Petrol Delivery Assignment with Multi-Product, Multi-Depot, Split Deliveries and Time Windows

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***Abstract*—The purpose of this study is to solve a planning problem faced by Pertamina, a state-owned Oil and Gas company in Indonesia, dealing with the delivery of petrol products. Based on Petrol Station Replenishment Problem (PSRP), a fleet of tank-trucks with different capacities has been assigned to deliver two petrol products from two depots with split deliveries and time windows to a set of petrol stations in the working area. The Tabu Search (TS) algorithm has been used to solve this problem. The problem consists of jointly determining the fleet assignment and of designing delivery routes to petrol stations to satisfy the orders using the available resources with the minimum total travel cost for delivery.**

***Index Terms*—Petrol delivery, multi-product, multi-depot, split deliveries, time windows, PSRP, tabu search.**

I. Introduction

The problem of physical distribution of goods or the delivery of services to customers' locations is necessary in most industries, where logistics cost is almost 30% of total cost in every industry [1]. In this case, proper routing and scheduling is crucial, as a modest improvement in fleet utilization can result in large profit improvements [2].

In recent years, a great deal of research has been carried out on the optimization of freight distribution planning and management. The applications developed in this field have shown that distribution planning techniques produce savings ranging from 5% to 25% of total travel costs [3]. The principal considerations when scheduling deliveries of goods are customer satisfaction and costs of distribution [4]. The same considerations also occur in the case of petrol delivery problem.

In the Petrol Station Replenishment Problem (PSRP) the aim is to optimize the delivery of petroleum products to a set of petrol stations using a limited fleet of tank-trucks. More specifically, one must determine the assignment of petroleum products to the available trucks, delivery routes, and schedules. The problem intensifies from a practical perspective when the fleet is hired, that is, the tank-trucks do not constitute company assets [5]. In such cases, effective planning is a critical success factor for operational efficiency and for the resulting service level, since non-company resources are responsible for the physical interface with the final customer [6].

Nowadays, many companies subcontract their distribution operations to private distributors [7]. For companies that have a large number of deliveries, hiring vehicles may be more expensive per unit distance travelled, but maintenance costs do not occur [8]. The latter is the main reason why more and more companies use hired fleet or allocate the distribution function to third party logistic (3PL) providers [5].

The objective of this paper is to solve petrol station delivery problem (PSRP) for multi-product, multi depot, split deliveries, and time windows. A major difference between the PSRP and most vehicle outing problems is the loading component; in the PSRP one must simultaneously design vehicle routes and assign petroleum products to truck compartments for each trip [9].

This problem is motivated by a real case faced by Pertamina, the state-owned Oil and Gas Company in Indonesia. Ever since the Oil and Gas Act No. 22 in 2001, Pertamina, which is previously had monopolized the oil and gas business activities in Indonesia, faced with the reality of the opening of downstream business activities of oil and gas in Indonesia for private companies, both national and foreign private companies. One of Pertamina's businesses in the downstream sector to face the competition of this Act is associated with the fuel retail industry. Currently, some petrol stations, which are owned by private companies, can be found in certain major cities in Indonesia.

A petrol station, which is known as SPBU in Indonesia, is a common infrastructure for the community to meet the needs of automotive fuel, which are RON 88, RON 92 and RON 95 as well as Cetane 48 and 53. At the Pertamina petrol stations, those fuel types are more commonly known as Premium, Pertamax, Pertamax Plus, Solar and Pertamina DEX. Up to this time, Premium is still subsidized by the Government, and it is the most widely purchased by the public. For Pertamina, SPBU is an agent for Pertamina in distributing fuel products as well as a marketing spearhead, because it deals directly with the end customer. Hence, improvement in service and operational reliability of SPBU should be a key priority for Pertamina to keep remains competitive; one way is to ensure the continuity of supply or the availability of fuel products at the SPBU. In addition, Pertamina is also required by the Government to be able to make efficiencies in distribution costs, particularly for the subsidized product (i.e., Premium) which is a Public Service Obligation (PSO).

