Multi-Objective Optimization Model for a Scrum-Based Software Development Organization

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Contents

1 1. Sets (Entities)

- $\mathcal{P}$ (P): set of Projects (*Project*)
- $\mathcal{T}$ (T): set of Teams (*Team*)
- $\mathcal{W}$ (W): set of Workers (*Worker*)
- $\mathcal{F}$ (F): set of Features (*Feature*)
- $\mathcal{S}$ (S): set of Skills (*Skill*)
- $\mathcal{R}$ (R): set of Roles (*Role*)
- $\mathcal{PO}$ (PO): set of Product Owners (*ProductOwner*)
- $\mathcal{SM}$ (SM): set of Scrum Masters (*ScrumMaster*)
- $\mathcal{PB}$ (PB): set of Product Backlogs (*ProductBacklog*)
- $\mathcal{SP}$ (SP): set of Sprints (*Sprint*)
- $\mathcal{SPP}$ (SPP): set of Sprint Planning events (*SprintPlanning*)
- $\mathcal{DS}$ (DS): set of Daily Scrums (*DailyScrum*)
- $\mathcal{SR}$ (SR): set of Sprint Reviews (*SprintReview*)
- $\mathcal{SRE}$ (SRE): set of Sprint Retrospectives (*SprintRetrospective*)
- $\mathcal{SBL}$ (SBL): set of Sprint Backlogs (*SprintBacklog*)
- $\mathcal{SG}$ (SG): set of Sprint Goals (*SprintGoal*)
- $\mathcal{E}$ (E): set of Epics (*Epic*)
- $\mathcal{US}$ (US): set of User Stories (*UserStory*)
- $\mathcal{TSK}$ (TSK): set of Tasks (*Task*)
- $\mathcal{DEV}$ (DEV): set of Development Snapshots (*DevelopmentSnapshot*)
- $\mathcal{BL}$ (BL): set of Blockers (*Blocker*)
- $\mathcal{SH}$ (SH): set of Stakeholders (*Stakeholder*)
- $\mathcal{VEL}$ (VEL): set of Velocity records (*Velocity*)
- $\mathcal{REP}$ (REP): set of Release Plans (*ReleasePlan*)
- $\mathcal{RM}$ (RM): set of Roadmaps (*Roadmap*)
- $\mathcal{SCB}$ (SCB): set of Scrum Boards (*ScrumBoard*)
- $\mathcal{FED}$ (FED): set of Feature Documents (*FeatureDocumentation*)

Relationship sets (from `Relationships.csv`):

- $\mathcal{R}^{\text{team\_proj}} \subseteq \mathcal{T} \times \mathcal{P}$ (R1: team assigned to project)
- $\mathcal{R}^{\text{worker\_team}} \subseteq \mathcal{W} \times \mathcal{T}$ (R2: worker belongs to team)[1]

[1] The CSV used "Employee"; here we map to *Worker*.

- $\mathcal{R}^{\text{worker\_skill}} \subseteq \mathcal{W} \times \mathcal{S}$ (R3)
- $\mathcal{R}^{\text{worker\_role}} \subseteq \mathcal{W} \times \mathcal{R}$ (R4)
- $\mathcal{R}^{\text{po\_pb}} \subseteq \mathcal{PO} \times \mathcal{PB}$ (R5)
- $\mathcal{R}^{\text{team\_sm}} \subseteq \mathcal{T} \times \mathcal{SM}$ (R6)
- $\mathcal{R}^{\text{pb\_feature}} \subseteq \mathcal{PB} \times \mathcal{F}$ (R7)
- $\mathcal{R}^{\text{pb\_epic}} \subseteq \mathcal{PB} \times \mathcal{E}$ (R8)
- $\mathcal{R}^{\text{epic\_us}} \subseteq \mathcal{E} \times \mathcal{US}$ (R9)
- $\mathcal{R}^{\text{us\_task}} \subseteq \mathcal{US} \times \mathcal{TSK}$ (R10)
- $\mathcal{R}^{\text{us\_sbl}} \subseteq \mathcal{US} \times \mathcal{SBL}$ (R11)
- $\mathcal{R}^{\text{sbl\_sp}} \subseteq \mathcal{SBL} \times \mathcal{SP}$ (R12)
- $\mathcal{R}^{\text{sp\_goal}} \subseteq \mathcal{SP} \times \mathcal{SG}$ (R13)
- $\mathcal{R}^{\text{scb\_task}} \subseteq \mathcal{SCB} \times \mathcal{TSK}$ (R14)
- $\mathcal{R}^{\text{fed\_feature}} \subseteq \mathcal{FED} \times \mathcal{F}$ (R15)
- $\mathcal{R}^{\text{task\_blocker}} \subseteq \mathcal{TSK} \times \mathcal{BL}$ (R16)
- $\mathcal{R}^{\text{sh\_review}} \subseteq \mathcal{SH} \times \mathcal{SR}$ (R17)
- $\mathcal{R}^{\text{sm\_retro}} \subseteq \mathcal{SM} \times \mathcal{SRE}$ (R18)
- $\mathcal{R}^{\text{vel\_team}} \subseteq \mathcal{VEL} \times \mathcal{T}$ (R19)
- $\mathcal{R}^{\text{rep\_feature}} \subseteq \mathcal{REP} \times \mathcal{F}$ (R20)
- $\mathcal{R}^{\text{rep\_rm}} \subseteq \mathcal{REP} \times \mathcal{RM}$ (R21)
- $\mathcal{R}^{\text{sp\_dev}} \subseteq \mathcal{SP} \times \mathcal{DEV}$ (R22)

