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DEVELOPMENT OF MATERIAL HANDLING AND PLANT LAYOUT CASE STUDIES

By

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PREFACE

This creative component involves the development of three material handling and plant layout case studies. Each case study is treated as a separate entity with its own table of contents and appendices. Along with development of a problem statement, each case presents a possible solution (in detail) and a brief discussion of other possible solutions.

The development of this creative component has been a very beneficial learning experience in my Master Degree Program. It has challenged my creativeness, as well as, my engineering and communication skills.

I wish to offer my appreciation to my advisor, Dr. Carl B. Estes, for his guidance throughout the project. His guidance and instructions increased the value of the learning experience. I would also like to thank my family and friends for their moral support.

INTRODUCTION

One of the major goals of a facility location and layout course is to introduce the basic layout and material handling concepts. In order to provide a chance to practice these concepts in a classroom situation, case studies are used. Unfortunately, there are only a few well developed case studies which exemplify actual plant layout or material handling problems. Therefore, this paper proposes a creative component (Project) for developing a set of case studies based upon problems dealing with material handling and plant layout.

PURPOSE

The purpose of this project will be to develop a set of three case studies. Each case study provides the opportunity to apply appropriate layout and material handling concepts, as well as, other related Industrial Engineering skills. For each case study, a detailed development of a possible solution will be included. Other possible solutions will be also briefly described including general concepts which should be recognized.

TYPES OF CASE STUDIES

The three case studies presented illustrate different industrial situations. These are

1. possible personnel facility inadequacies (Case 1),

2. improvement of the present material handling and development of a redesigned layout (Case 2) and

3. inadequacy of the present production area for both present and future production volume (Case 3).

CONTENT OF CASE STUDIES

The concept and purpose of each case study is introduced in the Notes to the Instructor. To insure the effectiveness of the learning experience, any pertinent information needed by the instructor is provided here.

The Statement of the Problem then presents the industrial situation under study. All relevant information (excluding Case 3) needed is provided.

Following the Statement of the Problem, a possible solution is presented in detail. Then, other possible solutions are briefly described.

The Statement of the Problem of each case study and the Collection of Data for Case 3 are provided in an unbounded form to facilitate copying. These are enclosed in separate envelopes for each case study.

CASE 1

PLANT WORKFORCE EXPANSION

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I. NOTES TO THE INSTRUCTOR

When an existing manufacturing plant's labor force significantly increases, the adequacy of the present personnel facilities become questionable. Therefore, the plant engineer must determine if any corrective action is necessary. In case of inadequacy, the engineer must make an economically feasible design change or expansion.

Case 1 illustrates the above situation. Furthermore, the case presents management's interest in installing a hot meal service. The only prerequisite required for this case is a basic understanding of personnel requirements planning.

II. PROBLEM STATEMENT

BACKGROUND INFORMATION

Printright Inc., a printing plant, presently is operating at less than full production capacity. An increase in the labor force is planned due to a forecasted sales increase.

In view of this, management is concerned with the following issues:

1. Will there be adequate restroom facilities?

2. Will the existing parking spaces accommodate the increase in employees?

Further, they would like to investigate the feasibility of providing an in-plant hot meal service. An employee committee has requested management to look into this possibility and have indicated that approximately 80 percent of all employees would utilize this service.

ASSIGNMENT

You are to consider the three issues above and make your recommendation for each. Your analysis will depend upon the data provided in the following section. Include cost estimates as appropriate and sketches to show any expansion or design improvements in the existing facilities.

RELEVANT DATA

The present and proposed employment levels are shown in Table 1. Figure 1 shows the present plant layout including restrooms and parking

TABLE 1. EMPLOYMENT LEVELS

Shift	Production Men	Production Women	Supervisors Men	Supervisors Women	Office Men	Office Women	Total
PRESENT							
Day	40	26	2	2	6	5	81
Night	45	21	3	1	-	-	70
Graveyard	45	18	2	1	-	-	66
PROPOSED							
Day	65	40	3	3	6	5	122
Night	57	48	4	2	-	-	111
Graveyard	55	23	4	1	-	-	83

area. As shown in this figure, office employees have separate restrooms from the plant employees. Table 2 provides information concerning the existing restroom facilities. Also, additional restrooms can be added adjacent to any of the present restrooms.

Parking accommodates 190 spaces with standard-sized 90 degree parking. Including the 10 spaces for visitors, additional spaces are provided to allow for overlap during working shift changes. About 40 percent of the workers drive compact cars while 10 percent of the workers (per shift) car pool with other workers. The main aisles must remain 28 feet wide for trucks going to and from shipping. Also, the present parking can be expanded south of the present parking area up to an additional 100 feet.

The lunchroom presently consists of five vending machines and eleven 6 ft. x 30 in. tables. Employees eat in two shifts, each lasting for 30 minutes. It has come to the attention of the management that

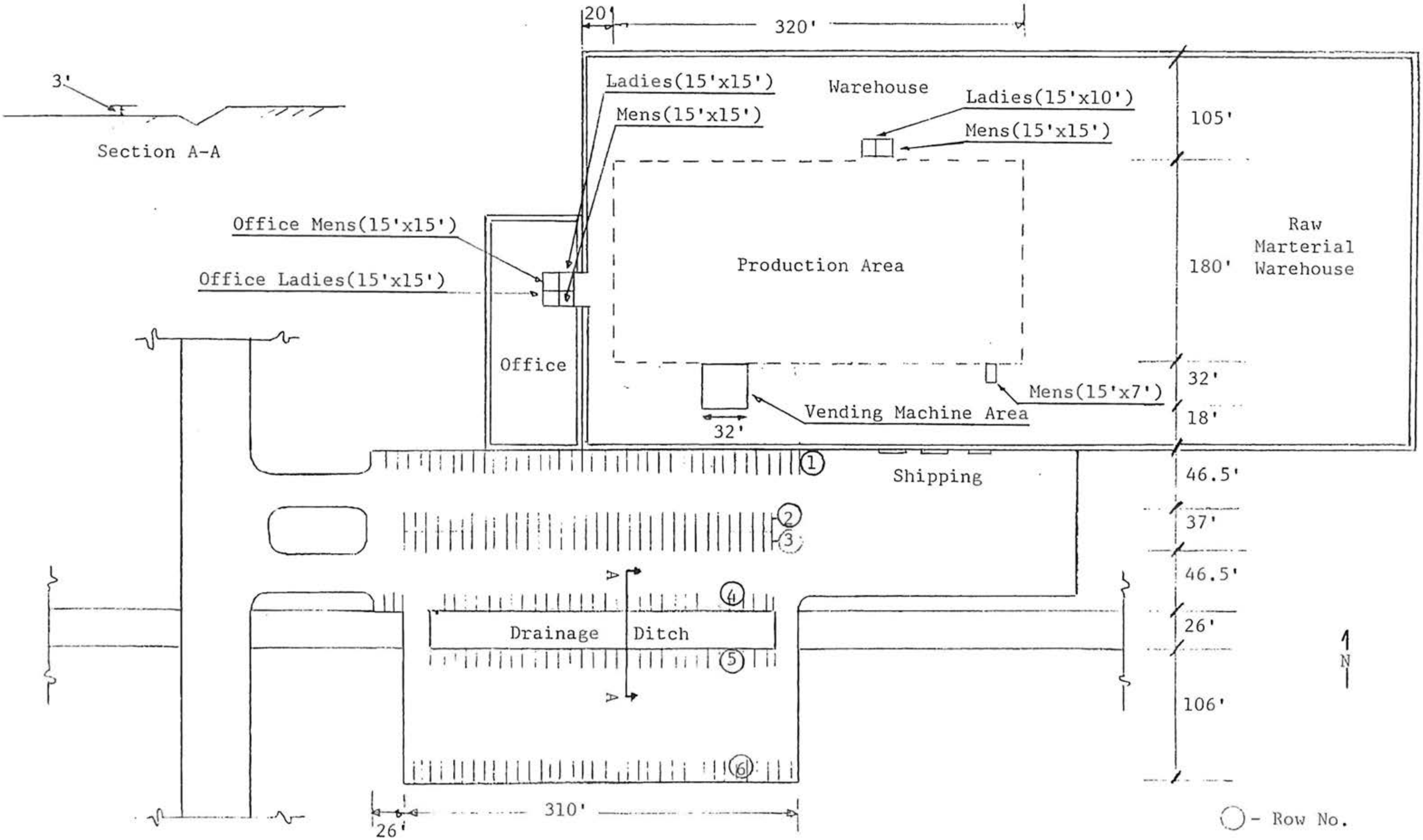


FIGURE 1: PLANT LAYOUT AND PARKING

TABLE 2. CURRENT RESTROOM FACILITIES

Type	No.	Size	No. of Toilets	No. of Urinals	No. of Lavatories
Mens	2	15' x 15'	4	3	3
Office Mens	1	15' x 15'	4	3	3
Mens	1	15' x 7'	2	2	2
Ladies*	1	15' x 15'	4	–	3
Ladies	1	15' x 10'	2	–	2
Office Ladies*	1	15' x 15'	4	–	3

*Includes a bed in each.

most employees would be in favor of a hot meal service for the day and night shifts. Two possible alternatives are being considered: (1) a full service cafeteria, or (2) a serving line (no cooking facilities on premise - food is brought in by a catering service). If additional space is needed, it is available south and east of the existing vending area.

COST ESTIMATES

Table 3 contains estimates of cost which should be used in your analysis.

TABLE 3. COST ESTIMATES

Type of Cost	Cost
Parking Lot:	
To increase	$10/sq. ft.
To paint lines	$0.50/ft.
Restrooms:	
Base cost for a two-toilet restroom	$3,000
Cost for each additional toilet and/or urinal	$ 500
Food Service:	
Full Service (Cafeteria)	
-initial investment	$100,000
-preparation cost	$2.00/meal
-life	10 years
-salvage	$0
Serving Line (food line)	
-initial investment	$10,000
-catering fee	$2.80/meal
-life	10 years
-salvage	$0
Other Economic Criteria Used by the Firm	
Mimimum Attractive Rate of Return (MARR)	15%

Note: Meal cost shown represent the cost to the company. Employees will pay only a nominal fee.

III. POSSIBLE SOLUTION

This section contains solutions addressing the three issues concerning Printright. Cost estimates are included where appropriate as are sketches to show any expansion or design improvements in the existing facilities.

PARKING

The present parking area in Figure 1 accomodates 190 automobiles (See Table 4). Since 81 employees is the maximum number of employees in the plant at one time (See Table 1), the number of parking spaces needed is

= [(maximum employees + visitor spaces) -
(% car pool with someone x maximum employees)]
(Adjustment for spaces needed during shift change)

= [(81 + 10) - (10% x 81)] (1.86)

= 154 spaces

By similar calculations, the total number of spaces needed for the proposed employment level is

= [(122 + 10) - (10% x 122)] (1.86)

= 224 spaces

Therefore, only an additional 20 (224 - 204) parking spaces are needed. It may be possible to acquire the additional spaces by redesigning the present parking layout. Thus, there are two possible alternatives:

TABLE 4. NUMBER OF PARKING SPACES FOR PRESENT PARKING

Row	Length of Row (feet)	Width of Space (feet)	Number of Spaces
1	336	8.5	39
2	284	8.5	33
3	284	8.5	33
4	288	8.5	33
5	262	8.5	30
6	310	8.5	36
			Total = 204

redesign the present parking area or expand the parking area. These two alternatives will be presented in the following sections.

Parking Redesign

Presently, the aisle between rows 5 and 6 is 69 feet wide. Therefore, the possibility may exist of adding extra rows between rows 5 and 6. Using the data in Table 5 (1), the width required to add two rows of 90° standard parking is

= Aisle + 2(90° standard parking depth) + Aisle

= 28 ft. + 2(18.5 ft.) + 28 ft.

= 93 ft.

Because the present aisle width (69 ft.) is less than 93 feet, the addition of two 90° parking rows is impossible.

TABLE 5. PARKING DIMENSIONS FOR A 7.5 ft. COMPACT AUTOMOBILE PARKING SPACE WIDTH AND A 8.5 ft. STANDARD SIZED AUTOMOBILE PARKING SPACE WIDTH

Angle (degrees)	Automobile	Parking Space Width Parallel to the Aisle (feet)	Parking Space Depth Perpendicular to the Aisle (feet)	Aisle Width (feet)	Cross Aisles, One Way (feet)	Cross Aisles, Two Way (feet)
45	Compact	10.5	17.0	11.0	12	22
45	Standard	12.0	17.5	13.0	14	24
60	Compact	8.7	17.7	14.0	12	22
60	Standard	9.8	19.0	18.0	14	24
75	Compact	7.8	17.3	17.4	12	22
75	Standard	8.8	19.5	25.0	14	24
90	Compact	7.5	16.0	20.0	12	22
90	Standard	8.5	18.5	28.0	14	24

However, two additional rows with 60° parking may be feasible. The aisle width required is

= 18 ft. + 2(19 ft.) + 18 ft.

= 74 ft.

This distance also exceeds the available width.

Since 40 percent of the employees drive foreign cars, two rows could be designed for compact cars only and the other two (in the upper parking area) can be maintained for standard parking. For this alternative, the aisle width required is

= 60° standard aisle + 60° standard parking

+ 60° compact parking + 60° compact aisle

= 18 ft. + 19 ft. + 17.7 ft. + 14 ft.

= 68.7 ft.

Therefore, this arrangement meets the criteria (69 ft.). This parking arrangement is shown in Figure 2.

The number of parking spaces in rows 5 and 7 will be

$$\frac{\text{Length of Row}}{\text{Parking Space Width}} = \frac{262 \text{ ft.}}{9.8 \text{ ft./space}} = 26 \text{ spaces}$$

Row 8 (60° compact spaces) can accommodate

$$\frac{262 \text{ ft.}}{8.7 \text{ ft./space}} = 30 \text{ spaces}$$

and row 6 (60° compact spaces) can accommodate

$$\frac{310 \text{ ft.}}{8.7 \text{ ft./space}} = 35 \text{ spaces}$$

From Table 4, the present number of parking spaces south of the drainage ditch is 66 (30 + 36) compared to 117 (2(26) + 30 + 35) for the proposed parking configuration. This is an increase of 51 (117 - 66) parking spaces. Therefore, the number of spaces needed can be satisfied by parking redesign.

