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2015 ABNMS Conference

Application of Bayesian Networks in Urban Growth Models

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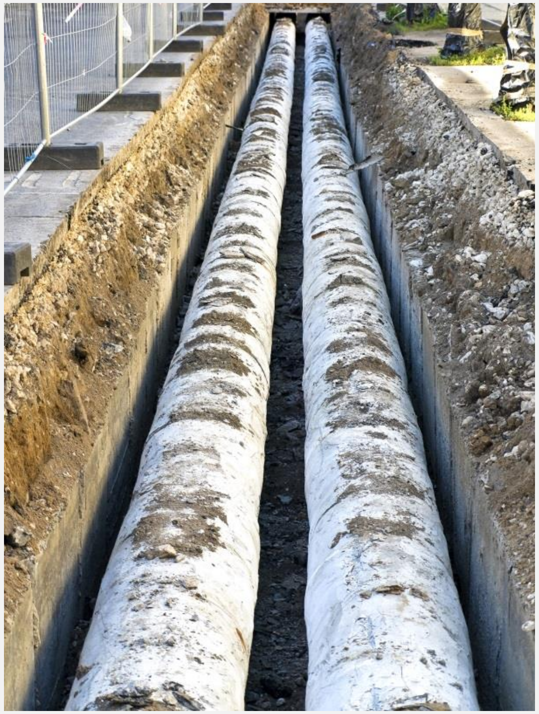
The Problem

- Majority of infrastructure projects at Local Government level
- Long term capital works programs to service future urban growth
  - Identify new infrastructure and upgrades to service urban growth for next 20 years
  - Required for all “trunk” infrastructure networks (water, sewerage, transport, stormwater, open space)
  - Associated financial models required to fund and deliver infrastructure



- Requires reliable urban growth models
- Producing urban growth models is difficult
  - Manually intensive typically taking 5-8 man months with external consultant involvement
  - No consist methodology or guidelines
  - Utilises broad assumptions
  - Models that are inaccurate, difficult to modify and prone to human error

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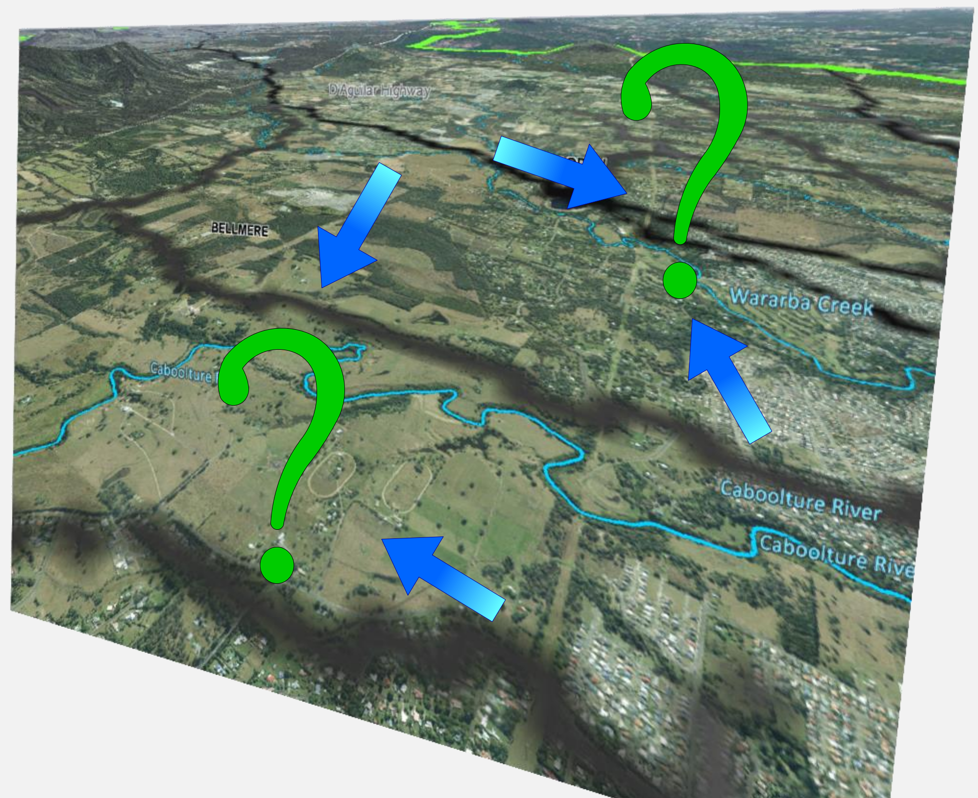
Forecaz Modeller

