RESEARCH BRIEF-TEAM 12

INTRODUCTION

Urban development encompasses the improvement and expansion of urban areas through infrastructure, housing and the provision of services. The effective and efficient management of urban areas is vital for the health of the national economy and to meet the needs of the increasing urban population and therefore, requires a combination of planning, governance and strategic implementation. Taking into account the existing Sustainable Development Goals, and standing urban development policies and principles, it is pivotal that we aim to build sustainable cities through an urbanisation process that is inclusive, liveable, green, equitable, and prioritises long-term durability while minimising the environmental impact.

There are a number of city management principles, frameworks and techniques to efficiently accomplish the above stated aims, including but not limited to:

1. SUSTAINABILITY: In order to ensure and enforce sustainability in the process of development, it is imperative that we leverage knowledge, information and new technologies in the planning and management of cities.

2. CITIZEN-CENTRISM: To foster transparency and interconnectivity, it is essential that citizens engage in decision making so as to effectively integrate the human, digital and spatial worlds to deliver a sustainable and inclusive future for citizens. It is crucial that citizen satisfaction, their quality of life and the improvement thereof remain a priority and the centre point around which the development of cities is defined.

3. RESILIENCE: The cornerstone of sustainability and durability is resilience. Cities must proactively anticipate and adapt to evolving challenges, and accommodate ever changing circumstances. Moreover, cities must be changeable. An incremental planning approach should be adopted allowing for constant and continuous feedback on the response of the system, ensuring responsiveness to evolving needs, challenges and insights.

4. EFFICIENCY AND EQUITY: It is of the utmost importance that sustainable and smart infrastructure decisions for the delivery of effective, efficient and reliable services are made in consideration of minimal waste and optimal functionality, emphasising resource optimisation, while also supporting long-term vitality, provision and access of services.

Effectively planning city development requires a thorough understanding of their key components. These include:

1. INFRASTRUCTURE: The most pronounced elements of urban design. Urban development aims to thoughtfully design individual and groups of buildings so as to establish a distinct sense of place.

2. PUBLIC “GREEN” SPACES: The availability of green spaces is essential for enhancing urban quality of life, serving as the canvas for interactions, events, and everyday experiences that give the city its character.

3. LAND USE: Zoning and land use planning governed by zoning regulations are essential tools for organising a city's space to ensure efficient and balanced land allocation. By balancing diverse land uses, zoning contributes to the city's functionality, sustainability, and liveability, ultimately supporting a harmonious urban environment.

4. TRANSPORTATION & ACCESSIBILITY: Transport systems shape and connect parts of cities, enabling movement throughout the city. Urban development must ensure that the experience of pedestrians and thus citizens is elevated, whilst the dominance of private transport use is minimised through the introduction of efficient public transit systems.

ASSUMPTIONS

These foundational components and principles informed the strategic planning and implementation of our city, grounded in assumptions drawn from a comprehensive understanding of urban development concepts and future-oriented projections. This approach enabled a cohesive, adaptable city blueprint designed to meet evolving needs and promote sustainable growth. With that being said, the following assumptions were made:

1. POPULATION GROWTH: The city is expected to grow steadily over the next few decades, with the urban population expected to double its current size by 2050. The scale and speed of urbanisation brings forth challenges including the accelerated demand for affordable housing, necessitating scalable infrastructure and job creation.

2. CLIMATE CHANGE AND ADAPTABILITY: As cities grow, their exposure to climate and disaster risk increases which calls for resilient features to withstand the impacts of climate change and the adaptability to rising temperatures and extreme weather. The city is responsible for ensuring the structure of its economy, and the state of their public health and service delivery systems are prepared to mitigate, navigate and respond to such crises.

3. TECHNOLOGY INTEGRATION: The city's design incorporates a forward-thinking approach to integrating emerging technologies, particularly smart systems in areas like energy, transportation, and infrastructure management. This commitment to technology integration allows the city to remain adaptable, efficient, and responsive to new innovations, ultimately enhancing residents' quality of life and promoting sustainable urban development.

4. A COMMITMENT TO SUSTAINABILITY: The city shall employ an approach that is responsive to the evolving needs and challenges faced by the citizens. The city is dedicated to prioritising sustainable practices and enforcing policies that foster environmental stewardship, conserve resources and ensure a healthier, more resilient environment for future generations. All policies enforced shall be at the benefit of citizens.

Taking into account the city management principles and the key components of the city, the following design decisions we made:

1. MIXED-USE ZONING: To encourage diverse, walkable communities, we have included mixed-use buildings in specific zones, blending residential, commercial and office spaces. This is done to optimise land allocation and accessibility to green spaces.

