Project

Okamura Furniture Company

Made by

Jasvitha Buggana

Sahaj Chakka

Introduction to Linear Programming

An optimization problem involves identifying the best potential solution to a problem given certain limitations and a certain goal. Linear programming is a mathematical technique for solving optimization problems with linear objective functions and constraints.

Linear programming is a subset of mathematical programming that is extensively used in industries such as manufacturing, financial services, transportation, agriculture, and energy. It is especially effective when resources are limited, and the goal is to deploy them optimally. It can also be used to solve problems in many different domains, including how to allocate resources, planning of production, managing inventory, portfolio optimization, and many more.

In a linear programming problem, the objective function is a linear function that is either maximized or minimized. Constraints are also linear functions that specify the limitations on the decision variables in a linear programming issue. These limits may relate to available resources, capacities, needs, or additional pertinent considerations.

A linear function has the properties of proportionality, additivity, and divisibility.

- Proportionality implies that the contribution of each given choice variable to the goal develops in proportion to its quantity. When a choice variable twice, its contribution to the goal doubles as well.
- Additivity means that the contribution of a single choice is added to (or sometimes reduced from) the contributions of other choices. We can isolate the contributions that come from each choice variable in an additive function.
- Divisibility denotes the significance of a fractional choice variable. When a decision variable is a fraction, its relevance can still be interpreted for managerial objectives.

Linear programming optimization models can be executed with spreadsheets such as Microsoft Excel. Spreadsheets are a popular tool for modelling and resolving linear programming problems due to their simplicity of use and accessibility. Here are some essential stages for establishing a linear programming model in a spreadsheet:

- **Identify the decision variables:** Proceed by specifying the decision variables that will be used to indicate the problem's decision. These variables can indicate output numbers, resource allocation, or any other significant factor.

- **Identify the objective function:** The quantity to be optimized is represented by the objective function, which can be profit, cost, or utility. It must be written as a linear function of the choice variables.

- **Identify the constraints:** The constraints describe the problem's restrictions or requirements, such as limited resources or capability. They should be stated in terms of the decision variables as linear equations or inequalities.

- **Enter the model into the spreadsheet:** In the spreadsheet, we use appropriate cell references to enter the decision variables, objective function, and constraints. To determine the goal function and restrictions, we use the SUMPRODUCT function or a comparable function.

- **Use the Solver add-in:** To solve the linear programming issue and identify the best solution, use the Solver add-in in Excel. Define the target cell (the objective function cell), the variables that need to be altered (the choice variable cells), and the limitations.

- **Analyse the results:** After the Solver has discovered the best solution, examine the results to ensure they make sense in the context of the problem. It is also critical to assess the solution's sensitivity to changes in the problem's parameters.

In this project, we are using Resource Allocation Optimization Models for determining how to make the greatest use of available but restricted resources to obtain the best results. In strategic planning, resource allocation is a plan for utilizing available resources, particularly soon, to achieve future goals.

Problem Statement:

OKAMURA CORPORATION is a Japanese furniture manufacturer established in Yokohama, Japan. Katsu Toshi Okamura launched the company in 1945 as a modest carpentry studio. It is now a significant maker of office furniture, having a strong presence in Asia, Europe, and the Americas.

Okamura's product line covers a wide selection of office furniture, including chairs, desks, tables, storage solutions, and partitions. The brand is noted for its unique designs, high-quality materials, and ergonomic features that encourage comfort and efficiency in the office.

Okamura Corporation is expanding a new production warehouse at the Tsukuba Plant to meet the increased demand for work booths, office furniture, mobile lockers, and other items in recent years. This will help for the reduction in the use of external warehouses and continuous production through a new plant building.

The new plant is currently under construction and will be opened in the August of 2023 and the operation will be beginning in the November of 2023

Using this data, we found the problem statement to analyse the production quantity of different products to maximize the overall profits coming from that specific plant for next year’s 2 quarters.

In this project, we researched into three most selling products of Okamura Corporation office furniture: Chair-Portone, Work Pods Drape, and Conference Table. Each product requires a varied number of fabrication hours, assembly hours, and manufacturing hours to complete. Also included are raw materials such as melamine, ocean recycled plastic, and die cast aluminium.