2 2. Indices

- $p \in \mathcal{P}$, $t \in \mathcal{T}$, $w \in \mathcal{W}$, $f \in \mathcal{F}$, $s \in \mathcal{S}$, $r \in \mathcal{R}$, $po \in \mathcal{PO}$, $sm \in \mathcal{SM}$, $pb \in \mathcal{PB}$, $\sigma \in \mathcal{SP}$, $spp \in \mathcal{SPP}$, $ds \in \mathcal{DS}$, $sr \in \mathcal{SR}$, $sre \in \mathcal{SRE}$, $sbl \in \mathcal{SBL}$, $sg \in \mathcal{SG}$, $e \in \mathcal{E}$, $u \in \mathcal{US}$, $k \in \mathcal{TSK}$, $v \in \mathcal{DEV}$, $b \in \mathcal{BL}$, $sh \in \mathcal{SH}$, $vel \in \mathcal{VEL}$, $rep \in \mathcal{REP}$, $rm \in \mathcal{RM}$, $scb \in \mathcal{SCB}$, $fd \in \mathcal{FED}$.

Selected parameters (from entity attributes):

- budget_p (Project.budget), priority_f^F (Feature.priority), $\text{effort}_{sbl}^{SBL}$ (SprintBacklog.total_effort), status_b^{BL} (Blocker.status; treated via binary condition), avail_w (Worker.availability), avgSP_{vel} (Velocity.avg_story_points), attend_{sr} (SprintReview.attendees_count), objdesc_{sg} (SprintGoal.objective_desc presence), acc_u (UserStory.acceptance_criteria presence), tests_v^{DEV} (DevelopmentSnapshot.test_status), cards_{scb} (ScrumBoard.number_of_cards), size_t (Team.team_size).

3 3. Goals

We formulate a scalarized multi-objective function using weights w_g from `Goals.csv`. For each goal g, let $\mathrm{dir}(g) = +1$ if `GoalType=max` and $\mathrm{dir}(g) = -1$ if `GoalType=min`. The master objective is:

$$\max \sum_{g \in \mathcal{G}} \mathrm{dir}(g)\, w_g \cdot \mathrm{GoalValue}_g$$

Below, each goal $G\# : \mathit{name}$ is defined.

