Description of the Demand Information, WIP Information, and Simulation Results

Contents

1. Structure of the Demand Folder

There are subfolders within the folder *Demand* that contain datasets with specific features. The subfolder structure corresponds to the length of the planning horizon, the bottleneck utilization, the coefficient of variation, and the type of correlation. Next, the meaning of the different folder names is explained.

1.1. Length of the planning horizon (H)

- **Demand_18**: datasets that contain demand data with a planning horizon of 18 weeks.
- **Demand_9**: datasets that contain demand data with a planning horizon of 9 weeks.

Note that folder *Demand_9* is meant to provide additional demand data for illustrative purpose. Its content is outlined more specifically in the last section of this document.

1.2. Bottleneck Utilization

- **70_BN_util**: datasets that lead to a bottleneck utilization about 70%.
- **90_BN_util**: datasets that lead to a bottleneck utilization about 90%.

1.3. Coefficient of Variation (CV)

- **CV_01**: $CV\left(D_{t,t+0}^{(i)}\right) = 0.1$ for the final demand $D_{t,t+0}^{(i)}$ in period t of product P_i. The demand information for product P_i available at period t concerning s periods ahead $D_{t,t+s}^{(i)}$ is less variable as s grows: $CV\left(D_{t,t+s}^{(i)}\right) = \frac{\sqrt{H-s}}{\sqrt{H}}\ 0.1$, where $s \in \{0, \dots, H-1\}$ as the length of the planning horizon is H weeks.
- **CV_025**: As above, but with $CV\left(D_{t0}^{(i)}\right) = 0.25$ for the final demand and more precisely $CV\left(D_{t,t+s}^{(i)}\right) = \frac{\sqrt{H-s}}{\sqrt{H}}\ 0.25$.

1.4. Type of Correlation (COR)

- **negativeCorrelated**: $P_1,\ P_3,\ P_4$ are negative correlated to P_2. More accurately the correlation of the demand information is as follows:

  $$COR\left(D_{t,t+s}^{(i)}, D_{t,t+s}^{(j)}\right) = \begin{cases} 1 & \text{if } i = j \\ 0.99 & \text{if } i \in \{1,3,4\}, j \in \{3,4\} \\ -0.99 & \text{if } i \in \{1,3,4\} \text{ and } j = 2. \end{cases}$$

  In this case no correlation across periods is modeled. Thus, $COR\left(D_{t,t+s}^{(i)}, D_{k,k+l}^{(j)}\right) = 0$ for $t \neq k$ and $s \neq l$.
- **negativeCorrelated_05**: $P_1,\ P_3,\ P_4$ are negative correlated to P_2. More accurately the correlation of the demand information is as follows:

  $$COR\left(D_{t,t+s}^{(i)}, D_{t,t+s}^{(j)}\right) = \begin{cases} 1 & \text{if } i = j \\ 0.5 & \text{if } i \in \{1,3,4\}, j \in \{3,4\} \\ -0.5 & \text{if } i \in \{1,3,4\} \text{ and } j = 2. \end{cases}$$

  In this case no correlation across periods is modeled. Thus, $COR\left(D_{t,t+s}^{(i)}, D_{k,k+l}^{(j)}\right) = 0$ for $t \neq k$ and $s \neq l$.

