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A Comparative Analysis of Vehicle Routing Problem in APSRTC Firm

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Abstract

The problem of designing routes for the vehicles that should supply goods to different customers with prescribed demand from a single or various depot is known as Vehicle Routing Problem (VRP). The main objective in this case is minimizing the total transportation cost based on the global distance traversed as well as the fixed costs associated with the used vehicles and drivers or minimize the number of vehicles needed to serve all customers (depots) or maximizing the profits and collection of optimal routes from one or several depots to a number of geographically scattered cities or consumers (depots) while taking into considerations some constraints like demand and maximum distance. This paper is to analysis the VRP problem of the firm APSRTC Stores in the transportation of components to the respective depots which is analyzed using VRP Spreadsheet Solver and Clark & Wright Savings Algorithm and the results are compared, which concludes that the VRP Spreadsheet Solver provides optimal values for the firm.

Keywords: Vehicle Routing Problem, APSRTC Stores, VRP Spreadsheet Solver, Clark & Wright Savings Algorithm, optimal routing, transportation costs, profits.

I. INTRODUCTION

Ever since Dantzig and Ramser initially introduced it, the vehicle routing problem started arousing the attention of many scholars due to its difficulty and practicality. The VRP constitutes a generic name that is given to an entire set of problem implicating the visiting of several “customers” by a given number of “vehicles” from a single or multiple depot. Its main aim is to obtain an optimal path for each vehicle while minimizing the total cost and considering the given constraints. Consequently, the major components of the vehicle routing problem are depots, vehicles, road routes, and drivers. The various constraints of these components and combinations can produce many variations of the VRP. The general variant of VRP is the Capacitated Vehicle Routing Problem (CVRP), the other variants are as described, VRP with Time Window constraints (VRPTW), Open VRP (OVRP), Multi Depot Vehicle Routing Problem (MDVRP), VRP with Backhauls (VRPB) and the VRP with Pickup and Delivery (VRPPD). In this problem, a complete study was done for the firm APSRTC Stores which provides various bus components to respective depots under its control, which is operated using a single Warehouse at a defined location, using homogeneous vehicles for delivery and pickup which are the modified buses of the firm and the customer are placed at different locations and depots are given code respectively according to the location of depots. The distance matrix is framed from warehouse to the depots. The main aim of the paper is to provide optimal solutions for the distance traversed, number of routes used, number of buses to be operated for prescribed demand and determine the savings percentage of the total transportation cost (profits). The results are computed using the tools VRP Spreadsheet Solver and Clark &Wright Algorithm to determine the optimal routes and then compared.

II. LITERATURE REVIEW

Günes Erdogan et al (2017) this paper mainly aims to reduce the transportation costs by a fleet of vehicles functioning in the depots. This paper presents an open source Excel based tool for solving many variants of the Vehicle Routing Problem by using the VRP Spreadsheet Solver. The solver is found to be capable of solving the Capacitated VRP.

Prateek Mittal et al (2017) in this paper the VRP problem is solved using the Clark and Wright Algorithm for an Indian transportation firm and established possible improvements in dynamic demand and routing of the freight.

Liong Choong Yeun et al (2008) in this paper represented different variants like exact algorithms based on the linear programming techniques and guided local search for a set of delivery routes based on prescribed constraints with the minimal transportation costs.

Mahdi Alinaghian et al (2015) in this paper represented a Green Clark and Wright Algorithm (GCW) for Green Vehicle Routing Problem which depicts the minimization of consuming oil of the vehicle and drivers as well as the vehicles operated using Exact methods for small sized problems and Differential Evolution Algorithm Solution for large scale algorithm with Clark and Wright Algorithm proving that CW provides the optimal solutions.

III. PROBLEM DATA

The current paper states the issue of APSRTC Stores in transporting the bus components to the respective depot under its control. The firm uses a single warehouse and contains 26 depots at defined locations. The motive to analyze the paper is APSRTC Strategy which uses a single server to every depot, i.e. single bus to single depot thus uses 26 buses to transport its components as well as 26 routes in satisfying the demand of the depots. Thus, the problem is considered to be a vulnerable situation to the firm economic conditions which can succeed using the Vehicle routing problem. Thus, the two approaches are used to solve the VRP and compared the results. The vehicles used by the firm are the modified buses.

