

DYNAMIC PROGRAMMING STRATEGY FOR DYNAMIC MULTIPLE ZONE EXPEDITION WITH MINIMAL IMBALANCE SCENARIO

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ABSTRACT

In a conventional multiple zone expedition problem, traveling to support random over the road freight between adjacent areas leads to different levels of total cost or load-imbalance. The objectives of this research are to examine configurations of zone expedition alternatives for use in truckload trucking operations and to eliminate empty repositioning movements between loads to maintain the high level of equipment utilisation. The conventional multiple zone expedition problems can be modeled as a Dynamic Multiple Zone Expedition problem (DMZE). In this problem, the rearrangement penalty will be added to the conventional model if there is a difference of the area arrangement in each zone. An optimal procedure, Dynamic Programming Strategy (DPS), will be applied to this system. The combination of expedition alternatives with penalty over a series of discrete time periods with the total minimal imbalance is chosen. DPS is practical merely for small problems. The results illustrate that minimising imbalance whilst controlling (minimising) runtime rely up-on the problem parameters, number of zone, area and consecutive time period, used.

KEYWORDS: Dynamic Programming, Dynamic Multiple Zone Expedition and Imbalance

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1. INTRODUCTION

Presently transportation system becomes to have a significant role toward business system and organisation; especially in the companies that operates a transportation business. They may not only operate it by themselves, but also needs support from others transportation company, which is essential to be consisted with the great capacity of human, car or a proper management system that could reduce cost for business organisation abundantly [1]. Besides, most of the big companies have a possible trend in using the specific operators instead to liberate the burden of transportation cost. Meanwhile, it is important to have a further research for this matter in order to generate the initiative procedure, which brings about the great efficiency in transportation and the objective of business to gain profits [2].

The prior transportation system uses the general approach which is a *Single Zone* transportation approach from point to point. The *single zone* approach is found that it will spend more times with the long distance of each journey and remain lots of available space when travel back. Later on, Taylor and Meinert [3] conducted the research to increase the efficiency of transportation. They mentioned the *Zone Dispatching or Zone Expedition* approach that will be easier to manage and control. Furthermore, Taylor and teams [4] proposes a *Zone Dispatching* approach endeavoring to enhance the efficiency of transportation system by adjusting the same point of products in and out to find the proper point of

transportation to minimise imbalance scenario. It aims to enhance the efficiency of transportation and pay more attention to the harmonious balance between cost and quantity which Dynamic Programming Strategy, DPS, could respond this complication that has a change of internal structure. DPS also suit for solving both linear and non-linear programming problems.

2. METHODS

In the research of *Multiple Zone Expedition* management, it consists of 2 main principles in transportation management which are *Area* and *Zone*. Taylor and teams [5] proposes the notion called *Minimal Imbalance Scenario* approach in term of load which contains 2 parts in each area; in-bound goods and out-bound goods in each area within each zone to find out the harmonious balance between inbound goods and outbound goods, which run parallel to this following mathematic programming:

$$\text{Minimise } \left(\sum_{\forall j} ZP_j - \sum_{\forall j} ZN_j \right) \quad (1)$$

Subject to:

$$\sum_{i \in F_j} I_i X_{ij} + I_j - ZP_j - ZN_j = 0 \quad \forall j \quad (2)$$

$$\sum_{j \in F_i} X_{ij} = 1 \quad \forall i \quad (3)$$

$$ZP_j \geq 0 \quad \forall j \quad (4)$$

$$ZN_j \leq 0 \quad \forall j \quad (5)$$

$$ZP_j, ZN_j = \text{integer} \quad \forall j \quad (6)$$

$$X_{ij} = \text{binary}(0,1)\text{integer} \quad \forall i, j \quad (7)$$

The equation above is to find out the number of *Minimal Imbalance* from the sum of the remainder between ZP_j and ZN_j in each zone. ZP_j in each zone is the positive valued imbalance (in loads) if the sum of in-bound goods in each zone is greater than the sum of out-bound freight. ZN_j in each zone is the negative valued imbalance if the sum of out-bound goods in that zone is greater than the sum of in-bound goods in that zone. ZN_j equals zero when in-bound goods in that zone equal the sum of out-bound goods in that zone. Besides, I_i is imbalance value of area i which came from in-bound goods of area i to minus with out-bound goods of area i . I_j is imbalance value of zone j that came from in-bound goods of zone j minus with out-bound goods of zone j . F_i is a set of feasible zones for area i . F_j is a set of feasible areas for zone j . Finally, x_{ij} is an integer that has 2 values; 1 and 0. The result comes to 1 when area i in zone j and it equals 0 when area i is not in zone j .

