Script for Production Planning Case Study

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1 Meta Information

This document contains the script to be used for a demo of the production planning case study of the ENTIRE EDIH skill development program on scheduling. The case study is based on a project with a local Cork medical devices company some time ago, but is using a different solution approach that is exploiting the scheduling tool at the core of this course.

N.B. The formatting of the slides is preliminary, I'm still waiting for the correct ENTIRE branded slide format.

2 Title Slide

Figure 1: Title Slide

As part of the skills development program on scheduling we look at a number of industrial case studies. Here we will briefly present a production planning and scheduling problem from a medical devices manufacturing company in Cork.

3 Key Points

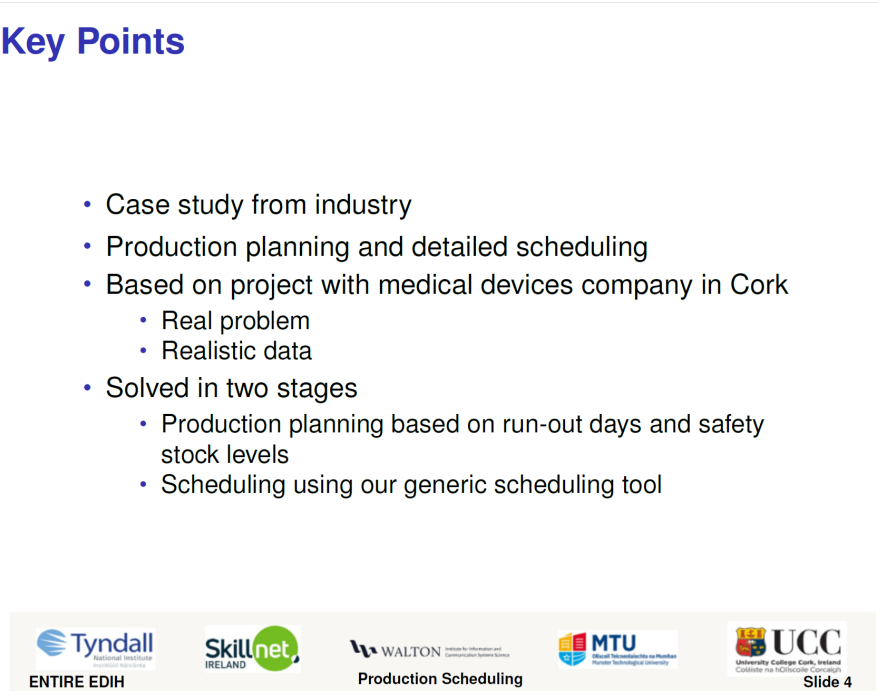

Figure 2: Key Points

This is a case study from industry, combining production planning and detailed scheduling. It is based on a project that some of my colleagues were working on for a local medical devices company.

The overall problem is to decide which products to make in which quantities over the planning horizon, so that we have enough stock to satisfy any customer demand, and make sure that we have some safety margin if the demand suddenly increases. At the same time we do not want to create inventory in products that we will not sell in the near future, as this increases our inventory carrying cost.

The company uses two main concepts for production planning: The run-out days for each product state how long the current stock will last, given a projected customer demand profile. We try to achieve the same run-out days value for all products, this works well for fast and slow moving products.

The safety stock values says how much stock we should have for each product. This gives us more control over the stock levels, this works better if the demand cannot be predicted as accurately as we would like, but it ismore difficult to compare the stock levels for different products.

The production planning part of the application decides how much to produce for which product, but this is based on a an estimate of the production

capacity for the planning period. We use the detailed scheduling part of the application to validate the plan generated, and make sure that we can really produce the required capacities in the given planning period.

