MGMT 630850 – DECISION ANALYSIS

Group Software Application Project – GROUP C

TRANSPORTATION PLANNING PROBLEM AND DATA ENVELOPMENT ANALYSIS

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# Introduction:

A computer method for computing the best outcome in a mathematical model with linear connections is called linear programming (LP). It is commonly used to handle allocation of resources and decision-making problems in domains such as the field of economics, operational research, engineering, and company administration. Optimizing or reducing an objective function that is linear according to a set of linear restrictions is the goal of linear programming models. Algorithms such as the Simplex approach or the Interior-Point technique are commonly used to tackle linear programming issues. These algorithms examine the possible area determined by the limitations iteratively in order to discover the best answer that maximizes or reduces the objective function. The “Data Envelopment Analysis”, or DEA, is a non-parametric statistical technique used to compare the effectiveness of a number of decision-making machines (DMUs) or organizations that employ numerous inputs in order to create multiple outputs. In the fields of operations research, the economics field, and managerial science, DEA is often used for assessing and contrasting the efficiency of organizations such as businesses, schools, hospitals, and governmental entities. In this report the linear programming model and DEA model is used to identify and problem solving skills using excel solver software.

# Discussion:

## Problem 1: Transportation planning Programs

The Transportation Planning issue (TPP) is a well-known optimization issue in logistics and operations research. It is concerned with establishing the best cost-effective method of transporting products from many suppliers (sources) to various destinations whilst meeting supply and demand restrictions (Alotaibi *et al*., 2021). The goal is to reduce transportation costs while still serving the needs of both suppliers and customers. A linear programming problem can be used to solve the Transportation Planning Problem. Optimization strategies such as the “Improved Distribution Technique, the Northwest Corner Method, the Vogel's Approximation Method, and linear programming solvers such as the Simplex method or interior-point techniques” are used to solve the Transport Planning Problem (Gião *et al*., 2021). Transportation planning is critical for the management of supply chains, transportation, and transportation networks because it allows firms to maximize the assets they have and reduce costs involved with efficiently moving items between providers and consumers.

Creating a program that is linear requires constructing a mathematical framework that represents the leadership challenge. Therefore, for one to develop a program that is linear, the managerial challenge at hand must be thoroughly understood (Britz, 2020). Once we understand this, we may begin to create the issue's formal solution. The procedures for creating a program that is linear are as follows:

1. Fully comprehend the managerial issue at hand.

2. Determine the goal and limitations.

3. Establish the decision variables.

4. Develop the mathematical equations for the goal functions and restrictions using the choice factors.

In an extensive variety of applications, linear programming (LP) is a strong tool for generating educated choices and optimizing resource allocation (Ersoy, 2021). It offers a methodical approach to problem resolution by modeling complex events from life in an organized statistical context.

The Hardrock Company is engaged in three plants for construction purposes and the company has gathered shipping cost per truck load. The company wants to know the least way for costing to meet the requirement for the construction sites. The data set is provided as follows,

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| To, From | ALBUQUERQUE | BOSTON | CLEVELAND | CAPACITY |
| DES MOINES | $5 | $4 | $3 | 300 |
| EVANSVILLE | $8 | $4 | $3 | 150 |
| FORT LAUDERDALE | $9 | $7 | $5 | 250 |
| REQUIREMENTS | 200 | 200 | 300 |  |

**Table 1: Data for formulating Linear programming**

(Source: Self-created in MS EXCEL)

Table 1 described that the departure areas of construction are Des Moines, Evansville, Fort Lauderdale and the departure cities are Albuquerque, boston and Cleveland. The company also provided the shipping cost per truckload, the company wants to know the required least cost for shipment.

Let xij be the total amount of truckloads of concrete that were transported from facility i to project j.