- **G0: maximize_team_velocity**
  $\mathrm{GoalValue}_{G0} = \sum_{vel \in \mathcal{VEL}} \mathrm{avgSP}_{vel}$
- **G1: minimize_cycle_time**
  Proxy via snapshot creation lag; let $\mathrm{cycle}(\sigma) = \mathrm{lag}(\sigma)$ be a given metric.
  $\mathrm{GoalValue}_{G1} = \sum_{\sigma \in \mathcal{SP}} \mathrm{cycle}(\sigma)$
- **G2: minimize_open_blockers**
  Let $\mathit{open\_b} \in \{0,1\}$ flag unresolved blockers. $\mathrm{GoalValue}_{G2} = \sum_{b \in \mathcal{BL}} \mathit{open\_b}$
- **G3: maximize_sprint_goal_achievement**
  Let $\mathit{ach}_\sigma \in \{0,1\}$ indicate Sprint goal achieved. $\mathrm{GoalValue}_{G3} = \sum_{\sigma \in \mathcal{SP}} \mathit{ach}_\sigma$
- **G4: minimize_total_effort**
  $\mathrm{GoalValue}_{G4} = \sum_{sbl \in \mathcal{SBL}} \mathrm{effort}^{SBL}_{sbl}$
- **G5: maximize_feature_priority_delivered**
  Decision link via $x^{rep}_{rep,f} \in \{0,1\}$. $\mathrm{GoalValue}_{G5} = \sum_{rep \in \mathcal{REP}} \sum_{f \in \mathcal{F}} \mathrm{priority}^F_f \, x^{rep}_{rep,f}$
- **G6: minimize_technical_debt_proxy**
  Proxy via high-effort tasks done: $z^{done}_{\sigma,k} \in \{0,1\}$. $\mathrm{GoalValue}_{G6} = \sum_{\sigma \in \mathcal{SP}} \sum_{k \in \mathcal{TSK}} \mathrm{effort}_k \, z^{done}_{\sigma,k}$
- **G7: maximize_stakeholder_satisfaction_proxy**
  $\mathrm{GoalValue}_{G7} = \sum_{sr \in \mathcal{SR}} \mathrm{attend}_{sr}$
- **G8: minimize_requirement_ambiguity_proxy**
  Missing acceptance criteria: let $m_u = 1$ if acc_u is missing, else 0. $\mathrm{GoalValue}_{G8} = \sum_{u \in \mathcal{US}} m_u$
- **G9: maximize_resource_availability**
  $\mathrm{GoalValue}_{G9} = \sum_{w \in \mathcal{W}} \mathrm{avail}_w$
- **G10: minimize_budget_usage**
  Let use_p be planned/used budget. $\mathrm{GoalValue}_{G10} = \sum_{p \in \mathcal{P}} \mathrm{use}_p$
- **G11: maximize_roadmap_progress**
  Let $\mathrm{milestonesHit}_{rm}$ be achieved milestones. $\mathrm{GoalValue}_{G11} = \sum_{rm \in \mathcal{RM}} \mathrm{milestonesHit}_{rm}$

- **G12: maximize_feature_throughput**
  Proxy via versions advanced: $\text{GoalValue}_{G12} = \sum_{v \in \mathcal{DEV}} \text{version\_number}_v$

4 4. Conditions

Each condition is encoded as a hard constraint (CriteriaType 2 = must-match, 0 = cannot-match) or a structural rule. Below, w_c denotes the weight of soft constraints (CriteriaType 1), if relaxed in a penalty term (not shown in the master objective for brevity).

- **C0: must_have_product_owner**
  For each $pb \in \mathcal{PB}$, $\exists\, po \in \mathcal{PO} :\ (po, pb) \in \mathcal{R}^{\text{po\_pb}}$ and $\text{avail}_{po} > 0$.

- **C1: must_have_scrum_master**
  For each $t \in \mathcal{T}$, $\exists\, sm \in \mathcal{SM} :\ (t, sm) \in \mathcal{R}^{\text{team\_sm}}$.

- **C2: must_define_sprint_goal**
  For each $\sigma \in \mathcal{SP}$, $\exists\, sg \in \mathcal{SG} :\ (\sigma, sg) \in \mathcal{R}^{\text{sp\_goal}}$ and objdesc_{sg} present.

- **C3: cannot_exceed_team_capacity**
  For each $\sigma \in \mathcal{SP}$ and team t active in σ:

  $$\sum_{k \in \mathcal{TSK}} \sum_{w \in \mathcal{W}} a^{\sigma}_{k,t}\, y^{alloc}_{k,w} \cdot \text{effort}_k \ \le\ \kappa \cdot \text{size}_t$$

  where $a^{\sigma}_{k,t} = 1$ if task k of sprint σ belongs to team t; κ converts headcount to capacity (hours/points).

- **C4: must_backlog_items_ready**
  If $x^{us}_{u,sbl} = 1$ (US u selected into sprint backlog sbl), then acc_u present. (Implication: $x^{us}_{u,sbl} \le \text{ready}_u$.)

- **C5: cannot_schedule_blocked_tasks**
  If a blocker b is active for task k in σ, then $z^{done}_{\sigma,k} = 0$. (i.e., $z^{done}_{\sigma,k} \le 1 - open\_b$.)

- **C6: must_lock_sprint_scope**
  For in-progress σ, sprint backlog sbl linked via $(sbl, \sigma) \in \mathcal{R}^{\text{sbl\_sp}}$ remains fixed: $\Delta x^{us}_{u,sbl} = 0$ after start.

- **C7: must_ci_green**
  For deployment decision $d^{prod}_v \in \{0, 1\}$ on snapshot v, require $\text{tests}^{DEV}_v = \text{pass}$: $d^{prod}_v \le pass_v$.