4 Application View: Products

Name	ShortName	Nr	DailySales	InventoryAtStart	CalcDaysCover	LotSize	CycleTime	LotDuration	Machine	ProductType	SafetyStock	SafetyAlert
P1	P1	1	3.20	877	274.06	163	1.33	217	8	pt1	66	253.44
P2	P2	2	11.40	1,011	88.68	240	1.20	288	8	pt2	774	20.79
P3	P3	3	796.20	26,204	32.91	420	2.10	882	5,7,9,10,13,14,16	pt3	12,108	17.70
P4	P4	4	233.80	7,877	33.69	420	2.00	840	5,7,9,10,13,14,16	pt4	3,358	19.33
P5	P5	5	267.30	7,152	26.76	350	2.30	805	5,7,9,10,13,14,16	pt5	3,906	12.14
P6	P6	6	606.20	18,654	30.77	350	2.30	805	5,7,9,10,13,14,16	pt6	9,293	15.44
P7	P7	7	137.30	4,939	35.97	420	2.00	840	5,7,9,10,13,14,16	pt7	1,979	21.56
P8	P8	8	88.30	3,152	35.70	350	2.30	805	5,7,9,10,13,14,16	pt8	1,342	20.50
P9	P9	9	77.20	2,688	34.82	420	2.10	882	5,7,9,10,13,14,16	pt9	1,082	20.80
P10	P10	10	165.60	5,971	36.06	420	2.10	882	5,7,9,10,13,14,16	pt10	2,649	20.06
P11	P11	11	60.70	2,310	38.06	420	2.10	882	5,7,9,10,13,14,16	pt11	877	23.61
P12	P12	12	51.80	1,928	37.22	350	2.30	805	5,7,9,10,13,14,16	pt12	883	20.17
P13	P13	13	79.00	2,231	28.24	320	2.30	736	5,7,9,10,13,14,16	pt13	1,193	13.14
P14	P14	14	271.20	8,951	33.01	432	2.10	908	5,7,9,10,13,14,16	pt14	3,732	19.24
P15	P15	15	86.60	3,244	37.46	336	2.00	672	5,7,9,10,13,14,16	pt15	1,454	20.67
P16	P16	16	42.40	2,110	49.76	420	2.10	882	5,7,9,10,13,14,16	pt16	875	29.13
P17	P17	17	17.60	681	38.69	420	2.00	840	5,7,9,10,13,14,16	pt17	290	22.22
P18	P18	18	217.50	5,710	26.25	336	2.00	672	5,7,9,10,13,14,16	pt18	2,814	13.31
P19	P19	19	56.30	2,450	43.52	420	2.00	840	5,7,9,10,13,14,16	pt19	804	29.24
P20	P20	20	13.60	506	37.21	480	2.00	960	5,7,9,10,13,14,16	pt20	272	17.21
P21	P21	21	10.80	977	90.46	360	2.10	756	5,7,9,10,13,14,16	pt21	293	63.33
P22	P22	22	21.80	1,538	70.55	420	2.00	840	5,7,9,10,13,14,16	pt22	349	54.54
P23	P23	23	189.10	5,195	27.47	360	2.30	828	5,7,9,10,13,14,16	pt23	2,941	11.92
P24	P24	24	9.50	886	93.26	350	2.30	805	5,7,9,10,13,14,16	pt24	191	73.16
P25	P25	25	7.50	326	43.47	120	2.30	276	5,7,9,10,13,14,16	pt25	210	15.47
P26	P26	26	11.60	418	36.03	360	2.10	756	5,7,9,10,13,14,16	pt26	187	19.91
P27	P27	27	16.50	1,388	84.12	480	2.10	1,008	5,7,9,10,13,14,16	pt27	218	70.91

Figure 3: Products List View

This tables shows use the basic input data for the application. We have one entry for each product, which describes the different feature values that are given. The main features are:

Daily Sales the number of units sold per day. We can see that there are some fast-moving products, Like P3, and many more slow moving products.

Inventory at Start the number of pieces held in stock at the start of the analysis.

Days Cover how many days the stock will last given the initial stock and the daily consumption, assuming we do not make any more of this product. Again we can see a wide range of value, depending on the product.

Lot Size The products are made in lots, the size of the lot depends on the product, and how the products held in the production process. We often make more than one lot of the same product in a production run, as this increases productivity an reduces the setup time when changing products.

Cycle Time How long does it take to make on item of this product. This value is in minutes.

Lot Duration How long does it take to produce one lot of this product. This is derived from the previous values.

Not all products can be made on all possible machines. Some products must be made on one specific machine, for others we can choose one of the possible machines. We can also make multiple production runs of the same product on different machines, if we need to make a large quantity.

Product Type The product types of two consecutive products made on the same machines determine the time needed to setup the machine between the two runs. This is typically based on some properties of the products: Similar products require less setup time, very different products require a much longer time to switch the machine one one configuration to another.

Safety Stock How much stock we would like to have in stock during the planning period. This value can be set by hand, or can be calculated by a more complex prediction model looking at the uncertainty of the demand prediction.

Safety Alert Derived value saying at which point we reach the safety margin, given the initial stock and the predicted consumption. A low value indicates that we need to make the product urgently, a value of zero states that even at the initial time we are already below the safety stock margin.

We can sort the products based on their feature values, to identify products with specific properties we want to watch.

If we sort products by decreasing sales *(Figure 4)*, we see that product P3 is the fastest moving of the products. We will use P3 as a running example in this section.

If we sort the products by increasing safety alert *(Figure 5)*, we see that product P35 has the lowest value, its stock is already below the safety level at the start of the planning period. We will check later on how the planner works for this product.

Finally, if we sort the products by the initial run-out days *(Figure 6)*, we see that the lowest value (20.0 days) is for product P35, but there are a number of other products that have run-out values below 30. In our solution we hope to maximize the worst case value over all products.

