Commercial Economics of Shale Oil-Modified Asphalt

Larry A. Lukens
The New Paraho Corporation
Aurora, Colorado

ABSTRACT

As reported previously (Lukens, 1989), in 1986 The New Paraho Corporation (Paraho) embarked on a program to assess the commercial feasibility of using shale oil to improve the performance characteristics of asphalt paving materials. This program has been focused on investigations of the technical performance characteristics of this new product, called SOMAT, and the commercial economics associated with its production.

The results of investigations to date of the technical performance characteristics of SOMAT are reported in a companion paper (Lukens and Plummer, this volume). This paper reports on the economic feasibility of producing SOMAT in commercial quantities.

INTRODUCTION

In order to avoid confusion as to the specific meaning of various terms used throughout this paper, the following glossary of terms is provided:

- shale oil modifier (SOM)—material that results when crude shale oil is converted by use of the SOMAT process.
- SOMAT—material that results when SOM is blended with a conventional asphalt binder. For all asphalt mix designs examined to date, SOMAT consists of a blend of 10% to 15% SOM and 85% to 90% conventional asphalt binder, on a weight percent basis.
- asphalt mix or asphalt concrete mix—material that results when SOMAT is combined with mineral aggregate. Typically, asphalt mix consists of 5% to 6% SOMAT and 94% to 95% aggregate, on a weight percent basis. Asphalt mix constitutes the final road-paving material.

In simple terms, the economic feasibility of producing shale oil-modified asphalt depends on the cost associated with the production of SOM for making SOMAT in comparison with the price that SOMAT can be expected to command in the market place. With regard to the market place, consumer acceptance of SOMAT will be dependent on the benefits to be derived from its use in comparison to the price to be paid for its purchase. In other words, SOMAT must demonstrate significant "life cycle cost" benefits to compete effectively for wide-scale acceptance and use in the market place.

As reported by Lukens and Plummer (this volume), laboratory and field test results obtained to date clearly show that roads built with SOMAT should provide extensions to serviceable road life and associated reductions in road maintenance costs that are more than sufficient to justify the price.

With regard to price, since SOMAT consists of a simple blend of SOM and conventional asphalt cement (AC), the impact of SOMAT price on the installed, or as-laid, cost of asphalt mix depends on both the SOM and AC price. This relationship is depicted in Figure 1, wherein the percentage increase in as-laid cost that results from the use of SOMAT is shown for a wide range of SOM and AC prices. This relationship is based on SOMAT consisting of a blend of 10% SOM and 90% AC, on a weight percent basis. For the Rocky Mountain region, the price of conventional asphalt cement has ranged from a low of \$100/ton to a high of \$175/ton over the past ten years. As shown in Figure 1, this AC price range, when combined with SOM prices of approximately \$75/bbl to \$140/bbl, would result in a 10% to 20% increase in the as-laid cost of asphalt mix.

Given these price considerations, Paraho has adopted a target price of \$100/bbl for SOM. Referring to Figure 1, this SOM price would result in a 10% to 15% increase in the as-laid cost for asphalt mix produced from SOMAT. By way of comparison and according to statistics compiled by the Colorado Department of Highways, approximately 941,000 tons of asphalt mix were laid under Colorado state contracts during the first six months of 1989. Of this amount, approximately 20% consisted of asphalt mixes modified with latex polymers. For this six-month period, the average as-laid cost for the conventional asphalt mixes was \$20/ton, whereas the polymer-modified asphalt mixes averaged \$26.60/ton in as-laid cost—a 33% increase. Polymer-modified asphalts are the principal products with which SOMAT must to compete.