- Forecaz Modeller developed to address this problem
    - Geospatial modelling tool that automates the generation of residential and non-residential development growth for a region
    - Provides demand growth assumptions for infrastructure networks and calculates infrastructure charges revenue generated by the development.
    - Geospatially aggregates and views forecast model data
    - Predicts
        - What type of growth
        - Location of growth
        - How much growth
        - When will it occur
    - When is important
    - $15M project deferred 1yr can result in $1M of savings



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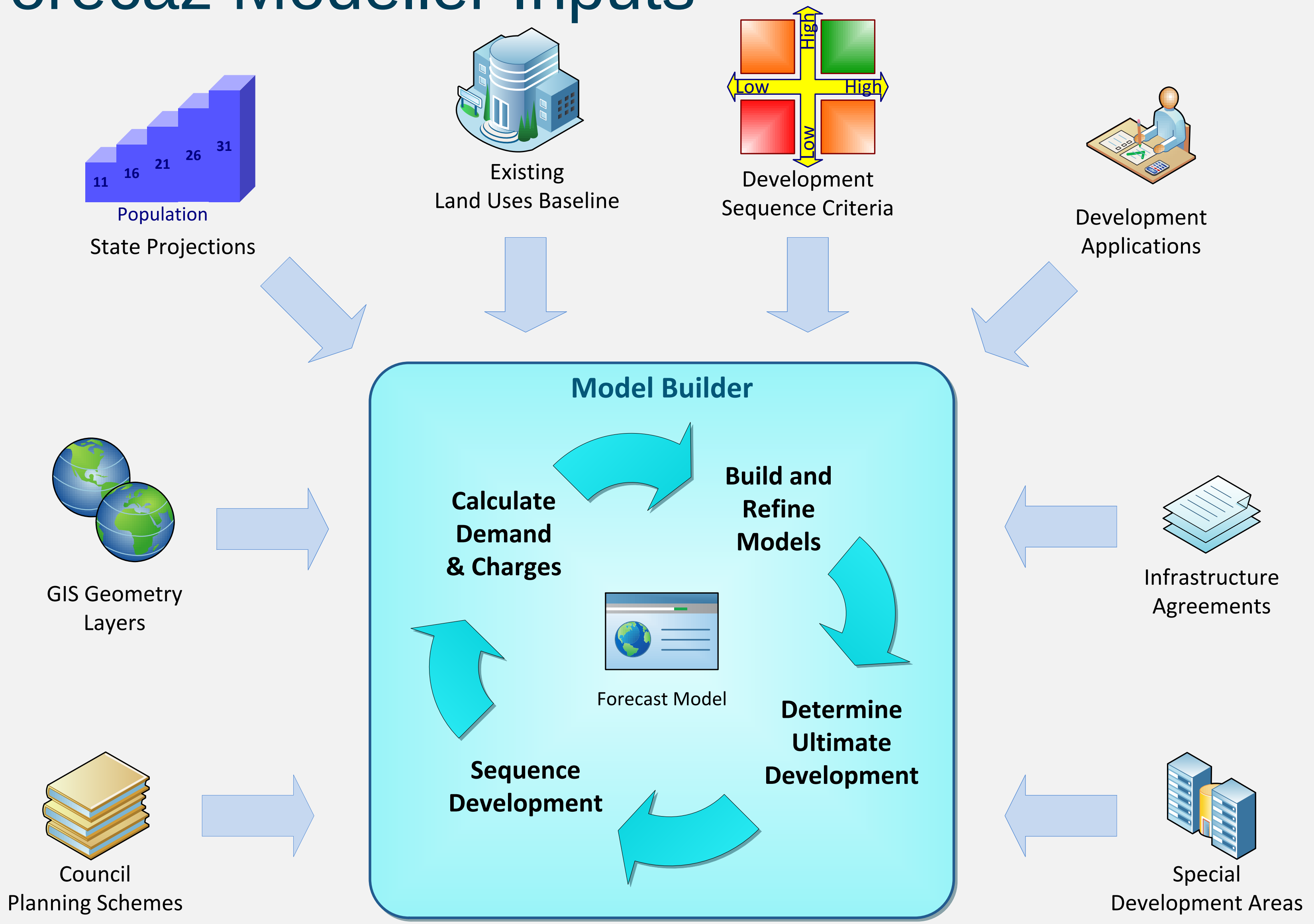
Forecaz Modeller Inputs



