SMT2020

Semiconductor Manufacturing Testbed

Data Specification

Release 1.0 - 03/2020

Contents

1. Introduction 2

2. Minimal Structure 2

2.1. options.def 2

2.2. tool.txt 2

2.3. part.txt 4

2.4. route_i.txt 4

2.5. order.txt 4

3. Additional Features 5

3.1. Tools Availability 5

3.1.1. Unscheduled Down Times: Breakdowns 6

3.1.2. Scheduled Down Times: Preventive Maintenance (PM) 7

3.2. Transport Times 8

3.3. Load and Unload 8

3.4. Setups 9

3.5. Batching 10

3.6. Cascading 10

3.7. Lot-to-Lens Dedications 11

3.8. Rework 11

3.9. Sampling of Lots 11

3.10. Dispatching 11

3.11. Hot Lots and Setup Avoidance 12

3.12. Super Hot Lots 12

3.13. Critical Queue Time 12

4. Reports 14

5. Characteristic Features of the Individual Datasets in SMT2020 15

1. Introduction

The purpose of this document is to provide the user of the Semiconductor Manufacturing Testbed 2020 (SMT2020) with the technical information necessary to navigate and use the data files. SMT2020 in its final version will include at least two fab models, one High Mix – Low Volume (HM/LV) model, denoted as dataset 1 and a Low Mix- High Volume (LM/HV) model denoted as dataset 2. This document may be subject to changes if improvements in the descriptions of the datasets are required in the future. We therefore ask the readers to pay attention to the version (release number in the title page) they use. We also invite users to contact the authors with any requests or suggestions.

The testbed was created and tested using the AutoSched AP simulation software. The interface for Autosched AP is a set of Excel sheets. Users can either use the model directly in Autosched AP or transfer the data from the Excel data sheets to the simulation tool of their choice. The main features of the two datasets are described in Sections 2 and 3 in an almost dataset-independent manner, whereas the main differences between specific datasets are summarized in Section 4.

An AutoSched AP simulation model is located in the folder model_name.asd. It consists of several files with extension .txt. To create or change a model, the Excel software can be used. The Excel sheets and the corresponding tables will be transformed into the model files (.txt) by exporting the model.

2. Minimal Structure

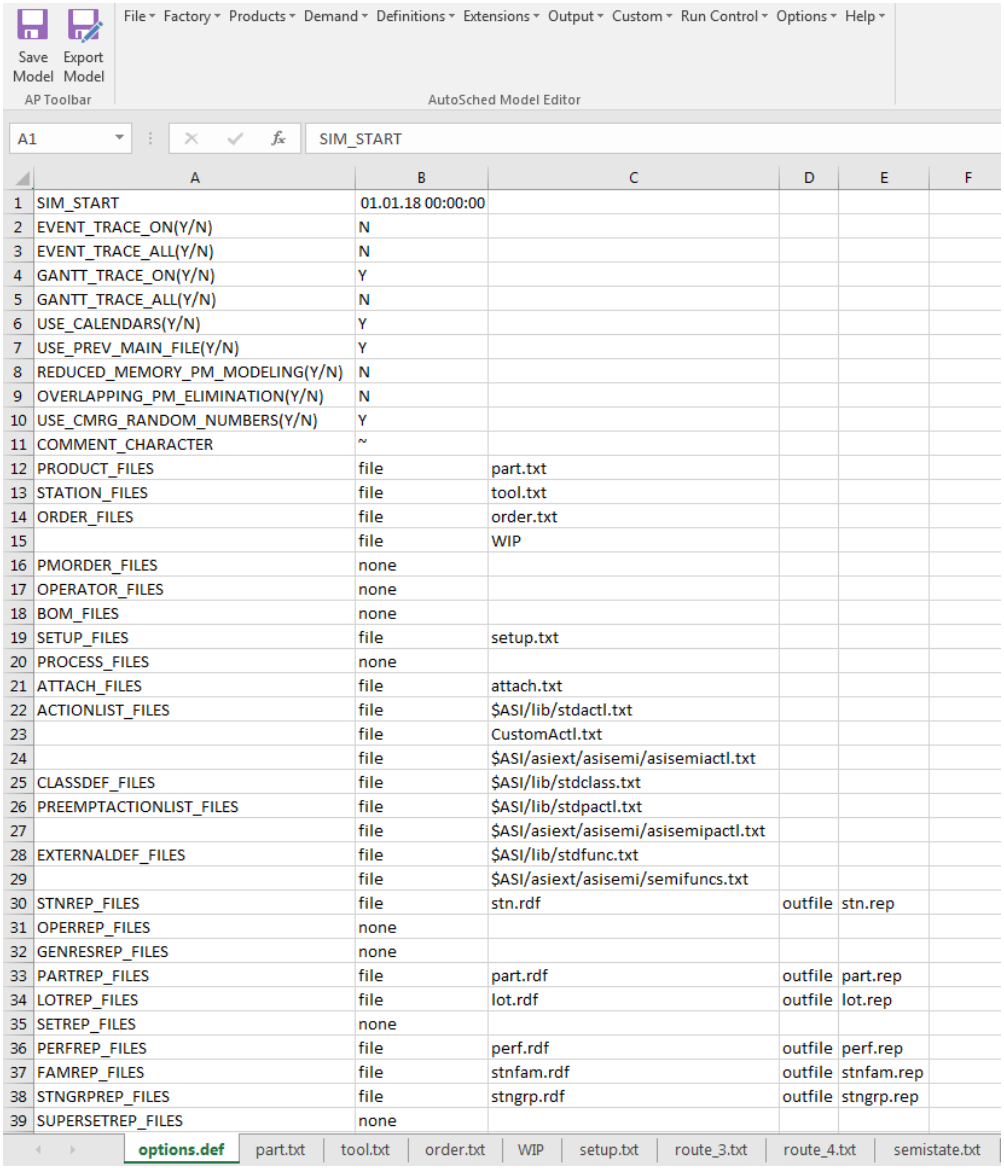
The minimal structure of the models consists of the products, the tools, and the basic data connecting between them (processing time, release rate in the fab, etc.). This minimal structure is fully contained in the five files necessary to run the simulation models in AutoSched AP. These files are described in the following subsections.

2.1. options.def

This master file is used to control the simulation model. Here, all files and options are listed, for instance, the start date of the simulation, see SIM_START (line 1) in Figure 1. The file names are assigned to the type of the file, e.g. part.txt is a PRODUCT_FILES file (line 12). Furthermore, files can be activated or deactivated, e.g. additional order files to include engineering lots can be used or not. STATION_FILES are the files describing the machines (tools). In our case, the file is called tool.txt (see Section 2.2 for a more detailed description of the file tool.txt).