- **C8: must_review_documented**
  For each $sr \in \mathcal{SR}$, $\text{feedback\_documentation}_{sr}$ present.

- **C9: must_retro_actions_tracked**
  For each $sre \in \mathcal{SRE}$, record $\text{improvement\_actions}_{sre}$ and team satisfaction.

- **C10: cannot_exceed_budget**
  $$\sum_{rep \in \mathcal{REP}} \sum_{f \in \mathcal{F}} \text{cost}_f\, x^{rep}_{rep,f} \ \le\ \sum_{p \in \mathcal{P}} \text{budget}_p$$

- **C11: must_prioritize_epics**
  If $(e, u) \in \mathcal{R}^{\text{epic\_us}}$, then priority^{E}_{e} defined.

- **C12: must_update_velocity_window**
  For each $vel \in \mathcal{VEL}$, avgSP_{vel} is computed over exactly $\text{number\_of\_sprints\_used}_{vel}$ recent sprints.

- **C13: cannot_overload_columns**
  For each $scb \in \mathcal{SCB}$, $\text{cards}_{scb} \leq \text{WIPLimit}_{scb}$.

5 5. DecisionVariables

Let the following decision variables encode assignment, selection, and capacity choices. Domains and bounds follow `DecisionVariables.csv`.

- **DV0: assign_user_story_to_sprint**
  $x^{us}_{u,\sigma} \in \{0,1\}$: 1 if user story u is assigned to sprint σ; else 0.

- **DV1: select_feature_for_release**
  $x^{rep}_{rep,f} \in \{0,1\}$: 1 if feature f is included in release plan rep.

- **DV2: allocate_task_to_worker**
  $y^{alloc}_{k,w} \in \{0,1\}$: 1 if task k is executed by worker w.

- **DV3: set_task_status_done**
  $z^{done}_{\sigma,k} \in \{0,1\}$: 1 if task k is completed within sprint σ.

- **DV4: activate_blocker_resolution**
  $r^{blk}_{\sigma,b} \in \{0,1\}$: 1 if blocker b is resolved in sprint σ.

- **DV5: choose_sprint_goal_commitment**
  $c^{goal}_{\sigma} \in \{0,1\}$: 1 if sprint goal for σ is committed.

- **DV6: allocate_team_to_project**
  $x^{tp}_{t,p} \in \{0,1\}$: 1 if team t is assigned to project p.

- **DV7: prioritize_user_story**
  $\pi^{us}_{u} \in \{1,2,3,4,5\}$: integer priority rank for user story u.

- **DV8: estimate_story_points**
  $sp_u \in \{1,2,3,5,8,13,20\}$: integer story-point estimate for u.

- **DV9: set_worker_availability**
  $\alpha_w \in [0,100]$: availability percentage for worker w in the sprint.

- **DV10: limit_sprint_wip**
  $L^{wip}_{\sigma,w} \in [1,10] \cap \mathbb{Z}$: max concurrent tasks per worker w in sprint σ.

- **DV11: select_epic_for_decomposition**
  $x^{epic}_{e} \in \{0,1\}$: 1 if epic e is selected for decomposition this increment.

- **DV12: choose_deployment_target**
  $d^{prod}_{v} \in \{0,1\}$: 1 if development snapshot v targets production.

Linking/structural constraints (typical):

- User Story–Sprint Backlog linkage: if $x^{us}_{u,\sigma} = 1$ then $\exists\, sbl : \ (u, sbl) \in \mathcal{R}^{\text{us\_sbl}} \wedge (sbl, \sigma) \in \mathcal{R}^{\text{sbl\_sp}}$.

- Task completion implies allocation: $z^{done}_{\sigma,k} \leq \sum_{w \in \mathcal{W}} y^{alloc}_{k,w}$.
- WIP limit: $\sum_k y^{alloc}_{k,w} \leq L^{wip}_{\sigma,w}$ for each σ, w concurrently active.
- Capacity vs availability: $\sum_k y^{alloc}_{k,w} \, \text{effort}_k \leq \gamma \cdot \alpha_w$ (calibration factor γ).
- Team–Project consistency: $x^{tp}_{t,p} = 1 \Rightarrow (t,p) \in \mathcal{R}^{\text{team\_proj}}$ (or create/activate such assignment).
- Release membership feasibility: $x^{rep}_{rep,f} = 1 \Rightarrow (rep, f) \in \mathcal{R}^{\text{rep\_feature}}$.