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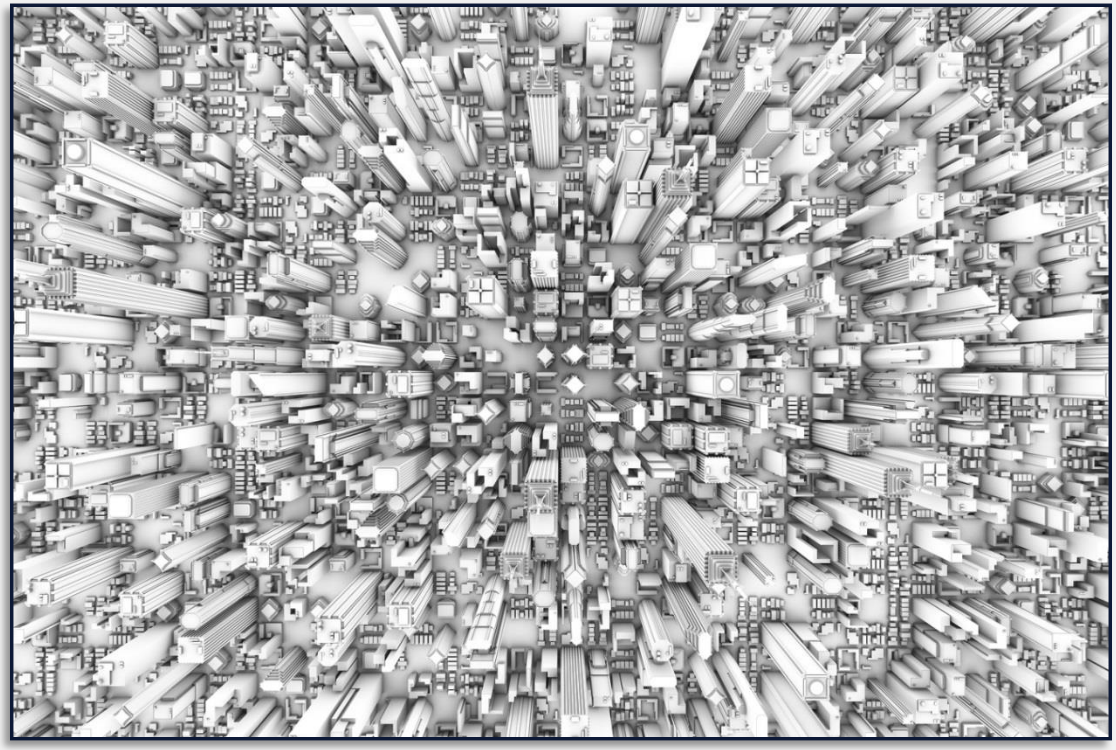
Forecaz Modeller
Determine Ultimate and Best Use

- Use planning zone density provisions and constraints to determine the ultimate development that can be achieved on land parcels.
- Compare existing baseline use with ultimate use to determine highest and best use.
- Determines if land parcel can be developed and the quantum of development.



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Forecaz Modeller
Sequence Development

- Utilise population and m2GFA growth projections as “control” targets for residential and non-residential development growth at specified projection years.
- Modeller employs a **Development Desirability Index (DDI)** indicator of the desirability for a developer to develop a land parcel.
- Utilise DDI to allocate and sequence developable land parcels to ultimate full development within projection years until control targets are reached.

