Integration of Reverse Logistics Network into an in-Plant Recycling Process: A Case Study of Steel Industry

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Abstract

A case study of a Bangladeshi steel industry is reported that is dealing with some aspects of reverse logistics operation in their organization for instance Bangladesh steel re-rolling mill (BSRM), Chittagong. In this paper, a transportation model is proposed to reduce the extent of internal steel scrap transportation based on real transport network. To validate these model linear optimization model (TORA) is used. This paper basically incorporates the characteristics of in-plant steel scrap transportation which means the most important factors are transported quantity, distance, variable cost and fixed cost. Five sources where scrap generated is found in the case study. In the proposed transportation model, Two collection sites are used, one collection site for two sources of scrap and the other sources is the direct transport of collected steel scrap from each individual to reprocessing units whereas the existing transport network shown two collection sites, one collected scrap source 1 and the other is used to collect scrap from the remaining sources. A methodology is also developed to accurately compute CO2 emission to evaluate the environmental performance depending on the transport distance and quantity. The developed method has shown that environmental performance of propose model is improved.

Index terms— reverse logistics, recycling, steel industry, environmental impact, TORA.

1 Introduction

he use of secondary resources, waste management and sustainable product policy has great impact in modern industrial societies to reduce environmental pollution, thus increasing of recycling activities and use of secondary resource decline mining and smelting industries. So it is necessary to focus these type of product in which 100 % recycling possible. In these cases we can consider the steel material which is totally recycled ??1]. In the production of steel 99.9% scrap melted is consumed in the new steel while producing negligible environmentally unwanted waste.

Thus Recycling of steel has becoming more Important to maximize the resource efficiency and reduce the environmental pollution. Iron, which includes its refined product steel, is most widely used of all metals. Consumption of iron and steel scrap and the health of the scrap industry depend directly the health of the steelmaking industry [2].

In this case study we incorporated reverse logistics in a steel industry. One of the most pragmatic issues in environmental economics and ever increasing steel scrap in steel recycling reverse logistics network is applied to maximize the efficiency of overall steel industry recycling process.

The reverse logistics process might be best understood as an "architectural innovation," because it changes the way that components of a process are linked together, while leaving the basic components design either untouched or incrementally altered ??Handerson and clark, 1990). We would expect established firms and highly institutionalized industries ??DiMaggio and Powell, 1983) to resist architectural innovation such as reverse logistics, while favoring ”component” innovation [3]. Bangladesh is the ninth most populous country and twelfth most densely populated countries in the world. In particular, the projected urban population growth rate from 2010 -2015 is 3%. With this population growth, there is an increasing problem of waste management particularly in the larger cities. Transport of steel materials is also energy intensive: fossil fuels are required for energy to transport materials at every stage of the product life cycle. This includes from mine-site to manufacturing facility to retail outlet to waste management facility. Every ton of recycled steel saves 1131kg of iron ore, 633kg of coal and 54 kg of limestone2 **??**4]. Among the support activities of any waste management actions, the optimal transport and logistics processes are essential in order to assure time and cost-effective recycling scheme. Transportation costs represent very important part of overall recycling costs balance. There are three ways to put the economic importance of transportation costs in perspective: by examining 1) transportation costs relative to the value of the goods being moved; 2) transportation costs relative to other known barriers to trade, like tariffs; and 3) the extent to which transportation costs alter relative prices [5]. Transport costs depend both on the infrastructure (road, rail, airports, or ports) and on the vehicle used (truck versus car, for road transport for instance). Energy represents the first source of costs leading to variations across transport odes. Other operating costs, as those related to the wages of vehicle operators/crew or to the vehicle maintenance, share the same feature [6].

The methodology we developed linear model for two different transportation models which is based on the real transport network and encompasses other distance and transport technology of the transport industry. We apply this methodology to France and road transport by truck, the most common mode for commodities in this country.

In the 1950s and 1960s, demand for high quantity steel encouraged the steelmaking industry to produce large quantities. Large, integrated steel mills with high capital costs and limited flexibility were built in the U.S. . Integrated steel plants produce steel by refining iron ore in several steps and produce very high quality steel with well controlled chemical compositions to meet all product quality requirements. The energy crisis of the 1970s made thermal efficiency in steel mills a priority [7]. The furnaces used in integrated plants were very efficient; however, the common production practices needed to be improved. The large integrated plants of the 1950s and 1960s tend to produce steel in batches where iron ore was taken from start to finish. This causes some equipment to be idle while other equipment was in use and a lot of heat losses. To help reduce energy used up during the idle time, continuous casting me thuds were developed. By keeping blast furnaces continually feed with iron ore, in this way heat is used more efficiently.

