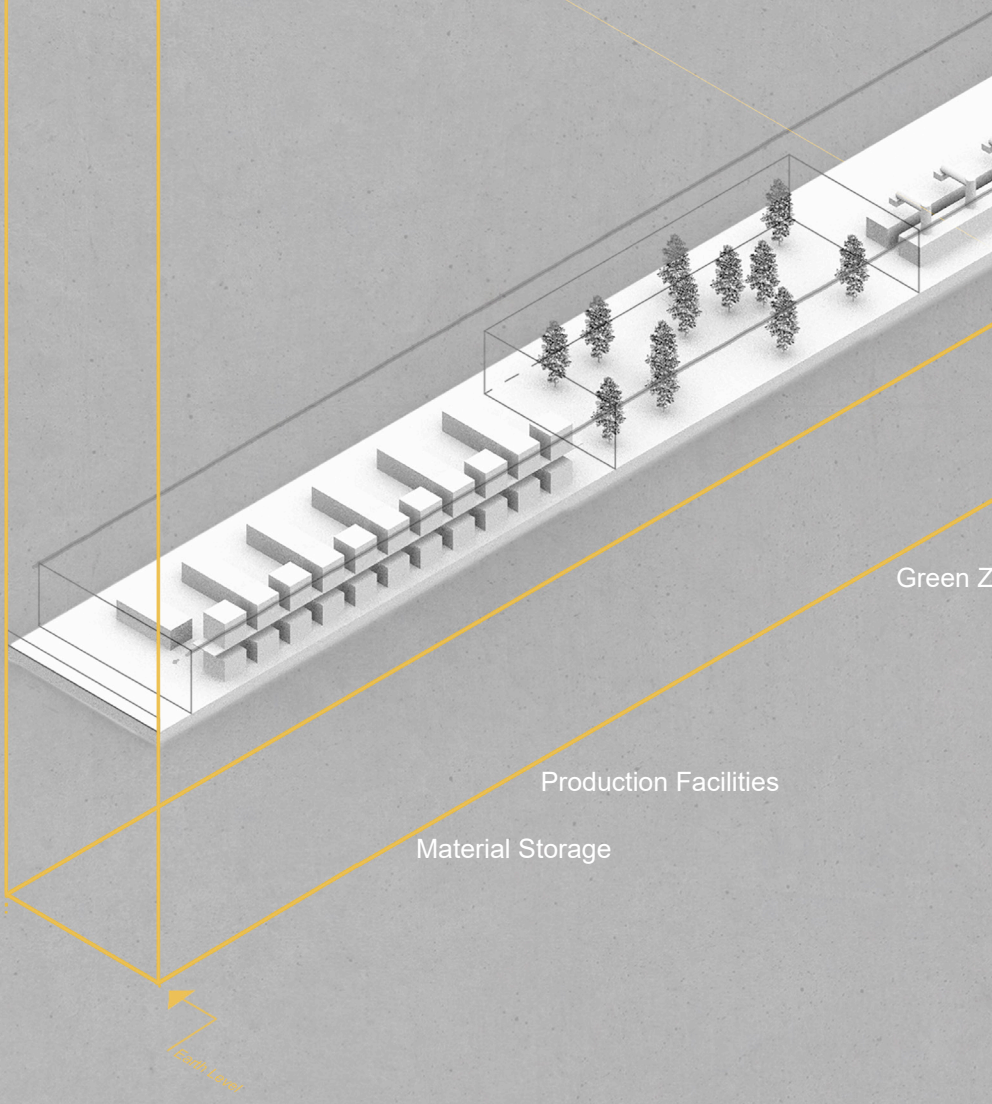
