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Product line performance assessment on order fulfilment cycle time: a case of microelectronic communication company

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The paper suggests data envelopment analysis (DEA) as a promising alternative technique to measure the relative efficiencies of production lines with several key performance indices. This study describes six key performance indices for a microwave communication company's order fulfilment process. We use four efficiency indices: global technical efficiency, pure technical efficiency, scale efficiency and mix efficiency to assess the performance of its nine production lines. The method is different from the traditional performance assessment and also considers the production line scale, management, operation and process.

Keywords: Data envelopment analysis; Key performance index; Order fulfilment cycle time; Supply chain management

1. Introduction

Microelectronics Technology Inc. (MTI) is a high-tech company specializing in wireless communication technology research, product development and production. Its current assets and yearly global revenues are more than one hundred million US dollars. Based on 20 years of valuable experience, possessing microwave and radio frequency (RF) technology core competence, MTI has established a global leading position in the fields of radio, VSAT (very small aperture terminals), satellite television transceiver systems, and personal wireless communications system. MTI has strategic alliances with many global leaders of wireless solution such STXN and UTStarcom.

Reduction of cost, enhancement of customer service and decrease of order cycle are three important factors needed to be the winner in this field. In order to improve these three factors, MTI defines several critical key performance indices (KPIs) for performance assessment. The study shows how to define the KPI and how to evaluate the performance of MTI's nine production lines based on the KPIs.

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In order to promote the company's operation efficiency and improve the inventory level to become the leader in the field, the company established an effective corporate structure and formulated sound strategies to orient employees in the proper use of resources. In this stage, the company set the company target by orientation and determination declaration. It then analysed and defined the critical success factors by comparing the benchmark in the same field and similar fields; this also helps the company become aware of the advantages by elimination.

The target of the KPIs is evaluating the implementation of the company goals and strategies. KPI is also a standard system for business activities; the purpose is setting a common language to evaluate the process performance. MTI uses four to-be-maximized and two to-be-minimized KPI indices to measure the relative efficiency of each production line among the nine lines. This study will describe the critical KPIs for the company's order fulfilment process and evaluation of the performance of the nine production lines. The assignment of the weights for the multiple KPIs is the main challenge for assessment.

Data envelopment analysis (DEA) is a multiple input–output efficient technique that measures the relative efficiency of decision-making units (DMUs) using a linear-programming-based model. DEA is non-parametric because it requires no assumption about the weights of inputs and outputs and it can further explore the characteristic of production lines (DMUs). DEA was originally proposed by Charnes *et al*. (1978) and this model is commonly referred to as a Charnes, Cooper, Rhodes (CCR) model The DEA frontier DMUs are those with maximum output levels for given input levels or with minimum input levels for given output levels. DEA provides efficiency scores for individual units as their technical efficiency measure, with a score of one assigned to the frontier (efficient) units.

A unit with 'efficiency score' one is on the 'efficiency frontier' and the score less than one indicates the unit is not on the frontier. DEA provides detailed information about these possibilities by calculating the projection of each observation upon the frontier. The projection points are called 'best practice'. Comparing the actual performance with the projected ones can provide the direction for improvement. In this paper, each production line of the company represents as a unit in DEA. We use four efficiency indexes: global technical efficiency, pure technical efficiency, scale efficiency and mix efficiency to assess the performance of the nine production lines. The four indices were determined by three DEA models: CCR, Banker, Charnes and Cooper (BCC), and slack-based measurement (SBM).

The CCR model (Charnes *et al*. 1978) is used to measure the relative efficiency rating is designated as the global technical efficiency. There are n DMUs under comparison for their performance. Banker *et al*. (1984) adjoined the convex constrain to the CCR model and obtained the BCC model, which is the one calculated under variable returns of scale. This type of relative efficiency rating is designated as the pure technical efficiency. The SBM model (Tone 2002) is non-radial and deals with input/output slacks directly. The SBM returns an efficiency measure between 0 and 1, and gives unity if and only if the DMU concerned is on the frontiers of the production possibility set with no input/output slacks. This type of relative efficiency rating is decomposition into global technical efficiency and mix efficiency (Banker *et al*. 1984).

