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AN OPTIMAL FERTILIZER DISTRIBUTION MODEL FOR IRAN, 1980- 88

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ABSTRACT

Chemical fertilizers are important but highly seasonal inputs in the production of wheat, barley, rice, cotton and sugar beets in Iran. However, geographic location, topography, other industries and national security interests present special problems in transportation of fertilizer from the coast to inland farms. Most chemical fertilizers must be transported from major ports on the Persian Gulf, the Oman Sea and the Caspian Sea, across one or more of three major mountain rifts to widely dispersed distribution centers. Because fertilizer is a relatively low valued input, the cost of domestic transportation is an important component in its total farmgate cost. This study uses a capacitated transshipment model to minimize the sum of customs, loading, unloading, transportation and warehousing fertilizer costs subject to a series of seasonal volume constraints. The transshipment model incorporates two types of fertilizer arriving through eight main entry ports, production from two domestic plants, and transport through three alternative networks to 182 final consumption sites. This study also assesses the impact of a new rail line on total fertilizer handling and transportation costs.

The base optimal transportation system relies heavily on truck transportation; approximately 77.3% of the fertilizer move directly by truck

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to final destinations, about 16.8% moves by truck to storage and the remainder is transported by rail (4.5%) or truck-rail (1.4%). The optimal plan results in a total cost of 9.8 billion Rials, a cost saving of 1.53 billion Rials or 13.4 percent over the current system cost of approximately 11.4 billion Rials. Nevertheless, the optimal base system suffers a number of bottlenecks. The ports of Chah Bahar (spring and fall) and Bandar Abbas (spring and fall) and Anzali-Noshahr (fall only) are three major bottlenecks to phosphate transportation and distribution in the base plan. The base optimal cost could be further reduced by 16.1 percent if up to 50% of fall fertilizer demands could be stored at these points during the spring season. This would require spring port capacity to be increased by 30%. A second alternative is the combination of the Bandar Abbas railway expansion and the Bandar Emam plant which could further reduce total costs by an additional 8.9% or a 23.5% reduction over the base optimal system.

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الگوی توزیع بهینه کود شیمیایی در ایران ، ۸۸ -۱۹۸۰

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چکیده
انواع کودهای شیمیایی یکی از دادههای تولیدات کشاورزی ایران هستند ولـی مصـرف آنهـا در طول سال از نوسانات شدیدی برخوردار میباشد. از سـوی دیگـر وضعیـت جغرافیـایی و طبیعـی،

موقعیت صنایع مختلف، و علائق امنیت ملی کشور مسائل ویژه‌ای را در خصوص حمل کود شیمیایی (تولید داخلی و واردات) از کارخانجات، بنادر، و مرزهای ورودی به انبارهای منطقه‌ای و مناطق کشاورزی ایجاد می‌کنند. اکثر کودهای شیمیایی باید از بنادر مهم خلیج فارس، دریای عمان، و دریای خزر و از طریق راههای کوهستانی به مراکز توزیع بسیار پراکنده حمل شود. از آنجا که به علت حمایتهای دولت (از طریق پرداخت یارانه) کود شیمیایی داده نسبتاً ارزانی می‌باشد و ضمناً یارانه به مصرف کننده نهایی پرداخت می‌شود هزینه‌های ترابری در داخل کشور فراسنجه عمده‌ای در هزینه نهایی توزیع کود شیمیایی است. در این تحقیق با استفاده از یک مدل ترابری غیرمستقیم ظرفیت دار، حاصل جمع هزینه‌های گمرکی، بارگیری، تخلیه، حمل و انبارداری کودشیمیایی با توجه به یک رشته محدودیت ها در رابطه با میزان مصرف به حداقل رسیده است. مدل شامل دو نوع کود شیمیایی، هشت مرز ورودی، تولیدات دو کارخانه داخلی، و حمل توسط سه نوع وسیله حمل (کامیون، راه آهن، ترکیب کامیون و راه آهن) و ۱۸۲ منطقه توزیع نهایی است. این بررسی همچنین تأثیر ایجاد خط جدید راه آهن (بافق- بندرعباس) بر هزینه کل لجستیک کودشیمیایی را ارزیابی می کند.

