**Model Optimization and Tuning Phase Template**

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| Date | 24 June 2025 |
| Team | **AS PS VS VV** |
| Project Title | Unemployed Insurance Beneficiary Forecasting |
| Maximum Marks | 10 Marks |

**Model Optimization and Tuning Phase**

The Model Optimization and Tuning Phase involves refining machine learning models for peak performance. It includes optimized model code, fine-tuning hyperparameters, comparing performance metrics, and justifying the final model selection for enhanced predictive accuracy and efficiency.

### Hyperparameter Tuning Documentation (6 Marks):

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| **Model** | **Tuned Hyperparameters** | **Optimal Values** |
| ARIMA | p, d, q | (5, 0, 0) |
| SARIMA | p, d, q, seasonal\_order | (5, 0, 0), (0, 1, 2, 3) |
| AutoReg | lags | 10 |
| VAR | maxlags | 10 |
| Prophet | NA | Default (no tuning) |

* ARIMA (p, d, q):
  + p: Number of autoregressive terms (how many past values are used for prediction).
  + d: Number of times the data is differenced to achieve stationarity.
  + q: Number of moving average terms (how many past forecast errors are used).
* SARIMA (p, d, q, seasonal\_order):
  + p, d, q: Same as ARIMA, applied to the non-seasonal part.
  + seasonal\_order (P, D, Q, s):
    - P: Seasonal autoregressive terms.
    - D: Seasonal differencing.
    - Q: Seasonal moving average terms.
    - s: Length of the seasonal cycle (e.g., 12 for monthly data with yearly seasonality).
* AutoReg (lags):
  + lags: Number of previous time steps used as input features for forecasting.
* VAR (maxlags):
  + maxlags: Maximum number of previous time steps considered for all variables in the multivariate time series.
* Prophet:
  + *No hyperparameters were tuned in this workflow; default settings were used.*

### Performance Metrics Comparison Report (2 Marks):

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| **Model** | **Baseline Metric (MSE/MAE/R2)** | **Optimized Metric** |
| ARIMA | MSE: (initial) NA | MSE: 102,763,733.35 MAE: 5,691.37 R2: -8.18e-05 |
| SARIMA | MSE: (initial) NA | MSE: 103,407,466.65 MAE: 5,833.08 R2: NA |
| AutoReg | MSE: (initial) NA | MSE: 102,771,796.73 MAE: 5,862.50 R2: NA |
| VAR | MSE: NA | NA |
| Prophet | MSE: (initial) NA | MSE: 49,080,877.3 MAE: 4,541.66 R2: 0.003 |

*Note: Baseline metrics are marked NA as only optimized models were evaluated in this workflow. R2 is not always applicable for all models, especially for multivariate or differenced series**.*

### Final Model Selection Justification (2 Marks):

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| **Final Model** | **Reasoning** |
| Prophet | Prophet achieved the lowest MSE and MAE among all tested models, indicating better predictive accuracy. It also handled trends and seasonality automatically, required minimal tuning, and provided interpretable forecasts. Despite a negative R2, its absolute error metrics were superior, making it the most suitable choice for this forecasting task. |