Product ×

Name	ShortName	Nr	DailySales	InventoryAtStart	CalcDaysCover	LotSize	CycleTime	LotDuration	Machine	ProductType	SafetyStock	SafetyAlert
P3	P3	3	796.20	26,204	32.91	420	2.10	882	5,7,9,10,13,14,16	pt3	12,108	17.70
P6	P6	6	606.20	18,654	30.77	350	2.30	805	5,7,9,10,13,14,16	pt6	9,293	15.44
P14	P14	14	271.20	8,951	33.01	432	2.10	908	5,7,9,10,13,14,16	pt14	3,732	19.24
P53	P53	53	267.70	8,264	30.87	504	1.20	605	1,2,3,8	pt2	3,734	16.92
P5	P5	5	267.30	7,152	26.76	350	2.30	805	5,7,9,10,13,14,16	pt5	3,906	12.14
P124	P124	124	242.70	16,503	68.00	240	5.00	1,200	15,18,19	pt65	3,595	53.19
P4	P4	4	233.80	7,877	33.69	420	2.00	840	5,7,9,10,13,14,16	pt4	3,358	19.33
P123	P123	123	223.40	7,600	34.02	490	2.33	1,142	1,2,3,8	pt51	3,738	17.29
P18	P18	18	217.50	5,710	26.25	336	2.00	672	5,7,9,10,13,14,16	pt18	2,814	13.31
P23	P23	23	189.10	5,195	27.47	360	2.30	828	5,7,9,10,13,14,16	pt23	2,941	11.92
P56	P56	56	168.20	4,824	28.68	504	1.20	605	1,2,3,8	pt2	2,660	12.87
P10	P10	10	165.60	5,971	36.06	420	2.10	882	5,7,9,10,13,14,16	pt10	2,649	20.06
P59	P59	59	152.80	5,666	37.08	420	1.33	559	1,2,3,8	pt51	3,095	16.83
P7	P7	7	137.30	4,939	35.97	420	2.00	840	5,7,9,10,13,14,16	pt7	1,979	21.56
P57	P57	57	134.80	5,358	39.75	588	1.10	647	1,2,3,8	pt53	2,294	22.73
P36	P36	36	133.50	3,895	29.18	336	2.00	672	5,7,9,10,13,14,16	pt36	2,057	13.77
P54	P54	54	122.40	5,059	41.33	480	1.33	639	1,2,3,8	pt51	1,965	25.28
P121	P121	121	98.10	4,334	44.18	588	1.10	647	1,2,3,8	pt53	1,524	28.64
P8	P8	8	88.30	3,152	35.70	350	2.30	805	5,7,9,10,13,14,16	pt8	1,342	20.50
P125	P125	125	86.90	8,593	98.88	240	5.00	1,200	15,18,19	pt65	1,022	87.12
P15	P15	15	86.60	3,244	37.46	336	2.00	672	5,7,9,10,13,14,16	pt15	1,454	20.67
P100	P100	100	85.20	2,665	31.28	420	1.33	559	1,2,3,8	pt56	1,115	18.19
P55	P55	55	79.50	2,876	36.18	441	2.33	1,028	1,2,3,8	pt52	1,367	18.98
P13	P13	13	79.00	2,231	28.24	320	2.30	736	5,7,9,10,13,14,16	pt13	1,193	13.14
P9	P9	9	77.20	2,688	34.82	420	2.10	882	5,7,9,10,13,14,16	pt9	1,082	20.80
P47	P47	47	74.60	5,391	72.27	160	6.84	1,095	2,11	pt47	1,132	57.09
P11	P11	11	60.70	2,310	38.06	420	2.10	882	5,7,9,10,13,14,16	pt11	877	23.61
P61	P61	61	60.30	2,758	45.74	490	1.33	652	1,2,3,8	pt56	1,073	27.94
P78	P78	78	57.60	2,234	38.78	588	1.10	647	1,2,3,8	pt59	824	24.48
P19	P19	19	56.30	2,450	43.52	420	2.00	840	5,7,9,10,13,14,16	pt19	804	29.24

Figure 4: Products Sorted by Decreasing Daily Sales

Product ×

Name	ShortName	Nr	DailySales	InventoryAtStart	CalcDaysCover	LotSize	CycleTime	LotDuration	Machine	ProductType	SafetyStock	SafetyAl...
P35	P35	35	1.30	26	20.00	120	2.30	276	5,7,9,10,13,14,16	pt35	33	0.00
P51	P51	51	5.70	405	71.05	140	4.50	630	2	pt50	381	4.21
P58	P58	58	55.00	1,590	28.91	420	2.33	979	1,2,3,8	pt54	1,208	6.95
P82	P82	82	6.10	259	42.46	441	1.33	587	1,2,3,8	pt51	189	11.48
P23	P23	23	189.10	5,195	27.47	360	2.30	828	5,7,9,10,13,14,16	pt23	2,941	11.92
P5	P5	5	267.30	7,152	26.76	350	2.30	805	5,7,9,10,13,14,16	pt5	3,906	12.14
P56	P56	56	168.20	4,824	28.68	504	1.20	605	1,2,3,8	pt2	2,660	12.87
P13	P13	13	79.00	2,231	28.24	320	2.30	736	5,7,9,10,13,14,16	pt13	1,193	13.14
P18	P18	18	217.50	5,710	26.25	336	2.00	672	5,7,9,10,13,14,16	pt18	2,814	13.31
P36	P36	36	133.50	3,895	29.18	336	2.00	672	5,7,9,10,13,14,16	pt36	2,057	13.77
P44	P44	44	5.50	205	37.27	360	2.10	756	5,7,9,10,13,14,16	pt44	126	14.36
P122	P122	122	45.40	1,421	31.30	490	1.33	652	1,2,3,8	pt56	725	15.33
P6	P6	6	606.20	18,654	30.77	350	2.30	805	5,7,9,10,13,14,16	pt6	9,293	15.44
P25	P25	25	7.50	326	43.47	120	2.30	276	5,7,9,10,13,14,16	pt25	210	15.47
P59	P59	59	152.80	5,666	37.08	420	1.33	559	1,2,3,8	pt51	3,095	16.83
P53	P53	53	267.70	8,264	30.87	504	1.20	605	1,2,3,8	pt2	3,734	16.92
P112	P112	112	3.40	134	39.41	588	1.20	706	1,2,3,8	pt2	76	17.06
P20	P20	20	13.60	506	37.21	480	2.00	960	5,7,9,10,13,14,16	pt20	272	17.21
P32	P32	32	5.40	222	41.11	480	2.00	960	5,7,9,10,13,14,16	pt32	129	17.22
P123	P123	123	223.40	7,600	34.02	490	2.33	1,142	1,2,3,8	pt51	3,738	17.29
P99	P99	99	5.70	247	43.33	96	2.00	192	1,2,3,8	pt60	148	17.37
P77	P77	77	33.00	1,146	34.73	336	1.20	404	1,2,3,8	pt61	565	17.61
P3	P3	3	796.20	26,204	32.91	420	2.10	882	5,7,9,10,13,14,16	pt3	12,108	17.70
P100	P100	100	85.20	2,665	31.28	420	1.33	559	1,2,3,8	pt56	1,115	18.19
P55	P55	55	79.50	2,876	36.18	441	2.33	1,028	1,2,3,8	pt52	1,367	18.98
P14	P14	14	271.20	8,951	33.01	432	2.10	908	5,7,9,10,13,14,16	pt14	3,732	19.24
P80	P80	80	7.20	293	40.69	420	1.33	559	1,2,3,8	pt51	154	19.31
P4	P4	4	233.80	7,877	33.69	420	2.00	840	5,7,9,10,13,14,16	pt4	3,358	19.33
P49	P49	49	50.90	2,273	44.66	378	1.00	378	2	pt48	1,260	19.90

