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TOTAL TIME MINIMIZATION SOLID TRANSPORTATION PROBLEM

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ABSTRACT

The problem of minimizing total cost of transportation problem is one of many well-structured problems in operations research that has been studied in detail. The transportation problem is one of the subclass linear programming problems which are similar in that they all require a linear function of a set of variables is optimized while the variables themselves satisfy a number of linear constraints for which simple and practical computational procedures have been developed.

The time minimization transportation problem is one in which a time is associated with each shipping route and the objective is to minimize the maximum time to transport all supply to the destinations. The problem become more complex in case of solid transportation problem .In the present work The total time solid transportation problem is considered in which the objective is to minimize the time of active transportation routes.

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INTRODUCTION

The problem of minimizing total cost of transportation problem is one of many well-structured problems in operations research that has been studied in detail. The transportation problem is one of the subclass linear programming problems which are similar in that they all require a linear function of a set of variables is optimized while the variables themselves satisfy a number of linear constraints for which simple and practical computational procedures have been developed.

The time minimizing transportation problem is one in which a time is associated with each shipping route and the objective is to minimize the maximum time to transport all supply to the destinations in place of minimizing cost.

In the present work a total time minimization solid transportation problem has been considered in which the objective is to minimize the total transportation time of active transportation routes.

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LITERATURE SURVEY:

The present work deals with multi-index time minimization transportation problem. The multi-index transportation problem is extension of classical transportation problem where there are three indices. The method of solution is an extension of the modi-method.

Later independently, by Koopman(1947).Koopman began to spearhead research on the potentialities of linear programs for the study of the problems in economics. His historic paper "optimum utilization of the transportation potations systems" was based on his war time experience. Because of this and the work done earlier by Hitchcock, the classical case is often referred as the Hitchcock-Koopman's transportation problem. Kantorovich (1942) publishes the paper on a continuous version of the problem and later with Gavurin, an applied study of the capacitated transportation problem (Kantorovich and Gavurin 1949).

The time minimizing transportation problem has been studied by Hammer (1969),Garfinkel and Rao(1971) and Szwarc (1971).Hammer (1969) and Szwarc(1971) used labeling techniques to solve the problem . Garfunkel and Rao(1971) solved the problem by introducing a sufficiently large cost M on certain routes. Sometimes there may exist emergency situations such as those requiring police services, fire services, ambulance services, etc., when the time of transportation is of greater importance than cost of transportation. Some methods for minimizing the time of transportation have been established. Several methods for minimizing the time of transportation are also developed. Then Bhatia *et.al*.(1975) developed a technique for minimizing time in a transportation problem. The procedure involved finite number of iterations and is based on moving from one basic feasible solution to another till the last solution is arrived at. Nikolic(2007) proposed that the total transportation time problem regarding the time of the active transportation routes. If the multiple optimal solution exist, it is possible to include other criteria as second level of criteria and find the corresponding solutions. Furthermore, if there is multiple solution, again, the third objective can be optimized in lexicographic order. Preetvantiand P.k. (2003) presented multiple objective time transportation problem with additional restrictions(MOTTP).This MOTTP with non-linear bottleneck objective function is related to Lexicographic Multiple Time Transportation Problem With Additional Restrictions, which is solved by a lexicographic primal code. An algorithm and its underlying theory is developed to determine an initial efficient basic solution of this MOTTP. The developed algorithm is supported by a real life example of minimizing the shipping time, loading/unloading time congestion time for transporting one from source i to destination j for a steel industry.

Haley(1962) considered the Multi-Index transportation problem in which there are three indices and presented an algorithm to solve the problem, the method of solution is an extension of Modi-method .Haley(1963) developed the theoretical concepts to justifying the methods and an

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extension of the necessary conditions laid down by Schell (1955). healso described the application of the technique to two special transportation problem and showed that the 'Three axial sums' problem of Schell (1955) can be written as 'Three planar sums'. Haley(1965)laid down a set of necessary conditions for a feasible solution to exist. He also proved that these conditions are sufficient. Smith(1973) gave further necessary conditions for the existence of a solution to the Multi-index transportation problem.

