ENS 491/2 ROKETSAN v QAISU Project
Formulation of OR-Based Decision Modules

Overall Framework Description

This study proposes an integrated Quality Analytics and Operations Research framework to support quality and production decisions in manufacturing systems. Given the synthetic nature of the available dataset, the primary objective is not numerical optimality, but the construction of structurally sound, reusable, and interpretable optimization formulations that reflect real-world decision problems. The framework follows a layered approach in which data mining and machine learning techniques are first employed to extract decision-relevant information from production and quality data, including defect classification results, empirical decision distributions, risk and priority indicators, and cycle time anomaly signals. These analytically derived outputs are subsequently treated as parameters within a set of five Operations Research modules, each addressing a distinct decision layer ranging from quality cost trade-offs and inspection resource allocation to production planning, anomaly-driven assignment, and cost-based quality decision evaluation. Rather than revisiting historical outcomes, the framework is designed to support systematic evaluation and planning of future actions. Its modular structure allows individual components to be applied, extended, or combined based on operational needs, enabling the framework to be transferable to Roketsan's industrial environment beyond the specific dataset used in this study.

Module 1: Poor Quality Cost Trade-off

This module minimizes the expected Cost of Poor Quality by explicitly modeling the trade-off between inspection effort and defect-related costs across alternative quality decisions such as acceptance, rework, return-to-vendor, restricted use, and scrap. The formulation captures how sampling decisions and defect handling choices jointly influence total quality-related cost, providing a structured basis for evaluating inspection intensity and decision policies.

The objective function minimizes a composite cost function consisting of inspection sampling costs, expected defect-related loss on uninspected quantities, and decision-dependent defect-handling costs..

Sets and Indices

- $i \in I$: Set of work orders (`IS_EMRI`).
- D : Set of defect classes (`HATA_TURU / HATA_SINIFI`).

- $K = \{\text{ACCEPT, REWORK, RTV, SCRAP, RU}\}$: Decision alternatives.

For each $i \in I$, the defect class of the order is denoted as $d(i) \in D$.

Parameters

- A_i : Total retained quantity for work order i (`ALIKONULAN_MIKTAR`).
- N_i : Number of inspected samples from A_i (`NUMUNE_MIKTARI`), reference for estimating P_i.
- R_i : Quantity identified as defective (`RET_MIKTAR`).
- C_i : Per-sample inspection cost allocated from the corresponding Cost Center (`MM`).
- F_i : Financial severity (risk weight) of the defect in work order i (`HATA_SINIFI / HATA_TURU` severity).
- P_i : Probability of defect occurrence based on historical defect class of order i.
- $c_{d,k}$: Unit defect-handling cost for defect class $d \in D$ under decision $k \in K$.

Decision Variables

- $n_i \geq 0$: Number of samples to be taken for work order i.
- $x_{i,k} \geq 0$: Amount of defective quantity R_i allocated to decision $k \in K$.
- $z_{i,k} \in \{0,1\}$: Binary decision variable, equals 1 if option k is selected for order i.

Objective Function

$$\min Z = \sum_{i \in I} \big(n_i C_i + (A_i - n_i) P_i F_i\big) + \sum_{i \in I} \sum_{k \in K} c_{d(i),k} x_{i,k} \tag{1}$$

Constraints

(1) Sampling size upper and lower bound:

$$0 \leq n_i \leq A_i \qquad \forall i \in I \tag{2}$$

(2) Allocation of defective quantity:

$$\sum_{k \in K} x_{i,k} = R_i \qquad \forall i \in I \tag{3}$$

(3) Exactly one final decision must be selected:

$$\sum_{k \in K} z_{i,k} = 1 \qquad \forall i \in I \tag{4}$$

$$0 \leq x_{i,k} \leq R_i z_{i,k} \qquad \forall i \in I, \forall k \in K \tag{5}$$

Module 2: MM Resource Allocation

This module allocates inspection activities across cost centers by prioritizing inspection types under capacity, budget, and regulatory constraints. The formulation determines how limited inspection resources should be distributed among measurement machines to ensure effective coverage of inspection demand while respecting operational limitations.

The objective function maximizes a weighted sum of assigned inspection quantities, where weights represent the relative risk or priority of each inspection type.

Sets

- $k \in K$: Cost Centers (`MM`)
- $j \in J$: Inspection types (`MUAYENE_TIPI`)

Parameters

- C_k : Maximum inspection capacity of MM k
- B_k : Budget limit of MM k
- $c_{j,k}$: Unit inspection cost of type j processed at MM k
- w_j : Time or effort per inspected unit for type j
- R_j : Risk or priority weight of inspection type j
- M_j : Legal minimum inspection requirement for inspection type j

Decision Variables

- $n_{j,k} \in \mathbb{Z}^+$: Assigned inspection quantity of type j to MM k

Objective Function

$$\max Z = \sum_{j \in J} \sum_{k \in K} R_j n_{j,k} \tag{6}$$

Constraints

(1) Capacity based allocation:

$$\sum_j n_{j,k} w_j \leq C_k \qquad \forall k \tag{7}$$

(2) Budget constrained allocation:

$$\sum_j c_{j,k} n_{j,k} \leq B_k \qquad \forall k \tag{8}$$

(3) Regulatory minimum sampling rule:

$$\sum_k n_{j,k} \geq M_j \qquad \forall j \tag{9}$$

$$n_{j,k} \in \mathbb{Z}^+ \qquad \forall j, k \tag{10}$$

Module 3: Inter-Operation Batch Size Optimization

This module optimizes production batch sizes and operation-to-location assignments by balancing setup, holding, and processing costs under capacity constraints. The formulation provides a planning-oriented structure for evaluating batch sizing and routing decisions in future production scenarios.

