Multi-Modal Modelling: BIM Template for Hub Connectivity and Networks

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16. Abstract

A multimodal, transportation-oriented approach to a Building Information Model (BIM) template advances the application of this technology to a new typology. Furthermore, the directive of the template explores equity diverse populations and communities through the development of user based BIM component assemblies ranging from air travel 3D model objects to high-speed rail hub components to slow-moving transportation circulation studies. Dissemination journal publication, studio book publication proposal and conference presentation would then sustain these metrics and methodology for future transportation development beyond the proposed research period. This proposal aims to deliver impactful output and technological transfer for the development of specialized research into the application of BIM technology for megaregion mobility.

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Chapter 1. Introduction: Building Information Modelling (BIM)

A Building Information Model platform supports the ability to coordinate, update, and share design data collaboratively throughout the design construction and management phases of a building's life. A key component in managing the BIM process is to establish a foundation for different types of projects by creating standard templates and custom 3D modelled elements. Having this in place makes the process of new (or renovated) project potentially smoother and with guided efficiency. For USDOT or private service providers involved in multi-modal services, BIM technology in general and a loaded template for multi-modal integration would advance and organize this effort.

Proprietary BIM software contains standard templates specific to an Architecture, Structural or Construction stakeholders. BIM content libraries exist with examples specific to certain typologies, like education or small scale residential, but are not however transportation specific, much less focused on multi-modal integration in transit hubs[1]. Furthermore, the National BIM Standard-United States® (NBIMS-US™) provides consensus based standards through referencing existing standards, documenting information exchanges and delivering best business practices for the entire built environment. From both forms of open BIM standards, a template for transportation hubs can expand upon the detailed models that exist, create new custom ones and give stakeholders accurate BIM models to optimize this network. This template could then be used at all stages of project development to ensure functionality throughout the life of the facility and to deliver high performance (and potentially net zero energy) based 3D modelled objects. In summation, a content library exists, but needs to be filtered and edited for transportation multi-modal hub design and more importantly supplemented.

Projects, especially broad network-based ones like a transportation hub, need standards and consistent object files[2]. Although many standards and templates exist, there is no one reliable source. These standards cannot just be explicit and written standards, but also in drawing (template format) for common use and distribution. Standards will begin to be established by the content in

[1] Afsari, Kereshmeh & Chuck Eastman (2014) "Categorization of building product models in BIM Content Library portals" In the 18th Conference of the Iberoamerican Society of Digital Graphics. Uruguay- Montevideo: 370-374.
[2] Grant, M. (1994) "Urban Gis - The Application of the Information Technologies to Urban Management." In Second Design and Decision Support Systems in Architecture & Urban Planning. Vaals: 15-19.

the template. Workflow redundancy of gathering basic 3D models can be alleviated for a new project. Without such basic template guidelines, project information can become difficult to interpret and responsibilities begin to blur. Important sustainability measures can also be forgotten.

Lastly, this proposal extends research with innovative design methodologies using Building Information Modelling (BIM) through the development, evaluation and definition of multi-modal networks which currently does not exist. This occurred through library development, collaboration with a national architecture firm and with students in an Advanced Design Studio. The research opens up the potential to use BIM in novel ways and to capture not only quantification of parts placed in the transportation User Based context but give rise to theoretical positioning of the software platform for the industry and academic realm.

1.1. Relevance and Contribution to CM2 Mission/Themes

CM2 has outlined six research themes that highlight the goals of the UTC. The research demonstrates the promotion of a Megaregional approach to equity. More specifically, the research contributes to the optimization of inter-modality through research on the applications of Building Information Modeling (BIM). In general, the project and its dissemination aims to improve multi-modal integration in transit hub network diagrams and design. Dissemination has occurred through conference presentation and publication. Collaboration and or discussion with industry has also occurred both formally and informally.

Chapter 2. Research Methods

2.1. Case Studies: Significant Multimodal Transportation Hub

The research modelled ten significant multi-modal transportation projects (and their surrounding urban context) in both the national and international cities. This procedure amplified the template collection of major 3D objects, like the network of rail lines, at a schematic understanding. The basic models further the CM2 agenda to promote BIM technology through diagram and design. Comparable items are: Location, Size, and Passenger footfall, Type, Modes served.[3] This study is an attempt to provide a better definition of the BIM comparisons in public transport and to develop a framework for measuring perception of accessibility and equity, one of the most important determinants of public transport convenience. Developing these models also confirmed the basic object library necessary to define a multi-modal hub in terms of its Indicators of Multimodal Transport as Parameters for BIM Families: Sustainability and Equity, Accessibility, Convergence, Integration.

2.1.1. National

1. 30th St Station, Philadelphia, PA

    9 island platforms (3 upper level, 6 lower level)
    Tracks 15 (6 upper level, 9 lower level)
    Connections
    Market–Frankford Line at 30th Street
    Subway–surface trolley lines at 30th Street
    City Bus SEPTA City Bus: 9, 12, 21, 30, 31, 42, 44, 62, LUCY
    Suburban Bus SEPTA Suburban Bus: 124, 125
    JFK Boulevard & 30th Street
    NJT Bus NJT Bus: 316, 414, 417, 555
    Intercity Bus Megabus: M21, M23, M29, M30, M31, M32, M34
    Intercity Bus BoltBus
    Intercity bus Martz Trailways
    Passengers (FY 2017) 4,411,662

[3] King, David. (2014*)* 3 Big Challenges for Planning Multi-Modal Cities. *https://www.citylab.com/design/2014/10/3-big-challenges-for-planning-multi-modal-cities/381254/*

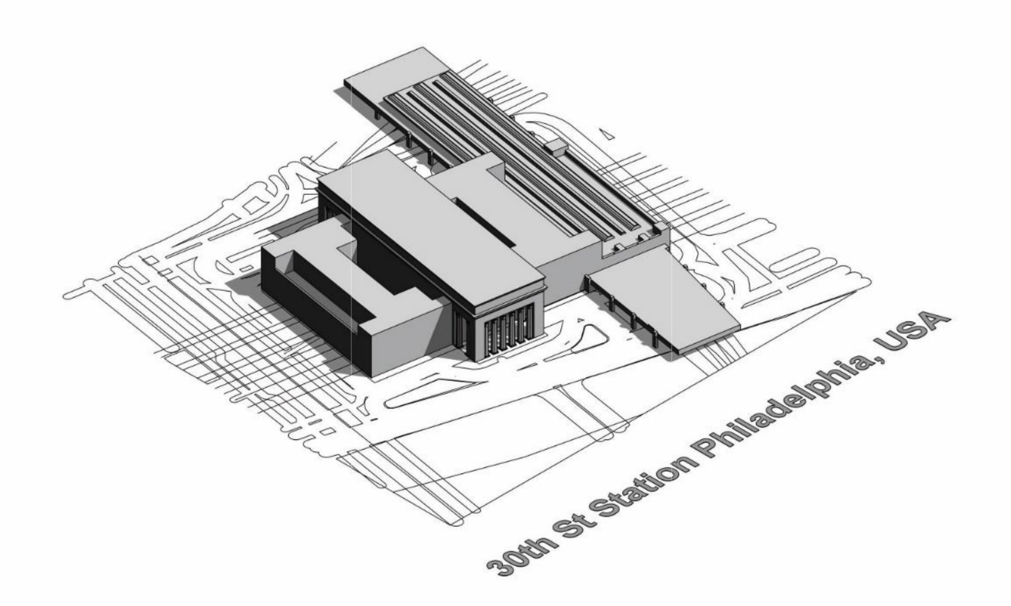

Figure 2.1.1 30th Street Station Case Study BIM

2. Union Station, Washington D.C.

Platforms 18
Tracks 22
Connections Washington Metro
WMATA Red.svg at Union Station
Tram interchange DC Streetcar
Bike transport Metropolitan Branch Trail
Passengers (2017) 5,225,460 annually

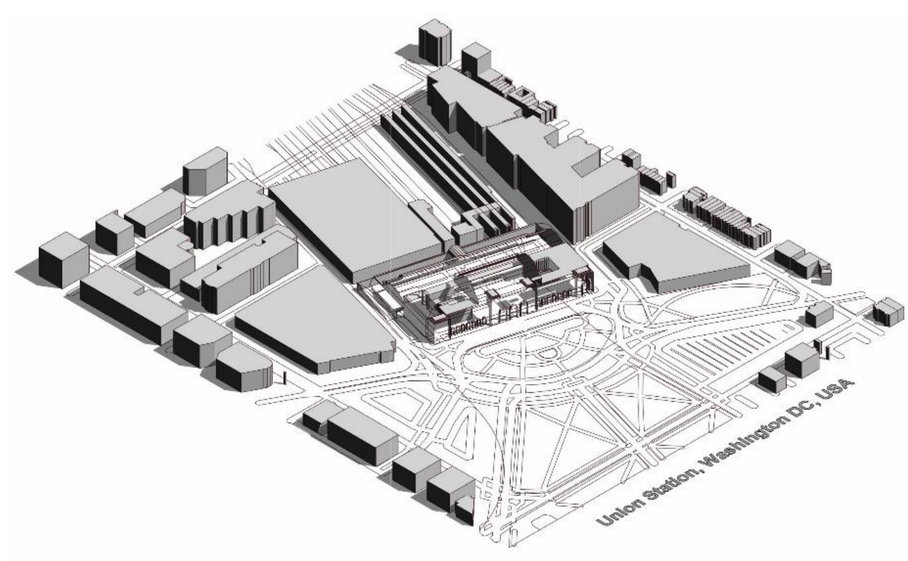

Figure 2.1.2 Union Station, Washington D.C.