**Objective Purpose:**

Reduce the overall cost of shipping: Reduce: $5x11 + $4x12 + $3x13 + $8x₂₁ + $4x₂₂ + $3x₂₃ + $9x₃₁ + $7x₃₂ + $5x₃₃

**Constraints**:

Capacity of the plant:

Albuquerque plant: 300 x11 + 300 x12 + 300

Plant Boston: 150 x21 + x22 + x23

Cleveland Plant: x31 + x32 + x33 = 250

Project prerequisites:

X11 + x21 + x31 equals 200 in Project Des Moines

Project Evansville: 12 plus 22 plus 32 equals 200

Project Fort Lauderdale: 13 plus 23 plus 33 equals 300

**Constraints against negativity:**

“xᵢⱼ ≥ 0 for all i, j”

**A whole linear program:**

Reduce: “5x11, 4x12, 3x13, 8x21, 4x22, 3x23, 9x31, 7x32, and 5x33”

According to:

“X11 + x12 + x13 = 300; x21 + x22 + x23 = 150; x31 + x32 + x33 = 250

X11 + x21 + x31 = 200, x12 + x22 + x32 = 200, and x13 + x23 + x33 = 300”

xᵢⱼ ≥ 0 for i, j

### Linear programming solver using excel

The total cost for carrying is $10400. Using the solver it is ascertained that the if the requirement meets the capacity the firm can do it with the least cost.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |
| To, From | ALBUQUERQUE | BOSTON | CLEVELAND | CAPACITY | Total cost |
| DES MOINES | $5 | $4 | $3 | 300 | $9,400 |
| EVANSVILLE | $8 | $4 | $3 | 150 |  |
| FORT LAUDERDALE | $9 | $7 | $5 | 250 |  |
| REQUIREMENTS | 200 | 150 | 250 |  |  |
| Cost | $4,400 | $2,250 | $2,750 |  |  |

**Table 2: Data for Solver**

(Source: Self-created in MS EXCEL)

Table 2 indicates that the Albuquerque requirement is 200, Boston requirement is 150 and Cleveland requirement is 250. These changes are observed through the excel solver, and the result is $9400 which is less than the previous cost. The transportation expenses for traveling from different plant locations to various project destinations are summarized in this table. It also comprises the needs of each project as well as the capabilities of each plant.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| To, From | ALBUQUERQUE | BOSTON | CLEVELAND | CAPACITY | Total cost |
| DES MOINES | $5 | $4 | $3 | 300 | $12,500 |
| EVANSVILLE | $8 | $4 | $3 | 210 |  |
| FORT LAUDERDALE | $9 | $7 | $5 | 250 |  |
| REQUIREMENTS | 300 | 210 | 250 |  |  |
|  | $6,600 | $3,150 | $2,750 |  |  |

**Table 3: Data for Solver**

(Source: Self-created in MS EXCEL)

Table 3 indicates that the planning of the company to increase its small plant’s capacity by 60 truckloads, caused an increase in $12500. It makes the requirement changes of the company sites. The initial transportation charges from Albuquerque to Des Moines, Boston, and Cleveland were $6,600, $3,150, and $2,750, respectively. The new transportation strategy will cost $12,500 in total, which is more than it would have. This suggests that the new transport strategy is less economical than the old one. Different supply and demand restrictions result from the adjustment of the plant capabilities and project requirements (Chen, 2023). The amounts of concrete moved between plants and projects may have been impacted by the current plant capabilities and project requirements. The best transportation strategy should be identified by utilizing Excel Solver to solve the linear programming issue. With the updated information, analysts may use the solver to discover the least-expensive option that still satisfies the project requirements by entering the updated expenses for transportation, abilities, and criteria.

## 

## Problem 2: DEA analysis for efficiency of hospitals

|  |  |  |  |
| --- | --- | --- | --- |
| Input Measures | | | |
| Hospital | Nonphysicians Working at Full-Time Equivalent | Supply Charges  ($1000s) | Days for Bed Available  (1000s) |
| A | 310 | 310 | 116 |
| B | 278.5 | 114.3 | 106.8 |
| C | 165.6 | 131.3 | 65.52 |
| D | 250 | 316 | 94.4 |
| E | 206.4 | 151.2 | 102.1 |
| F | 384 | 217 | 217 |
| G | 530.1 | 770.8 | 215 |