- **positiveCorrelated**: P_1, P_2, P_3, P_4 are positive correlated. More accurately the correlation of the demand information is as follows:
  $COR\left(D_{t,t+s}^{(i)}, D_{t,t+s}^{(j)}\right) = \begin{cases} 1 & \text{if } i = j \\ 0.99 & \text{if } i \neq j. \end{cases}$
  In this case no correlation across periods is modeled. Thus, $COR\left(D_{t,t+s}^{(i)}, D_{k,k+l}^{(j)}\right) = 0$ for $t \neq k$ and $s \neq l$.
- **positiveCorrelated_05**: P_1, P_2, P_3, P_4 are positive correlated. More accurately the correlation of the demand information is as follows:
  $COR\left(D_{t,t+s}^{(i)}, D_{t,t+s}^{(j)}\right) = \begin{cases} 1 & \text{if } i = j \\ 0.5 & \text{if } i \neq j. \end{cases}$
  In this case no correlation across periods is modeled. Thus, $COR\left(D_{t,t+s}^{(i)}, D_{k,k+l}^{(j)}\right) = 0$ for $t \neq k$ and $s \neq l$.
- **positiveCorrelatedProductsAndPeriods**: P_1, P_2, P_3, P_4 are positive correlated with
  $COR\left(D_{t,t+s}^{(i)}, D_{t,t+s}^{(j)}\right) = \begin{cases} 1 & \text{if } i = j \\ 0.55 & \text{if } i \neq j. \end{cases}$
  The correlation across periods is given by $COR\left(D_{t+s,t+k}^{(i)}, D_{t,t+k}^{(i)}\right) = \begin{cases} 1 & \text{if } s = 0 \\ \frac{3}{10s} & \text{if } s \neq 0. \end{cases}$
- **uncorrelated**: Neither correlation across periods nor across products is modeled: $COR\left(D_{t+s,t+s+l}^{(i)}, D_{t,t+k}^{(j)}\right) = \begin{cases} 1 & \text{if } s = 0, l = k, \text{and } i = j \\ 0 & \text{otherwise.} \end{cases}$

2. Contents of the Demand Files

Demand datasets are contained in the the correlation folders (*negativeCorrelated, positive-Correlated, positiveCorrelatedProductsAndPeriods, uncorrelated*). In the following, the contents of the files are explained.

2.1. Final Demand

The file *finalDemand.txt* contains the weekly final demand for the four products at the distribution center level. Files *finalDemand_i.txt* contain the final demand at distribution center i. Figure 1 is used to describe the contents of these files. The corresponding numbers are given in 1000 chips.

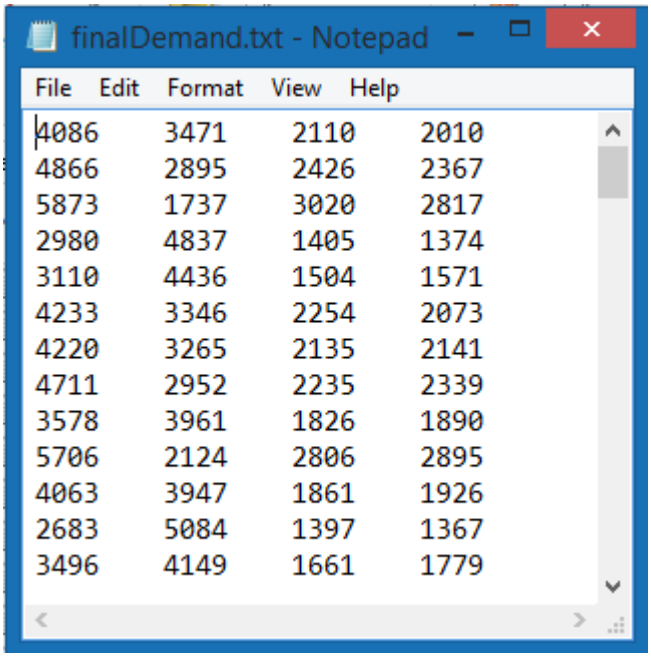

Figure 1: Contents of a Final Demand File

In the first line, the final demand for the first week ($t = 0$) is given for the four products by $D_{00}^{(1)} = 4086000$, $D_{00}^{(2)} = 3471000$, $D_{00}^{(3)} = 2110000$, and $D_{00}^{(4)} = 2010000$ chips. In line five the final demand for the fifths week ($t = 4$) can be found: $D_{4,4}^{(1)} = 3110000$, $D_{4,4}^{(2)} = 4436000$, $D_{4,4}^{(3)} = 1504000$, and $D_{4,4}^{(4)} = 1571000$ chips.