سیستم پایه بهینه ترابری به میزان زیادی به حمل با کامیون وابسته است ، به گونه ای که تقریباً ۷۷/۳٪ کود شیمیایی مستقیماً با کامیون به مقصد نهایی حمل می‌شود در حالی که حدود ۱۶/۸٪ با کامیون به انبار انتقال یافته و مابقی توسط راه‌آهن (۵/۴٪)یا کامیون-راه‌آهن (۱/۴٪) حمل می شود. هزینه کل برنامه حمل بهینه بالغ بر ۹/۸ میلیارد ریال می‌شود که معادل ۱/۵۳ میلیارد ریال یا ۱۳/۴ درصد نسبت به هزینه جاری سیستم (تقریباً ۱۱/۴ میلیارد ریال) صرفه جویی در بر دارد. با این وجود، سیستم پایه بهینه چندین تنگنا دارد. بنادر چاه‌بهار (بهار و پاییز) و بندرعباس (بهار و پاییز) و انزلی-نوشهر (فقط در پاییز) سه تنگنای اصلی برای حمل و توزیع کود فسفات در

سیستم پایه هستند. اگر بتوان پیشاپیش تا ۵۰٪ تقاضای فصل پاییز را در این سه نقطه انبار کرد (گزینه اول) هزینه کل سیستم پایه تا حد ۱۶/۱ درصد کاهش خواهد یافت که در این صورت باید ظرفیت فصل بهار بندرهای نامبرده ۳۰ درصد افزایش یابد. گزینه دوم شامل افزودن همزمان راه‌آهن بافق-بندرعباس و کارخانه کود شیمیایی بندر امام به سیستم است که باعث کاهش هزینه کل به میزان ۸/۹ درصد نسبت به گزینه اول یا ۲۳/۵ درصد نسبت به سیستم پایه بهینه خواهد شد.

INTRODUCTION

Chemical fertilizers are important and highly seasonal inputs in the production of wheat, barley, rice, cotton and sugar beets in Iran. Increased farm chemical fertilizer demand in Iran has been met mainly by increasing fertilizer imports which has strained domestic handling, distribution and transportation systems. Because fertilizer is a relatively low valued (subsidized) input, the cost of domestic transportation is an important component in its total farmgate cost. Iran's geographic location, topography, other industries and national security interets present special problems in moving fertilizer from the coast to inland farms. Most chemical fertilizers must be transported from major ports on the Persian Gulf, the Oman Sea and the Caspian Sea, across one or more of three major mountain rifts to widely dispersed distribtion centers. Transporation cost and efficient distribution are therefore, a major concern for the Iranian Government, because the purchasing, transporting, warehousing and distribution functions are carried out by a special government organization (Fertilizer Distribution and Pesticide Production Company, FDPPC). In order to facilitate future planning and minimize fertilizer farmgate costs, this study uses a multi-period, capacitated transshipment model to minimize customs and clearance charges, and the expenses of loading, transportation and warehousing of the chemical fertilizers during the spring and autumn seasons subject to a series of volume constraints. The transshipment model incorporates two types of fertilizer arriving through eight main entry ports, production from two domestic plants, transport through three alternative network to 182 final consumption sites. Finally, the Iranian government is interested in the impact of a new rail line on total fertilizer handling and transportation costs.