Figure 5: Products Sorted by Safety Alert Value

Product ×

Name	ShortName	Nr	DailySales	InventoryAtStart	CalcDaysCover	LotSize	CycleTime	LotDuration	Machine	ProductType	SafetyStock	SafetyAlert
P35	P35	35	1.30	26	20.00	120	2.30	276	5,7,9,10,13,14,16	pt35	33	0.00
P18	P18	18	217.50	5,710	26.25	336	2.00	672	5,7,9,10,13,14,16	pt18	2,814	13.31
P5	P5	5	267.30	7,152	26.76	350	2.30	805	5,7,9,10,13,14,16	pt5	3,906	12.14
P23	P23	23	189.10	5,195	27.47	360	2.30	828	5,7,9,10,13,14,16	pt23	2,941	11.92
P13	P13	13	79.00	2,231	28.24	320	2.30	736	5,7,9,10,13,14,16	pt13	1,193	13.14
P56	P56	56	168.20	4,824	28.68	504	1.20	605	1,2,3,8	pt2	2,660	12.87
P58	P58	58	55.00	1,590	28.91	420	2.33	979	1,2,3,8	pt54	1,208	6.95
P36	P36	36	133.50	3,895	29.18	336	2.00	672	5,7,9,10,13,14,16	pt36	2,057	13.77
P6	P6	6	606.20	18,654	30.77	350	2.30	805	5,7,9,10,13,14,16	pt6	9,293	15.44
P53	P53	53	267.70	8,264	30.87	504	1.20	605	1,2,3,8	pt2	3,734	16.92
P100	P100	100	85.20	2,665	31.28	420	1.33	559	1,2,3,8	pt56	1,115	18.19
P122	P122	122	45.40	1,421	31.30	490	1.33	652	1,2,3,8	pt56	725	15.33
P3	P3	3	796.20	26,204	32.91	420	2.10	882	5,7,9,10,13,14,16	pt3	12,108	17.70
P14	P14	14	271.20	8,951	33.01	432	2.10	908	5,7,9,10,13,14,16	pt14	3,732	19.24
P4	P4	4	233.80	7,877	33.69	420	2.00	840	5,7,9,10,13,14,16	pt4	3,358	19.33
P123	P123	123	223.40	7,600	34.02	490	2.33	1,142	1,2,3,8	pt51	3,738	17.29
P77	P77	77	33.00	1,146	34.73	336	1.20	404	1,2,3,8	pt61	565	17.61
P9	P9	9	77.20	2,688	34.82	420	2.10	882	5,7,9,10,13,14,16	pt9	1,082	20.80
P8	P8	8	88.30	3,152	35.70	350	2.30	805	5,7,9,10,13,14,16	pt8	1,342	20.50
P7	P7	7	137.30	4,939	35.97	420	2.00	840	5,7,9,10,13,14,16	pt7	1,979	21.56
P26	P26	26	11.60	418	36.03	360	2.10	756	5,7,9,10,13,14,16	pt26	187	19.91
P10	P10	10	165.60	5,971	36.06	420	2.10	882	5,7,9,10,13,14,16	pt10	2,649	20.06
P55	P55	55	79.50	2,876	36.18	441	2.33	1,028	1,2,3,8	pt52	1,367	18.98
P63	P63	63	42.40	1,565	36.91	490	1.33	652	1,2,3,8	pt51	689	20.66
P59	P59	59	152.80	5,666	37.08	420	1.33	559	1,2,3,8	pt51	3,095	16.83
P20	P20	20	13.60	506	37.21	480	2.00	960	5,7,9,10,13,14,16	pt20	272	17.21
P12	P12	12	51.80	1,928	37.22	350	2.30	805	5,7,9,10,13,14,16	pt12	883	20.17
P44	P44	44	5.50	205	37.27	360	2.10	756	5,7,9,10,13,14,16	pt44	126	14.36
P15	P15	15	86.60	3,244	37.46	336	2.00	672	5,7,9,10,13,14,16	pt15	1,454	20.67