PRESENT WORK

The present a total time minimization solid transportation problem is formulated and procedure to find it solution has been developed.

FORMULATION OF PROBLEM

The Multi-index total time minimization transportation problem in which there are m origins, n destinations and p type of commodities to be transported can be formulated as below.

$$Minimize\ \ T(x) = \sum_{i\in I}\sum_{j\in J}\sum_{k\in K} t_{ijk} h_{ijk} \qquad (1.1)$$

$$h_{ijk} = \begin{cases} 1 & if\ x_{ijk} > 0 \\ 0 & if\ x_{ijk} = 0 \end{cases} \qquad (1.2)$$

Subject to

$$\sum_{i=1}^{n} x_{ijk} = A_{jk'} \ \sum_{j=1}^{m} x_{ijk} = B_{ki'} \ \sum_{k=1}^{p} x_{ijk} = E_{ij'}$$

Where

$$\sum_{j=1}^{m} A_{jk} = \sum_{i=1}^{p} B_{ki'} \ \sum_{k=1}^{p} B_{ki} = \sum_{j=1}^{m} E_{ij'} \ \sum_{i=1}^{n} E_{ij} = \sum_{k=1}^{p} A_{jk}$$

And

$$\sum_{j=1}^{m}\ \sum_{k=1}^{p} A_{jk} = \sum_{k=1}^{p}\ \sum_{i=1}^{n} B_{ki} = \sum_{i=1}^{n}\ \sum_{j=1}^{m} E_{ij'} \ \ x_{ijk} \geq 0,$$

Here $i=1,2,\ldots,m$ are the origins,

$j= 1,2,\ldots,n$ are destinations,

$k = 1, 2,\ldots,p$ are the various type of commodities.

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h_{ijk} is auxiliary function show active and non -active transportation routes (activities),

x_{ijk} is amount of type k^{th} goods sent from the i^{th} factory to the j^{th} destination ,

t_{ijk} is the time of transporting type k^{th} of goods from the i^{th} source to the j^{th} destination,

A_{jk} the requirement at the j^{th} destination of type k^{th} of goods,

B_{ki} the availability of type k^{th} of goods at the i^{th} factory ,

E_{ij} the total amount of goods to be sent from the i^{th} factory to the j^{th} destination.

This constraints show that k^{th} type of commodities received by all destination is equal to k^{th} type of commodity supplied from all origins and different types of commodities supplied by the i^{th} source is equal to amount of commodity received by all destination from the i^{th} source. The amount of commodity supplied from all origins to j^{th} destination is equal todifferent types of commoditiesreceived by j^{th} destination and theamount of commodities received by all destination of different types of commodities is equal to amount of commodities supplied from all origins to alldestination is equal todifferent types of commoditiessupplied from all origins.

It has been assumed that the transportation starts simultaneously and the time of transportation does not depend on the amount of product transported.

1.3 SOLUTION PROCEDURE

In the solution procedure we make the use of the combination of approaches given by Haley (1962) and Nicolic (2007) and is given below.

Let $X^{(D)}$ and $X^{(D+1)}$ are two basis neighboring feasible solutions, where $X_{ijk}{}^{(D)}$ is entering basis variable and $X_{isk}{}^{(D)}$ is leaving basis variable for $X^{(D)}$:

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$X^{(D)}$ contain : ${X_{ijk}}^{(D)} = 0$ and ${X_{isk}}^{(D)} > 0$

$X^{(D+1)}$ contain : ${X_{ijk}}^{(D+1)} > 0$ and ${X_{isk}}^{(D+1)} = 0$

there is : ${X_{ijk}}^{(D+1)} = {X_{isk}}^{(D)}$

In moving from $X^{(D)}\, to\, X^{(D+1)}$ the total transportation time T(x) of problem (1.1) will be changed with the following values:

$$ {q_{ijk}}^{(D)} = t_{ijk} - t_{isk}. \tag{1.3}$$

The characteristics q_{ijk} are the change of transportation time in problem (1.1).