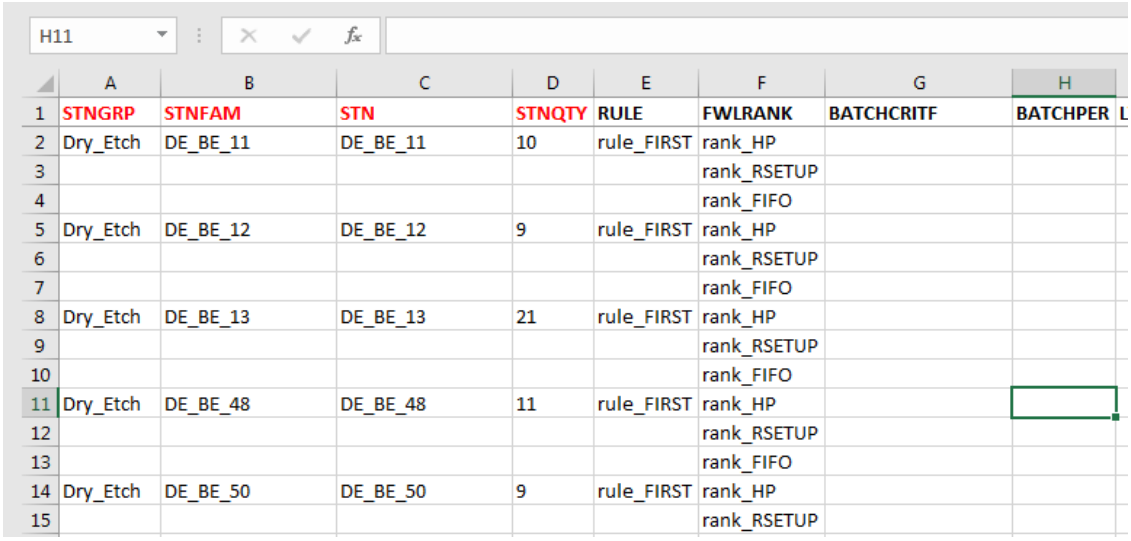
2.2. tool.txt

This file describes the machines, called tools, their quantity, and the related rules for lot dispatching. Station families (tool groups) are declared by theirs names in the column STNFAM and the number of tools in the column STNQTY (the default value is one if there is no number defined). All tools of a tool group are assumed to be identical. The name of the first tool (station) is defined in the column STN. Moreover, the tool groups (station families) are grouped in station groups (STNGRP) which can be considered as manufacturing areas. For example, the lithography area consists of eight different tool groups, while each tool group has at least two tools. Station groups can be used, for example, for statistics in the reports. The remaining declarations will be explained when the corresponding additional features are described. The mentioned columns are shown in Figure 2.



	A	B	C	D	E	F
1	SIM_START	01.01.18 00:00:00				
2	EVENT_TRACE_ON(Y/N)	N				
3	EVENT_TRACE_ALL(Y/N)	N				
4	GANTT_TRACE_ON(Y/N)	Y				
5	GANTT_TRACE_ALL(Y/N)	N				
6	USE_CALENDARS(Y/N)	Y				
7	USE_PREV_MAIN_FILE(Y/N)	Y				
8	REDUCED_MEMORY_PM_MODELING(Y/N)	N				
9	OVERLAPPING_PM_ELIMINATION(Y/N)	N				
10	USE_CMRG_RANDOM_NUMBERS(Y/N)	Y				
11	COMMENT_CHARACTER	~				
12	PRODUCT_FILES	file	part.txt			
13	STATION_FILES	file	tool.txt			
14	ORDER_FILES	file	order.txt			
15		file	WIP			
16	PMORDER_FILES	none				
17	OPERATOR_FILES	none				
18	BOM_FILES	none				
19	SETUP_FILES	file	setup.txt			
20	PROCESS_FILES	none				
21	ATTACH_FILES	file	attach.txt			
22	ACTIONLIST_FILES	file	$ASI/lib/stdactl.txt			
23		file	CustomActl.txt			
24		file	$ASI/asiext/asisemi/asisemiactl.txt			
25	CLASSDEF_FILES	file	$ASI/lib/stdclass.txt			
26	PREEMPTACTIONLIST_FILES	file	$ASI/lib/stdpactl.txt			
27		file	$ASI/asiext/asisemi/asisemipactl.txt			
28	EXTERNALDEF_FILES	file	$ASI/lib/stdfunc.txt			
29		file	$ASI/asiext/asisemi/semifuncs.txt			
30	STNREP_FILES	file	stn.rdf	outfile	stn.rep	
31	OPERREP_FILES	none				
32	GENRESREP_FILES	none				
33	PARTREP_FILES	file	part.rdf	outfile	part.rep	
34	LOTREP_FILES	file	lot.rdf	outfile	lot.rep	
35	SETREP_FILES	none				
36	PERFREP_FILES	file	perf.rdf	outfile	perf.rep	
37	FAMREP_FILES	file	stnfam.rdf	outfile	stnfam.rep	
38	STNGRPREP_FILES	file	stngrp.rdf	outfile	stngrp.rep	
39	SUPERSETREP_FILES	none				

Figure 1 - options.def



	A	B	C	D	E	F	G	H
1	STNGRP	STNFAM	STN	STNQTY	RULE	FWLRANK	BATCHCRITF	BATCHPER
2	Dry_Etch	DE_BE_11	DE_BE_11	10	rule_FIRST	rank_HP		
3						rank_RSETUP		
4						rank_FIFO		
5	Dry_Etch	DE_BE_12	DE_BE_12	9	rule_FIRST	rank_HP		
6						rank_RSETUP		
7						rank_FIFO		
8	Dry_Etch	DE_BE_13	DE_BE_13	21	rule_FIRST	rank_HP		
9						rank_RSETUP		
10						rank_FIFO		
11	Dry_Etch	DE_BE_48	DE_BE_48	11	rule_FIRST	rank_HP		
12						rank_RSETUP		
13						rank_FIFO		
14	Dry_Etch	DE_BE_50	DE_BE_50	9	rule_FIRST	rank_HP		
15						rank_RSETUP		

Figure 2 - tool.txt - part I

2.3. part.txt

In this file (see Figure 3), the different products are declared by name (PART) and their route (ROUTE). The names are used for providing lot release information in the order.txt file, see Figure 5. In addition, the file name of the route is required (ROUTEFILE). The columns PARTGRP and PARTFAM can be used to group related products (PART), e.g. for specific batching criteria. Further, these columns allow for differentiating between product types for reporting purposes.