THE MODEL

The problem to be studied is the familiar capacitated transshipment model which seeks to minimize total cost of shipping fertilizer from a series of source nodes to a series of sinks or destination nodes with a number of intermediate points or transshipment nodes. Dynamic grain transport and storage problems have recently been modelled as capacitated networks (4,6). The advantage of the capacitated network includes flexible modelling, ease of use and interpretation and the ability to solve large problems with many associated capacity constraints at relatively low costs. Here, the source nodes are ports or domestic plants, the sink nodes are points of agricultural consumption and the transshipment nodes are points of regional assembly, storage and redistribution. The objective function is to minimize the sum of transportation, storage and distribution costs across all methods of delivery:

$$\min \ TC = \sum_{l=1}^{3} \sum_{k=1}^{2} \sum_{t=1}^{2} \left(\sum_{i=1}^{10} \sum_{j=1}^{182} C_{ljikt} X_{ljikt} + \sum_{i=1}^{10} \sum_{s=1}^{16} C_{likst} Y_{likst} + \sum_{s=1}^{16} \sum_{j=1}^{182} C_{jlkst} Z_{jlkst} \right) \qquad [1]$$

where

t = season,

i = fertilizer supply from port and domestic production,

j = final destination,

k = fertilizer type,

l = 1 (truck-rail transportation), 2 (truck transportation) or 3 (rail transportation),

s = transshipment or storage point,

C = unit cost,

X = quantity of fertilizer from source to farmgate,

Y = quantity of fertilizer from source to storage/transshipment and,

Z = quantity of fertilizer from storage/transshipment to farmgate.

Two types of fertilizer (k), phosphate and urea, are delivered in two consumption periods (t), spring and autumn. There are 10 primary sources (i), 16 transshipment (s), and 182 final destination (j) points. In addition, there are three general delivery mechanisms: direct from source i to final destination j (X_{ij}), source i to transshipment s (Y_{is}), and transshipments to final destination j (Z_{sj}). Finally, there are three different modes of transportation (l): truck, rail and truck-rail which result in three types of arcs connecting the various nodes. The truck-rail combination arises because some destinations can be reached only by a combination of rail and truck.

Unit costs are calculated from a combination of eight ports or two internal manufacturing plants to each of 16 storage facilities and/or 182 final destinations. Unit cost components include:

1) customs inspection, port clearance charges, ship unloading, bag loading and dock loading,

2) transportation,

3) unloading, temporary storage and loading,

4) unloading and distribution.

The first cost category is FDPPC port costs that varies by port but is the same for both fertilizers. Transportation costs from port or storage areas to each destination are based on three different transportation methods: truck, rail and a combination of the two. While the railway is part of the public sector, all other transshipment functions are carried out by the private sector. Private sector costs are based on competitive prices published by the FDPPC (1).

The transshipment problem has three types of constraints: 1) shipment-route carrying capacity, 2) storage limits, 3) flow-balance accounting equations. The various train, truck, truck-train arcs (shipment routes) are constrained by two types of volume restrictions. The first represents volume restrictions on supply source to final demand or to intermediate storage (Eq. 2) and the other represents transshipment volume constraints from supply source or intermediate point to final demand (Eq. 3).

$$\sum_{k=1}^{2} (X_{ilst} + Y_{ilst}) \leq Q_{ils} \qquad [2]$$

$$\sum_{k=1}^{2} (X_{ljst} + Z_{ljst}) \leq Q_{ljs} \qquad [3]$$

where Q = route carrying capacity.

The eight supply ports and two manufacturing points and their associated capacities are listed in Table 1.

Most fertilizer in Iran is imported; domestic production is less than 1% of the phosphates but about 21% of all the urea used, mostly at Shiraz at the time of this study. Approximately 41.5% of all fertilizer shipped passes through the port of Bandar Abbas which is located on the Persian Gulf. The next most important ports are Anzali-Nowshahr, Bushehr and Razi. There are 16 storage and transshipment points and 182 demand points. Demand is summarized by province in Table 2.