The problem in Dynamic Multiple Zone Expedition, DMZE

However, business conditions are constantly changing, the need of a dynamic nature of the multiple zone expedition problems (new quantity of orders, new product lines, and technological advance) is proposed. There are a series of data in static problem with its own "in-bound and out-bound freights" matrix for given finite discrete time periods. A period can be given in terms of months, quarters, years. An additional rearrangement penalty in the objective function ties the static problems together whenever any area moves to the different zone in consecutive time period. The conventional multiple zone expedition model is extended to the dynamic nature of this problem. When time (t) value that is greater than a period, the set of data comes to $t = 1$ but if the data becomes more than one set, it comes to $t = 2, 3, \dots, 7$. These are beneficial in operation as following mathematical programming:

$$\text{Minimise } \sum_{t=1}^T \sum_{j=1}^{F_t} ZP_{jt} - \sum_{t=1}^T \sum_{j=1}^{F_t} ZN_{jt} + \sum_{i=1}^{F_j} \sum_{j=1}^{F_i} \sum_{k=1}^{F_i} \sum_{t=1}^{T-1} R_{ijk} \cdot X_{ijt} \cdot X_{ik(t+1)}$$

Subject to:

$$\sum_{t=1}^T \left(\sum_{i \in F_j} I_i X_{ijt} + I_{jt} - ZP_{jt} - ZN_{jt} \right) = 0;$$

$$\sum_{t=1}^T \left(\sum_{j \in F_i} X_{ijt} \right) = 1; \forall_i$$

$$ZP_{jt} \geq 0 \quad \forall j, t$$

$$ZN_{jt} \leq 0 \quad \forall j, t$$

$$ZP_{jt}, ZN_{jt} = \text{integer} \quad \forall j, t$$

$$X_{ijt} = \text{binary}(0,1) \text{ integer} \quad \forall i, j, t$$

$$R_{ijk} = \begin{cases} Pe_{jkt} & \text{if } (j \neq k) \text{ and } t = t; \\ 0 & \text{otherwise} \end{cases}$$

, where R_{ijk} is the rearrangement penalty (Pe_{jkt}) for area i moved from zone j to k in consecutive time.

Bring data in each period of time (t) to be continuously, the alteration of zone will reflect *Minimal Imbalance* as seen in the following testimony. A direction in searching a solution of DMZE has applied a method in solving problems of statistical multiple zone expedition. Firstly considering the imbalance proposed in a form of statistical multiple zone expedition at interval and then considering a rearrangement penalty generated from time alteration in such period by finding a series of any solutions through all intervals. The objection of this approach is to minimise an imbalance with some penalty in planning all the period of time.

Dynamic Programming Strategy, DPS

This strategy could tackle the complicated decisions by transforming them to one step of decision making which has 1-2 decisive variables to calculate. Each minor decision could provide many answers; the procedure needs to consider the previous reflection for the best answer [6]. Dynamic Programming Strategy is different from others strategies. It could alter the decisive problem with n variables to be n -minor problems. Each of them will have one decisive variable. Each of stage will consist of stage variable, S to connect each stage from the first to the last problem stages. In the study of transportation operations, Dynamic Programming Strategy is used as a tool tackling problems by creating model via computer simulation. DPS is also used for many engineering matter such as a Cost Reduction Strategy for signal controlling system industry and Raw Material Management which is insufficient including to Goods Collection [6]. The problem in use of DPS could be separated to minor problems which could arrange each area to each zone harmoniously.

Due to the enormousness of DMZE problem, the total number of possible zone arrangement solutions allocated is $\left[\sum_{i=1}^N (\text{No. of combination}_i) \left(\frac{\text{Area}_i!}{\text{Combination}_i} \right) \right]^T$, where N is total

number of possible combination; e.g. 3-Zone-5-Area problem: 5/0/0, 4/1/0, 3/2/0, 3/1/1, 2/2/1 for Zone 1/2/3 respectively and T represents time periods. For example, if there are 5 areas with 3 zones, it will be clarified for all cases that may happen. Each zone will consist of the 0 - 5 areas by using counting in mathematic knowledge by the combination of arrangement n of different things, r arrangement as follows: 5 areas with 3 zones could have 243 styles.

The advantage and disadvantage of DPS is that there are always the answers for each problem while it is obstructed by time consuming. However, we are able to decrease an answer set in each time we calculate the imbalance of inbound and outbound goods (best

answer in each period of time) through planning period. It demonstrates the below limitation of *Dynamic Multiple Zone Expedition*, DMZE.

There are 2 methods of upper limitation calculation which are the management of best zone in each period of time comprising of the calculation of the best zone in each period of time and of imbalance of inbound and outbound goods [7]. We have to monitor if there is a zone alteration during the times. If so, the compensation value will increase the imbalance of alterative positions. In process of imbalance calculation of inbound and outbound goods, the outcome value comes to limitation value on problems of DMZE.