3. Denver Union Station

Platforms 2 side platforms, 3 island platforms (commuter rail and Amtrak)
1 side platform, 1 island platform (light rail)
Tracks 8 (commuter rail and Amtrak)/ 3 (light rail)
Bus stands 22
Passengers (2017) 154,706

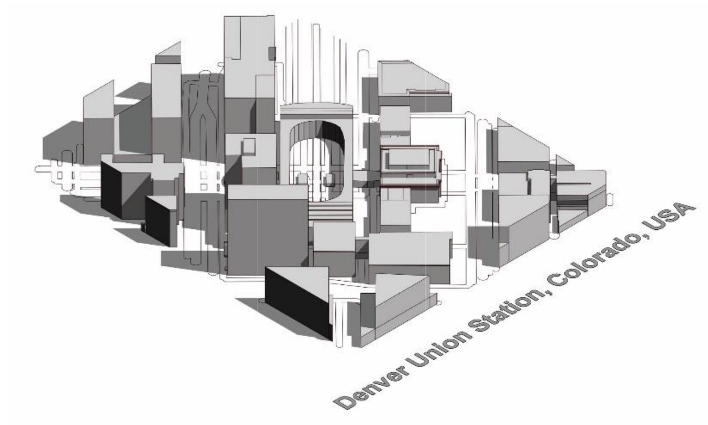

Figure 2.1.3. Denver Union Station

2.1.2. International

4. Vancouver, BC

Passengers (2017[1]) 37,500
Platforms 3 separate sets of center platforms
Tracks 6
Connections Translinkbus.svg 95 B-Line
Translink–Expo Line, Canada Line, SeaBus, West Coast Express

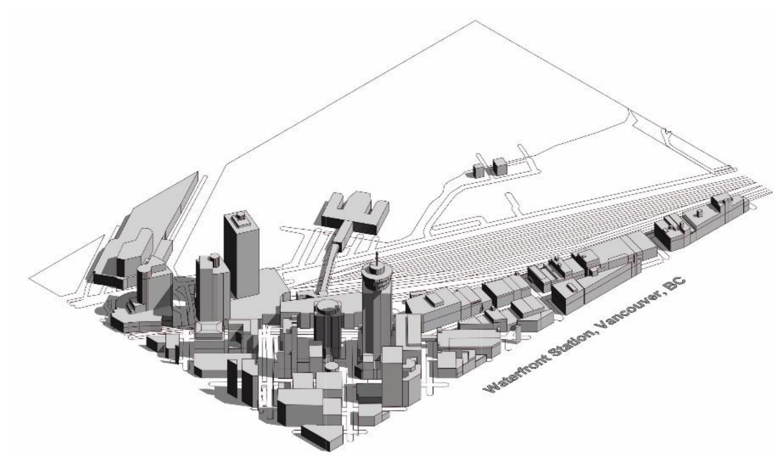

Figure 2.1.4 Waterfront Station, Vancouver

5. King’s Cross, London, UK

2017–18 33.905 million
Platforms 12
Hull High Speed Trains, Inter-city railways, Suburban, Semi-fast trains
Lists of stations
DLR Underground National Rail Tram link

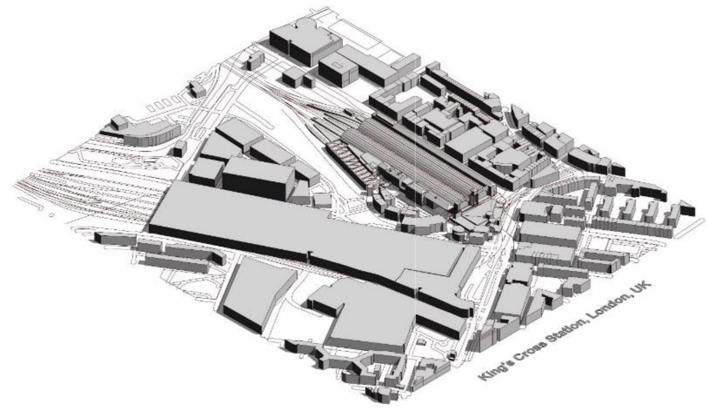

Figure 2.1.5. King’s Cross Station

6. Alexanderplatz, Berlin, GE

Lines– S-Bahn U-Bahn Tram
Regional-Express services RE
Local services RegionalBahn 14
S-Bahn services over ground S3, S5, S7, and S9
U-Bahn services underground U 2, U 5 and U9
The station is also served by four tram lines, two of which run continuously, as well as five bus lines during the day, one of which runs continuously and three night bus lines.

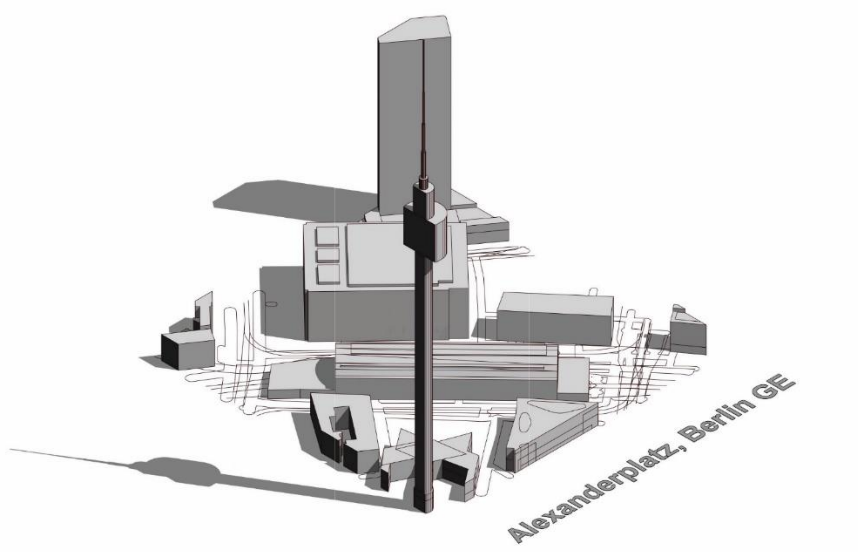

Figure 2.1.6. Alexanderplatz Station

7. Amsterdam, NE

Platforms 11
Tracks 15 total
Passengers 162.000 passenger daily (2013–2014 statistics)
Connections Mainline rail interchange GVB Amsterdam Metro
Mainline rail interchange GVB Amsterdam Tram
Ferry GVB Amsterdam
Bus transport Connexxion, Bus transport EBS, Bus transport GVB

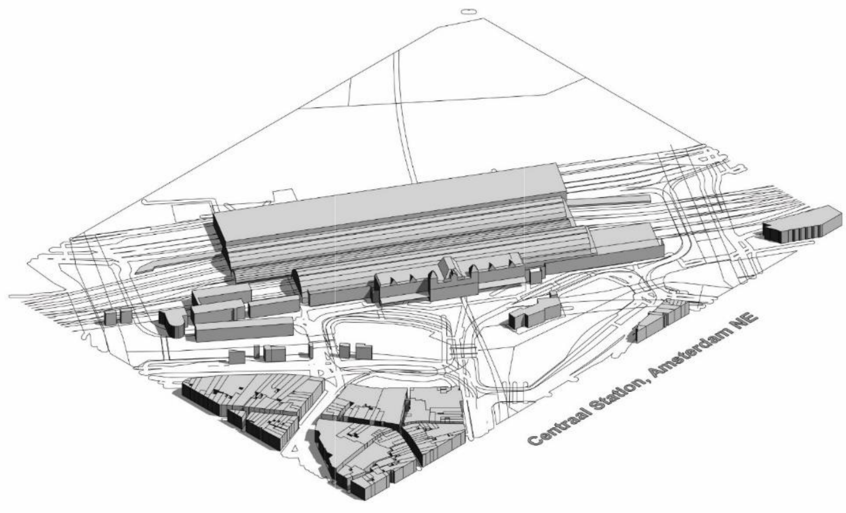

Figure 2.1.7. Central Station, Amsterdam

8. Florence, IT

Distance 314.077 kilometres (195.158 mi) from Roma Termini
Platforms 19
Line(s): Bologna–Florence (high speed), Bologna–Florence (traditional), Florence–Rome (high speed), Florence–Rome (traditional)

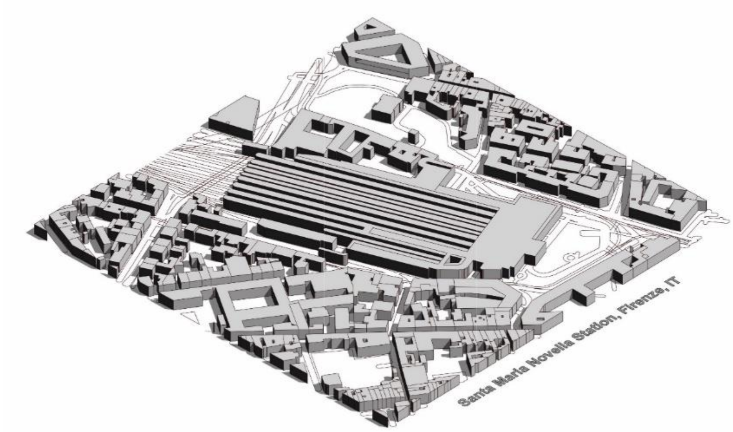

Figure 2.1.8. Santa Maria Novella Station

9. Gare du Nord, Paris, FR

Platforms 36 (two not in service)
Passengers 214 million
High Speed Rail, Inter-city, Regional Rail, Commuter Rail, Subway Metro

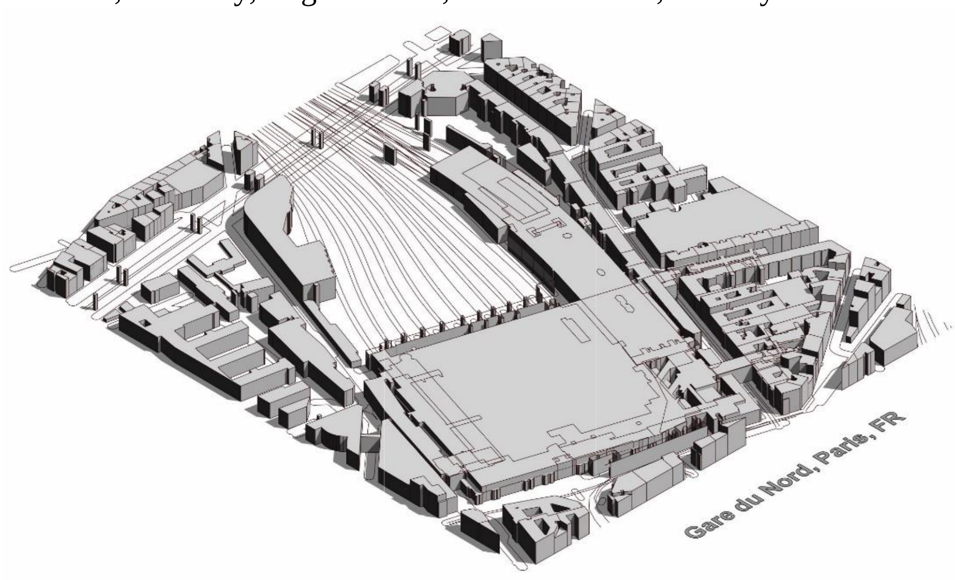

Figure 2.1.9. Gare du Nord Station

10. St. Lazare, Paris, FR

Line(s) Paris–Le Havre railway
Platforms 27
Passengers 100 million
Inter-city, Suburban