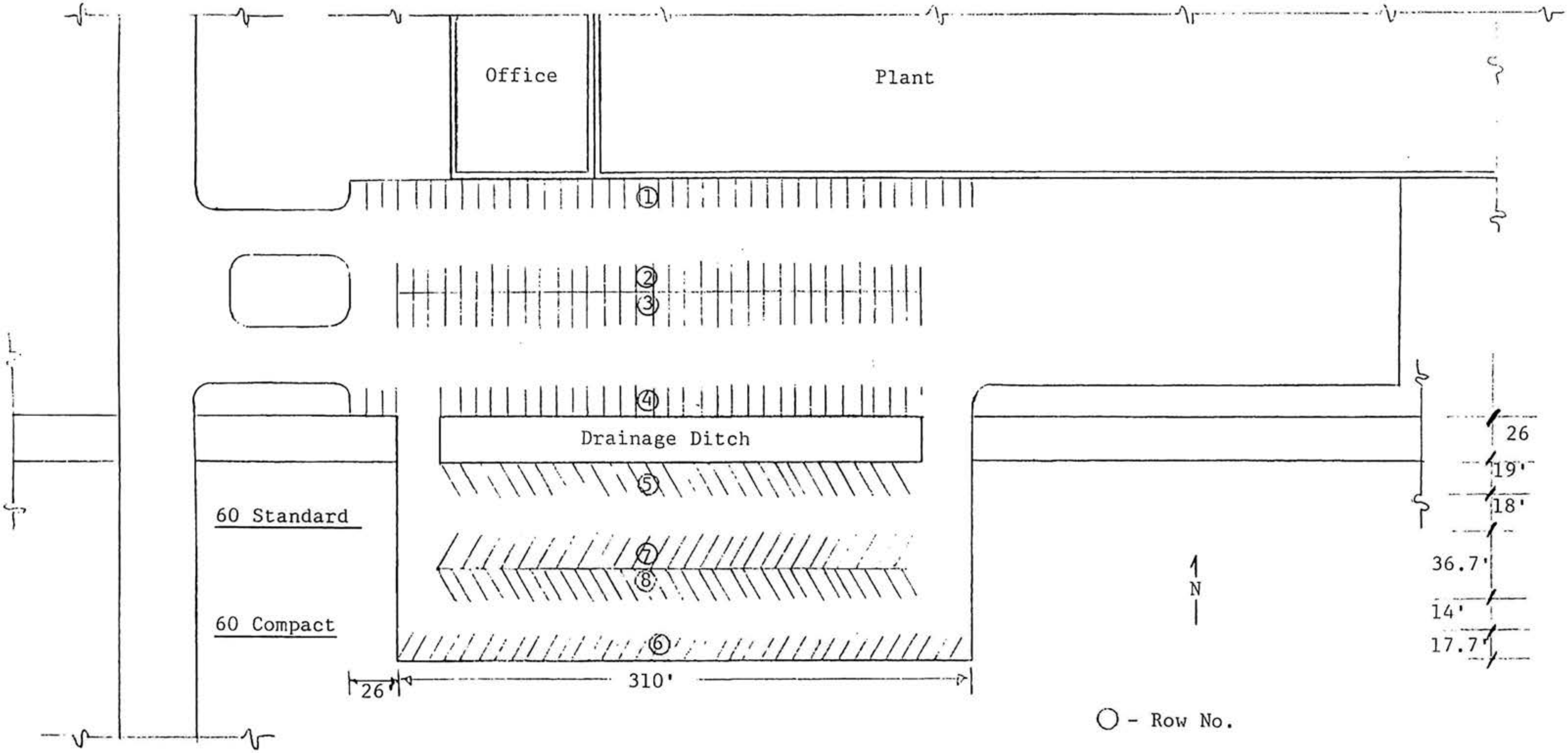


FIGURE 2: PROPOSED PARKING FOR REDESIGN ALTERNATIVE

Parking Expansion

Parking spaces can also be increased by parking area expansion. To add two 90° parking rows between rows 5 and 6, the parking area must be increased by 24 feet (69 ft. - 28 ft. - 18.5 ft. - 18.5 ft. - 28 ft.). The increase in parking spaces would be

$$\frac{262 \text{ ft.}}{8.5 \text{ ft./space}} + \frac{262 \text{ ft.}}{8.5 \text{ ft./space}} = 60 \text{ spaces}$$

which is more than required. Therefore, the proposed layout is shown in Figure 3.

Comparison

The cost for parking area redesign, paint new lines, is estimated at $1,368 (See Appendix A for calculations). The parking area expansion cost is $75,446 (See Appendix B). From economic veiwpoint, Printright should redesign the present parking area to acquire sufficient parking spaces. From a practical view, it might be difficult to enforce the use of the compact spaces by compact cars. Therefore, management would have to decide this issue.

RESTROOM FACILITIES

Two criteria must be satisfied for the present restroom facilities to be adequate. First, there must be a restroom located within 200 feet of every permanent work station(2). From Figure 1, this criteria is satisfied.

The second criteria requires the plant to have facilities avialable for the maximum number of employees present. Table 6 and 7 (2) show the number of toliets and lavatories for varying numbers of employees.

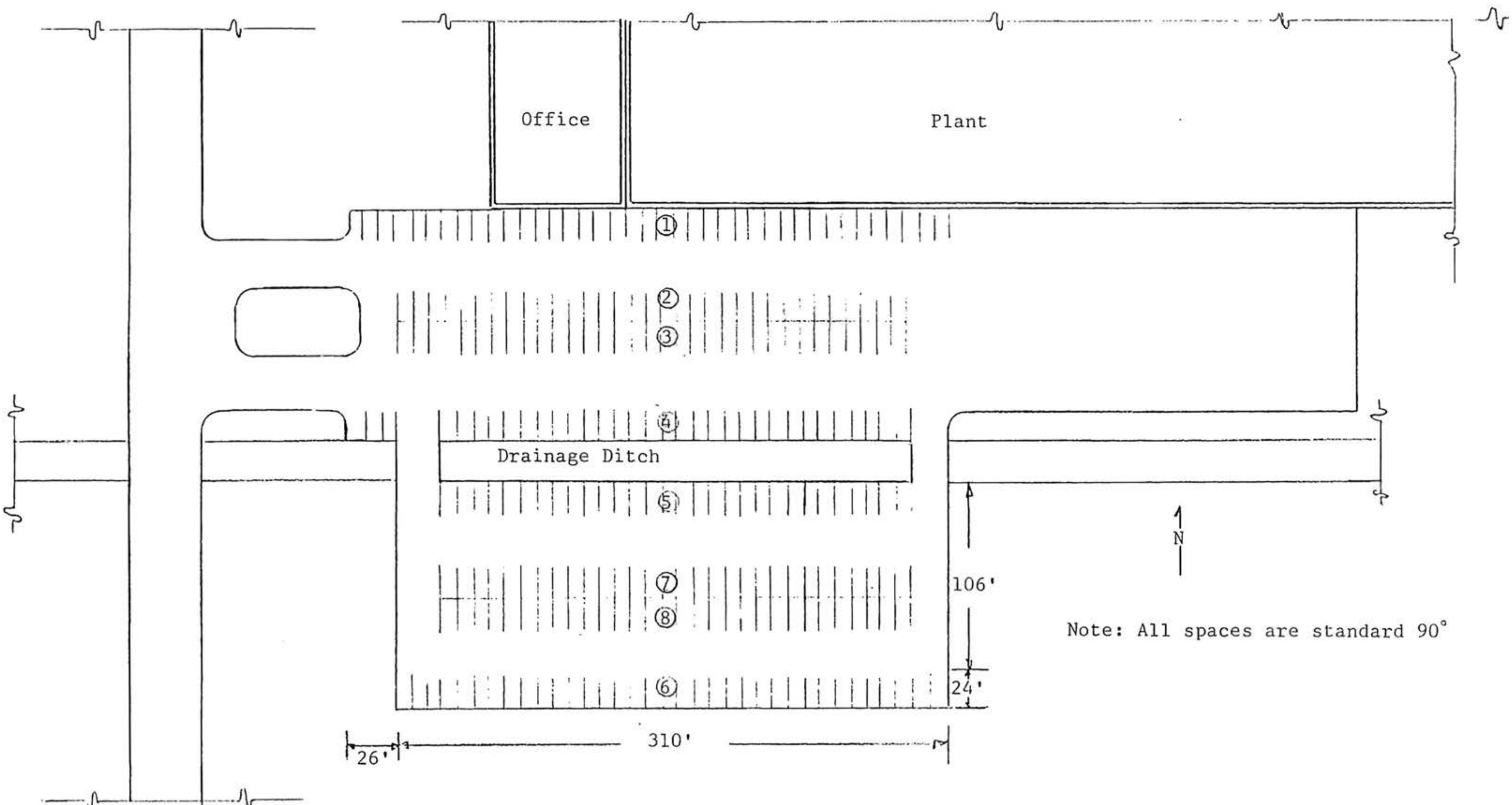


FIGURE 3: EXPANSION ALTERNATIVE PARKING

TABLE 6. NUMBER OF TOILETS NEEDED FOR NUMBER OF EMPLOYEES

Maximum Number of Employees Present at Any One Time	Minimum Number of Toilets Needed
1–15	1
16–35	2
36–55	3
56–80	4
81–110	5
111–150	6
Over 150	1 additional toilet for each additional 40 employees

TABLE 7. NUMBER OF LAVATORIES NEEDED FOR NUMBER OF EMPLOYEES

Type of Employment	Number of Employees	Minimum Number of Sinks
Nonindustrial	1–15	1
Office and public	16–35	2
facilities	36–60	3
	61–90	4
	91–125	5
	Over 125	1 sink for each additional 45 employees
Industrial	1–100	1 sink for each 10 employees
Manufacturing and	Over 100	1 sink for each additional 15
warehouse facilities		employees

TABLE 8. COMPARISON OF NEEDED AND AVAILABLE FACILITIES

Types of Restrooms	Maximum No. of Employees for Proposed Employment	No. of Toilets Needed	No. of Toilets Available	No. of Lavatories Needed	No. of Lavatories Available
Office Men	6	1	4	1	3
Office Ladies	5	1	4	1	3
Plant Men	68	4	10	7	8
Plant Ladies	50	3	6	5	5

Thus, Table 8 can be constructed for comparison of the number of toliets and lavatories available now to the requirements needed for the proposed employment levels. From this comparison, it is evident that sufficient facilities are present.

FOOD SERVICES

Breakeven Analysis

The two possible alternatives presently being considered for in-plant meal service are a full service cafeteria and a catered serving line. In order to compare the cost feasibility between the two alternatives, a breakeven analysis is performed in Appendix C. This analysis can be graphically presented as shown in Figure 4.

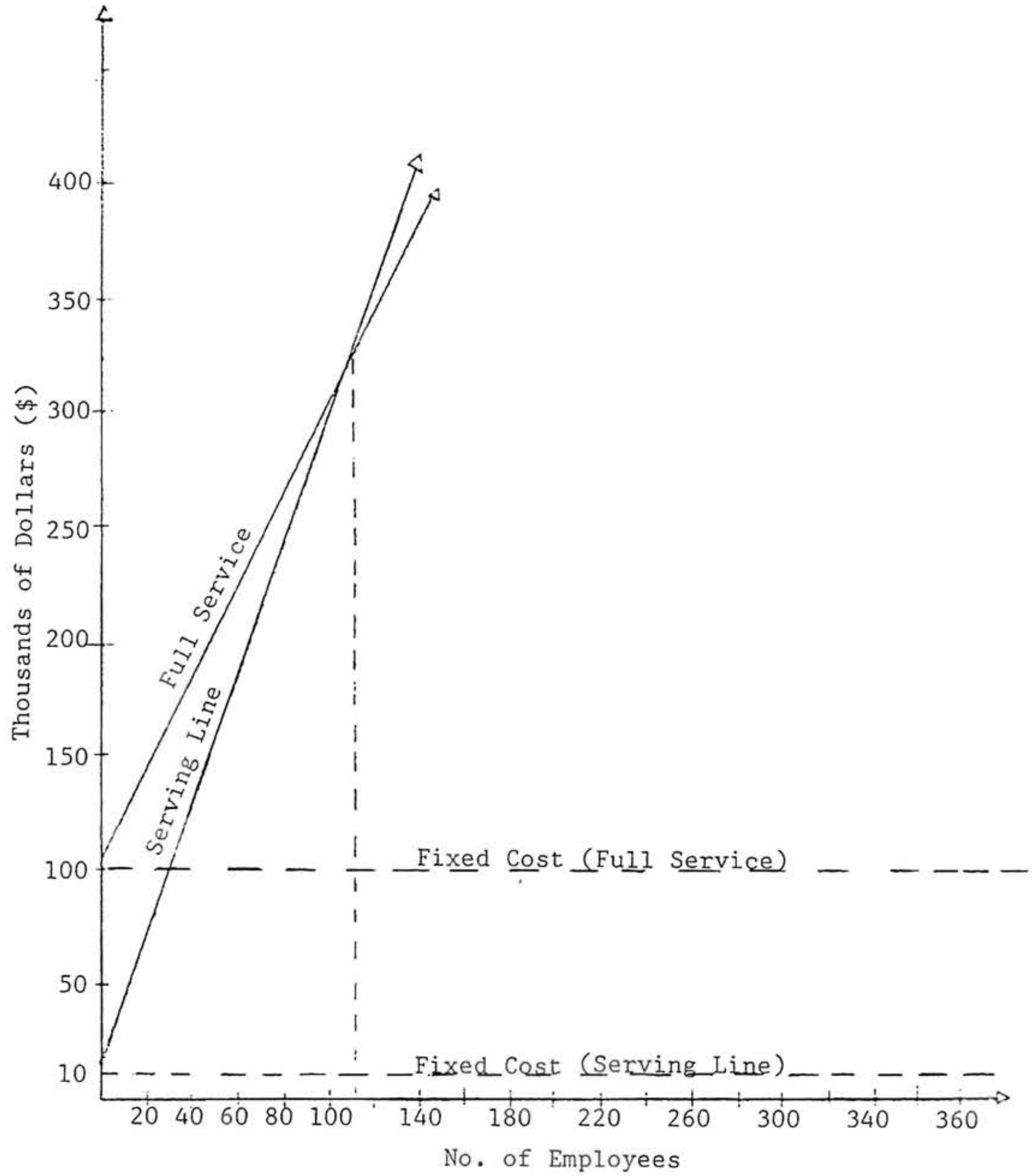


FIGURE 4: BREAKEVEN POINT

TABLE 9. SPACE REQUIRED FOR FULL KITCHENS

Number of Meals Served	Area Requirements (square feet)
100 - 200	500 - 1000
200 - 400	800 - 1600
400 - 800	1400 - 2800
800 - 1300	2400 - 3900
1300 - 2000	3250 - 5000
2000 - 3000	4000 - 6000
3000 - 5000	5500 - 9250

From this analysis, the serving line alternative is more feasible for employment levels less than 112. Since the maximum eating each day is 187 (80% of night and day shift), the full service cafeteria is more feasible.

Lunchroom Design

The maximum number of employees eating per working shift for the proposed employment level is 98 (122 x 80%). The lunchroom is designed to accommodate 49 (98/2) employees at one time with two lunch shifts per working shift. The estimated allowance for people eating at 6 ft. x 30 in. tables is 13.5 $ft.^2$ per person when the tables are end to end. Also, the 6 ft. x 30 in. tables accommodate three people(3). From Table 9 (3), approximately 1200 $ft.^2$ should be allowed for the kitchen area for the full service cafeteria. Therefore, the total area that should be provided for the cafeteria is

$$= (6 \text{ ft.} \times 2.5 \text{ ft. per table}) \left(\frac{49}{3} \text{ tables}\right) +$$

$$(13.5 \text{ ft.}^2/\text{person})(49 \text{ people}) + 1200 \text{ ft.}^2$$

$$= 2,106.5 \text{ ft.}^2 .$$

The maximum depth of the lunchroom can be 50 feet. Therefore, the width must be increased to 43 feet (2,106.5 ft.^{2} 50 ft.). The proposed layout is shown in Figure 5.