Then the solution $X^{(D+1)}$ has:

$$T^{(D+1)} = T^{(D)} + ({t_{ijk}}^{(D)} - {t_{isk}}^{(D)}). \tag{1.4}$$

Clearly, the total time $T^{(D+1)}$ is determined by values ${q_{ijk}}^{(D)}$ as:

$$T^{(D+1)} = \begin{cases} > T^{(D)} & if\ {q_{ijk}}^{(D)} > 0 \\ = T^{(D)} & if\ {q_{ijk}}^{(D)} = 0 \\ < T^{(D)} & if\ {q_{ijk}}^{(D)} < 0 \end{cases} \tag{1.5}$$

1.4 ALGORITHM

Step 0: Find basic feasible solution $X^{(1)}$ set number of iteration $D = 1$.

Step 1: Determine the indicators ${h_{ijk}}^{(D)}$ of active transportation routes ${X_{ijk}}^{(D)} > 0$, and the total time $T^{(D)} = T\left(X^{(D)}\right)$

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$$h_{ijk} = \begin{cases} 1 & if\ X_{ijk}^{(D)} > 0 \\ 0 & if\ X_{ijk}^{(D)} = 0 \end{cases}$$

$$T^{(D)} = \sum_{i\in I}\sum_{j\in J}\sum_{k\in K} t_{ijk} h_{ijk}^{(D)}$$

Step 2: Using equation (1.3),determine the characteristic $q_{ijk}^{(D)}$ for all non -basic variable $X_{ijk}^{(D)} = 0$ using (1.3) .Use the changing path of the basic solution (as in a stepping – stone method) and corresponding leaving basic variable, e.g. $X_{isk}^{(D)} > 0$ become $X_{isk}^{(D)} = 0$, if entering variable would be $X_{ijk}^{(D+1)} > 0.$

(If there is more then one path to calculate $q_{ijk}^{(D)}$ *then select thatminimum* $q_{ijk}^{(D)}$ *regarding* $q_{ijk}^{(D)} < 0$ *which minimize the total time simultaneously for various types of commodities)*

Step 3: Check the optimality of the total time (1.1), using (1.5). If all $q_{ijk}^{(D)} \geq 0$, the optimal solution X^* is found. Stop otherwise go to step 4.

Step4: Determine next basic solution, using the entering variable X_{ijk} with minimum $q_{ijk}^{(D)}$, regarding $q_{ijk}^{(D)} < 0$.If this minimum $q_{ijk}^{(D)}$ minimize the total time simultaneously for various types of commodities, then set $D = D+1$ & go to step 1.

Otherwise, consider next minimum $q_{ijk}^{(D)}$ regarding $q_{ijk}^{(D)} < 0$ and go to step 1.

1.5 NUMERICAL EXAMPLE

Consider a $3\times3\times3$ multi-index total time transportation problem.

$$\text{Minimize } T(x) = \sum_{i\in I}\sum_{j\in J}\sum_{k\in K} t_{ijk} h_{ijk} \quad (1.1)$$

$$h_{ijk} = \begin{cases} 1 & if\ X_{ijk} > 0 \\ 0 & if\ X_{ijk} = 0 \end{cases} \quad (1.2)$$

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Subject to $\sum_{i=1}^{n} x_{ijk} = A_{jk}, \sum_{j=1}^{m} x_{ijk} = B_{ki}, \sum_{k=1}^{p} x_{ijk} = E_{ij},$

where $\sum_{j=1}^{m} A_{jk} = \sum_{i=1}^{p} B_{ki}, \sum_{k=1}^{p} B_{ki} = \sum_{j=1}^{m} E_{ij}, \sum_{i=1}^{n} E_{ij} = \sum_{k=1}^{p} A_{jk}$

and $\sum_{j=1}^{m} \sum_{k=1}^{p} A_{jk} = \sum_{k=1}^{p} \sum_{i=1}^{n} B_{ki} = \sum_{i=1}^{n} \sum_{j=1}^{m} E_{ij}, \; x_{ijk} \geq 0,$