During the 20 th century, the consumption of steel increased at an average annual rate of 3.3%. In 1900, the United States was producing 37% of the world’s steel. With post war industrial development in Asia that region now (at the start of the 21st century) accounts for almost 40%, with Europe (including the former Soviet Union) producing 36% and North America 14.5%. Steel consumption increases when economies are growing, as governments invest in infrastructure and transport, and as new factories and houses are built. Economic recession meets with a dip in steel production as such investments falter. After being in the focus in the developed world for more than a century, attention has now shifted to the developing regions. In the West, steel is referred to as a sunset industry. In the developing countries, the sun is still rising, for most it is only a dawn. Towards the end of the last century, growth of steel production was in the developing countries such as China, Brazil and India, as well as newly developed South Korea. Steel production and consumption grew steadily in China in the initial years but later it picked up momentum and the closing years of the century saw it racing ahead of the rest of the world. China produced 220.1 million tons in 2003, 272.2 million tons in 2004 and 349.36 million tons in 2005. That is much above the production in 2005 of Japan at 112.47 million tons, the USA at 93.90 million tons million tons [8]. Recycling of steel has been a common practice in human history, with recorded advocates as far back as Plato in 400BC. During that period when resources were scare, archaeological studies of ancient waste dumps shows less household waste such as ash, broken tools and pottery. This implies that more waste was being recycled in the absence of new materials. In the pre-industrial times, there is evidence of scrap bronze and other metals being collected in Europe and melted down for perpetual reuse [9]. In Britain, dust ash from wood and coal fires was collected by dustmen and down cycled as a base material used in brick making .The driver for this type of recycling was the economic advantage of obtaining recycled feedstock instead of acquiring virgin material as well as lack of public waste removal in ever more dense populated areas. The use of recycling in the manufacturing process of metals has been a main driver of improvements in energy efficiency within the industry. Primary production, in which steel is made from iron ore and aluminum from bauxite ore, is energy intensive. However, secondary production, which involves the use of recycling scrap to make steel and aluminum, is much more energy efficient. The Environmental Protection Agency estimates that secondary steel production uses about 74% less energy than the production of steel from iron ore, while the US Department of Energy reports that secondary aluminum production requires 90% less energy than primary production. Secondary production accounts for nearly 60% of US aluminum production (counting both old and new scrap), while primary production accounts for almost 40%. Similarly, recycling is used in most steel production. According to the US Geological Survey (USGS), 40% of US steel production in 2011 came from basic oxygen furnaces (BOF), whose inputs are almost 80% pig iron (molten iron), whereas 60% of production came from electric arc furnaces (EAF), which use more than 90% scrap. Primary production of steel usually involves using a blast furnace to produce molten iron from iron ore, coal and coke, using fluxing agents such as limestone to remove impurities. The molten iron (pig iron) is then converted into steel by a BOF. Secondary production facilities typically use an electric arc furnace (EAF), with scrap providing the main input. In an EAF, scrap is melted using electric arcs, which can be supplemented with natural gas fueled combustion. The high energy use of a blast furnace is eliminated by secondary production, with the exception of small quantities of pig iron used as an input along with scrap. Another alternative to using a blast furnace to produce pig iron is using direct reduced iron (DRI), a process typically fueled by natural gas. Scrap continues to be the primary raw material used in EAFs, but DRI may become a larger component in the raw materials mix [10]. The process of steel manufacturing and internal flows are presented in fig. 1. From the fig it can be seen that the scraps which are generated into the production process are collected and then gathered in a cast house and from these cast house the scarps are transported to the reprocessing unit. The dotted line indicates the flow of internal scrap. Internal transportation represents the most complex situation of manufacturing process under the study. Consequently, reverse logistics model is also put on that particular problem. However, it is worth mentioning that such approach could also be applicable for transport optimization from any other production unit. From this production process it is possible to define five different sources where steel scrap generated. First when the raw material that means Billet is charged in the furnace. The second and third place where scrap is generated are crop crank shear and crop shear. The fourth and fifth sources of scrap are cut in multiple lengths of bars at dividing shear and Static cold cutting to-length services and shear.

In this case we formulate two different models depending on the five sources and also some other factors which influenced on the transportation model. The other factors are collection site, scrap quantity, transportation distances and reprocessing unit. Here we represented the collection site by the symbol I and the reprocessing site by the symbol j and for the transported quantity and transported distance respectively are Q and d.

The existing model fig. 2 used two collection site for accumulate the internal scrap. The first one is for collecting scrap from source one and the second is used for collecting scrap from other sources and for the proposed modelfig.5. we used only one collection site for collecting scrap From Source 1 and source 5. The number of reprocessing unit for two model are same which is Three. Where, m = k + r 1, n = m+ r 2 k = number of sources where scrap is generated r 1 = number of collection site r 2 = number of reprocessing units c ij = unit transport cost between source i and collection site j g ij = unit transport cost from source i or collection site j to reprocessing unit j x ij = quantity of scrap transported from source i or collection site j to reprocessing unit j.

2 b) The Constraints

From the transportation model we can see that as the assumption regarding the recycling capacities, the total sum of scrap quantities transported from source i and collection sites and to reprocessing units would be equal to the quantities of scrap generated in source i i.e.? ?? ???? = ?? ?? ?? ?? =??+1 ?? = 1, ? ? , ??**(2)**

Where Q i expressed the quantity of scrap generated at source i, for i = 1, . . . , k. and x ij is the quantity of scrap transported from source i or collection site j to reprocessing unit j and the quantities transported from collection site j to reprocessing unit would be equal to quantities transported to this same collection site. Thus, Where, g ij the unit transport cost from source i or collection site j to reprocessing unit j and x ij is the quantity of scrap transported from source i to collection site j or to reprocessing unit j.?

The optimal way of transport with minimum transport costs for the second transport model is obtained by the model-minimize ?? 2 = ? ? ?? ???? ?? ???? ?? ?? =??+1 ?? ??=1 + ? ? ð ??"ð ??" ???? ?? ???? ?? ?? =??+1 ?? ??=??+1 + ð ??"ð ??" 2 Subject to Constraints, ? ?? ???? = ?? ?? ?? ?? =??+1 ?? = 1, ? ? , ?? ? ?? ???? ? ?? ?? ?? ??=1 ?? = ?? + 1, ? ? ?? ? ?? ???? ? ? ?? ???? ?? ??=??+1 = 0 ?? = ?? + 1, ? ? . ?? ?? ??=1

By using those equations we get optimum transportation cost for in-plant recycling process in steel industry [3]. From equation (**??**), (**??**) and (**??**0) the model is written by- minimize ?? = ? ? ?? ???? ?? ???? 6 ?? =6 5 ??=1 + ? ? ð ??"ð ??" ???? ?? ????X ij ? 0, Q ij ? 0 g) TORA Implementation for Proposed Model

The Optimum solution of existing transportation model is solving by using TORA software which is given below- The development of a carbon reduction strategy it is necessary to analyze the main sources of CO_2 emissions and identify those activities upon which carbon mitigation measures should be targeted. For measuring transport emission, one may apply either a fuel-based or distance-based methodology to Calculate CO_2 emissions. In the fuel-based approach, fuel consumption is multiplied by the CO_2 emission factor for each fuel type. This emission factor is developed based on the fuel's heat content, the fraction of carbon in the fuel that is oxidized (generally approximately 99% but assumed to be 100% in this tool), and the carbon content coefficient. Since this approach uses previously aggregated fuel consumption data, it is considered "fuel-based." Fuel based approach can be used also when vehicle activity data and fuel economy factors are available that enables calculation of fuel consumption. The other is distance based. In this study we calculate the CO_2 emission Depending on the transportation distance and transported quantity.

ii. The Activity-based Method uses the following Formula

In the absence of energy data; it is possible to make a rough estimate of the carbon footprint of a transport operation by applying a simple formula: CO_2 emissions = Transport volume by transport mode x average transport distance by transport mode x average CO_2 -emission factor per ton-km by transport mode.