	A	B	C	D	E	F
1	PARTGRP	PARTFAM	PART	ROUTEFILE	ROUTE	
2	Saleable	product_3	part_3	route_3.txt	r_3	
3	Saleable	product_4	part_4	route_4.txt	r_4	
4						

Figure 3 - part.txt

2.4. route_i.txt

Overall, ten routes (products) are defined in the testbed. All the ten routes are used in dataset 2, while only the products 3 and 4 are included in dataset 1. The details of the required set of process steps are found in the set of files denoted as route_i.txt, i = 1,…,10. It is also possible to use only a single file that contains all routes.

Each route consists of multiple process steps, e.g. 583 process steps exist for part_3. Each step requires the name of the route (ROUTE), the name of the step (STEP; here an integer), the used tool group (STNFAM), and the processing time. The latter will be defined by a probability distribution (PDIST), the amount of time (PTIME and PTIME2), the time units (PUNITS; here in minutes), and the entity type (PTPER) (cf. Figure 4). Hence, the time can be applied for each single wafer (per_piece), for a lot (per_lot), or for a batch (per_batch) in which case the number of wafers in the batch are determined by a minimum and maximum batch size (BATCHMIN and BATCHMAX). Note that a continuous uniform distribution is used (PDIST) which requires two parameters (PTIME, PTIME2). PTIME is the mean, while PTIME2 represents the offset.

Important: The processing sequence is independent from step names (integer values), but it depends on the order from the top to the bottom. The process step is described in the column DESC, here by the original name of the process step. It is provided for the user, but does not affect the simulation. The remaining columns will be explained when the corresponding additional features are described.

2.5. order.txt

Lots have to be released into the simulation model. Therefore, the name of the lot (LOT), the name of the product (PART), the number of wafers of a lot (PIECES), and the release date (START) are required. To repeat the release of lots after a fixed amount of time, the length of the interval (REPEAT, RUNITS) and the number of replications (RPT#) have to be specified. The number of lots released per interval is defined in the column LOTSPERRPT (the default value is again 1). Furthermore, for each product at least one interval is defined, while a constant distribution is used (RDIST). It is also possible to assign more than one order to a product, for instance for regular lots and hot lots (cf. Figure 5 lines 2 and 4). There are priorities for the different lot types, they are used for lot ranking (PRIOR). A higher priority value indicates a higher importance of a lot. Note that the lot names starting from the second lot will be equipped with the suffix _i, starting with i = 2 in ascending order (for instance, Lot_3, followed by Lot_3_2 and Lot_3_3).

In addition, a due date (DUE) is given. For each lot released during a repeat cycle, a due date will be set based on the current release time and the offset DUE – START. Moreover, orders can be declared (ORDER) by assigning at least one lot to them, multiple lots are possible.

Moreover, lots can be released individually, i.e. without the repeat functionality. For instance, this is used to start with initial WIP ("WIP.txt"). Here the column CURSTEP refers to the current step of the lot.

1	ROUTE	STEP	DESC	STNFAM	PDIST	PTIME	PTIME2	PTUNITS	PTPER	BATCHMN	BATCHMX	SETUP	WHEN	STIME	STUNITS	SVESTN	FORSTEP	BatchInterval	BatchIntUnits	PartInterval	PartIntUnits	RWKSTEP	REWORK	RWKTYPE	StepPercent
2	r_3	1	001_Diffusion	Diffusion_FE_120	uniform	501.33	25.067	min	per_batch	125	150														
3	r_3	2	002_Wet_Etch	WE_FE_84	uniform	0.852	0.0426	min	per_piece											0.639	min				
4	r_3	3	003_Def_Met	DefMEt_FE_118	uniform	17.994	0.8997	min	per_lot																56
5	r_3	4	007_TF_Met	TF_Met_FE_45	uniform	8.514	0.4257	min	per_lot																36
6	r_3	5	008_Diffusion	Diffusion_FE_127	uniform	437.58	21.879	min	per_batch	100	125														
7	r_3	6	009_Def_Met	DefMEt_FE_118	uniform	23.658	1.1829	min	per_lot																59
8	r_3	7	010_TF_Met	TF_Met_FE_45	uniform	9.804	0.4902	min	per_lot																39
9	r_3	8	011_Wet_Etch	WE_FE_108	uniform	0.99	0.0495	min	per_piece											0.7425	min				
10	r_3	9	012_Wet_Etch	WE_FE_83	uniform	1.038	0.0519	min	per_piece											0.7785	min				
11	r_3	10	013_Wet_Etch	WE_FE_84	uniform	0.9	0.045	min	per_piece											0.675	min				
12	r_3	11	014_Litho	LithoTrack_FE_115	uniform	2.172	0.1086	min	per_piece																
13	r_3	12	015_Litho	LithoTrack_FE_115	uniform	2.676	0.1338	min	per_piece			SU015_3	need	8	min										
14	r_3	13	016_Litho	Litho_FE_92	uniform	2.64	0.132	min	per_piece							yes	113								
15	r_3	14	017_Litho_Met	LithoMet_FE_19	uniform	28.104	1.4052	min	per_lot																100
16	r_3	15	018_Litho_Met	Litho_REG_FE_64	uniform	25.272	1.2636	min	per_lot																100
17	r_3	16	019_Def_Met	DefMet_FE_10	uniform	6.876	0.3438	min	per_lot																57
18	r_3	17	020_Implant	Implant_128	uniform	1.14	0.057	min	per_piece			SU128_3	need							0.855	min				
19	r_3	18	021_Dry_Etch	DE_FE_1	uniform	135.23	6.7617	min	per_lot																
20	r_3	19	022_Dry_Etch	DE_FE_86	uniform	162.8	8.1399	min	per_lot																
21	r_3	20	023_Wet_Etch	WE_FE_108	uniform	1.002	0.0501	min	per_piece											0.7515	min				
22	r_3	21	024_Wet_Etch	WE_FE_108	uniform	0.978	0.0489	min	per_piece											0.7335	min				
23	r_3	22	025_Litho_Met	LithoMet_FE_19	uniform	18.906	0.9453	min	per_lot																100
24	r_3	23	026_Def_Met	DefMet_FE_43	uniform	19.374	0.9687	min	per_lot																57
25	r_3	24	027_Diffusion	Diffusion_FE_44	uniform	349.99	17.5	min	per_batch	100	125														
26	r_3	25	028_Def_Met	DefMet_FE_43	uniform	6.372	0.3186	min	per_lot																51
27	r_3	26	029_Dry_Etch	DE_FE_51	uniform	72.492	3.6246	min	per_lot																
28	r_3	27	030_Dry_Etch	DE_FE_86	uniform	84.336	4.2168	min	per_lot																
29	r_3	28	031_Wet_Etch	WE_FE_108	uniform	0.93	0.0465	min	per_piece											0.6975	min				
30	r_3	29	032_Wet_Etch	WE_FE_83	uniform	0.948	0.0474	min	per_piece											0.711	min				
31	r_3	30	034_Wet_Etch	WE_FE_84	uniform	1.14	0.057	min	per_piece											0.855	min				
32	r_3	31	035_Litho	LithoTrack_FE_95	uniform	2.784	0.1392	min	per_piece																
33	r_3	32	036_Litho	LithoTrack_FE_115	uniform	1.692	0.0846	min	per_piece			SU036_3	need	8	min										