The proper and possible zone management in each period of time by increasing equation in each problem of zone management as statistic and the limitation value equals to at least (k) to define the number of possible zone management in each period of time [8, 9]. The zone may be decreased or remain the same. Besides, the method to calculate the compensation value of imbalance of zone alteration in the continuous times and then, find out the best outcomes as shown in following equation:

$$L_{tm}^* = \text{Min} \{L_{t-1,k}^* + R_{km}\} + F_{tm} \quad [10]$$

where,

- L_{tm}^* = Minimal imbalance of the arrangement m at time t
- k = Arrangement (states) for each time period
- R_{km} = Rearrangement penalty for arrangement k to arrangement m
- F_{tm} = Imbalance of the arrangement m in time period t

Example: Specify the problem parameters. Given $T = 2$, Area = 5 and Zone = 3

Create randomized numbers of in-bound and out-bound freights to each area. Assume equal in-bound and out-bound freights in each time period; $t = 1$ and $t = 2$. Also create randomized numbers of rearrangement penalty to each area at $t = 1$, in this example, the rearrangement penalty for area 1 and 2 are set at 25 and 15 respectively.

Area	Load In	Load Out	fi (load in - load out)
1	71	81	-10
2	55	15	40
3	51	57	-6
4	91	67	24
5	40	66	-26

Select one of the possible solutions of the transportation arrangement.

Zone	Area										Fj		Total Imbalance in Zone	
	1		2		3		4		5					
	F1	F2	F1	F2	F1	F2								
1	1	0	0	1	0	0	0	0	0	0	1	1	(-20)	80
2	0	1	1	0	0	0	0	0	0	0	1	1	80	(-20)
3	0	0	0	0	1	1	1	1	1	1	3	3	(-16)	(-16)
Fi	1			116	116									

In the above example, imbalance with some penalty in planning 2 periods of time

$$\begin{aligned}
 &= \sum_{t=1}^T \sum_{j=1}^{Fj} ZP_{jt} - \sum_{t=1}^T \sum_{j=1}^{Fj} ZN_{jt} + \sum_{i=1}^{Fj} \sum_{j=1}^{Fj} \sum_{k=1}^{Fj} \sum_{t=1}^{T-1} R_{ijk,t} \cdot X_{ijt} \cdot X_{ik(t+1)} \\
 &= 116 + 116 + \text{Penalty of rearrangement of area 1 (from Zone 1 to 2) +} \\
 &\quad \text{Penalty of rearrangement of area 2 (from Zone 2 to 1)} \\
 &= 272
 \end{aligned}$$

3. RESULTS

For finding the optimal solution of the dynamic multiple zone expedition planning problem by DPS, a program written by Java has been developed to evaluate the results. It can be divided to two categories as follows. The problems considered compose of small problems: (Number of Area, Number of Zone, Number of Time Period) = {(4, 3, 2), (5, 4, 2), (6, 5, 2), (7, 6, 2)} and big problems: {(39, 3, 1), (76, 6, 2), (20, 8, 2)}. For solving small problems by DPS, it gives arrangement imbalance with penalty and the evaluation time as shown in the following table. Due to the hugeness of the big problems, searching for the optimal solution is limited from the run times.

Table 1. Optimal solutions in solving the small problems including the CPU evaluation runtime (unit: hour: minute: second)

Area	Zone	Time	Optimal Solution	Imbalance	Runtime
4	3	2	-/2/134*	418	0:08:984
			-/2/134		
5	4	2	145/-/2/3	348	0:09:650
			145/-/2/3		
6	5	2	1345/-/2/-/6	520	0:09:985
			1345/-/2/-/6		
7	6	2	1257/346/-/1/-/1-	398	0:08:988
			12/3467/5/-/1/-/1-		

Note: * -/2/134 →
 No Area assigned to Zone 1
 Area: 2 assigned to Zone 2
 Area: 1, 3 and 4 assigned to Zone 3

Table 2. Optimal solutions in solving the big problems including the CPU evaluation runtime (unit: hour: minute: second)

Area	Zone	Time	Optimal Solution	Imbalance	Runtime
39	3	1	1...26,28,30,33/27,29,31,34,37,38/32,35,36,39	394	142:29:55
76	-6	2	1...68,72/69,74/70,71/-/73,75/76	548	142:32:28**
			-		
20	8	2	1...12,14/13,15/11,16,19,20/-/1/-/17,18	174	142:12:8**
			-		

**Not completed

4. CONCLUSIONS

From the research of dynamic multiple zone expedition by DPS to find optimal solutions, it is found that in any small problems and big problems both with and without Rosenblatt's procedures in evaluation, DPS is able to give an optimal solution though it consumes very much of time, especially big problems. However, for combining Rosenblatt's procedures, speed to search for the optimum can be increased.

It is known that problems in planning of dynamic multiple zone expedition are seemingly huge and complex. To find out the best solution within a limited time is obviously difficult. Further research focusing on a heuristic procedure then is developed to solve this problem. These heuristic approaches could be extended to find the better performance, especially in terms of speed of convergence. Genetic and Tabu-search methods are techniques in solving an estimating problem. The first one is the process in obtaining a randomised solution developed from selecting strain and naturally spreading of biological process [11, 12]. The other is a process to getting a solution developed from memories for learning process of convergent solution [13].

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