[Tones CO_2 emissions = tones x km x g CO_2 per ton-km / 10, 00,000].

3 iii. Emission Factor for Road Transport Mode

The average CO_2 -emission factor recommended by McKinnon for road transport operation is 62g CO_2 /tonne-km. This value is based on an average load factor of 80% of the maximum vehicle payload and 25% of empty running. It is assumed that the above condition is fulfilled by the steel industry. Depending on the availability of data and differences between individual supply chains, companies may disaggregate and differentiate this calculation by region, country, business unit and/or product group. The following table provides a calculation of "overall CO_2 emission for two models using the activity-based approach [11].

4 Result Analysis

In this case study to evaluate minimum annual transportation cost of in-plant recycling, the linear optimization model was applied. The optimum solution of optimization model was calculated by computer program TORA. Data used to validate the model are presented in table v and table vi. Depending on data we got optimal solution for both existing and proposed model respectively. For existing and proposed transportation model, it was seen that the optimal objective value is 3445816 and 2787760 respectively. From this result it was found that the optimal objective value objective value for model 2 would be minimally decreased by 19% than model 1. To optimize the system on both economic and environmental performance the tradeoff between cost and environmental objective must be established [12].Corporate environmental performance indicators are usually divided into three main categories: 1) environmental impact (toxicity, emissions, energy use, etc.); 2) regulatory compliance (non-compliance status, violation fees, number of audits, etc.); and 3) organizational processes (environmental accounting, audits, reporting, Environmental Management System, etc.) [13].

In this case we measured CO_2 emission to evaluate the environmental performance. The value of minimal transportation cost and minimal CO_2 emission depend on same variables that is transported quantity and transported distance. We calculated CO_2 emission for existing and proposed model and it was found that CO_2 emission for model 2 was minimally decreased 7% of existing model which is shown in Table ??.2. CO_2 Emission was calculated on the basis of data for used transportation obtained by BSRM (2014).

5 Conclusions & Recommendations a) Conclusions

In conclusion, recycling has many positive effects for both the environment and the livelihoods of people with little to no negative impacts. Steel is one of the world's most recycled products. In fact, it is 100 percent recyclable which means its life cycle is potentially continuous. Steel scrap is a necessary component in the production of new steel [14]. Steel recycling has also important benefits regarding reduced environmental impact. In our research we applied reverse logistics model in steel industry. To minimize internal steel scrap transportation cost in in-plant recycling process, we proposed a transportation model with respect to existing transportation model. We showed which aspects influence reverse logistics model for in-plant recycling. Efficient implementation of recycling networks requires appropriate logistical structures for managing the reverse flow of materials from users to producers. This study proposed a new method for assessing a selected reverse logistics network for steel recycling [15]. In this case our measure integrates the characteristics of in-plant steel scrap transportation which means that the most important factors are transported quantity, distance, variable cost and fixed cost. In this case study five sources are used where scrap are transported to collection site to reprocessing units. The result obtained in this study proves that the transportation cost can be substantially reduced by using linear optimization model.

In in-plant recycling of steel scrap, the important factors like variable transport costs which depend on quantity, distance and volume of steel scrap and other cost associated in this case study. It was also found out that transported quantities and distance vary from sources to reprocessing units of in-plant recycling process. The model, developed in the present study, can also apply other in-plant recycling process. In this study we also improved environmental impact in in-plant recycling of steel scrap. In a steel industry CO_2 and fuel emission is most common emission which effect environmentally inside and outside the industry respectively. For measuring transport emission, one may apply either a fuel-based or distance-based methodology to Calculate CO_2 emissions. In proposed transportation model CO_2 substantially reduced as compared with existing transportation model. Actually CO_2 emission depends on distance and transported quantity. In in-plant steel recycling, to reduce environmental hazard air pollution control (APC) can be used which is most effective in a steel industry.

6 b) Recommendations

Bangladesh Steel industry is emerging as one of the major industrial sectors of the country. It consists of small up to the largest scale of steel melting and rerolling factories across the country that mostly produce deformed bar rod of different grade (40, 60, 500), angel, channel and coil for the construction industry. Though the history of Steel Industry is not older one but it can make a glorious future. Many steel producing companies have gained reputation as a brand. Among them, BSRM, KSRM, Anwar Steel, AK steel, Rahim steel, Abul khayer Group is worth mentioning. Today the highest steel producing company is BSRM. They are doing business for 60 years. Their production is almost six and half lakh ton per year which meets 26% demand of the local market. Now grade 60 rods are being slowly replaced by g500 rods which a number of rolling mills in our country are now manufacturing. With g500, the real estate builders and developers can also save minimum 15% further quantity of steel than g60 but then they have to maintain good quality of concrete [15].

In these cases recycling will be among the most important activities of steel industry in the future. Each year, steel recycling saves the energy equivalent required to electrically power about one-fifth of the households in the United States (about 18 million homes) for 1 year [16]. So the utilization of in plant steel scrap will maximize the resource efficiency and save the energy. Steel recycling has also important benefits to reduce environmental impact. In the case study we analyzed the transportation route to minimize the transportation cost in plant recycling steel. From the case it was seen that the proposed model will be very efficient, if the billet manufacturing and rolling process is done on the same plant. It will reduce transportation cost significantly. It will also manage the internal scrap very effectively. The internal scrap that is generated during the production shall not be underestimated. Because the following case study (BSRM) was shown that the amount internal scrap generated per year is approximately 14500 ton that will have a great impact for an industry. A company can be benefited from the utilization of resources.