The approach followed by the APSRTC consumes more transportation cost which is directly proportional to the distance traversed.

The warehouse and depots are described in Table 1 with respective demands and capacity of the vehicle are represented in the part v data collection and the visualization of the strategy followed by APSRTC is given below.

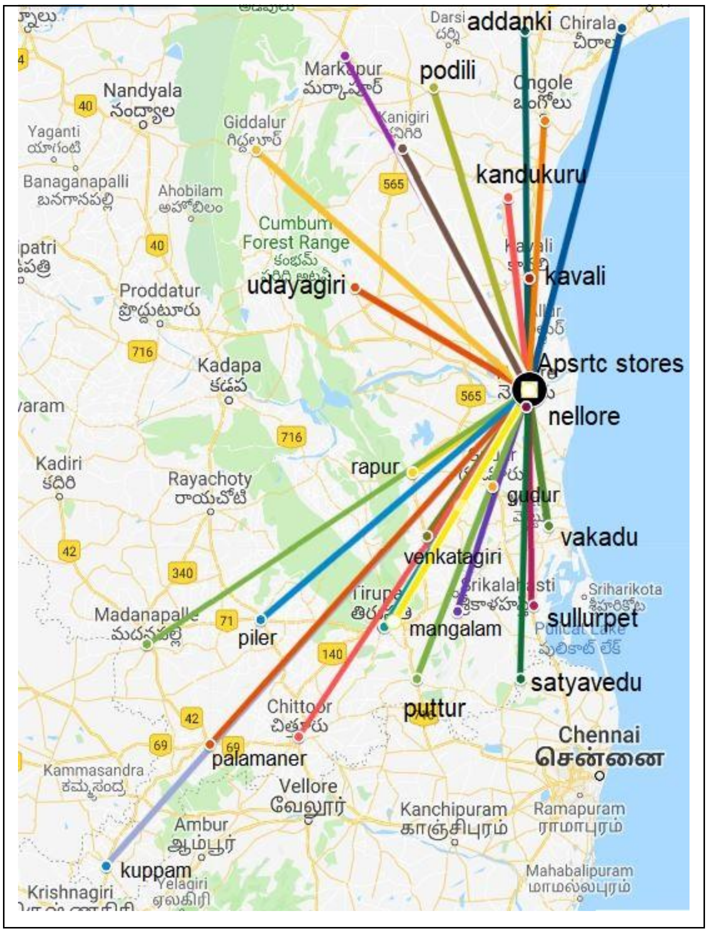

Fig 1: APSRTC Strategy for transportation.

The above visualization represents the warehouse in a black circle with a white square in it and 26 depots respectively with different color indication.

IV. METHODOLOGY AND METHODS

For solving the vehicle routing problem, the VRP Spreadsheet Solver and Clark and Wright Algorithm used in this paper.

This study prescribes the optimum routes, vehicles operated and distance travelled by comparing the two approaches.

A. VRP SPREADSHEET SOLVER

The current, VRP Spreadsheet Solver developed by Dr. Günes Erdogan in 2013 is an open and free source solver of vehicle routing problem which affords visualization and provide solution to different variants of vehicle routing problems.

The VRP Spreadsheet Solver follow an incremental flow of data, with subsets of data being kept in separate worksheets. Mainly, the workbook only contains the worksheet named VRP Solver Console. The remaining worksheets, 1. Location, 2. Distance, 3. Vehicle, 4. Solution, 5. Visualization should be generated and the optimal solutions are obtained.

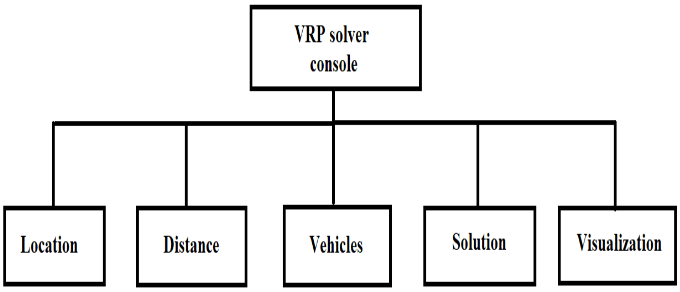

Fig 2: Structure of VRP Spreadsheet Solver

By providing the above data and generating the incremental flow of information. The optimal routes, travel distances are obtained.