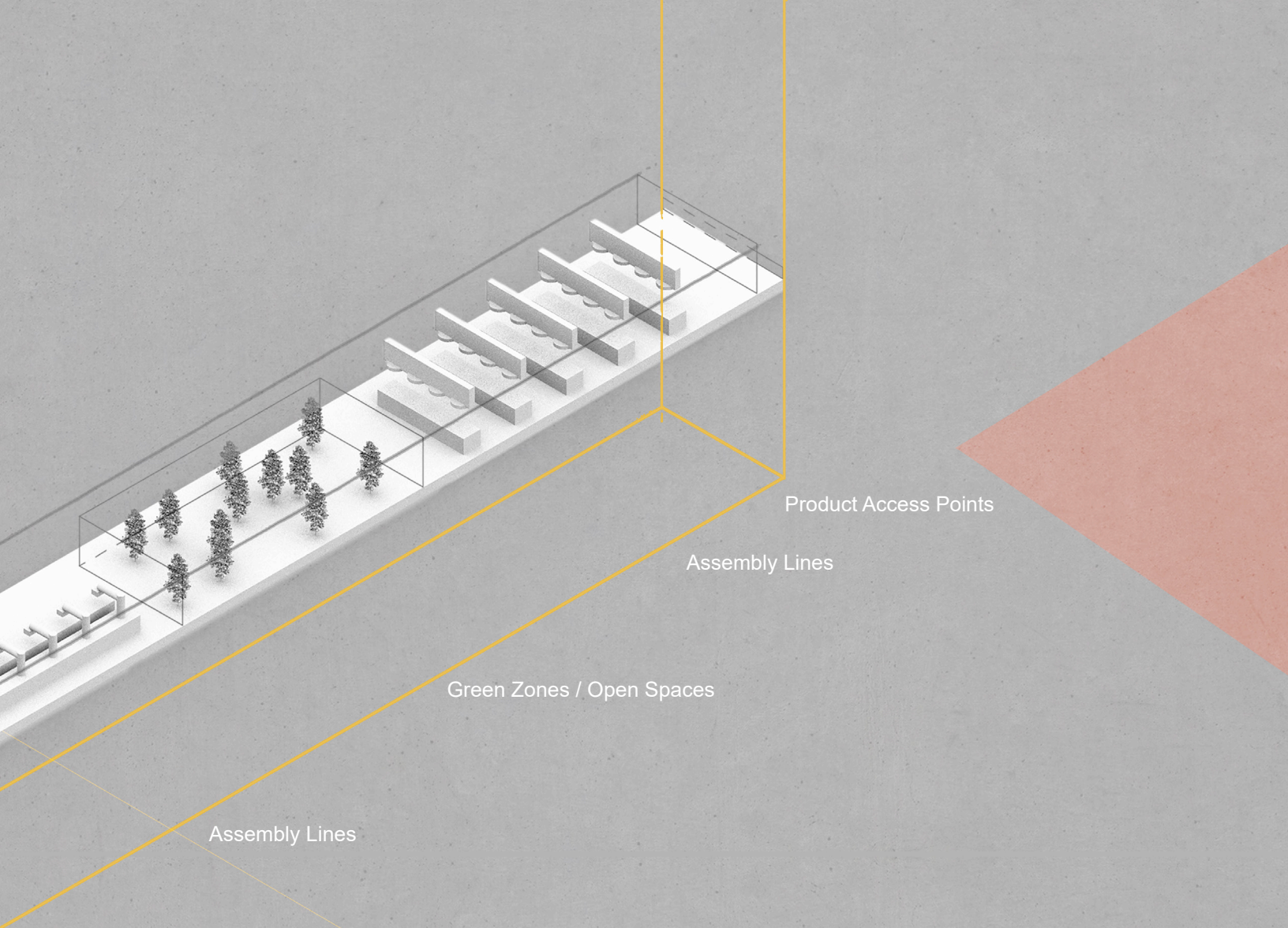