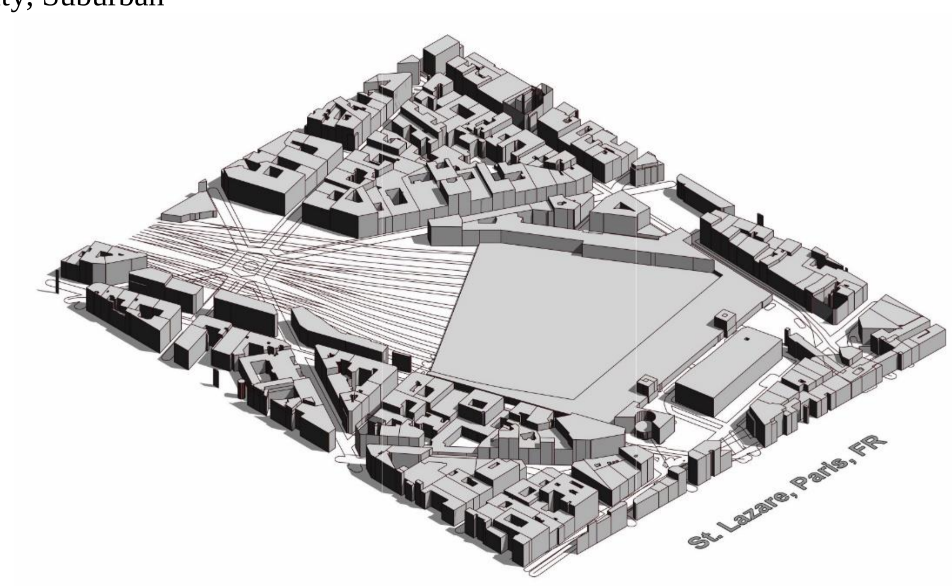

Figure 2.1.10. Saint Lazare Station

2.2. BIM Object Library

Development of (what the research notes as) “User Based Scenarios” (UBS) also helps predict relevant circumstances of multi-modal transit integration, for example analyzing the experience of a suburban commuter to an urban workplace. The user based BIM component assemblies range from air travel 3D model objects to high-speed rail hub components to slow-moving transportation circulation studies. The components facilitate modeled experiences and potential predicaments to develop further a multitude of necessary 3D BIM components for multimodal transport system, 4D assemblies necessary for transfer nodes, 5D cost implications, 6D robust multi-modal time factor elements, and 7D operational control of line-bound public transport services. These UBS are understood graphically, like reading a map of experienced networks. Through the development of a BIM 3D database template, this study becomes a critical reference to USDOT or private service providers in their future efforts to multi-modal services, ultimately effecting informed policy-making. A multi-modal approach to the template includes diverse populations and communities. The BIM template would also include the facilitation of public-private partnerships for freight mobility planning and operation efficiency, along with advanced thinking of the future of self-driving transportation networks. By cataloguing such information model specificity, the future city can benefit from a knowledge base of advanced and alternative transportation design elements, which promote safety, diversity, and environmental efficiency.

2.2.1. User Based Scenarios (UBS 1-3)

The UBS list below describe the context with which each one distinguishes itself, followed by the mode with which a user would use to get from one destination to the other, the infrastructure necessary to support that mode, along with nodes that would be necessary to have as a BIM object. The names of the BIM family objects are then listed to follow.

UBS-1: Satellite Home to Perimeter Core Workplace

1. Home → Park and Ride
    a. Mode: Personal Auto
    b. Transit Infrastructures: Surface Roads, Highway, Parking Lot
    c. Intermediate Nodes: Gas Station/Charging Station
    d. Families: Automobile, Road Stripes, Parking Stripes, Gas Pump, Car Charging Station, Ticket Machine, Road Signs, Park and Ride Signs, Traffic Signals,

Station Signage, Station Canopy, Curb, Curb Cut, Tactile Paving, Furniture, Planting, Lighting

2. Park and Ride → Central Transit Hub
    a. Mode: Light Rail
    b. Transit Infrastructures: Light Rail Track
    c. Intermediate Nodes: Rail Stations
    d. Families: Light Rail Train, Light Rail Track, Crossing Signage, Switch Signage
3. Central Transit Hub → Central Bus Stop
    a. Mode: Pedestrian
    b. Transit Infrastructures: Walkway, Sidewalk, Escalator, Elevator
    c. Intermediate Nodes: Bank/ATM, Restroom
    d. Families: Station Signage, Restroom Signage, Plumbing Fixtures, Lighting, Emergency Signage, Stairs, Escalator, Elevator, Doors, Curb, Curb Cut, Tactile Paving, PV Applications, Station Canopy, ATM, Furniture, Planting
4. Central Bus Stop → Perimeter Core Bus Stop
    a. Mode: Public Bus
    b. Transit Infrastructures: Road, Bus Lane
    c. Intermediate Nodes: Bus Stops
    d. Families: Bus, Road Striping, Bus Lane Striping, Bus Stop Shelter, Bus Stop Signage, Furniture
5. Perimeter Core Bus Stop → Perimeter Core Workplace
    a. Mode: Pedestrian
    b. Transit Infrastructures: Sidewalk, Crosswalk
    c. Intermediate Nodes: None
    d. Families: Curb, Crosswalk Striping, Traffic Signals, Planting, Lighting

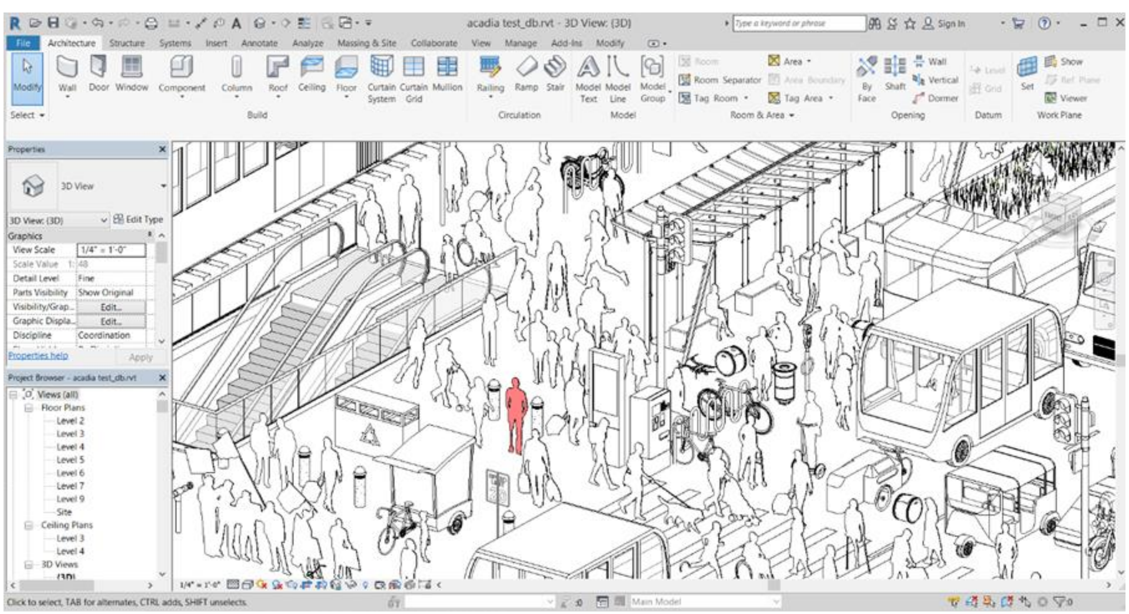

Figure 2.3.1. Diagram: Park and Ride – Central Transit Hub – Bus Stop (detail view)

UBS-2: Perimeter Core Workplace to Airport

1. Work → Subway Station
    a. Mode: Bicycle
    b. Transit Infrastructure: Roads, Bike Lanes, Bike Storage Tower
    c. Intermediate Nodes: Bicycle Maintenance Station
    d. Families: Bike Storage Tower, Road Stripes, Bike Lane Stripes, Traffic Signals, Bicycle Signage, Bicycle Maintenance Station, Bike Pumps, Air Compressor Station, Bike Rack, Planting, Lighting
2. Subway Station → Airport Monorail Station
    a. Mode: Subway Train
    b. Transit Infrastructures: Subway Third Rail
    c. Intermediate Nodes: Market/Restaurant/Café
    d. Families: Ticket Machine, Security Station, Security Turnstile, Station Signage, Lighting, Emergency Signage, Stairs, Escalator, Elevator, Tactile Paving, Food Service Appliances, Electronic Payment Systems, Furniture, Planting
3. Airport Monorail Station → Airport Terminal
    a. Mode: Monorail
    b. Transit Infrastructures: Monorail Track
    c. Intermediate Nodes: Security Station
    d. Families: Security Station, Security Turnstile, Monorail Doors, Monorail Signage, Tactile Paving, Lighting