The article by Gattoufia *et al*. (2004a) discusses statistical trends within the DEA literature. The number of articles published per year in refereed journals over the entire lifespan of the field, authorship and publishing outlets-of-choice statistics are used to indicate DEA's vitality, relevance, diffusion to other disciplines/professions and its worldwide acceptance. The article by Gattoufia *et al.* (2004b) presents a scheme for classifying the DEA literature that allows one to distinguish articles on the basis of the data source used if any, the type of envelopment invoked, the approach to analysis used, and the nature of the paper. The article by Gattoufia *et al.* (2004c) provided a bibliography of the published data envelopment analysis. It contains 1800 articles in refereed journals worldwide in addition to many books, conference proceedings and various types of monographs in 1951–2001. The text book by Cooper *et al.* (2000) would be a good resource to indicate who should enter the field of DEA.

2. Order fulfilment cycle and the key performance indices (KPIs)

Fulfilling customer orders is treated as the first priority in MTI to generate a profit. The cycle for fulfilling customer orders is depicted in figure 1. When a customer places an order, MTI completes three processes: (1) demand management; (2) making and sourcing; and (3) logistic management. In the customer-oriented environment, how to obtain feedback and ship product more rapidly than other competitors is always the key factor to obtain more orders. How to shorten lead time and increase production efficiency are the topics in this corporate reengineering process.

The demand management process always involves the processing and confirming the order with the customers. It is the beginning of the order fulfilment cycle. It includes items such as customer service, customer management, sales management, quotation service, order change process, available to promise, product price management and product management.

Making and sourcing are the manufacturing activities, which include material planning, capacity planning, material purchasing, material outsourcing and production line efficiency.

Logistic management is defined as making the product available and ready to ship. The process includes shipping inspection, package, combined delivery and transportation arrangement.

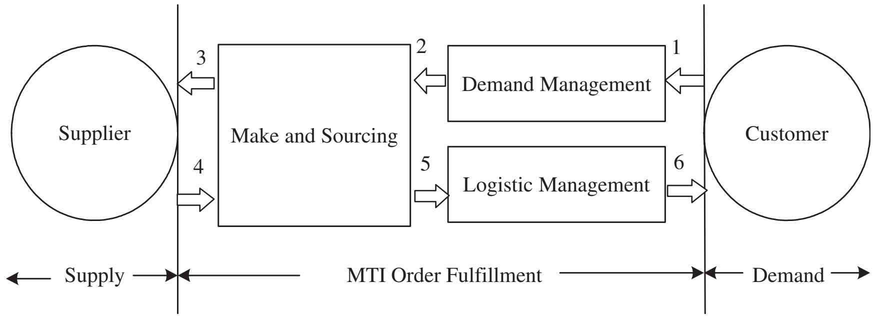

Figure 1. Order fulfilment cycle.

Logistic management is an element of the process under consideration as depicted in figure 1. Focus on logistic management in figure 1: its inbound and outbound are well described in literature of logistic management. Since the order fulfillment cycle considered in the paper consists of three processes, one should notice the inbound and outbound described in the entire process depicted in figure 1 are different from the literature of logistic management.

2.1 *Purposes of the key performance indices*

There are four major purposes for setting up KPIs.

1. To set-up a common language for measuring company performance; based on these indices, one finds a way to practice global supply chain management.
2. To help employees to understand the situation discrepancy of supply chain management between company and other competitors within the same industry and, in the process of planning and managing the supply chain, try to select the hottest focus area, so as to work together with suppliers and partners to take immediate action and improve continuously.
3. To provide a baseline for performance measurement and comparison between the company and other companies within the same industry, so as to recognize the advantages and disadvantages of supply chain management (SCM).
4. To provide tools for the company to perform the comparison and analysis on the current internal supply chain management and other competitively strategic supply chain management, so as to help the company to set up a target position inside the highly competitive market.