**Table 4: Input measures for hospitals**

(Source: Self-created in MS EXCEL)

Researchers can create a linear programming framework using the Data Envelopment Assessment (DEA) method to assess Hospital D's performance. By contrasting Hospital D with the other hospitals' input and output measures, the DEA model will determine Center D's relative productivity.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Output Measures | | | | |
| Hospital | Patient-Days (65 or older) (1000s) | Patient-Days (65 or older) (1000s) | Nurses Trained | Interns Trained |
| A | 55.31 | 49.52 | 291 | 47 |
| B | 37.64 | 37.64 | 156 | 3 |
| C | 32.91 | 25.77 | 141 | 26 |
| D | 33.53 | 41.99 | 160 | 21 |
| E | 32.48 | 55.3 | 157 | 82 |
| F | 48.78 | 81.9 | 285 | 92 |
| G | 58.41 | 119.7 | 111 | 89 |

**Table 5: Output measures for hospitals**

(Source: Self-created in MS EXCEL)

The DEA technique is used to compare the effectiveness of decision-making units (DMUs) based on their inputs and outputs (Fotova *et al*., 2022). In the scenario, there are seven teaching hospitals acting as DMUs, on a full- comparable non-physicians, supplies, and the number of beds available acting as inputs, and patient hours (65 and older), patients dates (under 65), nurse education, and trainee education acting as outputs.

### Decision-making factors for formulating linear programing

The Hospital D's relative efficiency ranking in relation to other hospitals.

**Input metrics**

x1: FTE Nonphysicians (Full-Time Equivalent Nonphysicians) at Hospital D.

x2: Hospital D Supply Costs ($1000s).

Bed-Days Offered at Hospital D, x3 (1000s).

**Output metrics**

y1: Patient-Days at Hospital D (65 or older) (thousands).

y2: Patient-Days at Hospital D (under 65) (1,000,000).

Nursing Students at Hospital D, y3.

y4: Hospital D's intern training program.

**Objective Purpose:**

Maximize: λ

**Subject to Restrictions**

**Constraint on Relative Efficiency:**

Except for D, each hospital in i: (i = A, B, C, E, F, G) = (x1i + x2i + x3i) - (y1i + y2i + y3i + y4i) 0

**Constraints on positive input:**

Positive Output Constraints: x1 0 x2 0 x3 0

Hospital D Input Constraints: y1 0 y2 0 y3 0 y 4 0

x₁ = 250 x₂ = 316 x₃ = 94.4

**Non-negativity Restrictions for:**

λ ≥ 0

**Explanation**

The DEA model's goal is to increase Hospital D's relative efficiency score () in comparison to other hospitals while upholding non-negativity requirements on inputs, outputs, and the efficiency constraint makes sure that, in comparison to other hospitals, the sum of the proportional inputs (FTE Nonphysicians, Supply Expense, and Bed Days Available) at Hospital D is at least equal to the sum of the weighted outputs (Patient Days, Nurses Trained, and Interns Trained) (Ghosh *et al*., 2020).

One may determine Hospital D's relative efficiency score () by resolving this DEA model. Hospital D is fully operational if = 1. If the answer is 1, it means that Hospital D is less effective than other hospitals and that there is opportunity for improvement in how it uses its resources to produce results.

### Linear programming using Excel Solver

Objective: “Minimum Efficiency Index”

“Wa Wights of Hospital A”

“Wb Wights of Hospital B”

“Wc Wights of Hospital C”

“Wd Wights of Hospital D”

“We Wights of Hospital E”

“Wf Wights of Hospital F”

“Wg Wights of Hospital G”

“E Efficiency Index”

Constraints are

**Inputs**

X is equal to FTE Non phy

Y is equal to Supply expenses

Z is equal to Bed Days Available

**Outputs**

“A Patient-Days (65 or older)”

“B Patient-Days (under 65)”

