

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

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Contents

1	1. Sets (Entities)	2
2	2. Indices	3
3	3. Goals	3
4	4. Conditions	5
5	5. DecisionVariables	6

Notation preface

Relations from the data are enforced as structural constraints. Where relationships used the label *Employee*, it refers to entity **Worker**. Where a relation used *Sprint Review*, it refers to entity **SprintReview**. Attributes from entities are treated as parameters (possibly normalized or binarized) when numeric optimization is required.

Decision Variables (subset; full list in Section 5):

$x_{t,p} \in \{0, 1\}$	team t assigned to project p (R1)
$y_{w,t} \in \{0, 1\}$	worker w belongs to team t (R2)
$smt_{t,sm} \in \{0, 1\}$	Scrum Master sm supports team t (R6)
$po_{po,pb} \in \{0, 1\}$	Product Owner po manages Product Backlog pb (R5)
$bf_{pb,f} \in \{0, 1\}$	feature f in Product Backlog pb (R7)
$be_{pb,ep} \in \{0, 1\}$	epic ep in Product Backlog pb (R8)
$ue_{ep,us} \in \{0, 1\}$	user story us in epic ep (R9)
$tu_{us,ts} \in \{0, 1\}$	task ts in user story us (R10)
$usbl_{us,sbl} \in \{0, 1\}$	user story us in sprint backlog sbl (R11)
$sblsp_{sbl,sp} \in \{0, 1\}$	sprint backlog sbl belongs to sprint sp (R12)
$tb_{scb,ts} \in \{0, 1\}$	task ts on scrum board scb (R14)
$rf_{rep,f} \in \{0, 1\}$	feature f in release plan rep (R20)
$pg_{sp,sg} \in \{0, 1\}$	sprint sp pursues sprint goal sg (R13)

Key Parameters (from entity attributes):

$SP_{us} := \text{UserStory.story_points of } us$
$EFF_{ts} := \text{Task.effort of } ts$
$SEV_{bl} := \text{Blocker.severity of } bl$
$AOG_{sp} := \text{Sprint.achievement_of_goal of } sp$
$\bar{V}_t := \text{Velocity.avg_story_points for team } t \text{ (via R19)}$
$NE_{pb} := \text{ProductBacklog.number_of_entries of } pb$
$BUD_p := \text{Project.budget of } p$
$PRI_f := \text{Feature.priority of } f$
$INF_{sh} := \text{Stakeholder.influence_level of } sh$
$SAT_{sre} := \text{SprintRetrospective.team_satisfaction of } sre$
$TPR_{dev} := \text{DevelopmentSnapshot.test_status mapped to } \{0, 1\}$
$ATT_{sr} := \text{SprintReview.attendees_count of } sr$
$CAP_{sbl} := \text{SprintBacklog.total_effort capacity of } sbl$

Further relational parameters include $B_{ts,bl} \in \{0, 1\}$ (R16: task ts is blocked by blocker bl).

1 1. Sets (Entities)

- P — Projects
- T — Teams
- W — Workers

- F — Features
- S — Skills
- R — Roles
- PO — ProductOwners
- SM — ScrumMasters
- PB — ProductBacklogs
- SP — Sprints
- SPP — SprintPlannings
- DS — DailyScrums
- SR — SprintReviews
- SRE — SprintRetrospectives
- SBL — SprintBacklogs
- SG — SprintGoals
- EPC — Epics
- US — UserStories
- TSK — Tasks
- DEV — DevelopmentSnapshots
- BL — Blockers
- SH — Stakeholders
- VEL — Velocity records
- REP — ReleasePlans
- RM — Roadmaps
- SCB — ScrumBoards
- FED — FeatureDocumentations

2 2. Indices

- $p \in P, t \in T, w \in W, f \in F, sk \in S, r \in R$
- $po \in PO, sm \in SM, pb \in PB, sp \in SP, sbl \in SBL, sg \in SG$
- $ep \in EPC, us \in US, ts \in TSK, dev \in DEV, bl \in BL$
- $sh \in SH, v \in VEL, rep \in REP, rm \in RM, scb \in SCB, fed \in FED$

3 3. Goals

Multi-objective model; we can solve via weighted sum $\max \sum_k \omega_k \mathcal{O}_k$ (for max goals) and $\min \sum_k \omega_k \mathcal{O}_k$ (for min goals), or via ϵ -constraints. Below each goal lists its ID, name, and mathematical form.

- [G0] **maximize_delivered_story_points**:

$$\max \mathcal{O}_0 = \sum_{us \in US} \sum_{sbl \in SBL} SP_{us} \cdot usbl_{us,sbl}.$$

- [G1] **minimize_total_task_effort**:

$$\min \mathcal{O}_1 = \sum_{ts \in TSK} \sum_{scb \in SCB} EFF_{ts} \cdot tb_{scb,ts}.$$

- [G2] **minimize_blocker_impact**:

$$\min \mathcal{O}_2 = \sum_{bl \in BL} SEV_{bl} \left(\sum_{ts \in TSK} \sum_{scb \in SCB} B_{ts,bl} \cdot tb_{scb,ts} \right).$$

- [G3] **maximize_sprint_goal_achievement**:

$$\max \mathcal{O}_3 = \sum_{sp \in SP} \sum_{sg \in SG} AOG_{sp} \cdot pg_{sp,sg}.$$

- [G4] **maximize_team_velocity**:

$$\max \mathcal{O}_4 = \sum_{t \in T} \bar{V}_t \left(\sum_{p \in P} x_{t,p} \right).$$

- [G5] **minimize_product_backlog_size**:

$$\min \mathcal{O}_5 = \sum_{pb \in PB} \left(\sum_{f \in F} bf_{pb,f} + \sum_{ep \in EPC} be_{pb,ep} \right).$$