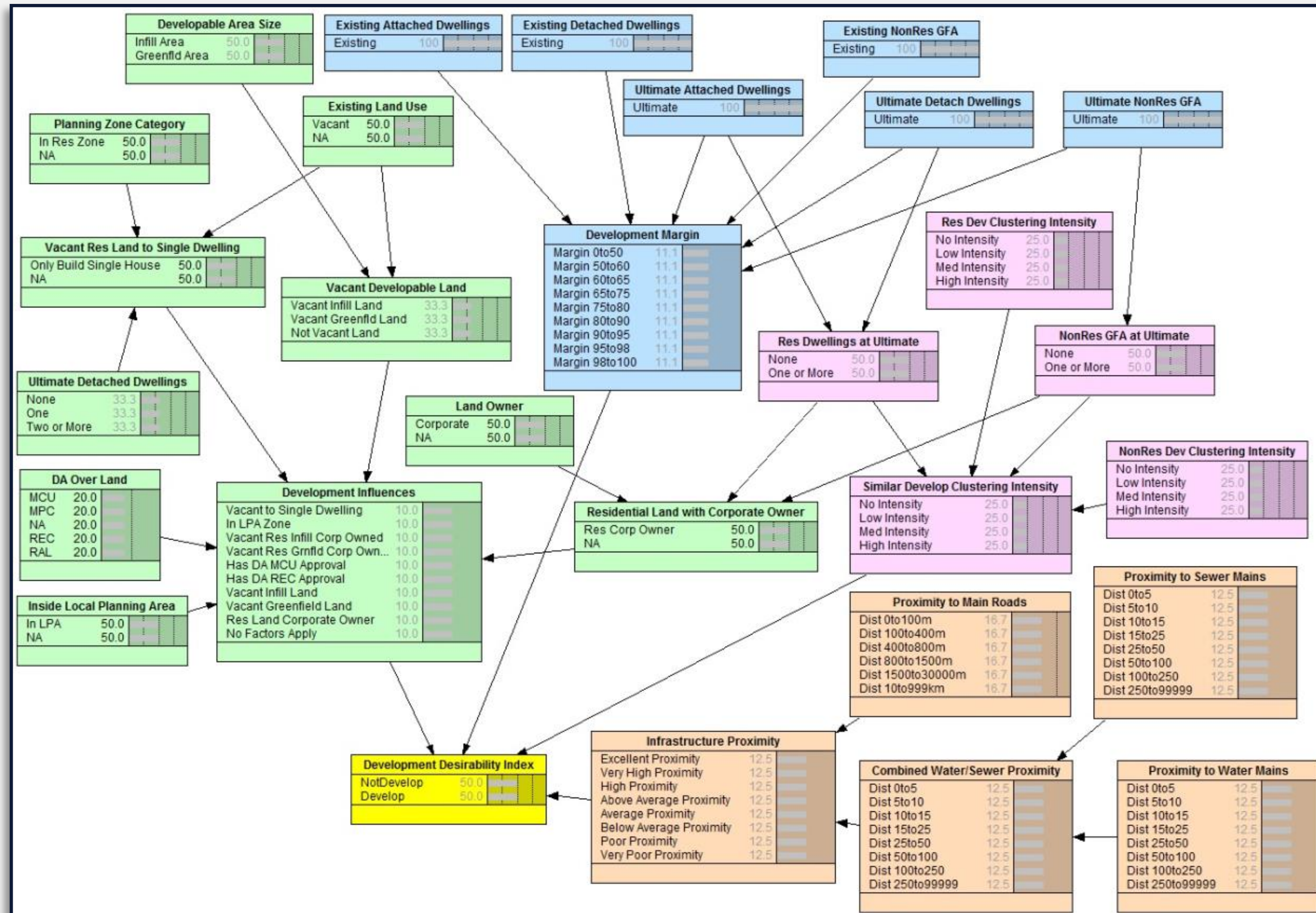
Develop land parcels with highest DDI until res & non-res control targets reached for a projection year

Modeller’s BN
Why Bayesian Networks

- Utilises a BN Model to describe a predictive development algorithm that determines a land parcel’s **Development Desirability Index**
- Why use Bayesian Networks?
  - Graphical models that have a clear schema and conditional probabilities that are easily understandable by non-experts
  - BNs incorporate the uncertainty of expert knowledge
  - Primary users are Urban Planners, safe to assume no Post Grad Mathematical Degree to maintain complex predictive models
  - The methodology used to determine growth assumptions needs to be public available and understood by a lay-person
  - The BN tools are mature, have a strong community, well supported and documented and have a comprehensive API

Modeller’s BN
Bayesian Network Submodules

- Development Margin
- Infrastructure Proximity
- Development Influences
- Similar Development Clustering