**“C** is equal to Nurses trained”

**“D** is equal toInterns trained”

**“E** is equal to Intern trained”

**Outcomes Inputs:** “Xwa+ Xwb+ Xwc+ Xwd+ Xwe + Xwf + Xwg < 206.4 E”

“Ywa + Ywb+ Ywc+ Ywd+ Ywe + Ywf + Ywg < 151.2E”

“Zwa + Zwb+ Zwc+ Zwd+ Zwe + Zwf + Zwg < 102.1E”

**Outputs derived:**

“Awa + Awb+ Awc+ Awd+ Awe + Awf + Awg > 33.53”

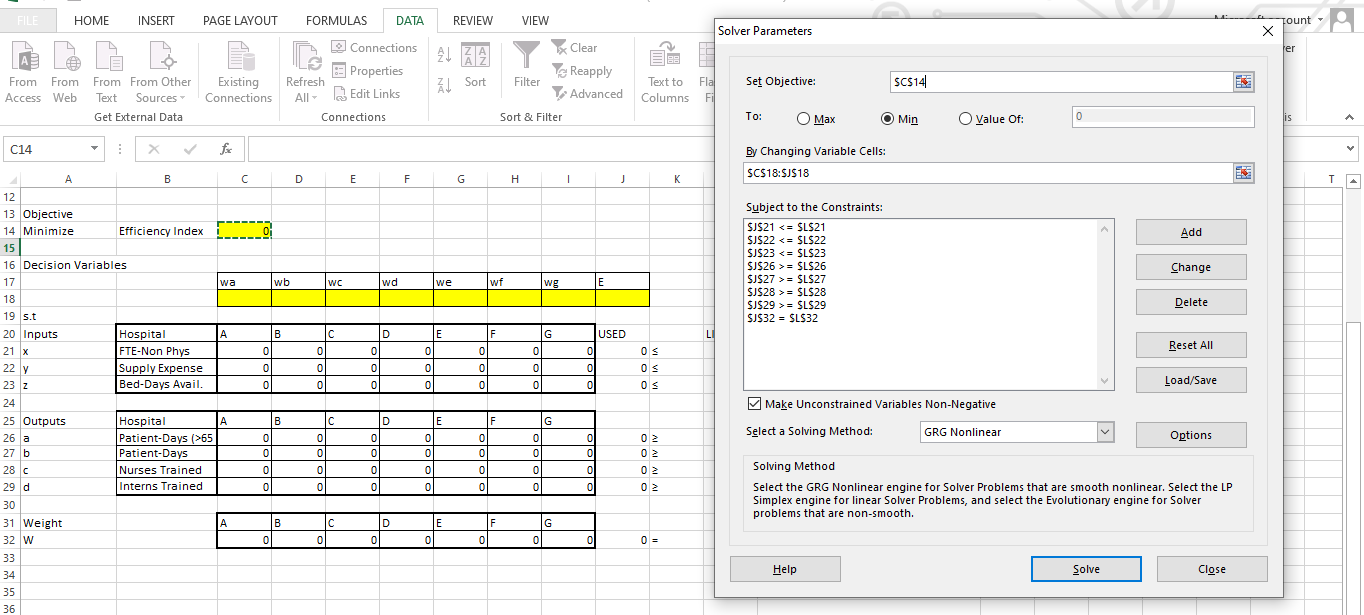
“Bwa + Bwb+ Bwc+ Bwd+ Bwe + Bwf + Bwg >41.99”

“Cwa + Cwb+ Cwc+ Cwd+ Cwe + Cwf + Cwg > 160”

“Dwa + Dwb+ Dwc+ Dwd+ Dwe + Dwf + Dwg > 21”

**Weights:**

“Wa + Wb + Wc + Wd + We + Wf + Wg = 1”



**Figure 1: DEA model formulation using solver**

(Source: MS EXCEL)

Figure 1 indicated that the Review the results after running Solver to see Hospital D's estimated relative efficiency score (Han *et al*., 2019). This rating will show how effectively Hospital D, in comparison to the other hospitals, uses its inputs in order to produce outputs.

Solver's ideal solution should give the Hospital D's relative efficiency score. The efficiency of Hospital D is indicated by a relative efficiency score that is close to 1 (Guan *et al*., 2021). If the score is far below 1, it means that there is room for development in how well it uses its resources to get better results.