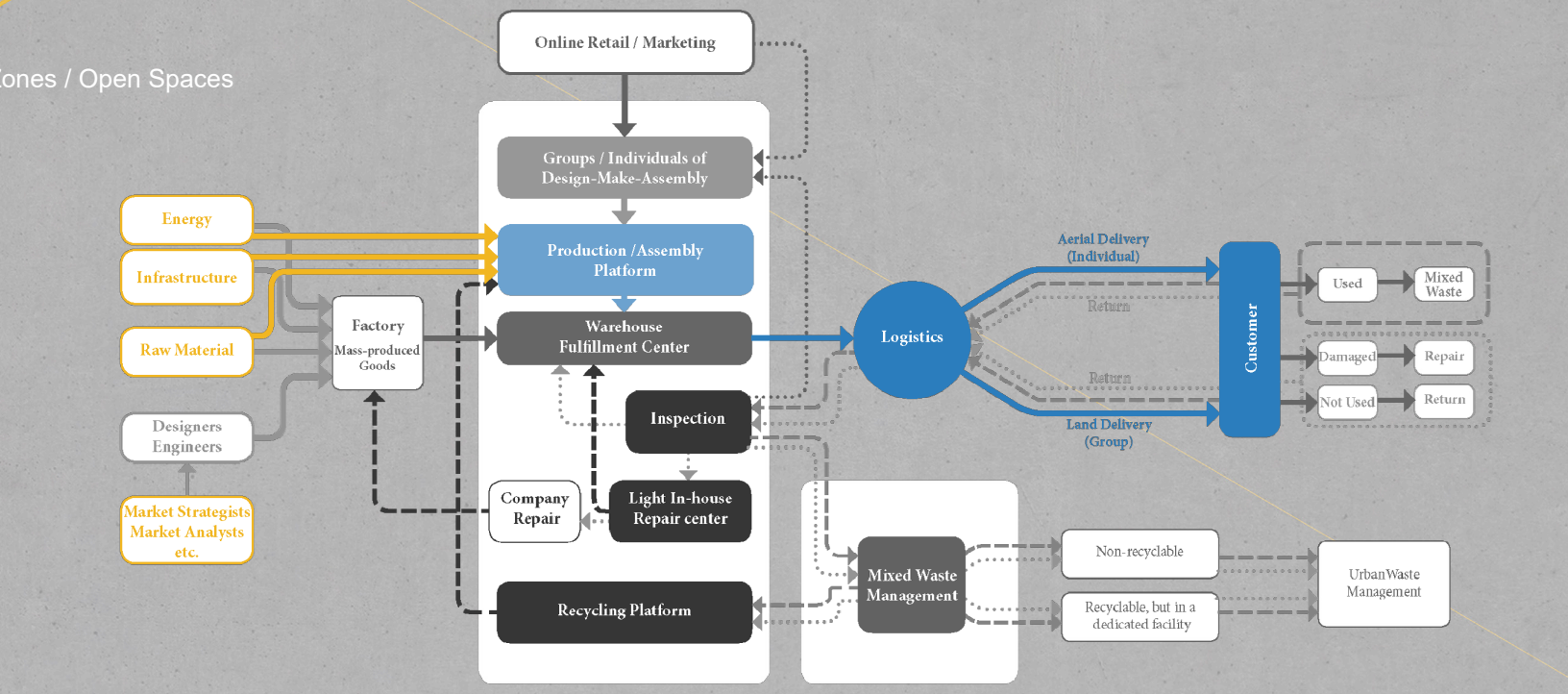