2.2 *Key performance index implementation steps*

The process of adopting KPIs in the order fulfilment cycle is critical to reengineer a company. With reference to the element's capabilities, a target is set for each KPI. Data collection is set and, in case performance is not up to target, a review process is in place to rectify the situation. This consists of five steps. These steps are designed to breakdown the company-wide supply chain operational KPI to element-level measurements. They include clarification, review, matching, and confirmation with supply chain and production of a set of KPIs.

Step 1. Review new company-wide SCM KPI definitions.
Discuss with supply chain manager any supply chain definition that requires clarifications and reconciliation.

Step 2. Breakdown into element's requirements.
After the supply chain KPI definitions are clarified, review the impact area in terms of management and operational area, external interface and activity content to define the functional/element's requirements.

Step 3. Design supporting element's KPI/
After understanding the order fulfilment element's business and process requirements, design the supporting logistics KPI, detailing the definition, calculation formula, frequency of measure, and measurement method, etc.

Step 4. Confirm KPI with process owners.
Communicate the element's KPI definition with the process owner of the impacted area and confirm the rationality and feasibility, and finalize the KPI details including any extra system or business resource requirement.

Step 5. Confirm SCM related element's KPI with supply chain manager.
Confirm with the supply chain manager the SCM related element's KPI for supply chain control and measurement monitoring.

2.3 *Key performance index description*

There is much literature on KPIs. The selection of a KPI is dependent on the system under consideration. The six KPI indices used by MTI are depicted in table 1 and are described below.

1. Y_1: Purchase order (PO) schedule evaluation
   MTI is set up in such a way that each customer order should be fulfilled within no more than three days. The production controller (PC) is informed of any order coming into the sales department. PC would commit the order if work-in-process (WIP) status and production capacity available for the required order. Then PC informs order administration (OA) and the order evaluation process is completed. Otherwise, PC will pass the work order to material control (MC) and purchasing section. Purchasing section will confirm the material schedule and make a feedback to MC.
2. Y_2: Inbound operation
   The inbound operation process starts as the warehouse receives an arrival material. Time spent on the material for unloading, receiving, inspecting and moving to points to be used and storage locations is recorded. The necessary book keeping for system control is also performed.
3. Y_3: Work order preparation and warehouse (W/H) material hand over
   Stopwatch is pressed as PC releases a work order to warehouse. Then, W/H spends time on launching the plan for material kitting task, generating dispatching assignment, picking, kitting, packing and handling the material to production lines.
4. Y_4: Outbound operation
   The outbound operation KPI is initialized by the production line releasing the packing list and transferring to OA. OA will follow the packing list to generate the shipping notice and then transfer to the logistic department. After the logistic department receives the shipping notice they arrange transportation and prepare all the freight information and documentation. When everything is ready, they will pass all related documents to W/H. The shipment is ready when W/H receives the product from the production line and documentation from logistic department. Total KPI is the collective responsibility of the production line, OA, logistic and W/H. The other KPI for manager review are OTD for first commitment date and customer required date. The OTD is the most important index for customer satisfaction and should be tracked monthly.

5. X_1: Engineering change order
   The purpose of this KPI is to evaluate the engineering change process (ECP). The process is initiated as a customer releases engineering change request to document control centre (DCC). The process is completed as OA feedbacks to the customer.

6. X_2: Production and testing
   This KPI is to evaluate the efficiency and productivity of a production line. The collection of KPI is from shop-floor control and analysed by the system. Two separate sets of data are collected: 'total build time' and 'work order completed ratio'. 'Total building time' is the average time for the line spends on production of customer orders. The process includes surface mount technology (SMT) production, semi-product staging, product integration, test, packaging, shipping inspection to put away finished goods in the assigned staging area. We can evaluate the test time and efficiency for each

Table 1. Key performance index description.