Activities	Chair-Portone	Work Pods Drape	Conference Table	Available Resources
Fabrication Hours	4	10	7	3000
Assembly Hours	6	9	5	3000
Production Hours	5	8	4	2500
Raw Materials				Sq. Foot
Melamine	-	32	25	97000
Ocean Recycled Fabric	20	120	-	480000
Die-cast Aluminium	18	80	48	270000

Decision Variables:

Cp = Number of chair-portone produced
Wp = Number of work pods drape produced
Ct = Number of conference tables produced
M = Melamine raw product used
Or = Ocean Recycled Fabric used
Da = Die-cast aluminium used
F = Number of Fabrication hours used
A= Number of Assembly hours used
P = Number of Production hours used
Ppu = Profit per unit
S = Selling price
C = Cost price
Tp = Total profit
Mu = Manufacturing units

Here selling price is the price at which a product or service is sold to customers. It is the amount of money paid by a consumer to the seller for a product or service. Various factors determine the selling price, including production costs, competition, market demand, and profit margins.

Cost price is the price at which a company acquires or produces a product or service. It is the cost incurred by the business to purchase or create the product or service, and it comprises charges such as the cost of raw materials, labour, and overhead costs.

Profit per unit is computed by subtracting the selling and cost prices.

Objective Function:

Our objective function is to maximize the overall profit of different manufactured products. We can mathematically define that as

Ppu = S-C
Tp = Mu * Ppu
Maximize Profit = Σ (Tp)

- As this organization is well established and contributes towards the less carbon food print on this planet, there are some constraints on the Raw materials used and acquiring the raw materials used.
- Okamura corporation uses multiple types of raw products for its broad segment of products ranging from office furniture to the display stalls for retail stores. for this project we are considering the major items such as Melamine, Ocean recycles fabric, Die-cast Aluminium.
- We are considering the production time of 2 quatres of the new year once the operations begin in November 2023.

As the 2 Quarters are 6 months in a year, we have converted the time into number of work hours available and have given those work hours as the constraints for our optimization model.

Our Constraints:

Fabrication hours (F) <= 5000 hrs
Assembly hours (A) <= 5000 hrs
Production hours (P) <= 3500 hrs

As the production starts after the fabrication and the assembly tasks are completed.

The manufacturing process followed by the Okamura is unique and they give a lot of importance to the details and customer experience from the using of their products.

Okamura acquires its major raw material recycled ocean fabric from Camira fabrics based in United Kingdom.
Camira Fabrics recycles the ocean plastic to produce the oceanic fabric which is used by our Okamura.

"For every two kilograms (four metres) of oceanic fabric sold, one kilogram of waste is removed from the ocean," said Camira. "One metre of fabric equates to 26 plastic bottles."

Okamura also uses, Melamine substance.

Melamine is converted from the raw material urea and consists of carbon, hydrogen, and nitrogen. It has become an essential raw material in the global production of synthetic resins. Other major raw material that we are considering is the Diecast Aluminium.

We got the raw materials from the Okamura's product catalogues and we have a budget allocated to the new facility which is being built. From the budget of 11 million we have deducted the price for machinery and building.

These values gave a estimate for how much raw materials can be acquired with available budget and we have also considered the actual wholesale prices of the raw materials in the region of the new facility.

So according to the prices –
Melamine costs $8.5 per Sq. Foot
Ocean recycled fabric $1.2 per Sq. Foot
Die-Cast Aluminium $3.5 per Sq. Foot

We have considered the raw materials acquired in the below quantities.
Our second set of constraints are below, The total mount of raw material used should be less that or equal to available material.

Melamine <= 97000 sq. Foot.
Ocean recycled fabric <= 480000 sq. Foot.
Die-Cast Aluminium <= 270000 sq. Foot.

As our optimization problem is to find the number of items to be manufactured, we cannot have a non-integer value in the optimal quantities.
We have a new constraint of OPTIMAL VALUE should be INTEGER.

Solution:

Now for the optimal solution we load the data in to a excel spreadsheet and perform the analysis through using the solver, solver table.

Once we load the data in and perform the solver with above mentioned constraints, we get the below results.