B. CLARK &WRIGHT SAVINGS ALGORITHM

Clark &Wright Algorithm is also called as CW Savings Algorithm which is used to depict the optimal routes and the optimal distance traversed.

The CW was proposed by Clark &Wright who introduced the savings concept which is framed by the computation of savings for uniting two customers into the same route. The CW is a widely known heuristic for solving the Vehicle Routing Problem (VRP), and the applications of CW has continued since it was proposed in 1964.

The steps involved in the Clark &Wright algorithm is as follows.

1. Determine the distance matrix from warehouse to various depots respectively.
2. Compute the savings matrix $S_{ij} = d_{i0} + d_{j0} - d_{ij}$ for every pair (i, j) of demand points.
3. Rank and list the savings S_{ij} values in the descending order of their magnitude.
4. Assigning of customers to the vehicles. Based on three steps
   i) A new route is initiated if either, neither i or j have previously been assigned to a route, including both i and j.
   ii) Exactly one of the two (i or j) has already been included in an existing route and that point is not interior to that route, in which case the link (i, j) is added to the same route.
5. Process the algorithm accordingly as mentioned till the savings list exhausts, if not then return to step 3, processing the next entry in the list; otherwise, stop.

V. DATA COLLECTION

The data of distance matrix and the demand is below.

DIJ	NLRZONE	NLR	KAVALI	UDGR	GUDUR	RPR	VNG	VKD	SLPT	ADNK	CHI	KNDU	ONG	GIDD	KNG	MRK	PODILI	TPT	SKHT	PTR	STYD	CTR	MDNP	PLMN	PIL	KPM	MNGL
NLRZONE	0	4.961	46.256	101.805	56.411	83.73	112.423	81.659	101.496	161.706	179.728	101.951	119.899	216.794	152.933	223.906	178.224	143.205	105.499	162.134	146.211	213.977	262.479	262.81	236.429	332.131	141.999
NLR	4.961	0	51.132	102.767	50.211	65.003	93.696	75.459	95.296	166.582	184.604	106.827	124.775	217.756	157.809	228.782	183.1	137.005	99.299	155.934	140.011	207.777	256.279	256.61	230.229	325.931	135.799
KAVALI	46.256	51.132	0	93.282	101.634	128.953	157.646	126.882	146.719	115.672	133.694	55.917	73.865	224.98	106.899	177.872	132.19	188.428	150.722	207.357	191.434	259.2	307.702	308.033	281.652	377.354	187.222
UDGR	101.805	102.767	93.282	0	154.06	125.875	154.568	172.843	192.68	201.226	219.248	110.991	159.419	119.704	86.234	161.886	126.245	203.973	196.683	222.902	237.395	273.174	228.625	292.479	245.219	361.63	202.767
GUDUR	56.411	50.211	101.634	154.06	0	32.529	61.222	43.384	63.221	215.651	233.673	155.896	173.844	261.591	206.878	277.851	232.169	104.93	67.224	123.859	107.936	175.702	224.204	224.535	198.154	293.856	103.724
RPR	83.73	65.003	128.953	125.875	32.529	0	33.038	71.431	91.268	243.698	261.72	183.943	201.891	240.813	183.274	305.898	260.216	82.443	75.83	101.372	135.983	153.215	182.439	202.048	146.682	271.369	81.237
VNG	112.423	93.696	157.646	154.568	61.222	33.038	0	87.6	63.045	272.438	290.46	212.683	230.631	269.553	212.014	334.638	288.956	49.404	42.791	68.333	103.098	120.176	168.678	169.009	142.628	238.33	48.198
VKD	81.659	75.459	126.882	172.843	43.384	71.431	87.6	0	70.307	241.659	259.681	181.904	199.852	287.599	232.886	303.859	258.177	112.016	74.31	130.945	115.022	182.788	231.29	231.621	205.24	300.942	110.81
SLPT	101.496	95.296	146.719	192.68	63.221	91.268	63.045	70.307	0	263.012	281.034	203.257	221.205	308.952	254.239	325.212	279.53	92.307	54.601	111.236	44.714	163.079	211.581	211.912	185.531	281.233	91.101
ADNK	161.706	166.582	115.672	201.226	215.651	243.698	272.438	241.659	263.012	0	84.943	83.722	40.73	153.47	85.448	88.141	62.524	303.187	265.481	322.116	306.193	373.959	422.461	422.792	396.411	492.113	301.98