The provinces featuring the greatest demand are Khorasan, East Azarbaijan, Fars, Markazi and Kermanshah, which together account for 29.2% of all fertilizer consumption. The transshipment constraint requires that the cumulative quantity shipped to (arcs in) a transshipment point be

Table 1. Iranian Fertilizer Supply, by Source, 1986

Ports and plants	Spring amount		Fall amount		Total annual amount available					
	Urea	Phosphate	Urea	Phosphate (tons)	Urea	(%)	Phosphate	(%)	Combined	(%)
Ports:										
Anzali	30,000	20,000	10,000	40,000	40,000	4,4%	60,000	5,5%	100,000	5.0%
Bandar Abbas	210,000	80,000	150,000	310,000	360,000	40,0%	490,000	44.5%	850,000	42.5%
Bazargan	30,000	20,000	10,000	40,000	40,000	4.4%	60.000	5.5%	100.000	5.0%
Bushehr	40,000	30,000	30,000	50,000	70,000	7.8%	80.000	7.3%	150.000	7.5%
Chah Bahar	30,000	50,000	30,000	90,000	60,000	6.7%	140,000	12.7%	200,000	10.0%
Jolfa	30,000	20,000	10,000	40,000	40,000	4.4%	60,000	5.5%	100,000	5.0%
Nowshar	30,000	20,000	10,000	40,000	40,000	4.4%	60,000	5.5%	100,000	5.0%
Razi	30,000	50,000	30,000	90,000	60,000	6.7%	140,000	12.7%	200,000	10.0%
Manufacturing plants:										
Isfahan	5,000	5,000	10,000	1.1%	0.0%	10,000	0.5%			
Shiraz	75,000	5,000	105,000	5,000	80,000	20.0%	10,000	0.9%	190,000	9.5%
Total	510,000	295,000	390,000	705,000	900,000	00.0%	1,100,000	100.0%	2,000,000	100.0%

Source: FDPPC (1).

Table 2. Fertilizer demand (tons), by province, Iran, 1986.

	Spring		Fall		Total			
Province	Urea	Phosphate	Urea	Phosphate	Urea	Phosphate	Combined	
Azarbaijan, East	59,103	21,378	18,887	62,054	77,990	83,432	161,422	8.1%
Azarbaijan, West	25,135	19,148	18,460	36,052	43,595	55,200	98,795	4.9%
Bushehr	1,736	1,068	1,745	1,612	3,481	2,680	6,161	0.3%
Eilam	5,923	3,248	1,861	5,973	7.784	9,221	17.005	0.9%
Isfahan	40,226	30,742	26,261	47,159	66,487	77,901	144,388	7.2%
Fars	30,107	24,489	37,693	60,043	67,800	84,532	152,332	7.6%
Chaharmahal	6,169	4,665	3,729	11,569	9,898	16,234	26,132	1.3%
Gilan	35,380	20,583	6,101	7,821	41,481	28,404	69,885	3.5%
Gorgan	17,807	28,567	27,195	43,068	45,002	71,635	116,637	5.8%
Hamadan	20,778	15,064	14,230	25,679	35,008	40,743	75,751	3.8%
Hormozgan	2,987	3,047	6,796	7,484	9,783	10,531	20,314	1.0%
Kerman	23,599	21,437	11,904	50,788	35,503	72,225	107,728	5.4%
Kermanshah	8,435	26,744	19,557	20,371	27,992	47,115	75,107	3.8%
Khorasan	60,221	50,539	62,868	97,151	122,989	147,690	270,679	13.5%
Khuzestan	35,436	20,507	35,313	50,788	70,746	71,495	142,241	7.1%
Kohkiloe	2,690	1,585	2,689	3,349	5,379	4,934	10,313	0.5%
Kordestan	14,894	0	0	18,923	14,894	18,923	33,817	1.7%
Lorestan	14,540	5,867	11,210	35,531	25,750	41,398	67,148	3.4%
Markazi	22,460	9,269	7,604	26,464	30,064	35,733	65,797	3.3%
Mazandaran	37,484	36,070	16,365	15,264	53,849	51,334	105,183	5.3%
Semnan	2,720	5,386	10,987	10,986	13,707	16,373	30,080	1.5%
Sistan	8,438	6,234	3,236	5,411	11,674	11,645	23,319	1.2%
Tehran	20,052	17,677	16,406	27,463	36,458	45,140	81,598	4.1%
Yazd	4,093	4,435	2,718	6,467	6,811	10,902	17,713	0.9%
Zanjan	16,112	13,267	19,763	31,313	35,875	44,580	80,455	4.0%
Total	516,525	391,016	383,578	708,783	900,000	1,100,000	2,000,000	100.0%