- [G6] **minimize_project_budget_consumption** (proxy):

$$\min \mathcal{O}_6 = \sum_{p \in P} \sum_{t \in T} BUD_p \cdot x_{t,p}.$$

- [G7] **maximize_priority_of_released_features**:

$$\max \mathcal{O}_7 = \sum_{rep \in REP} \sum_{f \in F} PRI_f \cdot rf_{rep,f}.$$

- [G8] **maximize_stakeholder_participation_impact**: Let $part_{sh,sr} \in \{0,1\}$ denote stakeholder participation in Sprint Reviews (R17). Then

$$\max \mathcal{O}_8 = \sum_{sr \in SR} \sum_{sh \in SH} INF_{sh} \cdot part_{sh,sr}.$$

- [G9] **maximize_team_satisfaction**:

$$\max \mathcal{O}_9 = \sum_{sre \in SRE} SAT_{sre}.$$

- [G10] **minimize_unfinished_tasks_on_board**: Let $done_{ts} \in \{0,1\}$ from Task.status. Then

$$\min \mathcal{O}_{10} = \sum_{ts \in TSK} \sum_{scb \in SCB} (1 - done_{ts}) \cdot tb_{scb,ts}.$$

- [G11] **maximize_test_pass_rate**: Let $pass_{dev} \in \{0,1\}$ mapped from DevelopmentSnapshot.test_status. Then

$$\max \mathcal{O}_{11} = \sum_{dev \in DEV} pass_{dev}.$$

4 4. Conditions

Each condition encodes logical and relational constraints derived from the relationships and attributes.

- [C0] `team_assigned_to_exactly_one_project` (R1):

$$\sum_{p \in P} x_{t,p} = 1 \quad \forall t \in T.$$

- [C1] `worker_belongs_to_exactly_one_team` (R2):

$$\sum_{t \in T} y_{w,t} = 1 \quad \forall w \in W.$$

- [C2] `scrummaster_supports_one_team` (R6):

$$\sum_{sm \in SM} smt_{t,sm} = 1 \quad \forall t \in T.$$

- [C3] `product_owner_manages_one_backlog` (R5):

$$\sum_{po \in PO} po_{po,pb} = 1 \quad \forall pb \in PB.$$

- [C4] `feature_in_at_most_one_backlog` (R7):

$$\sum_{pb \in PB} bf_{pb,f} \leq 1 \quad \forall f \in F.$$

- [C5] `epic_in_at_most_one_backlog` (R8):

$$\sum_{pb \in PB} be_{pb,ep} \leq 1 \quad \forall ep \in EPC.$$

- [C6] `user_story_in_exactly_one_epic` (R9):

$$\sum_{ep \in EPC} ue_{ep,us} = 1 \quad \forall us \in US.$$

- [C7] `task_in_exactly_one_user_story` (R10):

$$\sum_{us \in US} tu_{us,ts} = 1 \quad \forall ts \in TSK.$$

- [C8] `user_story_in_at_most_one_sprint_backlog` (R11):

$$\sum_{sbl \in SBL} usbl_{us,sbl} \leq 1 \quad \forall us \in US.$$

- [C9] `sprint_backlog_belongs_to_one_sprint` (R12):

$$\sum_{sp \in SP} sblsp_{sbl,sp} = 1 \quad \forall sbl \in SBL.$$

- [C10] **sprint_backlog_capacity_respected**:

$$\sum_{us \in US} \sum_{ts \in TSK} \text{EFF}_{ts} \cdot tu_{us,ts} \cdot usbl_{us,sbl} \leq \text{CAP}_{sbl} \quad \forall sbl \in SBL.$$

(This bilinear form can be linearized using standard techniques, e.g., auxiliary variables and McCormick envelopes.)

- [C11] **release_only_features_in_backlog (R20 & R7)**:

$$rf_{rep,f} \leq \sum_{pb \in PB} bf_{pb,f} \quad \forall rep \in REP, \forall f \in F.$$

- [C12] **sprint_pursues_exactly_one_goal (R13)**:

$$\sum_{sg \in SG} pg_{sp,sg} = 1 \quad \forall sp \in SP.$$

5 5. Decision Variables

- **DV0**: $x_{t,p} \in \{0, 1\}$ — team t assigned to project p .
- **DV1**: $y_{w,t} \in \{0, 1\}$ — worker w belongs to team t .
- **DV2**: $sm_{t,sm} \in \{0, 1\}$ — Scrum Master sm supports team t .
- **DV3**: $po_{po,pb} \in \{0, 1\}$ — Product Owner po manages Product Backlog pb .
- **DV4**: $bf_{pb,f} \in \{0, 1\}$ — feature f in Product Backlog pb .
- **DV5**: $be_{pb,ep} \in \{0, 1\}$ — epic ep in Product Backlog pb .
- **DV6**: $ue_{ep,us} \in \{0, 1\}$ — user story us in epic ep .
- **DV7**: $tu_{us,ts} \in \{0, 1\}$ — task ts in user story us .
- **DV8**: $usbl_{us,sbl} \in \{0, 1\}$ — user story us in sprint backlog sbl .
- **DV9**: $sblsp_{sbl,sp} \in \{0, 1\}$ — sprint backlog sbl belongs to sprint sp .
- **DV10**: $tb_{scb,ts} \in \{0, 1\}$ — task ts on scrum board scb .
- **DV11**: $rf_{rep,f} \in \{0, 1\}$ — feature f in release plan rep .
- **DV12**: $pg_{sp,sg} \in \{0, 1\}$ — sprint sp pursues sprint goal sg .