CHI	179.728	184.604	133.694	219.248	233.673	261.72	290.46	259.681	281.034	84.943	0	101.407	58.415	204.157	136.135	157.049	111.367	320.872	283.166	339.801	323.878	391.644	440.146	440.477	414.096	509.798	319.666
KNDU	101.951	106.827	55.917	110.991	155.896	183.943	212.683	181.904	203.257	83.722	101.407	0	41.844	144.199	52.093	112.577	100.169	243.433	205.727	262.362	246.439	314.205	362.707	363.038	336.657	432.359	242.227
ONG	119.899	124.775	73.865	159.419	173.844	201.891	230.631	199.852	221.205	40.73	58.415	41.844	0	154.328	86.306	107.22	61.538	261.31	223.604	280.239	264.316	332.082	380.584	380.915	354.534	450.236	260.104
GIDD	216.794	217.756	224.98	119.704	261.591	240.813	269.553	287.599	308.952	153.47	204.157	144.199	154.328	0	95.479	83.646	108.077	307.033	302.827	343.264	352.372	308.492	263.943	327.797	280.537	396.948	313.929
KNG	152.933	157.809	106.899	86.234	206.878	183.274	212.014	232.886	254.239	85.448	136.135	52.093	86.306	95.479	0	63.812	40.01	293.727	256.021	312.656	296.733	362.415	317.866	381.72	334.46	450.871	292.521
MRK	223.906	228.782	177.872	161.886	277.851	305.898	334.638	303.859	325.212	88.141	157.049	112.577	107.22	83.646	63.812	0	60.996	348.819	327.665	384.3	368.377	350.278	305.729	369.583	322.323	438.734	355.715
PODILI	178.224	183.1	132.19	126.245	232.169	260.216	288.956	258.177	279.53	62.524	111.367	100.169	61.538	108.077	40.01	60.996	0	319.689	281.983	338.618	322.695	375.085	330.536	394.39	347.13	463.541	318.483
TPT	143.205	137.005	188.428	203.973	104.93	82.443	49.404	112.016	92.307	303.187	320.872	243.433	261.31	307.033	293.727	348.819	319.689	0	37.664	37.376	90.659	71.881	115.022	120.714	88.972	190.035	5.621
SKHT	105.499	99.299	150.722	196.683	67.224	75.83	42.791	74.31	54.601	265.481	283.166	205.727	223.604	302.827	256.021	327.665	281.983	37.664	0	56.854	58.34	108.697	157.199	157.53	131.149	226.851	36.719
PTR	162.134	155.934	207.357	222.902	123.859	101.372	68.333	130.945	111.236	322.116	339.801	262.362	280.239	343.264	312.656	384.3	338.618	37.376	56.854	0	60.875	64.029	152.805	111.381	126.755	180.702	39.478
STYD	146.211	140.011	191.434	237.395	107.936	135.983	103.098	115.022	44.714	306.193	323.878	246.439	264.316	352.372	296.733	368.377	322.695	90.659	58.34	60.875	0	120.646	206.104	167.998	180.054	285.304	92.777
CTR	213.977	207.777	259.2	273.174	175.702	153.215	120.176	182.788	163.079	373.959	391.644	314.205	332.082	308.492	362.415	350.278	375.085	71.881	108.697	64.029	120.646	0	104.67	51.399	89.716	120.72	78.423
MDNP	262.479	256.279	307.702	228.625	224.204	182.439	168.678	231.29	211.581	422.461	440.146	362.707	380.584	263.943	317.866	305.729	330.536	115.022	157.199	152.805	206.104	104.67	0	63.318	89.837	132.469	121.551
PLMN	262.81	256.61	308.033	292.479	224.535	202.048	169.009	231.621	211.912	422.792	440.477	363.038	380.915	327.797	381.72	369.583	394.39	120.714	157.53	111.381	167.998	51.399	63.318	0	138.548	83.413	127.255
PIL	236.429	230.229	281.652	245.219	198.154	146.682	142.628	205.24	185.531	396.411	414.096	336.657	354.534	280.537	334.46	322.323	347.13	88.972	131.149	126.755	180.054	89.716	89.837	138.548	0	207.871	95.154
KPM	332.131	325.931	377.354	361.63	293.856	271.369	238.33	300.942	281.233	492.113	509.798	432.359	450.236	396.948	450.871	438.734	463.541	190.035	226.851	180.702	285.304	120.72	132.469	83.413	207.871	0	196.529
MNGL	141.999	135.799	187.222	202.767	103.724	81.237	48.198	110.81	91.101	301.98	319.666	242.227	260.104	313.929	292.521	355.715	318.483	5.621	36.719	39.478	92.777	78.423	121.551	127.255	95.154	196.529	0