Source: FDPPC(2)

greater than or equal to the quantity shipped out (arcs out) for a given period. If an inequality holds, then there is storage:

$$\sum_{l=1}^{3} \left(\sum_{i=1}^{10} Y_{jkist} - \sum_{j=1}^{182} Z_{jkst} \right) \leq G_{ikt} \qquad [4]$$

where G = storage limit.

The three flow balance constraints are accounting which require fertilizer supply arcs out to be less than or equal to total supply, the destination arcs to be equal to demand, and the transshipment arcs out to be less than or equal to the cumulative transshipment arcs in for a given time period.

$$\sum_{l=1}^{3} \left(\sum_{j=1}^{182} X_{ljikt} + \sum_{s=1}^{16} Y_{likst} \right) \leq S_{lkt}$$

$$\sum_{l=1}^{3} \left(\sum_{i=1}^{10} X_{ljikt} + \sum_{s=1}^{16} Z_{jlkst} \right) = D_{jt} \qquad [5]$$

where

S= fertilizer supply from port and domestic productions and,

D= fertilizer final demand.

The supply constraint restricts the quantity transported by rail, truck and truck-rail directly to a final destination and transshipment(arcs out) to be less than the amount available at each of the 10 supply points.

The resulting transshipment problem is solved using a conventional linear programming (LP) algorithm MPSX (3). One of the problems associated with using the conventional LP formulation, is that the resulting problem has 20,404 rows and 21,128 columns. Besides the base formulation, two additional alternatives are studied:

1) Increasing spring supply capacity by 30% and increase spring storage by 50%.

2) Add it the new Bandar Abbas railway and the Bandar Emam plant.

Peak fertilizer demands fall within the spring season (Table 1). Accordingly, one way to relax the bottleneck is to increase spring port supply and increase the transshipment storage capacity (Alternative 1). In addition to adding port or storage capacity, two events are expected to occur after the study: the new Bandar Abbas railway will be opened and the reopening of the war-damaged Bandar Emam plant (Alternative2).

RESULTS

The optimal system relies heavily on truck transport of agricultural fertilizers. Approximately 77.3% of the fertilizer move directly by truck to final destinations (Table 3) and about 16.8% move by truck to storage.

Table 3. Optimal transportation (tons) by carrier, base scenario.

Transportation Type	Spring		Fall		Total Amounts		Total Fertilizer	
	Urea	Phosphate	Urea	Phosphate	Urea	Phosphate	Combined	Proportion
Truck	412,700	297,571	297,794	538,174	710,494	835,745	1,546,239	77.3%
Rail	7,762	22,527	12,292	47,439	20,054	69,956	90,010	4.5%
Truck-rail	1,420	10,711	1,196	13,922	2,616	24,633	27,249	1.4%
Truck-storage	94,641	60,383	72,195	109,283	166,836	169,666	336,502	16.8%
Total	516,523	391,192	383,477	708,807	900,000	1,100,000	2,000,000	100.0%

The remainder is transported by rail (4.5%) or truck-rail (1.4%). The optimal total cost is 9.8 billion rials and results in a cost saving of 13.4 percent over the current cost (Table 4). (the time of this study, the official and unofficial exchange rates were 72 and 600 Rials to one US dollar respectively).

Table 4. Actual and optimal total transportation cost(million Rials), by alternative.

Alternative	Total cost	Improvement over base alternative		Improvement over previous alternative	
Actual	11,409	-	-	-	-
Base	9,884	1,526	13.4%	1,526	13.4%
Alternative 1	9,575	1,834	16.1%	308	3.1%
Alternative 2	8,727	2,682	23.5%	848	8.9%

The base system suffers a number of bottlenecks as indicated by the shadow prices in Table 5.