### Inefficiency of Hospital D

Hospital D's efficiency score is below one, which indicates that it is less effective than other hospitals. According to the result of the function with an objective, hospital D only uses 33.1 percent of the inputs to create its outputs, with the remaining inputs being squandered or used inefficiently (Haslbeck *et al*., 2022). This suggests that in order to improve its efficiency, facility D might boost the outcomes or lessen its inputs (Lozić, 2022). If the estimated value is considerably less than 1 (for example, if it is 0.8), it indicates that hospital D is less effective than the other hospitals. In this situation, Hospital D's use and distribution of resources could be improved in order to provide better results with the available inputs. In comparison to the other hospitals, hospital D may be functioning at a comparatively high degree of efficiency if the estimated value is higher than 1 (Martínez *et al*., 2019). This less frequent case, nevertheless, might point to problems with the model used for DEA or the data.

### Visitor days created by composites institution for each type patient

Using their inputs and outputs, decision-making units (DMUs) are compared for efficiency using the DEA approach (Palacio *et al*., 2019). The seven teaching hospitals in your situation serve as the DMUs, the Client hours (65 and older), days spent with patients (under 65), nursing instruction, and intern training are the outputs, with on a full- comparable non-physicians, supply expenses, and days in bed available being the inputs. Applications may be done for the concept to design a composite hospital, a hypothetical establishment that uses hospital D's inputs while producing the facility's highest-quality outputs (Osman, 2019). The combined hospital is built using the most effective weights as well as the input and output values from the other hospitals.

Patient’s days are calculated as below

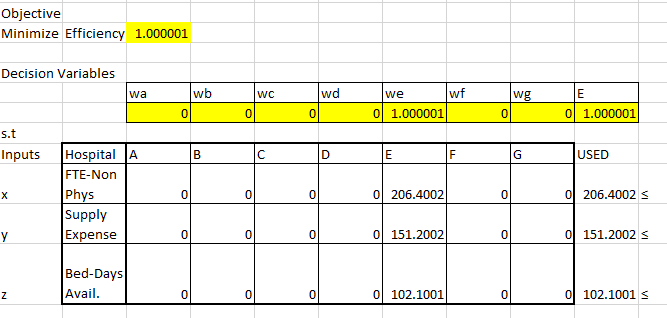
Patients days 65 and older: sum\_{k=1}^{7} u\_1 y\_{1k} = 0\* 55.31 + 0 \* 37.64 + 0 \* 32.91 + 0 \* 33.53 + 0 \* 32.48 + 0 \* 48.78 + 0 \* 58.41 = 0

Patient-days (under 65): ∑k=17​u2​y2k​=0.0008×49.52+0.0008×37.64+0.0008×25.77+0.0008×41.99+0.0008×55.3+0.0008×81.9+0.0008×119.7=0.331

Nurses trained: ∑k=17​u3​y3k​=0×291+0×156+0×141+0×160+0×157+0×285+0×111=0

### Hospital E to emulate by Hospital D

It must analyze the relative efficiency scores ( values) of all the hospitals, which were determined using Data Envelopment Analysis (DEA), in order to suggest one hospital for Hospital D to imitate and enhance its efficiency (Runkler, 2020). Because it is working quite efficiently and effectively employing its inputs to produce outputs, a hospital having a higher relative efficiency rating (closer to 1) is a viable candidate for emulation.



**Figure 2: DEA model formulation using solver for Hospital E**

(Source: MS EXCEL)

Figure 2 indicates that after running Solver to see the computed Effectiveness Index for Hospital E. This metric measures the degree to which Hospital E's relative effectiveness score is kept at 1 (Wang *et al*., 2021). while keeping the Efficiency Index to a minimum. The nearer the Efficiency Score is to 1, the more efficiently Hospital E is operating.

## Problem 4: Project Management of Accounting Audit Scenario

1. Propose the project network (i.e., the PERT diagram for the Audit Trail Program). Your network must show the precedence relationships of all the 19 tasks. You may choose to use an AOA or an AON diagram.

