
List of Symbols

Miscellany

$:=$	Equal by definition
\square	End of proof
$\lceil x \rceil$	Smallest integer greater than or equal to x
$(x)^+$	Maximum of 0 and x

Sets

\emptyset	Empty set
$[a, b[$	Half open interval $\{x \in \mathbb{R} \mid a \leq x < b\}$
$ X $	Cardinality of finite set X
$B_\varepsilon(S)$	Ball of radius ε around S in \mathbb{R}^{n+2}
ℓ	Line segment in \mathbb{R}^{n+2}
\mathbb{N}	Set of all positive integers
\mathcal{O}	Landau's symbol
$\mathbb{P}(X)$	Power set of set X
\mathbb{R}	Set of all real numbers
\mathbb{R}^n	Set of all n -tuples of real numbers
$\mathbb{R}_{\geq 0}$	Set of all nonnegative real numbers
$X \subset Y$	X is proper subset of Y
$X \subseteq Y$	X is subset of Y
$X \setminus Y$	Difference of sets X and Y
$X \cap Y$	Intersection of sets X and Y
$X \cup Y$	Union of sets X and Y
\mathbb{Z}	Set of all integers
$\mathbb{Z}_{\geq 0}$	Set of all nonnegative integers

Projects and project activities

b_i	Activity calendar for activity i
$b_{i,j}$	Time lag calendar for arc (i, j)
d_{ij}^{max}	Maximum time lag between the starts of activities i and j
d_{ij}^{min}	Minimum time lag between the starts of activities i and j
\bar{d}	Prescribed maximum project duration

m_i	Execution mode for activity i
\mathcal{M}_i	Set of alternative execution modes for activity i
p_i	Duration (processing time) of activity i
p_{im_i}	Duration of activity i in execution mode m_i
ϑ_{ij}^k	Sequence-dependent changeover time from activity i to activity j on resource k
V	Set of all activities
$V^a \subset V$	Set of all real activities
$V^e \subseteq V$	Set of all fictitious activities (events)
V_k^a	Set of all real activities using renewable resource k
V_k^{e-}	Set of all events depleting cumulative resource k
V_k^{e+}	Set of all events replenishing cumulative resource k

Directed graphs and networks

D	Distance matrix for project network N
d_{ij}	Length of a longest directed path (distance) from node i to node j in project network N
δ_{ij}	Weight of arc (i, j)
δ_{im_i, jm_j}	Weight of arc (i, j) for mode combination (m_i, m_j)
E	Arc set of project network N
$G = (V, E)$	Directed graph with node set V and arc set E
$G = (V, E, \delta)$	Weighted directed graph (network) with node set V , arc set E , and vector δ of arc weights
(i, j)	Arc with initial node i and terminal node j
$m = E $	Number of arcs in project network N
$n + 2 = V $	Number of nodes in project network N
N	Project network
$Pred(i)$	Set of all direct predecessors of node $i \in V$
$Succ(i)$	Set of all direct successors of node $i \in V$
V	Node set of project network N

Resources

F	Forbidden set of activities
\mathcal{F}	Set of all minimal forbidden sets
\mathcal{F}_k^+	Set of all minimal k -surplus sets
\mathcal{F}_k^-	Set of all minimal k -shortage sets
r_{ik}	Requirement of activity i for resource k
r_{ik, m_i}	Requirement of activity i for resource k in execution mode m_i
$r_k(S, \cdot)$	Loading profile for resource k given schedule S
R_k	Capacity of renewable resource k or availability of nonrenewable resource k
\underline{R}_k	Safety stock of cumulative resource k
\overline{R}_k	Storage capacity of cumulative resource k
\mathcal{R}^d	Set of all (discrete) cumulative resources
$\overline{\mathcal{R}}^c$	Set of all continuous cumulative resources
\mathcal{R}^v	Set of all nonrenewable resources
\mathcal{R}^r	Set of all renewable resources

