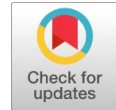# Probing Low Productive area in Steel Re-Rolling Mills

Rita k. Jani, J.A.Vadher, Anand D.Kalani

Abstract: Steel Re-Rolling mill is the second most important steel forming industry in India. The manufacturing process of steel re-rolling from ingots to finished products has high energy consumption and it directly affects productivity and manufacturing cost. Measuring the productivity of the process can unleash the low productive process, which leads towards rectification for increasing the productivity of lean area. The productivity of Steel Re-Rolling mill is measured by Performance Objective – Productivity model. Key performance areas were identified by intensive survey and process of prioritization was carried out. The actual values of the Key performance Areas of the system were compared with the objectivated values of the system. The outcomes lead to Productivity Index of the system, sub-system and key performance areas of the process revealing the areas with low-performance index which have the highest impact on productivity of the process. The energy subsystem is having the lowest performance index and is the main source of loss and recommendations are made to increase the productivity of energy sub-system.

Keywords: Key Performance Areas, Performance objective productivity Model, Productivity, Productivity Index, Steel re-rolling mill.

I. INTRODUCTION

Steel Re-Rolling Mills (SRRM) is the backbone of the secondary steel market. The steel re-rolling mills always have a cutting edge over primary steel market due to its raw material i.e. scrap steel and flexibility in manufacturing beams and channels of the different cross section. The major manufacturing done by SRRM is used in the infrastructure development.

Steel Re-Rolling process is an energy demanding process. The energy utilized for process is generated by burning of fuels like coal, diesel oil, natural gas or by electric power. Nearly 70% of the total energy is used for heating of steel for rolling process and it costs nearly 35% of overall production cost [1].

U. P. Singh [2] suggested some of the solutions for saving the energy in steel re-rolling mills. Till date different suggestion and modifications are applied to the process by considering the heat loss in furnace.

The productivity of steel re-rolling process is always a vital concern for earning a profit. The main aim is to develop a high productive manufacturing system.

Sardana and PremVrat [3] developed the "Performance Objectives-Productivity" PO-P model to measure the productivity of an organization. This model emphasis on performance objectives: actual and prospective, representing the total output of a system.

This paper presents the Performance Objectives-Productivity Model of Steel Re-Rolling Mills through detailed methodology leading to energy and cost efficient manufacturing of whole system.

II. PO-P: METHODOLOGY

Productivity measurement by PO-P approach developed by Sardana and Prem Vrat [3] comprises of the following steps:

i.   Identification of Sub-systems
ii. Identification of KPA'S [Key Performance Area] in each of the Sub-systems.[4,5,6]
iii. The setting of Performance Objectives.
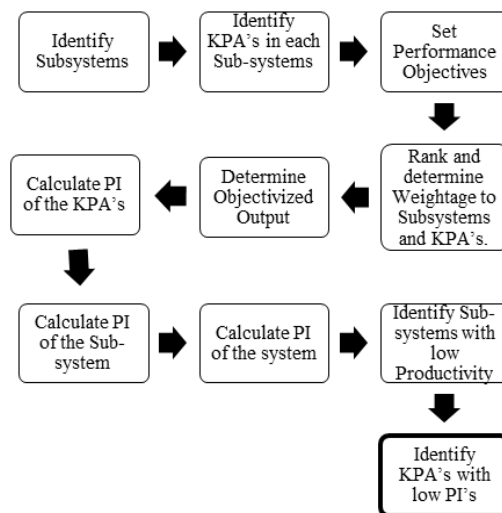iv. Ranking and Weighing of Sub-systems, KPA's and Performance Objectives.

Fig. 1. Flow Chart of PO-P model for productivity measurement

v.   Determination of objectivized output.
vi.   Calculation of productivity index
vii. Identification of Sub-system, KPA's with low performance.

The flow chart of PO-P Model is shown in Figure 1.

A   Po-P Model

The PO-P Model [3,7] is a system approach model which is developed in the integration of all the systems and sub-systems of the organization. The Productivity index of a sub-system is generated from the productivity indices of the key performance areas [KPA'S] of the sub-system.