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Modeller’s BN
Assumptions

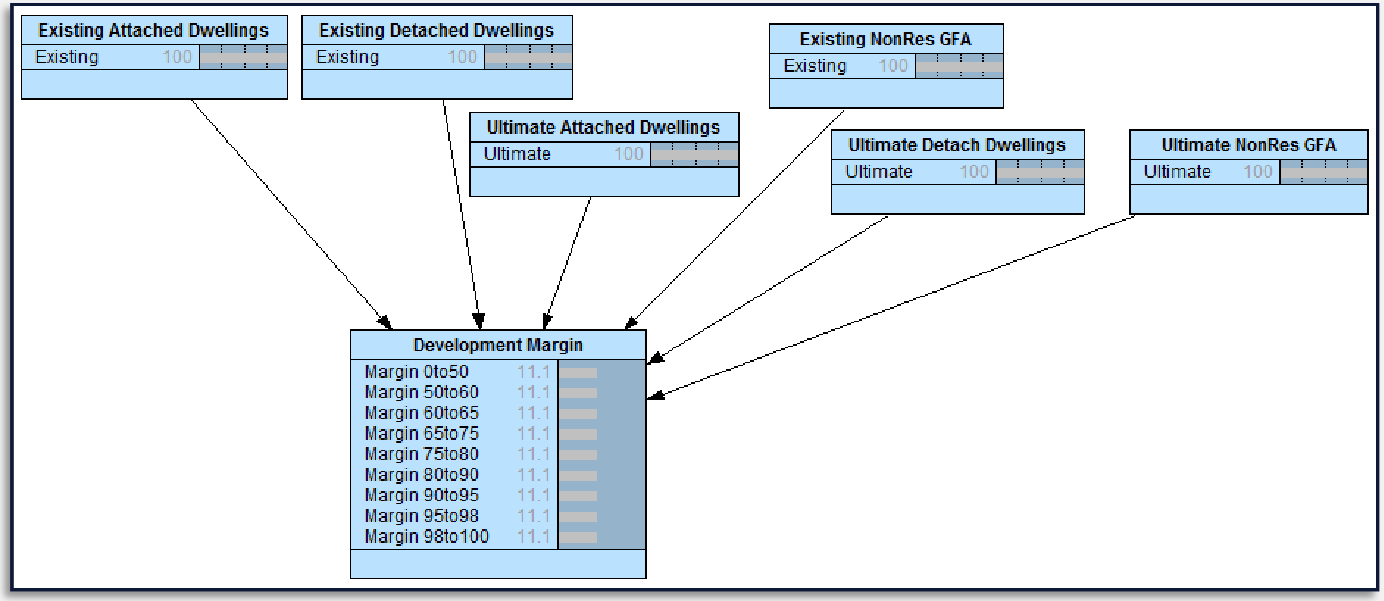
- Only land parcels that can be developed are presented to the BN Model
  - No BN consideration for: flooding, reserves, fully developed land, etc.
- No accounting for proximity to Community Facilities (i.e. shops, parks, schools)
  - Assumed these factors taking into consideration when local governments construct their planning schemes and master plans
- No environment considerations are provided for by the BN Model
  - Development constraints are applied through a “constraints” GIS layer by the Modeller
  - Only parcels with developable area are presented to the BN Model

Modeller's BN
Development Margin Submodule

- Calculates the development margin being:

$$\frac{\textbf{Ultimate Development – Existing Development}}{\textbf{Ultimate Development}}$$

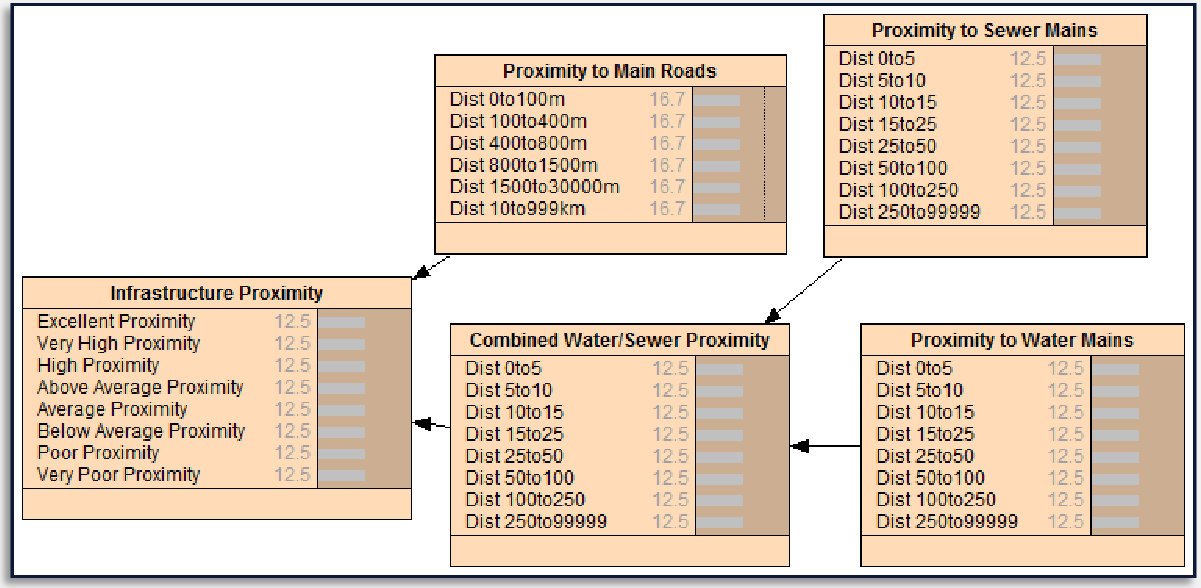
- Node discretisation has been structure to transpose development margin to Development Yield. "*Margin 0to50*" represents poor yield of less than 200%
- Development Yield is a primary development factor. High yield -> high probability of development.