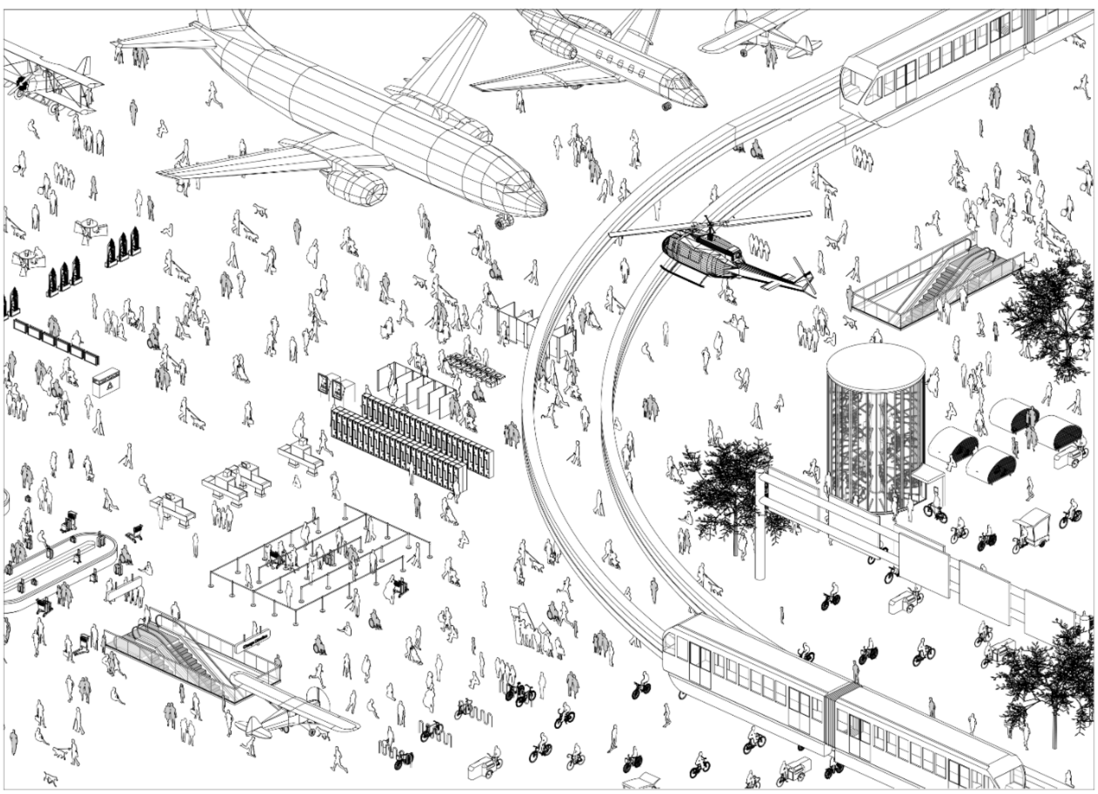

Figure 2.3.2. Diagram: Bicycle Hub – Subway Station – Airport Monorail Station

UBS-3: Airport to Dining with a view

1. Airport → Ferry Port
    a. Mode: Autonomous Ride Share Automobile
    b. Transit Infrastructure: Ride Share Stand, Roads
    c. Intermediate Nodes: Phone Charging Station
    d. Families: Road Stripes, Ride Share Stand, Phone Charging Station, Airport Signage, Bollards, Traffic Signals, Planting, Lighting
2. Ferry Port → Gondola Platform
    a. Mode: Autonomous Marine Vessel
    b. Transit Infrastructures: Dock, Water
    c. Intermediate Nodes: Ticket Machine
    d. Families: Ticket Machine, Port Signage, Lighting, Emergency Signage, Stairs, Escalator, Elevator, Doors, Curb, Curb Cut, Tactile Paving, Turbine Applications, Food Service Appliances, Electronic Payment Systems, Furniture, Planting
3. Gondola Platform → Dining with a view
    a. Mode: Gondola
    b. Transit Infrastructures: Gondola Cable
    c. Intermediate Nodes: None
    d. Families: Gondola Cable, Gondola Car, Gondola Platform, Sidewalk, Planting, Lighting

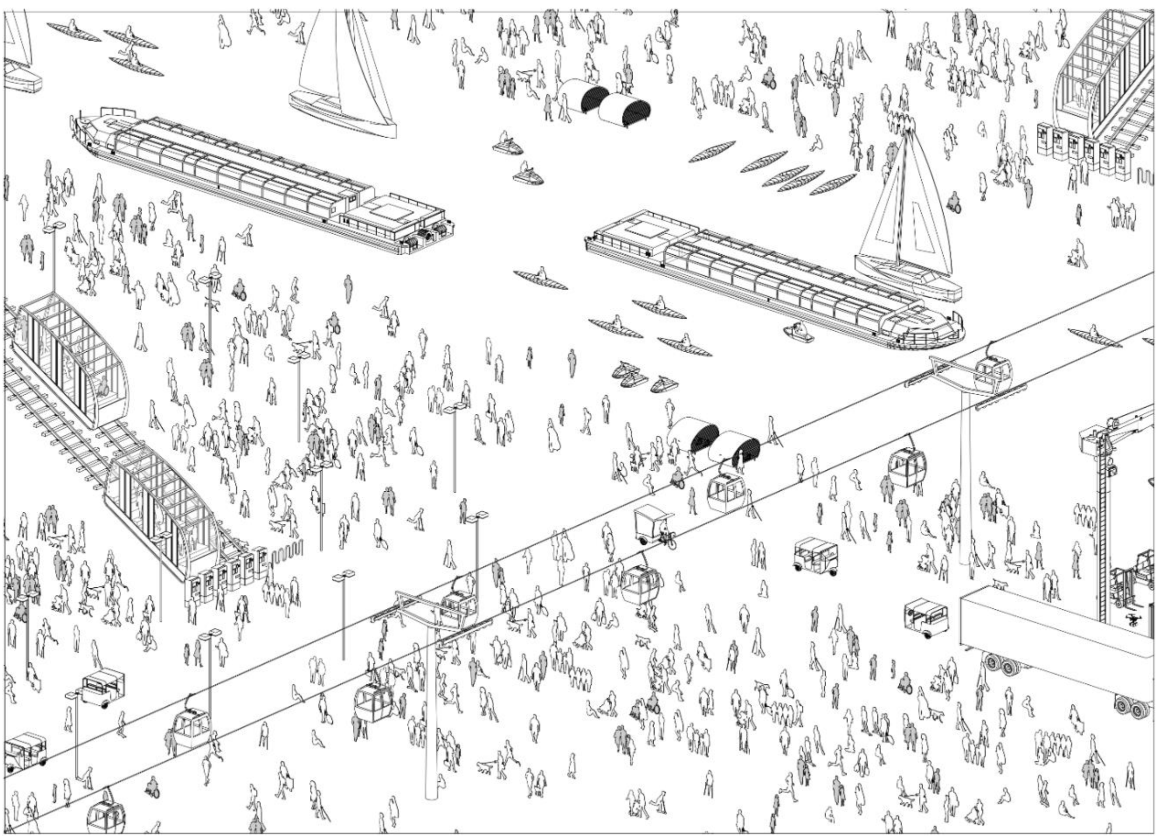

Figure 2.3.3. Diagram of Ferry Port – Gondola Platform

2.2.2. Work Objects

The "User Based Scenarios" (UBS) facilitate further development of a multitude of 3D BIM components for multimodal transport integration (4). This design methodology proposes a data structure based on a focus and context approach (5) in which information is mapped from diverse demographics in order to imagine the multi-modal transportation transfers they would potentially encounter. Particular necessary objects in these design scenarios would become content for the template. To further advance this BIM modelling technique, 4D time based assemblies necessary for transfer nodes could start to include 5D cost implications and 6D schedule design of robust multi-modal time-tables. Laying down metro rail tracks or other BIM object models becomes a scheduled endeavor, whereby every part and piece can be accounted for early on the schematic phases of design. One specific model could serve as the pilot for what a 7D (operational control) could mean for a line-bound public transport service.

As proof of concept, the direction of custom components for use in multi-modal transportation networks took on the idea of "work" as directed by the theme of the current issue of Journal of Architectural Education, Volume 73, Issue 2. Novel examples were explored to work through the 3D-7D research proposal (described above), specifically (for this report explanation) the Freeway Wind Turbines[4]-- a prototype/ invention by Capture Mobility. The turbine proposal has been recognized by Shell and awarded by the United Nations. The turbine stands two-and-a-half meters tall, weighs just nine kilograms and is made of recyclable carbon fiber. The fully-charged battery can hold a kilowatt of electricity, enough to run two lamps and a fan for around 40 hours. The idea is that this could be a source of electricity for rural communities in developing countries, or could power traffic lights or road signs in urban areas. Such projects would be able to reduce the Carbon particles from the environment 450 grams per year per turbine by our integrated filtering sheets. Working with a BIM model, such items such as the cost of each turbine (around $200) demonstrates the work able to be produced to be around 300 Watt. This would be 90% efficient and much more competitive than the typical solar or wind products.[5]

[4] https://www.shell.com/inside-energy/turbine-turns-traffic-into-energy.html
http://www.bestclimatepractices.org/practices/capture-mobility/
https://www.facebook.com/CaptureMobility/videos/1174143536021440/.
[5] https://weather.com/science/video/highway-traffic-powers-wind-turbine
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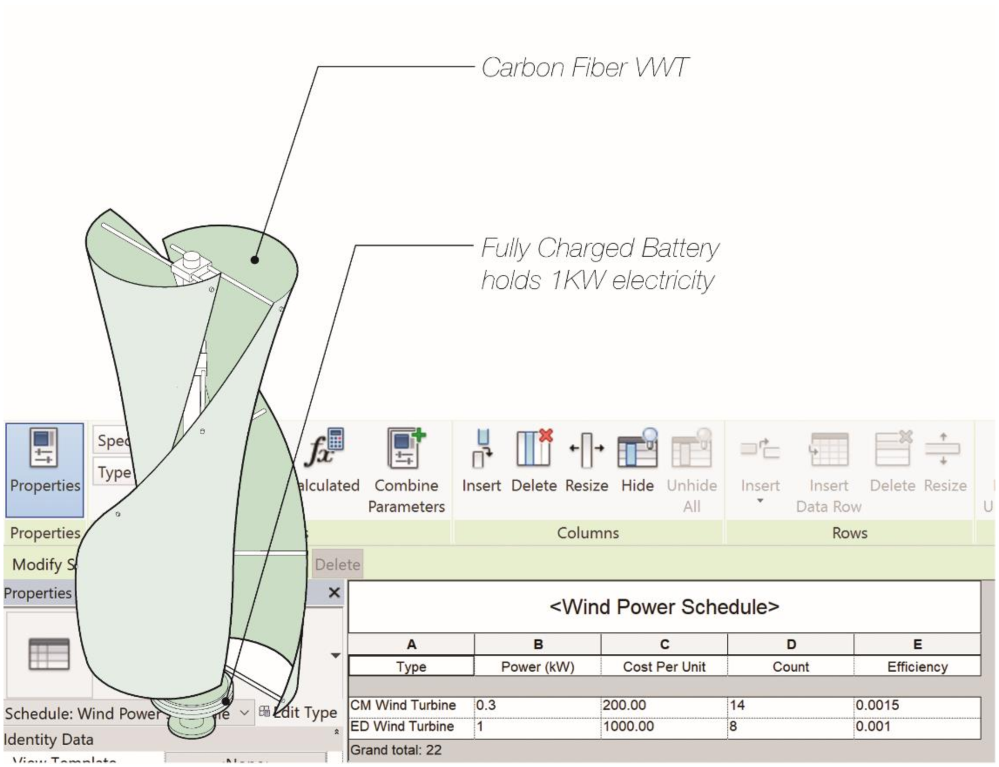