Figure 4 - route_3.txt part I

1	LOT	PART	PRIOR	PIECES	START	RDIST	REPEAT	RUNITS	RPT#	LOTSPERRPT	DUE	ORDER	HOTLOT
2	Lot_3	part_3	10	25	01.01.18 00:00:00	constant	51.69	min	200000	1	02.24.18 21:05:23	O_Lot_3	no
3	Lot_4	part_4	10	25	01.01.18 00:00:00	constant	51.69	min	200000	1	01.31.18 16:02:08	O_Lot_4	no
4	HotLot_3	part_3	20	25	01.01.18 00:00:00	constant	2016	min	20000	1	02.03.18 06:37:38	O_HotLot_3	no
5	HotLot_4	part_4	20	25	01.01.18 00:00:00	constant	2016	min	20000	1	01.20.18 13:36:16	O_HotLot_4	no
6	SuperHotLot	part_3	30	25	01.01.18 00:00:00	constant	27397.61	min	2000	1	02.03.18 06:56:37	O_SuperHotLot_3	no

Figure 5 - order.txt

3. Additional Features

Used files: options.def, external definition files

The simulation models have several features that will be described next with the related files necessary for their implementation. Activating some of these features requires adding the "semiconductor extension" which is located in the directory of AutoSched AP. It enables further functions, actions or action lists, and rules. There are additional entries in the options file (cf. Figure 1), e.g. ACTIONLIST_FILES in line 24 for the additional action lists and the location of the corresponding file. For more information, the AutoSched AP Help needs to be consulted.

3.1. Tools Availability

The file attach.txt (see Figure 6) is used to connect each downtime event (unscheduled or scheduled) represented by the name (CALNAME) with the CALTYPE (here down or pm) to a group of tools. The latter is defined by the resource type (RESTYPE) and its name (RESNAME).

Note that CALNAME stands for the name of the downtime event as described in the files downcal.txt and pmcal.txt. For instance, the scenario BREAK_Def_Met specified in the file downcal.txt (cf. Figure 7, line 2) defines a breakdown type valid for all tools of the station group Def_Met (cf. Figure 6, line 2). This station group includes several station families (tool groups) and tools.

1	CALNAME	CALTYPE	RESTYPE	RESNAME	FOADIST	FOA	FOAUNITS
2	BREAK_Def_Met	down	stngrp	Def_Met	exponential	10080	min
3	BREAK_Dielectric	down	stngrp	Dielectric	exponential	10080	min
4	BREAK_Diffusion	down	stngrp	Diffusion	exponential	10080	min
5	BREAK_Dry_Etch	down	stngrp	Dry_Etch	exponential	10080	min
6	BREAK_Implant	down	stngrp	Implant	exponential	10080	min
7	BREAK_Litho	down	stngrp	Litho	exponential	10080	min
8	BREAK_Litho_Met	down	stngrp	Litho_Met	exponential	10080	min
9	BREAK_Planar	down	stngrp	Planar	exponential	10080	min
10	BREAK_TF	down	stngrp	TF	exponential	10080	min
11	BREAK_TF_Met	down	stngrp	TF_Met	exponential	10080	min
12	BREAK_Wet_Etch	down	stngrp	Wet_Etch	exponential	10080	min
13	DefMet_BE_33_MN	pm	stnfam	DefMet_BE_33	constant	27.3	day
14	DefMet_BE_33_QT	pm	stnfam	DefMet_BE_33	constant	82.8	day
15	DefMet_BE_42_MN	pm	stnfam	DefMet_BE_42	constant	27	day
16	DefMet_BE_42_QT	pm	stnfam	DefMet_BE_42	constant	81.9	day
85	LithoTrack_FE_96_WK	pm	stnfam	LithoTrack_FE_96	constant	6.5	day
86	LithoTrack_FE_96_MN	pm	stnfam	LithoTrack_FE_96	constant	27.9	day
87	LithoTrack_FE_96_QT	pm	stnfam	LithoTrack_FE_96	constant	84.6	day
88	TF_Met_FE_45_MN	pm	stnfam	TF_Met_FE_45	constant	26.1	day
89	TF_Met_FE_45_QT	pm	stnfam	TF_Met_FE_45	constant	79.2	day
90	TF_Met_FE_61_MN	pm	stnfam	TF_Met_FE_61	constant	33.9	day
91	TF_Met_FE_61_QT	pm	stnfam	TF_Met_FE_61	constant	102.8	day
92	DE_BE_11_WK	pm	stnfam	DE_BE_11	constant	1880	
93	DE_BE_11_MN	pm	stnfam	DE_BE_11	constant	8178	
94	DE_BE_11_QT	pm	stnfam	DE_BE_11	constant	24534	
95	DE_BE_12_WK	pm	stnfam	DE_BE_12	constant	1100	

Figure 6 - attach.txt

3.1.1. Unscheduled Down Times: Breakdowns

Used files: downcal.txt, attach.txt

Breakdowns are described in downcal.txt, i.e. different down scenarios with their probability distributions of the corresponding Time To Failure (TTF) and Time To Repair (TTR) values are collected (see Figure 7).

For every station group (area) a down scenario is defined which can be identified by its name (DOWNCALNAME). Breakdowns are triggered based on calendars (mttf_by_cal in column DOWNCALTYPE), and the tool usage has no impact on their occurrence. Each breakdown type is characterized by the probability distributions of its TTF and TTR values. The distribution type is given (MTTFDIST and MTTRDIST, here both exponentially distributed). The mean of TTR and TTF (MTTF, MTTR) and their time units are needed (MTTFUNITS and MTTRUNITS, here in minutes).

In addition, in the file “attach.txt” the distribution of the first TTF is defined. In the column FOADIST, the distribution type is stated (here exponentially distributed). The mean of the first TTF (FOA) and the time units are needed (FOAUNITS).