Figure 6: Products Sorted by Initial Run-Out Days

5 View: Setup Matrix

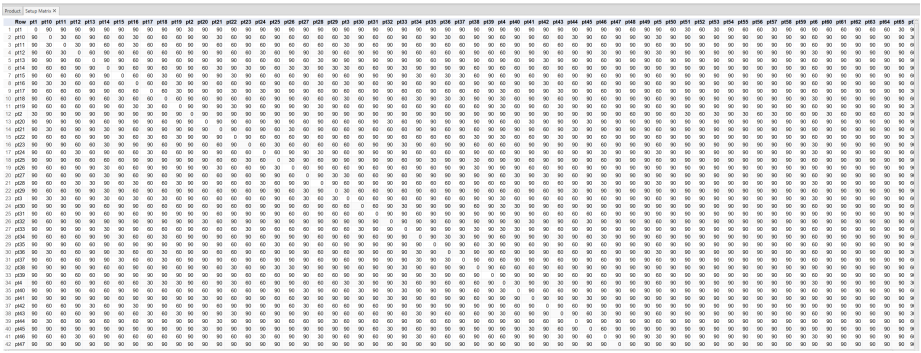

Figure 7: Setup Time Matrix Between Different Product Types

We have seen that each product has a product type, which in this case is derived from different product features. When changing from one product type to another on a machine, we have to spend the setup time, which is larger if the two products involved are more different from each other. We can have a look at the setup matrix generated, this is used in the detailed scheduling to determine the minimum time between to consecutive tasks on a machine. In our example, the times vary between zero and 90 minutes, with zero minutes used if the product types of the products are the same.

6 Running Planner

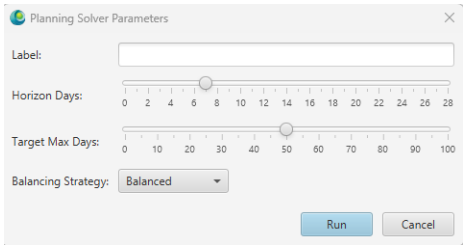

Figure 8: Running Planner Dialog Box

We now run the production planning tool, this brings up the following dialogue box *(Figure 8)*.

We can decide on the value of the planning horizon, the period for which we are making the planning decisions. The further we look into the future, the more freedom we have in our planning process. At the same time, the uncertainty about future demands and other events limit the accuracy that we can achieve with the planning tool. We use seven days as our default planning horizon.

The second parameter is the maximal run-out target value. We would like to achieve a high value, but our limited production capacity will limit what can be achieved in the given period.

The last parameter lets us choose the sizing strategy if we need more than one production run. By default, we attempt to make the required quantity of the product in a single run, thi reduces the setup time needed, and improves product quality. If the time needed to make the product exceeds the planning period, we need to make multiple, parallel runs to achieve the required quantity. In a balanced mode, we try to make the runs roughly the same length, in the Largest Possible mode we make some runs as long as possible, and then have a shorter run to achieve the remaining lots.

When we run the planner, the system performs three steps:

1. For each product, it analyses the stock situation, and determines the product need to achieve a given target.

2. The planner then considers the demand for each product, and estimates which target we can achieve in a given planning period. It uses a model of the production capacity to make an accurate estimate.

3. It then runs a detailed scheduling model to validate the plan, and see if the given target really can be achieved in the planning period. This more is much more detailed than the capacity model, and determines the precise start and end times for each production run.

7 Planner Results

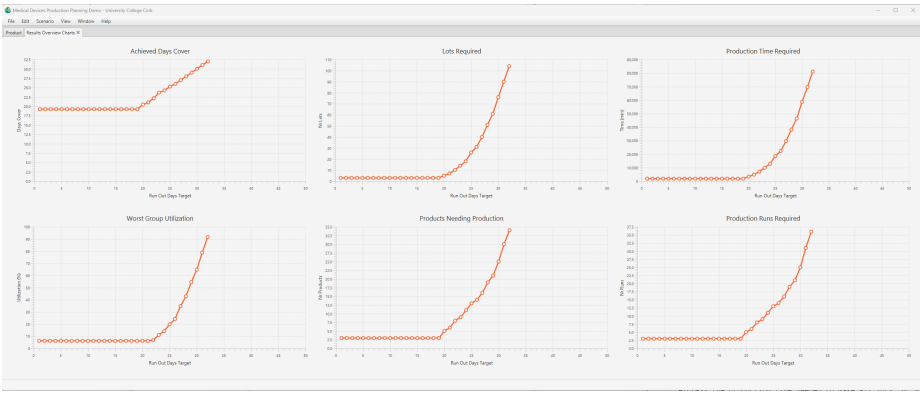

Figure 9: Planner Results

When the production planning module has finished, we present an overview of the results in the form of some charts. In each we see one of the KPIs of the planner as a function of the target run-out value. We only show those target values that the planner estimates can be achieved.

In our example,we see that the planner thinks that a target of 32 days can be achieved for all products. It shows

Achieved Days Cover A value of nineteen days can be achieved just by respecting the safety stock foreach product during the planning period. As the aim for a specific target value, the actual achieved run-out target might be slightly higher than planned, as we make the products in fixed lot sizes.

Lots required How many lots to we need to make to achieve the target value. Initially, there are only a few lots that need to be made to satisfy the safety margin, but then we need a rapidly increasing number of lots to achieve the target run-out value for all products.

Production Time Required As the lot size and cycle time vary between the products, the number of lots is perhaps not the most accurate prediction of the effort required to achieve the target value. Here we express the production time needed to make all lots. At some point the total exceeds the capacity of the machines during the planning period, and we know that that target cannot be reached.

Worst Group Utilization We were not discussing the details of the planning process, but one way of checking the production capacity is to identify a group of machines that acts as a bottleneck. In this plot we show the utilization of the bottleneck group for a given target, any value above 100% cannot be achieved. For 32 days, the required utilization is over 90%.