Accordingly, Paraho has established a median price of \$100/bbl for its shale oil asphalt modifier (SOM). We

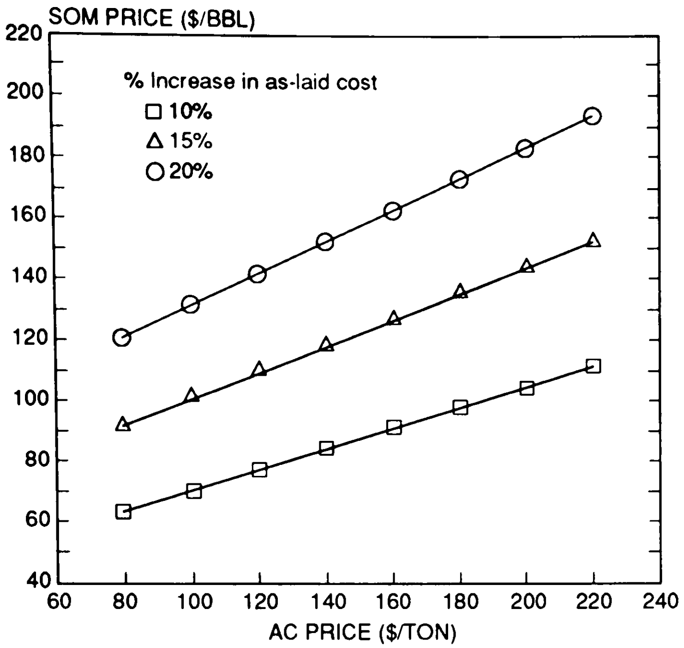

Figure 1. Impact of SOM price on as-laid cost of asphalt mix.

believe that this price is reasonable, given the life-cycle cost benefits that SOMAT will provide to the consumer. Moreover, at this price level, SOMAT will provide highway engineers and managers a lessor cost alternative, with comparable if not superior performance characteristics, than other asphalt modifiers now commonly in use.

This price assumption for SOM is supported by a recent study funded by the U.S. Department of Energy (Sinor, 1989). This study, performed by J.E. Sinor Consultants Inc., determined that if roads are built or rehabilitated on a least life-cycle cost basis, the value of the portion of shale oil marketed as an asphalt modifier (SOM) would be worth $100/bbl if use of the resulting material (SOMAT) resulted in at least a 10% increase in pavement life. Thus far and based on the test results to date (Lukens and Plummer, this volume), there is every reason to believe that SOMAT will effect at least a 10% improvement in pavement life.

ECONOMIC ANALYSIS

Having established the selling price of SOM, the economic feasibility of producing shale oil-modified asphalt now can be determined. The economic analysis described below assumes that SOM production facilities would be constructed on either the Mahogany Project property, located in the Piceance Creek basin in northwestern Colorado, or the Paraho-Ute property, located in northeastern Utah. The design basis for the production facilities as currently envisioned and on which the economic analysis is based is as follows:

Mining Facilities	
Mine type	Underground or surface, pending final site selection and associated cost analysis
Mining method	Room and pillar or strip
Oil shale grade	28.5 gal/ton (nominal)
Production days	357 days/year
Annual production	1,915,000 tons
Process Facilities	
Retort technology	Paraho Direct Heated
Retort feed rate	5,245 tons/day
Shale grade	28.5 gal/ton
Liquid recovery	95% of Fischer assay
Steady-state stream factor	90%
Crude shale oil capacity	3,380 bbl/day
Asphalt technology	Paraho SOMAT
Crude feed rate	3,380 bbl/day
Product/By-Product Capacities	
Asphalt modifier (SOM)	2,028 bbl/day
Light oil	1,352 bbl/day
Potential by-product	15 MW of electrical power

Note that the economic analysis presented herein assumes that SOM and light oil (to be marketed as a refinery feedstock) are the only two products produced for sale from the facility described above. Electrical power could, however, be produced and sold from the facility, assuming an attractive economic case can be made for same.

The base-case plant configuration contains a conventional, gas-fired power plant and flue-gas desulfurization unit. This power plant, which uses the product gas from retorting, produces sufficient electrical power to satisfy all the power requirements for operating the mine and processing facilities but will not produce any power for export. In addition, the base-case configuration assumes that raw-shale fines generated during crushing and screening operations and spent shale from retorting will be stockpiled and/or disposed on the surface.