Table 1.1 gives the data-time t_{ijk} at the top left corners of the respective cells, B_{ki} at the right extreme of rows, A_{jk} at the bottom of columns and E_{ij} in the $(i, j)^{th}$ cell consisting of cells $(i, j, 1), (i, j, 2), (i, j, 3)$ $i = 1, 2, 3;$ $j = 1, 2, 3.$

Table 1.1

	$j=1$	$j=2$	$j=3$	
$i=1$	6 7 $E_{11}=10$ 6	5 6 $E_{12}=6$ 10	7 3 $E_{13}=9$ 11	$B_{11}=6$ $B_{21}=9$ $B_{31}=10$
$i=2$	11 8 $E_{21}=21$ 13	9 15 $E_{22}=10$ 12	13 7 $E_{23}=14$ 8	$B_{12}=13$ $B_{22}=15$ $B_{32}=17$
$i=3$	5 6 $E_{31}=22$ 7	8 9 $E_{32}=13$ 7	10 6 $E_{33}=12$ 12	$B_{13}=15$ $B_{23}=14$ $B_{33}=18$

$A_{11}=15$	$A_{21}=8$	$A_{31}=11$	
$A_{12}=18$	$A_{22}=12$	$A_{32}=8$	
$A_{13}=20$	$A_{23}=9$	$A_{33}=16$	

Using the North-West corner rule, an initial basic feasible solution is obtained as shown in Table 1.2, 1.3, 1.4.

Table – 1.2

Destination $j \rightarrow$ *Origin* $i \downarrow$	1	2	3
1	8 (6)	5	7
2	11 (9)	9	13(4)
3	5	8 (8)	10 (7)

Table – 1.3

Destination $j \rightarrow$ *Origin* $i \downarrow$	1	2	3
1	7 (4)	6(5)	3
2	8 (10)	15 (2)	7(3)
3	5 (4)	9 (5)	6 (5)

Table – 1.4

Destination $j \rightarrow$ *Origin* $i \downarrow$	1	2	3
1	6	10(1)	11 (9)

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2	13(2)	12 (8)	8 (7)
3	7 (18)	7	12

8 **6**			5			7		
	7 **4**			6 **5**			3	
		6			10 **1**			11 **9**
11 **9**			9			13 **4**		
	8 **10**			15 **2**			7 **3**	
		13 **2**			12 **8**			8 **7**
5			8 **8**			10 **7**		
	6 **4**			9 **5**			6 **5**	
		7 **18**			7			12

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The value of total time, $T^{(1)} = 175$

Applying Step 2, the values q_{ijk} are calculated, for all $i, j, k \notin B$ which are given in Table 1.5.

Table – 1.5

ijk	121	131	132	113	221	311	323	333
q_{ijk}	-8	-6	-4	-4	-4	-5	-5	5

In Table 1.5, it is observed that

$$Min\left\{q_{ijk}, q_{ijk} < 0, i, j, k \notin B\right\} = -8 \ at\,(1,2,1)\,cell.$$

Therefore, the variable to enter the basis is x_{121} and the new solution is given in Table 1.6, 1.7, 1.8.

Table – 1.6

Destination j → *Origin i* ↓	1	2	3
1	8 (2)	5(4)	7
2	11 (13)	9	13
3	5	8 (4)	10 (11)

Table – 1.7

Destination j → *Origin i* ↓	1	2	3
1	7 (8)	6(1)	3
2	8 (6)	15 (2)	7(7)
3	5 (4)	9 (9)	6 (1)

Table – 1.8

Destination j →	1	2	3

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Origin i↓			
1	6	10(1)	11 (9)
2	13(2)	12 (8)	8 (7)
3	7 (18)	7	12

8 **2**			5 **4**			7		
	7 **8**			6 **1**			3	
		6			10 **1**			11 **9**
11 **13**			9			13		
	8 **6**			15 **2**			7 **7**	
		13 **2**			12 **8**			8 **7**
5			8 **4**			10 **11**		
	6 **4**			9 **9**			6 **1**	
		7 **18**			7			12

The value of total time, $T^{(2)} = 167$.