Table 5: Estimated shadow prices (Rials ton^{-1}) by Source, Base Scenario.

Supply source	Spring		Fall	
	Urea	Phosphate	Urea	Phosphate
Ports:				
Anzali-Nowshar	614	51	673	2,698
Bandar Abbas	3,311	3,045	3,219	3.071
Bandar Abbas-Kerman	2,311	3,045	3,219	3,071
Bazargan	544	544	544	544
Bushehr	1,321	776	1,029	882
Chah Bahar	3,961	4,195	3,926	4,285
Jolfa	962	1,800	347	1,577
Razi	1,234	1,234	1,234	1,234
Manufacturing plants:				
Isfahan plant	303	1,940	395	1,940
Shiraz plant	2,081	1,736	2,197	1,762

Three major bottlenecks to phosphate transportation and distribution are the Chah Bahar (spring and fall), Bandar Abbas (spring and fall) and Anzali-Nowshahr (fall only) ports/routes. The Chah Bahar port with only a 20,000/40,000 ton spring/fall limit of available phosphate generates the highest shadow prices: 4,195 and 4,285 Rials ton^{-1}, per spring and fall seasons, respectively. The Chah Bahar urea port limitations are only slightly less restrictive. The high shadow price associated with Chah Bahar is due to its proximity to major demand areas which are remote from other cities. However, its hot climate, shortage of accommodation and residential services make it unpopular among truck drivers. Even though the Bandar Abbas port has the highest combined fertilizer throughput capacity of 310,000 and 490,000 tons, respectively, for spring and fall, it still generates the second highest shadow prices of 3,045 to 3,311 Rial/ton. Bandar Abbas became the only useable port in southern Iran after the khorramshahr port was closed due to the Iraq-war against Iran. Khorramshahr was previosly the major port on the Persian Gulf, and its closure generated major port bottlenecks which are reflected by the high Bandar Abbas shadow prices, indicating that its closure and the inability of the Bander Abbas port to handle the combined traffic is a major impediment to the current system. High Anzali-and Nowshahr fall phosphate supply shadow prices are due to their small size and undersized unloading facilities.

In addition to the problem of port capacity, there are problems of seasonality for phosphate and the lack of domestic urea production. The spring phosphate shadow prices associated with alternative 2 are considerably lower than the base and alternative 1 shadow prices (Table 6), indicating that fertilizer distribution/storage activities should be redirected towards spring fertilizer movement and storage. In addition, domestic manufacturing plant shadow prices are lower than the port shadow prices of Bandar Abbas and Chah Bahar. The Isfahan urea shadow prices are the lowest in the country due to its central location and associated low distribution costs.

Table 6. Estimated spring phosphate supply shadow prices (Rial ton^{-1}) by port and alternative.

Supply point	Base	Alternative	
		1	2
Ports:			
Anzali-Nowshar	51	2,797	899
Bandar Abbas	3,045	1,390	1,258
Bazargan	544	2,301	349
Bushehr	776	2,190	251
Chah Bhar	4,195	2,347	2,671
Jolfa	1,800	1,611	341
Razi	1,234	1,268	684
Manufacturing plants:			
Isfahan	1,940	-	-
Shiraz	1,736	1,309	195

The optimal total costs of the two alternative systems are presented in Table 74. As previously noted, the current system suffers from the inefficient use of storage and lack of delivery timeliness. One of the reasons that growth in crop yields have not met expectations in the past 3 decades, is that fertilizer has not been available in a timely fashion to producers. Annual

Table 7. Sensitivity analysis of spring phosphate transportation from different ports.