The productivity indices of the system is

$$PI = \sum_{u=1} W_u (PI)_u \qquad eq.1$$

Where,

$$\sum_{u=1} W_u = 1$$

$(PI)_u$, the Productivity Index of a Sub-system u, is determined as

$$(PI)_u = \sum_{v=1} W_{vu}(PI)_{vu} \qquad eq.2$$

Where, for all u's

$$\sum_{u=1} W_{vu} = 1$$

$(PI)_{vu}$, the Productivity Index of a Key Performance Indicator, v of Sub-system u, is determined as

$$PI_{vu} = \sum_{y=1} W_{yuv} \frac{O_{yuv}}{O_{yuv}^*} \qquad eq.3$$

Where, for all u's and v's

$$\sum_{u=1} W_{yvu} = 1$$

Substituting the values of eq. 3 in eq. 2 the productivity index of the Sub-system u, is

$$PI = \sum_{y=1}\sum_{v=1} W_{vu} W_{yvu} \frac{O_{yvu}}{O_{yvu}^*} \qquad eq.4$$

Substituting the values of eq.4 in eq.1 the productivity index of the system S, is

$$PI = \sum_{u=1}\sum_{v=1}\sum_{y=1} W_u W_{vu} W_{yuv} \frac{O_{yuv}}{O_{yuv}^*} \qquad eq.5$$

III. RESEARCH AND METHODOLOGY

Bhavnagar district which is located in southern part of Gujarat state, India have clusters of steel re-rolling mills working on small scale and large scale. The supply of the raw material is accomplished from the Asia's largest ship breaking yard Alang 50 km away from Bhavnagar. Most of the mills run on traditional way of manufacturing having high loss of energy

and low productivity. Willingness of the owners of the mills for giving authentic data related to their industries was the main criteria.
Data related to manufacturing process and other data required for further calculation of steel re-rolling mills was obtained from 05 full working steel re-rolling mills of the Bhavnagar cluster. Policy norms and other stipulated requirements of the industries are included in Appendix – I.

IV. PRODUCITIVTY MODEL

To develop a productivity model of manufacturing system, two sub-systems and their respective KPA's were taken into account after having a conversation with the directors of the industries. The prioritization of KPA'S was analytically sequenced by Analytical Hierarchical Process (AHP). The Subsystems and their importance KPA's are listed in table 1.

Table 1 : Sub-system and their KPA's

Sub-System	KPA'S
Energy	• Energy Consumption • Fuel Consumption • Energy Generation • Fuel Waste • Energy Waste • Water Utilization • Idle Energy Consumption
Cost	• Raw Material Cost • Raw Material Availability • Inventory Cost • Maintenance Cost • Material Loss • Labour Cost • Fuel Cost

The productivity measurement structure developed as per PO-P Model for the all the industries is as shown in fig. 2.
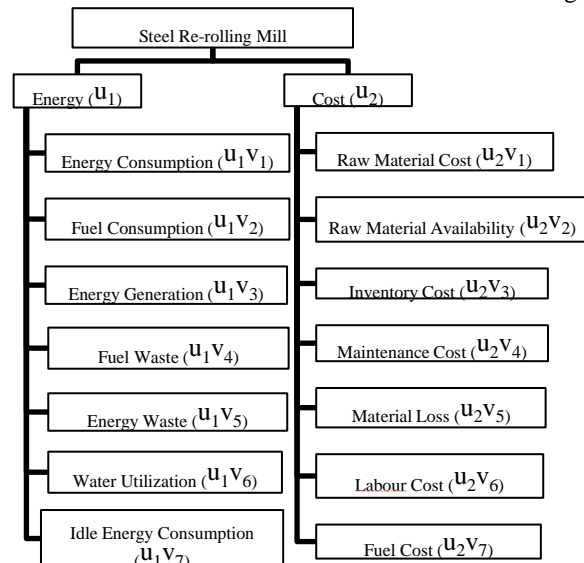

Fig. 2 Productivity measurement structure for Steel Re-Rolling Mill

Comprehensive conversation was carried out with the senior personnel of the industries to determine the relative ranking of the sub-systems, their weighting. The result is shown in table 2.

Table 2 Sub-system's relative priorities and weightage

Sub-Systems	Sachdeva Steels		Triveni Steels		Vinubhai Steels		JRsteels		Laxmi Steels	
	I	II	I	II	I	II	I	II	I	II
Energy	7	0.44	8	0.47	8	0.47	7	0.44	9	0.56
Cost	9	0.56	9	0.53	9	0.53	9	0.56	7	0.44

I – Relative Grades; II – Weightage

The key performance areas, relative ranks and weightage related to sub-systems energy and cost are shown in table 3 and 4 respectively. Data related to the performance of the industries was extracted in the form of actual and objectivated values as listed in table 5.The weightage factors of the KPA's of the subsystems with respect to their objectivated values and actual values are shown in table 6.

