

Indices, Parameters and Decision Variables

a_j, a_r, a_q	Assembly content of orders j, r, q at each station
$a_{j,w}$	Assembly content of order j for worker w
A_j	Total assembly content of order j
α	Lower limit in workload equilibrium as a function of β ; relative value
β	Maximum allowed overtaking; relative value
C_b	Actual capacity required
C_v	Capacity provided
D_i	Distance to the next unit of an order from takt time group i or launching distance of the orders from takt time group i
D_j	Distance to the next unit of the order j or launching distance of job j
E_{ma}	Design-for-Assembly index
E_{AL}	Balancing efficiency of the assembly line
E_{WSn}	Balancing efficiency of workstation n
e_a	Total allowance ; time that must be mapped in the assembly line
e_{fa}	Factual allowance ; time that must be mapped in the assembly line
e_{pa}	Personal allowance ; time that must be mapped in the assembly line
$h(A)$	Relative frequency of operation time of job A
Y	Maximum drift range
i	Index of takt time groups
I	Total number of takt time groups
j	Index of orders
J	Total number of orders
l	Index of assembly operation per station
L_n	Index set of assembly operations l assigned to station n
m	Index product group, one or more products can be combined into one product group
M	Total number of product groups
n	Index of workstations of the assembly line
N	Total number of workstations in an assembly line
N_{\min}	Theoretically lowest number of parts (see DFA)
ot_l	Operation time of assembly process l
θ_i	Overtaking limit of takt time group i ; relative value

(continued)

$OV1, OV2, OV3$	Short form for option variant 1, 2 and 3 of a product
$P1, P2, P3$	Short form for product 1, 2 and 3
$P1a, P1b, P1c$	Short form for product 1 with option a, b or c
P_l	Probability of occurrence of assembly operation l
p_i	Proportion of the number of orders in takt time group i in relation to the total number of orders I
q	Index of orders
\underline{Q}	Index of the largest order not yet assigned in the VTGA
r	Index of orders
R_n	Weighted workload at station n
$R_{w,i}$	Weighted workload of worker w in takt time group i
s	Station index
S	Total number of stations in an assembly line
TA	Takt time gap
t_a	Standard assembly time of a part (see DFA)
t_{ma}	Determined time for the total assembly of a part (see DFA)
T	Takt time/cycle time
T_i	Takt time of the takt time group i
T_j	Takt time of order j
T_{Vario}	Takt time within VarioTakt
V_{CS}	Flow velocity of the assembly line, the conveyor system respectively
V_n	Flow velocity at station n
w	Index of workers on an assembly line
W	Total number of workers on an assembly line
wd	Workforce density
wlo	Workload per unit length on the assembly object (workload unit length object)
wls	Workload per unit length of assembly access surface (workload unit length assembly access surface)
X_{ji}	Binary variable of order j (not) assigned to takt time group i

Abbreviations

AD for MMA	Assembly Design for Mixed-Model Assembly
AGV	Automated guided vehicle
AR	Augmented reality
ARC	Assembly Revolution Cell
BOM	Bill of materials
CIP	Continuous improvement process
CPS	Cyber physical systems
DFA	Design-for-Assembly
k.o.	Knockout
FLDP	Flexible layout design problem
IAA	International Motor Show in Germany (Internationale Automobilausstellung)
IT	Information technology
IOT	Internet-of-Things
I4.0	Industry 4.0 (The fourth industrial revolution)
JIT	Just-in-time
JIS	Just-in-sequence
AI	Artificial intelligence
CIP	Continuous improvement process
LM-structure	Line-matrix structure (variant of a hybrid assembly)
LML-structure	Line-matrix-line structure (variant of a hybrid assembly)
MES	Manufacturing Execution System
ML-structure	Matrix-line structure (variant of a hybrid assembly)
MMAD	Mixed-Model Assembly Design
MMAL	Mixed-model assembly line
MTM	Methods-Time Measurement; is a method for analyzing workflows and determining target times
MTB	Mountain bike (Canyon Bicycles product group)
NP-hard	Non-polynomial, i.e. exponential computation time is required
PDCA	Plan-Do-Check-Act cycle, also known as Deming cycle

(continued)

PD for MMA	Product Design for Mixed-Model Assembly
PLC	Programmable logic controller
POC	Proof of concept
REFA	Reich committee for working time determination
RWTH	Rheinisch-Westphalian Technical University (Aachen, Germany)
SaaS	Software as a Service
SWS	Standard worksheet
SD for MMA	Sequence Design for Mixed-Model Assembly
SMED	Single minute exchange of dies (method for reducing setups/changeover)
TPS	Toyota Production System
TU	Time unit
TUM	Munich University of Technology (Munich, Germany)
WATT	Weighted average takt time
WHU	WHU - Otto Beisheim School of Management (Vallendar near Koblenz, Germany)
WO	Work operation or activity module