INDUSTRIAL ENGINEERING
SPRING 2022

ENGINEERING CO-OP
WITH
FEDEX SUPPLY CHAIN

FINAL REPORT

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1. Background

FedEx Supply Chain (FSC) is one of the biggest 3PL organizations in the United States that operates under the corporate name FedEx Corporation. A major part of its revenue comes from serving/accommodating warehouse operations owned by third part companies and Bayer AG is one such organization that chose FedEx Supply Chain to run their warehouse.

Bayer is one of the world's leading pharmaceutical companies and requires massive distribution centers to store/ship the product to their customers and the geographical location of the distribution center is an extremely crucial factor that impacts their net revenue. Bayer owned and FSC operated warehouse located in New Galilee, PA was up and running until June 6th, 2022, when Bayer and FSC started distribution of same product from a new warehouse at Saxonburg, PA which is located 37 miles from the previous site at New Galilee. The business analytics that lead to this strategic decision by Bayer's leadership team to change the warehouse was kept confidential but having it just next to their manufacturing facility from where the products come certainly hinted FSC leadership that Bayer is trying to save on their time and transportation money.

Rest of this report describes various ways in which I contributed to setup/go-live at the new warehouse and showcases different Operations Research techniques and Data analytics tools that I have used for betterment of work quality and keeping in mind the consequences of my work's final output on future operations.

2. Product transition

2.1 Cubiscanning for case dimensions

The goal of this project is to calculate total number of truckloads it would take to transfer all the product from old warehouse and manufacturing facility to new warehouse. This number is very crucial to plan the truck arrivals (at Saxonburg) and departures (from New Galilee) as we need to schedule trucks a week in prior to the shipping date.

The new warehouse at Saxonburg consists of a little over 12500 racking positions and the products come as single/multiple units packed in a single carton box and many such boxes are wrapped on pallets. Every box on a pallet has the same SKU as they all hold same number of units of same product. This is a packaging standard Bayer follows to not reinvent the wheel with their packaging machines for every new piece of order. The size of the boxes, the number of units each box would hold and height to which they are packed is different on different pallets. So, when given a SKU and asked to find how many pallets it would take to hold a specific number of units associated with that SKU one needs two pieces of information, 'units per box' and 'boxes per pallet'.

This information can be found in the warehouse management system database but unfortunately for FSC it was reported that the data was inaccurate and cannot be used to calculate the truckload count. Also, number of boxes on a full pallet cannot be counted manually as the boxes/units were already being picked and one would never see a fully stacked pallet for a particular SKU. (Figure 01)

Hence a manual attempt was made using Cubiscan (Figure 02) to calculate box dimensions from which I was able to determine maximum boxes that could fit on a pallet by modelling a binary linear program using Gurobi/Python. (Appendix 01). Cubiscan is a 3D dimensioning device that automatically populates to an excel file the dimensions and weight of a box when placed on it.

Figure 01 Pallet that has its SKU being picked

Figure 02 Cubiscan model 100

2.2 Transition plan

After executing the master data collection plan (Table 01) together from the Cubiscan and Optimization program the total pallet count that takes to fit given (from Bayer) number of units of a SKU was calculated. Every truck that had been scheduled was of an LTL (Large Truck Load) capacity which could fit 30 pallets. The total number of trucks calculated to ship a category of SKU called the SD (Sterile Disposal) low runners was 46 which upon actual execution took 47 truck loads.

(Table 01) shows the master data collection set for 4 SKUs as an example. Originally the master data file has more than 1300 rows (SKUs) of data and python data science libraries, Pandas and NumPy were extensively used to handle/clean and calculate the total truckloads for SKUs of different individual categories.

All units are in inches

SKU	EM/SD	SKU Description	Length	Width	Height	Weight	Volume	fit	levels	total boxes that could fit	total units that could fit
86698242	SD	STLNT,KIT,SYR,CT,SNGL,60",SPK,MC,WLD	22.7	14.9	14.3	18.5	4836.689	5	4	20	1000
86660512	SD	ASSY,TBG,SWAB VALVE,TNSFR SET,MC,WLD	13.91	10.41	9.01	2.95	1301.04	11	6	66	3300
60729393	SD	SYRINGE KIT, PACKAGED,150FT,M7,MC	11.71	11.61	11.91	9.1	1615.068	12	5	60	1500
86566621	SD	ASSY,TBG,SAS,SPIKE,T-CONN, MC,WLD	20.71	15.81	12.91	10.2	4219.074	5	4	20	400

Table 01 Master dataset that shows cubiscanned dimensions of different SKUs and box placement attributes

(Table 02) shows the SKUs and total number of units Bayer wanted to move to new facility (usually all available units) and total pallets it would take to hold those units which was calculated with information from Table 01. Now with total pallet information, truckloads could be calculated as we know that 30 pallets fit in a truck.