Port	Capacity	Activity range		Optimal		Cost ranges	
		LL†	UL§	LL	UL	LL	UL
Ports:							
Anzali-Nowshar	40,000	40,000	50,000	49,811	50,739	1,526	1,526
Bandar Abbas	80,000	80,000				1,390	1,390
Bazargan	20,000	20,000	25,000	24,266	27,739	1,033	1,033
Bushehr	30,000	30,000	37,500	36,766	38,239	800	800
Chah Bhar	50,000	50,000	62,500	49,909	50,128	2,347	2,347
Razi	50,000	50,000	62,500	61,766	63,239	343	343
Manufacturing plants:							
Isfahan						3,517	3,517
Shiraz	5,000	5,000	6,250	4,266	5,739	91	81

† Lower limit.
§ Upper limit.

fertilizer demand has increased an average of 20% outstripping supply capability (2). Accordingly, alternative 1 features increased port supplies and reduced storage limits to even out the seasonality of fertilizer demands. The base optimal cost is reduced by 16.1% if up to 50% of fall fertilizer demands could be stored during the spring season for summer and fall delivery under alternative 1. While this would require spring port capacity to be increased by 30%, there is little overall increase in investment. Moreover, available warehouses and stores along transport routes and at consumption nodes are better utilized. Of course, more intensive spring use of entry ports increases the severity of the bottlenecks associated with Bandar Abbas and Chah Bahar and is reflected in their spring shadow prices. Overall, less fertilizer is supplied via these ports in alternative 1 than in the base plan.

The second alternative features the expansion of the Bandar Abbas railway to interconnect with the remainder of the railway network and the reopening of the war-damaged Bandar Emam plant. Adoption of alternative 2, could further reduce total costs by an additional 8.9% over alternative 1 or a 23.5% reduction over the base optimal system. Under alternative 2 optimal seasonal port use results in less reliance on the four major ports of Bandar

Abbas, Chah Bahar, Razi and Bushehr and greater use of other ports and the Bandar Emam plant. As expected, the main mode of fertilizer transportation is the railway. The other methods of transportation - trucks and truck-rail - are little utilized. By substituting rail for trucks, trucks are released for use in other sectors of the Iranian economy. Since alternative truck uses are not included as activities and trucking capacity is a major constraint in other sectors, secondary benefits according to alternative 2 are the reduction in transportation costs for other sectors. While these benefits are not estimated, they should be included as cost savings. The combination of expanded fertilizer manufacturing capability and the expanded railroad network eases the demands on the major ports as indicated by reduced shadow prices.

SUMMARY AND CONCLUSIONS

A major concern to many developing economies is the timely delivery of fertilizer from a variety of ports to widely dispersed locations, at as low a cost as possible. The Iranian government heavily subsidizes agricultural fertilizer to farmers. Annual total subsidy for fertilizer was 28 billion rials in 1986 (2). Hence, the reorganization of fertilizer storage and distribution could reduce government subsidies by 2.7 billion rials, or about 10% while improving fertilizer delivery timeliness and operational efficiency. In addition, trucks would be freed to be used elsewhere in the economy. Moreover, much of the cost savings could be realized without major new capital investment. Many developing countries, despite a shortage of capital expenditure requirements and foreign reserves, tend to invest heavily in capital- intensive infrastructure. These results indicate that reorganization of fertilizer transportation, taking into account seasonality and storage, can result in cost savings without incurring any additional capital expenditures in transportation networks, storage or port unloading facilities. Optimal utilization of infrastructure helps to reduce rail maintenance costs, transfer transportation resources to other sectors and make better use of available motor vehicles. Further, implementing the results of this study would help the government of Iran meet a projected annual increase of 20% in fertilizer transport without incurring additional costs. This study supports the contention by many international development specialists that improving the overall efficiency of governmental management and planning through the adoption of management scientific techniques can help generate economic growth while saving overhead expenditures.

The data used for this study was collected in 1986, two years after initiation of the war by Iraqi government against Iran. Iranian economy suffered, then, from slack and under utilization of social overhead, including fertilizer plants, ports, roads, and transportation networks. Therefore, the conclusion and the recommendations of this study are conditioned by the prevailing situation then, and should be applied to the post war period with due care.

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