2.2. Firm Orders and Supply Reservations

forecast.txt refers to supply reservations and *order.txt* to firm orders. Again, the extension *_i* refers to distribution center i.

Figure 2 is used to describe the contents of these files. Here, a firm order file is considered. The contents are arranged in blocks of four lines. The first line in each block contains demand information for P_1, the second line for P_2, the third for P_3, and the fourth for P_4. Each line consists of 18 entries with tabs as field delimiter, as this is the length of the planning horizon H. The last section of this document describes how the last nine entries of the planning horizon are populated in the corresponding files in folder *Demand_9*

The first line in the t-th block gives the information of the firm orders for P_1 in the t-th week: $D_{t-1}^{F(1)} = \left(D_{t-1,t-1}^{F(1)}, \dots, D_{t-1,t+H-2}^{F(1)}\right)$. In the third line of the second block, the firm orders for P_3 starting in the second week ($t = 1$) are given by $D_{11}^{F(3)} = 2426000$, $D_{12}^{F(3)} = 2644000$, $D_{13}^{F(3)} = 1183000$ chips.

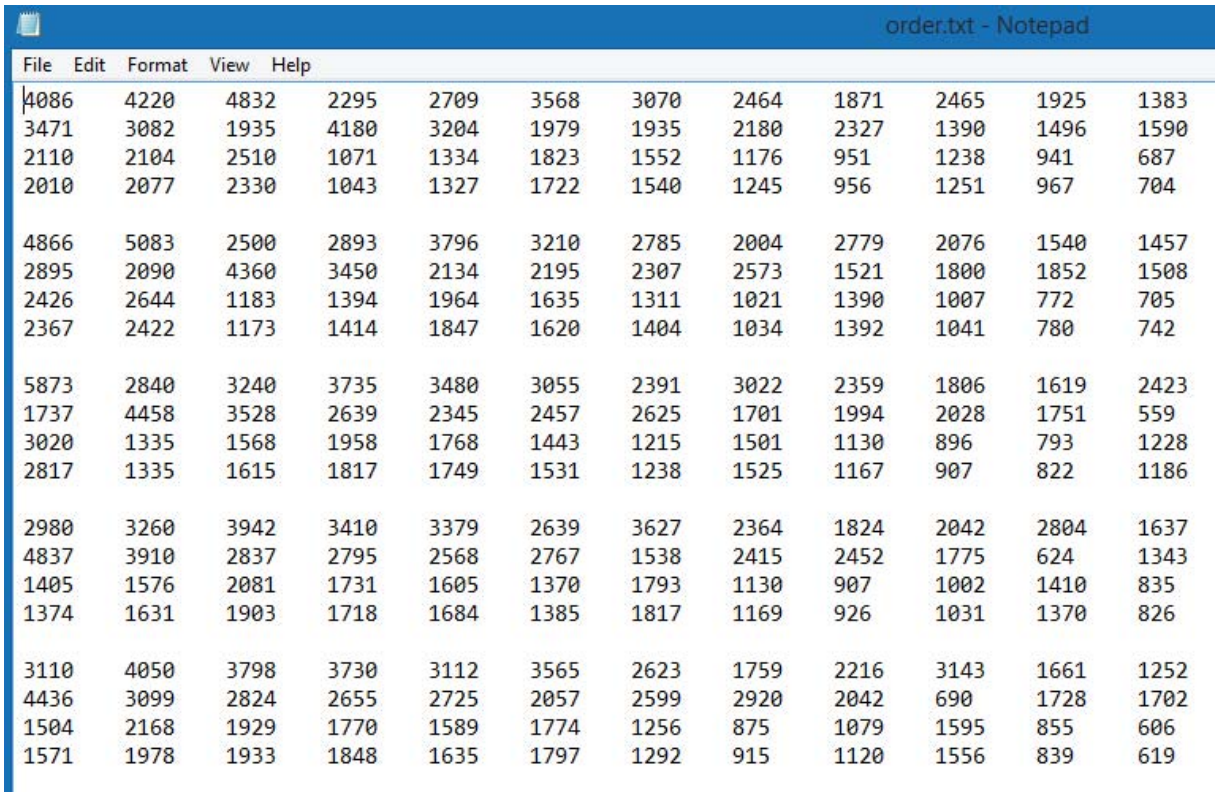

Figure 2: Contents of an Order File

Note that one of these blocks of four lines is sufficient if no rolling horizon approach is taken. In this case the same block (e.g. the fourth block) of the firm order file and the supply reservation file has to be chosen.