A   Productivity Index of the system

The productivity index of the subsystem Energy and Cost is achieved by summation of product of weightage of KPA, weightage of observed value and weightage of actual value are shown in figure 3 and the detailed calculation are shown in Appendix – II table 1.

The productivity index of whole system is achieved by summation of product of productivity index of sub-systems and their respective weightage as shown table 7 and detailed calculations to achieve the performance index of the system is shown in Appendix – II table 2.
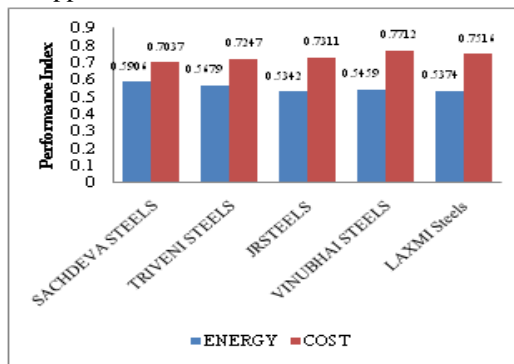

Fig. 3 Productivity Index of the subsystem Energy and Cost

Table 7 Productivity Index of Steel Re-rolling mills.

Sr. No.	Steel Re-Rolling mills	Performance Index
1.	Sachdeva Steels	0.6542
2.	Triveni Steels	0.6509
3.	J.R.Steels	0.6450
4.	Vinubhai Steels	0.6652
5.	Laxmi Steels	0.6311

Table 3 Key performance areas, relative ranks and weightage related to sub-system energy.

KPA's	Sachdeva Steels		Triveni Steels		Vinubhai Steels		JR Steels		Laxmi Steels	
	I	II	I	II	I	II	I	II	I	II
Energy Consumption	7	0.15	8	0.16	8	0.17	8	0.17	9	0.17
Fuel Consumption	8	0.17	8	0.16	8	0.17	8	0.17	8	0.15
Energy Generation	7	0.15	7	0.14	8	0.17	7	0.15	9	0.17
Fuel Waste	6	0.13	7	0.14	7	0.15	7	0.15	8	0.15
Energy Waste	9	0.19	9	0.18	8	0.17	8	0.17	9	0.17
Water Utilization	5	0.1	5	0.1	4	0.08	4	0.08	4	0.08
Idle Energy Consumption	6	0.13	6	0.12	5	0.1	6	0.13	5	0.1

I – Relative Grades; II – Weightage

Table 4 Key performance areas, relative ranks and weightage related to sub-system cost.

KPA's	Sachdeva Steels		Triveni Steels		Vinubhai Steels		JR Steels		Laxmi Steels	
	I	II	I	II	I	II	I	II	I	II
Raw Material Cost	7	0.16	7	0.16	8	0.17	7	0.15	7	0.15
Raw Material Availability	6	0.14	6	0.14	5	0.11	6	0.13	5	0.11
Inventory Cost	5	0.12	6	0.14	6	0.13	6	0.13	6	0.13
Maintenance Cost	5	0.12	6	0.14	6	0.13	6	0.13	6	0.13
Material Loss	7	0.16	7	0.16	8	0.17	8	0.17	9	0.2
Labour Cost	5	0.12	4	0.09	5	0.11	5	0.11	6	0.13
Fuel Cost	8	0.19	8	0.18	8	0.17	8	0.17	7	0.15

I – Relative Grades; II - Weightage

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Table 5 Objectivated and actual values of system