CONCLUSION

From the above analysis, the present restroom facilities were shown to be adequate. However, the present parking was found to be insufficient. To increase the parking spaces, two alternatives, parking redesign and parking expansion, were compared. The parking redesign was found to be more economical but required compact cars to use compact spaces.

Through a breakeven analysis, a full service cafeteria was found to be more cost effective. Therefore, the lunchroom was expanded to allow for eating and kitchen space.

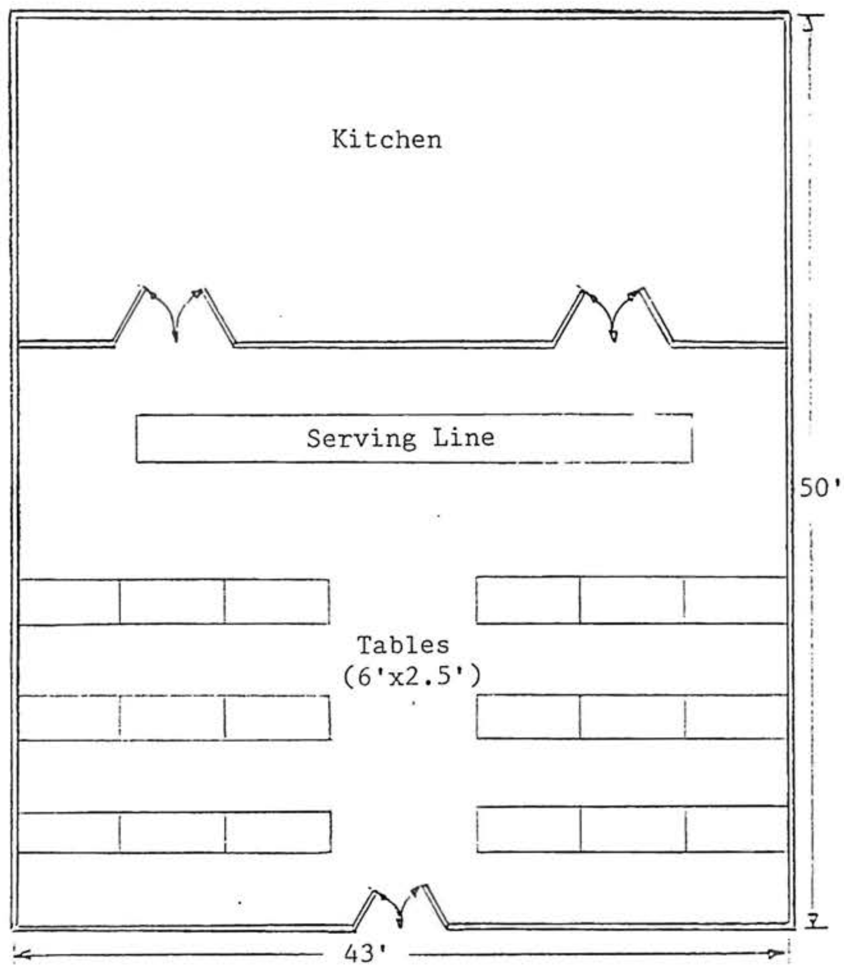


FIGURE 5: PROPOSED LUNCH ROOM

IV. OTHER POSSIBLE SOLUTIONS

Because of the nature of the above case study, the possible solutions should be similar with only minor differences. These differences are discussed in the following sections.

PARKING

Both alternatives for increasing the number of parking spaces, parking redesign and parking area expansion, should be covered in the case analysis. However, the actual redesign or expansion design will vary between each individual.

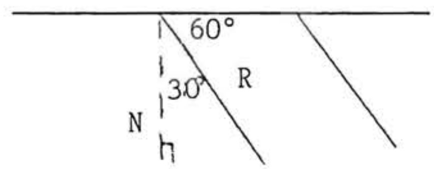
FOOD SERVICES

The individual should perform a breakeven analysis or a similar economic analysis showing the full service lunchroom will be the most economical alternative. However, the design of the lunchroom will vary with each individual.

APPENDIXES

APPENDIX A

PAINTING LINES COST



- To find the length of painted lines:

For standard spaces:

$N = 19$ feet

$\cos 30° = \frac{19}{R}$

$R = 21$ ft.

For compact spaces:

$N = 17.7$ ft.

$\cos 30° = \frac{17.7}{R}$

$R = 20$ ft.

TABLE A-1: COST FOR PAINTING LINES

Type of Space	(1) No. of Rows	(2) No. of Spaces/Row	(3) No. of* Lines/Row	(4) Length of Line	(5) Cost/ ft.	(1,3,4,5) Cost
Standard 60°	2	26	21	21 ft.	$.50	$567
Compact 60°	1	30	31	20 ft.	$.50	$310
Compact 60°	1	35	36	20 ft.	$.50	$360
Cost for one middle line 262 feet long (262 x .50)						$131
				Total Cost		$1368

*Number of lines = 1 + spaces per row

APPENDIX B

PARKING EXPANSION COST

Cost for Expansion:

(area of expansion) (cost for expanding/feet)

(24 ft. x 310 ft.) ($10/ft.) = $74,400

Cost for Painting New Lines:

TABLE B-1. PAINTING LINE COST FOR EXPANSION

Type of Space	(1) No. of Rows	(2) No of Spaces/Row	(3) No of* Lines/Row	(4) Length of Line	(5) Cost/ ft.	(1)(3)(4)(5) Cost
Standard 90°	2	30	31	18.5ft.	$.50	$573
Standard 90°	1	36	37	18.5ft.	$.50	$342
Cost for one middle line 262 feet long						$131
				Total Cost		$1046

*Number of lines = 1 + spaces per row.

Total Expansion Cost:

$74,400 + 1046 = $ 75, 446

APPENDIX C

BREAKEVEN ANALYSIS

The present worth of the variable cost for each alternative is calculated below:

Full Service Cafeteria: PW = \$2.00 (80%) (1 meal/day/person) (250 days/year) (P/A, 15%, 10)

PW = 400 (P/A, 15%, 10)

PW = \$2,007.51/person

Serving Line: PW = \$2.8 (80%) (1 meal/day/person) (250 days/yr) (P/A, 15%, 10)

PW = 560 (P/A, 15%, 10)

PW = \$2,810.51/person

The number of employees (X) required to make the cost of the full service cafeteria equal to the serving line cost is obtained below:

Full Service Cost = Serving Line Cost

\$100,000 + \$2,007.51X = \$10,000 + \$2,810.51X

X = 112 employees

REFERENCES

1. Tompkins, James A. and John White. Facilities Planning. New York: John Wiley and Sons, 1984, p. 100.

2. Tompkins, pp. 103-4.

3. Tompkins, pp. 105-8.

CASE 2

MATERIAL HANDLING AND PLANT REDESIGN

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I. NOTES TO THE INSTRUCTOR

Most common material handling and layout problems deal with the improvement of an existing material handling system or the redesign of the present system. To illustrate similar situations, Case 2 presents three proposals:

1. Adding a conveyor system to an existing plant.
2. Adding a AGVS to an existing plant.
3. Redesigning the existing system for proposed production changes.

To benefit from this case, there should be a basic understanding of material handling and plant layout principles. Furthermore, the case is appropriate as a term project for a basic material handling and plant layout course.

II. STATEMENT OF PROBLEM

INTRODUCTION

Printright Inc., located in Stillwater, Oklahoma, produces standard computer paper and twenty-seven different types of custom computer forms. Seventy-five percent of their production is for standard computer paper (no copies and standard color) and twenty-five percent is for custom ordered computer paper (multiple copies and/or special printing).

At the present time, Printright operates on a three-shift basis (24 hours a day), five days a week. The company employs 195 hourly workers and 11 salary workers.

FLOW OF MATERIALS

The plant's present layout is shown in Figure 1. To introduce the production process of the plant, the material flow through the plant beginning with the raw material will be discussed.

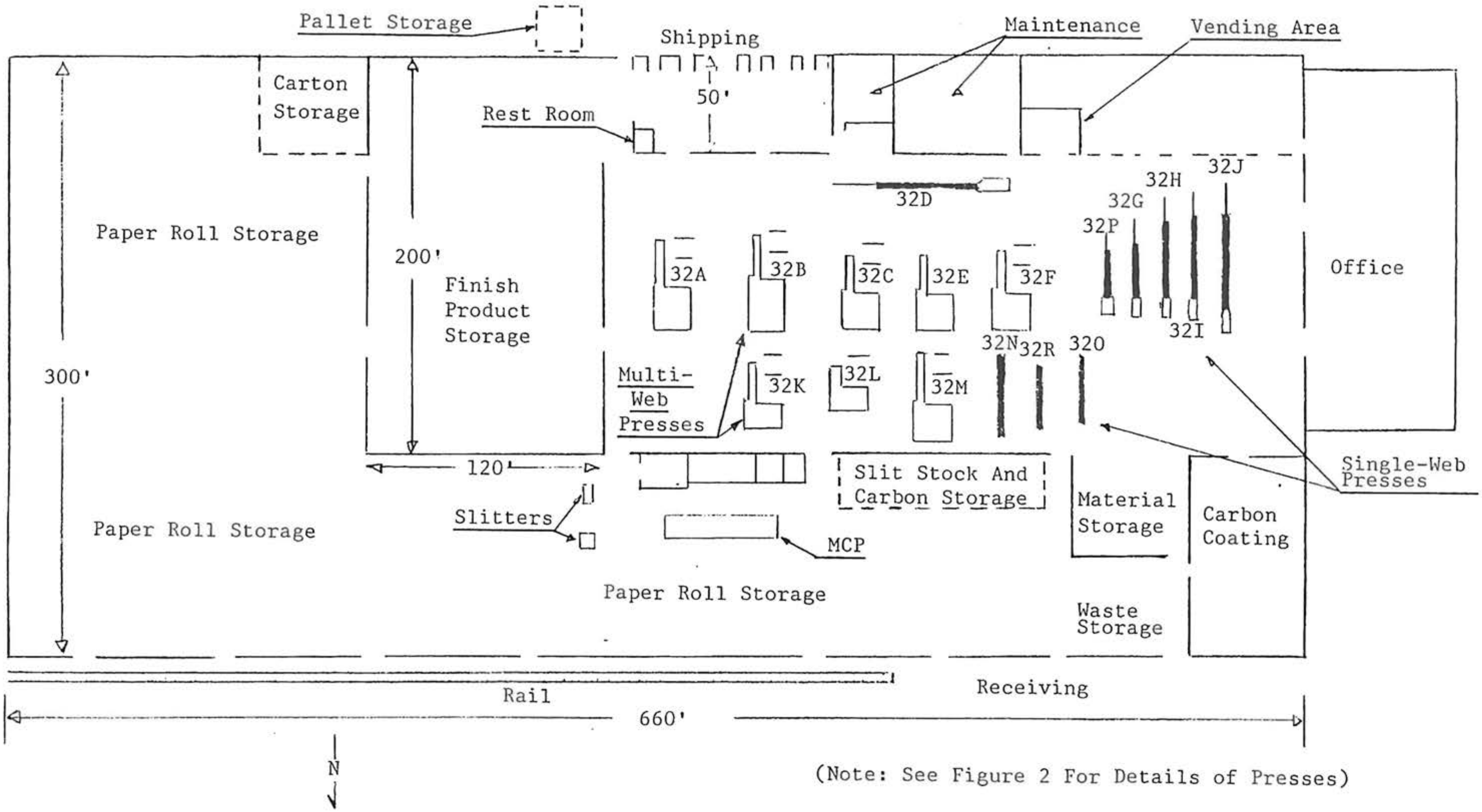
Incoming Raw Material

Raw materials are delivered to the plant both by rail and truck. The truck receiving dock is located on the north side of the plant and one door on the south side (see Figure 1). The rail spur is located on the north side of the plant.

Ninety percent of the major raw material, paper rolls, is brought by rail while the remaining 10% is brought to the north side of the plant by truck. Cartons used for packaging printed forms are delivered on pallets by truck to the south side of the plant. Empty pallets (40 in. x 48 in.) are brought by truck and are stored outside near the truck shipping dock due to fire codes.

Raw Material Storage

Incoming paper rolls are taken to the paper roll storage area by fork trucks equipped with clamp attachments. Here, they are stacked on top of each other within



(Note: See Figure 2 For Details of Presses)

FIGURE 1: PLANT LAYOUT

classification areas (type and grade of paper). It is estimated that the average inventory of paper is approximately 20 million pounds. The palletized cartons (packaging material) are stored on racks at the south side of the warehouse.

Manufacturing Processes

Press operators monitor the raw material levels (paper rolls, and cartons) of their presses. When more material is needed, the operator signals for a material handler who then locates and brings the appropriate raw material. The raw material is handled by fork trucks with either a clamp attachment for the paper rolls or a fork attachment for pallets. Each press is equipped with a hoist for loading paper rolls onto the feed station of the press. Paper rolls are distributed throughout the facility to any of four different production areas: press department, slitting operation, carbon coating operation, and MCP operation. These departments are discussed below and are also indicated in Figure 1.

Press Department

The press department consists of two types of presses: multi-web presses and single-web (high volume) presses. The multi-web presses produce forms containing multiple copies which allow for the transfer of information to each copy by either a carbon paper insert or by a carbon coated paper called MCP. The eight multi-web presses print approximately 90% of the custom forms and 10% of the standard forms. These presently operate close to maximum production capacity.

Nine single-web presses produce standard computer paper with a maximum speed of 1500 feet per minute. Historical monthly press production measures in linear feet per month and pounds per month are shown in Table 1 and Table 2, respectively.

After the forms are printed, they are manually inserted and sealed into cartons by the press operator, generally assisted by one or more helpers. Next, they are accumulated on short roller conveyor awaiting palletization. The common unit loads used are shown in Table 3.