Figure 2.3.2.1. Scheduled BIM Object that creates energy from placement in real-world context

2.3. Template Development

Proprietary BIM software contains standard templates specific to an Architecture, Structural or Construction stakeholders. BIM content libraries exist with examples specific to certain typologies, like education or small scale residential, but are not however transportation specific, much less focused on multi-modal integration in transit hubs (2). Furthermore, the National BIM Standard-United States® (NBIMS-US™) provides consensus based standards through referencing existing standards, documenting information exchanges and delivering best business practices for the entire built environment. From both forms of open BIM standards, a template for transportation hubs can expand upon the detailed models that exist, create new custom ones and give stakeholders accurate BIM models to optimize this network. This template could then be used at all stages of project development to ensure functionality throughout the life of the facility and to deliver high performance (and potentially net zero energy) based 3D modelled

https://buzzonearth.com/enlil-turbines-generating-power-through-passing-vehicles/

objects. In summation, a content library exists, but further filtering and editing for transportation multi-modal hub design proves necessary.

In the fall of 2018, the BIM template development focused on the graphic capability and modifications that could improve the User Based Scenarios with so many objects. A workflow was tested with rendering through Enscape and also a method for transferring BIM object insertion to these urban scenes of transportation complexity.

Figure *2.4.1. Template development through graphic consideration and translation*

2.3.1. Re-Categorization

In 2019, the research began by re-categorizing the objects in the BIM template. The general headings of this re-categorization—being Vehicles, Transit Infrastructure, and Other (Landscape and Entourage)—give broader structure to the template allocation. Finding existing BIM family categories within a default template were stated as necessary by Autodesk consultants as the research has come to find that these headings for families cannot change. Families were equally puled form existing online libraries and well as custom generated as generic models.

Vehicles	Land	Water	Air
	Car (Fuel/Electric)	Kayak	Airplane
	Public utilities (Ambulance/Fire truck)	Passenger vessels/Ferry	Helicopter/Jet
	Taxi/Van	High-speed boat	Cableways
	Delivery bot (AV)	Bulk carriers	Unmanned Air Taxi/Hovercraft/Zeppelin
	Bus	General Cargo	Shuttle
	Trucks (Freight)	RO-RO Ships (roll-on roll-off)	Hot-air balloon
	Motorcycle		
	Bicycle (Docked/-less)		
	Tram (sloped)		
	Railway (passenger)		
	High-speed Rail, Bullet train TGV		
	Freight trains/Rail tankers		
	Metro/Subway		

Transit infrastructure	facilities Construction	Operations and handling	Maintenance and security
	Temporary equipment	Bike racks	Handicapped access lifts
	Modular cubicles	Containerization equipment	
	Scaffolding	Conveyor belt	
	Trusses and frames	Logistics /cargo	
	Safety netted surface on edges	Ticketing and document processing	Fire truck
	Construction site cabins	Shade Sail Canopy roofs	Street cleaning truck
	Escalators	Turnstiles	
	Parking space lifts	Charging pods	
	Parking space ADA		
	KITO		
	Crosswalk pattern		
	Utility supply pipelines		
	Lavatories		
	Cubbies		

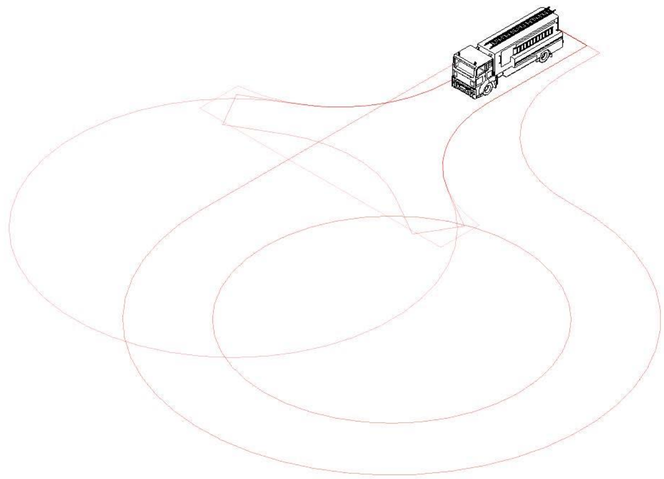

Figure 2.4.2. BIM Object, Firetruck with Parametric Turn Around options

Other	Landscape and recreational	POI (Point of interface)	Entourage
	Topographical features	Ticketing	Humans (Families/Elderly/Kids)
	Wind turbines (electrical)	Auto parking pay stations	Handicapped Staff/Personnel
	Trees	Inspection booths	Artists and performers
	Tree pods	Wayfinding and signage	Animals
	Planters		
	Bollards		
	Prayer area		
	Play area		
	Sports playground		

2.4. Assemblies

The notion of Assemblies redefines the original User-based Scenarios (UBS) premise from the 2017-2018 grant period. The four spatial scenarios explored conditions for multi-modal transit hub. These scenarios demonstrate the complex networks for transfer and relay of goods and people between points of source and destination. General graphic work to explain the position of context of UBS and Assemblies was done for dissemination.