VII. [1]

Figure 1: 2

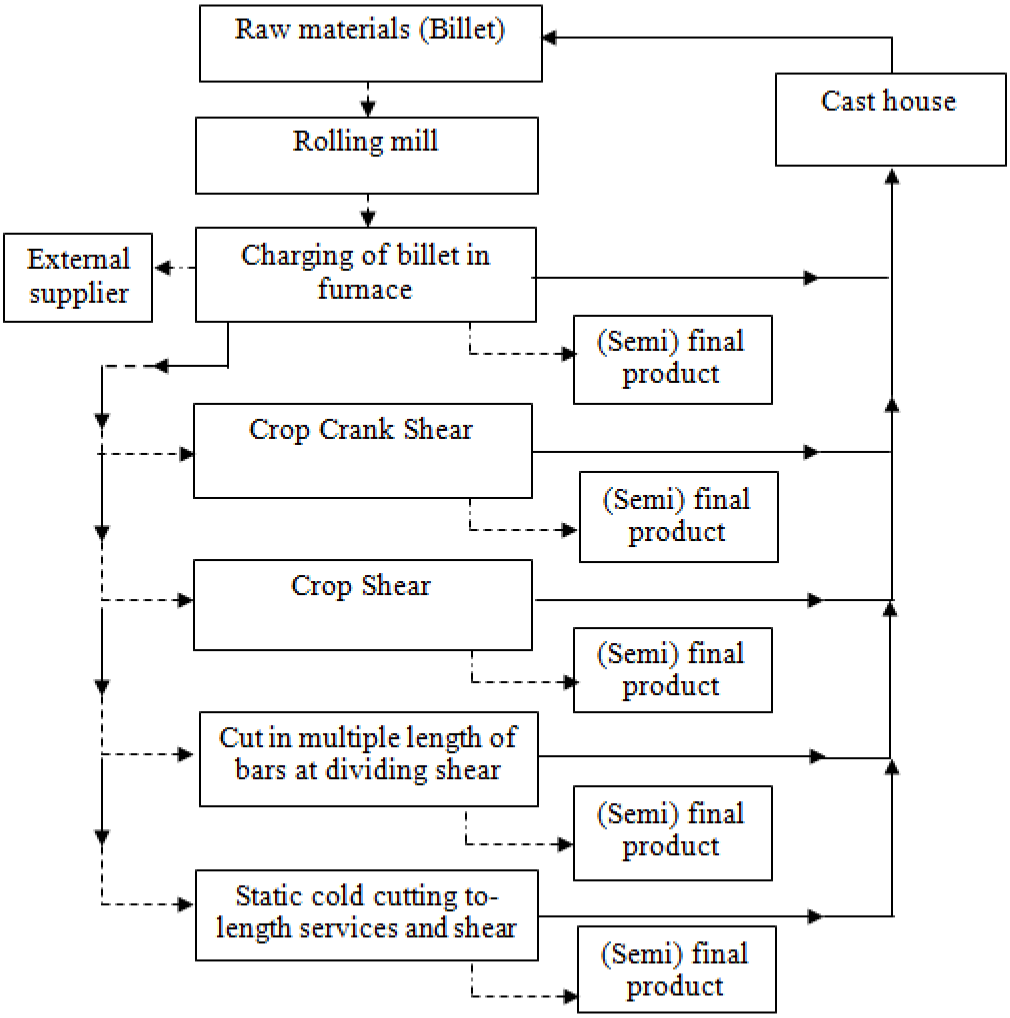

Raw materials (Billet)
Cast house
Rolling mill
External supplier
Charging of billet in furnace
(Semi) final product
Crop Crank Shear
(Semi) final product
Crop Shear
(Semi) final product
Cut in multiple length of bars at dividing shear
(Semi) final product
Static cold cutting to-length services and shear
(Semi) final product

Figure 2: ?

1

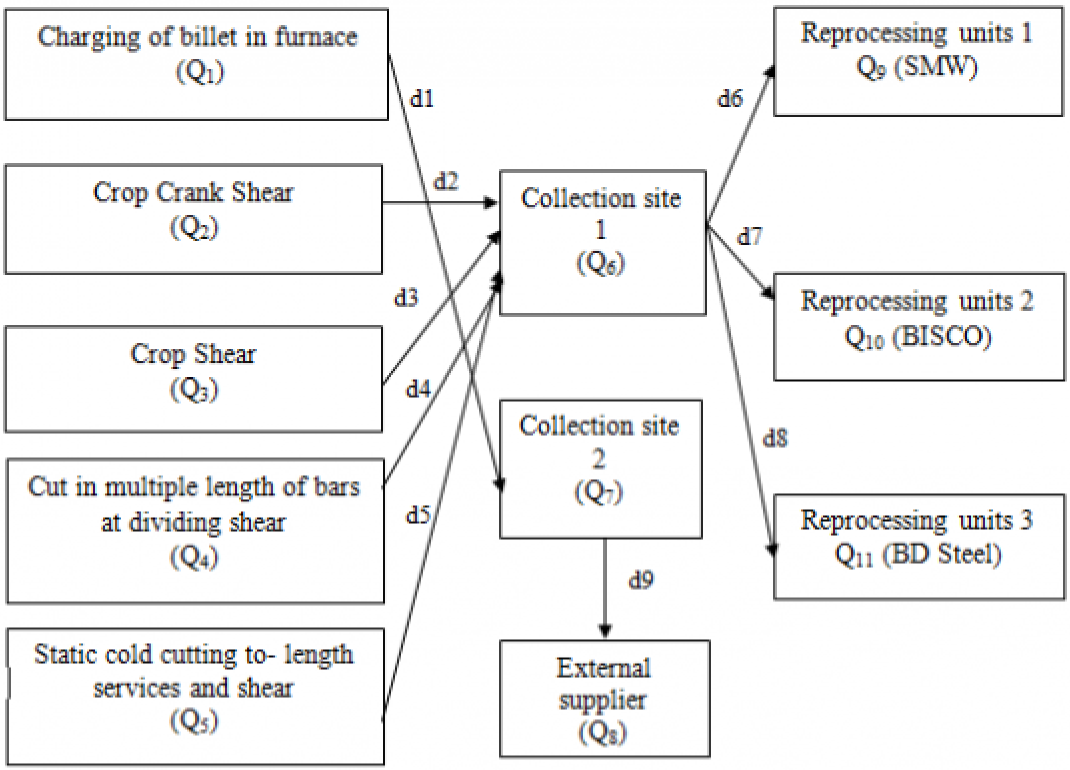


Figure 3: Fig. 1 :