Sub systems	KPA of subsystems	Performance Objectives	Sachdeva Steels O	A	Triveni Steels O	A	Vinubhai Steels O	A	JRsteels O	A	Laxmi Steels O	A
ENERGY	Electric Energy Consumption	kwh/month	216000	240000	198400	213334	168000	186667	210800	226667	138000	153334
	Fuel Consumption	Coal Ton/month	200	210	144	151	146	153	130	153	138	144
	Fuel Waste	Coal Ton/month	3	6	2	5	2	6	3	7	1	5
	Energy Generation	kwh/month	1465380	1465380	1053678	1053678	1067634	1067634	960871	960871	1004832	1004832
	Energy Waste	kwh/month	732690	879228	474155.1	632206.8	533817	640580.4	432391.95	576522.6	502416	602899.2
	Water Utilization	liter/day	12000	15000	10000	12000	6500	6500	6500	6500	6000	6000
	Idle electric Energy Consumption	kwh/month	3800	4000	3200	3500	2700	3000	2700	3000	2500	3500
COST	Raw Material Cost	Rs/month	57600000	64800000	39600000	43200000	27000000	30600000	24000000	27200000	24000000	27200000
	Inventory Cost	Rs./ton	1710000	1980000	1260000	1440000	1305000	1665000	960000	1360000	1120000	1440000
	Maintenance Cost	Rs/ton	900000	1260000	720000	900000	540000	675000	480000	600000	520000	640000
	Material Loss	ton/month [Rs.]	864000	1600000	1188000	2592000	810000	1836000	720000	1632000	810000	1836000
	Labour Cost	Rs./ton	693000	720000	456000	540000	369000	585000	328000	400000	320000	488000
	Fuel Cost	Rs./month	1360100	1404000	978200	1014000	991600	1033500	891100	928000	931300	968500

O – Objectivated Value; A – Actual Value

Table 6 Weight factors of the KPA are of the subsystems - objectivated values and actual values.

Sub-systems		KPA' Ratio	Sachdeva Steels W_F	O_W	A_W	Triveni Steels W_F	O_W	A_W	Vinubhai Steels W_F	O_W	A_W	JRsteels W_F	O_W	A_W	Laxmi Steels W_F	O_W	A_W
ENERGY	Electric Energy Consumption	Useful Energy Consumption /Total Electric Units consumed	0.15	0.9827	0.9836	0.16	0.9841	0.9839	0.17	0.9842	0.9842	0.17	0.9874	0.9869	0.17	0.9822	0.9777
	Coal Consumption	Coal Used/Total Coal	0.17	0.9852	0.9722	0.16	0.9863	0.9679	0.17	0.9865	0.9623	0.17	0.9774	0.9563	0.15	0.9928	0.9664
	Useful Heat Energy	Heat Energy Used/Total Heat Generated	0.19	0.5000	0.4000	0.18	0.5500	0.4000	0.17	0.5000	0.4000	0.17	0.5500	0.4000	0.17	0.5000	0.4000
	Water Utilization	Used Water /Total Water	0.10	0.8000	1.0000	0.10	0.8333	1.0000	0.08	1.0000	1.0000	0.08	1.0000	1.0000	0.08	1.0000	1.0000
COST	Material Yield Cost	Useful Conversion Of Material/Cost Of Raw Material	0.16	0.9850	0.9753	0.16	0.9700	0.9400	0.17	0.9700	0.9400	0.15	0.9700	0.9400	0.15	0.9663	0.9325
	Inventory Turnover COST	Inventory Cost/Cost Of Raw Material	0.12	0.0297	0.0306	0.14	0.0318	0.0333	0.13	0.0483	0.0544	0.13	0.0400	0.0500	0.13	0.0467	0.0529
	Maintenance Cost	Maintenance Cost Of Raw Material	0.12	0.0156	0.0194	0.14	0.0182	0.0208	0.13	0.0200	0.0221	0.13	0.0200	0.0221	0.13	0.0217	0.0235
	Labour Cost	Labour Cost/Cost Of Raw Material	0.12	0.0120	0.0111	0.09	0.0115	0.0125	0.11	0.0137	0.0191	0.11	0.0137	0.0147	0.13	0.0133	0.0179
	Fuel Cost Index	Fuel Cost/ Cost Of Raw Material	0.19	0.0236	0.0217	0.18	0.0247	0.0235	0.17	0.0367	0.0338	0.17	0.0371	0.0341	0.15	0.0388	0.0356

W_F – Weigth Factors; O_W – Objectivated Values Weight factors; A_W – Actual Values Weight factors

V. CONCLUSION

The performance index of the systems so obtained by PO-P [Performance Objective – Productivity] model aided to identify the weak areas, KPA's and subsystems to improve the productivity of the system.

PO-P model not only identified the KPA's with low performance but also helped in appreciating the significance of their inclusion in an exercise of productivity measurement.