KPI No.	KPI name	KPI definition	To-Be KPI Sponsor
Y_1	Percentage of order confirmed	The percentage of purchase orders confirmed that could be delivered within 3 days.	PC, MC
Y_2	Percentage of inbound operation complete	The number of inbound orders/lines that are operated divided by the total inbound orders/lines in the measurement period.	WH
Y_3	Percentage of work order material planning ans kitting orders/lines processed (planning, picking and material kitting) complete	The number of work order material kitting orders/lines that are kitted on-time to demand requirements divided by the total work order material kitting orders/lines requested in the measurement period.	WH
Y_4	Percentage of delivery performance to first committed date	The percentage of orders that are fulfilled on or before the first committed date.	All
X_1	ECO (engineering change order) cycle time	The total time for request for change from customer engineering, production or quality control to revising a blueprint or design released by engineering, and implement the change within the make operation.	SM and Engineer
X_2	Total build time	Total build time is the average time for MTS, MTO semi-products from when production begins on the released work order until the build is completed and unit is ready to be inspected.	PH

work centre and test station. 'Work order complete ratio' begins on the released work and end by the work order been closed. The work order completed ration will impact the on time delivery (OTD).

3. The performance data

The nine production lines of MTI are denoted as line 1, 2, ..., and 9. Their data on the six indices are depicted in table 2. For each line, say *Line j*, y_{rj} denotes the data on index Y_r, $r=1$, 2, 3 and 4, and x_{ij} denotes the data on index X_i, $i=1$ and 2. We use the following equation (1) to measure the efficiency of each *Line j*. As the six KPIs are defined, larger values (to-be-maximized) at Y_1, Y_2, Y_3 and Y_4, smaller values (to-be-minimized) on X_1 and X_2 indicate the better performance of the production line. The terms production lines, the to-be-maximized indices and the to-be-minimized indices in our problem have equivalent characteristics of the terms DMUs, 'output' indices and 'input' indices in DEA literature, respectively. The notations n, m and s denote the total number of production lines, the total number of input indices (to-be-minimized), and the total number of output indices (to-be-maximized), respectively, in this paper they are equal to 9, 2 and 4.

$$P_j = \sum_{r=1}^{s} y_{rj} u_r \Big/ \sum_{i=1}^{m} x_{ij} v_i \qquad (1)$$

The notations u_r and v_i are the weights that should be assigned to index Y_r and X_i, respectively. It is a challenge to have a set of proper weights of the indices to measure the relative performance of production lines. We employ the theory of DEA to assess the relative efficiencies of the nine lines.

4. Implement data envelopment analysis models

The relative efficiency of *Line k* is evaluated by following input-oriented CCR-I model (Cooper *et al.* 2000).

[CCR-I-FP$_k$]

$$\text{Maximize } P_k = \sum_{r=1}^{s} y_{rk} u_r \Big/ \sum_{i=1}^{m} x_{ik} v_i$$

$$\text{Subject to: } P_j = \sum_{r=1}^{s} y_{rj} u_r \Big/ \sum_{i=1}^{m} x_{ij} v_i \le 1, \quad j = 1, \ldots, n;$$

$$u_r \ge \varepsilon > 0,\ r = 1, \ldots, m;\ v_i \ge \varepsilon > 0,\ i = 1, \ldots, s.$$

ε is a Archimedean infinitesimally small number.

[CCR-I-FP$_k$] tries to maximize the efficiency score for the object *Line k* while keeping the efficiency scores for each *Line j* being no greater than one. [CCR-I-FP$_k$] is a fractional programming model and is transformed into a linear programming model as shown below. The lower bound conditions for the decision variables u_r

Table 2. KPI data for the production lines.

KPI scores *Line j*	y_{1j}	y_{2j}	y_{3j}	y_{4j} (y_{sj})	x_{1j}	x_{2j} (x_{mj})
1	56%	56%	65%	95%	45	78
2	50%	87%	55%	76%	33	67
3	45%	54%	83%	55%	30	56
4	67%	76%	65%	66%	21	45
5	53%	66%	83%	55%	30	22
6	60%	45%	45%	56%	56	23
7	44%	93%	77%	76%	12	28
8	87%	88%	96%	87%	34	22
9(=n)	53%	78%	76%	55%	12	21

and v_i would guarantee the proper transformation given the data of a line are non-negative and at least one is positive.