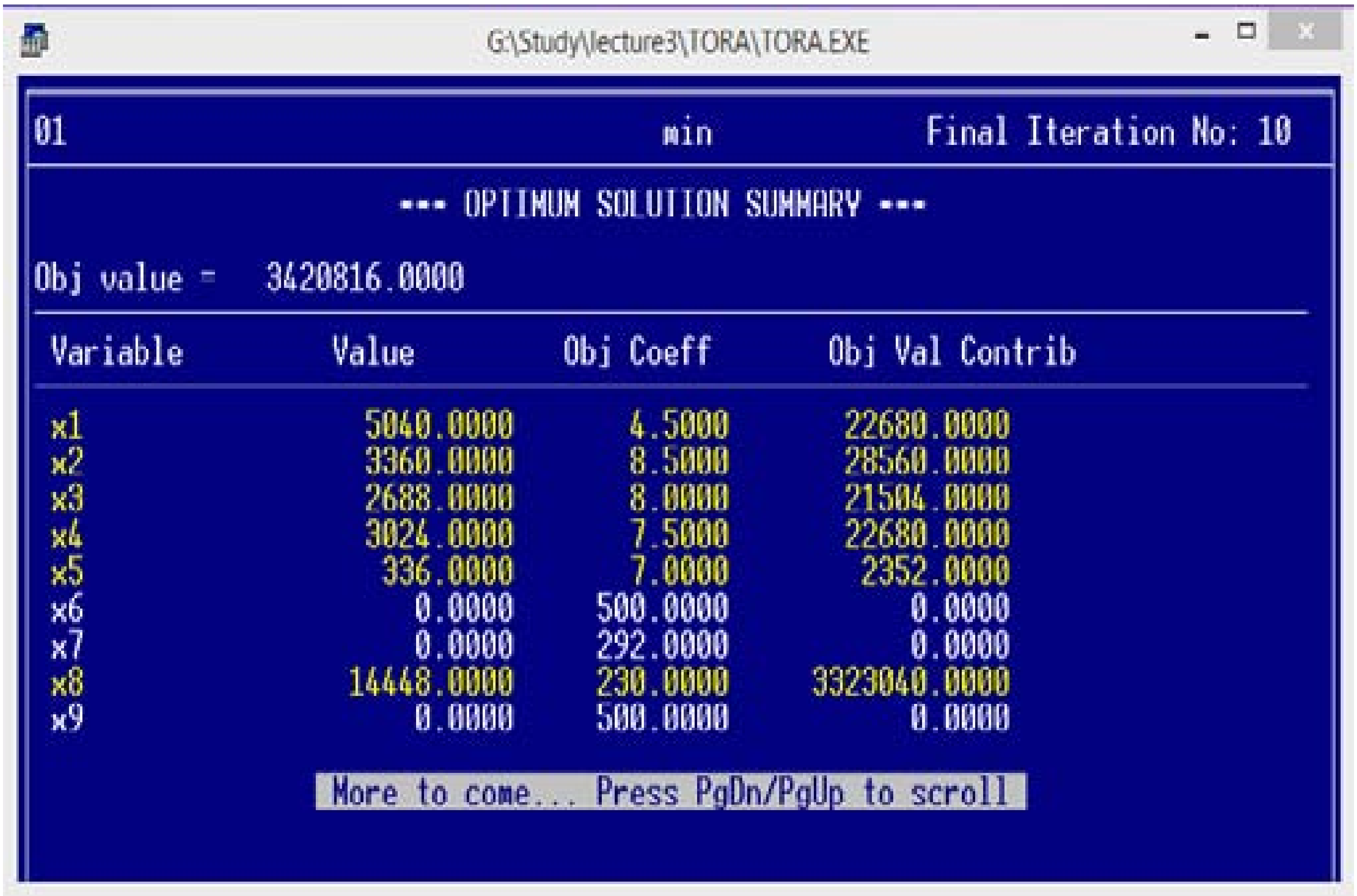

G:\Study\lecture3\TORA\TORA.EXE
01
min
Final Iteration No: 10
--- OPTIMUM SOLUTION SUMMARY ---
Obj value = 3420816.0000
Variable Value Obj Coeff Obj Val Contrib
x1 5040.0000 4.5000 22680.0000
x2 3360.0000 8.5000 28560.0000
x3 2688.0000 8.0000 21504.0000
x4 3024.0000 7.5000 22680.0000
x5 336.0000 7.0000 2352.0000
x6 0.0000 500.0000 0.0000
x7 0.0000 292.0000 0.0000
x8 14448.0000 230.0000 3323040.0000
x9 0.0000 500.0000 0.0000
More to come... Press PgDn/PgUp to scroll

Figure 4:

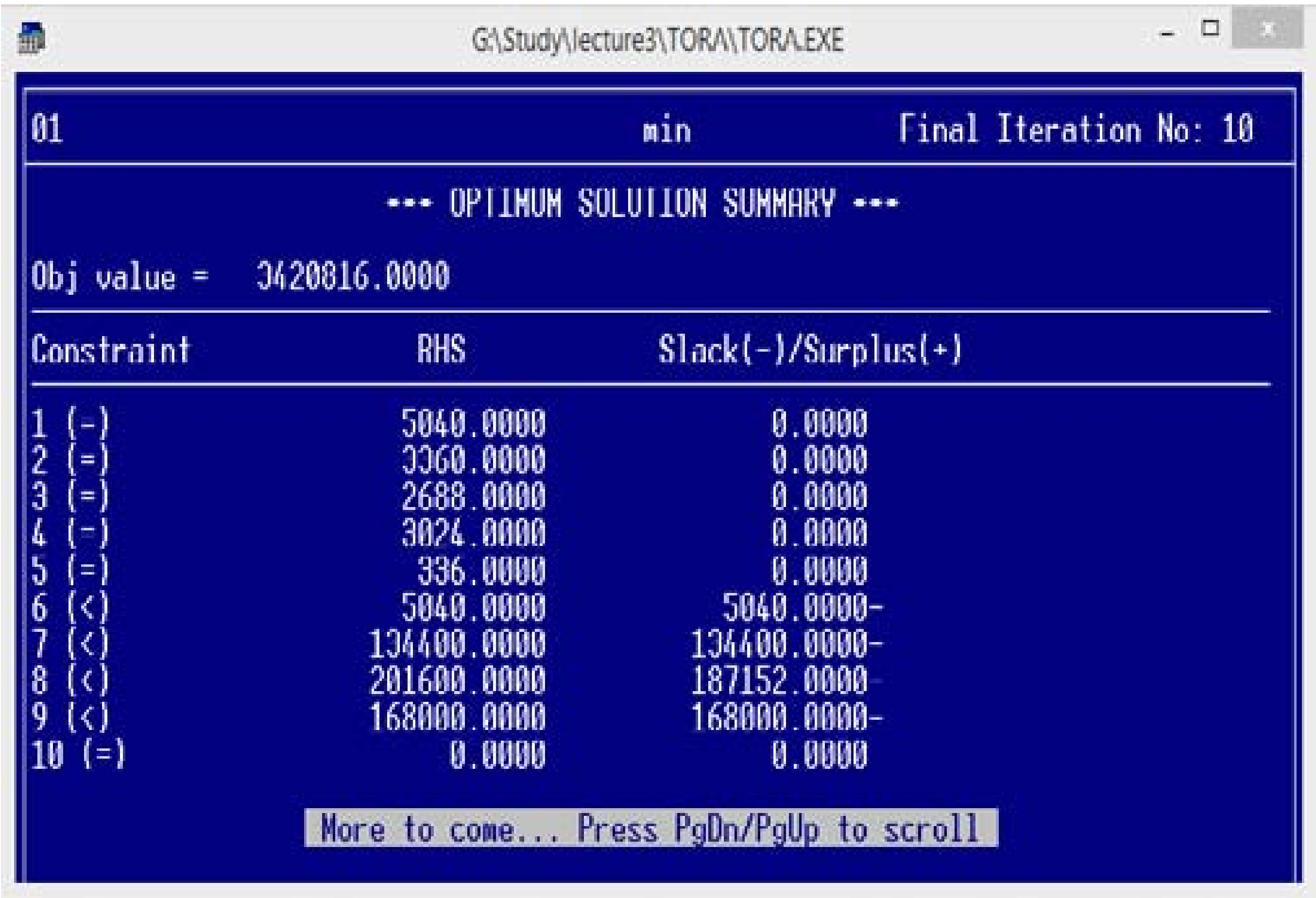
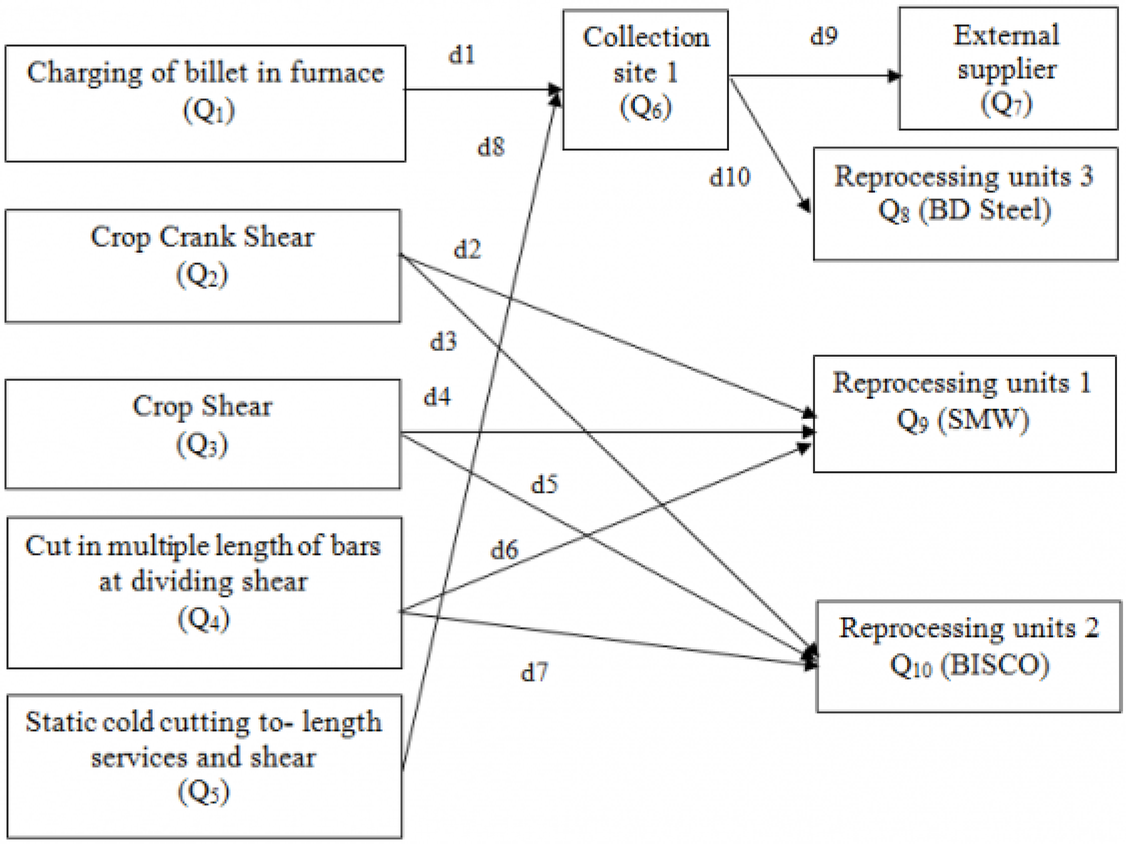