IMPLEMENTATION

Mixed-use zoning is applied in central areas, creating vibrant districts where residential spaces are within walking distance of shops, offices, and public spaces. Industrial zones are located at the city outskirts, reducing their impact on residential neighbourhoods, while green corridors and parks are interwoven across all zones to provide easy access to nature. This approach reduces commute times, and promotes sustainability by encouraging walkability and reducing traffic congestion.

2. GREEN BUILDING STANDARDS: We make sure to adhere to green building standards and incorporate designs that support environmental goals and withstand potential climate-related challenges, while preserving the city's aesthetic appeal.

IMPLEMENTATION

New buildings are designed to meet LEED(Leadership in Energy and Environmental Design) certification standards, using energy-efficient materials, solar panels, and green roofs to minimise their environmental impact. Existing structures are retrofitted for energy efficiency wherever feasible.

3. SUPPORT FOR LOCAL INDUSTRY: The city promotes small business and innovative enterprises through grants and tax incentives. This not only drives job creation but also encourages a culture of innovation and entrepreneurship, fuelling sustainable economic growth across sectors.

IMPLEMENTATION

The city budget will be allocated to provide tax incentives and grants to startups, reducing initial costs and encouraging local investments.

4. SUSTAINABLE MINING AND RESOURCE EXPORTS: The city recognised the importance of natural resources and thus leverages exports from nearby mines. Responsible mining practices are enforced to ensure environmental stewardship while maximising the economic benefit. The presence of the industrial sector within the city not only ensures job creation, but also facilitates the exporting of finished products which increases the local economy.

IMPLEMENTATION

Mining operations are managed under strict environmental regulations to minimise ecological impact and promote sustainable practices. Export processing zones near mining sites streamline the export process, while partnerships with national and international logistics firms ensure efficient global distribution. The city also encourages value-added processing industries near mining areas, creating jobs in refining and manufacturing to add value to raw materials before export.

5. INTEGRATED MULTI-MODAL TRANSPORTATION NETWORKS: The transportation system prioritises multimodal connectivity, enabling residents to move seamlessly between different modes of transit.

IMPLEMENTATION

The city provides multiple modes of transport that allow them to move in and out of the city, and facilitate the movements and transportation of resources into and out of the city ensuring connectivity and accessibility. Additionally, accessible road networks are planned to accommodate future needs, with adaptable traffic lanes and designated areas for autonomous vehicles.

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DESIGN PATTERNS APPLICATION REPORT

In developing a smart city framework, effective and scalable digital architecture is essential to support the seamless functioning of various urban services. We leverage design patterns to structure a system that is scalable, sustainable, responsive and adaptive to the needs of a growing city and increasing urban population. After extensive discussions and careful evaluations of the advantages and disadvantages of various applicable design patterns, each pattern was selected to address distinct challenges within our system.