Fig 3: Distance matrix with warehouse and depots in Km

The data of demand of various depots are as tabulated below

Table 1: Depots and vehicle capacity

DEPOT	DEMAND
NLR	31
KAVALI	28
UDGR	15
GUDUR	23
RPR	32
VNG	38
VKD	19
SLPT	35
ADNK	27
CHI	31
KNDU	22
ONG	28
GIDD	27
KNG	39
MRK	30
PODILI	16
TPT	36
SKHT	37
PTR	29
STVD	21
CTR	32
MDNP	21
PLMN	29
PIL	33
KPM	28
MNGL	19
VEHICLE CAPACITY	500

VI. RESULT ANALSIS

The results are obtained for the problem of APSRTC Stores and is given below. The evaluated results of routes visualization is provide for the two tools used.

A. VRP SPREADSHEET SOLVER

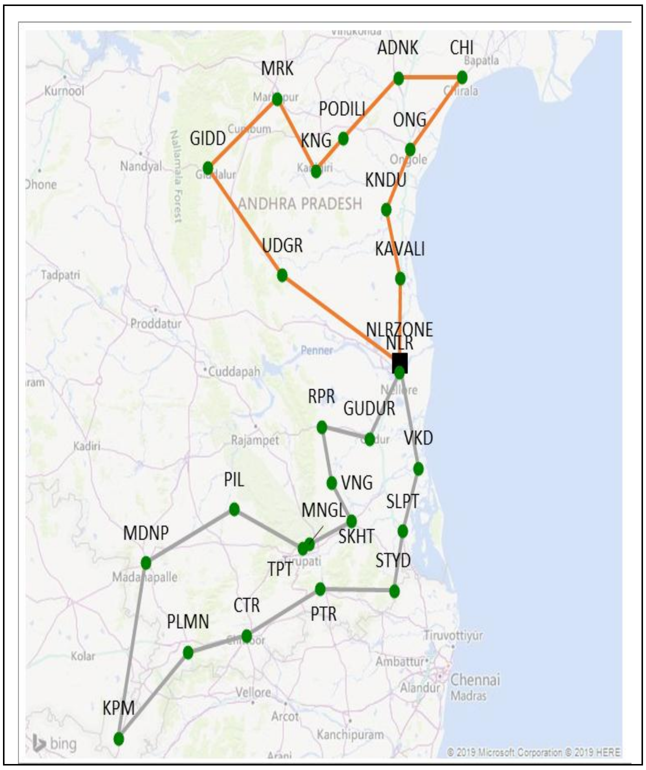

Fig 4: Visualization of VRP Spreadsheet Solver

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B. CLARK & WRIGHT SAVINGS ALGORITHM

The savings list is computed using the formulae $S_{ij} = d_{i0} + d_{j0} - d_{ij}$, the saving list is arranged in the descending order and then assignment of vehicles to the customer is done based on the steps involved in solving CW Algorithm.

The list of assigned ranking list are (Mdnp-Plmn), (Plmn-Kpm), (Ctr-Kpm), (Mdnp-Pil), (Gidd-Mrk), (Mrk-Podili), (Ctr-Ptr), (Podili-Kng), (Pil-Mngl), (Tpt-Mngl), (Adnk-Chi), (Ptr-Stvd), (Chi-Ong), (Tpt-Skht), (Slpt-Stvd), (Kndu-Kng), (Udgr-Gidd), (Vng-Skht), (Rpr-Vng), (Vkd-Slpt), (Gudur-Rpr), (Kavali-Adnk), (Nlr-Gudur).