1	DOWNCALNAME	DOWNCALTYPE	MTTFDIST	MTTF	MTTFUNITS	MTTRDIST	MTTR	MTTRUNITS
2	BREAK_Def_Met	mttf_by_cal	exponential	10080	min	exponential	35.28	min
3	BREAK_Dielectric	mttf_by_cal	exponential	10080	min	exponential	604.8	min
4	BREAK_Diffusion	mttf_by_cal	exponential	10080	min	exponential	151.2	min
5	BREAK_Dry_Etch	mttf_by_cal	exponential	10080	min	exponential	231.84	min
6	BREAK_Implant	mttf_by_cal	exponential	10080	min	exponential	604.8	min
7	BREAK_Litho	mttf_by_cal	exponential	10080	min	exponential	705.59	min
8	BREAK_Litho_Met	mttf_by_cal	exponential	10080	min	exponential	35.28	min
9	BREAK_Planar	mttf_by_cal	exponential	10080	min	exponential	201.6	min
10	BREAK_TF	mttf_by_cal	exponential	10080	min	exponential	453.6	min
11	BREAK_TF_Met	mttf_by_cal	exponential	10080	min	exponential	35.28	min
12	BREAK_Wet_Etch	mttf_by_cal	exponential	10080	min	exponential	221.76	min

Figure 7 - downcal.txt

3.1.2. Scheduled Down Times: Preventive Maintenance (PM)

Used files: pmcal.txt, attach.txt

The representation of PMs works almost in the same way as for breakdowns (cf. Figure 8). Here, two types for the Mean Time Between PM (MTBPM) values are distinguished (PMCALTYPE). The PM is time-based for diffusion, lithography, and metrology represented by mtbm_by_cal to consider the calendar time. For all other tool groups, the PM is counter-based by applying mtbpm_by_pieces, i.e., a PM must be executed after processing a prescribed number of wafers. Hence, the corresponding numbers and units are needed in the columns MTBPM and MTBPMUNITS. Note that no special probability distribution is defined for MTBPM (the default is constant). However, the time-based PMs are practically launched as Mean Time **Before** PM, so that the PM duration itself is included in the MTBPM value.

A continuous uniform distribution is used to represent the TTR value that requires values for the two parameters MTTR and MTTR2 (mean and offset) and the time unit (MTTRUNITS). For instance, each 30 days a monthly PM and each 91 days a quarterly PM is modeled for the station family DefMet_BE_33 in the lines 2 and 3. In attach.txt file, line 13, a monthly PM is allocated to the station family (RESTYPE = stnfam). Moreover, counter-based PMs are also applied for each station family, i.e., the used RESTYPE is stnfam and the RESNAME is the name of the tool group (see file “attach.txt” or Figure 6, line 92). The prescribed number of wafers is valid for each individual tool of the tool group.

The distribution of the first PM for the tools of a tool group is defined in the column FOADIST (see file “attach.txt”). The constant distribution means that the first PM for the tools of a tool set is evenly distributed based on the value in the column FOA. For example, a FOA value of 80 days with four tools lead to PMs for tool 1, 2, 3, and 4 at the following days: 20, 40, 60, and 80. For counter-based PMs it works in the same way, but FOAUNITS are not necessary.

1	PMCALNAME	PMCALTYPE	MTBPM	MTBPMUNITS	MTTRDIST	MTTR	MTTR2	MTTRUNITS
2	DefMet_BE_33_MN	mtbpm_by_cal	30	day	uniform	13.76	2.75	hr
3	DefMet_BE_33_QT	mtbpm_by_cal	91	day	uniform	27.52	5.5	hr
4	DefMet_BE_42_MN	mtbpm_by_cal	30	day	uniform	13.76	2.75	hr
5	DefMet_BE_42_QT	mtbpm_by_cal	91	day	uniform	27.52	5.5	hr
74	LithoTrack_FE_96_WK	mtbpm_by_cal	7	day	uniform	6.65	1.33	hr
75	LithoTrack_FE_96_MN	mtbpm_by_cal	30	day	uniform	13.29	2.66	hr
76	LithoTrack_FE_96_QT	mtbpm_by_cal	91	day	uniform	26.59	5.32	hr
77	TF_Met_FE_45_MN	mtbpm_by_cal	30	day	uniform	13.76	2.75	hr
78	TF_Met_FE_45_QT	mtbpm_by_cal	91	day	uniform	27.52	5.5	hr
79	TF_Met_FE_61_MN	mtbpm_by_cal	30	day	uniform	13.76	2.75	hr
80	TF_Met_FE_61_QT	mtbpm_by_cal	91	day	uniform	27.52	5.5	hr
81	DE_BE_11_WK	mtbpm_by_pieces	2000	pieces	uniform	8.74	1.75	hr
82	DE_BE_11_MN	mtbpm_by_pieces	8700	pieces	uniform	17.47	3.49	hr
83	DE_BE_11_QT	mtbpm_by_pieces	26100	pieces	uniform	34.94	6.99	hr
84	DE_BE_12_WK	mtbpm_by_pieces	1111	pieces	uniform	8.74	1.75	hr
85	DE_BE_12_MN	mtbpm_by_pieces	4778	pieces	uniform	17.47	3.49	hr
86	DE_BE_12_QT	mtbpm_by_pieces	14333	pieces	uniform	34.94	6.99	hr

Figure 8 - pmcal.txt

3.2. Transport Times

Used files: fromto.txt, tool.txt

Transportation is modeled in SMT2020 in the most basic way. All transport times are sampled from the continuous uniform distribution U(5, 10). For this purpose, a location is defined for each tool group in the column STNFAMLOC (see tool.txt or Figure 10). An identical tool group location called Fab is used. The times from a specific location (FROMLOC) to another (TOLOC) have to be specified in the fromto.txt file (see Figure 9). In the datasets, we use only from Fab to Fab as described before. The duration follows a continuous uniform distribution (DDIST) with the given parameter values (DTIME, DTIME2, and DUNITS). There is one exception for the delay steps with respect to the delay tool group since no transport time is applied by defining the location Delay instead of Fab (see tool.txt, line 86).

1	FROMLOC	TOLOC	DDIST	DTIME	DTIME2	DUNITS
2	Fab	Fab	uniform	7.5	2.5	min

Figure 9 - fromto.txt

3.3. Load and Unload

Used files: tool.txt, CustomActl.txt

Loading and unloading is included for each process step (with the exception of delay steps). The load and unload times are the same for all tool groups, their duration is 1 minute each (LTIME, LTUNITS for load and ULTIME, ULUNITS for unload in tool.txt). Note that load and unload times are not included in the processing time. At first, a lot is loaded, processing then occurs, and finally, the lot is unloaded. To implement this behavior, it is necessary to use an appropriate action list (CustomActl.txt, Figure 14). Moreover, this is valid for each process step or each tool. Therefore, it is sufficient to define the used action list for each tool group (see column STNFAMSTEP_ACTLIST in tool.txt shown in Figure 10).