G:\Study\lecture3\TORA\TORA.EXE
01 min Final Iteration No: 10
*** OPTIMUM SOLUTION SUMMARY ***
Obj value = 3420816.0000
Constraint RHS Slack(-)/Surplus(+)
1 (-) 5040.0000 0.0000
2 (=) 3360.0000 0.0000
3 (=) 2688.0000 0.0000
4 (-) 3024.0000 0.0000
5 (=) 336.0000 0.0000
6 (<) 5040.0000 5040.0000-
7 (<) 134400.0000 134400.0000-
8 (<) 201600.0000 187152.0000-
9 (<) 168000.0000 168000.0000-
10 (=) 0.0000 0.0000
More to come... Press PgDn/PgUp to scroll

Figure 5:



2

Figure 6: Fig. 2 :

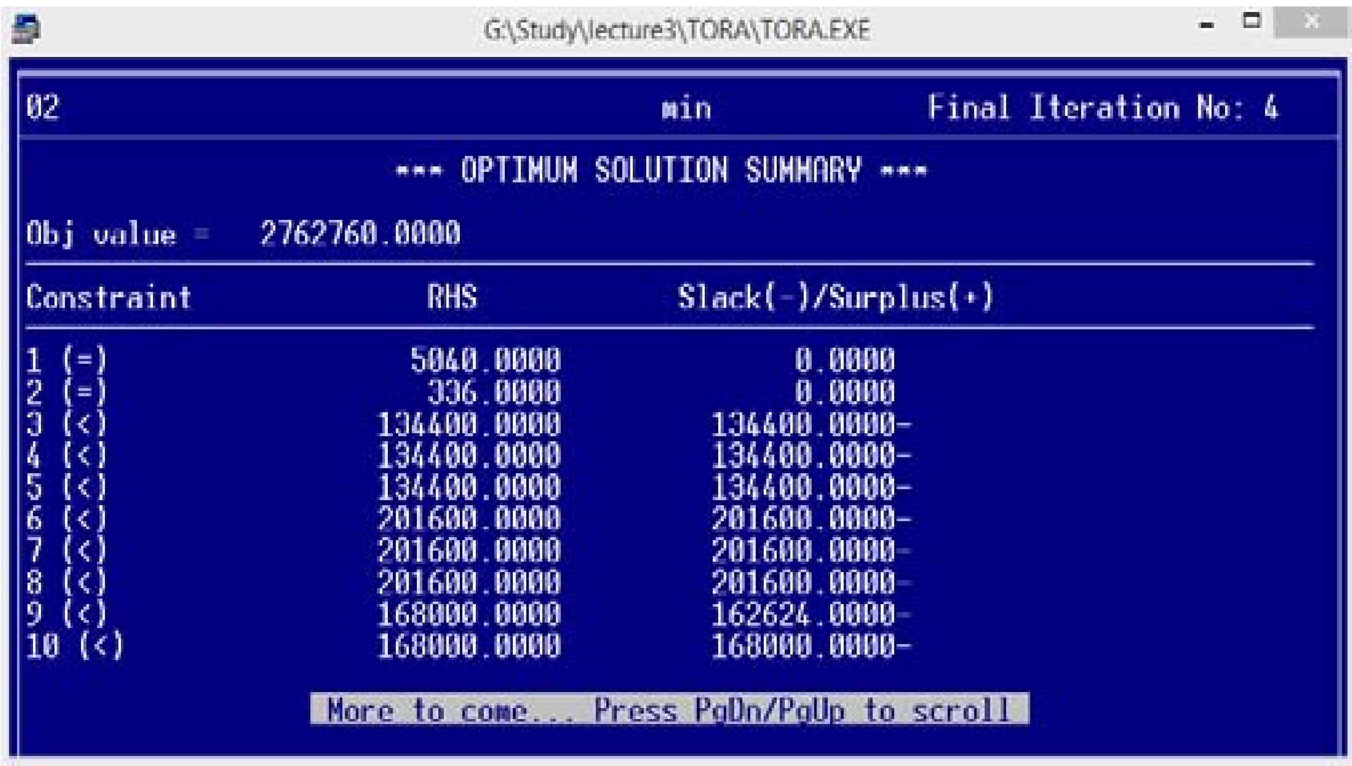
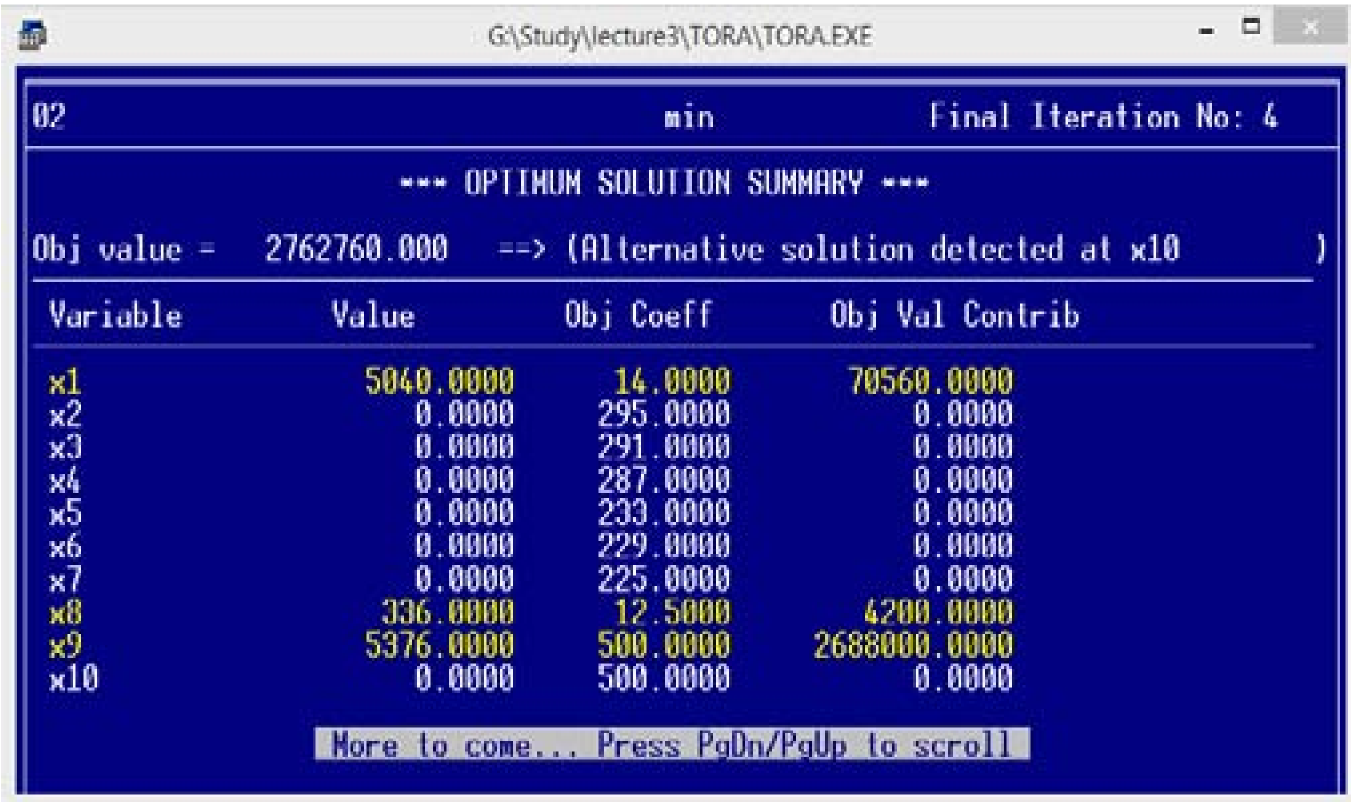