Modeller's BN

Infrastructure Proximity Submodule

- Combines proximity to Water, Sewerage and Main Roads infrastructure into a single distance state representing proximity to network infrastructure.
- The node is weighted towards the proximity to water mains. A water connection is required, before a Land Parcel can have a sewerage connection.
- Infrastructure Proximity is a primary development factor. Developers face significate costs to expand trunk infrastructure to service their development.



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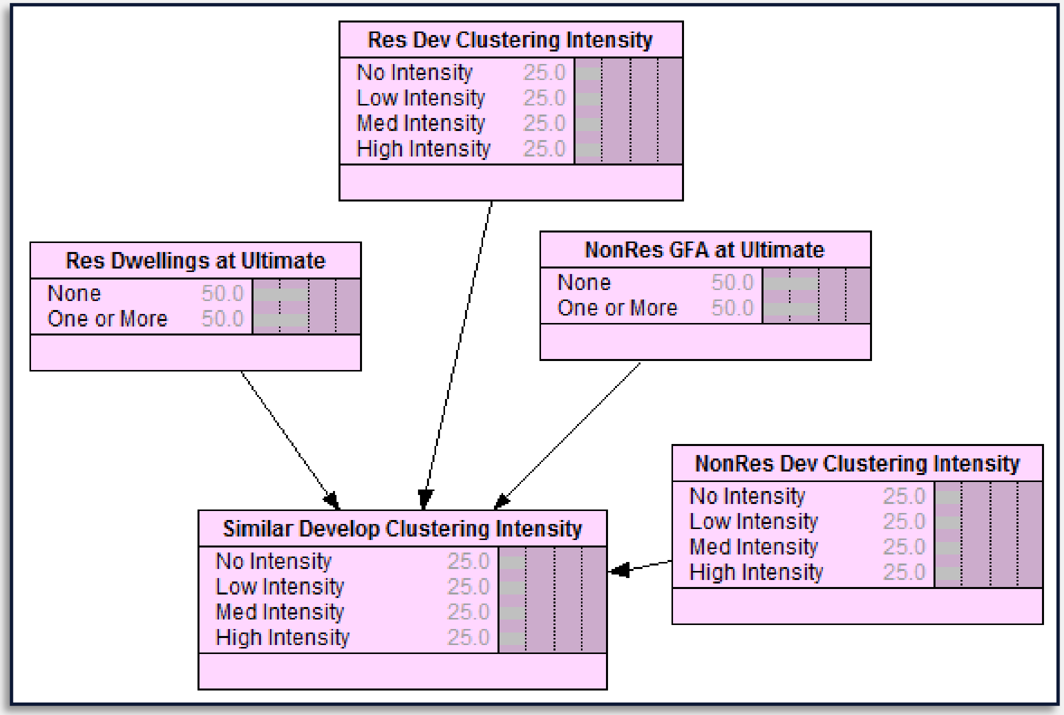
Modeller's BN

Similar Development Clustering Submodule

- Represents a simular development clustering/precedence within 100m from boundary of a land parcel.
- This node combines the states of residential and non-residential simular development clustering
- Only the clustering types (res / non-res) that matches the land parcel's ultimate development are considered.