As an alternative to this base-case configuration and considering the fact that raw-shale fines and spent shale contain significant heating value, the conventional power plant could be replaced with a fluidized-bed power-production facility. This facility would be used to combust the fines, spent shale, and retort product gas, resulting in approximately 15 MW of power available for sale after satisfying all onsite power requirements. In addition and by virtue of the sulfur absorption characteristics of the mineral compounds present in the raw shale and spent shale, the flue-gas desulfurization unit also could be eliminated.

While more detailed engineering studies must be completed before a definitive economic analysis can be performed, preliminary estimates indicate that $12 million to $15 million in additional capital cost would be required, and approximately $3.5 million of additional annual revenues would result if this alternative were selected.

The economic assumptions which have been utilized and which govern the analyses presented herein are as follows:

Steady-state production capacity:	
Light oil	444,130 bbl/year
Shale oil modifier (SOM)	666,200 bbl/year
Product prices, f.o.b. plant (mid-1990 dollars)	
Light oil	$22.00/bbl
Shale oil modifier (SOM)	$100.00/bbl
Capital cost (mid-1990 dollars)	$179,185,000 ($5.38/bbl)
Operating cost (mid-1990 dollars)	$18,410,000/year ($16.58/bbl)
Working capital (mid-1990 dollars)	60 days of operating cost
Method of financing	100% equity
Depreciation tax life	7 years
Depreciation option	Double declining balance
Depletion allowance	
Point of depletion	Crude shale oil
Market value (mid-1990 dollars)	80% of total revenues
Percentage depletion	15%
Income tax rates	
Federal	35%
State	5%
Combined	37.3%
Economic plant life	30 years

The project schedule provides for 48 months from initiation of the project until full production capacity is attained. Actual construction of the surface plant facilities is estimated to require 18 months after site permitting, site preparation, and detailed engineering have been completed. The startup schedule provides for 9 months to achieve full production capacity after plant operations are initiated. Production targets for the startup period are an average of 37.5% of design capacity for the first 4 months of startup operations, and an average of 87.5% of design capacity for the next 5 months of startup operations.

Three inflation and product-pricing scenarios have been analyzed, as follows:

- Case 1—Assumes constant 1990 dollars for both costs (capital and operating costs) and product prices; that is, 0% inflation for the life of the project.
- Case 2—Assumes 5% inflation as applied to both costs (capital and operating costs) and product prices, starting in year 1 and continuing for the life of the project.
- Case 3—Assumes 2.5% inflation as applied to both costs (capital and operating costs) and product prices, starting in year 1 and continuing for the life of the project, plus 2.5% real growth in product prices until the price of light oil reaches $31/bbl, which occurs in year 7 of the project.

A comparison of the economic benefits associated with each of these cases is presented in Table 1.

The major risk factors that will affect the profitability of the project are considered to be as follows:

Table 1. Economic comparisons.

Economic Parameter	Case 1	Case 2	Case 3
DCFROI (%)	22.05	27.60	28.09
Net present value ($MM)			
@10%	162.12	395.62	333.52
@20%	12.16	63.08	59.60
Payback occurs between years	6–7	5–6	5–6

- Technical—Will the plant operate at or in excess of its rated design capacity at a 90% or better stream factor?
- Economic—How will variations in capital and operating costs and product pricing assumptions affect profitability of the project?
- Market—Can the products be sold in the quantities and at the price required to satisfy the rate of return projections?