[CCR-I-LP$_k$]

$$\text{Maximize } P_k = \sum_{r=1}^{s} y_{rk} u_r$$

$$\text{Subject to } \sum_{r=1}^{s} y_{rj} u_r - \sum_{i=1}^{m} x_{ij} v_i \leq 0 \quad j = 1, \ldots, n;$$

$$\sum_{i=1}^{m} x_{ik} v_i = 1;$$

$$u_r \geq \varepsilon > 0,\ r = 1, \ldots, m;\ \ v_i \geq \varepsilon > 0,\ i = 1, \ldots, s$$

The dual of [CCR-I-LP$_k$] can be written:

[CCR-I-DLP$_k$]

$$\text{Minimize } \theta_k - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

$$\text{Subject to } \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta_k x_{ik},\ i = 1, \ \ldots, m;$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{rk},\ r = 1, \ldots, s;$$

$$\text{all } \lambda_j,\ s_i^-, s_r^+ \geq 0$$

The variable λ_j denotes the weight of DMU$_j$ while assessing the performance θ_o of the object DMU$_o$. s_r^- and s_r^+ are the *excess* of the to-be-minimized index X_i and *shortfall* of the to-be-maximized index Y_r of this expression, respectively, and are called *slacks*. We add the superscript '∗' on the variable to represent its optimal value of the model. According to the solution of the model *Line k*'s performance could be one of the following categories.

$$\text{Pure efficient: } \theta_k^* = 1 \text{ and } \left(\sum_{i=1}^{m} s_i^{-*} + \sum_{r=1}^{s} s_r^{+*}\right) = 0$$

$$\text{Pure inefficient: } \theta_k^* < 1 \text{ and } \left(\sum_{i=1}^{m} s_i^{-*} + \sum_{r=1}^{s} s_r^{+*}\right) = 0$$

$$\text{Mixed inefficient : } \theta_k^* < 1 \text{ and } \left(\sum_{i=1}^{m} s_i^{-*} + \sum_{r=1}^{s} s_r^{+*}\right) > 0$$

$$\text{Weak efficient: } \theta_k^* = 1 \text{ and } \left(\sum_{i=1}^{m} s_i^{-*} + \sum_{r=1}^{s} s_r^{+*}\right) > 0.$$

The [CCR-I-FP$_k$] model assumes constant returns-to-scale. To identify the property of *Line k*, increasing or decreasing returns-to-scale, Banker *et al*. (BCC) (1984) proposed a model that measures so-called pure technical efficiency and scale efficiency. It is called the BCC model. Starting out from Shephard's definition of a production possibility set, BCC-I assumes that this set satisfies basic axioms of convexity, inefficiency, ray unbounded and minimum extrapolation, $\lambda_j \geq 0$, $j = 1, \ldots, n$ and $\sum_{j=1}^{n} \lambda_j^* = 1$.

BCC-I used the axioms and Shephard's distance function to drive a model that measures *pure technical efficiency*.

[BCC-I-DLP$_k$]

$$\text{Maximize } \eta_k - \varepsilon\left(\sum_{i=1}^{m} s_i^{-*} + \sum_{r=1}^{s} s_r^{+*}\right)$$

$$\text{Subject to } \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \eta_k x_{ik},\ i = 1, \ldots, m;$$

$$\sum_{j=1}^{n} y_{ij}\lambda_j - s_r^+ = y_{rk},\ r = 1, \ldots, s;$$

$$-\sum_{j=1}^{n} \lambda_j = -1 \text{ and all } \lambda_j,\ s_i^-,\ s_r^+ \geq 0$$

The dual form of above [BCC-I-DLP$_k$] is expressed as follows:

[BCC-I-LP$_k$]

$$\text{Maximize } \sum_{r=1}^{s} u_r y_{rk} - u_{0k}$$

$$\text{Subjectto } \sum_{r=1}^{s} y_{rj} u_r - \sum_{i=1}^{m} x_{ij} v_i - u_{0k} \leq 0,\ j = 1, 2, \ldots, 9;$$

$$\sum_{i=1}^{m} x_{ik} v_i = 1;$$

$$u_r \geq \varepsilon > 0,\ r = 1, \ldots, m;\ v_i \geq \varepsilon > 0,\ i = 1, \ldots, s,\ u_{0k} \text{ free in sign}$$

Measure by the intercept u^*_{0k} its sign, positive or negative, allows the magnitude of the returns-to-scale to be determined, whether *Line k* currently evaluated is operating under increasing or decreasing returns-to-scale. Thus $u^*_{0k} > 0$, $u^*_{0k} = 0$ and $u^*_{0k} < 0$ imply *Line k* is operating under conditions of decreasing (DRS), constant (CRS), and increasing (IRS) returns-to-scale, respectively.