SKU	# Units to move	Total pallets
86698242	502550	506
86660512	185555	57
60729393	1250	1
86566621	8740	22

506 + 57 + 1 + 22 = 586 Pallets
= (586/30) Truck loads

Table 02 Shows number of units to move to new facility and total pallets it would take to fit them all

3. Outbound automation

The goal of this project is to validate an outbound conveyor at the new facility by performing and passing all checklist items/tests each resembling daily operations performed on the conveyor. My role was to coordinate with vendors to schedule the conveyor shipment, installation and validation, ensuring that testing/validation on test/dupe server resembled daily operations right from the point on backend where the WMS (warehouse management system) pick location assignment would generate and as exactly how FSC General Manager intended it to be when operated on production server. Some scenarios were tested by intentionally inducing a wrong methodology or an error by engineering team on the conveyor and check if it responds back to that error. (Figure 03) shows the conveyor and (Figure 04) shows key functioning equipment of the conveyor.

Figure 03 Outbound conveyor

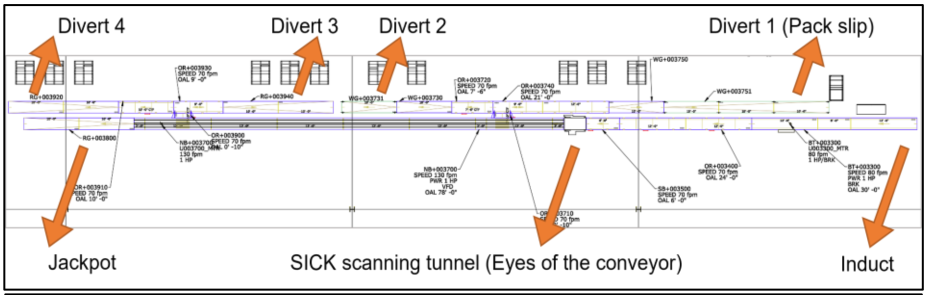


Figure 04 Outbound conveyor drawing with 4 diverts, an induct and a jackpot

4. General automation equipment and warehouse keeping.

A part of my duty also made me responsible for installation of a couple of automation equipment and house keeping items. This was accomplished through the help of vendors and FSC labor's co-operation. Created punch list items associated with warehouse construction and facility layout (Figure 05). Data wrangling and munging (cleaning) for location master file of the warehouse (Figure 06). Extensive use of Cubiscan inspired me to create a Cubiscan work instruction manual for future operators to use (Figure 07). Accommodated vendors with required tools/machinery and manpower to install Stretch Wrapper (Figure 08).

