**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: 5,692.99 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 the R2 score, its absolute error metrics were superior, making it the most suitable choice for this forecasting task. |