3. WIP Information

The WIP information is generated for each demand scenario from 52 weeks of demand data that was generated along the specified data. As ATO is a mixture of MTS and MTO, this strategy is chosen for each product to generate the WIP information.

3.1. WIP Lots

The files *WIPlots_XX.txt* contain the information to start WIP lots for the simulation model XX where $XX \in \{FM, BM, RM\}$. The contents of the files are arranged in eight columns with tabs as field delimiter. They can be easily copied into an Excel worksheet. The first line contains the headings of the columns. These are:

- PRODUCT: the name of the product,
- RELEASED AT: the name of the facility where the lot was released,
- PLANNED FOR: the name of the die bank or distribution center to which the lot is routed,
- RELEASE DATE: date and time when the lot was released (format: M/D/YY h:mm:ss),
- DUE DATE: the due date of the lot,
- CUR STEP: the identifier of the current processing step,
- STEP START: the time when the lot entered CUR STEP,
- REMAINING PROC SEC: the remaining processing time in seconds at CUR STEP; this field is only used in case of silicon foundries or subcontractors.

IMPORTANT: The start date of model runs using the WIP information has to be set to June the 8th, 2015 at 9 AM.

Figure 3 shows some WIP lots of a FM. Line 2 holds information regarding a lot of P_2 that has been released at A/T facility BE1 on June the 1st, 2015 at 9 AM and is planned for distribution center DC2. The current processing step of the lot is S20 and the lot started this step on June the 7th at 7:19 AM and 40 seconds.

In our model, the STEP START information is only used to rank the lots according to FIFO. When the simulation starts with WIP lots, the lots reenter CURSTEP. On the one hand, this leads to WIP lot information that is easy to read, understand, and to use. On the other hand, the WIP lot information of FM is used to generate WIP lot information for BM and RM and thus this simplification enhances the comparability of the models.

As the processing time at silicon foundries and subcontractors is both long and deterministic, the REMAINING PROC SEC field is used in these cases (cf. Figure 3, lines 14 and 16). Hence, these lots do not restart their processing, but continue instead.

When CUR STEP is set to *Transportation* the lot is being transported from RELEASED AT to PLANNED FOR (cf. Figure 3, lines 3, 8, 12, 15, and 17).