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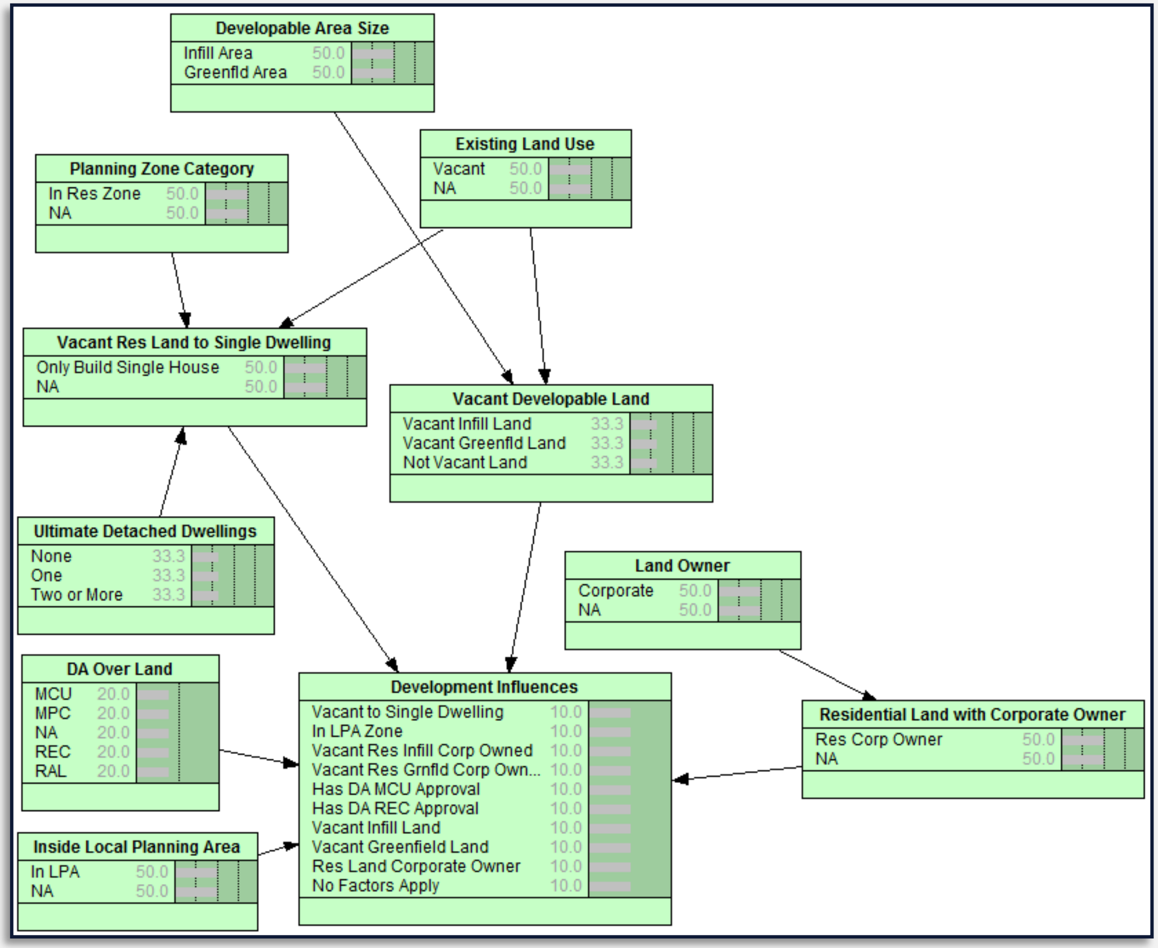
Modeller's BN

Development Influences Submodule

- This node combines the factors that influence development from its various input nodes and weights them as discrete states for input into the Development Desirability Index node



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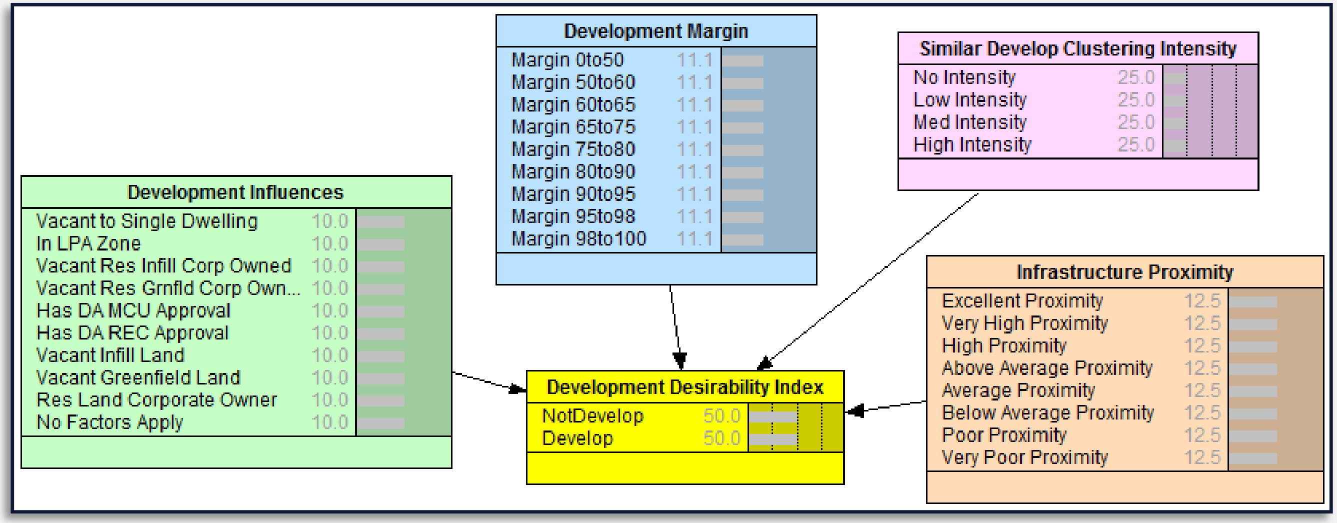
Modeller's BN
Development Desirability Index Node

- This Node contains the Development Desirability Index (DDI) for the Land Parcel.
- Heavy weighting is given to Development Margin and Infrastructure Proximity
- The highest DDI occurs when Development Influences has a state of "*Vacant to Single Dwelling*". Represents vacant land created from a recent sub-division.
- Forecaz Modeller extracts the DDI from the BN Model after: populating all nodes; computing any equations within model; compiling the model to obtain the model's beliefs which produces the DDI for a developable land parcel.