INFRASTRUCTURE – BUILDINGS AND TRANPORTATION

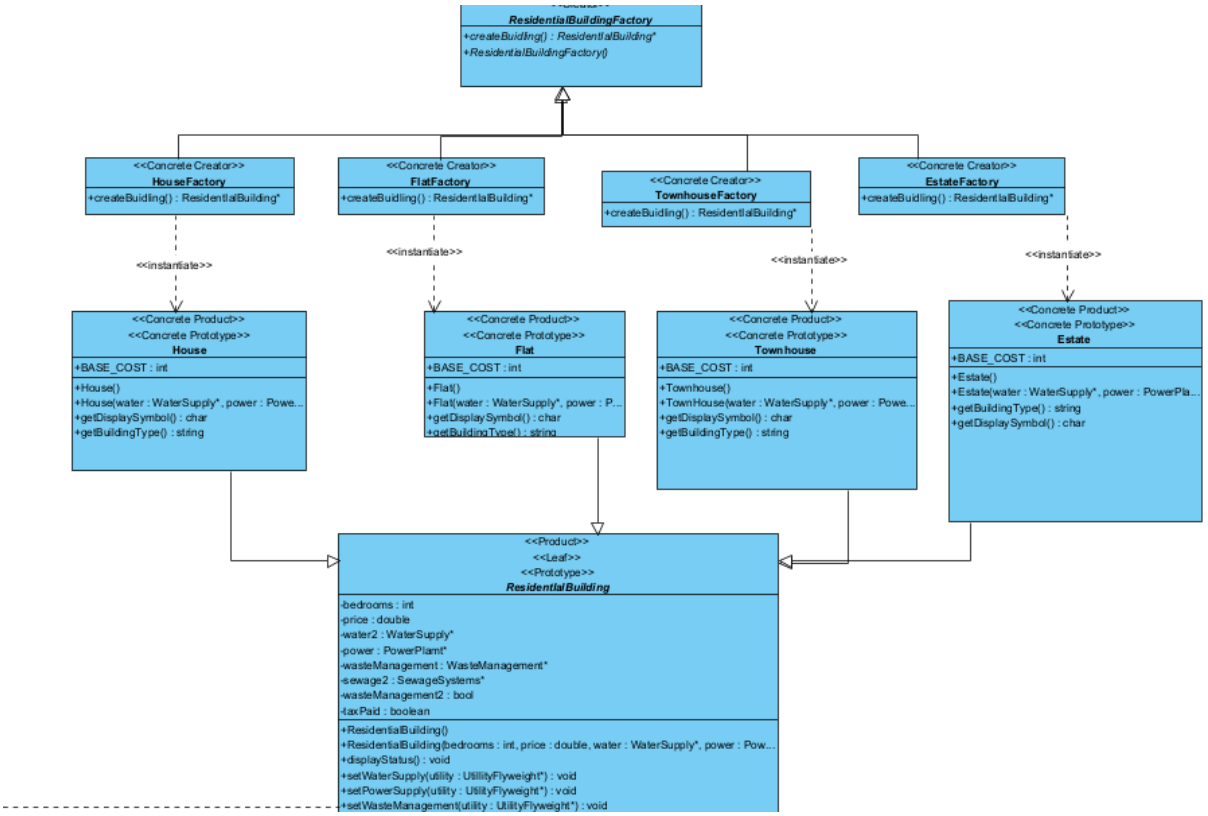
To support the sustainable development of city infrastructure, we leverage the **Factory Method** and **Prototype Pattern** to streamline and optimize resource creation and replication processes.

The **Factory Method** allows for the efficient creation of different types of infrastructure components, such as transportation, residential, commercial and industrial buildings, utilities as well as landmarks and governmental buildings, based on the city's evolving needs.

By centralising the creation process, this approach not only simplifies the management of varied infrastructure types but also ensures that resources are allocated and produced according to specific environmental and economic criteria, fostering sustainable growth.

In tandem, the **Prototype Pattern** is used to replicate infrastructure elements where uniformity and rapid deployment are required, such as street lighting systems, public kiosks, or modular housing units. By cloning pre-configured prototypes, the city can avoid redundant setup processes and deploy consistent, quality-controlled components quickly and cost-effectively.

Together, these patterns enable a highly adaptable, scalable approach to infrastructure development, ensuring the city can meet current demands efficiently while maintaining a focus on sustainability.