The objective function minimizes the sum of batch-size–dependent setup and holding cost terms and operation–location–specific transfer costs.

Sets and Indices

- $i \in I$: Set of work orders (`IS_EMRI`).
- $o \in O$: Operations (`OPERASYON_NO`).
- $s \in S$: Stock locations (`IS_EMRI_TAMAMLANMA_STOK_YERI`).

Parameters

- D_i : Total quantity in work order m.
- C_{s} : Setup batch cost.
- C_{h} : Unit inventory holding cost.
- $q_{i,o}$: Quantity processed in operation o of order m.
- $c_{o,s}$: Transfer cost for operation o at location s.
- K_s : Capacity of location s.

Decision Variables

- $Q_i \geq 1$: Batch size for order i.
- $x_{i,o,s} \in \{0,1\}$: Equals 1 if operation o of order i is assigned to location s.
- $y_{i,s} \in \{0,1\}$: Equals 1 if work order i is routed to location s.

Objective Function

$$\min Z = \sum_{i \in I} \left(\frac{D_i}{Q_i} C_{\mathrm{s}} + \frac{Q_i}{2} C_{\mathrm{h}} \right) + \sum_{\substack{i \in I \\ o \in O \\ s \in S}} c_{o,s}\, q_{i,o}\, x_{i,o,s} \tag{11}$$

Constraints

(1) Batch size range:

$$1 \leq Q_i \leq D_i \qquad \forall i \tag{12}$$

(2) Exactly one location must be selected per work order:

$$\sum_{s \in S} y_{i,s} = 1 \qquad \forall i \tag{13}$$

(3) Routing decisions must match assigned location:

$$x_{i,o,s} = y_{i,s} \qquad \forall i, o, s \tag{14}$$

(4) Stock capacity constraint:

$$\sum_{i \in I} \sum_{o \in O} q_{i,o} x_{i,o,s} \leq K_s \qquad \forall s \tag{15}$$

Module 4: Cycle Time Anomaly-Based Assignment

This module assigns operations exhibiting abnormal cycle times to more suitable responsible roles in order to improve operational performance. By linking anomaly indications to assignment decisions, the formulation supports systematic reassignment of responsibilities where performance deviations are observed.

The objective function maximizes a linear net benefit function defined by anomaly severity–weighted efficiency gains minus reassignment costs.

Sets

- $o \in O$: Operations (`OPERASYON_NO`).
- $r \in R$: Responsible roles.

Parameters

- $A_o \geq 0$: Severity score of cycle time anomaly for operation o.
- $e_{o,r}$: Expected efficiency of role r when assigned to operation o.
- $c_{o,r}$: Cost of reassigning operation o to role r.
- C_r : Maximum number of operations that role r can handle.

Decision Variables

- $x_{o,r} \in \{0,1\}$: Equals 1 if operation o is assigned to role r.

Objective Function

$$\max \sum_{o \in O} \sum_{r \in R} (A_o \, e_{o,r} - c_{o,r}) \, x_{o,r} \tag{16}$$

Constraints

(1) Each operation must be assigned to exactly one responsible role:

$$\sum_{r \in R} x_{o,r} = 1 \qquad \forall o \in O \tag{17}$$

(2) Capacity limitation of responsible roles:

$$\sum_{o \in O} x_{o,r} \leq C_r \qquad \forall r \in R \tag{18}$$

Module 5: Strategic Quality Decision Policy Optimization

This module evaluates alternative quality decisions based on their expected Cost of Poor Quality using historical decision distributions, and identifies the cost-minimizing option for each record. The formulation represents a cost-based evaluation of quality decisions rather than a revision of historical outcomes.

The objective function minimizes an expected cost function computed as the probability-weighted sum of decision-specific quality costs over defective quantities.

Sets

- $i \in I$: Set of work orders (`IS_EMRI`).
- $k \in K$: {ACCEPT, REWORK, RTV, SCRAP, RU} : Decision alternatives.

Parameters

- R_i : Quantity identified as defective associated with work order i (`RET_MIKTAR`).
- c_k : Unit Cost of Poor Quality for decision k, defined according to domain knowledge:

$$c_{\text{ACCEPT}} < c_{\text{RTV}} < c_{\text{RU}} \ll c_{\text{REWORK}} \lll c_{\text{SCRAP}}$$

- $p_{i,k}$: Empirical probability of decision k for work order i, obtained directly from historical decision labels .

Decision Variables

- $z_{i,k} \in \{0, 1\}$: Indicates whether decision k is selected for record i in the policy evaluation.

Objective Function

$$\min Z = \sum_{i \in I} \sum_{k \in K} p_{i,k} \, c_k \, R_i \, z_{i,k} \tag{19}$$

Constraints

(1) Exactly one decision must be selected for each record:

$$\sum_{k \in K} z_{i,k} = 1 \qquad \forall i \in I \tag{20}$$

(2) Binary decision selection:

$$z_{i,k} \in \{0, 1\} \qquad \forall i \in I, \forall k \in K \tag{21}$$