DETERMINATION OF RESERVOIRS' RELATIVE EFFICIENCY AND A WAY TO OPTIMIZE INEFFICIENT ONES: APPLICATION OF DATA ENVELOPMENT ANALYSIS AND RESERVOIR SIMULATION MODEL

BY

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ABSTRACT

The current practice measuring oil reservoir efficiency uses ratio analysis from cumulative oil production to oil initially in place. It does not mention any input parameters that contribute to the output. There is no explanation which input is in excess to generate output, and which oil reservoirs are measured on an individual basis, leaving no indication of efficient input targets from inefficient ones. This research measures relative efficiencies of oil reservoirs and identifies the inefficient ones. The efficiency is measured as a distance between the input and output quantity of a decision making unit (DMU) and the input and output quantity defined as a frontier line. A slack improvement is used to modify the input to optimise an inefficient DMU. Started with performing optimisation of each DMU for no further action (NFA) stage and enhanced oil recovery (EOR) process by utilizing a reservoir simulation model (RSM), then efficiency of each DMU is measured using DEA method. Utilising this method, the efficient input target from inefficient ones is estimated to measure a slack improvement to modify the RSM inefficient inputs before rerunning the model. To this end, 12 oil reservoirs as DMUs operating in NFA and EOR development stages are analysed. The constant return to scale (CRS) input-oriented model is selected to measure the efficiency. The first case shows that DMU8 has 100% efficiency and DMU11 is found to be the least one and therefore it is selected for optimisation. The efficient input target generated by the DEA model is to recalculate the output using RSM. By rearranging the well locations, RSM can produce the same output as the initial input. The number of producers could be reduced from 21 to 5 wells to get the same level of output. Similar for the EOR case, we reduce the number of producers from 21 to 12 wells and injectors from 6 to 4 wells to get the same level of output. The contributions of the research include methodological and practical contributions. The methodological contribution includes developing an integrated DEA model and RSM to improve an inefficient DMU to become an efficient one and developing a framework optimization model to maximize oil recovery. The practical contribution includes assigning an oil reservoir as a DMU in the DEA model for measuring its efficiency with multiple inputs and outputs. The other practical contribution is providing a solution to improve a project economic by reducing its cost to get the same output.