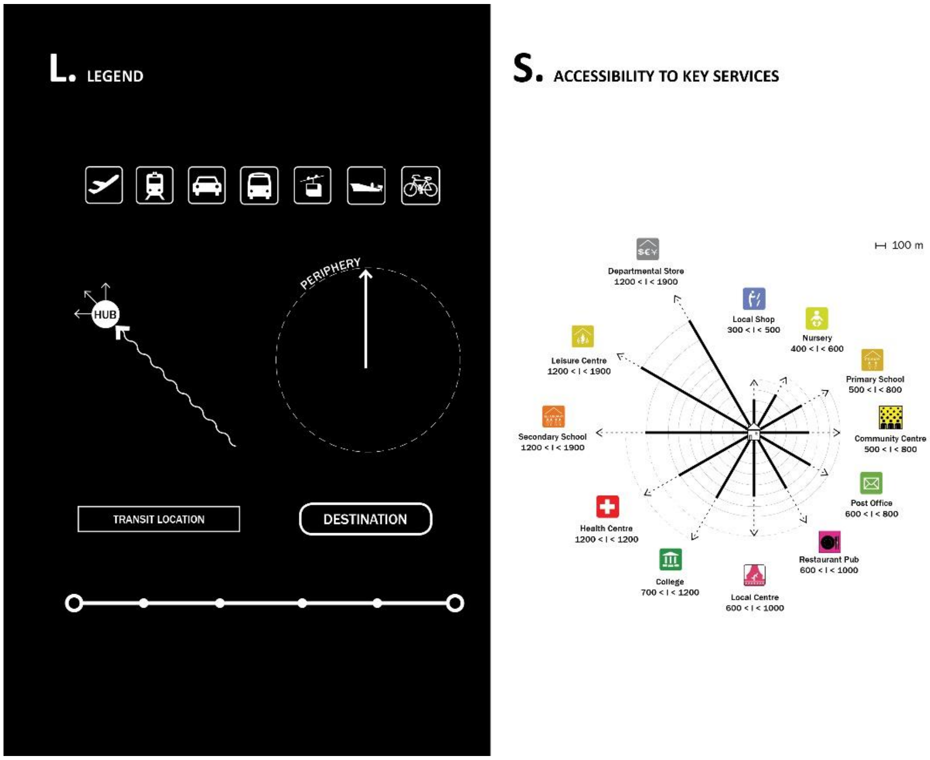

Figure 2.4.3. Graphic explanation and diagram of accessibility strategy

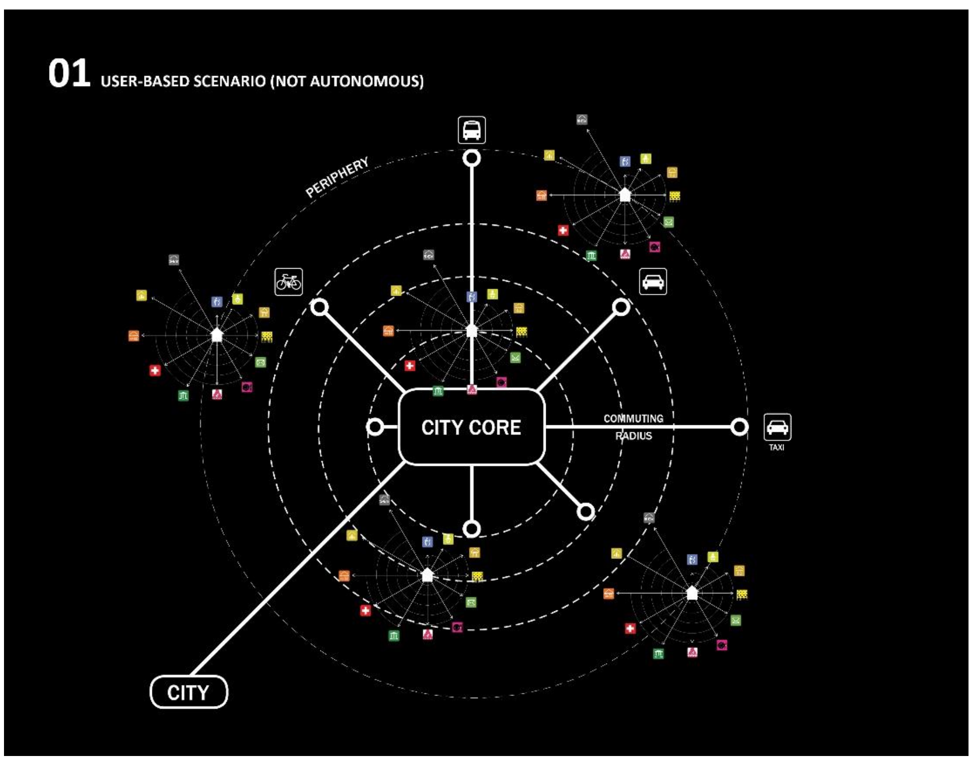

Figure 2.4.4. Graphic explanation and diagram of accessibility strategy

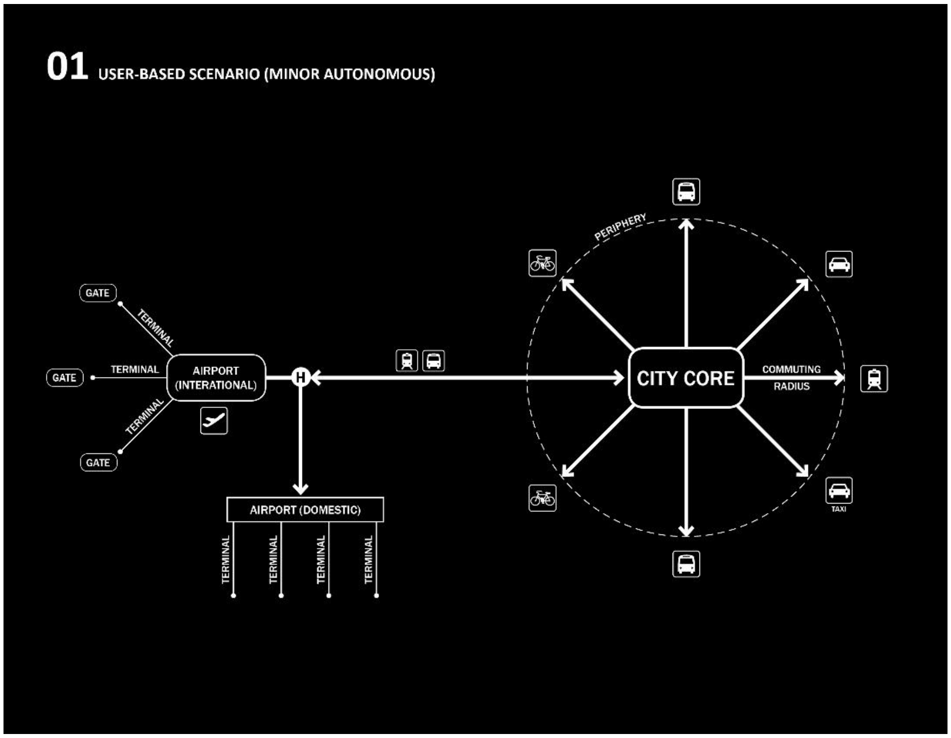

Figure 2.4.5. Graphic explanation and diagram of accessibility strategy

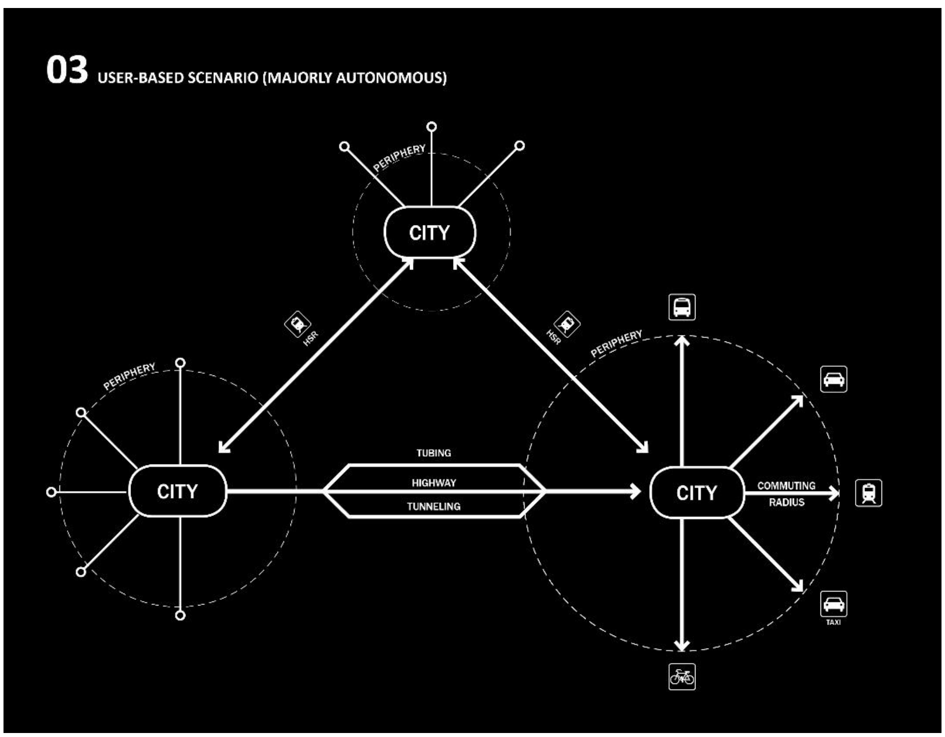

Figure 2.4.6. Graphic explanation and diagram of User Based Scenario

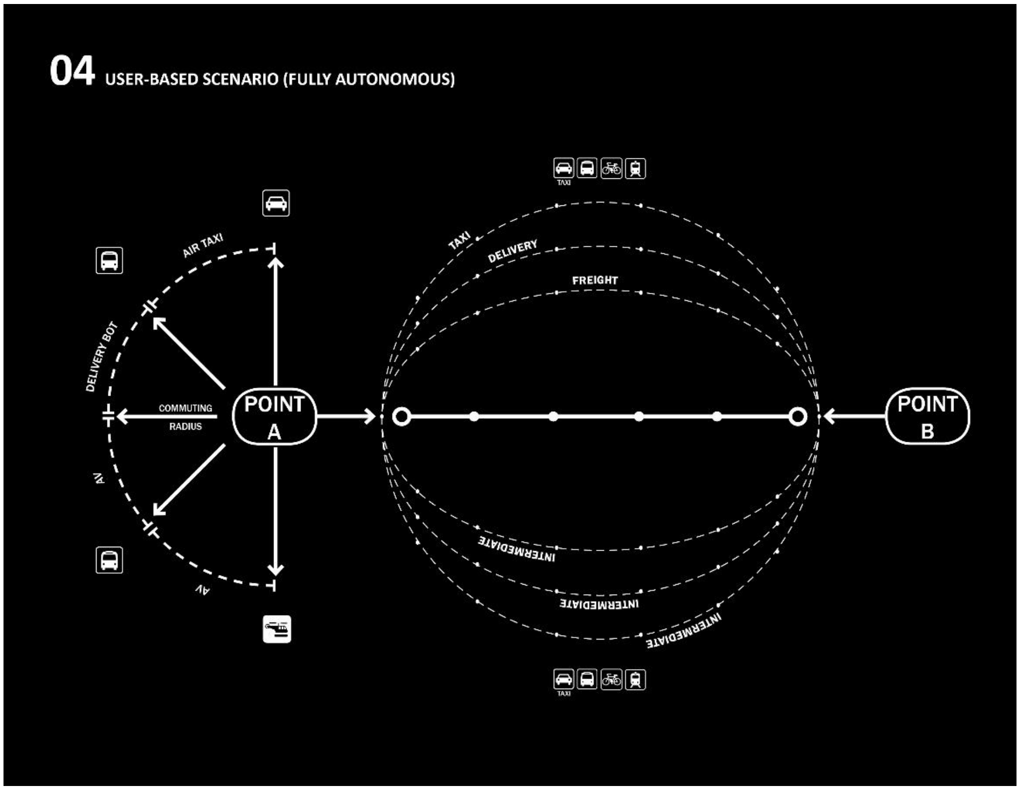

Figure 2.4.7. Graphic explanation and diagram of User Based Scenario

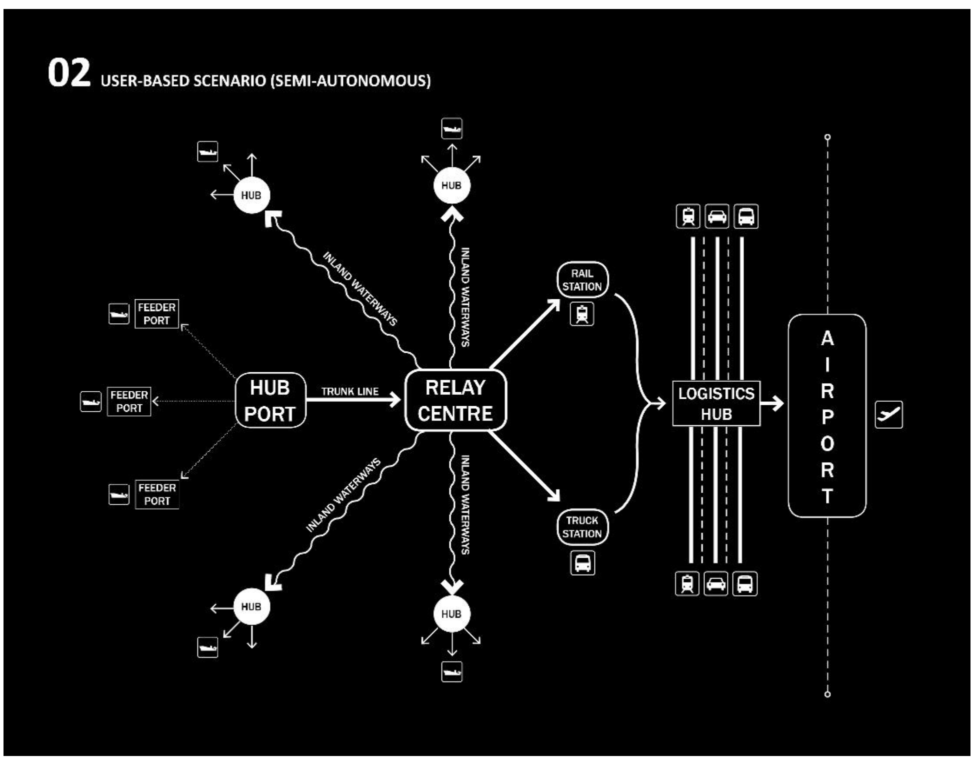

Figure 2.4.8. Graphic explanation and diagram of User Based Scenario

2.4.1. Airport

The Airport Assembly is depicted with a Centralized terminal with finger piers. An Optimal terminal size is established through precedent case study. The Assembly prioritizes an Express commute to intermediate transfers (domestic-international) with an additional airport express train and rail link to city core. Passenger transport terminal (in urban core dense areas) are the primary means of Public Transit, which include modes, such as: Bus, Light rail/Tram, Subway/Metro/Elevated rail/Commuter rail (Inter-city or Suburb-City). Some alternatives might be: Gap-filler micro-transit (e.g. E-Tuks in Kansas and Seattle), Docked bikes, Private companies such as LYFT. The Assembly also recognizes the need for Taxi, Bus, and Automobiles.