Products Needing Production It is also interesting how many different product we need to produce during the planning period. Initially, there are only three products that require production runs to satisfy the safety stock constraint. This value increases rapidly as the target value increases.

Production Runs We have seen that for fast moving products, wee may need more than one run during the planning period to make the needed quantity. The last plot shows use how many runs will be needed over all products.

8 View: Product Level Chart

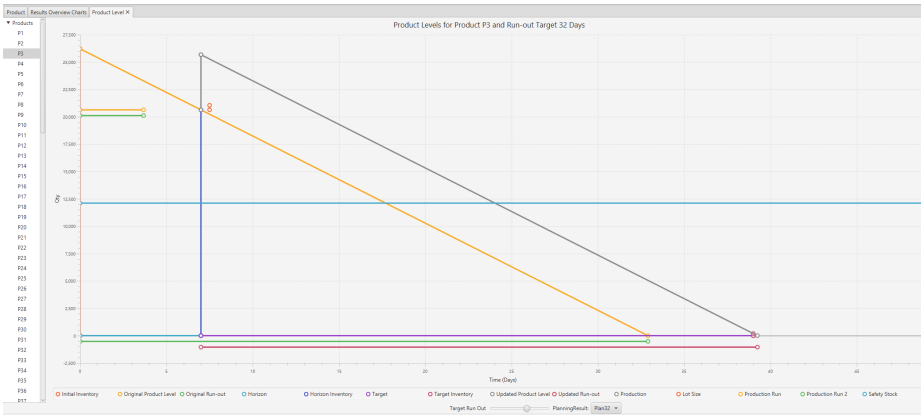

Figure 10: Product Level Chart for Product P3

The product level chart shows the analysis we perform for each of the products. We initially look at a fast moving product, P3.

At the start of the planning period, we have the initial stock for the product. Over time, the stock available drops due to the daily demand. We hit the safety stock level after 17 days, and run out of product completely after 33 days. This is not enough to achieve our target of 32 days after the planning period 7+32 = 39 days.

In order to reach the target, we need to make the product within planning period. The quantity required can be calculated by shifting the consumption curve up to reach the target horizon. The increase compared to the stock at the horizon date gives us the required production during the planning period. As we make each products in lots, we may have to overshoot the required stock a bit to account for an integer number of lots. The size of a lot for this product is indicated on the plot. We also show the production time needed to make the required number of of lots, we also indicate if we need one or multiple production runs.

The display is interactive, as we change the target value with the slider, we see how the target moves in time, resulting in more or less production need for a product. For some products, or when the target is small enough, the need for production disappears completely, we can reach the target value with the initial stock. In that case, we do not ask to make any lots of the product in our plan.

We can see that for each product, we can come up with the way of achieving any wished for run-out target by increasing the number of lots to be made. But when considering all products together, this may require too much production time to fit into the planning period, given the number of machines that are available, and the restrictions on which product can be made on which machines.

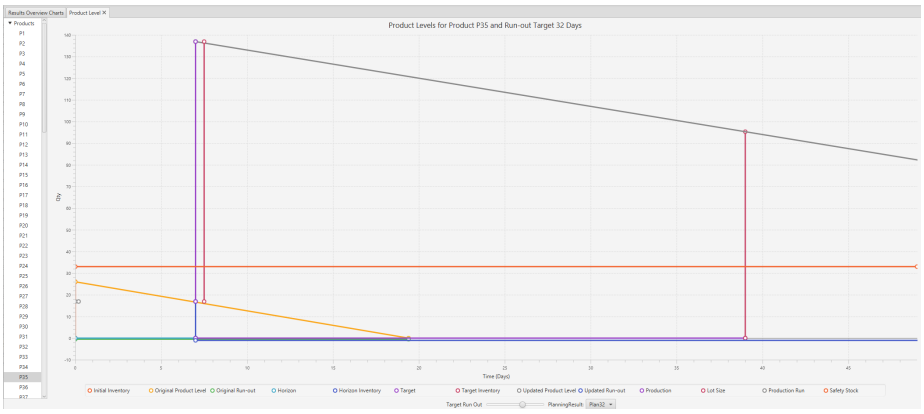

Figure 11: Product Level Chart for Product P35

If we analyze the product levels for the different products, we find some products that require additional attention. If we look at product P35 for example, we see that the initial stock is already below the safety stock level. We plan to make a single lot of this product, as this is enough to push the stock up well beyond the required target run-out date. But we also want to make sure that we achieve the safety stock level as quickly as possible. For the detailed scheduling problem, we set the due date of the production run to the time when the safety stock level is reached. In this case, it will be at time zero. As we cannot start the run before time zero, we will not achieve the safety stock at all

times. But the due date will force this run to be scheduled as early as possible, reducing the time that the safety stock level is not reached.

The planning module has its own capacity model, which we will not discuss in detail. But that capacity model is only an approximation of the actual production capacity of the factory. To really validate the plan, we need to schedule all requested runs on the machines in a detailed schedule. Our tool calls the scheduling tool as a sub-routine to do this, starting with the most promising candidate. If we can find a schedule where all tasks can be produced in the planning period, then that plan is workable and will be published as our result. If the due dates can be achieved, then the safety stock will be satisfied as well, but as we have seen before, this may not be possible for all products.