In terms of distribution, Pertamina has made various efforts to improve efficiency, one of which is to do a leasing system in the management of tank-trucks for petrol delivery. With this leasing system, Pertamina leases tank-trucks from a third party, whereas the operation of these trucks in the process of distributing fuel from depots to SPBU is managed by Pertamina through one of its subsidiaries. However, the effort to increase efficiency is not followed by good

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transportation management. Sometimes it still happens of a delay in fuel delivery to SPBU that resulted in shortage or even unavailability of fuel at SPBU, which has led to dissatisfaction from the SPBU management for the services provided by Pertamina.

To optimize the distribution activity, it is necessary to design a system that can assist Pertamina, in a daily basis, in determining the assignment and routes of the fleet in distributing the fuel products to each SPBU. The determination of routes and scheduling of fuel delivery to the SPBU can be modeled as a Petrol Station Replenishment Problem (PSRP) with the multi-depot, multi-product, split deliveries, and time windows, which in this study will be completed by the Tabu Search algorithm (TS).

The challenge in this study is to construct routes and schedules for the fleet of trucks so as to maximize profit. More specifically, a Decision Support System (DSS) for petroleum delivery will be developed by which Pertamina is able to obtain an optimal solution for tank-trucks routing and scheduling assignments under complicated constraints and with real-time information. A DSS is a computer-based interactive system utilizing data and embedding models to support decision-makers in the process of making decision on various problems [10].

In practice, Pertamina has to determine routing and scheduling of the fleet on a daily basis, which should be done at the beginning of each day, where the ordered products should be delivered within the following working hours. Currently, the assignment and routing plans were set using the experience and preference of the individual planner. Hence, an algorithmic approach is thus needed. It could become the computational engine of a decision support system devoted to solving the problem efficiently. Hence, it is worth noting that, in practice, the DSS has less than 2 hour to solve the PSRP at the beginning of each day.

II. Current Practices and Challenges

Fig. 1. Bandung sales area.

Fig. 2. Geographical locations of the SPBU

This study was conducted on Pertamina Fuel Retail Marketing in the Bandung sales area, where it includes 6 counties and 2 municipalities (see Fig. 1). The petrol delivery is carried out from two depots (i.e., Ujung Berung and Padalarang) to 208 SPBU. The distance between the two depots is about 25 kilometers. Ujung Berung Depot is designed to be able to serve the demand for Premium, Solar and Pertamax, whereas Depot Padalarang is designed to be able to deliver premium and Solar. Delivery scheduling is done every day refers to the demand of each SPBU. Currently, the assignment and routing plans were set using the experience and preference of the individual planner. In general, the petrol delivery in the Bandung Sales Area has unique characteristics and high complexity. This is because the area is extensive and includes urban, suburban, and rural areas. The frequency of the orders made by each SPBU is also variable as it depends on many factors. Some of the SPBU are located in tourist areas, so the demand for fuel will be different between weekdays, weekends, and holiday season. Fig. 2. shows a visual illustration of the SPBU and depot locations.

The daily delivery process is performed according to the following steps: first, SPBU reports the amount of fuel that is still available in the station and also the demand for fuel delivery via Short Text Messages (SMS) to Pertamina a day before delivery. Based on this information, the Sales Services at the Depot will determine the amount of fuel that will be delivered to the SPBU. Then the fuel delivery plan was submitted to Patra Niaga as Pertamina's subsidiary that manages the tank-trucks to make fuel deliveries into SPBU on the same day delivery.

TABLE I: Number of Trucks and Capacities

No	Capacities (kiloliter)	Number of Comp	Total Comp	Number of Trucks	Total Capacitie s
1	16	2	32	30	480
2	24	3	72	39	936
3	32	4	128	7	224
		TOTAL	232	76	1.640

The company manages a fleet of 76 trucks with different capacities, as shown in Table 1. The truck is divided into compartments each having a capacity of 8 kiloliters. Each truck can be assigned more than one trip and visit more than one SPBU in one day, with the maximum of 4 SPBU that can be visited in each trip. Compartments are not equipped with a flow meter, which implies that they must be entirely emptied once replenishment has started. Hence, the minimum volume of each replenishment process at each SPBU is 8 kiloliter. In each delivery, all petrol in the compartment is unloaded and thus only empty compartments will be returned to the depot. Also, due to the layout and size of the SPBU, only 2 trucks can make fuel delivery at the SPBU at the same time.