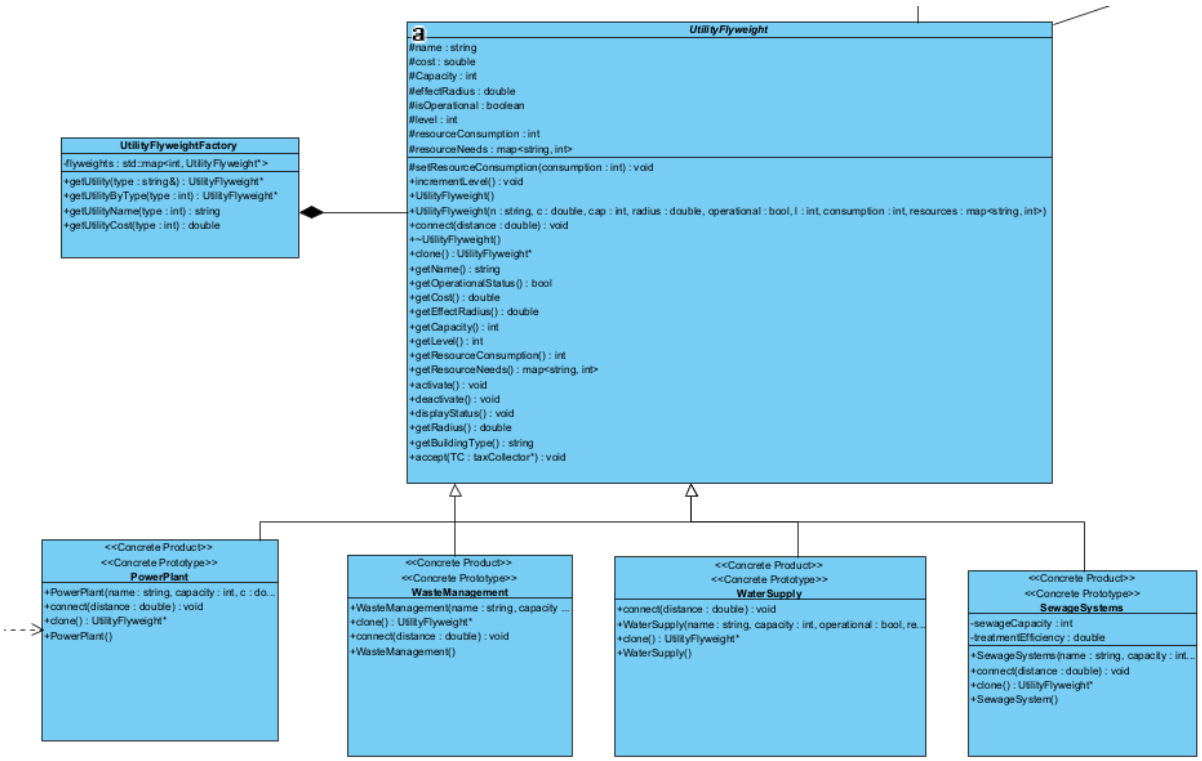


UTILITIES

The creation of utilities employs the Factory Method and Prototype patterns.

To efficiently manage the **addition** of utility services across the city, we employ the **Flyweight Pattern**. This pattern is particularly valuable for utilities like water supply and plumbing, sewage systems and waste management services which need to be deployed at scale while minimising memory usage and resource consumption.

By using the Flyweight Pattern, we reduce memory overhead, streamline resource allocation, and increase system efficiency. This approach supports sustainable city management by lowering hardware and computational demands, allowing utility services to scale effectively as the city grows without unnecessarily duplicating resources



RESOURCES – CREATION AND COLLECTION

The **Abstract Factory Pattern** plays a crucial role in the city's resource management system by providing a structured way to create families of related resources, including **income resources** (e.g., gold, diamonds and coal) and **construction resources** (e.g., wood, steel and concrete). This pattern ensures that all resource types are produced consistently and can be easily managed, allowing for effective urban planning and development.

We define two key abstract product types:

· Income Resources: This includes resources that are mainly for exportation.

· Construction Resources: This encompasses materials necessary for construction projects.

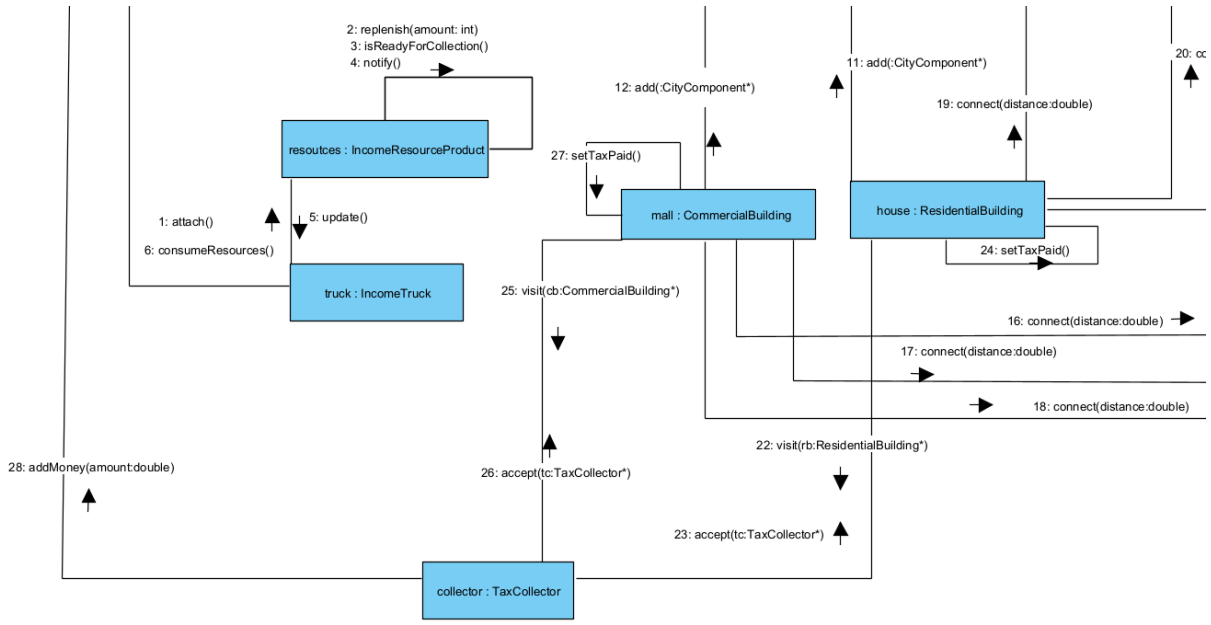
Implementing the **Abstract Factory Pattern** allows for an efficient and organised approach to resource management within the city. The Abstract Factory ensures that all income and construction resources are produced in a consistent and scalable manner. This approach supports sustainable urban development by ensuring that resources are allocated and utilised effectively.