Tone (2000) introduced the slack-based measurement model. We consider an expression for describing the data for *Line k* as

$$y_{rk} = \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+$$

$$\lambda_j \geq 0,\ j = 1, \ldots, n, \text{ and } s_r^+ \geq 0,\ r = 1, \ldots, s. \tag{2}$$

From the conditions, $x_{ij} > 0$ and $\lambda_j \geq 0$, it holds

$$x_{ik} \geq s_i^- \tag{3}$$

Using s_i^- and s_r^+, we define the SBM efficiency as follows

$$\rho_k = \frac{1 - (1/m)\sum_{i=1}^{m} s_i^-/x_{ik}}{1 + (1/s)\sum_{r=1}^{s} s_r^+/y_{rk}}. \tag{4}$$

It can be verified that ρ_k satisfies properties (a) units invariant and (b) monotone decreasing in input/output slack. Furthermore, from equation (1), it holds $0 < \rho_k \leq 1$.

Another variation of SBM model [SBM-I] is also introduced to estimate the efficiency of *Line k*.

[SBM-I]

$$\text{Minimize } \rho_k^* = 1 - \frac{1}{m}\sum_{i=1}^{m} s_i^-/x_{ik}$$

$$\text{Subject to } x_{ik} = \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^-,\ i = 1, \ldots, m;$$

$$y_{rk} = \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+,\ r = 1, \ldots, s;$$

$$\lambda_j \geq 0,\ j = 1, \ldots, n,\ s_i^- \geq 0,\ i = 1, \ldots, m,\ s_r^+ \geq 0 \text{ and } r = 1, \ldots, s.$$

[SBM-I] can be transformed into a linear program using the Charnes–Cooper transformation in a similar way to the CCR model. Refer to Tone (2001) and Cooper *et al.* (2000) for details.

Let optimal solution for [SBM-I] is (ρ_k^*, λ_j^*, s_i^{-*}, s_r^{+*}). Based on this optimal solution, we define *Line k* as being *SBM-efficient* as follows:

(*SBM-efficient*) *Line k* is efficient if $\rho_k^* = 1$. This condition is equivalent to $s_i^{-*} = 0$ and $s_r^{+*} = 0$, i.e. no excesses and no shortfalls in any optimal solution.

4.1 *Cross-sectional results*

Banker *et al*. (1984) suggested splitting the overall CCR efficiency-global technical efficiency (θ_k^*) into two factors: pure technical efficiency (η_k^*) and scale efficiency (S_k^*) in the following manner

$$\theta_k^* = \eta_k^* \times (\theta_k^*/\eta_k^*) = \eta_k^* \times S_k^* \tag{5}$$

The BCC efficiency used the axioms and Shephard's distance function to drive a model that measures pure technical efficiency. The scale efficiency (S_k^*) can't exceed one. When the scale efficiency of a line is less than one, a further step can be taken to decide whether it is located at a stage of IRS or DRS.

The calculations of economies of scale u_{0k}^* have a direct interpretation in terms of the underlying dynamic evolution. In an obvious sense, a production line with DRS has pushed its expansion too far, and management can be expected to consider the possibility of downsizing and reducing its scale of operation. Conversely, a production line with IRS will typically be engaged in rapid economic growth. The mix efficiency, M_k^*, is not greater than one and we have a decomposition of the non-radial efficiency into radial and efficiency as

$$\rho_k^* = \theta_k^* \times M_k^* \tag{6}$$

Based on equation (3), we have the decomposition of the non-radial technical efficiency ρ_k^* into M_k^*, pure technical efficiency (θ_k^*) and scale efficiency (S_k^*)

$$\rho_k^* = \theta_k^* \times M_k^* = \eta_k^* \times S_k^* \times M_k^* \tag{7}$$

5. Interpretation to the efficiency scores

Apply the models, **[CCR-I-LP$_k$], [BCC-I-LP$_k$] and [SBM-I]** for the data depicted in table 2, the objective function values and the cross section results are listed in table 3.