Applying Step 2, the following results are obtained as shown in Table 1.9.

Table – 1.9

ijk	131	132	113	221	231	311	323	333
q_{ijk}	2	-3	-4	4	8	-3	-5	5

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In Table 1.10, it is observed that

$$Min\left\{q_{ijk}, q_{ijk} < 0, i, j, k \notin B\right\} = -5 \; at \, (3,2,3) \, cell.$$

Therefore, the variable to enter the basis is x_{323} and the new solution is given in Table 1.10, 1.11, 1.12.

Table – 1.10

Destination j → *Origin i* ↓	1	2	3
1	8 (2)	5(4)	7
2	11 (13)	9	13
3	5	8 (4)	10 (11)

Table – 1.11

Destination j → *Origin i* ↓	1	2	3
1	7 (8)	6(1)	3
2	8	15 (8)	7(7)
3	5 (10)	9 (3)	6 (1)

Table – 1.12

Destination j → *Origin i* ↓	1	2	3
1	6	10 (1)	11 (9)
2	13(8)	12 (2)	8 (7)
3	7 (12)	7 (6)	12

8 **2**		5 **4**		7	

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	7 **8**			6 **1**			3	
		6			10 **1**			11 **9**
11 **13**			9			13		
	8			15 **8**			7 **7**	
		13 **8**			12 **2**			8 **7**
5			8 **4**			10 **11**		
	6 **10**			9 **3**			6 **1**	
		7 **12**			7 **6**			12

The value of total time, $T^{(3)} = 166.$

Applying Step 2, the following results are obtained as shown in Table 1.13.

Table – 1.13

ijk	131	132	113	221	231	311	212	333
q_{ijk}	2	-3	-4	4	8	-3	1	5

In Table 1.13, it is observed that

$$Min\left\{q_{ijk}, q_{ijk} < 0, i, j, k \notin B\right\} = -4 \; at\,(1,1,3)\,cell.$$

Therefore, the variable to enter the basis is x_{113} and the new solution is given in Table 1.14, 1.15, 1.16.

Table – 1.14

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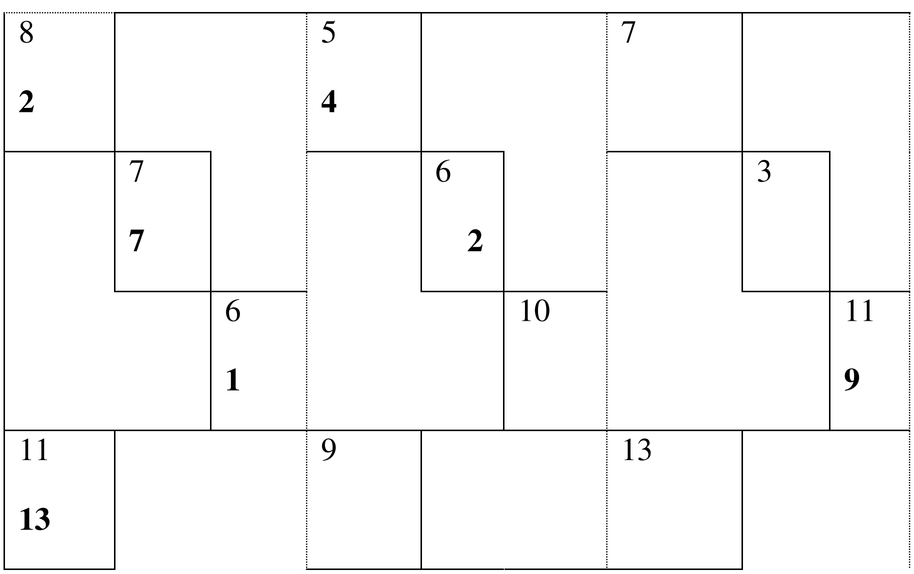
Destination j → *Origin i* ↓	1	2	3
1	8 (2)	5(4)	7
2	11 (13)	9	13
3	5	8 (4)	10 (11)

Table – 1.15

Destination j → *Origin i* ↓	1	2	3
1	7 (7)	6(2)	3
2	8	15 (8)	7(7)
3	5 (11)	9 (2)	6 (1)

Table – 1.16

Destination j → *Origin i* ↓	1	2	3
1	6 (1)	10	11 (9)
2	13(8)	12 (2)	8 (7)
3	7 (11)	7 (7)	12



	8			15 **8**			7 **7**	
		13 **8**			12 **2**			8 **7**
5			8 **4**			10 **11**		
	6 **11**			9 **2**			6 **1**	
		7 **11**			7 **7**			12

The value of total time, $T^{(4)} = 162$.