9 View: Production Runs

Product | Results Overview Charts | Product Level | Scheduled Production Level | ProductionRun ×

Name	Product	NrLots	Qty	Due	Start	End	Duration	StartDay	EndDay
job3_0	P3	6	2,520	10,080	366	5,658	5,292	0.25	3.93
job3_1	P3	6	2,520	10,080	4,712	10,004	5,292	3.27	6.95
job4_0	P4	3	1,260	10,080	0	2,520	2,520	0.00	1.75
job5_0	P5	10	3,500	10,080	1,794	9,844	8,050	1.25	6.84
job6_0	P6	7	2,450	10,080	4,224	9,859	5,635	2.93	6.85
job6_1	P6	8	2,800	10,080	0	6,440	6,440	0.00	4.47
job7_0	P7	1	420	10,080	7,442	8,282	840	5.17	5.75
job8_0	P8	1	350	10,080	816	1,621	805	0.57	1.13
job9_0	P9	1	420	10,080	3,282	4,164	882	2.28	2.89
job10_0	P10	2	840	10,080	0	1,764	1,764	0.00	1.23
job11_0	P11	1	420	10,080	6,500	7,382	882	4.51	5.13
job12_0	P12	1	350	10,080	1,651	2,456	805	1.15	1.71
job13_0	P13	3	960	10,080	0	2,208	2,208	0.00	1.53
job14_0	P14	4	1,728	10,080	0	3,632	3,632	0.00	2.52
job15_0	P15	1	336	10,080	2,580	3,252	672	1.79	2.26
job17_0	P17	1	420	10,080	5,718	6,558	840	3.97	4.55
job18_0	P18	9	3,024	10,080	3,144	9,192	6,048	2.18	6.38
job20_0	P20	1	480	10,080	3,692	4,652	960	2.56	3.23
job23_0	P23	7	2,520	10,080	2,516	8,312	5,796	1.75	5.77
job26_0	P26	1	360	10,080	0	756	756	0.00	0.53
job35_0	P35	1	120	0	0	276	276	0.00	0.19
job36_0	P36	4	1,344	10,080	6,618	9,306	2,688	4.60	6.46
job44_0	P44	1	360	10,080	2,298	3,054	756	1.60	2.12
job46_0	P46	1	350	10,080	8,372	9,177	805	5.81	6.37
job51_0	P51	1	140	6,064	0	630	630	0.00	0.44
job53_0	P53	5	2,520	10,080	707	3,732	3,025	0.49	2.59
job55_0	P55	1	441	10,080	2,580	3,608	1,028	1.79	2.51
job56_0	P56	4	2,016	10,080	7,218	9,638	2,420	5.01	6.69
job58_0	P58	2	840	10,002	3,668	5,626	1,958	2.55	3.91
job59_0	P59	1	420	10,080	464	1,023	559	0.32	0.71
job63_0	P63	1	490	10,080	0	652	652	0.00	0.45
job77_0	P77	1	336	10,080	0	404	404	0.00	0.28
job78_0	P78	1	588	10,080	0	647	647	0.00	0.45

Figure 12: Production Runs for Validated Schedule

When we have run the detailed schedule, we import the information about

the schedule of the production runs back into the planner. This gives us the list of the production runs, which show the start and end dates that were set in the scheduler for each run. We can compare this to the due dates of the runs, which were set to achieve the required safety stock for the product in the planning period.

10 View: Production Level Chart

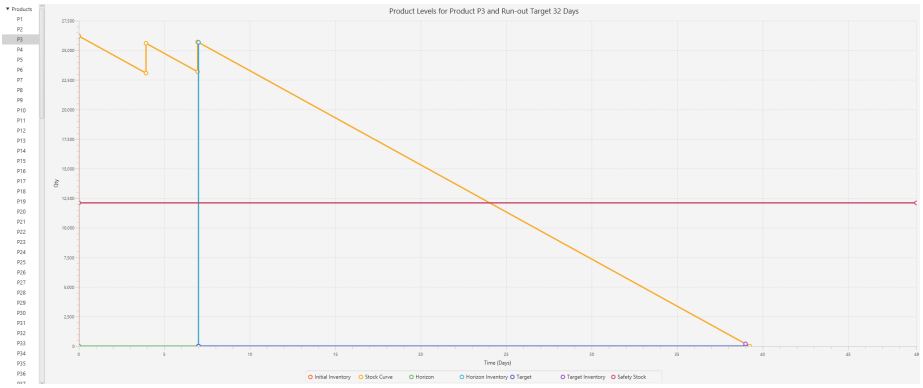

Figure 13: Production Level Chart for Product P3

We can visualize the stock levels of each product in the validated schedule, we here see the chart for product P3. The plot is very similar to the chart of the product levels used in the planning process, but now shows how the stock level increases at the end of each production run with the full quantity produced. The plot shows that we now reach the target run-out date for this product, while also satisfying the safety stock level during hte planning period.

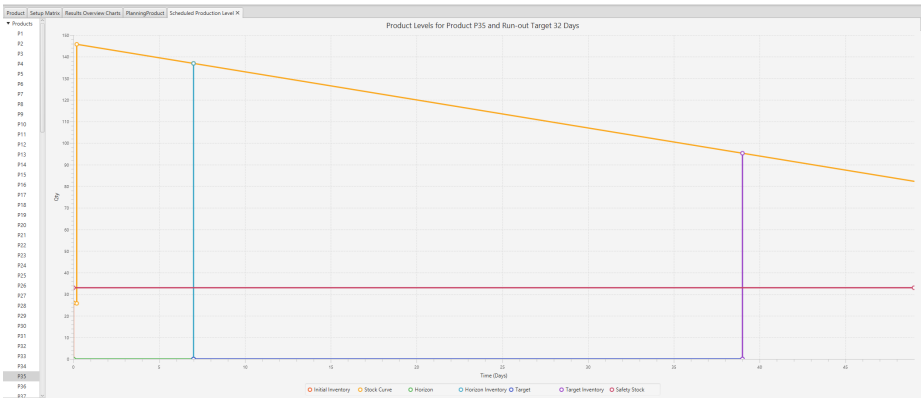

Figure 14: Production Level Chart for Product P35

If we select product P35 in the tree view on the left, we see the production level chart for that product. The initial stock is below the safety level, but we make one lot immediately at the start, that quantity is large enough to provide

stock for much longer than our target rout-out date, as the daily demand is quite low.