TABLE 1: PRODUCTION VOLUME FOR TEN MONTH PERIOD (LINEAR FT./MONTH)

PRESS TYPE	PRESS NO.	LAYOUT* LOC. NO.	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
MULTI-WEB	01	32K	4,953,800	3,216,300	2,550,900	1,239,200	2,167,400	4,038,000	3,030,200	2,976,600	2,350,700	3,671,200
	04	32L	3,749,700	2,983,200	2,520,000	2,474,200	2,727,300	3,357,700	3,023,600	5,002,900	2,708,800	2,328,200
	10	32C	6,880,400	4,775,400	6,571,100	1,900,800	4,079,800	6,700,300	7,076,100	7,187,800	4,877,000	5,244,800
	11	32M	2,828,800	6,609,400	5,571,000	2,190,400	4,609,900	4,589,800	4,127,400	3,954,600	4,983,400	4,645,000
	13	32E	3,279,900	4,924,400	4,250,800	4,838,400	4,148,100	4,367,900	4,475,700	5,057,700	3,492,300	3,426,000
	14	32B	3,721,000	6,393,200	5,935,600	6,285,100	3,394,300	5,176,300	6,131,500	5,645,700	6,212,300	4,285,400
	21	32A	3,793,800	4,743,200	5,684,900	4,208,500	4,403,100	5,544,600	5,491,000	4,455,400	4,507,400	4,894,300
	24	32F	4,338,300	3,838,500	4,695,000	3,585,000	2,835,100	2,992,000	4,283,400	4,283,400	3,875,300	3,307,500
SINGLE-WEB	02	32H	12,235,800	13,542,700	13,893,300	8,981,100	6,898,300	9,767,200	11,870,000	16,264,000	14,526,000	14,460,000
	03	32J	12,889,500	18,336,800	15,595,200	10,107,600	19,270,200	12,750,800	13,786,200	16,468,700	16,249,500	15,277,500
	06	32N	11,202,800	13,471,200	8,235,800	6,446,900	8,903,300	3,286,000	9,038,600	12,348,300	12,294,200	9,166,800
	07	32R	8,479,800	8,462,500	8,162,700	8,166,100	7,257,300	8,766,200	7,449,500	9,887,300	6,269,800	8,752,400
	15	32G	20,990,500	21,445,600	12,194,800	19,389,700	10,632,000	18,876,900	24,813,100	25,367,700	19,014,500	23,167,400
	19	32P	17,705,800	17,521,700	9,416,700	15,924,300	15,445,200	16,768,400	9,185,700	15,740,300	19,038,000	22,[illegible],700
	20	32I	13,334,600	18,176,200	15,595,200	13,854,300	10,678,600	16,964,300	18,698,400	13,303,500	19,303,800	11,798,100
	22	32O	10,074,300	7,984,000	8,625,700	9,639,300	6,283,300	10,021,400	9,948,100	7,541,100	3,890,600	3,127,400
	23	32D	14,992,900	716,000	8,072,900	3,978,000	11,711,800	9,576,900	6,419,000	9,673,000	10,814,400	13,694,400

*The layout location number corresponds to the identification number for each press in Figure 1.

TABLE 2: PRODUCTION VOLUME FOR TEN MONTH PERIOD (LB./MONTH)

PRESS TYPE	PRESS NO.	LAYOUT* LOC. NO.	JAN.	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT
MULTI-WEB	01	32K	259,500	107,100	78,300	38,500	69,200	129,000	89,800	91,100	77,600	122,800
	04	32L	102,600	81,500	61,400	54,500	60,100	89,600	74,800	130,900	63,100	67,400
	10	32C	429,800	304,300	459,300	119,800	224,400	454,000	427,100	464,500	288,300	335,200
	11	32M	95,300	290,700	231,500	80,200	216,800	219,100	161,200	140,300	234,000	184,700
	13	32E	167,600	267,400	327,800	217,600	198,900	225,500	199,100	215,200	179,100	186,100
	14	32B	342,200	961,300	548,400	365,000	233,600	333,400	419,100	344,800	356,100	282,700
	21	32A	176,000	198,000	255,100	186,000	208,600	246,500	264,000	211,400	226,100	236,500
	24	32F	137,000	126,200	172,600	101,800	87,600	115,900	139,300	149,900	148,400	125,900
SINGLE-WEB	02	32H	410,600	441,500	445,700	310,700	245,700	354,700	326,600	528,200	521,500	352,300
	03	32J	425,500	484,800	479,500	311,800	291,300	388,100	431,800	479,300	520,200	480,000
	06	32N	466,400	267,300	206,000	157,600	773,200	85,500	1,128,100	315,400	543,500	182,000
	07	32R	157,300	152,800	120,600	168,900	140,700	122,200	117,300	187,200	112,600	140,800
	15	32G	600,800	618,000	348,300	698,600	379,000	664,200	821,300	890,300	645,600	819,700
	19	32P	652,700	635,900	347,100	454,900	441,100	478,300	261,800	448,600	559,900	627,400
	20	32I	422,000	589,200	486,600	436,000	345,700	540,600	607,400	419,006	602,000	371,400
	22	32O	210,400	146,900	157,000	190,700	175,200	206,600	203,100	152,700	72,800	61,800
	23	32D	596,300	28,400	337,500	161,700	480,800	393,800	267,200	399,000	446,500	561,700

*The layout location number corresponds to the identification number for each press in Figure 1.

Palletized loads are taken to either the finished product warehouse or directly to shipping. Sixty percent of the standard computer paper is sent to finished product

TABLE 3: COMMON UNIT LOADS

Form Size (in. x in.)	Carton Per Pallet	Weight Per Carton (lbs.)
14 7/8 x 11	40	43
14 7/8 x 8 1/2	52	34
9 7/8 x 11	48	27
9 1/2 x 11	64	28
8 1/2 x 11	68	25

warehouses while the remaining forty percent are sent directly to shipping. All custom orders are sent directly to the staging area of the shipping dock.

MCP Operation

MCP, a special type of self-copying paper, is produced in this operation. After the coating process, fifty percent of the production is sent either to the multi-web presses or to storage racks for later internal use. The other 50 percent of the coated papers are sold to other customers and thus are sent to shipping.

Carbon Coating Operation

Paper rolls are delivered to the carbon coating process, the carbon applied and the paper is rerolled. After the carbon coating process, the rolls of carbon paper are taken to storage until needed by the multi-web presses (see Figure 1).

Slitting Operation

This operation is used to cut paper rolls into the required width needed by the multi-web presses for custom orders. Approximately 20 rolls are slitted per day. After being slit, the smaller width rolls are stored on racks near the slitter or sent directly to the multi-web presses.

Finished Products Storage

The pallets containing standard computer paper in cartons are stored on drive-thru racks in the finished products warehouse. Finished products are stored on a last-in-first-out basis.

MATERIAL HANDLING DEVICES

The major handling devices used at Printright are industrial trucks equipped with either a clamp or fork attachment. Table 4 lists the material handling devices used.

PROBLEM STATEMENT

Management is concerned with the present material handling system. They want to investigate the economic feasibility of installing either a conveyor or an automatic guided vehicle system (AGVS).

On a more long-range basis, management wants to consider abandoning all of the custom work and vastly expanding the standard computer paper portion of their business. Their best estimate is that they could sell about four times the current sales volume of standard paper.

ASSIGNMENT

Using information already presented along with the additional information in Tables 5, 6, and 7 and in Figure 2, the following is to be done:

1. Prepare a proposal utilizing conveyors for the present mix of products.
2. Prepare a proposal utilizing AGVS for the present mix of products.
3. Prepare a complete redesign of the current system (production and material handling) under the assumption management does abandon all custom work.

In each of the above, complete documentation and economic measures should be clearly presented.

TABLE 4: MATERIAL HANDLING EQUIPMENT

Type of Equipment	Capacity (lbs.)	Power By (Gas or Electric)	Type Of Attachment	No. Of	No. Used Per Shift Day	Night	Graveyard
Industrial Truck	4,000	Gas	Fork	1	1	1	1
Industrial Truck	3,500	Gas	Fork	1	1	1	1
Industrial Truck	3,000	Electric	Fork	3	3	3	3
Industrial Truck	5,000	Gas	Paper Roll Clamp	3	3	3	3
Standup Truck	2,000	Gas	Fork	1	1	1	1
Mule	1,500	Electric	Fork	1	1	1	1

TABLE 5: NO. OF OPERATORS AND HELPERS PER PRESS

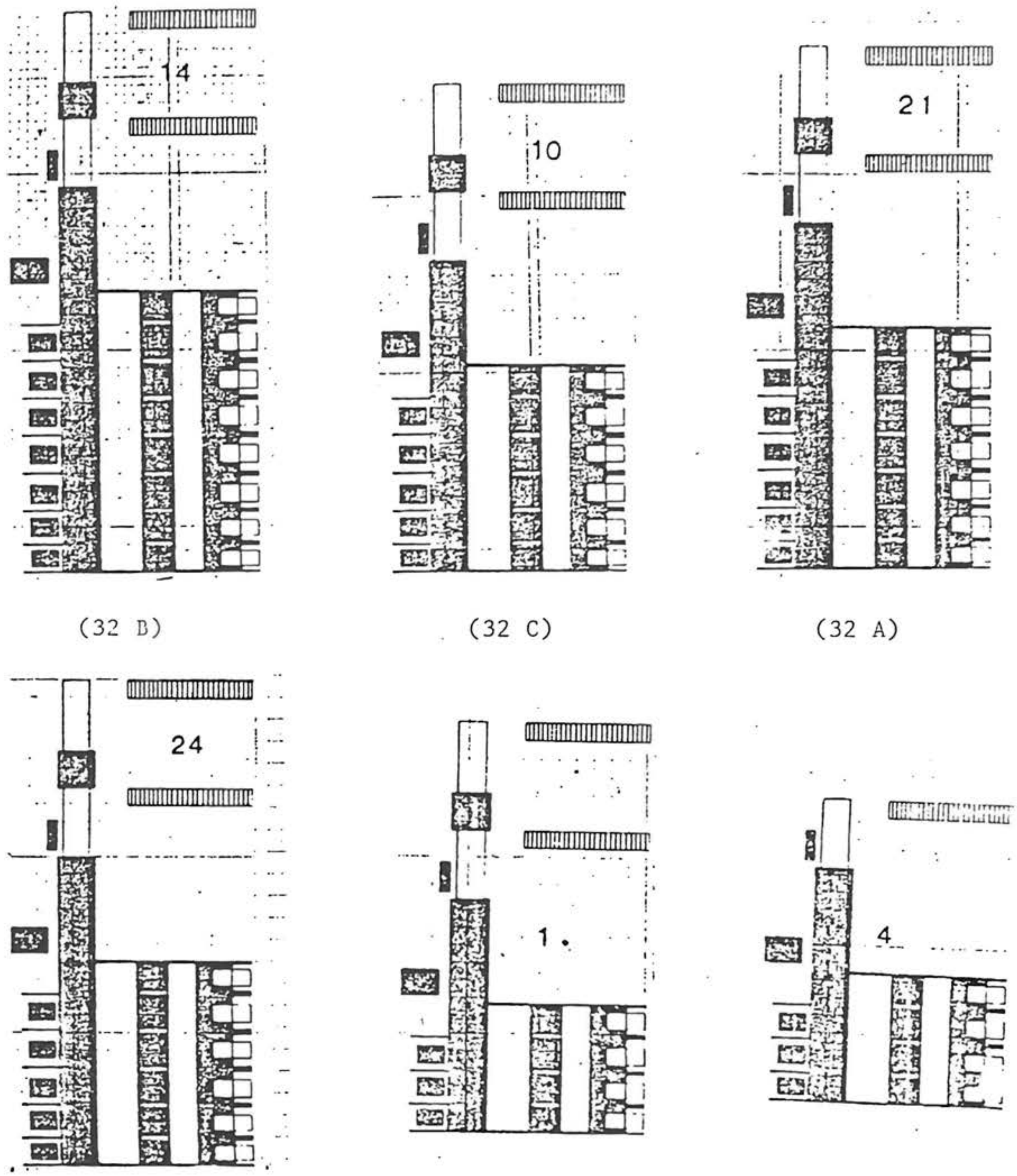
Type Of Press	Press No/Loc. No.	No. Of Operators	No. Of Helpers
MULTI-WEB	01/32K	1	1
	04/32L	1	1
	10/32C	1	2
	11/32M	1	1
	13/32E	1	1
	14/32B	1	2
	21/32A	1	1
	24/32F	1	1
SINGLE-WEB	02/32H	1	1
	03/32J	1	1
	06/32N	1	1
	07/32R	1	0
	15/32G	1	1
	19/32P	1	0
	20/32I	1	1
	22/32O	1	0
	23/32D	1	2

TABLE 6: COST INFORMATION

Type Of Cost	Cost
Labor rates (loaded)	
Press Operator	$13.00/hr.
Press Helper	10.38/hr.
Material Handler	9.43/hr.
Carrying Cost of raw material	12.5% annual
Cost of raw material	$ .50/lb.
Annual fork truck cost/truck	$25000/yr.
Salvage of all presses	Cost of removal
Plant Rearrangement cost Walls are non-load bearing	$35/man hour

TABLE 7: ADDITIONAL INFORMATION

Description Of Information	Information
Lead time for shipment of raw material	2 months
Safety Stock (raw material)	2 weeks
Average weight of paper rolls	1200 lbs.
Maximum weight of paper rolls	1500 lbs.
Press operation delay	
1. Setup time	3%
2. Maintenance time	4%
3. Break downs	5%
% Scrap	5.9%
Height of finish goods warehouse	25 ft.
Column Characteristics of all Operations Areas	Structural steel, 30' x 50' center-to-center
Number of Working days/year	250 days/yr.
Number rolls slitted per day	20
Percentage of multi-web press input from:	
MCP	80%
uncoated paper	10%
carbon paper	10%
Minimum Attractive Rate of Return	15%
Maximum time at each AGV stop	5 min.