Steel Re-rolling mill is an energy demanding industry which can also be seen from the PI of the Sub-systems. The performance indexes of the energy subsystem are nearly 60% while that of the cost are nearly 70%-75%. Thus this result reveals that energy sub-system is the weak performer in the re-rolling mills.

The overall productivity index of the steel rolling mill is raging from 63 % to 66%.

In an energysub-system, the maximum weight is given to useful heat energy for the production system, coal consumption, electric energy consumption and then water utilization. So to increase productivity, energy saving is the point of attention. By saving energy in the process the productivity index can be stretched nearer to desirable level.

There is substantial scope for energy efficiency enhancements both in thermal and electrical regions.

1. Energy efficient reheating furnace

Reheating furnace accounts for 80% of energy usage in steel re-rolling mills. There is huge potential to improve the existing design in terms of fuel feeding, firing, monitoring and control of various furnace parameters.

2. Waste heat recovery system:

Local manufactured sub-standard non-efficient recuperator was used. Efficient waste heat recovery system can be designed to extract maximum possible waste heat available in flue gases.

As a thumb rule, about 20°C rise in preheat air temperature would result in 1% fuel saving.

3. Improved insulation and refractories of reheating furnace.

The efficiency of a furnace is directly dependent on the method of combustion and heat stored within the furnace structure. Heat loss from the furnace wall and discharge doors is about 3-5% which is significant. The potential energy savings for insulating a continuous furnace were estimated to range from 2-5%. Replacement of worn-out insulation and sheathing the furnace with a better insulation material such as ceramic fiber blankets would help in reducing surface heat losses in the furnace.

4. Energy efficiency drives for rolling mills

Motor systems, which include motor driven units, such as rolling mills, combustion air blowers, sharing machine, and material handling equipment consume a substantial amount of energy used in steel rolling mills. About 70% of the energy input to motor-driven systems is lost due to system inefficiencies. The use of energy-efficient motors in milling can improve efficiency up to 5%–6%.

5. Use of CNG as fuel in reheating furnaces

All steel rolling facilities in the cluster use coal as main fuel in reheating furnaces. The fuel handling system includes electrical operated coal pulverizer. The performance of the coal-fired reheating furnace is always dependent on high accuracy control and monitoring system.

The use of CNG as fuel in reheating furnaces will not only improve the efficiency levels but also help to maintain specific energy consumption.

APPENDIX – I

POLICY NORMS

➢ **Policy Norms at Sachdeva Steels.**
  • Turnover growth rate of 10% per year.
  • Electricity consumption should reduce by 10%
  • Always use the best quality of coal available in market.
  • Fuel waste should be as low as possible
  • Loss of water should not be greater than 10%.
  • Loss of heat energy should not be less than 40%.
  • Inventory should not be greater than 40%.
  • Maintenance cost should not exceed 700/ton.
  • Material loss should not exceed 3% of total raw material.
  • Labour cost should not exceed 400/ton.
  • Working days 06/week and Friday holiday.
  • 08 hours /day working time 10:00pm to 06:00 am.

➢ **Policy Norms at Triveni Steels.**
  • Turnover growth rate of 7% per year.
  • Electricity consumption should reduce by 7%
  • Always use the best quality of coal available in market.
  • Fuel waste should be as low as possible
  • Loss of water should not be greater than 10%.
  • Loss of heat energy should not be less than 40%.
  • Inventory should not be greater than 40%.
  • Maintenance cost should not exceed 750/ton.
  • Material loss should not exceed 6% of total raw material.
  • Labour cost should not exceed 450/ton.

➢ **Policy Norms at JR Steels.**
  • Turnover growth rate of 7% per year.
  • Electricity consumption should reduce by 7%
  • Always use the best quality of coal available in market.
  • Fuel waste should be as low as possible
  • Loss of water should not be greater than 10%.
  • Loss of heat energy should not be less than 40%.
  • Inventory should not be greater than 40%.
  • Maintenance cost should not exceed 750/ton.
  • Material loss should not exceed 6% of total raw material.
  • Labour cost should not exceed 450/ton.

➢ **Policy Norms at Vinubhai Steels.**
  • Turnover growth rate of 7% per year.
  • Electricity consumption should reduce by 7%
  • Always use the best quality of coal available in market.
  • Fuel waste should be as low as possible
  • Loss of water should not be greater than 10%.