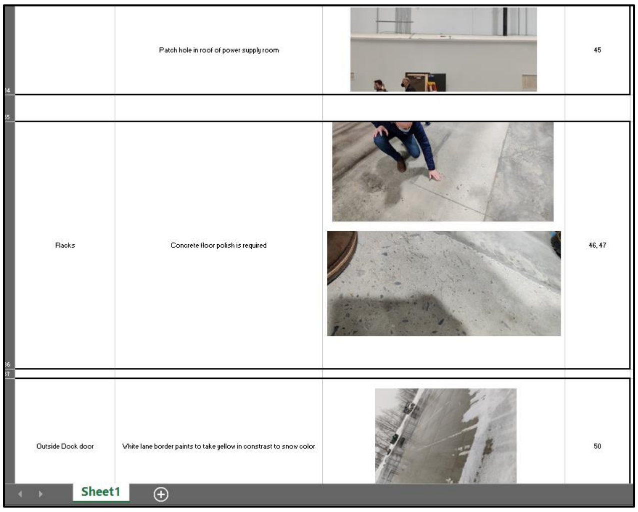


Figure 05 Snapshot of excel file with punch list/rework items

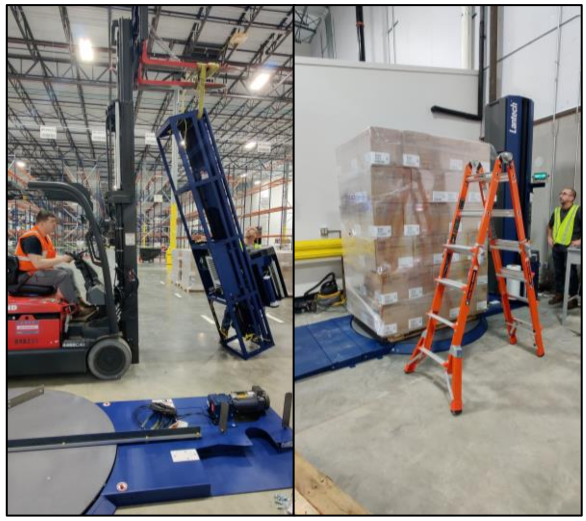


Figure 08 Shows stretch wrapper being setup with forklift

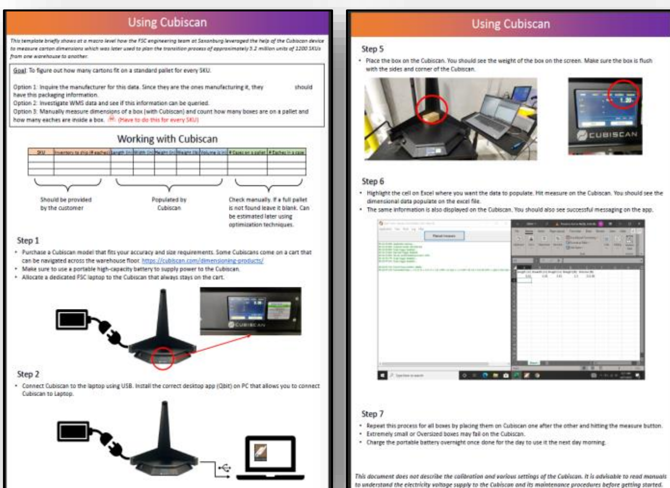


Figure 07 Snapshot of Cubiscan work instructions

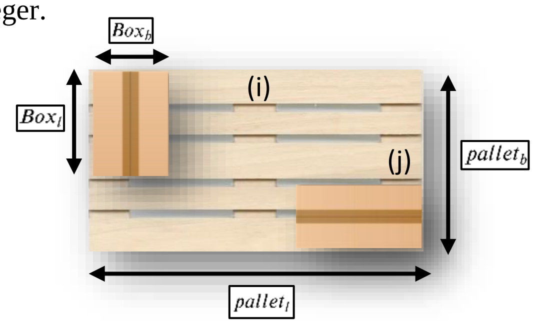
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	BU	Area	Zone	Aisle	Bay	Level	Position	Location Barcode	Display Location	Check Digit	Location Type	Disabled Location (YES/NO)	Rack Elevation Type	Even/Odd (True) Bay	Reserve/Case Pick/Active Pick	Work
2	BAYER	W	R7	300	002	A	01	WR7300002A01	300-002-A01	1P	SD RESERVE		A	FALSE	Reserve	RS
3	BAYER	Q	RS	101	001	A	01	QRS101001A01	101-001-A01	E0	RETAINS PALLET LOCATION	NO	A	TRUE	Reserve	QU
4	BAYER	W	R7	300	002	A	02	WR7300002A02	300-002-A02	4F	SD RESERVE		A	FALSE	Reserve	RS
5	BAYER	W	R3	102	001	A	01	WR3102001A01	102-001-A01	B6	SD RESERVE		A	TRUE	Reserve	QU
6	BAYER	W	R7	300	002	A	03	WR7300002A03	300-002-A03	1I	SD RESERVE		A	FALSE	Reserve	RS
7	BAYER	W	R3	102	001	A	02	WR3102001A02	102-001-A02	5B	SD RESERVE		A	TRUE	Reserve	QU
8	BAYER	W	R7	300	002	B	01	WR7300002B01	300-002-B01	4Z	SD RESERVE		A	FALSE	Reserve	RS
9	BAYER	Q	RS	101	001	A	02	QRS101001A02	101-001-A02	W5	RETAINS PALLET LOCATION	NO	A	TRUE	Reserve	QU
10	BAYER	W	R7	300	002	B	02	WR7300002B02	300-002-B02	0N	SD RESERVE		A	FALSE	Reserve	RS
11	BAYER	W	R3	102	001	A	03	WR3102001A03	102-001-A03	H5	SD RESERVE		A	TRUE	Reserve	QU
12	BAYER	W	R7	300	002	B	03	WR7300002B03	300-002-B03	6D	SD RESERVE		A	FALSE	Reserve	RS
13	BAYER	W	R3	102	001	B	01	WR3102001B01	102-001-B01	6V	SD RESERVE		A	TRUE	Reserve	QU
14	BAYER	W	R7	300	002	C	01	WR7300002C01	300-002-C01	8S	SD RESERVE		A	FALSE	Reserve	RS
15	BAYER	Q	RS	101	001	A	03	QRS101001A03	101-001-A03	G6	RETAINS PALLET LOCATION	NO	A	TRUE	Reserve	QU
16	BAYER	W	R7	300	002	C	02	WR7300002C02	300-002-C02	4Y	SD RESERVE		A	FALSE	Reserve	RS
17	BAYER	W	R3	102	001	B	02	WR3102001B02	102-001-B02	K9	SD RESERVE		A	TRUE	Reserve	QU
18	BAYER	W	R7	300	002	C	03	WR7300002C03	300-002-C03	0P	SD RESERVE		A	FALSE	Reserve	RS
19	BAYER	W	R3	102	001	B	03	WR3102001B03	102-001-B03	3F	SD RESERVE		A	TRUE	Reserve	QU
20	BAYER	W	R7	300	002	D	01	WR7300002D01	300-002-D01	1M	SD RESERVE		A	FALSE	Reserve	RS
21	BAYER	Q	RS	101	001	B	01	QRS101001B01	101-001-B01	X1	RETAINS PALLET LOCATION	NO	A	TRUE	Reserve	QU
22	BAYER	W	R7	300	002	D	02	WR7300002D02	300-002-D02	4K	SD RESERVE		A	FALSE	Reserve	RS