From table 3, we can see *Lines* 7, 8 and 9 exhibit high efficient performances at any scale. The three production lines could be the benchmark of all the others. Scale efficiency S_k^* is equal to (θ_k^*/η_k^*). If $S_k^* = 1$, then the *Line k* is operating at CRS, which is the optimal level.

Line 1 and *Line* 4 have a fully efficient η_1^* and η_4^* score and low efficiency of $\theta_1^*(0.423)$ and $\theta_4^*(0.722)$. The low efficiency is caused by scale $0 < S_k \leq 1$. The lines

Table 3. Efficiency scores.

Line k	θ_k^*	η_k^*	S_k^*	ρ_k^*	M_k^*	u_{0k}^*	RTS
1	0.423	1.000	0.423	0.393	0.929	−2.609	IRS
2	0.413	0.447	0.923	0.407	0.984	−0.706	IRS
3	0.436	0.632	0.690	0.423	0.971	−2.572	IRS
4	0.722	1.000	0.722	0.656	0.908	−1.051	IRS
5	0.893	0.970	0.920	0.783	0.877	0.782	DRS
6	0.660	0.922	0.715	0.539	0.817	0.845	DRS
7	1.000	1.000	1.000	1.000	1.000	0.000	CRS
8	1.000	1.000	1.000	1.000	1.000	0.000	CRS
9	1.000	1.000	1.000	1.000	1.000	0.000	CRS

operate at an inappropriate scale either increasing or decreasing returns-to-scale. The values of u_{01}^* and u_{04}^* for production *Line* 1 and *Line* 4 are negative, indicating that they are IRS; this shows that it is possible for them to improve their efficiency by scaling up their production activities.

It is observed that production *Line* 5 with low $\rho_5^*(0.783)$ is caused by $M_5^*(0.877)$, and $S_5^*(0.920)$. Also, it is observed that production *Line* 6 with low $\rho_6^*(0.539)$ is caused by $M_6^*(0.817)$, and $S_6^*(0.715)$. Both u_{05}^* and u_{06}^* values are positive, which indicate that they are DRS, showing that they can improve their efficiency by scaling down their production activities.

The production *Line* 2 low efficiency of $\rho_2^*(0.407)$ is caused by $S_2^*(0.923)$ and $\eta_2^*(0.447)$. The production *Line* 3 low efficiency of $\rho_3^*(0.423)$ is caused by $S_3^*(0.690)$ and $\eta_3^*(0.632)$. Both of u_{02}^* and u_{03}^* values are negative ones which shows that they have a possibility to improve their efficiency by scaling up their production activities. η_k^* is pure technical efficiency and low efficiency caused by technical and management. So, we can improve the efficiency by increasing scale, improving operation and management.

6. Conclusions

In the present paper, we illustrate the KPI target and definition in the order fulfilment cycle. We list several KPIs and evaluate the nine production lines of MTI. The method introduced should not only be for the specific company. It should be generalized for different companies in assessing the performance of multiple production lines with multiple to-be-maximized and to-be-minimized KPIs. We provide example and interpretation intending to indicate direction of improvement. We decompose the efficiency score of each production line into technical, pure, scale and mix efficiencies. DEA is successfully implemented on the assessment of the production lines. With the scale unit, we know that the production is at the optimal level or that the production line can be improved by either scaling up or scaling down its production activities. Production lines with low technical efficiency indicate they need improve technical and management operations.

We define the correspondence between the terms DMUs, input indices and output indices in data envelopment analysis literature and production lines, to-be-maximized performance indices and to-be-minimized performance indices in a production process under consideration. It is possible to apply DEA to many performance evaluation occasions if multiple indices are involved.

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