III. Model Formulation

Currently, the company determines the routes and the daily delivery plan for each truck based on previous experience, where SPBU located close to the depot will be supplied first. This study designed the route and schedule of the fleet for the distribution of two fuel products, that is, Premium and Solar, where the sales proportion of these two products is more than 98%.

In this study, a DSS is designed for the company to determine the petrol delivery assignments in a systematic and efficient manner. The front-end user interface is a Microsoft Excel spreadsheet which is available on the company computers and which requires no special training for the planner. The back-end of the system such as mathematical optimization utilizes Visual Basic Application (VBA) in Microsoft Excel 2007.

This real-life problem is considered under the following assumptions:

- Planning period is made for 1 day delivery (single period).
- Each SPBU requires delivery within a given time window.
- Petrol distribution cost per unit distance is known and constant.
- Loading time at the Depot and unloading time at the SPBU are known and constant.
- Several trips can be assigned to the same truck.
- Each pump can receive more than one delivery (call) in one day.
- SPBU will order the amount of fuel that is a multiple of 8 kiloliters (according to the capacity of each compartment).

Although the assignment and routing is considered in terms of truck units, the petrol products are delivered in terms of compartment units. Only one product is loaded into each compartment. SPBU may be visited by more than 1 truck and a truck may deliver to multiple SPBU (multi trip). These considerations lead to binary decision variables, including an indicator if a truck will be assigned.

Notations of parameters used for the tank-trucks assignment and trip route are as follow.

τ_{ij}	:	time from *i* to *j*
d_{ij}	:	distance from *i* to *j*
C	:	transportation cost per kilometer (covering cost of fuel, tires and lubricants)
K	:	Tank-trucks, where *k* = 1, 2, 3, ..., K
O	:	trip , where *o* = 1, 2, 3, ..., O
I	:	point of departure, where *i* = 1, 2,3, ..., N (the depot is at *i* = 1 and 2)
J	:	destination point, where *j* = 1, 2, 3, 4, ..., M
Q_p	:	demand quantity for product *p*
V_k	:	number of compartments of vehicle *k*
T_{aj}	:	starting time at point *j*
T_{bj}	:	closing time at point *j*
T_L	:	fuel loading/unloading time

The decision variables are:

$$z_{imjnko} = \begin{cases} 1; & \text{If truck } k\text{, trip to } o\text{, visiting from } i \text{ with call number } m\text{, to } j \text{ with call number } n \\ 0; & \text{Otherwise} \end{cases}$$

$$y_{ipkov} = \begin{cases} 1; & \text{If truck } k\text{, trip to } o\text{, compartment } v \text{ in } j\text{, containing the product } p \\ 0; & \text{Otherwise} \end{cases}$$

t_{ajnko}	:	arrival time at *j*, call number *n*, truck *k*, trip *o*
t_{bjnko}	:	departure time at *j*, call number *n*, truck *k*, trip *o*

The mathematical formulation for the tank-trucks assignment and trip route is as follows.

$$Min\ \sum_i \sum_m \sum_j \sum_n \sum_k \sum_o C\ .\ d_{ij}\ .\ Z_{imjnko} \quad (1)$$

$$\sum_i \sum_m \sum_k \sum_0 Z_{imjnko} = 1\ ;\quad \forall\,(j,n) \quad (2)$$

$$\sum_i \sum_m \sum_k \sum_o Z_{imjnko} = \sum_i \sum_m \sum_k \sum_o Z_{jnimko} \quad (3)$$

$$\sum_j \sum_n Z_{0mjnko} = \sum_j \sum_n Z_{jn0mko}\ ;\ \ \forall\,(k,o) \quad (4)$$

$$\sum_j \sum_n Z_{jn0mko} \geq \sum_j \sum_n Z_{0mjnk,o+1} \quad (5)$$

$$Z_{imjnko} + Z_{jnimko} = 1 \quad (6)$$

$$\sum_j \sum_n \sum_k Z_{01jnk1} \leq K \quad (7)$$

$$\sum_k \sum_0 \sum_v Y_{ipkov} = Q_p \quad (8)$$

$$\sum_p \sum_v Y_{jpkov} \leq V_k\ ;\ \ \forall\,(k,o) \quad (9)$$

$$\sum_i \sum_m \sum_j \sum_n Z_{imjnko} \leq V_k + 1\ ;\ \forall\,(k,o) \quad (10)$$