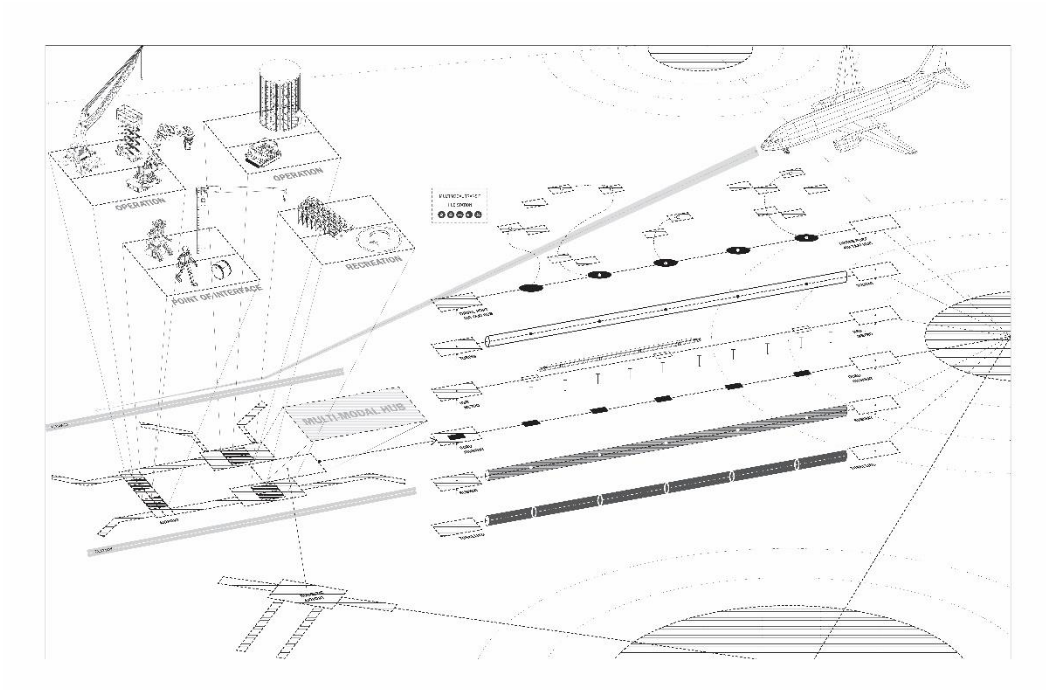

Figure 2.4.9. Graphic explanation and diagram of Assembly 1

2.4.2. Freight hub containerization

A Port terminal for ships (Hub-and-spoke operations along coasts) is a critical Assembly for understanding the BIM logistics of freight and distribution. Transfer to railway or truck its own layout for Logistics facility operations. Freight rail terminal to road highways (port-hinterland connectivity) must also be considered. BIM quantification and scheduling could be especially useful here.

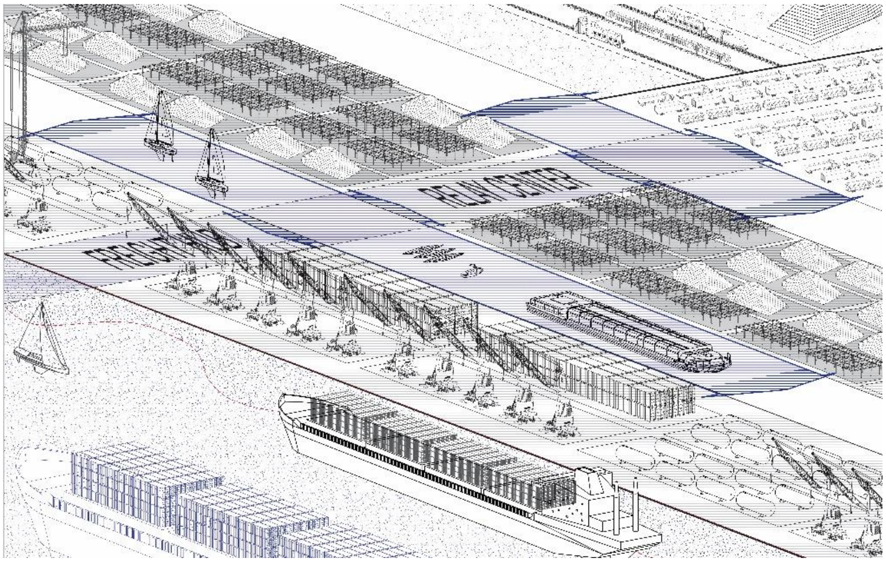

Figure 2.4.10. Graphic explanation and diagram of Assembly 2

2.4.3. Port terminal for passengers

A High speed rail network reference graphically[6] assists the production of this assembly.
The assembly also takes broad strokes to include the BIMs of Inland waterways transport (see US inland waterways map), Tubing for inter-city transport (Hyperloop) and Tunneling for inter-city transport (The Boring Company).

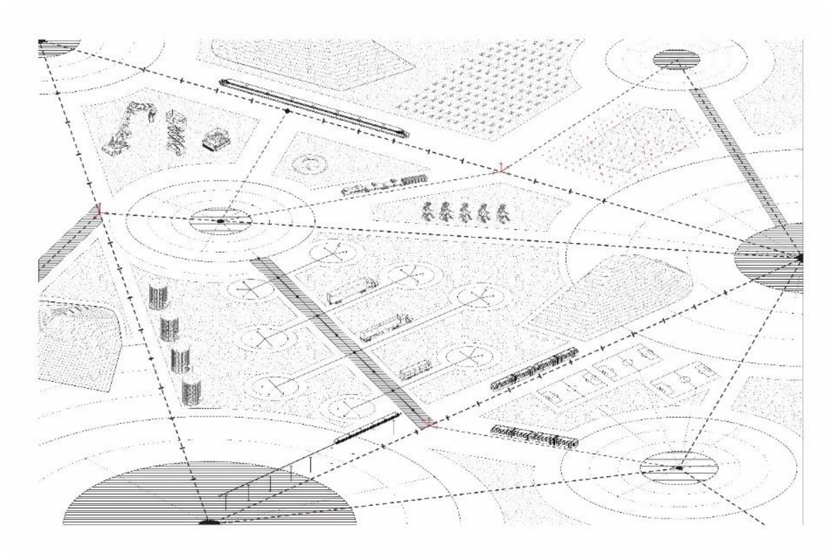

Figure 2.4.11. Graphic explanation and diagram of Assembly 3

[6] http://www.ushsr.com/ushsrmap.html

2.4.4. Autonomous vehicles (no private vehicles)

Autonomous marine transport (freight) mixes with unmanned air-taxis as a statement on the implications for land use due to roof-to-roof, or intermediate pickup. Drop-off scenarios are considered and modeled, as well as development air rights. As delivery drones will increasingly be present as a means of freight transportation, the BIM Assembly acts as an agent of exchange and modeled delivery proposal.