Location Master | Reserve Breakdown | ZONES AND LOGIC | ACTIVE PICK PATH | CASE PICK PATH | RESERVE PICK F ...

Figure 06 Shows a snapshot of master location excel file

5. Appendix 01: Binary linear program to fit maximum possible boxes on a pallet

A standard pallet is 48 ($pallet_l$) x 40 ($pallet_b$) x 60 when measured in inches and dimension of a box is different for different SKUs. Box edge is not allowed to overhang from pallet edge even by an inch and the top face of the box always comes facing upward which makes this optimization program a 2D model. Both decision variables are binary, and every other variable is a positive integer.



Sets

$$\mathcal{I} = 1, 2, \ldots, \lfloor pallet_l / Box_b \rfloor$$

$$\mathcal{J} = 1, 2, \ldots, \left\lfloor \frac{pallet_b}{Box_b} \right\rfloor$$

Variables

$yl_{i,j}$: Would be 1 if length of box aligns along length of pallet in a slot (i,j), else 0

$yb_{i,j}$: Would be 1 if breadth of box aligns along length of pallet in a slot (i,j), else 0

Constraints

$$\forall\ j \in J\ \forall\ i \in I \quad yl_{i,j} + yb_{i,j} \leq 1$$

In a slot (i,j) a box can sit either along its L or B but not both

$$\forall\ j \in J \quad Box_l \sum_i yl_{i,j} + Box_b \sum_i yb_{i,j} \leq pallet_l$$

$$\forall\ i \in I \quad Box_l \sum_j yb_{i,j} + Box_b \sum_j yl_{i,j} \leq pallet_b$$

Total edge length occupied by boxes when measured along pallet length/breadth should not exceed pallet length/breadth respectively

Objective function

$$\max_{yl,yb} \sum_{i \in I,\ j \in J} yl_{i,j} + \sum_{i \in I} \sum_{j \in J} yb_{i,j}$$

Maximize sum of boxes where breadth aligns with pallet length and breadth aligns with pallet breadth

The output of the program gives out three different results. 'Fit', 'Levels' and position matrix (Figure 09). 'Fit' describes maximum number of boxes that could fit on the pallet without stacking upon levels. 'Levels' indicate number of levels of such arrangements that can be placed one upon the other until total height is not more than 60 inches. The position matrix as shown in (Figure 09) depicts the positional arrangement of the boxes.

Below example with SKU 86698242 (Figure 10) has dimensions as shown in (Table 03) and the program outputs a positional matrix (Figure 09), 'Fit' as 5 and 'Levels' as 4 which brings the 'total boxes that could fit' to 20. 'units that could fit' was later calculated by grabbing 'number of units' information printed on the box label.

SKU	EM/SD	SKU Description	Length	Width	Height	Weight	Volume	fit	levels	total boxes that could fit	total units that could fit
86698242	SD	STLNT,KIT,SYR,CT,SNGL,60",SPK,MC,WLD	22.7	14.9	14.3	18.5	4836.689	5	4	20	1000

All units are in inches

Table 03 Master dataset that shows cubiscanned dimensions of a SKU 86698242 and box placement attributes

Figure 10 Arrangement of SKU 86698242 on pallet

```
i =  1 j =  1 solution =  1.0
i =  1 j =  2 solution =  -0.0
i =  2 j =  1 solution =  -0.0
i =  2 j =  2 solution =  -0.0
i =  3 j =  1 solution =  1.0
i =  3 j =  2 solution =  -0.0
================================
i =  1 j =  1 solution =  0.0
i =  1 j =  2 solution =  1.0
i =  2 j =  1 solution =  0.0
i =  2 j =  2 solution =  1.0
i =  3 j =  1 solution =  0.0
i =  3 j =  2 solution =  1.0
================================
['L', '0', 'L']
['B', 'B', 'B']
5.0
4
```

Figure 09 Positional matrix