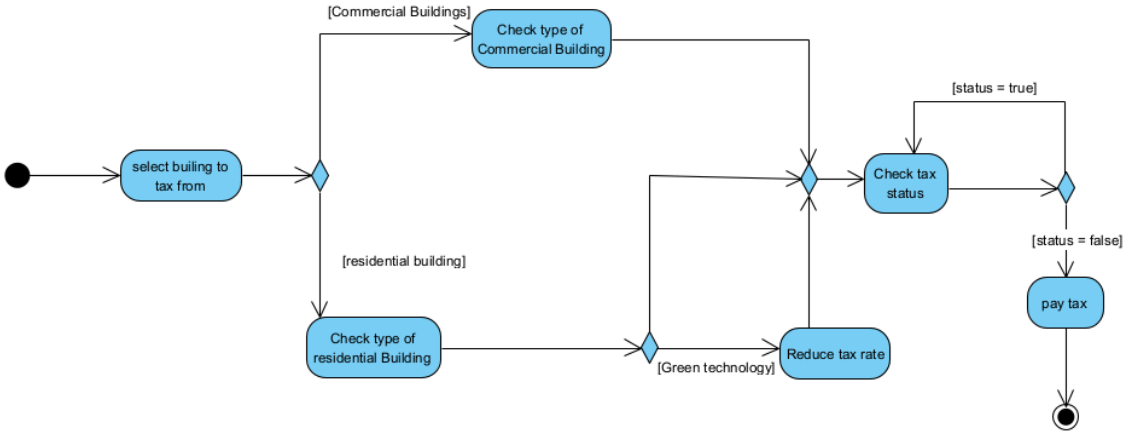
TAX LAWS AND COLLECTION

The **Visitor Pattern** streamlines tax collection by allowing a centralised approach to handle diverse entities—residential buildings, commercial properties and their respective zones. The implementation involves creating a TaxVisitor object that traverses these entities, applying appropriate tax calculations tailored to each category.

This pattern ensures consistent application of tax calculations across various property types, reducing discrepancies and ensuring fairness in tax assessment. Employment of the Visitor Pattern allows for flexibility. If tax policies change, the Visitor Pattern allows for easy updates. New tax calculation methods can be introduced without modifying existing entity classes, thus adhering to the Open/Closed Principle. As new property types or tax policies emerge, new visitor implementations can be added to accommodate these changes, ensuring the system remains robust and adaptable, increasing the scalability of our system.

This pattern allows the system to respond quickly to changes in legislation or tax incentives. For example, if a new tax incentive is introduced for green buildings, a corresponding strategy can be implemented without disrupting existing calculations intensifying the adaptability of our approach. By encapsulating tax calculation strategies, the system avoids unnecessary complexity within the main logic. It can select the appropriate strategy at runtime based on predefined criteria, leading to more efficient processing.





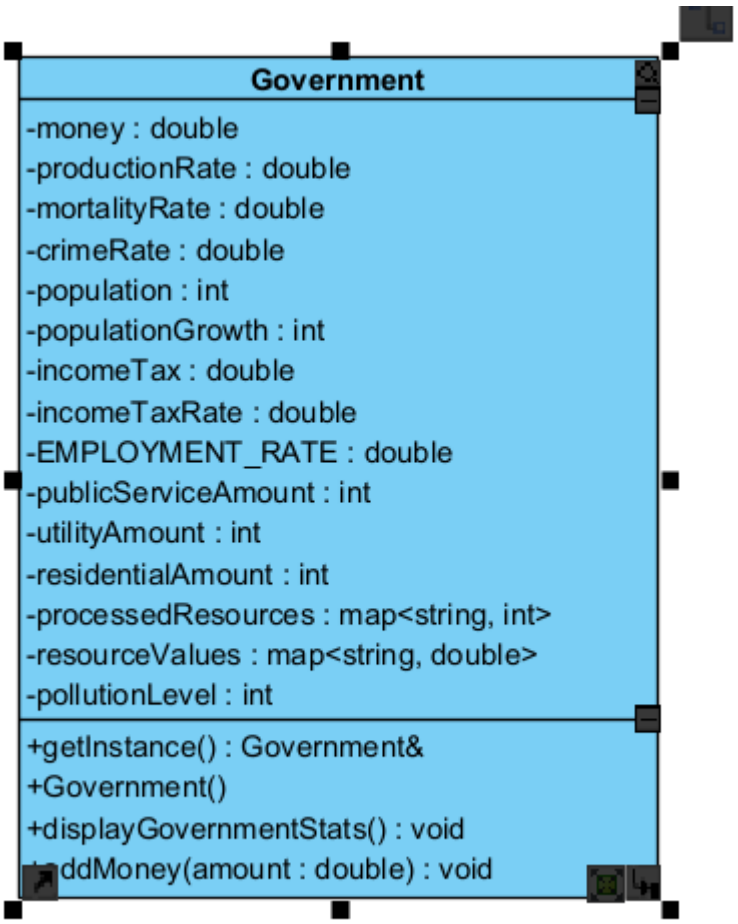
The laws governing taxes and all policies to be employed and enforced in the city are defined and regulated by the Government.