First, with regard to technical risks, the retort vessel is considered to be the only unit of operations that has yet to be proven at full commercial scale. In this regard, the patented Paraho oil shale retorting technology, with in excess of 15 years and $65 million spent to date on its development, generally is considered to be one of the more advanced retorting technologies for near-term commercial application. The Paraho process has been used to produce in excess of 100,000 bbl of shale oil, a large portion of which was refined into transportation fuels by the U.S. Department of Defense, and all such products were found to perform quite satisfactorily. The Paraho process has been tested and operated successfully over extended periods of time, with sustained operational runs in excess of 100 days. Moreover, this process has been tested in bench, pilot, and semiworks-scale plants, representing a 100-to-1 scale-up factor. The largest, or semiworks level, demonstration of the Paraho retorting process was conducted near Rifle, Colorado, in a 250-ton/day unit and, in engineering terms, a full-scale commercial production module would represent a 3-to-1 scale-up of this well proven semiworks experience. Accordingly, the scale-up risks associated with the use of the Paraho retorting process for commercial applications is considered to be acceptable and well within engineering standards associated with processes of this nature. The remainder of the plant processes and systems, including mining, materials handling, product recovery, and SOM production, use state-of-the-art, commercially proven technologies and, accordingly, represent minimum technical risks.

Next, with regard to economic risks, the major factors affecting the profitability of the project are the accuracy of capital and operating cost estimates and the validity of product-pricing assumptions. Capital and operating (that is, O&M) cost estimates for the most part were obtained by factoring detailed estimates developed previously for the Paraho-Ute Project. The capital and O&M cost estimates for the Paraho-Ute Project, a 14,500-bbl/day facility previously pursued but not constructed, under joint federal government and private industry sponsorship, were developed by major engineering firms and reviewed by government and private industry sponsors at that time. Paraho believes the accuracy of these estimates to be within ±25% and therefore of sufficient quality to support valid economic assessments of the project at this time.

The product-pricing assumptions used in the economic analysis were addressed earlier.

An assessment of the sensitivity of the project, as measured by the discounted cash-flow return on investment (DCFROI), to variations in the major economic assumptions is shown in Figures 2 through 6. Figure 2 shows the impact of variations (–25% to +25%) in base-case assumptions for capital cost, O&M costs, and total revenues on the DCFROI of the project under the Case 1 economic assumptions defined above. With regard to total revenues, variations could be due to changes in output product capacity, product prices, or combinations of both. As seen in Figure 2, profitability of the project is most sensitive to variations in total revenues, less so for variations in capital cost, and least sensitive to variations in O&M costs.

Comparisons of the impact on DCFROI for Cases 1, 2, and 3 due to variations in capital cost, O&M costs, and total revenues are presented in Figures 3, 4 and 5, respectively. Figure 6 shows the cumulative effect of these variations on DCFROI for both the worst-case and best-case scenarios for Case 1. The worst-case scenario assumes that base-case estimates for capital and O&M costs are exceeded by 25% and that total revenues are reduced by 25%. The best-case scenario, on the other hand, assumes that base-case estimates for capital and O&M costs are reduced by 25% while total revenues are increased by 25%.

We believe that these sensitivity analyses demonstrate that the production of shale oil-modified asphalt is economically viable over a reasonable range of economic uncertainty and, accordingly, has a respectable profit-making potential.

SUMMARY

While we recognize that this commercial project for the production of shale oil-modified asphalt is quite small in comparison to most oil shale projects envisioned in the past, it nonetheless offers several advantages:

- Reduced capital exposure, both in terms of dollar magnitude and payback time;
- Less market risk in comparison to products to be used for fuel applications;
- In engineering terms, manageable and reasonable scale-up risks in comparison to the scale at which the key technologies have been successfully demonstrated;
- The opportunity to gain a valuable base and level of experience in the construction and operation of oil shale plants prior to future expansion to serve fuel and nonfuel markets;
- The opportunity to better understand and effectively deal with the environmental and socioeconomic impacts at a smaller versus larger scale; and
- Accomplish all of the above and return a profit on initial investment.