11 Detailed Schedule

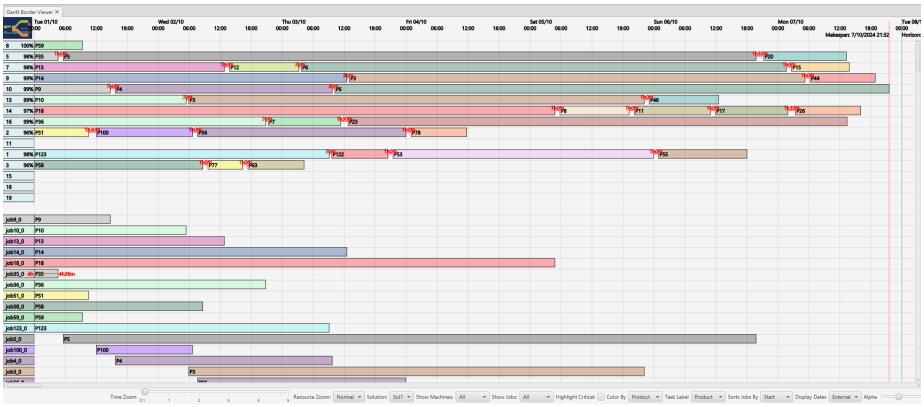

Figure 15: Detailed Schedule for Target 32 Days

In the planning application itself, the scheduling tool is running as a subroutine, with data and results exchanged between planner and scheduler without human intervention. But we can also look at the schedule results inside the scheduling tool. If we look at the Gantt chart of the validated schedule for the 32 day target, we can see the production runs scheduled on the machines, and the initial jobs being scheduled. Each job only consists of a single task, the production run itself, which makes the required number of lots.

In the Machine Gantt at the top, we see the production runs together with the setup time needed between the tasks. All tasks finish before the end of the planning horizon, and only one task does not achieve its due date. For P35, the due date is zero, as the stock is already below the safety level at the start of the planning period. We schedule the required production run as early as possible, but the end of the run cannot be at time zero, so that order is late.

We see that some machines are not utilized at all in this schedule, we do not need a production run of any of the products that can use these machines. On the other hands, many machines are utilized more than 90%, as predicted by the production planning tool. If we select a task on one of those machines, for example one of the runs of product P3 *(Figure 16)*, the system highlights the alternative machines on which this task could be run. We see that all the alternatives are also highly utilized, indicating that these machines form a production bottleneck in the factory.

The result means that this is a valid schedule. We can further optimize the schedule by trying to find a better solution, by selecting a slightly different objective function, but we will not explore this here.

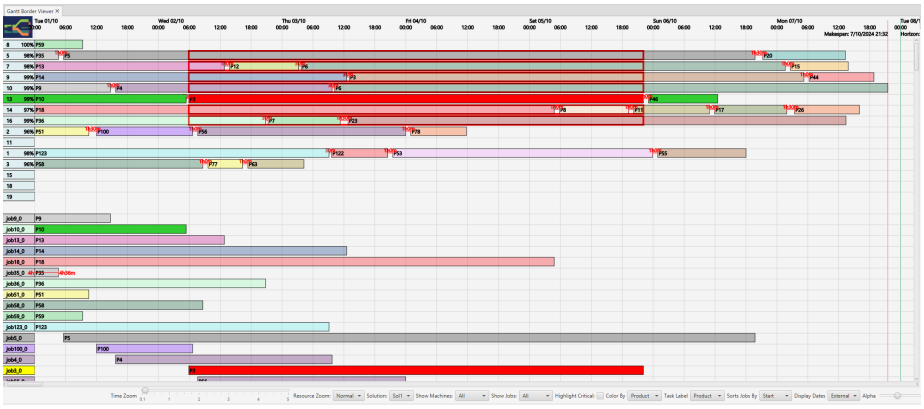

Figure 16: Alternative Machines for Production Run of Product P3

Summary

- We demonstrated the use of our scheduling tool inside a production planning problem from industry
- Production planning decides which products to make in which quantity
  - Balance stock levels against projected demand
  - Allow for product specific safety stock levels
- Uses estimate of production capacity over planning horizon
- Use detailed scheduling to validate plan

ENTIRE EDIH Production Scheduling Slide 5

Figure 17: Summary Slide

12 Summary Slide

In this demonstration of a industrial use case, we have shown how the scheduling tool can help to solve a production planning problem from industry. The overall solution consists of two parts.

- The production planning part decides which products to make in which quantity, by analyzing the stock levels of each product, and the required demand for the product over time. The capacity model of the planner can identify a promising production plan.
- The scheduling tool is used to validate the plan by generating a detailed schedule satisfying all constraints of the factory. If we find a feasible solution, then the generated plan is valid. If we do not find a solution, then we need to relax some constraints or reduce the desired target run-out value.