$$\sum_i \sum_m \sum_j \sum_n Z_{imjnko} \geq \sum_j \sum_p \sum_v Y_{jpkov}\ ;\ \forall\,(k,o) \quad (11)$$

$$t_{ajnko} = \sum_i \sum_m \left(t_{bimko} + \tau_{ij}\right).Z_{imjnko};\qquad \forall\,(j,n,k,o) \quad (12)$$

$$t_{ajnko} \geq T_{aj} \quad (13)$$

$$t_{bjnko} = t_{ajnko} + T_L.\sum_p \sum_v Y_{jpkov};\ \ \forall\,(j,n,k,o) \quad (14)$$

$$t_{bjnko} \leq T_{bj} \quad (15)$$

In the model above, the objective function is minimizing the total cost of fuel distribution (formula 1). Constraints 2 states that there is only one point *j* in call number *n* that will be visited from various origin *i* in call number *m* by truck *k* of trip *o*. Constraint 3 states that the number of trucks that come to the point *j* must leave j. Constraint 4 ensures that truck depart from the depot should be returned to the depot. Constraint 5 states that truck *k* that had been carrying out trip *o* can continue to trip *o +1*. Constraint 6 ensures that the truck did not return to the previous point. Constraint 7 states that the number of trucks on the first departure from the depot is in accordance with the number of trucks available. Constraint 8 ensures that the amount of product *p* that is delivered must match the SPBU demand (Qp). Constraint 9 states that the number of truck compartments that are filled must be less than or equal to the number of compartments which are available. Constraint 10 restrict the number of visits that can occur in one trip is at most equal to the numbers of compartment + 1. Constraint 11 states that the number of trips that carrying fuel must be greater than or equal to the number of compartments that fill with fuel.

Constraints 12-15 express the time windows constraints, where constraint 12 states that the arrival time at point *j*, call number *n*, truck *k*, and trip to *o*, is the same as the departure time from point *i* plus the travel time from *i* to point *j*. Constraint 13 states that the arrival time at the point *j*, call number n, from truck k, on a trip to o, cannot be less than the start time of opening in j. Constraint 14 states that the departure time from point j, call number n, from truck k, on a trip to o, is equal to the departure time plus the unloading time of product p at point j. While the constraint 15 ensures that the departure time from point j, call number n, on trips to o, must not exceed the closing time at the point j.

The problem in this study has formulated as PSRP with multi-product, multi-depot, split deliveries, and time windows. PSRP is an extension of Vehicle Routing Problem (VRP). To solve this problem, a tabu search will be used to find the optimal solutions. Since the seminal paper of Dantzig and Ramser (1959), a huge number of contributions to solving VRP have been presented in literature [3]. Numerous heuristics have been developed for related routing problems, and among these, tabu search heuristics have been considered by many authors as an efficient approach for several families of node and arc routing problems [2].

IV. Results and Discussion

The computation were performed on a PC with processor Intel®Core™2 Duo P9700 (2,8GHz) with internal memory of 6GB. The source code was written using VBA applications in Microsoft Excel 2007 with Basic programming language.

In order to solve the PSRP to optimality in a reasonable computation time, it is crucial to set some controllable parameters, which are the number of neighboring solution and the length of the taboo list. Experimental tests were performed for the number of neighborhood solutions between 10-80, and length of tabu list in the midst of 10-50. The results show that the computational efficiency obtained for the neighboring solution of 60 and the length of tabu list of 30, as shown in Fig. 3. and 4. Whereas Fig. 5. shows a summary of the trial program to determine the termination criteria (i.e., 500 iterations).