خلاصة البحث

تستخدم الممارسة الحالية لقياس كفاءة خزان النفط في تحليل نسبة من إنتاج النفط التراكمي إلى النفط في البداية في المكان. وهو لا يذكر أي معامل المدخلات التي تساهم في الناتج. ولا يوجد أي تفسير للمدخلات الزائدة لتوليد الناتج، وتقاس خزانات النفط على أساس فردي، دون ترك أي مؤشر يميز بين أهداف المدخلات الفعالة عن تلك التي لا تتسم بالكفاءة. ويقيس هذا البحث الكفاءات النسبية لخزانات النفط ويحدد الكفاءات غير الفعالة. كما تقاس الكفاءة على أنها مسافة بين كمية المدخلات والمخرجات لوحدة صنع القرار (د.م.و)، وكذلك كمية المدخلات والمخرجات المعرفة كخط حدودي. ويستخدم تحسين الركود لتعديل المدخلات لتحسين دمو غير فعالة. بدأت مع أداء الأمثل من كل وحدة دمو لمرحلة مزيد من العمل (ن.ف.أ) وتعزيز عملية استرداد النفط (ي.و.ر) من خلال الاستفادة من نموذج محاكاة الخزان (ر.س.م)، ثم يتم قياس كفاءة كل وحدة د.م.و باستخدام طريقة د.ي.أ. وباستخدام هذه الطريقة، يقدر أن الهدف الفعال من المدخلات غير الفعالة لقياس التحسن في الركود لتعديل المدخلات غير الفعالة في نظام رسم قبل إعادة تشغيل النموذج. ولتحقيق هذه الغاية، يتم تحليل 12 خزانا نفطيا ك د.م.و تعمل في مراحل تطوير ال ن.ف.. و أ.و.ر. يتم اختيار نموذج العودة إلى مقياس ثابت (س.ر.س) المدخلات لقياس الكفاءة. وتبين الحالة الأولى أن DMU8 لديها كفاءة 100٪، في حين وجد DMU11 أن يكون أقل، وبالتالي يتم الاختيار للتحسين. يهدف الإدخال الفعال الذي تم إنشاؤه بواسطة نموذج د.ي.أ. هو إعادة حساب الناتج باستخدام ر.س.م. من خلال إعادة ترتيب مواقع البئر، يمكن أن تنتج ر.س.م نفس الناتج المدخلات الأولية. ويمكن تخفيض عدد المنتجين من 21 إلى 5 آبار للحصول على نفس مستوى الإنتاج. وعلى غرار حالة اليورانيوم الموسع، نخفض عدد المنتجين من 21 إلى 12 بئرا، وعدد الحقن من 6 إلى 4 آبار للحصول على نفس المستوى من الإنتاج. وتشمل مساهمات البحث مساهمات منهجية وعملية. وتشمل المساهمة المنهجية تطوير منوذج متكامل من نموذج د.ي.أ. ور.س.م. من أجل تحسين كفاءة د.م.و لتصبح وحدة فعالة وتطوير نموذج تحسين الإطار لتعظيم استخلاص النفط. وتشمل المساهمة العملية تخصيص خزان نفطي باعتباره وحدة د.م.و في نموذج د.ي.أ. لقياس كفاءته مع المدخلات والمخرجات المتعددة. والمساهمة العملية الأخرى هي توفير حل لتحسين المشروع الاقتصادي عن طريق خفض كلفته للحصول على نفس الناتج.

APPROVAL PAGE

The thesis of Slamet Riyadi has been approved by the following:

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DECLARATION

I hereby declare that this dissertation is the result of my own investigation, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Slamet Riyadi

Signature ………………………. Date ……………….………

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DEDICATION

I dedicate this thesis to my wife Ningrum, my daughters Noerma, Fatimah, Hamidah, and my son Zaky for their supports.

Also, I dedicate this thesis to my sister Suratmi who takes care of our parents for more than 10 years.

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LIST OF ABBREVIATIONS

ASP	Alkaline-surfactant-polymer
AE	Allocative efficiency
AHP	Analytic hierarchy process
BCC	Banker, Charnes and Cooper
B/C	Benefit to cost ratio
BHP	Bottom hole pressure
CCR	Charnes, Cooper and Rhodes
CRS	Constant returns to scale
DEA	Data envelopment analysis
DEAP	Data envelopment analysis program
DMU	Decision making unit
DRS	Decreasing return to scale
E & P	Exploration and production
EMS	Efficiency measurement system
EOR	Enhanced oil recovery
GOR	Gas oil ratio
HMQI	History matching quality indicator
HCPV	Hydrocarbon pore volume
IRS	Increasing return to scale
LGR	Local grid refinement
MPI	Malmquist productivity index
MPSS	Most productive scale
NDRS	Non-decreasing return to scale
NFA	No further action
NIRS	Non-increasing return to scale
NPV	Net present value
NW	North West
OIP	Oil in place
OIIP	Oil initial in place
OWC	Oil water contact
P&L	Profit and loss
PI	Profitability index
PIR	Profit to investment ratio
POP	Put on production
PSC	Production sharing contract
RF	Recovery factor
RMP	Reservoir management process
ROE	Return on expenditures
RQI	Reservoir quality index
RSM	Reservoir simulation model
RTS	Returns to scale
SAGD	Steam-assisted gravity drainage
SPE	Society of petroleum engineer
STOIIP	Stock tank oil initial in place

TE	Technical efficiency
VRS	Variable return to scale
WAG	Water-alternating-gas
WC	Water cut