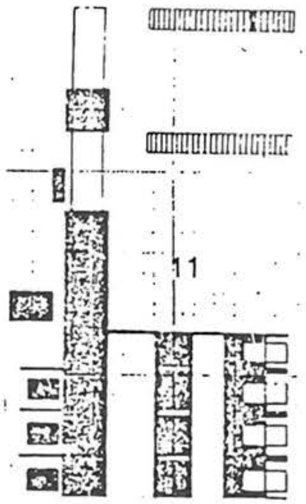


(32 B) (32 C) (32 A)

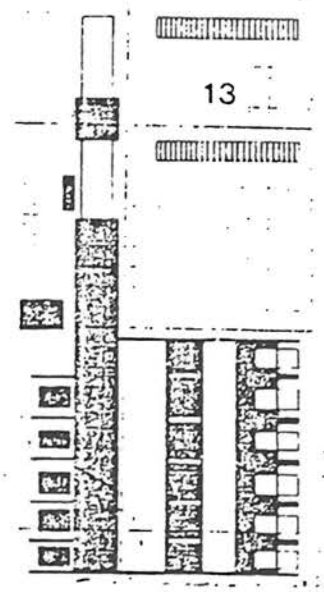
(32 F) (32 K) (32 L)

Note: (   )- Layout Location Number
Scale- 1'=1/16"

FIGURE 2: PRESS TEMPLATES



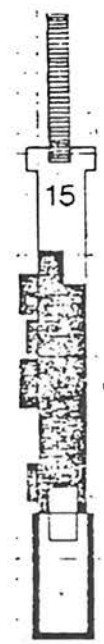
(32 M)



(32 E)

Single- Web Presses

(32 P)



(32 G)

(32 N)

FIGURE 2: (CONTINUED)

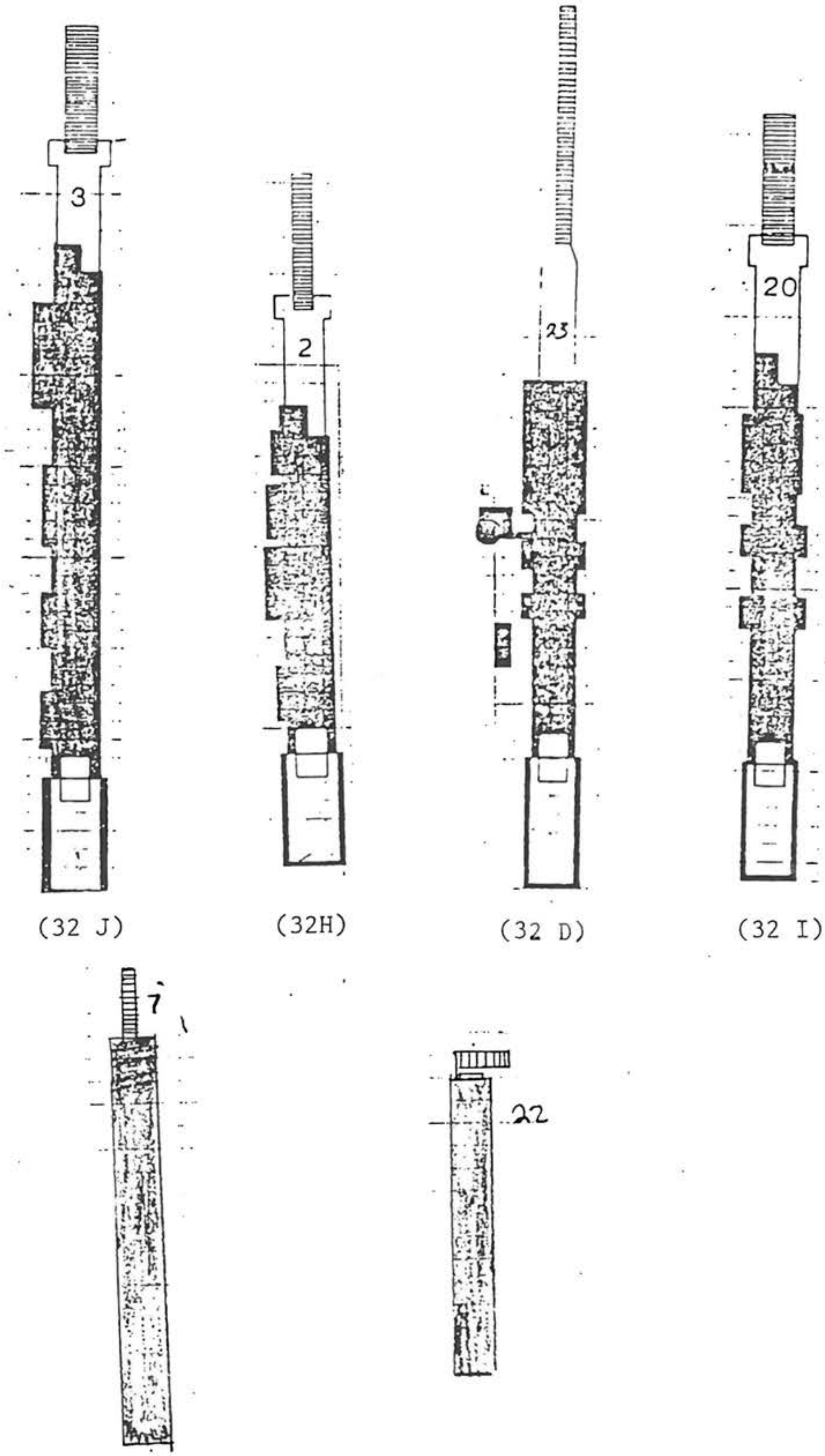


FIGURE 2: (CONTINUED)

III. PROBLEM ANALYSIS

Several distinct material handling and plant layout problems can be identified. These include the material handling system, inventory system, and press utilization.

MATERIAL HANDLING SYSTEM

The current material handling system consists of fork trucks. More automated systems, such as conveyors and AGVS, could reduce the annual cost of material handling (labor and truck operation cost). The addition of these systems will be considered in later sections.

INVENTORY SYSTEM[1]

The present paper roll inventory level, 20 million pounds, is more than the required inventory level. From Table 8, the average monthly press production is 5,229,860 pounds. With a lead time of two months, the inventory can be reduced to 13,074,650 pounds (two months of productivity and two weeks of safety stock). Therefore, the initial dollar savings is

= (Present Inventory Level - Proposed Inventory Level) (Raw Material Cost)

= (20,000 lbs. - 13,074,650 lbs.) ($.50/lb.)

= $3,462,675.

---

[1] Analysis of inventory levels and their associate carrying cost is not a requirement of the problem statement. It can be ignored or considered as an ancillary part of a solution.

The annual savings is

= (Initial savings due reduction of inventory levels) (Carrying cost percentage)

= ($3,462,675) (.125)

= $432,834/year.

TABLE 8: MONTHLY PRESS PRODUCTION

Type of Press	Press No.	Average Production Feet/Mo.	Average Production lbs./Mo.	Total Average Production Feet/Mo.	Total Average Production lbs./Mo.
Multi-web					
	01	3,019,430	106,290		
	04	3,087,560	78,590		
	10	5,529,350	350,170		
	11	4,410,920	186,180		
	13	4,226,120	218,130		
	14	4,318,520	418,660		
	21	4,806,700	224,820		
	24	3,763,350	130,400	34,161,950	1,713,240
Single-web					
	02	12,243,840	393,700		
	03	15,073,200	428,730		
	06	9,409,390	406,500		
	07	8,160,360	142,040		
	15	19,589,220	648,880		
	19	15,878,180	490,770		
	20	15,170,700	481,990		
	22	7,713,020	157,720		
	23	8,964,930	366,290	112,202,840	3,516,620
Total				146,363,790	5,229,860

PRESS UTILIZATION

The maximum speed of the single-web presses was given as 1500 ft./min. With an allowance for scrap, setup, and maintenance; the maximum monthly capacity is 35,773,056 feet (see Appendix A). Therefore, the percentage utilization of each single-web press can be determined as shown in Table 9.

Since the presses are under utilized, the number of presses actually needed is

= (Maximum Volume of Single-Web Presses)*/Maximum Capacity)

= (126,590,000 ft./mo.) / (35,773,056 ft./mo.)

= 4 Presses.

Therefore, a minimum of four single-web presses is required. The reduction of presses will provide labor savings of $576,840 monthly. (see Appendix A, pages 38-39).

TABLE 9: PERCENT UTILIZATION OF SINGLE-WEB PRESSES

No. of Press	Layout Location No.	Average Ft./Month	100% Capacity Ft./Month	% Utilization
02	32H	12,243,843	35,773,056	34
03	32J	15,073,200	35,773,056	42
06	32N	9,409,390	35,773,056	26
07	32R	8,160,360	35,773,056	23
15	32G	19,589,220	35,773,056	55
19	32P	15,878,180	35,773,056	44
20	32I	15,170,700	35,773,056	42
22	320	7,713,020	35,773,056	22
23	32D	8,964,930	35,773,056	25

*See Table D-1, Appendix D

IV. PRESENT PRODUCT MIX PROPOSALS

To improve the material handling of the present plant design, two alternatives are considered: installation of an AGV system, and installation of a conveyor system. The design of each alternative is discussed in the following sections.

AGV SYSTEM

The Automated Guided Vehicle System (AGVS) is designed to use a combination of AGV's and fork trucks. The system includes the following advantages:

1) Provides material handling to and from areas only when needed.

2) Adapatable to both low and high volume applications.

3) Reduces the number of fork trucks needed (therefore reduces annual operational cost).

System Description

The proposed system in Figure 3 consists of two AGV loops. Both loops begin at stations 1 through 4 in the paper storage area. Here, fork trucks load raw material (paper rolls, packaging material, pallets, MCP, etc.) onto the AGV's traveling to the presses.

Raw material for presses 1, 4, and 11 are unloaded from the AGV's at station 5. A fork truck with a clamp attachment is used to transfer material to each press. Raw material for the remaining presses are unloaded at stations 6 through 14. At each station, a fork truck with

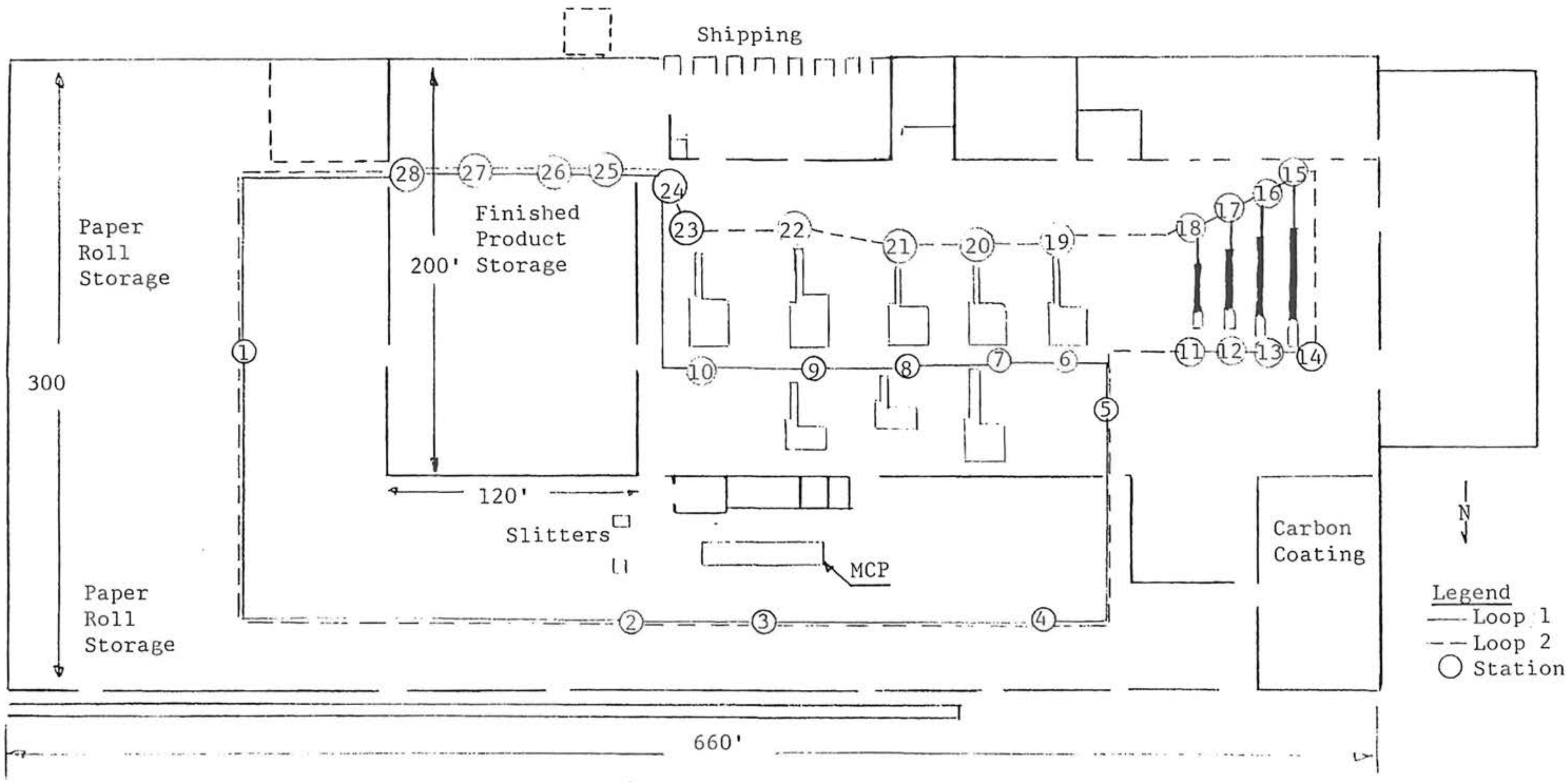


FIGURE 3: PROPOSED AGV SYSTEM

a clamp attachment unloads the paper rolls from the AGV's.

Unit loads consisting of cartons of finished printed forms are loaded at stations 7 through 9 and 15 through 23. The AGV's are loaded by manually operated chain conveyors shown in Figure 4. Each pick-up point is designed with an adjustable platform to allow workers to stack cartons on the upper levels of the unit load. After loading, the AGV travels to either shipping (station 24) or storage (stations 25 through 28).

Six AGV's are required. This is based on the assumption that the AGV stops four times on a complete loop (see Appendix B).

Cost and Savings

The cost of the proposed system is $699,975. The related savings is the reduction of 3(8-5) fork trucks with an annual savings of $244,740 (see Appendix C, page 46).

CONVEYOR SYSTEM

The present raw material flow is very diversified because of the many different sources of raw material (MCP, stitting, carbon coating, paper roll storage, packaging material storage). A unit conveyor system would therefore require an intricate merge and divert system in order to route all possible types of raw stock to all possible presses. This system would be only justified for high volumes. The present maximum usage of paper rolls (raw rolls, MCP, coated, stitted) is approximately 12 rolls per hour (see Appendix B page 41). Therefore, an unit conveyor system for a raw material would not be practical.