	A	B	C	D	E	F	G	H
1	PRODUCT	RELEASED AT	PLANNED FOR	RELEASE DATE	DUE DATE	CUR STEP	STEP START	REMAINING PROC SEC
2	p_2	BE1	DC2	6/1/15 9:00:00	6/13/15 9:00:00	S20	6/7/15 7:19:40	
3	p_3	BE1	DC3	5/25/15 9:00:00	6/7/15 9:00:00	Transportation	6/5/15 12:13:08	
4	p_1	BE2	DC3	6/1/15 9:00:00	6/10/15 9:00:00	S23	6/7/15 16:02:58	
5	p_2	BE2	DC3	6/1/15 9:00:00	6/14/15 9:00:00	S20	6/7/15 7:19:40	
6	p_2	BE2	DC2	6/1/15 9:00:00	6/14/15 9:00:00	S22	6/8/15 5:47:55	
7	p_2	BE2	DC1	6/1/15 9:00:00	6/14/15 9:00:00	S23	6/8/15 8:17:53	
8	p_1	FE1	DB1	5/11/15 9:00:00	6/11/15 9:00:00	Transportation	6/7/15 11:33:21	
9	p_2	FE1	DB1	5/4/15 9:00:00	6/8/15 9:00:00	213	6/8/15 7:11:37	
10	p_2	FE1	DB1	5/4/15 9:00:00	6/8/15 9:00:00	222	6/8/15 7:00:29	
11	p_2	FE1	DB1	4/27/15 9:00:00	6/1/15 9:00:00	230	6/8/15 7:33:44	
12	p_3	FE1	DB2	5/4/15 9:00:00	6/3/15 9:00:00	Transportation	6/8/15 8:23:51	
13	p_2	FE2	DB2	5/4/15 9:00:00	6/8/15 9:00:00	244	6/8/15 5:04:03	
14	p_2	SIFO1	DB2	4/20/15 9:00:00	6/20/15 9:00:00	1	4/20/15 9:00:00	604800
15	p_1	SIFO2	DB2	4/20/15 9:00:00	6/13/15 9:00:00	Transportation	6/8/15 9:00:00	
16	p_2	SUBCON1	DC3	5/25/15 9:00:00	6/19/15 9:00:00	S1	5/25/15 9:00:00	604800
17	p_2	SUBCON1	DC1	5/18/15 9:00:00	6/12/15 9:00:00	Transportation	6/8/15 9:00:00	

Figure 3: Contents of a WIPlots_FM.txt File

The WIP lot files for BM and RM are generated from the FM files and contain the same lots. In case of BM, CUR STEP is set to the equivalent bottleneck or delay processing step. For RM, the CUR STEP information is not needed. In order to take the lot's current position into account the cycle time which is calculated using empirical cycle time distributions, linear interpolation, and exponential smoothing, is reduced by the amount of time the WIP lot already spent in the system.

3.2. Bottleneck Utilization and Cycle Times

As BM and RM calculate the delay times and cycle times subject to the current state, the current bottleneck utilization and the current mean cycle times are needed. These can be found in the files *WIP_util.txt* and *WIP_ct.txt*.

Figure 4 shows the contents of a *WIP_util.txt* file. Here, the current bottleneck utilization at FE1 is 80.1801%, 77.0486% at FE2, 74.4999% at BE1, and 73.9005% at BE2. The bottleneck utilization is calculated as the percentage of time when the bottleneck tool group is not idle in the last simulated seven days.

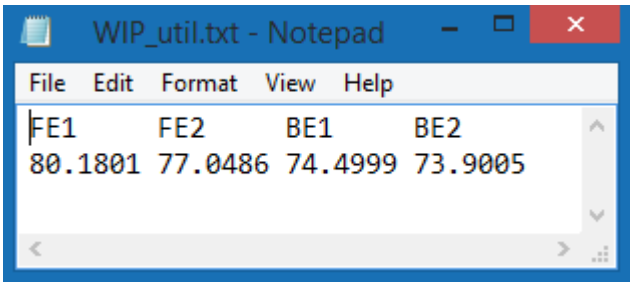

Figure 4: Contents of a WIP_util.txt File

Figure 5 shows the contents of a *WIP_ct.txt* file. Here, the current mean cycle times in days are given for every facility and product. Product P_1 has a mean cycle time of 39.1833 days at FE1, 37.2807 days at FE2, 9.37407 days at BE1, and 10.0635 days at BE2.

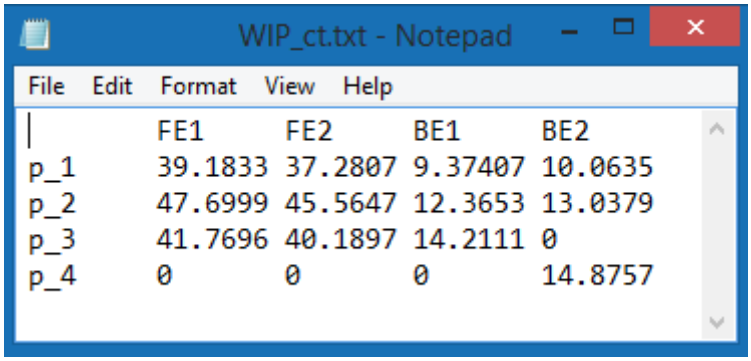

Figure 5: Contents of a WIP_ct.txt File

As P_4 and P_3 have the same parent dies, the cycle times for FE1 and FE2 are listed for P_3 and not for P_4. In addition, P_3 is only processed at BE1 and P_4 at BE2. The average cycle time is calculated from all lots of the same product and facility that were completed in the last seven days.