GOVERNMENT AND GOVERNANCE

The **government entity** within our city's digital infrastructure is implemented as a **Singleton** to ensure that there is only one unified instance overseeing city governance. This design decision centralises control, allowing for consistent policy enforcement and streamlined decision-making across various city functions, such as taxation, infrastructure, and public services.

By using the **Singleton Pattern**, the government entity acts as a single source of truth for regulations, urban planning directives, and resource allocation decisions. This centralised structure helps maintain coherence across the city's subsystems, ensuring that all departments and systems adhere to the same policies and standards. Additionally, it prevents the risk of duplication or conflicting policies that could arise from having multiple instances.

The Singleton approach also facilitates efficient interaction with other systems within the city's digital architecture, such as those handling tax collection, infrastructure maintenance, and public service delivery. As the city grows, this single-instance government entity supports scalability by managing expansions, policy updates, and interactions with external agencies from one authoritative point, ensuring consistency and efficient governance throughout the city.



THE CURRENT STATE OF THE CITY

The **Composite Pattern** is effectively implemented in our city's digital infrastructure to manage building structures, facilitating hierarchical organisation and enabling seamless operations across various levels of building data. Here's how the CityComposite class works and why the pattern is beneficial for this system:

The **CityComposite** class acts as the central composite component within the city's structure. Individual buildings , utilities and NPCs (leaf nodes), and neighbourhoods or groups of buildings (composite nodes) are represented uniformly, allowing the system to treat them as part of a cohesive hierarchy. This pattern enables different components to be aggregated and managed within a single organisational framework.

By representing both individual buildings and grouped structures (like neighbourhoods or zones) in the same hierarchy, the system can perform operations like adding, removing, or modifying components consistently across all levels. This unified structure simplifies the management of complex urban environments, as developers and planners can handle buildings, neighbourhoods and zones through common operations.

The composite hierarchy enables complex operations, such as applying tax calculations across various organisational levels. This flexibility supports administrative tasks, from urban planning to resource allocation, while keeping the city's operational efficiency intact. For