	Chair-Porton	Work Pods-Drape	Conference Table-NT	Total used	<=	vailable Resources	
Activities							
Fabrication Hours	4	10	7	40640.625	<=	50000	
Assembly Hours	6	9	5	41351.5625	<=	50000	
Production Hours	5	8	4	35000	<=	35000	
Raw Materials							**Price per Square Feet**
Melamine	_	32	25	97000	<=	97000	8.5
Ocean Recycled Fabric	20	120	_	258437.5	<=	480000	1.2
Die-Cast Aluminium	18	80	48	270000	<=	270000	3.5
Manufacturing Quantity	2937.5	1664.0625	1750				
Selling Price	636	2400	1434				
Cost Price	210	750	445				
Profit Per Unit	426	1650	989				
					Objective Function		
Total Profit	1251375	2745703.125	1730750		5727828.125		

Through solver we have found an optimal mix of quantities which need to be produced to get a maximum profit by following our constraints.

If Okamura follows the above-mentioned plan in the manufacturing of the most sold items from the new plant based in Tsukuba it can achieve the maximum profit.

In this model the Objective function is defined in USD for easy understanding, we have taken the effort and changed the prices from Japanese Yen to USD for the Total profit row and objective function cell.

- Now for the main part, we have performed some broad range of possible outcomes and scenarios varying the raw materials and many other constraints.

To perform a general solver analysis if we change the available time to manufacture the complete product to some fixed constraint, we have considered a new order that Okamura is taking up after the new production plant establishment.

There is an order of 50 Work pods to be manufactured for an organization which has a deadline to open their new office in next 1 month.

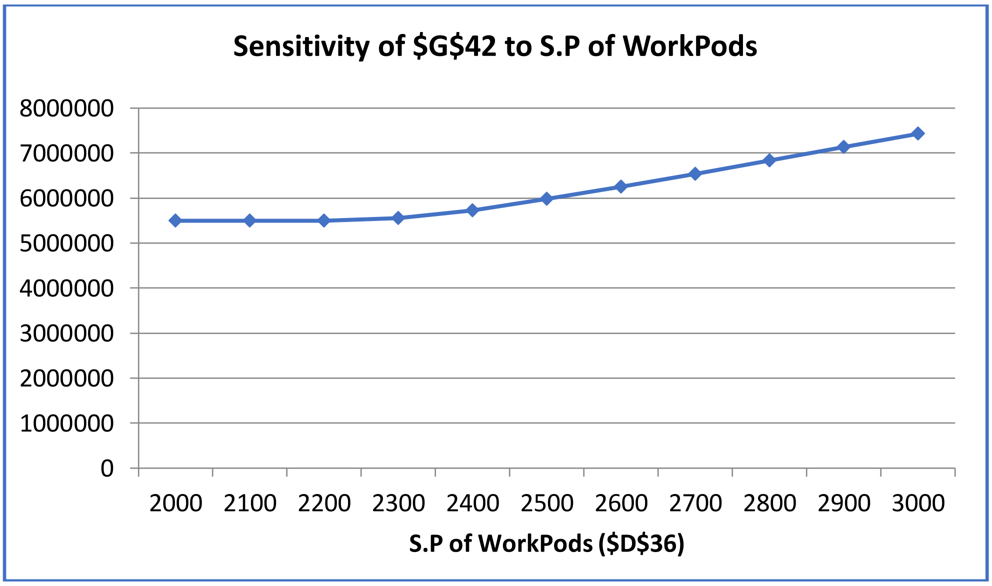
So, we have given a time constraint of 600 hrs which is the time of 1 month time to Okamura to produce 50 work pods.

Using this constraint, we have got the below result.

	Chair-Portone	Work Pods-Drape	Conference Table-NT	Total used	<=	Available Resources	Price per Square Feet
Activities							
Fabrication Hours	4	10	7	587.5	<=	600	
Assembly Hours	6	9	5	512.5	<=	600	
Production Hours	5	8	4	450	<=	450	
Raw Materials							Price per Square Feet
Melamine	_	32	25	1912.5	<=	97000	8.5
Ocean Recycled Fabric	20	120	_	6000	<=	480000	1.2
Die-Cast Aluminium	18	80	48	4600	<=	270000	3.5
Manufacturing Quantity	0	50	12.5				
Selling Price	636	2400	1434				
Cost Price	210	750	445				
Profit Per Unit	426	1650	989				
					Objective Function		
Total Profit	0	82500	12362.5		94862.5		