Fig. 149. Sectional 3D Plan, level 3


Product Access Points
Assembly Lines
Green Zones / Open Spaces
Assembly Lines


Online Retail / Marketing
Groups / Individuals of Design-Make-Assembly
Energy
Infrastructure
Raw Material
Production /Assembly Platform
Factory
Mass-produced Goods
Warehouse Fulfillment Center
Designers Engineers
Market Strategists Market Analysts etc.
Inspection
Company Repair
Light In-house Repair center
Recycling Platform
Logistics
Aerial Delivery (Individual)
Return
Return
Land Delivery (Group)
Customer
Used
Mixed Waste
Damaged
Repair
Not Used
Return
Mixed Waste Management
Non-recyclable
Recyclable, but in a dedicated facility
UrbanWaste Management

Level 4:

Procedures include working of designers and engineers, meetings in different formats and for different group sizes, assembly with a large number of staffs, prototyping, and other related processes.

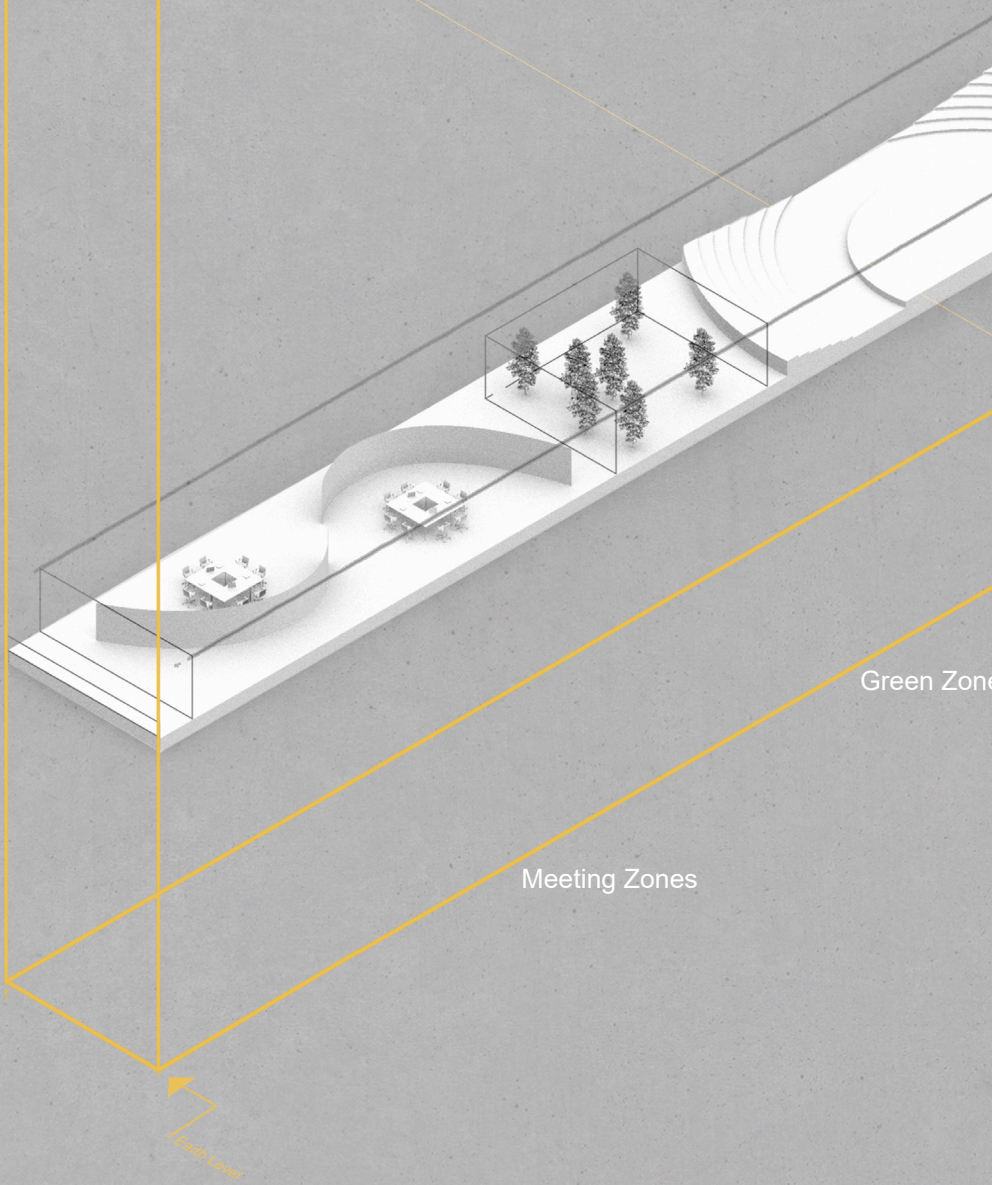
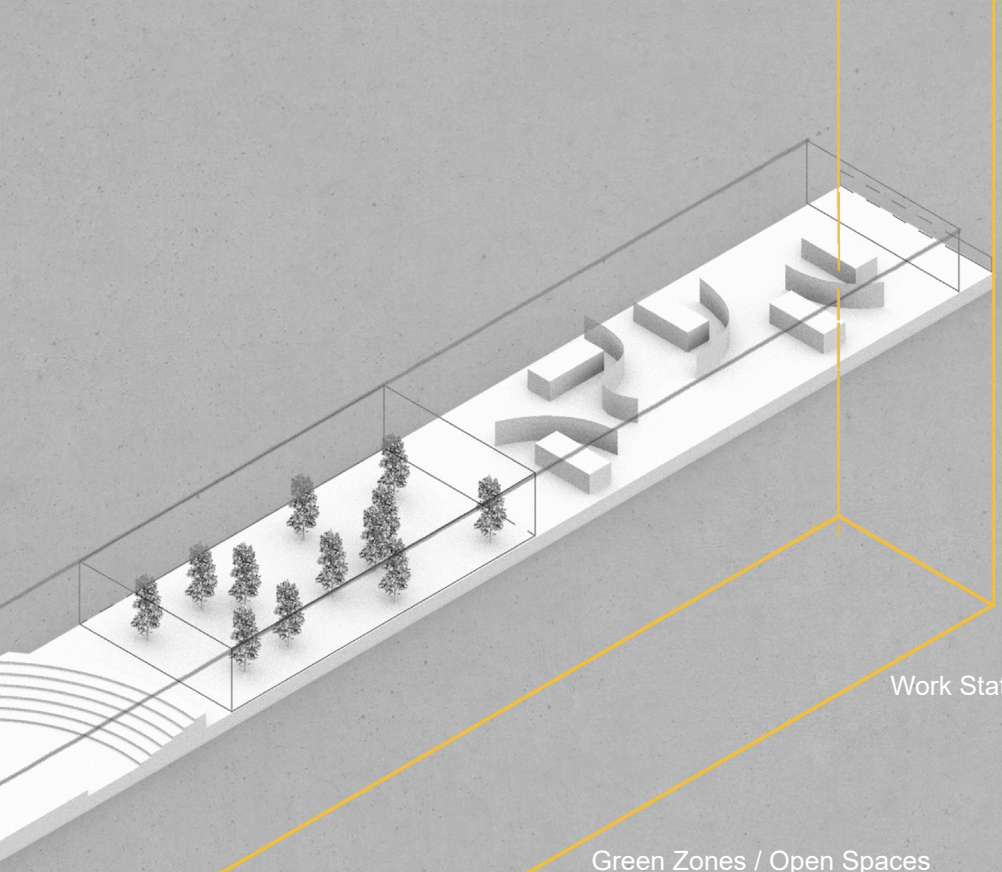
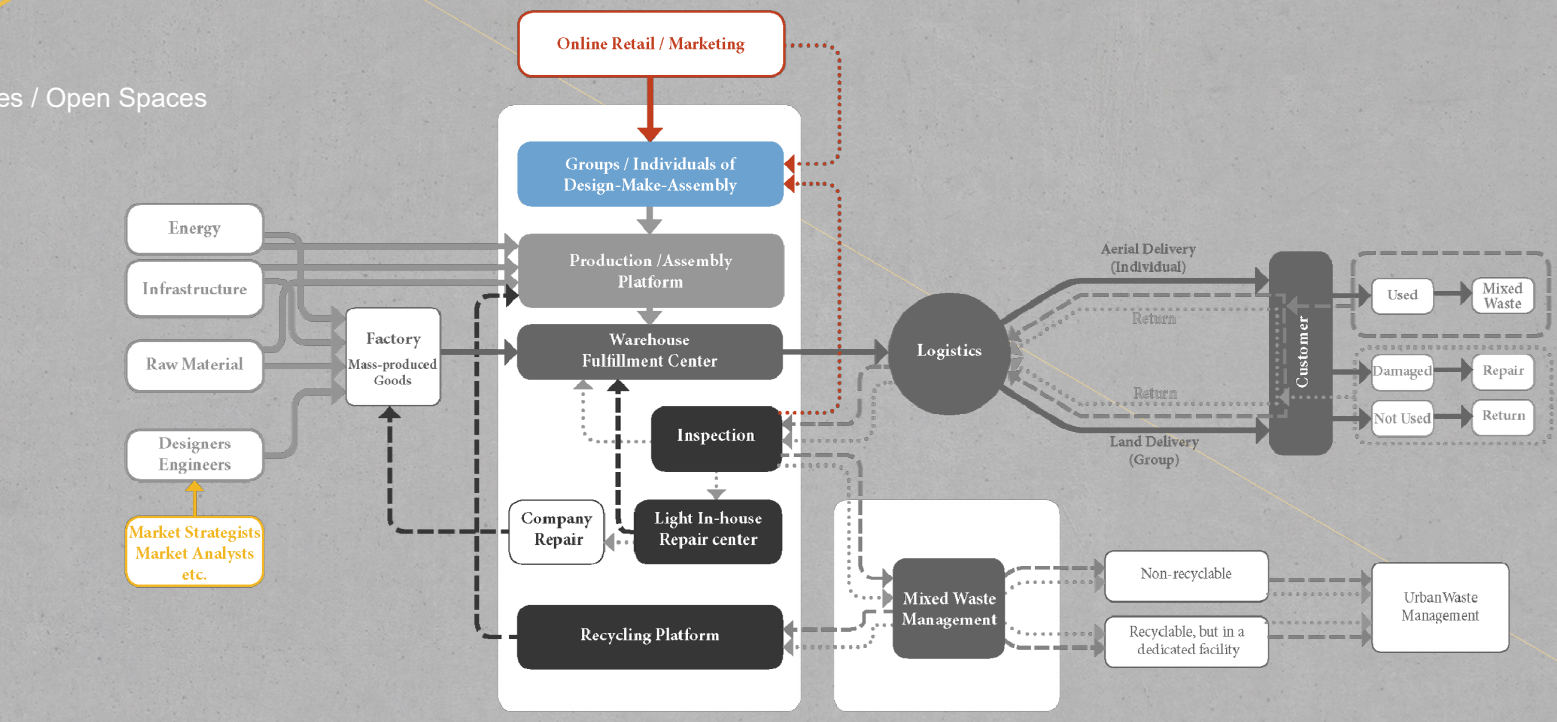