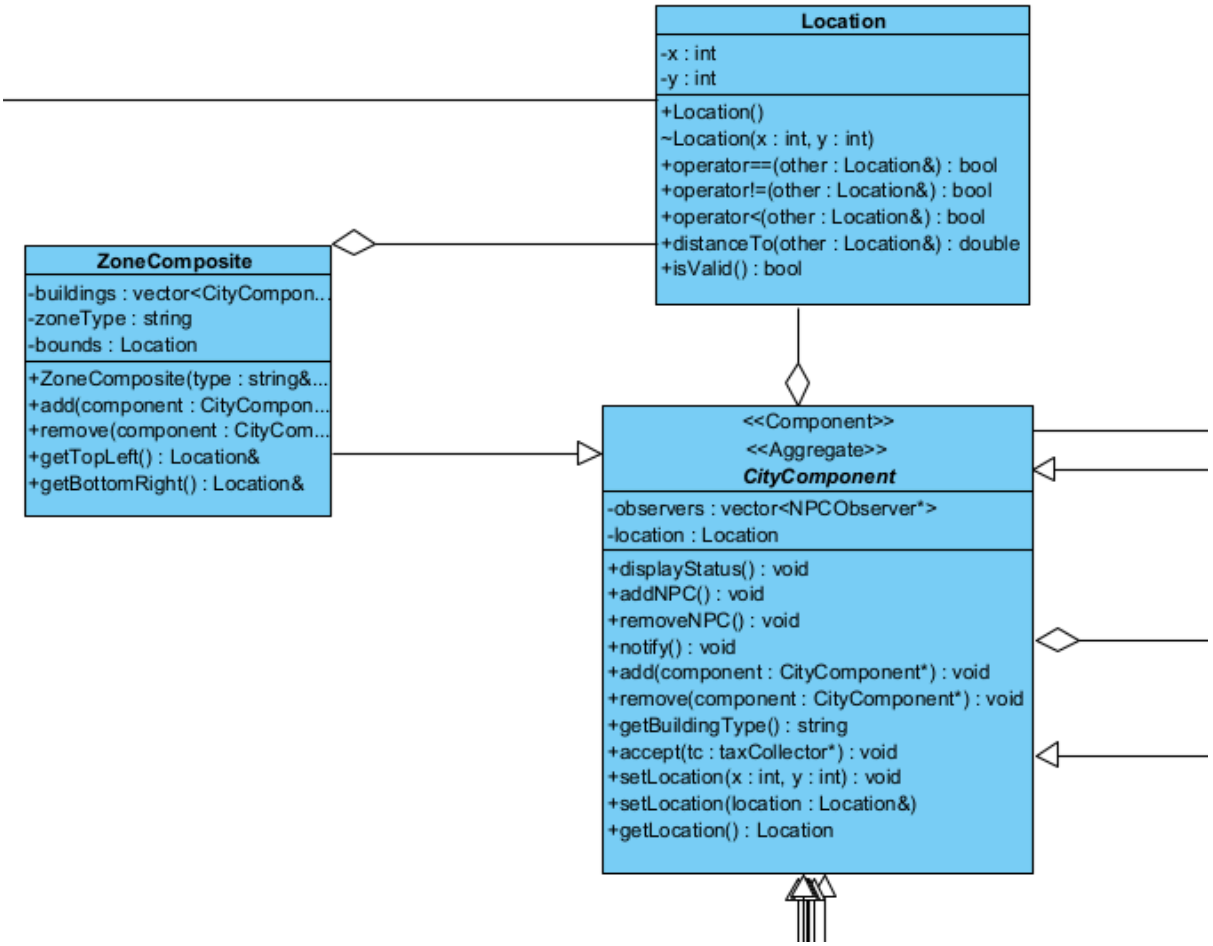
example, tax laws or budgeting adjustments can be applied to an entire neighbourhood or just a single building.

Additionally, the **CityComposite** class works in conjunction with the **Memento Pattern** to store snapshots of the city's state, including tax laws, population counts, and resource allocations.

The **StoreBuildingMemento** object in conjunction with the CityHistoryManager that acts as the CareTaker, captures a snapshot of the current city state, making it possible to track changes, analyse historical data, or revert to previous conditions if needed.

The **CityComposite** class also holds the state of each building, allowing it to restore or update attributes effectively. Each building's state is managed through StoreBuildingMemento , which retains critical information such as population, tax laws, and resource allocations, enabling both granular and aggregate updates.

The **Composite Pattern** thus proves invaluable to the city's digital infrastructure by enhancing the scalability, flexibility, and manageability of building records. As the city grows and becomes more complex, the Composite Pattern will ensure that all components—from single structures to entire neighbourhoods—can be managed in a unified, efficient, and adaptable manner.



CITIZENS/NPCs

The city's digital infrastructure employs a combination of the **Observer Pattern** and **State Pattern** to dynamically manage citizen satisfaction levels and adapt urban services in real-time based on feedback. This approach ensures that each **NPC** (Non-Playable Character, representing a citizen) can signal changes in satisfaction, prompting timely adjustments to city policies and services.

The **Observer Pattern** is implemented to create a responsive system that tracks citizen satisfaction across the city. Each **NPC** acts as a subject capable of notifying observers—such as city officials or service departments—whenever their satisfaction state changes.

The Observer Pattern facilitates a continuous feedback loop where citizen satisfaction levels trigger notifications to relevant city departments. For instance, if a cluster of citizens expresses dissatisfaction with waste management services, the government entity alerts the waste management department immediately and can promptly investigate or make adjustments.

By structuring each **NPC** as a leaf component that serves as an observer subject, the city can receive detailed, citizen-specific feedback. Departments can adapt policies or services based on trends observed in various NPC groups (e.g., neighbourhoods) without requiring direct intervention, promoting a decentralised yet cohesive urban management model.