3.3. Inventory and Backlog per Facility

The file *Inventory.txt* contains information about the current inventory or backlog of the facilities. Figure 6 shows an example of an *Inventory.txt* file. The columns refer to the die banks and distribution centers and the rows to the four products. As in the demand files the numbers are given in wafers (DB) or 1000 chips (DC). In Figure 6, we have 8496 wafers of P_3 at DB1, 8464 wafers of P_3 at DB2, 407000 chips of P_3 at DC1 and DC2 and 234000 chips of P_3 at DC3. Again, the inventory at the die bank level are not listed for P_4. Negative inventory is backlog.

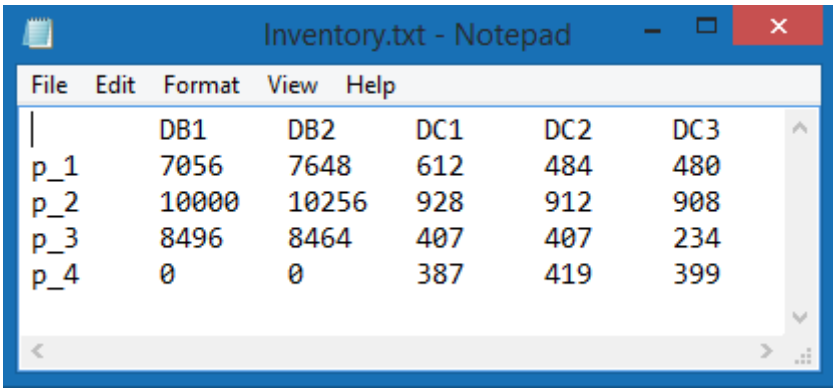

Figure 6: Contents of an Inventory.txt File

4. Results of Simulation Runs

The files *Result_XX.txt* contain the results of simulation runs of 104 weeks with the demand and WIP data given in the same directory for the simulation model XX, where $XX \in \{FM, BM, RM\}$. The contents of the files are arranged in 20 columns with tabs as field delimiter. They can be easily copied into an Excel worksheet. The first line contains the headings of the columns. These are:

- *Strategy*: the partition of the four products into MTO (=0), ATO (=1), and MTS (=2), the string "0120" means that P_1 is produced MTO, P_2 ATO, P_3 MTS, and P_4 MTO,
- *SLC*: the code for product *Product*: 0 (MTO), 1 (ATO), or 2 (MTS),
- *Product*: the name of the product,
- *Total Cost*: the weighted sum of inventory costs, backlog costs, and manufacturing costs for the four products
- *Cost per Product*: the weighted sum of inventory costs backlog costs, and manufacturing costs for product *Product*
- *Inventory DB (wafers/week):* the mean inventory of product *Product* at DB1 and DB2 throughout the simulation run,
- *Inventory DC (1000 chips/week):* the mean inventory of product *Product* at DC1, DC2, and DC3 throughout the simulation run,
- *Backlog DB (wafers/week) :* the mean backlog of product *Product* at DB1 and DB2 throughout the simulation run,
- *Backlog DC (1000 chips/week) :* the mean backlog of product *Product* at DC1, DC2, and DC3 throughout the simulation run,
- *WIP FE (wafers/week)*: the mean WIP of product *Product* at FE1, FE2, SIFO1, and SIFO2 throughout the simulation run,
- *WIP BE (1000 chips/week)*: the mean WIP of product *Product* at BE1, BE2, SUBCON1, and SUBCON2 throughout the simulation run,
- *CT FE (days/lot)*: the mean cycle time of product *Product* at FE1, FE2, SIFO1, and SIFO2 throughout the simulation run (WIP lots are not considered),
- *CT BE (days/lot)*: the mean cycle time of product *Product* at BE1, BE2, SUBCON1, and SUBCON2 throughout the simulation run (WIP lots are not considered),
- *Starts FE (wafers)*: the total number of wafers of product *Product* started at FE1, FE2, SIFO1, and SIFO2,