Figure 7:



3

Figure 8: Fig. 3 :

I

Sources of scrap Qi	Total scrap generated (ton/day)	Total scrap generated (ton/year)
Q 1	15	5040
Q 2	10	3360
Q 3	8	2688
Q 4	9	3024
Q 5	1	336

Table II : Capacity of Reprocessing Unit

Reprocessing unit Q j	Capacity (Ton/day)	Capacity (Ton/year)
Q 9	400	134400
Q 10	600	201600
Q 11	500	168000

[Note: Integration of Reverse Logistics Network into an in-Plant Recycling Process: A Case Study of Steel Industry © 2014 Global Journals Inc. (US) Global Journal of Researches in Engineering]

Figure 9: Table I :

III

Transportation distance	Transportation distance (km)	Transportation cost (C_{ij})
d_{ij}		C_{ij} (tk)
d_{17}	0.1	C_{17}
d_{26}	0.2	C_{26}
d_{36}	0.19	C_{36}
d_{46}	0.18	C_{46}
d_{56}	0.17	C_{56}
d_{78}	12	C_{78}
d_{69}	7	C_{69}
d_{610}	5.5	C_{610}
d_{611}	12	C_{611}

Let us assume that f_j are the annual fixed cost caused by the investment needed for the transportation model. The optimal transportation model is developed below-

From equation (1), (2), (3), (4) the model is written by,

5 7 8

minimize ?? = ? ? ?? ???? ?? ???? + ? ? ð ??"ð ??" ???? ?? ????

??=1 ?? =6 ??=6

Or, minimize $z = 4.5X_{17} + 8.5X_{26} + 8X_{36} + 7.5X_{46} + 7X_{56} + 500X_{78} + 292X_{69} + 230X_{610} + 500X$

Subject to Constraints,

$X_{17} = 5040$

$X_{26} = 3360$

$X_{36} = 2688$

$X_{46} = 3024$

$X_{56} = 336$ (v)

X_{78} ? 5040 (vi)

X_{69} ? 134400

X_{610} ? 201600

X_{611} ? 168000

$X_{17} + X_{26} + X_{36} + X_{46} + X_{56} - X_{78} - X_{69} - X_{610} - X_{611} = 0$

X_{ij} ? 0, Q_{ij} ? 0

This Model is written by,

Minimize $z = 4.5X_1 + 8.5X_2 + 8X_3 + 7.5X_4 + 7X_5 + 500X_6 + 292X_7 + 230X_8 + 500X_9 + 25000$.

For solving this model annual depreciation cost was evaluated BDT 25,000tk and the optimum solution of optimization model was calculated by computer program TORA.

e) TORA Implementation for Existing Model

The Optimum solution of existing transportation model is solving by using TORA software which is given below-

Figure 10: Table III :

7 10
+ ð ??"ð ??" 2
??=6 ?? =7
or, minimize z = 14 X 16 + 295X 29 + 291X 39 + 287X 49 + 233X 210 + 229X 310 +225X 410 + 12.5X 56 +500X 67 + 500X 68 + 25000.
Subject to Constraints,

X 16 = 5040 (i)
X 56 = 336 (ii)
X 29 ? 134400 (iii)
X 39 ? 134400 X 49 ?134400 (iv) (v)
X 210 ? 201600 (vi)
X 310 ?201600 (vii)
X 410 ? 201600 (viii)
X 67 ?168000 (ix)
X 68 ? 168000 (x)
X 16 + X 56 -X 67 -X 68 = 0 (xi)

Figure 11:

V

Route	Transport distance	Model Transport Volume	CO_2 emission (gm/ton)
1-7	0.1	5040	.03124
2-6	0.2	3360	.0416
3-6	0.19	2688	.03166
4-6	0.18	3024	.0337
5-6	0.17	336	.0035
6-9	12	5408	3.7
6-10	7	3000	1.736
6-11	5.5	1000	1.364
7-8	12	5040	1.07
			Total = 8.0517

Figure 12: Table V :

VI

Route	Transport distance	Model Transport Volume	CO_2 emission (gm/ton)
1-6	0.2	5040	.0624
2-9	7.05	1000	.4371
3-9	7	1200	.5208
4-9	6.9	1512	.6468
2-10	5.6	1360	.829
3-10	5.5	1488	.507
4-10	5.4	1512	.506
5-6	0.3	336	.00624
6-7	12	5040	3.74
6-8	12	336	.2499
			Total=7.49
	v.		

Figure 13: Table VI :

VII

for In-Plant Recycling Process

Transportation Model	Optimal Objective Value
Existing model (1)	3445816.00
Proposed model (2)	2787760.00

Figure 14: Table VII :

VIII

Process

Transportation model	CO_2 emission (gm/ton)
Existing model (1)	8.0517
Proposed model (2)	7.49
vi.	

Figure 15: Table VIII :

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