NORTHEASTERN UNIVERSITY

School of Engineering

MECHANICAL & INDUSTRIAL ENGINEERING DEPARTMENT

IE7200 Supply Chain Engineering

2ND Take-home Assignment

Instructor: Dr. Cesar Martinez Olvera

Members

Aaditya Gupta 002831774

Problem Statement:

Our task is to develop a Bill-of-Material (BOM) tree for a specific LEGO Truck, which will be provided in the report. The LEGO Truck comprises seven starting components. These components must be distributed across BOM levels 0, 1, 2, and 3.

Additionally, the objective is to determine the Buy cost/Make cost of the LEGO Truck through supply chain optimization. This involves analyzing factors such as Buy cost / Make cost associated with acquiring or producing the components and assembling the truck. The aim is to optimize the supply chain to minimize costs while ensuring timely delivery and meeting quality standards.

Parameters:

• Develop a Bill-of-Material (BOM) tree for the LEGO Truck that you selected to build:
• Make sure that your BOM uses seven (7) starting components.
• Distribute those seven (7) starting components in BOM levels 0,1,2 or 0,1,2,3.

For each of the items present in the developed BOM tree, calculate the Make cost, using.
the following data:

• Element cost:
o in Level 3 ➔ $1.25/Element
o in Level 2 ➔ $3/ Element
o in Level 1 ➔ $5/ Element
• Assy Operation:
o in Level 3 ➔ $2.5/Assy Operation
o in Level 2 ➔ $5/Assy Operation
o in Level 1 ➔ $7.5/Assy Operation
• Assy Operation cost at any St i:
o in Level 3 ➔ $5/Assy Operation
o in Level 2 ➔ $10/Assy Operation
o in Level 1 ➔ $25/Assy Operation
• Buy cost:
o in Level 3 ➔ 80% of the calculated Make Cost, i.e., if the calculated Make Cost of a Component is $5, then the Buying Cost = 0.8 * 5 = $4
o in Level 2 ➔ 115% of the calculated Make Cost, i.e., if the calculated Make Cost of a Component is $20, then the Buying Cost = 1.15 * 20 = $23
o in Level 1 ➔ 90% of the calculated Make Cost, i.e., if the calculated Make Cost of a Component is $60, then the Buying Cost = 0.9 * 60 = $54
o in Level 0 ➔ 120% of the calculated Make Cost, i.e., if the calculated Make Cost of a Component is $120, then the Buying Cost = 1.2 * 120 = $144

Bill of Materials:

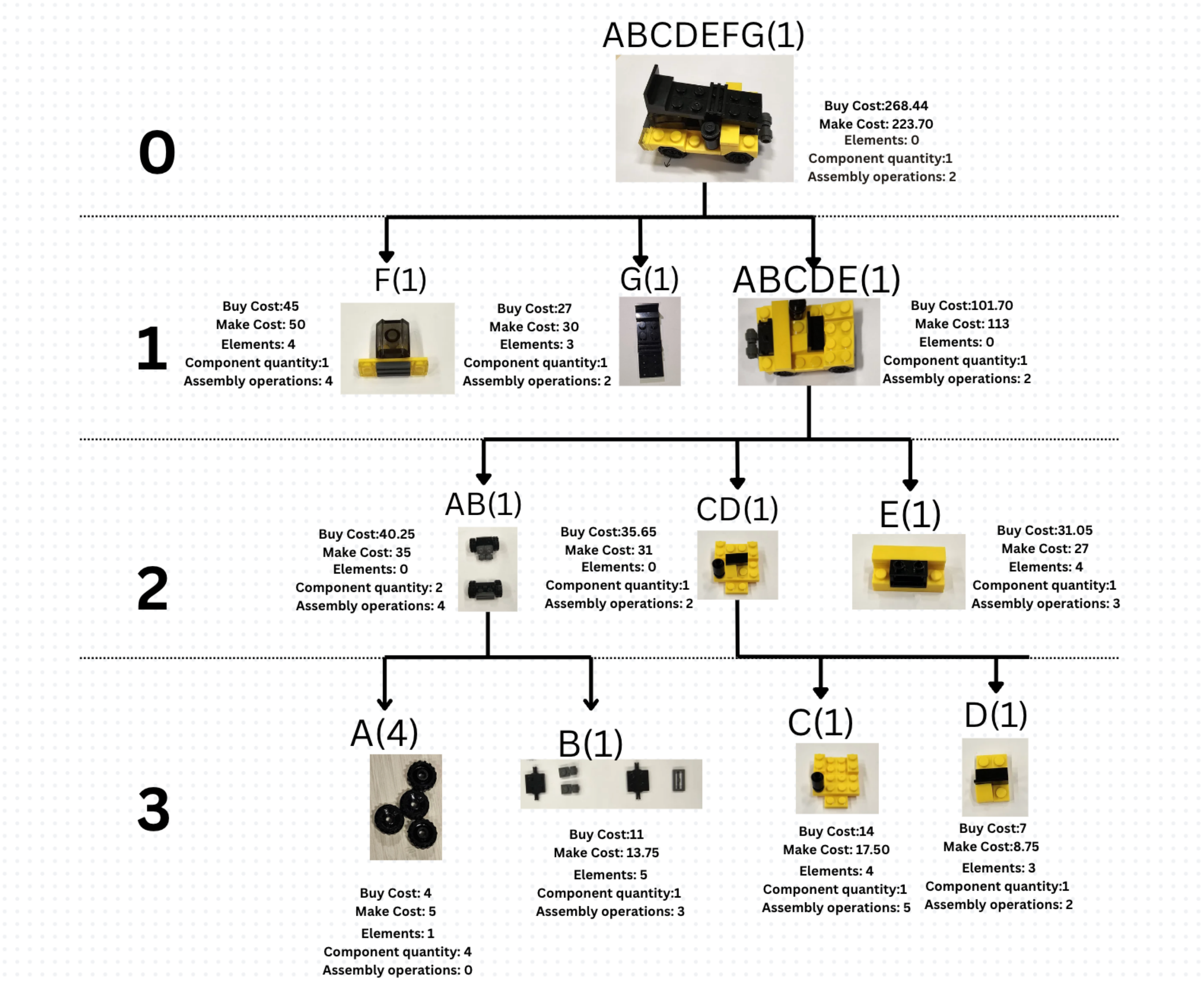

Fig: 1 Bill of Material of the Lego Truck

The Bill of Materials (BOM) presented outlines the hierarchical structure of components required for the assembly of a complex product, identified as ABCDEFG (1). The BOM is organized into four levels, demonstrating the breakdown from complete products to basic components necessary for assembly. At the top level (Level 0), the complete product ABCDEFG (1) is listed with its associated costs. This initial breakdown leads to Level 1, where the product is divided into its primary sub-components: F (1), G (1), and ABCDE (1), each with specified costs and attributes related to their procurement and assembly.

Moving further down, Level 2 breaks these sub-components into smaller parts: AB (1), CD (1), and E (1), highlighting the continuing specificity in the assembly process. Finally, at Level 3, the focus is on the base components required for the construction of the product, including A (4), B (1), C (1), and D (1). These components represent the most fundamental elements used in the manufacturing process, each detailed with their respective buy and make costs, as well as the quantities needed. This hierarchical organization facilitates a clear understanding of the product's structure and the relationships between its parts, aiding in efficient assembly and inventory management.

Assembly Line Layout:

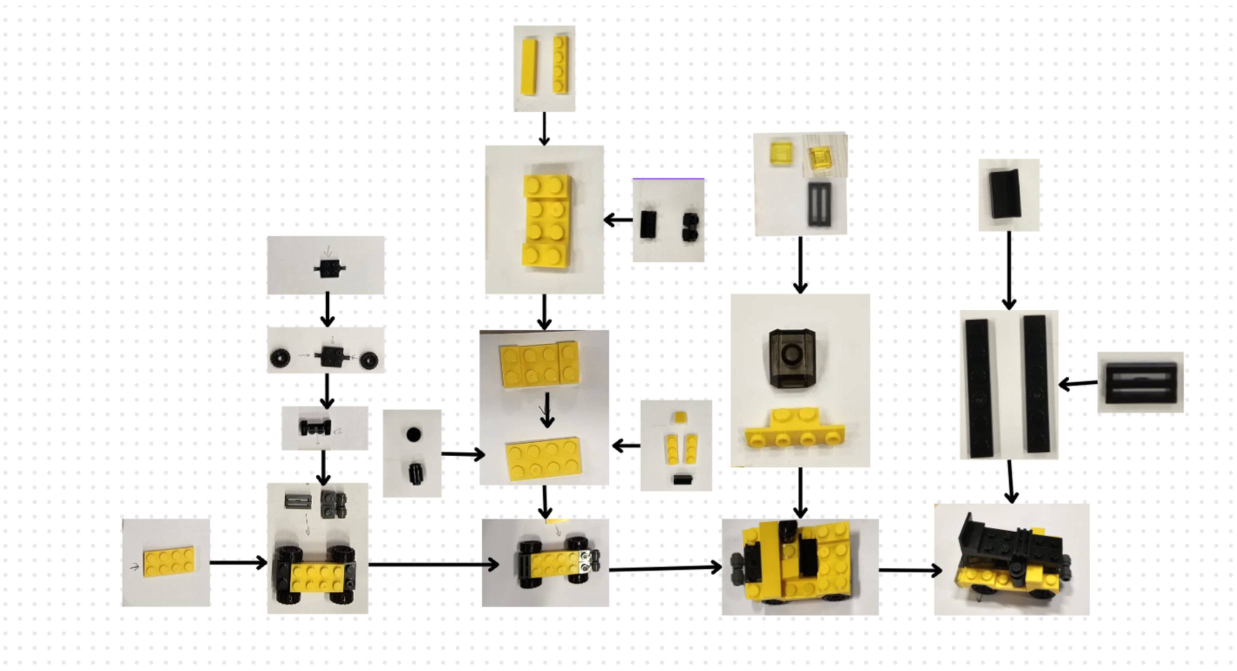

Fig: 2 Assembly Line Layout of the Lego Truck

The above image is a detailed representation of an assembly line of the Lego truck that we are building, to illustrate the fundamental concepts of manufacturing and production processes. It is laid out in a sequential format, employing construction blocks like LEGO to depict the incremental steps involved in assembling a complex product from simpler components.

The image illustrates a step-by-step assembly line layout using construction or building blocks like LEGO. It demonstrates the process of manufacturing a complex object from individual parts. The schematic layout visualizes the flow and progressive assembly stages, from simple initial components to the final assembled product, guided by directional arrows. This process is used to explain manufacturing principles, showcasing the importance of efficiency and systematic processing in assembly line production.

Buy cost / Make cost Table:

LEVEL 3									
Component	Qty.	# Elements	# Assy Operations	Raw Material Cost	Total	Assy Operation Cost	Total	Make Cost Total	Make Cost Total/Component
A	4	1	0	1.25	5	2.5	0	5	1.25
B	1	5	3	1.25	6.25	2.5	7.5	13.75	13.75
C	1	4	5	1.25	5	2.5	12.5	17.5	17.5
D	1	3	2	1.25	3.75	2.5	5	8.75	8.75
LEVEL 2									
Component		# Elements	# Assy Operations	Raw Material Cost	Total	Assy Operation Cost	Total	Make Cost Total	Make Cost Total/Component
AB	1	NA	4	NA		5	20	20	20
CD	1	0	2	NA		5	10	10	10
E	1	4	3	3	12	5	15	27	27
LEVEL 1									
Component		# Elements	# Assy Operations	Raw Material Cost	Total	Assy Operation Cost	Total	Make Cost Total	Make Cost Total/Component
ABCDE	1	NA	2	NA		10	20	20	20
F	1	4	4	5	20	7.5	30	50	50
G	1	3	2	5	15	7.5	15	30	30
LEVEL 0									
Component		# Elements	# Assy Operations	Raw Material Cost	Total	Assy Operation Cost	Total	Make Cost Total	Make Cost Total/Component
ABCDEFG	1	NA	2	NA		25	50	50	50

Fig: 3 Make cost table of the Lego Component

Buy Cost calculated based on per component make cost and adding assembly operations to component B

LEVEL 3		Buy		Make					
Component	Qty.	Cost	Total	Cost	Total	Minimum	Decision		
A	4	1.00	4.00	1.25	5.00	4.00	Buy A	36.00	==> ABCD
B	1	11.00	11.00	13.75	13.75	11.00	Buy B		
C	1	14.00	14.00	17.50	17.50	14.00	Buy C		
D	1	7.00	7.00	8.75	8.75	7.00	Buy D		
LEVEL 2		Buy		Make					
Component		Cost	Total	Cost	Total	Minimum	Decision		
AB	1	40.25	40.25	20.00	35.00	35.00	Make AB	93.00	==> ABCDE
CD	1	35.65	35.65	10.00	31.00	31.00	Make CD		
E	1	31.05	31.05	27.00	27.00	27.00	Make E		
LEVEL 1		Buy		Make					
Component		Cost	Total	Cost	Total	Minimum	Decision		
ABCDE	1	101.70	101.70	20.00	113.00	101.70	Buy ABCDE	173.70	==> ABCDEFG
F	1	45.00	45.00	50.00	50.00	45.00	Buy F		
G	1	27.00	27.00	30.00	30.00	27.00	Buy G		
LEVEL 0		Buy		Make					
Component		Cost	Total	Cost	Total	Minimum	Decision		
ABCDEFG	1	268.44	268.44	50.00	223.70	223.70	Make ABCDEFG		

Fig: 4 Buy cost calculation based on the Make cost table of the Lego Component

Linear Programming: (One Period MRP Problem)

Notations:

M = Make
B = Buy
MP = Make Price
BP = Bought Price
NEED = Demand =. 100
MM = Materials made
MB = Materials bought
MMP = Materials make price
MBP = Materials buy price
SMM = Number of Sub materials made
SMB = Number Sub materials bought
SMP = Sub materials make price
SBP = Sub materials bought price
TMM = Number of Tertiary materials made
TMB = Number of Tertiary materials bought
TMP = Tertiary materials make price
TBP = Tertiary materials bought price
MATREQ = Materials required
SMATREQ = Sub-materials required
TMATREQ = Tertiary materials required

LINGO Code:

```
MODEL:
SETS:
  TYPES/L/: M, B, MP, BP, NEED;
  MATERIALS/F,G,ABCDE /: MM, MB, MMP, MBP;
  SUBMATS/AB,CD,E /:SMM, SMB, SMP, SBP;
  TMATS/A,B,C,D/:TMM, TMB, TMP, TBP;
  REQ(TYPES, MATERIALS): MATREQ;
  MREQ(MATERIALS, SUBMATS): SMATREQ;
  TREQ(SUBMATS, TMATS): TMATREQ;
 ENDSETS
 DATA:
  NEED    = 100;
  MP      = 223.70;
  BP      = 268.44;
  MMP     = 50 30 113;
  MBP     = 45 27 101.70;
  SMP     = 35 31 27;
  SBP     = 40.25 35.65 31.05;
  TMP     = 5 13.75 17.50 8.75;
  TBP     = 4 11 14 7;
```

```
 MATREQ = 1 1 1 ;
 SMATREQ = 0 0 0
           0 0 0
           1 1 1;
 TMATREQ = 4 1 0 0
           0 0 1 1
           0 0 0 0;
ENDDATA
```

The above section of the report outlines a comprehensive linear programming framework aimed at optimizing decision-making in production and procurement. The framework includes constructs such as 'TYPES' to represent choices between manufacturing or purchasing and their respective costs; 'MATERIALS', 'SUBMATS', and 'TMATS' to categorize various levels of materials, detailing their production and purchasing parameters; and 'REQ' matrices, which connect these components by defining the necessary quantities of each material for production. The 'DATA' segment provides actual values for variables like demand, pricing, and material needs. The goal of the model is to minimize total costs while ensuring demand and material requirements are met across all levels, presenting a systematic approach to managing resources within the supply chain or production planning.

```
MIN = @SUM(TYPES: M * MP + B * BP)
   + @SUM(MATERIALS: MM * MMP + MB * MBP)
   + @SUM(SUBMATS: SMM * SMP + SMB * SBP)
   + @SUM(TMATS: TMM * TMP + TMB * TBP);
 @FOR (TYPES: M + B = NEED);
 @FOR (MATERIALS (I): MM (I) + MB (I) = @SUM (TYPES (J): M(J) * MATREQ(J, I)));
 @FOR (SUBMATS (I): SMM(I) + SMB(I) = @SUM (MATERIALS (J): MM(J) *
SMATREQ(J, I)));
 @FOR (TMATS (I): TMM(I) + TMB(I) = @SUM (MATERIALS (J): MM(J) * TMATREQ(J,
I)));
END
```

In this section of the model, the objective function aims to minimize the total cost, calculated as the sum of the costs of types (manufactured and bought), materials, sub-materials, and tertiary materials, each weighted by their respective prices. Constraints ensure that production and procurement align with demand: the total manufactured and bought must meet the set demand for types, materials must satisfy the demands derived from types, sub-materials from materials, and tertiary materials from sub-materials, thereby ensuring a comprehensive alignment from top-tier needs to base materials. This structure provides a holistic approach to minimizing expenses while adhering to production and supply requirements, enabling efficient resource allocation across the supply chain.

Lingo Output

```
Global optimal solution found.
Objective value:                              22370.00
Infeasibilities:                              0.000000
Total solver iterations:                             0
Elapsed runtime seconds:                          0.07

Model Class:                                        LP

Total variables:                    22
Nonlinear variables:                 0
Integer variables:                   0

Total constraints:                  12
Nonlinear constraints:               0

Total nonzeros:                     54
Nonlinear nonzeros:                  0


                    Variable           Value        Reduced Cost
                       M( L)        100.0000            0.000000
                       B( L)        0.000000            128.9600
                      MP( L)        223.7000            0.000000
                      BP( L)        268.4400            0.000000
                    NEED( L)        100.0000            0.000000
```

Inferences:

The LINGO analysis suggests that producing the composite item 'M' (ABCDEFG) and particular parts such as 'MP' (AB) and 'MP' (E) is more advantageous than purchasing them. This recommendation underscores a strategy that prioritizes in-house manufacturing to enhance cost savings and operational efficiency. It is advised against acquiring components that are not earmarked for in-house production, aligning with a strategy to optimize expenses and production processes.