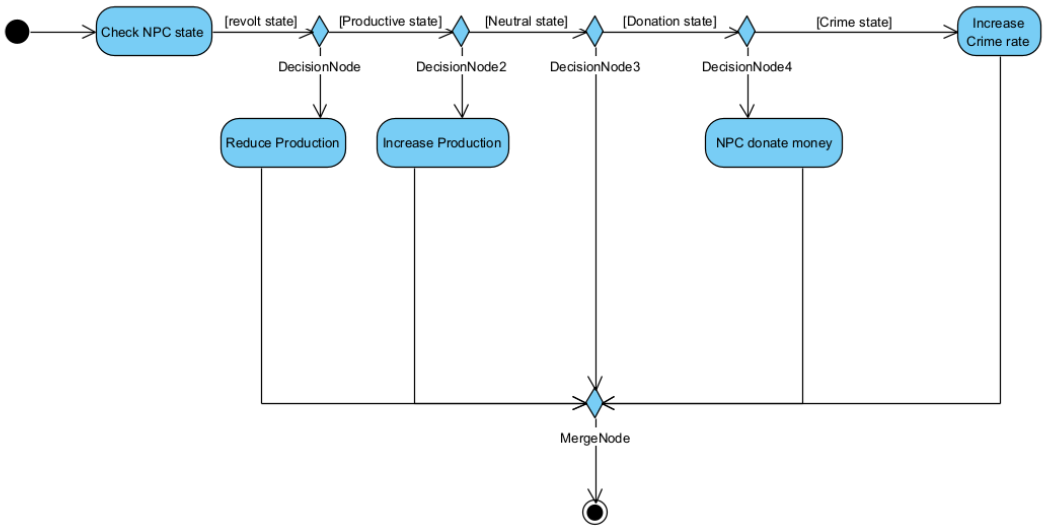
The **State Pattern** complements the Observer Pattern by encapsulating each NPC's satisfaction state, allowing their behaviour to reflect current satisfaction levels. This pattern provides a structured way to handle different states, with each state encapsulating distinct behaviours and responses.

Each NPC's satisfaction level is represented by states like **HappyState**, **NeutralState**, , and **AngryState**. The NPCs' behaviours adjust based on their current state, influencing their interactions with the city system and how they provide feedback. For instance, an NPC in an **AngryState** might initiate more frequent complaints, strikes or participate less in community activities, which in turn decreases production, signalling dissatisfaction.

When NPCs' satisfaction level changes, the state transition triggers a notification to observers, updating city departments on the specific needs or grievances of its citizens. This adaptability allows the city to tailor responses based on real-time satisfaction data, enhancing citizen engagement and support.

The Observer and State Patterns together create a responsive and adaptive urban management system that prioritises citizen engagement and satisfaction, ultimately fostering a high quality of life. Each NPC's role as a leaf component in the city hierarchy enables the collection of granular feedback, leading to informed decisions across departments.

The **Observer Pattern** plays a part in the collection and delivery of resources around our city. When the quantity of resources surpasses a certain threshold, the system will notify the relevant truck -either one designated for Income resources, or one designated for construction resources – and the truck will collect the resource and deliver it to the relevant place.



THE CITY SIMULATION/GAME INTERFACE

In the city's simulation or game interface, we use the **Command Pattern** to manage and streamline user interactions, providing players or administrators with a flexible and reversible way to control various actions.

Each user action, like "build a structure," "allocate resources," or "upgrade building," is encapsulated as a command object. These command objects implement a common interface, making it easy to handle them consistently within the system.

With the Command Pattern, actions can be easily undone or redone, enhancing the user experience and supporting experimentation. For instance, if a player changes their mind about a building placement, the system can call the command's undo() method to revert the action. This feature is invaluable in a simulation or game, where users may frequently want to try different approaches and easily backtrack.

The Command Pattern makes user interaction with the simulation modular, flexible, and easily manageable. By decoupling commands from the core logic, we can add new commands (new user actions) without impacting the system's architecture, enhancing maintainability. This approach also provides a smooth and engaging experience for users, allowing them to explore, experiment, and manage their virtual city efficiently

In conclusion, our city's digital infrastructure is designed as a comprehensive and adaptable system that leverages multiple design patterns to address the complexities of urban management and citizen engagement. Each design pattern plays a strategic role in enhancing functionality, efficiency, scalability, and responsiveness.

This thoughtful integration of design patterns creates a robust, scalable, and adaptive digital infrastructure that not only supports current urban demands but also anticipates future growth and technological advancements. This architecture allows the city to maintain high levels of service, prioritise sustainability, and engage citizens meaningfully, ensuring a well-functioning, forward-looking urban environment.

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