1	STNFAM	STN	LTIME	LTUNITS	ULTIME	ULTUNITS	STNCAP	STNFAMSTEP_ACTLIST	STNFAMLOC
2	DE_BE_11	DE_BE_11	1	min	1	min		Custom_actlist_ASISemiOpersDuringSetupAndAdditionalLoadUnload	Fab
3									
4									
5	DE_BE_12	DE_BE_12	1	min	1	min		Custom_actlist_ASISemiOpersDuringSetupAndAdditionalLoadUnload	Fab
6									
7									
8	DE_BE_13	DE_BE_13	1	min	1	min		Custom_actlist_ASISemiOpersDuringSetupAndAdditionalLoadUnload	Fab

Figure 10 - tool.txt - part II

3.4. Setups

Used files: setup.txt, setupgrp.txt, route_i.txt files, tool.txt

Since setups are needed for certain process steps, the name of the setup has to be defined in the column SETUP in the corresponding route file (Figure 4). Furthermore, it is stated in the column WHEN whether the setup will be always executed or only if the tool does not have already this setup, i.e., if the setup is needed. Sequence-independent setups, e.g. for lithography, are entirely defined in the route files. This means the setup times are specified in the STIME und STUNITS columns for the setup duration and the time units, respectively. However, the times could also be provided in the setup.txt file, as is done for the setups concerning the implant tool groups, see Figure 11, line 6-14. The name of the setup is stated in the column NEWSETUP while the CURSETUP column is not set. This means that from any current setup to the new setup the defined time is valid. Moreover, there are sequence-dependent setups. For them both the CURSTEP and the NEWSTEP information has to be stated (e.g. see lines 2 and 3 in Figure 11).

In addition, the setup times for changing the gas types are huge for the implant_128, implant_91, and implant_132 tool groups. To avoid frequent setups, the setup avoidance rule rule_LSSU (see tool.txt, line 158) is used which is based on specific setup criteria. They are defined in the file setupgrp.txt (see Figure 12). Here, the gas setups are grouped by the name Implant_Gas (SETUPGRP), the names of the corresponding setups are set in the column SETUP for which the criterion has to be applied. Here, the criterion MINRUN is used, i.e., for a new setup, a minimum number of processed lots is required after a tool has changed its setup. This set is called a run. In addition, the setup group has to be defined for the corresponding tool group in column SETUPGRP in the file tool.txt (e.g. line 158).

1	CURSETUP	NEWSETUP	STIME	STUNITS
2	DE_BE_13_1	DE_BE_13_2	7	min
3	DE_BE_13_2	DE_BE_13_1	12	min
4	DE_BE_66_1	DE_BE_66_2	15	min
5	DE_BE_66_2	DE_BE_66_1	10	min
6		SU128_1	72	min
7		SU128_2	72	min
8		SU128_3	72	min
9		SU132_1	60	min
10		SU132_2	60	min
11		SU132_3	60	min
12		SU91_1	80	min
13		SU91_2	80	min
14		SU91_3	80	min

Figure 11 - setup.txt

1	SETUPGRP	SETUP	MINRUN
2	Implant_Gas	SU128_1	7
3		SU128_2	7
4		SU128_3	7
5		SU132_1	7
6		SU132_2	7
7		SU132_3	7
8		SU91_1	7
9		SU91_2	7
10		SU91_3	7

Figure 12 - setupgrp.txt

3.5. Batching

Used files: tool.txt, route_i.txt files

Diffusion tools are able to process several lots at the same time on the same tool. We refer to the resulting group of jobs as a batch. Both the minimum possible batch size (BATCHMN) and the maximum possible batch size (BATCHMX) are defined at the relevant steps in the route files, e.g. in route_3.txt, lines 2 and 6 (see Figure 4). The sizes are given in number of wafers. Hence, in the column BATCHPER of tool.txt file piece has to be entered for each batch processing tool group, e.g. in line 119. Note that only lots of the same product at the same process step can be used to form a batch. For this purpose, the crit_sameroutestep batch criterion (BATCHCRITF) is used.

It is also possible to allow batches with production lots belonging to a particular product and engineering lots from a specific engineering product derived from the former product. First, the same PARTFAM, e.g. “product_3”, has to be defined for the production product and the corresponding engineering product (see Figure 3). Moreover, two batch criteria crit_samepartfam and crit_samestepname has to be used, so that only lots with the same name of PARTFAM and at the same process step, i.e. the same name of the step, can be used to build a batch.

3.6. Cascading

Used files: options.def, tool.txt, route_i.txt files

Cascading is a characteristic of some stations that are composed of a series of modules able to process materials simultaneously. Wafers/lots need to be processed by several modules one after the other, but while an earlier lot/wafer is undergoing a later phase in the process, the following lot/wafer can be undergoing an earlier phase in the process. As a result, the time required for the first wafer (or lot) to exit the machine is different (longer) than the time between successive lots.

In order to model this, the semiconductor extension is applied. It is necessary to distinguish between cascading lots or wafers, i.e. whether the processing on a tool is per wafer or per lot. In any case, a station capacity (STNCAP) of 2 has to be stated in the tool.txt file, see lines 89 and 95 for each corresponding tool group. If there is no entry, e.g. line 92, no cascading is implemented since the default is 1. The processing times of the process steps are set in the route_i.txt file as described before, a non-cascading tool only takes into account the columns PDIST, PTIME, PTIME2, PTUNITS, and PTPER. The specified time is valid for each lot or wafer (PTPER). Hence, the time between two finished lots or wafers on a tool is at least this stated time. For a cascading tool (STNCAP = 2), the same time is valid for lots and wafers, but in contrast, during the processing of the first lot or wafer, the processing of the second begins in parallel, since the capacity is 2. Therefore, the time between finished lots depends on

the time defined in the BatchInterval and BatchIntUnits columns. The processing of the second lot can start after the time interval. This is also true for lots on different operations with different processing times since a cascading machine (capacity of 2) can be seen as a tool with two successively slots. After the cascading time interval (BatchInterval), the first lot goes from slot 1 to slot 2. At the same time, the processing of the second lot begins (slot 1). After the time interval of the second lot, it can again go from slot 1 to slot 2, if the first lot is finished (slot 2 is free). As soon as slot 1 is free, the next lot can be started.

Cascading of wafers is modeled in an analogous way, while the PartInterval and PartIntUnits columns are used (e.g. see Figure 4, line 3). There is an option to add a setup delay to the interval time. The SEQ_ADDS_SETUP_DELAYS flag takes the value N in the options.def file if there is no setup, while the default value is Y. Hence in the former case, the interval time includes only the processing part, defined in the mentioned columns, setup times are not included in addition. Sequential processing of lots are applied for the tools in the planar, thin films, and half of the tools in dielectric areas. Cascading takes place for wafers in the wet etch and implant areas.