A diagram of a network

Description automatically generated

**PERT Diagram using AON (Orange Activities represent the Critical Path)**

2. Compute the expected completion times and variances of each activity on the network.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Task** | **Predecessor** | **Optimistic Time (a)** | **Pessimistic Time (b)** | **Most Likely Time (m)** | **Expected Time, t = (4m + a + b)/6** | **Variance = ((b-a)/6)\*2** |
| A - Audit Planning | - | 44 | 52 | 48 | 48 | 1.7689 |
| B - Observe Inventory | A | 16 | 30 | 25 | 24.33 | 5.4289 |
| C - General Audit Procedures | B | 6 | 13 | 11 | 10.5 | 1.359556 |
| D - Audit Cash | B | 18 | 30 | 19 | 20.66 | 4 |
| E - Inventory Pricing | B | 90 | 150 | 145 | 136.66 | 100 |
| F - Audit Receivables | D | 6 | 14 | 10 | 10 | 1.7689 |
| G - Audit Other Corporate Assets | C | 9 | 16 | 11 | 11.5 | 1.359556 |
| H - Audit Liabilities | E | 50 | 100 | 93 | 87 | 69.3889 |
| I - Audit Sales | F | 5 | 7 | 6 | 6 | 0.1089 |
| J - Audit Cost Of Goods Sold | E | 10 | 30 | 25 | 23.33 | 11.0889 |
| K - Audit Other Revenues/Expenses | I,J | 6 | 12 | 10 | 9.66 | 1 |
| L - Audit Fixed Assets | G | 20 | 24 | 22 | 22 | 0.443556 |
| M - Audit Capital Stock/RE | K | 1 | 1 | 1 | 1 | 0 |
| N - Management's Letter | L,M | 1 | 1 | 1 | 1 | 0 |
| O - Subsequent Review | L,M | 16 | 20 | 18 | 18 | 0.443556 |
| P - Lawyer's Letter | H | 1 | 1 | 1 | 1 | 0 |
| Q - Prepare Final Statements | N,O,P | 12 | 24 | 15 | 16 | 4 |
| R - Prepare Tax Returns | N,O,P | 8 | 30 | 12 | 14.33 | 13.3956 |
| S - Partner/Manager Review | Q,R | 5 | 7 | 6 | 6 | 0.110889 |

Note: All time and variance values are in hours.

3. Compute the ES, EF, LS, and LF of all activities on the project network.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Task** | **Predecessor** | **Early Start (ES)** | **Early finish (EF)** | **Late Start (LS)** | **Late Finish (LF)** |
| A - Audit Planning | - | 0 | 48 | 0 | 48 |
| B - Observe Inventory | A | 48 | 72.33 | 48 | 72.32 |
| C - General Audit Procedures | B | 72.33 | 82.83 | 234.99 | 245.49 |
| D - Audit Cash | B | 72.33 | 92.99 | 231.67 | 252.33 |
| E - Inventory Pricing | B | 72.33 | 208.99 | 72.33 | 208.99 |
| F - Audit Receivables | D | 92.99 | 102.99 | 252.33 | 262.33 |
| G - Audit Other Corporate Assets | C | 82.83 | 94.33 | 254.49 | 256.99 |
| H - Audit Liabilities | E | 208.99 | 295.99 | 208.99 | 295.99 |
| I - Audit Sales | F | 102.99 | 108.99 | 262.33 | 268.33 |
| J - Audit Cost Of Goods Sold | E | 208.99 | 232.32 | 245 | 268.33 |
| K - Audit Other Revenues/Expenses | I,J | 232.32 | 241.98 | 268.33 | 277.99 |
| L - Audit Fixed Assets | G | 94.33 | 116.33 | 256.99 | 278.99 |
| M - Audit Capital Stock/RE | K | 241.98 | 242.98 | 277.99 | 278.99 |
| N - Management's Letter | L,M | 242.98 | 243.98 | 295.99 | 296.99 |
| O - Subsequent Review | L,M | 242.98 | 260.98 | 278.99 | 296.99 |
| P - Lawyer's Letter | H | 295.99 | 296.99 | 295.99 | 296.99 |
| Q - Prepare Final Statements | N,O,P | 296.99 | 312.99 | 296.99 | 312.99 |
| R - Prepare Tax Returns | N,O,P | 296.99 | 298.32 | 311.66 | 312.99 |
| S - Partner/Manager Review | Q,R | 312.99 | 318.99 | 312.99 | 318.99 |

Note: This table is in continuation with previous question.