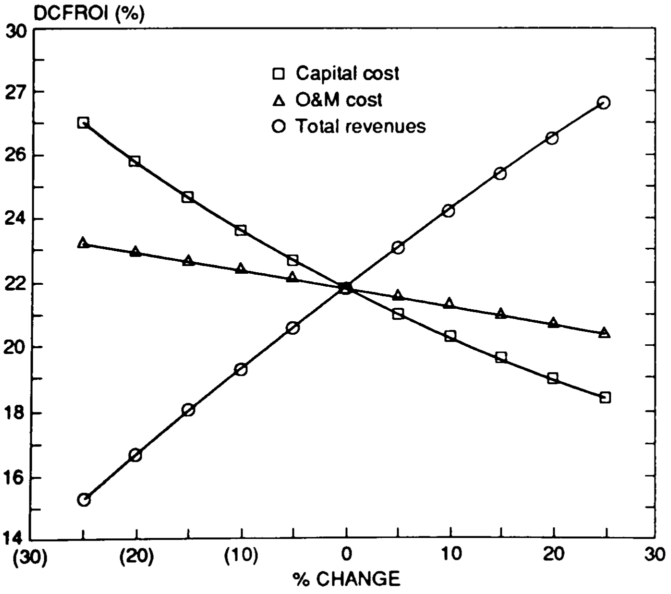

Figure 2. Economic sensitivity—Case 1.

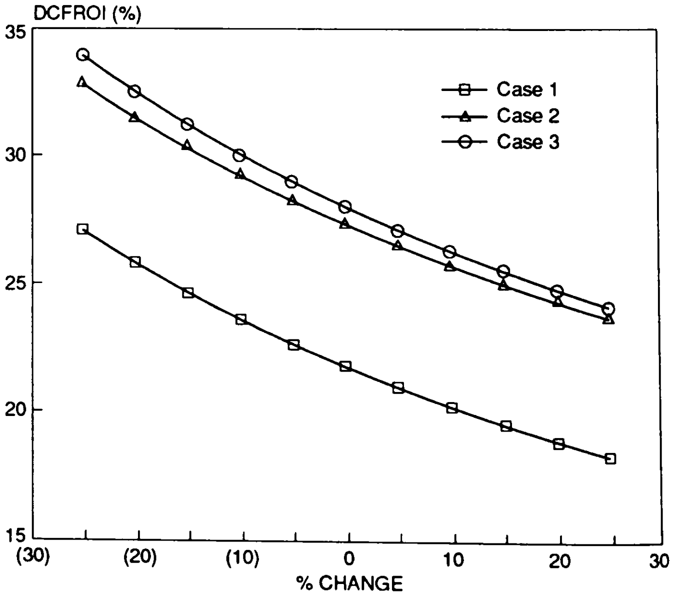

Figure 3. Economic sensitivity—Capital cost.

In summary, Paraho believes that it now possesses the proprietary technology and know-how and the right product to proceed with commercial oil shale development. By doing so now, Paraho and its partners will be uniquely positioned to earn profits in the short term, while establishing a firm economic, technological, and environmentally sound basis for future expansion.

REFERENCES

Lukens, L.A., 1989, New Paraho shale oil 1988 program results, *in* Gary, J.H., ed., Twenty-Second Annual Oil Shale Symposium Proceedings: Colorado School of Mines Press, p. 199–206.

Sinor, J.E., 1989, Niche market assessment for a small-scale western oil shale project: U.S. Dept. of Energy Rept. DOE/MC/11076-2759.