3.7. Lot-to-Lens Dedications

Used files: route_i.txt files

In some critical Litho layers, wafers are required to return to the same specific tool for a series of consecutive layers to reduce the yield loss due to overlay issues. We refer to this issue as Lot-to-lens dedication. To ensure that exactly the same tool is used for process step i and process step *j* ($i < j$), the name of process step *j* has to be entered in the FORSTEP column at operation i and “yes” has to be included in the SVESTN column (see route_3.txt or Figure 4, line 14). This behavior can be extended for process step *k* etc. ($i < j < k$) by including the corresponding information of step *k* at step *j* in the same way as described before (see route_3.txt, line 14 and 114).

3.8. Rework

Used files: route_i.txt files

Implementing rework requires the use of the RWKSTEP, REWORK, and RWKTYPE columns in the route files. REWORK refers to the probability that a lot needs rework and is presented as a percentage of the overall number of lots sent to rework. As an example, in route 3, 1.7% of the lots are reworked, i.e., a lot has a probability of 0.017 of being sent to rework. It is defined in the RWTYPE column whether the rework is applied to the entire lot or to a single wafer (in the provided datasets, only entire lots are reworked). The lot will be sent to the process step stated in the RWSTEP column. For instance, the lot is sent from process step 67 to step 65 of the route_3.txt file when rework occurs.

3.9. Sampling of Lots

Used files: route_i.txt files

Not all lots are inspected at metrology operations, but rather some lots are sampled to monitor the health of the preceding process. It is possible to simulate sampling by using the semiconductor extension, i.e. to process only a random sample of lots at a specific operation. In the StepPercent column, the probability that a lot will be processed is given (see route_3.txt or Figure 4, line 4).

3.10. Dispatching

Used files: tool.txt, order.txt

In both models, a baseline rule is used to prioritize between lots queueing in front of any tool group. The First-Come First-Served (FCFS) dispatching rule is applied in dataset 1 representing a fab owned by a semiconductor company that produces to stock. For dataset 2 representing a foundry, i.e. it produces to order a large variety of products, the Critical Ratio (CR) dispatching rule is applied. Local rules and special lots that break the baseline rule are described in the following subsections.

3.11. Hot Lots and Setup Avoidance

Here, the rule_FIRST rule (RULE) and multiple ranking functions (FWLRANK) are used. They are defined for each tool group. At first, highest priority lots are preferred, i.e. hot lots before regular lots (rank_HP). This is stated in the PRIOR column in the order.txt file (Figure 5). Ranking is then carried out based on the least setup time (rank_RSETUP) and finally the FIFO (rank_FIFO) criteria. If there is one hot lot chosen, it can trigger a setup. If there are two or more hot lots (same priority), they will be ranked by least setup time and then by FIFO (dataset 1). The critical ratio (CR) dispatching rule is applied in dataset 2. The rule_FIRST rule means that the first ranked lot is chosen. A specific setup criterion, namely rule_LSSU, is applied at the implant tool groups. Lots are processed as described above, but a minimum number of lots is ensured in a run (Figure 12). The behavior described so far refers to the situation that a tool chooses the next lot out of all waiting lots in front of the tool group. In addition, if a lot arrives at a tool group with more than one idle tool, applying the wake_LeastSetupTime criterion in the WAKERESRANK column in tool.txt ensures that the tool that causes the least setup time is used. This is defined for all tool groups with setups.

3.12. Super Hot Lots

Used files: tool.txt, order.txt, route_i.txt files

Using the semiconductor extension, it is possible to include Super Hot Lots which can reserve a tool at the next process step. First of all, Super Hot Lots have the highest priority (i.e. 30, see the order.txt file). To enable the reservation function, the lot has to be set as a “HOTLOT” and the rule_HotLotFirst rule (column RULE in tool.txt) has to be applied. It can be set in the order file if a lot is a HOTLOT or not (Figure 5). If there is a yes for the Super Hot Lots, they reserve a tool at the next downstream step. The tool only waits until the Super Hot Lot arrives. A setup will be performed if necessary. The setup is carried out as soon as the Super Hot Lot is at the tool and not before. The rule_HotLotFirst rule is a combination of Hot Lot first and rule_SemiFirst second. The latter is very similar to rule_FIRST. This rule for Super Hot Lots is not used for the implant tool groups with the special setup criterion since a specific rule for considering the setup criterion is applied (rule_LSSU). The duration of the reservation can be adjusted in the route_i.txt files using the HOTLOTDELAY% column. Here, the column is not explicitly used since the default is 0.

3.13. Critical Queue Time

Used files: userdef.txt, route_i.txt files

There is no extension for critical queue times provided by AutoSched AP. Therefore, customizing is necessary to take into account critical queue times, i.e. custom functions e.g. for a dispatching strategy. However, here only the corresponding data is provided for all routes and it is prepared for customization.

The critical queue times refer to a set of consecutive process steps. Therefore, the data is stated in the route files, see Figure 13. First, the new columns STEP_CQT, CQT, and CQTUNITS has to be defined, see the file “userdef.txt”, Figure 14. The FIELDNAME is the custom name for the field, while these fields can be added in the file stated in the column FILETYPE, here route file. The required type of data for the fields is set in the DATATYPE column. TYPESTRING refers to text, TYPEREAL to real numbers, and TIMEUNITS to time units (seconds, minutes, etc.). Further, these are no default fields by creating new route files (DEFAULTFIELD) and the data is not protected as read-only (PROTECT). In addition, a description is set for all new fields (DESCRIPTION).

The critical queue time is defined by the amount of time (CQT) and the time units (CQTUNITS; here in hours). The time between the end of processing on a certain step and the begin of processing on a specific step must not exceed the critical queue time. For example, the critical queue time (CQT) has to be considered after processing on step 413 (STEP) until the begin of the processing on step 414 (STEP_CQT), see Figure 13 lines 414 and 415. That means, on the step, where the critical queue time starts (STEP), the information is given about the critical queue time (CQT, CQTUNITS) and the step, where the constraint ends (STEP_CQT).