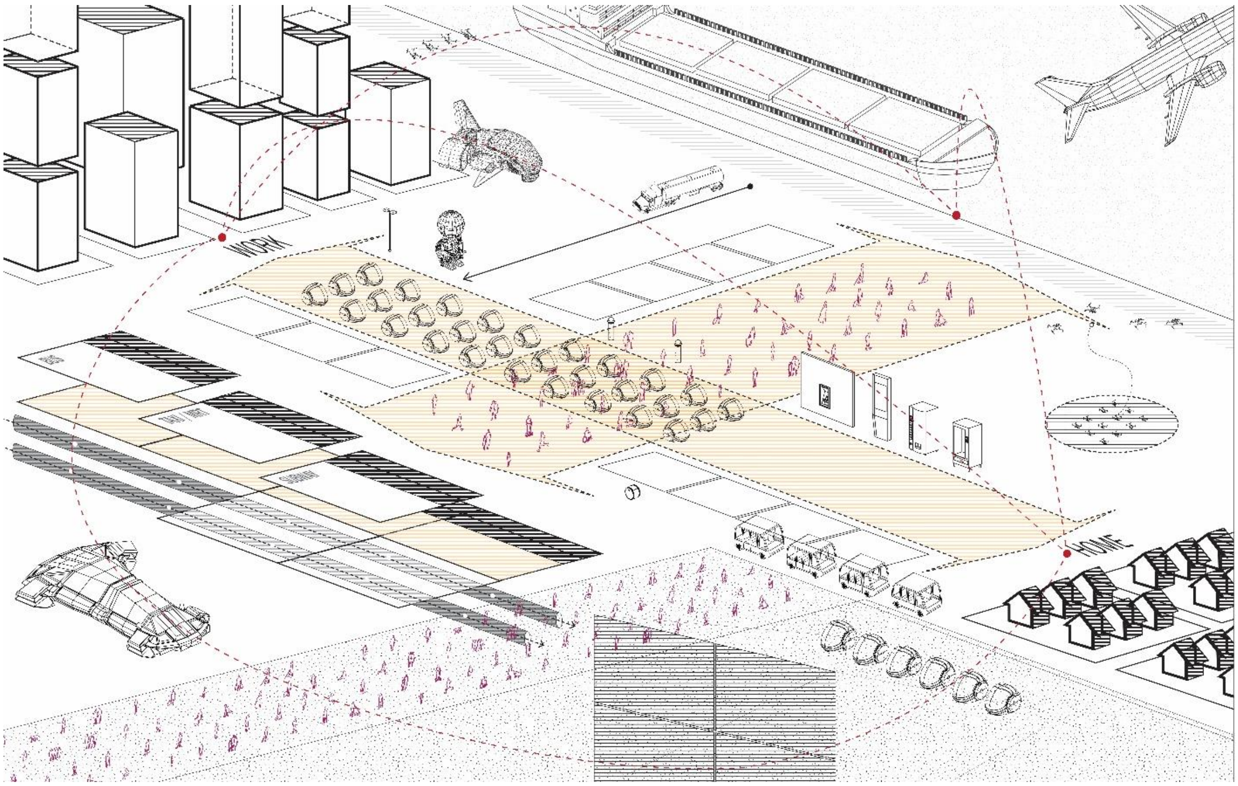

Figure 2.4.10. Graphic explanation and diagram of Assembly 4

Chapter 3. Industry Collaboration: PAGE

Through my research with the CM2 grant, I have an opportunity to further research on the Austin State Hospital traffic planning. I have met only once with Ryan Losch of Page Architects and have begun looking through their drawing files. . I would be applying one of my User Based Scenario BIM templates (which I showed in the lunchtime presentation) to this project. I feel this would be very beneficial for testing how it applies to a real world project that is essentially master planning a traffic proposal here in central Austin. CM2 Directors have stated this is not in conflict with CM2 to work with industry in such a way. This aspect of the research gave us insight as to how practice might find the template and approach useful. Several studies were done to accompany the UBS drawing file to demonstrate how a traffic APP, such as WAZE, would be sending traffic through the ASH campus. The BIM multi-modal study encouraged transportation currently under-utilized in this area of Austin.

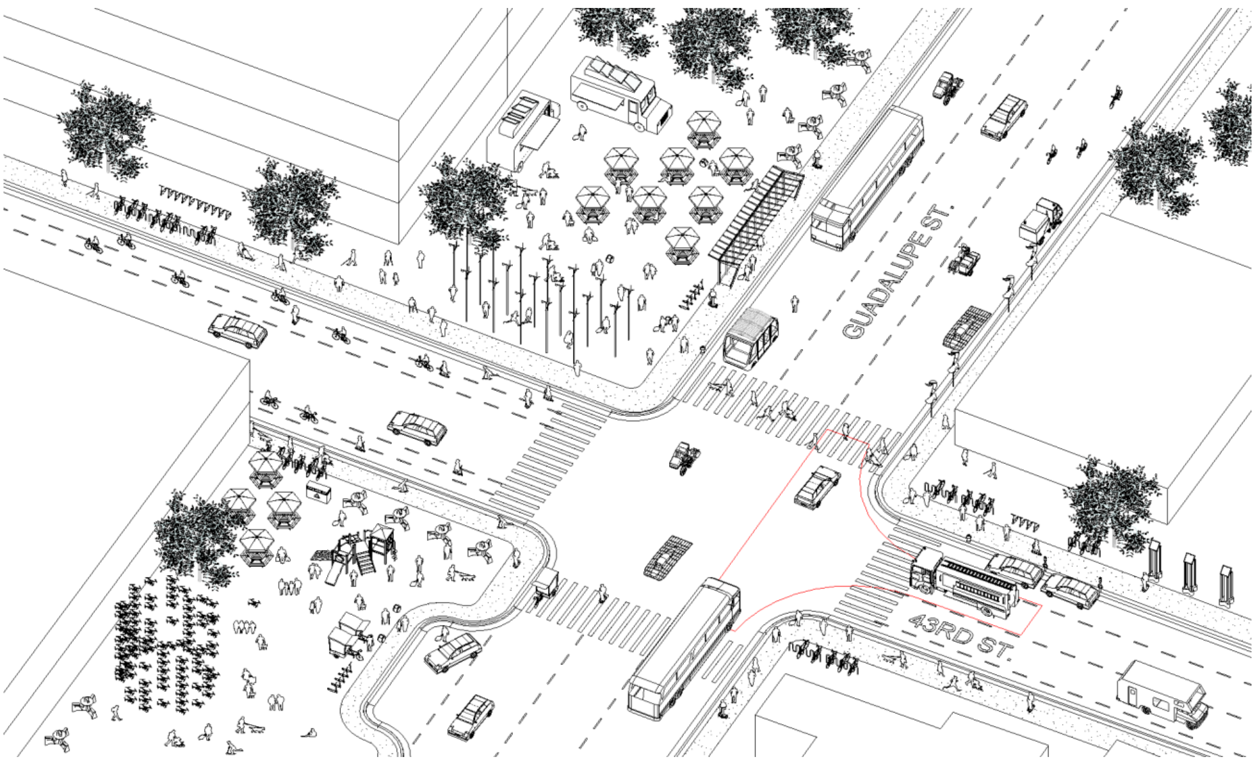

Figure 3.1. User Based Scenario developed for the corner of Guadalupe and 43rd Street, Austin

Chapter 4. UTSOA Advanced Studio Offering

This studio agenda works in conjunction with ongoing research afforded by the USDOT University Transportation Center and Center of Cooperative Mobility for Competitive Megaregions (CM2). Undergraduate and graduate students were prompted to design a 30,000 sf multi-modal transportation hub, an established building typology that is a ripe candidate for redefinition and reinvention. The studio allowed students to complete the conceptual development of a building with consideration of structural, mechanical, electrical, and site integration needs while simultaneously designing an exemplary work of architecture. As a proposed process, the re-scripting of Building Information Modelling allowed students to have a more focused integration of the user base and the discrete object scale within the urban and infrastructural context. The intention was to then understand the whole of the network, devoid of its formal "architecture." The studio site was located at the designated Houston-to-North Texas High-Speed Railroad Corridor station in the urban context of downtown Dallas.

Lastly, Texas Central named global railway company *Renfe* as its high-speed train operating partner. *Renfe* is one of the world's most significant railways operators, running 5,000 trains daily on 7,500 miles of track. The company is integral to the transport system in Spain, its home base, handling more than 487 million passengers and 19.6 million tons of freight moved in 2017. New York Policy Analyst, Benjamin Villanti, also reminds us that the Madrid subway system is an example that other cities can learn from. For these reasons, the studio will travel and research the rail system in Spain, experiencing first-hand the *Renfe* HSR system and its architecture and urbanism from Madrid to Barcelona and back. This distance is comparable to the Houston-Dallas Corridor.

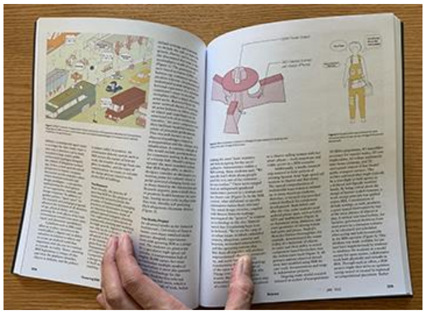

Figure 4.1. JAE Article of Studio Research

Chapter 5. Conclusion and Recommendations

RESULTS

This research has created a thorough and complete archive of highly detailed information models to serve the transportation typology with regard to multi-model transit hubs. The innovation of these file lies in the collection of multi-modal database components, for the transportation sector in general, and particularly for the development t of a multimodal transportation network. The proposal develops a fundamental BIM component and assembly library via the template format for future use, ultimately resulting in a multi-modal center design guideline of standards for intra-megaregion travel ease, sustainability and metrics. The template identifies and includes networks for private transport, public transport, and other transport services that are part of the multimodal transport system, including sustainable transfer possibilities between these networks. Having this in place makes the process of any new (or renovated) project potentially smoother and with guided efficiency. For USDOT or private service providers involved in multi-modal services, BIM technology in general would advance and optimize multi-modal integration in transit hubs.

CONCLUSIONS

A multi-modal approach to the template itself creates a revamping of the BIM platform. This study becomes a critical reassignment of the role of BIM as active player in the betterment of multi-modality design thinking. With reference to governmental departments of transportation or private service providers, their future efforts to multi-modal services, ultimately effect informed policy-making. The BIM template would then also include the facilitation of public-private partnerships for freight mobility planning and operation efficiency, along with advanced thinking of the future of self-driving transportation networks. By cataloguing such information model specificity, the future city can benefit from a knowledge base of advanced and alternative transportation design elements, which promote cost effective safety, diversity, and environmental efficiency.

Appendix A: Additional Considerations for BIM Template

1. Table of Contents of BIM Assembly Qualifications

Performance Index	Transportation Metrics	BIM Families and Parameters
Sustainability □ Environmental impact Climate-neutral station operation □ “GreenHub” Green roofs Renewable construction material and glass Geothermal, photovoltaic, and solar thermal energy Rainwater harvesting □ Supply chain efficiency □ Emission load □ Mode share □ Willingness of transportation provider to accept impact on environment Equity □ Safety □ Accessibility □ Accountability □ Flexibility □ Ease of travel “Digital reception” Wayfinding Orientation-friendliness Floor-heated waiting areas □ Affordability □ Willingness to pay Diversity of commuters	□ Spatial structure of the city □ Land use pattern □ Land acquisition □ Built-to-open space ratio (Land use vis-à-vis land cover) □ Degree of accidents □ Speed of commute mode □ Service coverage □ Service frequency □ Timeliness □ Intelligent systems–security and surveillance Passenger □ Average footfall □ Traffic management of passenger and vehicular circulation □ Convenient pass-through for inter-modal transfers □ Average dwell time Freight □ Average time for delivery □ On-time loading and departure □ Accurate temperature maintenance for goods □ Freight cost per unit shipped □ Human labor Number of ships taking optimal routes, as compared to total number of shipments	Relationship between each other Energy □ Emission load (tons/peak-hour) □ Temperature required □ Power consumed □ Area built □ Occupancy load Cost □ Level of service □ Transportation □ Warehousing □ Administrative □ Order processing □ Inventory carrying Time □ Estimated time to reach destinations □ Truck turnaround time–pickup, delivery and back for pickup □ Average dwell time Distance □ Trip distance □ Modes between start and end destination (measured by number of modes, or percentage by distance/time) □ Passenger transfer minimum distance □ Distance between passenger terminals □ Turning radius for vehicles □ Egress

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