To convey the finished product (cartons of forms), two possible

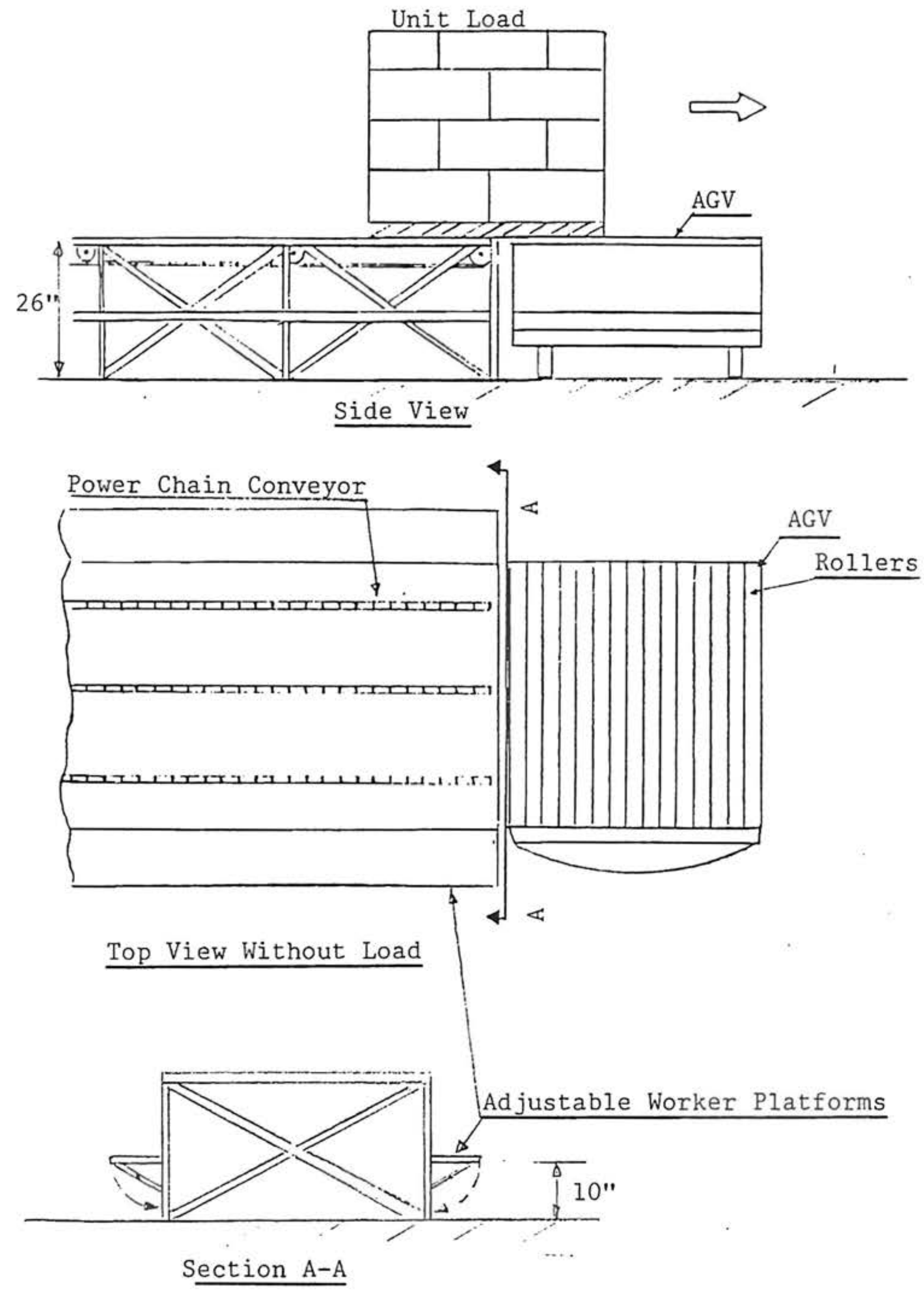


FIGURE 4. AGV PICK-UP POINT LAYOUT

alternatives are feasible: a unit load conveyor or a carton conveyor. A carton conveyor allows centralizing all palletizing at one location and eliminates the need for helpers at each press. Further, the load carrying capacity of the carton conveyor will be considerably less than for a unit conveyor.

System Description

The selected conveyor system incorporates a computer controlled carton conveyor in conjunction with fork trucks. The fork trucks will handle all raw material operations while the carton conveyor will convey each finished carton to a palletizing area. The proposed system is illustrated in Figure 5.

After the operator seals a carton of forms, it is sent down a powered conveyor. The electronic eye at the merger signals to the computer the location of each carton. As each carton is conveyed to the spurs, the computer activates the appropriate diverter sending the cartons down specific spurs for order accumulation.

Since the proposed system does not require palletizing at each press, less help is needed. Therefore, 13 helpers (one from each press) can be reduced.

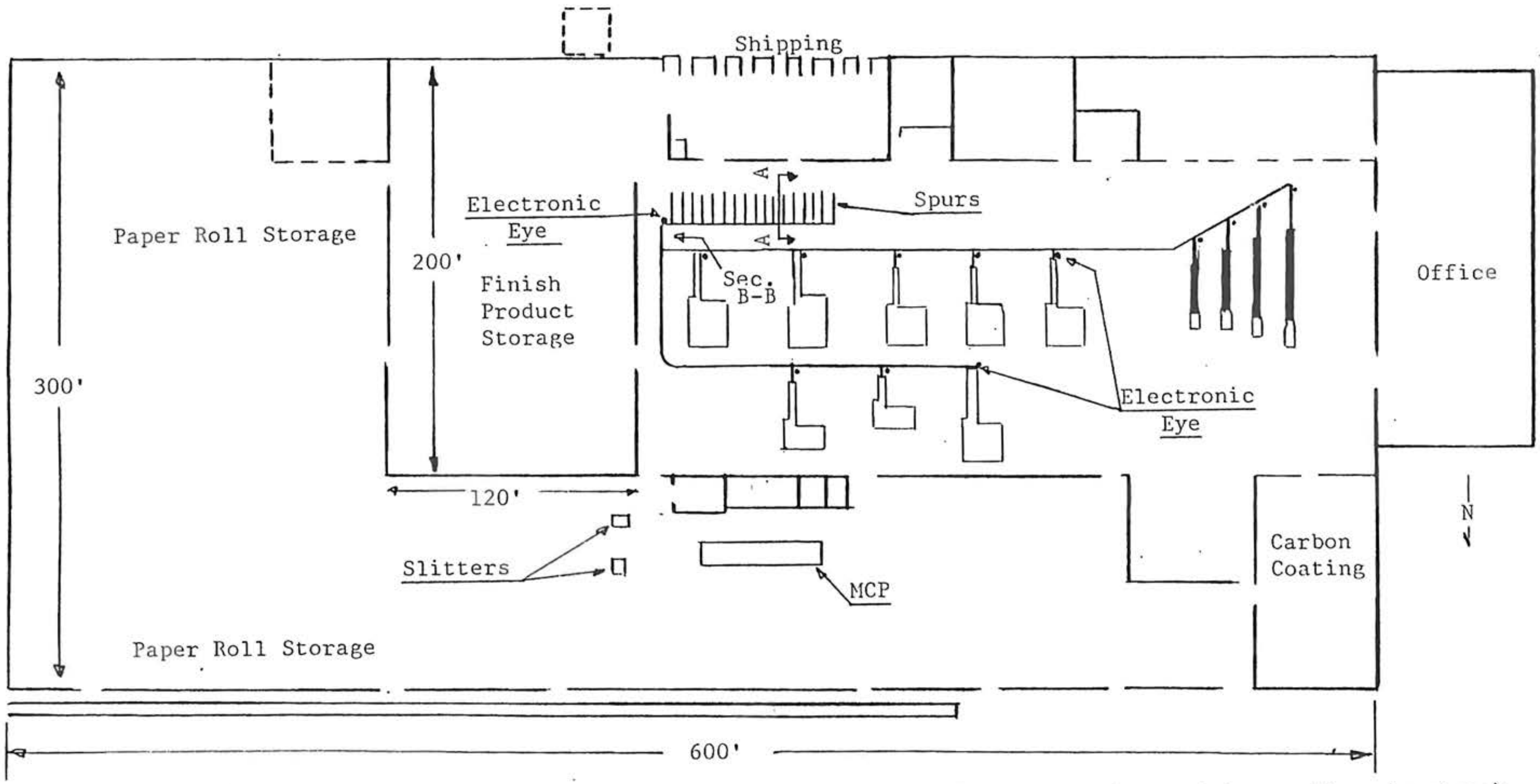
The maximum volume of cartons being conveyed is:

$$= \text{(Maximum Volume of Production)*} \left(\frac{\text{month}}{\text{20 days}}\right) \left(\frac{\text{day}}{\text{24 hr.}}\right) \left(\frac{\text{hr.}}{\text{60 min.}}\right) / \text{(Average Box Weight)}$$

$$= \text{(5,942,000 lbs./month)} \left(\frac{\text{month}}{\text{20 days}}\right) \left(\frac{\text{day}}{\text{24 hr.}}\right) \left(\frac{\text{hr.}}{\text{60 min.}}\right) / \text{(31 lbs.)}$$

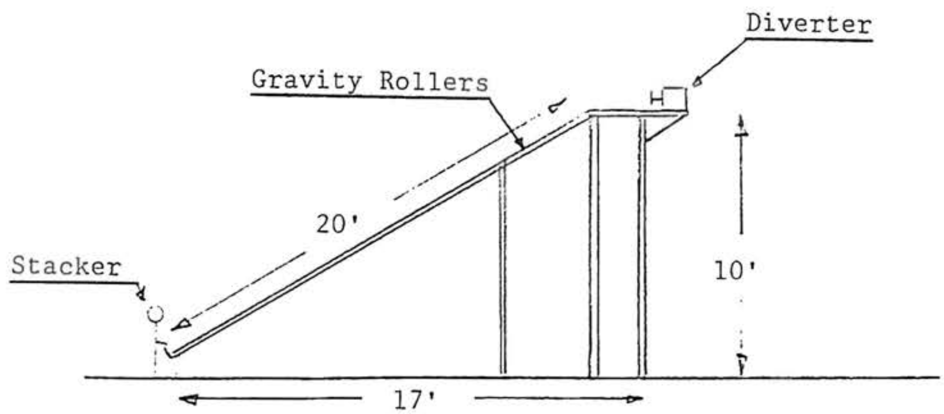
$$= \text{7 cartons / min.}$$

*See Table B-1, Appendix B.

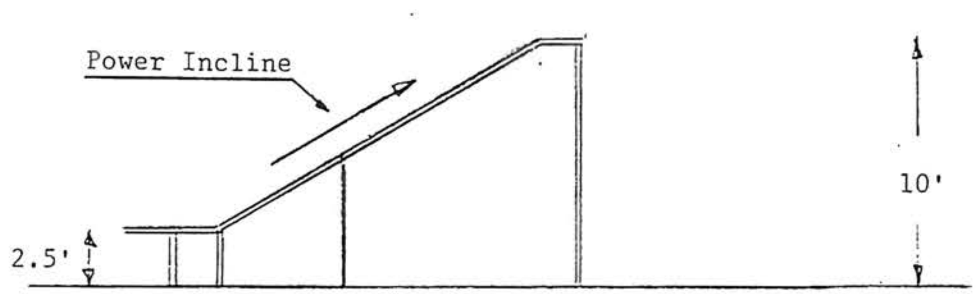


(Note: See Figure 6 for section drawings)

FIGURE 5: PROPOSED CONVEYOR SYSTEM



Section A-A



Section B-B

FIGURE 6: SIDE VIEWS

By simulation the number of cartons which can be stacked in a minute was determined to be five. Therefore, two of the eliminated helpers can be used as stackers.

Thirteen spurs are provided to allow for a maximum of 13 different orders at one time. This could be reduced if historical information on average number of different orders was available.

Cost and Savings

The cost of the proposed system includes the system cost (conveyor cost) and the removal of the wall between shipping and production (allowing room for the spurs). The total cost is $229,973 (see Appendix C, page 47).

The savings include the reduction of 3(8-5) fork trucks (see Appendix F) and reduction press helpers. The total annual savings are $929,820 per year (see Appendix C, page 48).

ECONOMIC COMPARISON

Table 10 compares the cost savings, payback, and present worth of the two present product mix alternatives. The conveyor system should be chosen because of its more favorable present worth and payback.

TABLE 10: ECONOMIC ANALYSIS - PRESENT PRODUCT MIX

Alternatives	Total Installed Cost	$ Savings Per Yr.	Economic Analysis: Payback (Yrs.)	Economic Analysis: Present Worth* ($)
Conveyor System	$229,973	$929,820	0.2	$2,886,927
AGV System	$699,975	$244,740	2.8	$ 120,431

*Life of 5 yrs. was used based on Accelerated Cost Recovery System (ACRS)

V. REDESIGN OF CURRENT SYSTEM

With the consideration of abandoning all custom work and expanding production of computer paper, new material handling and layout designs are proposed. The development of the redesigns are described below.

PRESS CONSIDERATIONS

There are two alternatives that could be made by the management concerning the number of required presses:

1. Keep all present presses and all additional single-web presses as needed. (Multi-web presses can be used for standard items but are much slower than single-web presses).

2. Dispose of all multi-web presses and add all single-web presses.

It was decided to dispose of all multi-web presses for the following reasons.

1. Single-web production speed is much greater than multi-web.

2. It is assumed that management has no plan to return to custom work.

3. More flexibility to the increase in production.

The number of single-web presses required for the increased production was determined to be 14 (see Appendix D). Therefore five additional single presses must be purchased. The new press cost is not included in the redesign cost, since it represents a capacity expansion cost, not a layout/material handling cost.

LAYOUT REDESIGN

Because of the strong departmental relationship, the single-web presses should be positioned close to both the raw material storage and the finished product warehouse. Therefore, all presses should be moved to the present location of the multi-web presses.

SYSTEM DETERMINATION[1]

To determine the most cost effective material handling system, two alternatives are considered:

1) AGV system

2) Conveyor system.

Each alternative's description, savings, and cost are discussed below.

AGV System

The proposed system in Figure 7 consists of one loop. At stations 1 and 2, the fork trucks bring the raw materials to the AGV's. The raw materials are then taken to the appropriate station (3 through 16) for unloading. Unloading at each station is accomplished by a fork truck with a clamp attachment.

The AGV's load unit loads at stations 17 through 30. Each pick up point is designed as in the present product mix alternative (Figure 4). Unit loads ready for shipment are unloaded at station 31 while unit loads bound for storage are unloaded at stops 32 through 34.

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[1]The cost of extra presses and fork trucks was not added in this analysis. These are assumed to be added before the material handling analysis was made.

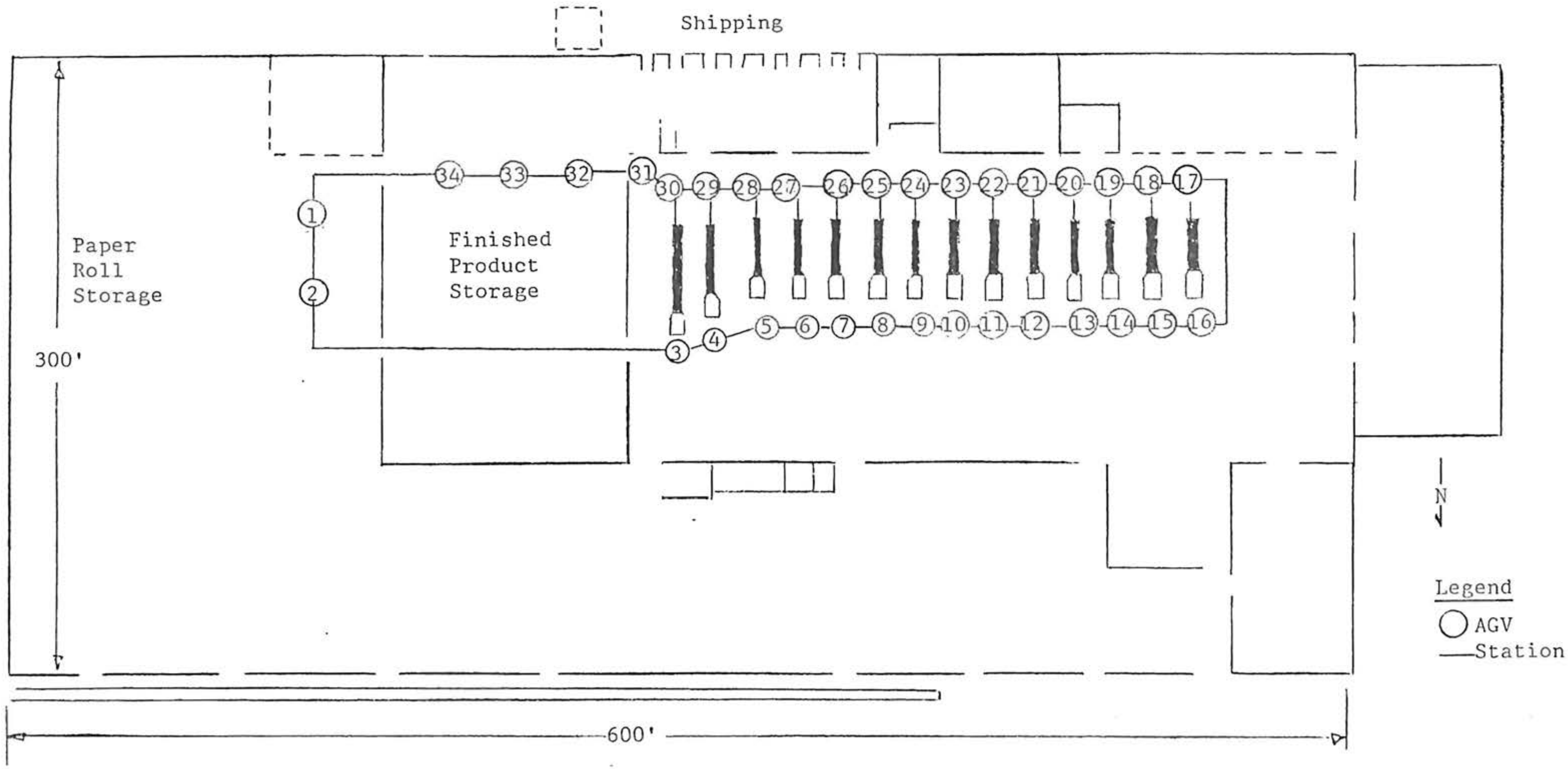

FIGURE 7: PROPOSED LAYOUT (AGVS)

Fourteen AGV's are required. This is based upon the assumption that each AGV will make four stops during each loop (see Appendix E).