- *Starts BE (1000 chips)*: the total number of chips (in 1000 chips) of product *Product* started at BE1, BE2, SUBCON1, and SUBCON2,
- *Comps FE (wafers)*: the total number of wafers of product *Product* completed at FE1, FE2, SIFO1, and SIFO2,
- *Comps BE (1000 chips)*: the total number of chips (in 1000 chips) of product *Product* completed at BE1, BE2, SUBCON1, and SUBCON2,
- *Total Final Demand (1000 chips)*: the total final demand (in 1000 chips) of product *Product* at DC1, DC2, and DC3,
- *Util FE:* the mean bottleneck utilization at FE1 and FE2 throughout the simulation run,
- *Util BE*: the mean bottleneck utilization at BE1 and BE2 throughout the simulation run.

In this file four subsequent lines belong to one model run and hold the information for P_1, P_2, P_3, and P_4. Figure 7 shows an example of a Result_FM.txt file. Lines two to five contain the results of the first simulation run. Here, the strategy is 0000, i.e. all products are produced MTO. Line two refers to P_1, line three to P_2, line four to P_3, and line five to P_4. The columns *Total Cost*, *Util FE*, and *Util BE* contain general information that is the same for the four products in one run. Similarly, the results for the second strategy (0001) where products P_1, P_2, and P_3 are produced MTO, while P_4 is produced ATO, can be found in lines six to nine.