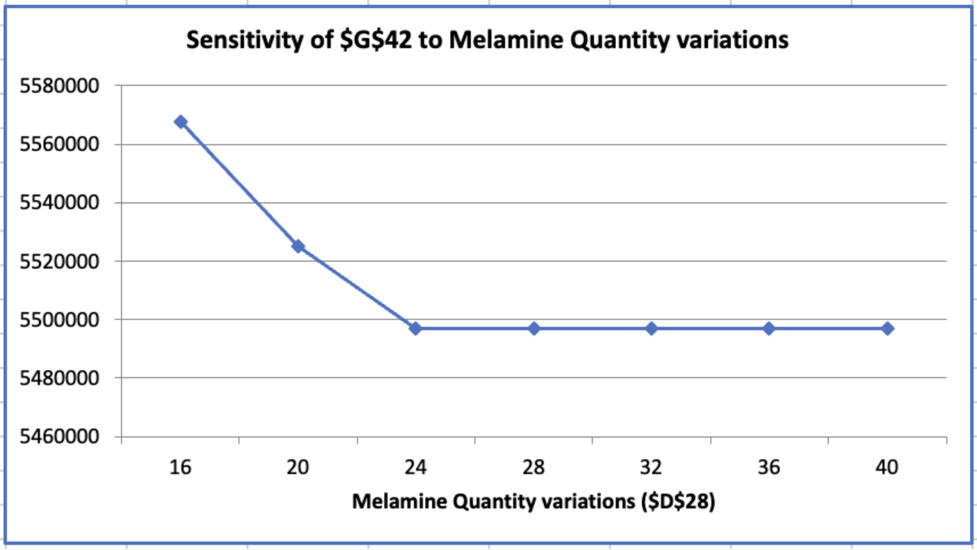
This will result in the optimal profit of $94,862 in a period of 1 month.

Now for the next analysis, we are varying the selling price of work pods to gain the max profit,
We have taken a range of work pod prices ranging from 2000 USD to 3000 USD,
If we perform a solver table analysis on this data, we can observe that increasing in the selling price of work pods results in increase in optimal profit, From the table we can observe that the increase in selling prices of work pods is directly proportional to maximization of profit.



S.P of WorkPods (cell D36) values along side, output cell(s) along top				
	G42	C34	D34	E34
2000	5497016	3896	0	3880
2100	5497016	3896	0	3880
2200	5497016	3896	0	3880
2300	5561421.88	2937.5	1664.0625	1750
2400	5727828.13	2937.5	1664.0625	1750
2500	5981581.25	2525	2746.875	100
2600	6256268.75	2525	2746.875	100
2700	6542643.75	1608.33333	2953.125	100
2800	6837956.25	1608.33333	2953.125	100
2900	7133268.75	1608.33333	2953.125	100
3000	7428581.25	1608.33333	2953.125	100

- As the price of melamine is so high compared to other raw materials so we tried to vary the complexion of melamine used in work pods accordingly varied prices and did sensitivity analysis surprisingly the results are conveying a very reasonable up in profit with less usage of melamine.



So, we found the prices of wood per square feet in the market and replaced the melamine with wood in the Work Pods and Conference Tables as the gradation in price is very high we can even have the luxury of using more quantity of resources. This time with wood the optimization model gave 7125000$. i.e 15% additional profit.

But only Work Pods are suggested by the model, so we gave minimum number of Chair-Portone, Conference table NT to be produced and we observed very little reduction in optimal profit 7113050$.

				Total used	<=	Available Resources	
	Chair-Portone	Work Pods-Dr	Conference Table-NT				
Activities							
Fabrication Ho	4	10	7	38575	<=	50000	
Assembly Hou	6	9	5	35657.5	<=	50000	
Production Ho	5	8	4	31440	<=	35000	
Raw Materials							Price per Square Feet
Ocean Recycl	20	120 _		432100	<=	480000	1.2
Die-Cast Alum	18	80	48	300000	<=	300000	3.5
Wood	_	40	32	147100	<=	150000	4.5
Manufacturin	500	3517.5	200				
Selling Price	636	2400	1434				
Cost Price	210	500	350				
Profit Per Unit	426	1900	1084				
					Objective Function		
Total Profit	213000	6683250	216800		7113050		