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- Loss of heat energy should not be less than 40%.
- Inventory should not be greater than 40%.
- Maintenance cost should not exceed 750/ton.
- Material loss should not exceed 6% of total raw material.
- Labour cost should not exceed 450/ton.
- ➢ **Policy Norms at Laxmi Steels.**
  - Turnover growth rate of 7% per year.
  - Electricity consumption should reduce by 10%.
  - Always use the best quality of coal available in market.
  - Fuel waste should be as low as possible

- Loss of water should not be greater than 09%.
- Loss of heat energy should not be less than 40%.
- Inventory should not be greater than 40%.
- Maintenance cost should not exceed 650/ton.
- Material loss should not exceed 7% of total raw material.
- Labour cost should not exceed 400/ton.

APPENDIX – II

Table 1 Productivity Index of the subsystem Energy and Cost

Industry	Subsystems			
	Energy	PI	Cost	PI
Sachdeva Steels	(0.15 x 0.9827 x 0.9836) + (0.17 x 0.9852 x 0.9722) + (0.19 x 0.50 x 0.40) + (0.10 x 0.80 x 1)	0.5906	(0.16 x 0.9850 x 0.9753) + (0.12 x 0.0297 x 0.0306) + (0.12 x 0.0156x 0.0194) + (0.12 x 0.0120 x 0.0111) + (0.19 x 0.0236 x 0.0217)	0.7037
Triveni Steels	(0.16 x 0.9841 x 0.9839) + (0.16 x 0.9863 x 0.9679) + (0.18 x 0.5 x 0.4) + (0.10 x 0.8333 x 1.00)	0.5679	(0.16 x 0.97 x 0.94) + (0.14 x 0.0318 x 0.0333) + (0.14 x 0.0182 x 0.0208) + (0.09 x 0.0115 x 0.0125) + (0.18 x 0.0247 x 0.0235)	0.7247
Vinubhai Steels	(0.17 x 0.9874 x 0.9869) + (0.17 x 0.9774 x 0.9563) + (0.17 x 0.55 x 0.40)+ (0.08 x 1.00 x 1.00)	0.5342	(0.15 x 0.97 x 0.94) + (0.13 x 0.04 x 0.05) + (0.13 x 0.02 x 0.0221) + (0.11 x 0.0137 x 0.0147)+ (0.17 x 0.0371 x 0.0341)	0.7311
JRSteels	(0.17x 0.9842 x 0.9842) + (0.17 x 0.9865 x 0.9623) + (0.17 x 0.50 x 0.40) + (0.08 x 1.00 x 1.00)	0.5459	(0.17 x 0.97 x 0.94) + (0.13 x 0.0483 x 0.0544) + (0.13 x 0.02 x 0.0221) + (0.11 x 0.137 x 0.0191) + (0.17 x 0.0367 x 0.0338)	0.7712
Laxmi Steels	(0.17 x 0.9822 x 0.9777) + (0.15 x 0.9928 x 0.9664) + (0.17 x 0.50 x 0.40) + (0.08 x 1.00 x 1.00)	0.5374	(0.15 x 0.9663 x 0.9325) + (0.13 x 0.0467 x 0.0529) + (0.13 x 0.0217 x 0.0235) + (0.13 x x0.0133 x 0.0179) + (0.15 x 0.0388 0.0356)	0.7516

Table 2 Productivity Index of the System

Industry	System				
	Energy		Cost		Overall Performance Index
	PI	Weightage	PI	Weightage	
Sachdeva Steels	0.5906	0.44	0.7037	0.56	(0.5906 x 0.44) + (0.7037 x 0.56) **0.6542**
Triveni Steels	0.5679	0.47	0.7247	0.53	(0.5679 x 0.47) + (0.7247 x 0.53) + **0.6509**
Vinubhai Steels	0.5342	0.47	0.7311	0.53	(0.5342 x 0.47) + (0.7311 x 0.53) **0.645**
JRSteels	0.5459	0.44	0.7712	0.53	(0.5459 x 0.44) + (0.7712 x 0.53) **0.6652**
Laxmi Steels	0.5374	0.56	0.7516	0.44	(0.5374 x 0.56) + **0.6311**
					(0.7516 x 0.44)

ACKNOWLEDGEMENT

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