No	Neighborhood Solutions	Cost (in million Rupiah)	Computing Time (Second)
1	10	34.98	80
2	20	34.72	136
3	30	33.40	206
4	40	32.80	276
5	50	33.30	355
6	60	30.66	417
7	70	32.66	465
8	80	32.93	531

Fig. 3. Neighborhood solutions

No	Length of Tabu List	Cost (in million Rupiah)	Computing Time (second)
1	10	32.39	351
2	20	32.30	331
3	30	31,16	347
4	40	31.83	341
5	50	32.41	341

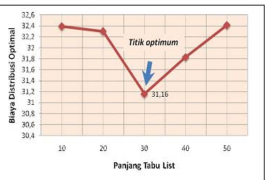

Fig. 4. Length of tabu list

Iterations	Computing Time (second)	Cost (in million Rupiah)	(%)
1	41	34.54	
5	87	35.03	1.4
10	166	32.82	-6.3
50	658	29.32	-10.7
100	1367	27.89	-4.9
500	6558	24.52	-12.1
1000	12705	24.44	-0.3

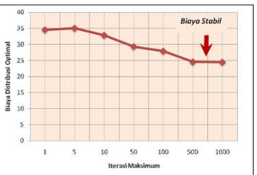

Fig. 5. Termination criteria

Fig. 5. shows that the computational time increases with increasing number of iterations, but the optimization of the distribution cost is not significantly decreased. In practice, processing time exceeding 2 hours are less effective, given the scheduling can be done only after a request via SMS of all SPBU have been summarized by the Depot Sales Services, which generally is around 4 PM every day. Therefore, the maximum iteration is set to 500 with a processing time around 1.5 hours.

PSRP calculations in this study are based on fuel demand data on June 7, 2011, which is the highest daily demand in 2011. Hence, the results can be considered representative of the daily fuel demand in Bandung Sales Area. Figure 6 and 7 shows display of sample screens of data input for this study.

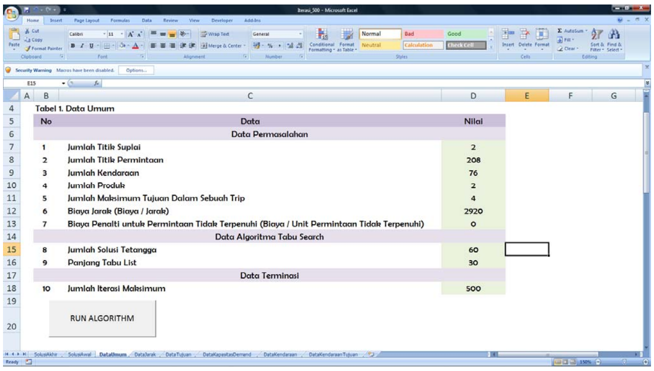

Fig. 6. Display of input data in general

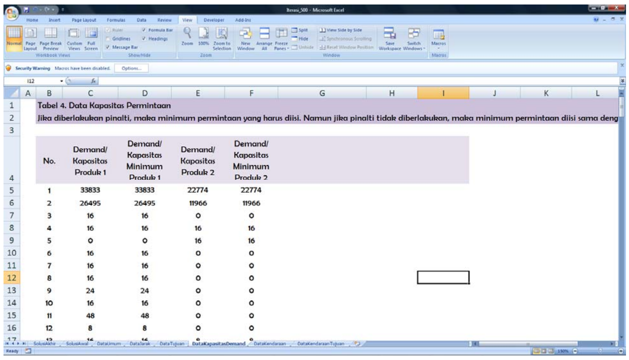

Fig. 7. Display of fuel demand

The output generated from this system is the total cost of distribution, total distance traveled, number of trips, fuel delivery route sequence on each trip, as well as delivery capacity. The system can also display the assignment of each tank-truck in order to meet fuel demand by SPBU. Figure 8 shows a display of summary of computational results, whereas Figure 9 shows part of the scheduling of fuel deliveries to each SPBU.