	A	B	C	D	Z	AA	AB
1	ROUTE	STEP	DESC	STNFAM	STEP_CQT	CQT	CQTUNITS
410	r_3	409	462_Litho	LithoTrack_FE_95			
411	r_3	410	463_Delay	Delay_32			
412	r_3	411	464_Dry_Etch	DE_BE_12			
413	r_3	412	465_Wet_Etch	WE_BE_16			
414	r_3	413	467_Wet_Etch	WE_BE_17	414	10	hr
415	r_3	414	468_Diffusion	Diffusion_BE_123			
416	r_3	415	469_Litho_Met	LithoMet_BE_18			
417	r_3	416	471_TF	TF_BE_24	419	8	hr
418	r_3	417	472_Def_Met	DefMet_BE_42			
419	r_3	418	473_TF	TF_BE_40			
420	r_3	419	474_Wet_Etch	WE_BE_82			
421	r_3	420	476_Planar	Planar_BE_75	430	24	hr
422	r_3	421	477_Def_Met	DefMet_BE_42			
423	r_3	422	478_Dielectric	Dielectric_BE_20			
424	r_3	423	481_Def_Met	DefMet_BE_33			
425	r_3	424	482_TF	TF_BE_26			
426	r_3	425	483_Wet_Etch	WE_BE_81			
427	r_3	426	484_Wet_Etch	WE_BE_82			
428	r_3	427	485_Litho	LithoTrack_FE_95			
429	r_3	428	486_Litho	LithoTrack_BE_117			
430	r_3	429	487_Litho_Met	LithoMet_BE_18			
431	r_3	430	488_Litho_Met	Litho_REG_BE_63			
432	r_3	431	490_Dry_Etch	DE_BE_50	439	8	hr
433	r_3	432	491_Wet_Etch	WE_BE_14			

Figure 13 – route_3.txt part II

FIELDNAME	DATATYPE	FILETYPE	DEFAULTFIELD	PROTECT	DESCRIPTION
STEP_CQT	TYPESTRING	ROUTE_FILES	no	no	Name of the step until its beginning the critical queue time is valid.
CQT	TYPEREAL	ROUTE_FILES	no	no	Critical queue time from the end of the current step (process on station) until the begin of STEP_CQT
CQTUNITS	TIMEUNITS	ROUTE_FILES	no	no	Time units for critical queue time (CQT). Default is hours.

Figure 14 – userdef.txt

4. Reports

Used files: *.rdf files, state.txt, CustomActl.txt, period.txt

For those users that choose to run the models in AutoSched AP, some basic instructions to navigate the report options are provided.

There are report files (with file extension .rdf) for different entities (part, lot, station etc.). It is possible to extend a report by using additional columns, while a description of each value will be provided. Load and unload are introduced as new states (see the state.txt file in Figure 13). Both states are no unavailable states (UNAVAILSTATE), they belong to the utilization for the statistic (UTILSTATE), and a percentage statistic is also provided (PERCENTSTATE).

1	STATE	UNAVAILSTATE	PERCENTSTATE	UTILSTATE	OVERRIDESTATE	PRIOR
2	LOAD	no	yes	yes		22
3	UNLOAD	no	yes	yes		25

Figure 13 - state.txt

A state has to be included at the used action list to provide the appropriate information (see CustomActl.txt, Figure 14). That means if there is, for instance, a loading action the corresponding time is considered for the report. Report values are added for both new states in the corresponding report files.

1	ACTIONLIST	ACTION	REFID	PREEMPTACTIONLIST	STATE
2	Custom_actlist_ASISemiOpersDuringSetupAndAdditionalLoadUnload	act_SkipStep	act_SkipStep		
3		act_ConvertWaferToDie	act_ConvertWaferToDie		
4		act_SplitLots	act_SplitLots		
5		act_ChangeAllStepSets	act_ChangeAllStepSets		
6		act_WaitIfOnHold	act_WaitIfOnHold		
7		act_TravelToStnFamLoc	act_TravelToStnFamLoc		
8		act_CloneAlternates	act_CloneAlternates		
9		act_EstimateStepProc	act_EstimateStepProc		
10		act_QueryMultiStepResources	act_QueryMultiStepResources		
11		act_QueryStepResources	act_QueryStepResources		
12		act_CreateReworkQTTrigger	act_CreateReworkQTTrigger		
13		act_QueryReticle	act_QueryReticle		
14		act_RclAllResources	act_RclAllResources(1)		
15		act_TravelToStnLoc	act_TravelToStnLoc		
16		act_ClaimInternalCapacity	act_ClaimInternalCapacity		
17		act_WaitStationProcessDelay	act_WaitStationProcessDelay		
18		act_StepSaveStn	act_StepSaveStn		
19		act_GetSubPartRqmts	act_GetSubPartRqmts		
20		act_WaitStepSetup	act_WaitStepSetup		SETUPSTATE
21		act_WaitStepProcLoad	act_WaitStepProcLoad		LOAD
22		act_ReleaseAllOpers	act_ReleaseAllOpers		
23		act_QueryAndWaitStepProc	act_QueryAndWaitStepProc		
24		act_QueryStepOpers	act_QueryStepOpers		
25		act_RclAllResources	act_RclAllResources(2)		
26		act_WaitStepProcUnload	act_WaitStepProcUnload		UNLOAD
27		act_ReleaseAllStepResources	act_ReleaseAllStepResources		

Figure 14 - CustomActl.txt

Moreover, the statistics can be separately reported for time periods like years. Four periods are defined with their name (PERIOD), start date (PERIODSTART), and information on whether the statistics will be reported or not (REPORT) in the file period.txt (Figure 15). The RESET column provides the option to delete previous statistics. Here, the first year represents the warm-up phase, while the statistics are reported. However, these numbers are not included in the statistics of the following years since it is a reset.

1	PERIOD	PERIODSTART	REPORT	RESET
2	WarmUp	01.01.18 00:00:00	yes	yes
3	Period_1	01.01.19 00:00:00	yes	no
4	Period_2	01.01.20 00:00:00	yes	no
5	Period_3	01.01.21 00:00:00	yes	no

Figure 15 - period.txt

5. Characteristic Features of the Individual Datasets in SMT2020

The main differences between the two datasets and important similarities are summarized in Table 1. A file WIP.txt represents an ORDER_FILE (see Figure 1). It contains initial WIP arising from a simulation run at high utilization.

Table 1 - Datasets specifics

Feature	dataset 1 (HV/LM)	dataset 2 (LV/HM)
#products	2 (route_3.txt, route_4.txt)	10 (route_1.txt – route_10.txt)
initial WIP	for 2 products, dataset-specific WIP.txt	for 10 products, dataset-specific WIP.txt
#tools	dataset-specific tool.txt	dataset-specific tool.txt
counter-based PM	dataset-specific pmcal.txt	dataset-specific pmcal.txt
due date setting	(optional) dataset-specific order.txt	(mandatory) dataset-specific order.txt, multiple due date scenarios
dispatching rules	FIFO, treatment of hot lots and setup avoidance is unified in both datasets	CR, treatment of hot lots and setup avoidance is unified in both datasets