4. Provide a table of all the activity slack times and the critical path on the network. How many activities are critical, and how many are not?

|  |  |  |
| --- | --- | --- |
| **Task** | **Predecessor** | **Slack Time (LS-ES)** |
| A - Audit Planning | - | 0 |
| B - Observe Inventory | A | 0 |
| C - General Audit Procedures | B | 162.66 |
| D - Audit Cash | B | 159.34 |
| E - Inventory Pricing | B | 0 |
| F - Audit Receivables | D | 159.34 |
| G - Audit Other Corporate Assets | C | 171.66 |
| H - Audit Liabilities | E | 0 |
| I - Audit Sales | F | 159.34 |
| J - Audit Cost Of Goods Sold | E | 36.01 |
| K - Audit Other Revenues/Expenses | I,J | 36.01 |
| L - Audit Fixed Assets | G | 162.66 |
| M - Audit Capital Stock/RE | K | 36.01 |
| N - Management's Letter | L,M | 53.01 |
| O - Subsequent Review | L,M | 36.01 |
| P - Lawyer's Letter | H | 0 |
| Q - Prepare Final Statements | N,O,P | 0 |
| R - Prepare Tax Returns | N,O,P | 14.67 |
| S - Partner/Manager Review | Q,R | 0 |

**Critical Path** – The critical path of this network of activities is A-B-E-H-P-Q-S. The same is depicted in question 1- PERT diagram.

5. Do you identify any activities that are driving this project? What are your recommendations with respect to these activities?

Activities A, B, E, H, P, Q, S are driving the project. By managing critical path activities effectively, we can ensure that the project is completed on time, meeting stakeholders' expectations and minimizing the negative impact of potential delays. In some cases, critical path activities can be optimized to reduce the overall project duration. By focusing on the critical path, we can identify opportunities to streamline processes, allocate resources more efficiently, and accelerate project delivery.

6. Compute the probabilities of the project completions for the following time periods in hours (290,300, 310, 319, 330, 340 and 350) and construct a diagram (illustrating the pairs of completion times and probabilities).

The critical path analysis helped determine the expected project completion time of 13.29 days (318.99 hrs).

If the activities are not completed in 15 days, the audit will be delayed.

Project variance = 180.52 (sum of variances of critical path).

Project standard deviation = σ = √180.52 = 13.43

The standard normal equation can be applied as follows:

Z = (due date – expected date of completion) / σ

= (15 days −13.29 days) / 13.43 days

= 0.1273

That means the probability this audit activity can be completed in 15 days or less is 0.1273. There is a 12.7% chance that the activity will be done within 15-days.

7. For extra Bonus Points - Use MS project to produce a Gantt chart of the project.

A screenshot of a computer

Description automatically generated

**GANTT Chart**

# Conclusion:

The Transportation Management Problem, which involves reducing transportation costs while satisfying supply and demand constraints, can be successfully solved using linear programming in conjunction with transportation planning. This issue can be resolved and supply chain management optimized using a number of techniques and solutions. DEA offers a framework to compare hospital performance using input and output measures for hospital efficiency evaluation. One can evaluate the relative efficacy of hospitals and pinpoint areas for improvement by developing DEA models and using tools like Excel Solver. In numerous real-world circumstances, combining linear programs and data envelope analysis are useful techniques for generating informed decisions, improving resource allocation, and boosting efficiency. These methods provide quantitative and systematic methodologies to handle complicated issues and aid in better resource management as well as decision-making.

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