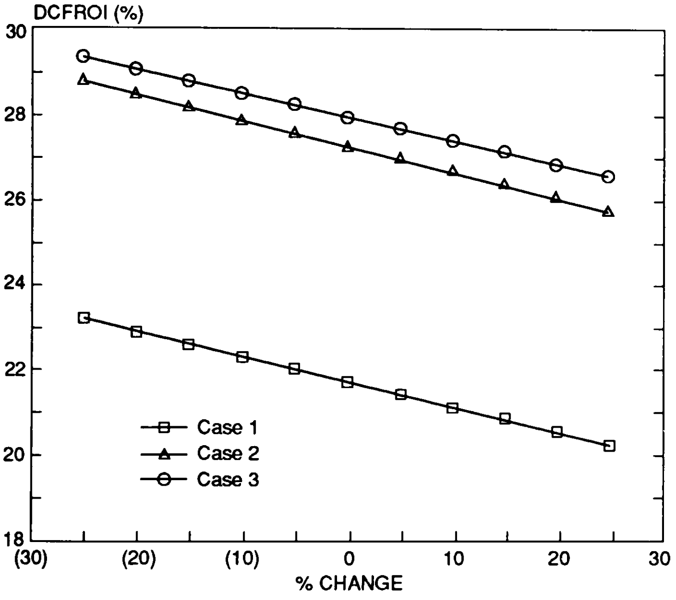

Figure 4. Economic sensitivity—O&M costs.

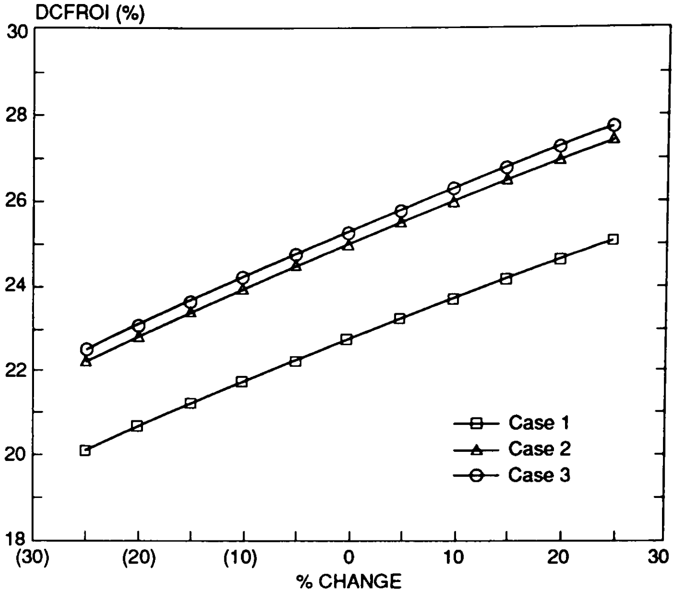

Figure 5. Economic sensitivity—Total revenues.

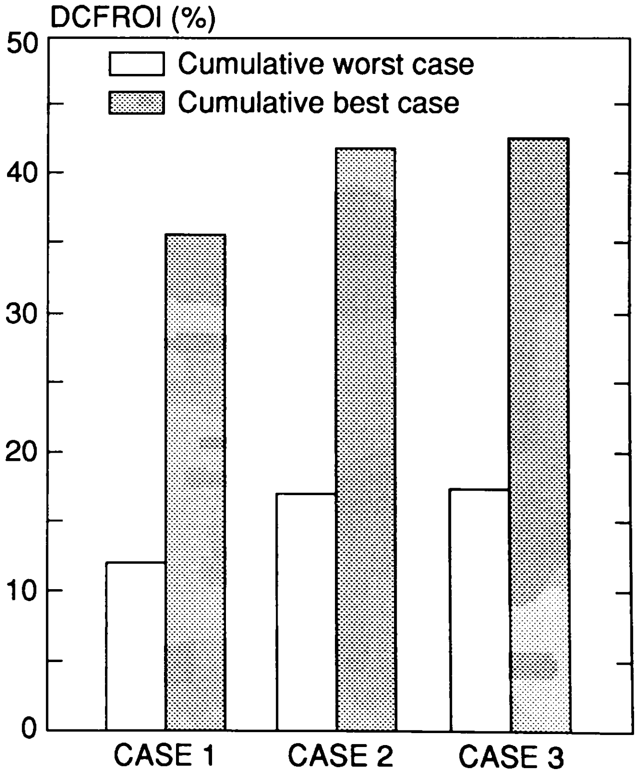

Figure 6. Economic sensitivity—Cumulative impact.