The proposed system eliminates 3(8-5) fork trucks (see Appendix F). The resulting savings are $244,740 per year while the initial cost is $1,095,400 (see Appendix C, page 49).

Conveyor System

The proposed conveyor system is very similar to the present product mix conveyor system. The system is shown in Figure 8.

The maximum volume of cartons coming down the conveyor is:

$$= \text{(Maximum Volume of Production)} \left(\frac{\text{month}}{\text{20 days}}\right) \left(\frac{\text{day}}{\text{24 hr.}}\right) \left(\frac{\text{hr.}}{\text{60 min.}}\right) / \text{(Average Carton Weight)}$$

$$= \text{(17,826,000 lbs./month)} \left(\frac{\text{month}}{\text{20 days}}\right) \left(\frac{\text{day}}{\text{24 hr.}}\right) \left(\frac{\text{hr.}}{\text{60 min.}}\right) / \text{(31 lbs.)}$$

$$= \text{20 cartons / min.}$$

Through simulation, time needed to stack five cartons was determined to be one minute. Therefore, four stackers are required to stack cartons from the spurs. The stackers can be obtained from the elimination of 14 helpers from the presses. These eliminated helpers are no longer required because of the elimination of palletizing at each press.

The number of fork trucks eliminated is 3(8-5) (see Appendix F). Therefore, the total savings (labor and equipment) is $867,550 per year while the initial cost is $203,812 (see Appendix C, pages 49-50).

Economic Comparison

Table 11 compares the cost, savings, payback, and present worth for the two material handling alternatives. Again, the conveyor system is more cost effective.

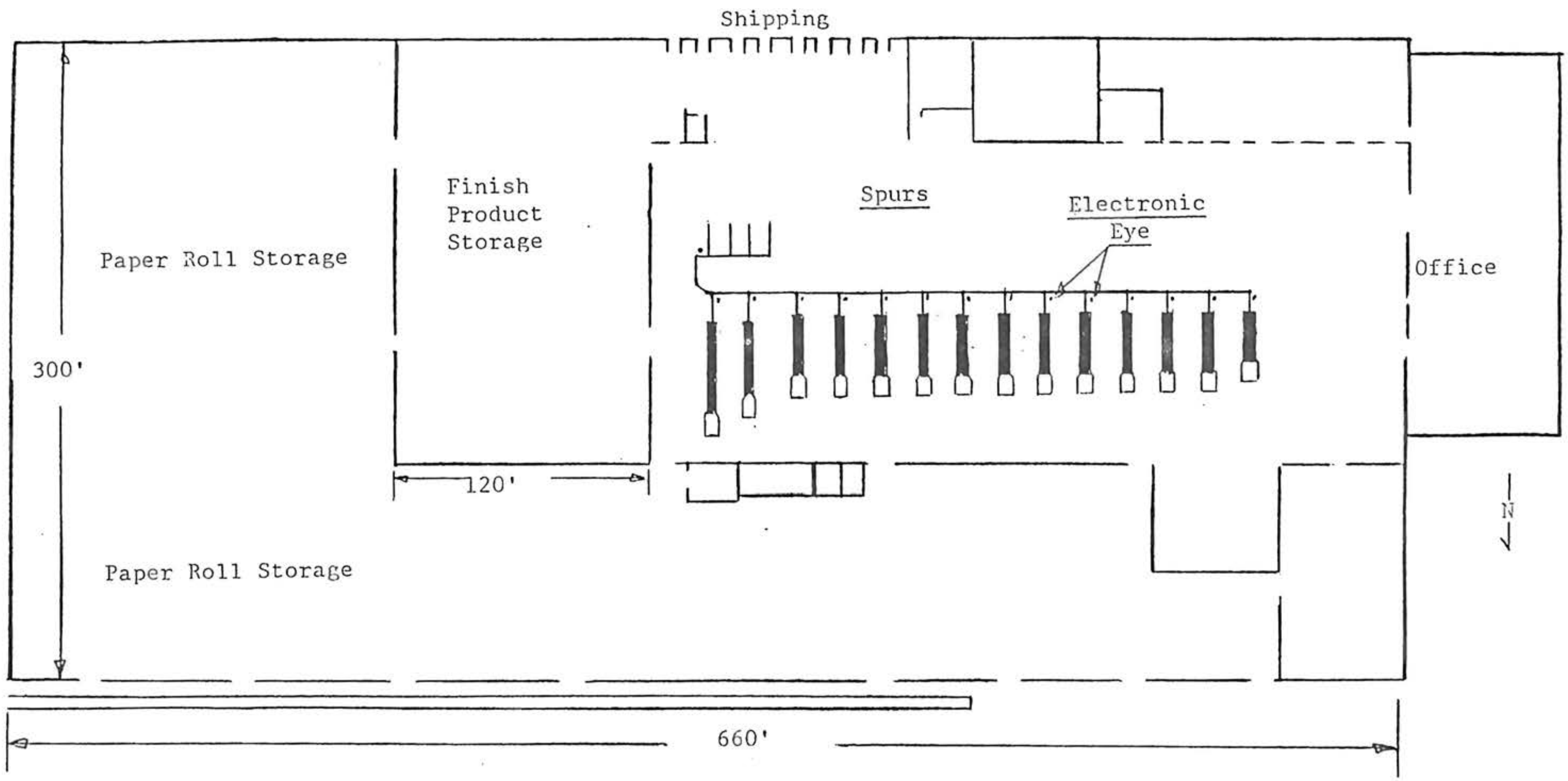

FIGURE 8: PROPOSED LAYOUT (Conveyor System)

TABLE 11: ECONOMIC ANALYSIS - PROPOSED PRODUCT MIX

Alternatives	Initial Total Cost	$ Savings Per Yr.	Economic Analysis Payback (Yrs.)	Present Worth* ($)
Conveyor System	$ 203,812	$867,550	0.2	$2,704,350
AGV System	$1,095,400	$244,740	4.5	$ 274,994

*Life of 5 years was based on ACRS.

VI. SUMMARY

Printright Inc. and its related material handling and layout problems were presented. Between the two present product mix alternatives (addition of AGVS or a conveyor system), a "take-away conveyor system" was chosen. The system has an initial cost of $229,973 while its savings and payback were $929,820/yr. and .2 yr. respectively.

The redesign system included an increase of five single-web presses and an addition of a "take away conveyor." The respective initial cost, savings, and payback were $203,812, $867,550/yr., and .2 yr.

VII. OTHER POSSIBLE SOLUTIONS

Because the development of new material handling systems are based upon personal design assumptions and approaches, solutions to Case 2 will vary. However, some material handling systems appear to be more appropriate than others. Some other appropriate systems will be discussed for each product mix.

CURRENT PRODUCT MIX

Since the material sent to the presses comes from many different sources (MCP, slitting, carbon coating, paper roll storage, packaging, material storage), a unit conveyor transfering raw material (rolls) to the presses is not practical. A system such as this would be only justifiable for high volumes.

Another appropriate conveyor system would be a tow-line. Along with being adaptable to varying production volumes, a tow-line system would decrease aisle blockage.

PROPOSED PRODUCT MIX

During the redesign process, the present machine utilization should be recognized as being low. Therefore, the increase in production will only require approximately five additional single-web presses.

The material handling systems adaptable to the redesign are similar to the present product mix alternatives. The major difference lies in the inclusion of unit conveyors for the transfer of raw material. This system becomes justifiable because of the elimination of raw material diversification.

APPENDIXES

APPENDIX A

REDUCTION OF SINGLE-WEB PRESSES

CAPACITY/MONTH

Capacity of Single-web Presses = (Press Speed) (Conversion to per month)

$$= (1500 \text{ ft./min.}) \left(\frac{60 \text{ min.}}{\text{hr.}}\right) \left(\frac{24 \text{ hrs.}}{\text{day}}\right) \left(\frac{20 \text{ days}}{\text{month}}\right)$$

= 43,200,000 ft./month

Capacity Less Scrap = (Capacity of Press) (1 - % Scrap)

= (43,200,000 ft./month) (1 - 5.9%)

= 40,651,200 ft./month

Capacity Less Break-downs, maintenance, setup = (Capacity Less Scrap) (1 - 12%)

= (40,651,200 ft./month) (1 - 12%)

= 35,773,056 ft./month

TABLE A-1: REDUCTION IN OPERATORS AND HELPERS

Press No. of Presses Eliminated	No. of Operators	No. of Helpers
19	1	0
6	1	1
7	1	0
22	1	0
23	1	2
Total	5	3

LABOR SAVINGS

= (Press Operator labor rate) (No. of Press Operators) (Working hours/yr.) + (Press Helper labor rate) (No. of Press Helpers) (Work hours/yr.)

$$= (13.00/\text{hr.})\ (5)\ (\frac{24\ \text{hrs.}}{\text{day}})\ (250\ \text{days/yr.})\ +$$

$$(\$10.38/\text{hr.})\ (3)\ (\frac{24\ \text{hrs.}}{\text{day}})\ (250\ \text{days/yr.})$$

$$= \$390{,}000/\text{yr.}\ +\ \$186{,}840/\text{yr.}$$

$$= \$576{,}840/\text{yr.}$$

APPENDIX B

CALCULATION OF NUMBER OF AGV'S REQUIRED

RAW MATERIALS CONSIDERATIONS

TABLE B-1: TOTAL MONTHLY PRESS PRODUCTION (lb./MONTH)

Month	Multi-web*	Single-web*	Total Production
January	1,705,000	3,876,000	5,581,000
February	2,338,500	3,364,800	5,703,300
March	2,177,400	2,919,300	5,096,700
April	1,163,400	2,890,900	4,054,300
May	1,298,600	3,272,700	4,571,300
June	1,813,000	3,233,500	5,046,500
July	1,774,400	4,167,600	5,942,000**
August	1,748,100	3,819,700	5,567,800
September	1,572,700	4,024,600	5,597,300
October	1,541,300	3,597,100	5,138,400

<u>No. of Paper Rolls/hr.</u>

Multi-web:

= (Maximum Production Volume)*** (Roll/Average Weight) (1 + % Scrap) (Conversion to per hr.)

= (1,774,400 lbs./month) (Roll/1200 lbs.) (1.059) $\left(\frac{\text{month}}{\text{20 days}}\right)\left(\frac{\text{day}}{\text{24 hr.}}\right)$

= 4 rolls/hr.

Single-Web:

= (Maximum Production Volume)*** (Roll/Average Weight) (1 + % Scrap) (Conversion to per hr.)

= (4,167,600 lbs./month) (Roll/1200 lbs.) (1.059) $\left(\frac{\text{month}}{\text{20 days}}\right)\left(\frac{\text{day}}{\text{24 hr.}}\right)$

= 8 roll/hr.

*These numbers are a summation of columns in Table 2.
**Maximum monthly production
***See Table B-1

FINISHED UNIT LOAD CONSIDERATIONS

TABLE B-2: AVERAGE PALLET WEIGHT

Form Size	Cartons/Pallet	Average Wt. Per Carton (lbs.)	Wt. Per Pallet
14 7/8 x 11	40	43	1720
14 7/8 x 8 1/2	52	34	1768
9 7/8 x 11	48	27	1296
9 1/2 x 11	64	28	1792
8 1/2 x 11	68	25	1700
Average Wt. Per Pallet			1655

<u>No. of Palletized Loads/Hr.</u>

Multi-web:

= (Total Production Volume) (Pallet/Average Weight)*
(Conversion to per hr.)

= (1,774,400 lbs./month) (Pallet/1,655 lbs.) $\left(\frac{\text{month}}{\text{20 days}}\right)$ $\left(\frac{\text{day}}{\text{24 hr.}}\right)$

= 3 pallets/hr.

Single-web:

= (Total Production Volume) (Pallet/Average Weight)*
(Conversion to per hr.)

= (4,167,600 lbs./month) (pallet/1,655 lbs.) $\left(\frac{\text{month}}{\text{20 days}}\right)$ $\left(\frac{\text{day}}{\text{24 hr.}}\right)$

= 6 pallets/hr.

*Average lbs. per pallet is calculated in Table B-2.

TIME CONSIDERATIONS

Time and AGV to Complete Loop

Loop 1:

Number of Stops	= 4
Loop Distance	= 1,000 ft.
Length of Each Stop	= 5 min.
Total Stopping Time	= (4) (5 min.) = 20 min.
Speed of AGV	= 200 ft./min.**
Total Time for a Complete Cycle	=
	= (1,000 ft.)/(200 ft./min.) + 20 min.
	= 5 min. + 20 min.
	= 25 min.

Loop 2:

Number of Stops	= 4
Loop Distance	= 1,410 ft.
Length of Each Stop	= 5 min.
Total Stopping Time	= (4) (5 min.) = 20 min.
Speed of AGV	= 264 ft./min.
Total Time for a Complete Cycle	=
	= (1,410 ft.)/(200 ft./min.) + 20 min.
	= 7 min. + 20 min.
	= 27 min.

**The AGV chosen can handle the maximum load of 1,500 lbs.

NUMBER OF AGV'S DETERMINATION

Loop 1

Average Number of Paper Rolls/hr.	:	1.5
Average Number of Pallets/hr.	:	1.12
Number of Trips around first loop	:	2
Total Time AGV used/Loop 1	:	50 min.