The assignment of the above ranked lists is assigned using the step 4 in CW Algorithm. Thus, the visualization of the Clark &Wright algorithm is as follows.

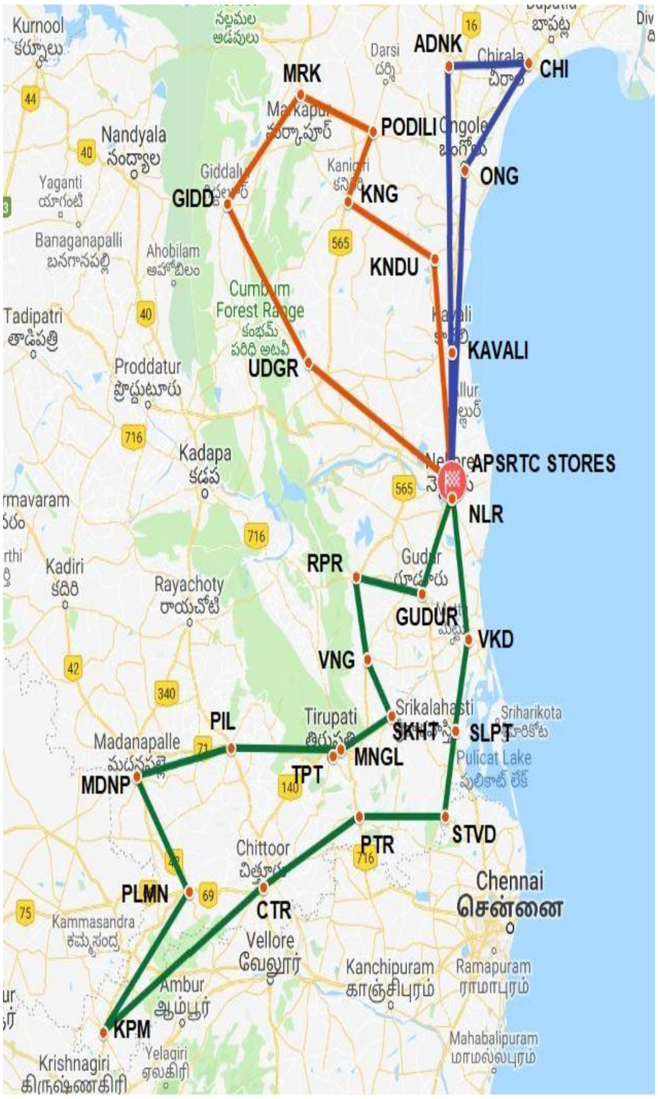

Fig 5: Visualization of Clark & Wright Algorithm

VII. RESULT

The final results of the following tools are compared with the APSRTC Strategy.

COMPARISON TABLE

Table 2: Comparison table for Distance, Routes and Vehicles used

	ASPRTC STRATEGY	VRP SPREADSHEET SOLVER	CLARK &WRIGHT ALGORITHM
TRAVEL DISTANCE (Km)	7862	1643	1931
NUMBER OF ROUTES	26	2	3
NUMBER OF VEHICLES	26	2	3

COST COMPARISON TABLE

Table 3: Cost Comparison of Total Cost of Transport per trip

	APSRTC STRATEGY	VRP SREADSHEET SOLVER	CLARRK & WRIGHT ALGORITHM
TRAVEL DISTANCE (KM)	7862	1643	1931
FIXED COST	100	100	100
TCT	7,86,200	1,64,300	1,93,100

VIII. CONCLUSION

The usual objective in the Vehicle Routing Problem is to minimize the total distance traversed. However, in several real-life applications other aims such as minimizing the total number of vehicles used, equalizing the loads of tours, or minimizing the length of the longest route are also important.

The above depicted results for VRP of ASPRTC suggests that VRP Spreadsheet Solver is the best tool to be integrated by the firm in solving VRP further to effectively solve the current issues like number of routes, number of buses operated to transport and distance of travel which also makes the firm becomes economically healthier.

The comparison gave a savings of 79.10% in case of VRP Spreadsheet Solver and 75.43% in case of Clark & Wright Algorithm with respect to the current APSRTC Strategy. In addition, the number of buses to be operated have also been reduced significantly for the present demand and may vary with the dynamic demand.

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