Objective functions

α	Continuous interest rate
c_i^f	Cash flow associated with the start of activity i
ck	Per unit cost for resource k
$\partial^- \bar{f} / \partial S_i(S)$	Left-hand S_i -derivative of \bar{f} at S
$\partial^+ \bar{f} / \partial S_i(S)$	Right-hand S_i -derivative of \bar{f} at S
$f : S_T \rightarrow \mathbb{R}$	Objective function to be minimized
$\bar{f} : C \rightarrow \mathbb{R}$	Continuation of objective function f
$\varphi : S_T \rightarrow X$	C^1 -diffeomorphism
$\nabla \bar{f}(S)$	Derivative of \bar{f} at S
$\nabla^- \bar{f}(S)$	Left-hand derivative of \bar{f} at S
$\nabla^+ \bar{f}(S)$	Right-hand derivative of \bar{f} at S
$d\bar{f} _S(z)$	Directional derivative of \bar{f} at S in direction z
w_i	Weight of activity i
w_i^e, w_i^t	Earliness and tardiness costs for activity i per unit time
w_i^f	Weight of free floats for activity i

Relations and preorders

$cr(\theta)$	Covering relation of strict order θ
$D(\rho)$	Distance matrix for relation network $N(\rho)$
d_{ij}^ρ	Distance from node i to node j in relation network $N(\rho)$
δ_{ij}^ρ	Weight of arc (i, j) in relation network $N(\rho)$
$G(\theta)$	Precedence graph of strict order θ
MFR	Set of all \subseteq -minimal feasible relations
$\min M$	Minimal point of ordered set (M, \leq) with $M \subseteq \mathbb{R}^{n+2}$
$N(\rho)$	Relation network belonging to relation ρ
$Pred^\theta(i)$	Set of all predecessors of i in preorder θ
ρ, ϱ	Relation in set V
SIO	Set of all schedule-induced strict orders in set V^a
SIP	Set of all schedule-induced reflexive preorders in set V^e
$S_T(\rho)$	Relation polytope of relation ρ
$S_T^\theta(\theta)$	Equal-preorder set of preorder θ
$tr(\rho)$	Transitive hull of relation ρ
θ	Strict order in set V^a or reflexive preorder in set V^e
$\theta(S)$	Schedule-induced preorder
$\Theta(D)$	Strict order in set V^a or reflexive preorder in set V^e induced by distance matrix D

Schedules

AS	Set of active schedules
ES	Earliest schedule
LS	Latest schedule
PSS	Set of all pseudostable schedules
QAS	Set of all quasiactive schedules
QSS	Set of all quasistable schedules
S	Schedule
S	Set of all feasible schedules

S_C	Set of all resource-feasible schedules with respect to cumulative resources
S_R	Set of all resource-feasible schedules with respect to renewable resources
S_T	Set of all time-feasible schedules
SS	Set of all stable schedules

Temporal scheduling

C_i	Completion time of activity i
d_{ij}	Induced minimum time lag between the starts of activities i and j
EC_i	Earliest completion time of activity i
EFF_i	Early free float of activity i
ES_i	Earliest start time of activity i
LC_i	Latest completion time of activity i
LFF_i	Late free float of activity i
LS_i	Latest start time of activity i
S_i	Start time of activity i
TF_i	Total float of activity i

Resource allocation

A	Maximal feasible set
$A(S, t)$	Active set at time t given schedule S
B	Minimal delaying alternative
B	Set of all minimal delaying alternatives
C	Set of all activities scheduled
C'	Set of all activities shifted
C	Set of candidate schedules
D_j	Set of all tentative start times for activity j (decision set)
G	Spanning forest of project network N with arc set E_G
$g(z)$	Directional derivative of \bar{f} at iterate S in direction z
lb	Lower bound on minimum objective function
P	Search space
σ	Stepsize
u, v	Enumeration nodes
$w_k(a, b)$	Workload for renewable resource k in time interval $[a, b]$
x	Full mode assignment
\underline{x}	Partial mode assignment
z	Steepest descent direction