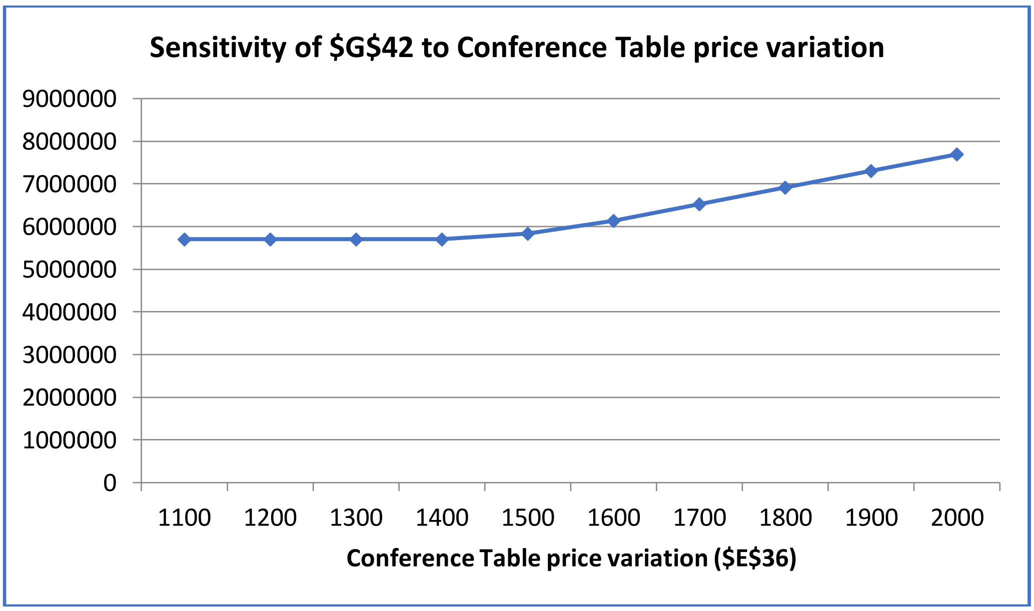
So, we recommend the Okamura enterprise to try wood in place of melamine with a little bit of reduced selling price.

- Now, for the next analysis we are varying the price of the conference table to check if that is the optimal price in giving us the maximum profits from the main model.

We have given a range of price for the conference table ranging from $1300 USD to $1800 USD

When we select the Solver table analysis and perform the action, we will be asked to select an input cell which is our Conference table selling price and the output cell will be our Optimal Profit.

We have got the below result and we have derived some analysis from the obtained report.



From the data we have got in the table we can see that the increase in the conference table price will result in the higher optimal profit and if we are decreasing the price then the optimal profit is being reduced.

Please refer the excel sensitivity analysis for the detailed values for each increment of price.

Input (cell E36) values along side, output cell(s) along top

	G42	C34	D34	E34
1300	5705625	2500	2812.5	0
1350	5705625	2500	2812.5	0
1400	5705625	2500	2812.5	0
1450	5755828.13	2937.5	1664.0625	1750
1500	5843328.13	2937.5	1664.0625	1750
1550	5947096	3896	0	3880
1600	6141096	3896	0	3880
1650	6335096	3896	0	3880
1700	6529096	3896	0	3880
1750	6723096	3896	0	3880
1800	6917096	3896	0	3880

Reference links

- https://www.okamura.com/de_eu/investor_relations/pdf/financial_reports_bm/2021_11_08_1_e.pdf - Problem Statement and Organizational information.
- https://pdf.archiexpo.com/pdf/okamura/risefit/56536-107089.html - Categories of products produced by Okamura corporation.
- https://www.back2.co.uk/okamura-folding-table-nt.html - Cost of conference table information.
- https://www.back2.co.uk/okamura-portone-office-chair.html - Cost of chair Portone information.
- https://www.back2.co.uk/okamura-portone-office-chair.html - Cost of Work-Pods Drape information.
- https://sites.google.com/site/automaticdeskchair/hardware-implementation/electrical-hardware - Manufacturing time and process needed for chair preparation.
- https://www.camirafabrics.com/us/contract/fabrics/oceanic - Ocean recycled fabric information.