Applying Step 2, the following results are obtained as shown in Table 1.17

Table – 1.17

ijk	131	132	123	221	231	311	212	333
q_{ijk}	2	-3	4	4	8	-3	1	5

In Table 1.17, it is observed that

$$Min\{q_{ijk}, q_{ijk} < 0, i, j, k \notin B\} = -3 \; at \, (3,1,1) \, cell.$$

Therefore, the variable to enter the basis is x_{311} and the new solution is given in Table 1.18, 1.19, 1.20.

Table – 1.18

Destination $j \rightarrow$ *Origin* $i \downarrow$	1	2	3
1	8	5(6)	7
2	11 (13)	9	13
3	5 (2)	8 (2)	10 (11)

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Table – 1.19

Destination j → *Origin i ↓*	1	2	3
1	7 (9)	6(0)	3
2	8	15 (8)	7(7)
3	5 (9)	9 (4)	6 (1)

Table – 1.20

Destination j → *Origin i ↓*	1	2	3
1	6 (1)	10	11 (9)
2	13(8)	12 (2)	8 (7)
3	7 (11)	7 (7)	12

8			5 **6**			7		
	7 **9**			6 **0**			3	
		6 1			10			11 **9**
11 **13**			9			13		
	8			15 **8**			7 **7**	
		13 **8**			12 **2**			8 **7**

5 **2**			8 **2**			10 **11**		
	6 **9**			9 **4**			6 **1**	
		7 **11**			7 **7**			12

The value of total time, $T^{(5)} = 159$.

Applying Step 2, the following results are obtained as shown in Table 3.21.

Table – 3.21

ijk	131	132	123	221	231	111	212	333
q_{ijk}	2	-3	4	4	8	3	1	5

In Table 1.21, it is observed that

$$Min\{q_{ijk}, q_{ijk} < 0, i, j, k \notin B\} = -3 \ at\,(1,3,2)\,cell.$$

Therefore, the variable to enter the basis is x_{132} and the new solution is given in Table 1.22, 1.23, 1.24.

Table – 1.22

$Destination\ j \rightarrow$ $Origin\ i \downarrow$	1	2	3
1	8	5(6)	7
2	11 (13)	9	13
3	5 (2)	8 (2)	10 (11)

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Table – 1.23

Destination j → *Origin i* ↓	1	2	3
1	7 (7)	6(0)	3 (2)
2	8	15 (10)	7(5)
3	5 (11)	9 (2)	6 (1)

Table – 1.24

Destination j → *Origin i* ↓	1	2	3
1	6 (3)	10	11 (7)
2	13(8)	12	8 (9)
3	7 (9)	7 (9)	12

8			5 **6**			7		
	7 **7**			6 **0**			3 **2**	
		6 **3**			10			11 **7**
11 **13**			9			13		
	8			15 **10**			7 **5**	
		13 **8**			12			8 **9**

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5 **2**			8 **2**			10 **11**		
	6 **11**			9 **2**			6 **1**	
		7 **9**			7 **9**			12

The value of total time, $T^{(6)} = 150$.

Applying Step 2, the following results are obtained as shown in Table 1.25.

Table – 1.25

ijk	131	223	123	221	231	111	212	333
q_{ijk}	2	9	4	4	3	3	1	5

Since all $q_{ijk} \geq 0$ for non basic cells.

Hence the total time is 150.

1.6 CONCLUSION

A total time minimization solid transportation problem is formulated and a procedure has been developed to find its solution.

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