Note that *Total Cost* and *Cost per Product* are divided by 1300 in order to obtain smaller numbers.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Strategy	SLC	Product	Total Cost	Cost per Product	Inventory DB (wafer/week)	Inventory DC (1000 chips/week)	Backlog DB (wafer/week)	Backlog DC (1000 chips/week)	WIP FE (wafer/week)	WIP BE (1000 chips/week)	CT FE (days/lot)	CT BE (days/lot)
2	0000	0	p_1	316940	93700	5016.92	1377.08	18	205.923	25746.9	7491.54	42.5446	13.3912
3	0000	0	p_2	316940	113531	4836.15	2023.28	204.769	382.058	30603.2	10915.2	49.8661	18.1134
4	0000	0	p_3	316940	82995	3405.23	987.51	0	58.5962	27020.8	5456.92	44.1338	18.951
5	0000	0	p_4	316940	26713	2866.31	754.615	1.84615	92.75	0	5743.85	0	19.2442
6	0001	0	p_1	344507	93802	4957.54	1364.77	20.9231	230.385	25809.2	7525.54	42.5479	13.4266
7	0001	0	p_2	344507	113487	4822.92	2009.46	186.462	383.317	30598.2	10947.5	49.8546	18.1396
8	0001	0	p_3	344507	83572	3387.69	980.683	0	58.2308	27353.1	5463.38	44.0768	18.9673
9	0001	1	p_4	344507	53645	9724.77	914.75	0	10.1154	0	5503.08	0	19.4867
10	0002	0	p_1	347651	93774	4926.31	1360.71	14.6154	234.635	25834.2	7540.15	42.5789	13.4312
11	0002	0	p_2	347651	113766	4723.69	1959.91	218.769	440.692	30729.7	11023.1	49.9968	18.1394
12	0002	0	p_3	347651	83741	3363.69	971.067	0	69.2308	27439.8	5484	44.1536	18.9428
13	0002	2	p_4	347651	56371	9655.23	1663.35	0	0.557692	0	5546	0	19.5577
14	0010	0	p_1	344370	93642	4928.92	1355.31	30.1538	222	25847.1	7517.54	42.5601	13.4015
15	0010	0	p_2	344370	113406	4776.62	2012.21	193.231	383.913	30651.2	10938.5	49.8988	18.0963
16	0010	1	p_3	344370	110469	10202.3	1064.54	0	8.85577	27335.1	5330.15	44.0982	19.0989
17	0010	0	p_4	344370	26853	2914.31	770.875	7.38462	85.3173	0	5714.77	0	19.196
18	0011	0	p_1	372281	93805	5074	1365.86	25.2308	207.163	25697.1	7496.92	42.3595	13.4455
19	0011	0	p_2	372281	113397	4871.38	2015.03	164.308	363.5	30527.5	10944.2	49.689	18.1585
20	0011	1	p_3	372281	111251	10277.1	1061.65	0	11.0481	27568.6	5335.23	43.7939	19.1379
21	0011	1	p_4	372281	53829	9773.69	900.269	0	11.7885	0	5519.23	0	19.4823
22	0012	0	p_1	374966	93777	5013.08	1339.28	40	221.817	25772.8	7523.54	42.4602	13.4574
23	0012	0	p_2	374966	113518	4768.31	1968.83	214.923	405.452	30681.2	10981.5	49.9497	18.1506
24	0012	1	p_3	374966	111348	10215.7	1059.68	0	9.69231	27748.6	5335.85	43.9843	19.1293
25	0012	2	p_4	374966	56323	9648.31	1653.5	0	0.557692	0	5555.85	0	19.5146
26	0020	0	p_1	347212	93471	4944.31	1387.61	10.9231	195.375	25812.5	7477.85	42.4827	13.4304
27	0020	0	p_2	347212	113463	4830.77	2023.82	143.538	376.288	30547.4	10969.8	49.7605	18.1626
28	0020	2	p_3	347212	113355	10200.2	1783.51	0	0.75	27310.2	5397.23	44.0155	19.2291
29	0020	0	p_4	347212	26923	2926.31	757.106	0	88.7788	0	5739.38	0	19.2528
30	0021	0	p_1	375147	93804	5002	1354.99	23.3846	223.683	25767.2	7526.15	42.4655	13.4623
31	0021	0	p_2	375147	113641	4845.23	1996.55	165.846	396.865	30555.2	10994	49.7917	18.1683
32	0021	2	p_3	375147	114087	10175.7	1787.66	0	0.75	27720.5	5393.08	43.9332	19.2236
33	0021	1	p_4	375147	53615	9715.54	906.76	0	12.4327	0	5513.38	0	19.4861
34	0022	0	p_1	377824	93747	4965.23	1347.51	16.6154	226.817	25797.2	7543.69	42.5202	13.4781
35	0022	0	p_2	377824	113483	4747.38	1986.44	170	402.606	30657.2	11006.2	49.8915	18.1798
36	0022	2	p_3	377824	114128	10150.3	1805.71	0	1.56731	27769.8	5375.85	43.9605	19.2033
37	0022	2	p_4	377824	56466	9684.77	1651.96	0	0.557692	0	5557.38	0	19.551
38	0100	0	p_1	381289	94132	4951.23	1362.59	17.8462	265.125	25812.5	7565.23	42.551	13.451
39	0100	1	p_2	381289	177170	20711.8	2775.15	0	0.0865385	31624.2	9986.31	49.832	18.4767

Figure 7: Contents of a Result_FM.txt File

5. Additional Demand Data

The directory Demand_9 is organized as the Demand_18 directory. The difference is a planning horizon of $H = 9$ weeks instead of 18 weeks as above. For reasons of compatibility, the remaining nine weeks of the demand vector are filled with the mean demand in case of supply reservation and are set equal to zero in case of firm orders. As this data is additional, neither WIP information nor results of simulation runs are included.