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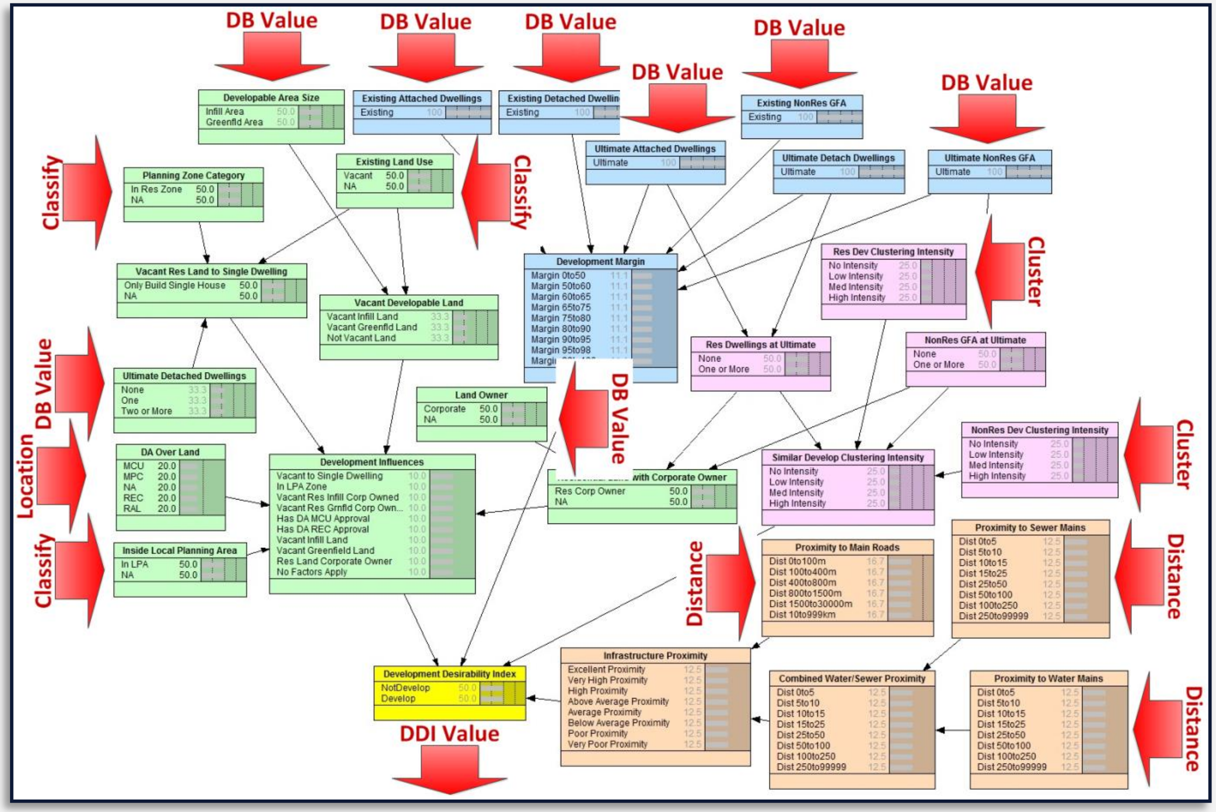
BN Integration
Overview

- The BN nodes are populated by extracting and filtering data from the database or performing spatial operations.
- The Modeller provides computation methods that can be configured to extract and correctly format data for nodes.



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BN Integration
Computation Methods

- Development Desirability Index Method
  - Identifies the node and state that contains the DDI Value
- Database Value Method
  - Extracts and filters values from the database
- Distance Method
  - Minimum distance between parcel and GIS layer features
- Located Method
  - Parcel located within a GIS feature returns an attribute from feature
- Classify Method
  - Classify various values of an attribute in an intersected GIS feature into a single classification value
- Cluster Method
  - Count of parcels meets Res/Non-Res thresholds within specified distance from parcel

Next Steps

- Used the modeller to build urban growth models for:
  - Noosa Shire Council
  - Sunshine Coast Council
- Currently developing Moreton Bay Regional Council model
- Take 3 data sets and apply leaning from data to further validate the BN
- Use learning to expand the nodes (i.e. distance to bus stops/train stations) and evaluate sensitivity
- Investigate the use of Decision Networks

Thank You

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