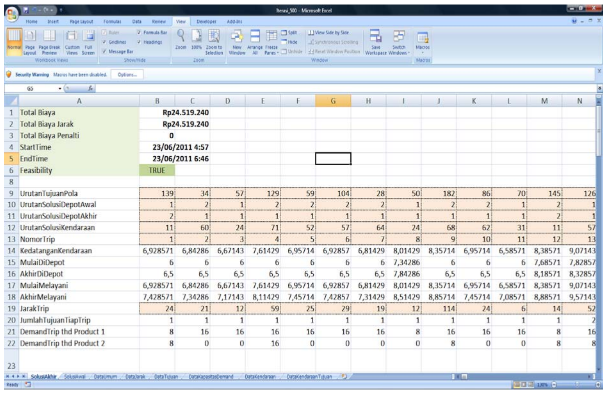

Fig. 8. Display of summary of computational results

No	SPBU	Permintaaan		PREMIUM															SOLAR														
				CALL 1			CALL 2			CALL 3			CALL 4			CALL 5			CALL 1			CALL 2			CALL 3			CALL 4			CALL 5		
		Prem	Solar	Truk	Trip	Jml	Truk	Trip	Jml	Truk	Trip	Jml	Truk	Trip	Jml	Truk	Trip	Jml	Truk	Trip	Jml	Truk	Trip	Jml	Truk	Trip	Jml	Truk	Trip	Jml	Truk	Trip	Jml
3	31.402.01	16	0	12	130	8	7	164	8																								
4	31.405.01	16	16	72	15	16													72	15	16												
5	31.406.01	0	16																47	60	8	39	77	8									
6	31.411.01	16	0	40	120	16																											
7	31.411.02	16	0	8	52	8	74	233	8																								
8	34.401.01	16	0	8	93	8	76	250	8																								
9	34.401.02	24	0	60	129	16	70	185	8																								
10	34.401.03	16	0	10	70	8	49	240	8																								
11	34.401.04	48	0	50	20	16	63	206	16	27	221	16																					
12	34.401.05	8	0	14	122	8																											
13	34.401.06	16	8	50	115	16													50	115	8												
14	34.401.08	16	0	68	162	16																											
15	34.401.09	32	0	56	59	16	64	74	16																								
16	34.401.10	8	0	74	233	8																											
17	34.401.11	16	0	56	204	16																											
18	34.401.13	48	16	32	102	16	12	153	8	7	199	8	64	248	16				32	102	8	12	153	8									
19	34.401.14	16	0	40	111	16																											
20	34.401.15	16	0	16	75	16																											
21	34.401.16	16	0	76	131	16																											
22	34.401.18	16	0	37	66	16																											
23	34.401.19	16	16	43	166	16													43	166	8	62	175	8									
24	34.401.20	16	16	59	57	16													59	57	8	35	91	8									
25	34.401.21	16	0	38	218	16																											
26	34.401.22	24	16	12	23	8	39	64	16										12	23	8	39	64	8									
27	34.401.23	16	0	54	191	16																											
28	34.401.24	32	0	64	7	16	53	232	16																								
29	34.401.25	16	8	40	157	16													40	157	8												
30	34.401.26	16	0	28	203	16																											
31	34.401.27	16	0	17	150	16																											
32	34.401.28	32	0	29	107	16	31	224	16																								
33	34.401.29	16	0	58	32	16																											
34	34.401.30	16	0	60	2	16																											
35	34.401.31	32	0	56	119	16	62	175	16																								
36	34.401.32	16	8	43	58	16													43	58	8												
37	34.401.33	0	8																54	200	8												
38	34.401.34	8	0	67	215	8																											

Fig. 9. Display of part of the scheduling

With the sample data provided, the solution generated by the system performs better than current practice. Table 2 shows the comparisons in terms of total volume delivered and number of trips made.

Total mileage on the existing condition is 10042 km, while the total mileage based on the suggested solution is 8397 km, meaning that there is a decrease in the total mileage of 16.38%. Total trip is also decreased, from the existing condition of 261 trips to 251 trips, meaning a decline of about 3.83% of total trips. Total cost of fuel distribution in a single day also decreased by a new route optimization results, i.e. a decrease of Rp.4, 803, 400, - or by 5.22% compared with existing routes used today.

TABLE 2: COMPARISON OF CURRENT PRACTICE AND PROPOSED MODEL

	Total Distance (km)	Total Number of Trip
Current Practice	10,042	261
Model Results	8,397	251
	-16.38%	3.83%

V. CONCLUSION

This study takes a case study of the Petrol Station Replenishment Problem (PSRP) in the Pertamina Fuel Retail Sales Marketing in the Bandung area by using the Tabu Search (TS) algorithm written in Visual Basic Application (VBA) programming language on Ms. Excel 2007. The results showed that the determination of daily fuel delivery routes using TS algorithm has produced a new distribution route better than that of the existing used by the company. There is a decrease in the total mileage, trip costs and total distributions amounting to 16.38%, 5.22% and 3.83%. With the current successful implementation of this system, Pertamina is looking to develop to develop the model on a larger scale so it can be applied in other sales area.

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