Fig. 150. Sectional 3D Plan, level 4


Work Stations
Green Zones / Open Spaces
Assembly Hall


es / Open Spaces
Online Retail / Marketing
Groups / Individuals of Design-Make-Assembly
Energy
Infrastructure
Raw Material
Designers Engineers
Market Strategists Market Analysts etc.
Factory
Mass-produced Goods
Production /Assembly Platform
Warehouse Fulfillment Center
Inspection
Company Repair
Light In-house Repair center
Recycling Platform
Logistics
Aerial Delivery (Individual)
Return
Return
Land Delivery (Group)
Customer
Used
Mixed Waste
Damaged
Repair
Not Used
Return
Mixed Waste Management
Non-recyclable
Recyclable, but in a dedicated facility
UrbanWaste Management

4.7. Conclusion

The Amazon fulfillment center that is designed and presented in this research is leaning more towards a prototype than a project. It tries to examine the integration of various material and goods procedures in one warehouse. In fact, it combines a current fulfillment center with production and assembly platforms to be able to partially produce some goods and also integrates a recycling platform to be able to manage the afterlife of at least its own produced goods. This model has the flexibility to produce various products and could adapt itself to the changes that happen in the market, as the production platforms are all based on new digital types of machinery. As discussed before, the argument that Amazon and similar companies can still benefit from the production of smaller companies and work as the logistic company, without actually having all the production facilities in-house. This is what actually happens these days. There are many startup companies that are working in this way. But in order to convert this idea into something inclusive, and its method to be applicable to many more products and many more locations, there needs to be the power and establishment like Amazon to make it possible. Such a warehouse with all its “facilities” could actually “facilitate” the production of goods and delivery of them to the customers in an on-demand fashion. Otherwise, smaller companies which are focusing on one product are again going to produce that one product in a mass-produced way, just in smaller quantities. We are sure that not all small companies should be merged into Amazon eventually, and we know that it is impossible, yet we believe that if we want to push the idea of on-demand production and we want to take care of the wastes and afterlife of products, such integration of facilities in a larger setup would be a great step towards the realization of the idea.

Studies of this research started on the foundation of information technologies, fourth industrial revolutions, cyber-physical societies, and their impact on our life and architecture. Based on the texts, suggestions, anticipations, and facts, we proposed the idea of warehouses of the future in which not only the current operations of warehouses are easily possible, but also additional operations like recycling of materials and products, production and assembly, and even design and prototyping is possible. We pursued this model based on two main factors: 1. An urge to produce more individualized items in an on-demand production procedure, and 2. An endeavor to be responsible for material and energy, to produce carefully, and to recycle after the use. With these two main goals, the warehouse suitable for the age of the fourth industrial revolution was proposed in this thesis, yet the goals could even expand beyond the initial ones mentioned.

The 2020 pandemic of Covid-19 across the globe is a new situation which has not been around for decades, and affected everyone’s life and works tremendously. Although images of empty shelves in supermarkets were captured at the very beginning of the pandemic and supermarkets started to keep up with the demand after a short while, we know that there are still many products that are out of stock or at least not easily available[8]. It is clear that during such rare occasions, the focus should be on food, medicine, and sanitary products, and other essential items for everyone's benefit. But we again know that even some of those essential products became out of stock, at least for a while. This phenomenon pushed us to think that having a “stock” of materials/goods is good but never enough. In fact, being able to “produce” some of the immediate needs would also be very important.

It is clear that we are all enjoying the globalization in different scales and scopes and satisfied with having goods produced elsewhere at our disposal and at a reasonable price. We are not against the idea of free trade or anything politically related to that. What we are seeing is that having the potentials to produce some of the products that we are using on a daily basis is crucial, especially when there is a difficult situation like the pandemic. In this case, our production facilities could shift their focus to produce essential products needed by the public. This emphasis on the fact that from being a consumer-only society to a smart society which at least has the potential to produce some of its needs, is a huge

difference that could become very important in a scenario like the pandemic that we are experiencing now. Of course, responsible use of material and energy, responsible strategy for the afterlife and life-cycle of products, and adaptiveness to the needs of markets and demands are all still the foundation of this research but responding to new scenarios could be an added value for this research, without sacrificing any of the initial goals, and even reinforcing them.

***

Endnotes:

1. DePillis, Lydia and Ivory Sherman. “Amazon’s Extraordinary 25-Year Evolution.” . Published Oct 4,2018. Accessed Aug 15, 2020. https://www.cnn.com/interactive/2018/10/business/amazon-history-timeline/index.html.
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8. Tralton, Amanda. “24 Things that have been Selling Out Online during the Coronavirus Pandemic.” *USA Today,* Apr 20, 2020, Online. https://www.usatoday.com/story/tech/reviewed-com/2020/04/20/24-products-selling-out-online-due-coronavirus-pandemic-toilet-paper-cleaning-wipes-yeast-and-more/5161629002/.

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capstonequadrangle.com
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RBP - Overall IND. Plan 01.25.19 WEB no list.jpg 2118K

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Bibliography

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