Loop 2

Average Number of Paper Rolls/hr.	:	10.5
Average Number of Pallets/hr.	:	7.88
Number of trips around Loop 2	:	11
Total time AGV used/Loop 2	:	297 min.

Number of AGV's Required

Total Time for Trips/hr.	=	347 min.
Number of AGV's	=	347 min./60 min./hr.
	=	5.8 hrs.
	=	6 AGV's

APPENDIX C*

INVESTMENT COST AND SAVINGS

*See Appendix G for Cost Data

PRESENT PRODUCT MIX

AGV System

Cost:

Cost of Guide Path ($45/ft.)	:	$ 80,775
Cost of Computer Control	:	$120,000
- Unit Cost	:	$120,000
- Installation	:	$ 1,200
Vehicle Cost for 6 Vehicles ($50,000/unit)	:	$300,000
Manual Operated Power Loaders (1/2 units x $16,500/unit)	:	$198,000
Total		$699,975

Savings:

Reduction of Fork Trucks = 8 - 5 = 3 (see Appendix F):

Annual Savings = (Fork Truck Operation Cost) (No. of Fork Trucks Reduced)

= ($25,000/yr.) (3)

= $75,000/yr.

Reduction of 3 Fork Truck Operators Per Shift:

Annual Savings = (No. of Shifts) (No. of Operators Reduced) (Labor Cost) (Operating Hours)

= (3) (3) ($9.43/hr.) (8 hrs./day) (250 day/yr.)

= $169,740/yr.

Total Savings = (Savings in Fork Truck Reduction) + (Savings in Operator Reduction)

= ($75,000) + ($169,740)

= $244,740/yr.

Conveyor System

Cost:

Remove Wall by Shipping	
($30/hr.) (50 hrs.)	$ 1,500
Conveyor System (24" belt)	
- 930 ft. Straight Conveyor	$ 47,700
- 20 ft. Inclined Conveyor	3,400
- 14 Diverters	35,000
- Two 90° Turns	8,800
- 260 ft. Gravity Roller Conveyor	6,500
Freight Charges (Total Weight = 43,590 lbs.)	6,539
Installation (725 hrs.)	25,375
Compressed Air Cost	15,552
Computer Control System	39,600
Field Wiring Cost	30,154
Engineering Cost	6,084
Tune and Test	3,769
Total Cost	$ 229,973

Savings:

Reduction of Fork Trucks = 8 - 3 = 3 (see Appendix F)

Annual Savings = ($25,000/yr.) (3) = $75,000/yr.

Reduction of 3 Fork Truck Operators Per Shift:

Annual Savings = (No. of Shifts) (No. of Operators Reduced) (Labor Cost) (Operating Hours)

= (3) (3) ($9.43/hr.) (8 hrs./day) (250 days/yr.)

= $169,740/yr.

Reduction of 11 helpers:

Annual Savings	= (No. of Shifts) (No. of Helpers) (Labor Cost) (Operating Hours)
	= (3) (11) ($10.38/hr.) (8 hrs./day) (250 days/yr.)
	= $685,080/yr.
Total $ Savings	= $75.000 + $169,740 + $685,080
	= $929,820

PROPOSED PRODUCT MIX

<u>AGV System</u>

Cost:

Cost of Guide Path for 960 ft.	$ 43,200
Cost of Computer Control	
- Unit Cost	$ 120,000
- Installation	1,200
Vehicle Cost for 14 Vehicles	700,000
Manual Operated Power Loaders (14 units x $16,500/unit)	231,000
Total	$1,095,400

Savings:

Reduction of Fork Trucks = 8 - 5 = 3 (see Appendix F)

Total Savings = $244,740/yr. (see page 46)

<u>Conveyor System</u>

Cost:

Remove Wall by Shipping ($30/hr.) (50 hrs.)	$ 1,500
Conveyor System (24" belt)	
- 633 Ft. Straight Conveyor	$ 1,500
- 20 ft. Inclined	3,400
- 14 Diverters	35,000
- Two 90° Turns	8,800
- 280 ft. Gravity Roller Conveyor	7,000
Freight Charges (Total Weight 36,031 lbs.)	5,404
Installation (580 hrs.)	20,300
Compressed Air Cost	15,470
Computer Control System	38,800
Field Wiring	26,724
Engineering Cost	5,223
Tune and Test	3,391
Total Cost	$ 203,812

Savings:

Reduction of Fork Trucks = 8 - 5 = 3 (see Appendix F)

Annual Savings = ($25,00/yr.) (3) = $75,000/yr.

Reduction of 3 Fork Truck Operators Per Shift:

Annual Savings = (No. of Shifts) (No. of Operators Reduced) (Labor Cost) (Operating Hours)

= (3) (3) ($9.43/hr.) (8 hrs./day) (250 days/yr.)

= $169,740/yr.

Reduction of 10 Helpers:

Annual Savings = (No. of Shifts) (No. of Helpers) (Labor Cost) (Operating Hours)

= (3) (10) ($10.38/hr.) (8 hrs./day) (250 days/yr.)

= $622,800

Total $ Savings = $75,000 + $169,750 + $622,800

= $867,550

APPENDIX D

CALCULATION OF NUMBER OF PRESSES NEEDED

TABLE D-1: TOTAL MONTHLY PRESS PRODUCTION (ft./month)

Month	Multi-Web*	Single-Web*	Total Production
January	33,545,700	121,910,000	155,455,700
February	37,483,600	119,660,000	157,143,600
March	37,779,300	99,792,300	137,571,600
April	26,322,400	90,871,000	117,193,400
May	28,364,500	97,080,000	125,444,500
June	32,732,638	106,780,000	139,512,640
July	34,911,900	111,210,000	146,121,900
August	38,608,100	126,590,000	165,198,100**
September	33,307,200	121,400,000	154,707,200
October	31,802,400	121,470,000	153,272,400

*These tables area summation of columns in Table 1.
**Current maximum monthly production

Forecasted Monthly Production (ft./month)

= (demand)[(current maximum monthly production)(% standard paper produced)]

= (4) [(165,198,100 ft./month)(.75)]

= 495,594,300 ft./month

Number of Single-Web Presses Needed

= (Forecasted monthly production)/(capacity of single-web press)***

= (495,594,300 ft./month)/(35,773,056 ft./month)

= 13.9 = 14 presses

Forecasted Production (lb./month)

= (demand) [(current maximum monthly production)**** (% standard paper produced)]

= (4) [(5,942,000 lb./month)(.75)]

= 17,826,000 lbs./month

***See Appendix A
****See Table B-1, Appendix B

APPENDIX E

CALCULATION OF PROPOSED NUMBER AGV'S

MATERIAL FLOW CONSIDERATIONS

No. of Paper Rolls/Hr.

= (total production volume)* (Roll/average lbs.)
(1 + % scrap) (conversion to hrs.)

= (17,826,000 lbs./month)(Roll/1200 lbs)(1.059)

$\left(\frac{\text{month}}{\text{20 days}}\right)\left(\frac{\text{day}}{\text{24 hour}}\right)$

= 33 rolls/hr.

No. of Palletized Loads/hr.

= (total production volume)*(Pallet/average lbs.)
(conversion to hours)

= (17,826,000 lbs./month)(Pallet/1655 lbs.)$\left(\frac{\text{month}}{\text{20 days}}\right)$

$\left(\frac{\text{day}}{\text{24 hr.}}\right)$

= 23 pallets/hr.

TIME FOR AGV TO COMPLETE LOOP

Number of stops per loop = 4
Loop Distance = 960 ft.
Total time complete cycle = (distance/AGV speed)
+ (length of stops)(No. of stops)

= (960 ft./200 ft./min)+(5 min)(4)

= 4.8 min. + 20 min.

= 24.8 min $\left(\frac{\text{hr}}{\text{60min.}}\right)$

= .4 hr/cycle

NO. OF AGV'S NEEDED

= (largest material flow level)/(AGV cyles/hr)

= (33 rolls/hr.)/(2.42 cycles/hr.)

= 14 rolls/cycle, or

= 14 AGV's

*See Appendix D

APPENDIX F

NUMBER OF FORK TRUCKS NEEDED

The number of fork trucks needed for each alternative can be estimated by finding the maximum time required for a fork truck to complete an operation (load or unload). The speed of the fork truck is found from manufacturer's literature.

Travel Speed (Loaded)	- 6.8 mph or 598.4 ft./min
Travel Speed (Unloaded)	- 7.4 mph or 651.2 ft./min
Lifting Speed (Loaded)	- 51.2 ft./min
Lifting Speed (Unloaded)	- 66.9 ft./min

The maximum distance traveled by a fork truck is approximated below:

For Roll Storage	- 160 feet
For Finish Product Warehouse	- 200 feet
Distance Between Presses	- 320 feet
For Shipping	- 100 feet

The maximum lifting height is shown below:

For Roll Storage	- 15 feet
For Loading AGV's	- 3 feet
For Finished Product Storage	- 20 feet
For Pallets on the floor	- 2 feet

Therefore, the above data can be used to find the approximate maximum time needed for each operation. For example, the time required to lift with a load (getting a paper roll).

= (maximum height)(maximum speed loaded)

= (15 feet)(51.2 feet/min.) = .29 min.

These time calculations are tabulated for all alternatives in Table F-1, F-2, F-3, and F-4.

Each operation of the fork truck in the process of loading and unloading from one point (point 1) to another (point 2) is totaled in column 10. The total time is compared with time between loads needed for loading or unloading (column 11). By comparing columns 10 and 11, the approximate number of forks trucks needed can be estimated. One extra truck is added to each system for a backup.

TABLE F-1: NUMBER OF TRUCKS NEEDED FOR AGV'S FOR PRESENT PRODUCT MIX

Location	Point 1	Point 2	Time at Point 1		Time at Point 2		Travel Time from 1 to 2		Total Time	Between Loads for Loading or Unloading	No. of Trucks Needed
			Lifting Time Without Load	Lifting Time With Load	Lifting Time Without Load	Lifting Time With Load	Without Load	With Load			
Roll Storage	AGV stop 1	Max Dist to stock	.03	.04	.29	.22	.25	.27	1.10		
Roll Storage	AGV Stop 2&3	Max Dist to stock	.03	.04	.29	.22	.31	.33	1.22	4 min.	1
Roll Storage	AGV Stop 1	AGV 2&3	--	--	--	--	.49	.53	1.02		
Production Area (for rolls)	At any press	Max Dist to Next Press	.03	.04	.03	.04	.49	.49	1.12	5.45 min	1
Shipping	AGV Stop	Max Dist for Loading	.04	.06	.04	.06	.15	.17	.52	9.71 min	1

TABLE F-1 (Continued)

Location	Point 1	Point 2	Time at Point 1		Time at Point 2		Travel Time from 1 to 2		Total Time	Between Loads for Loading or Unloading	No. of Trucks Needed
			Lifting Time Without Load	Lifting Time With Load	Lifting Time Without Load	Lifting Time With Load	Without Load	With Load			
Ware-house	AGV Stop	Max Dist for Stor-age	.03	.04	.03	.39	.23	.25	1.24	19.23 min	1
										Extra	1
										Total	5

TABLE F-2: NUMBER OF TRUCKS NEEDED FOR CONVEYOR SYSTEM FOR PRESENT PRODUCT MIX

Location	Point 1	Point 2	Time at Point 1		Time at Point 2		Travel Time from 1 to 2		Total Time	Between Loads for Loading or Unloading	No. of Trucks Needed
			Lifting Time Without Load	Lifting Time With Load	Lifting Time Without Load	Lifting Time With Load	Without Load	With Load			
Shipping and Ware-house	Spur Area	Max. dist. to take load	.03	.04	.3	.39	.36	.4	1.52	9 min.	1
						All trucks with clamp attachments should be kept since conveyor system does not convey paper rolls					3
										Extra	1
										Total	5

TABLE F-3: NUMBER OF TRUCKS NEEDED FOR AGVS FOR REDESIGN

Location	Point 1	Point 2	Time at Point 1 Lifting Time Without Load	Time at Point 1 Lifting Time With Load	Time at Point 2 Lifting Time Without Load	Time at Point 2 Lifting Time With Load	Travel Time from 1 to 2 Without Load	Travel Time from 1 to 2 With Load	Total Time	Between Loads for Loading or Unloading	No. of Trucks Needed
Roll Storage	AGV Stop 1	Max dist to stock	.03	.04	.29	.22	.25	.27	1.10 min	2 min	1
Production area (for paper rolls)	At any press	Max dist to next press	.03	.04	.03	.04	.49	.49	1.12 min	2 min	1
Shipping	AGV Stop	Max dist for loading	.03	.04	.03	.04	.15	.17	.46 min	5 min	1
Warehouse	AGV stops	Max dist for storing	.03	.04	.3	.39	.23	.25	1.24 min	7.5 min	1
										Extra	1
										Total	5

TABLE F-4: NUMBER OF TRUCKS REQUIRED FOR CONVEYER SYSTEM FOR REDESIGN

Location	Point 1	Point 2	Time at Point 1 Lifting Time Without Load	Time at Point 1 Lifting Time With Load	Time at Point 2 Lifting Time Without Load	Time at Point 2 LIfting Time With Load	Travel Time from 1 to 2 Without Load	Travel Time from 1 to 2 With Load	Total Time	Between Loads for Loading or Unloading	No. of Trucks Needed
Shipping and ware-house	Spur Area	Max dist to take load	.03	.04	.3	.39	.36	.4	1.52	3 min	1
						All trucks with clamp attachment should be kept since conveyor system does not convey paper rolls					3
										Extra	1
										Total	5

APPENDIX G

COST SOURCE

Systems Configuration

Classically this follows the avenue of the three primary innovation methods:

* Creativity through technology synthesis
  - for example, putting known wire-guidance principles to known fork truck designs.
* Creativity through deductive methodologies
  - for example, to have a think-tank-team arrive at the best facility design by "cross-pollination" while following established innovation goals along also defined innovation parameters
* Creativity through idea sparks
  - for example, some of Edison's accomplishments

...... which, however, availed themselves and were inspired by the happy blend of really all three of these creativity exercises.

XII) COST CONSIDERATIONS

MOST COSTING FOR TRANSPORT SYSTEMS SERVES THE INITIAL PURPOSE OF ESTABLISHING FEASIBILITY AND COMPARATIVE CAPITAL EXPENDITURE AND OPERATING COSTS TO ARRIVE AT A VALUATION OF A PROJECT.

TO THIS END BALL PARK ESTIMATES of 10%-20% accuracy levels are acceptable and a 1979 (February Modern Materials Handling Magazine article by Jon Wiltse of Syracuse, NY) will serve as base-pricing-data; though updated and appropriated to this paper.

OVERVIEW COST CONSIDERATIONS

1. Conveyor equipment - $
2. Freight - $
3. Mechanical installation - $
4. Air piping - $
5. Controls - $
6. Field wiring - $
7. Engineering - $
8. Tune and test - $

1. CONVEYOR EQUIPMENT COST

The equipment represents the costliest part of any system. Because of this you can simply determine the system price and multiply it by 2.4.

It takes only a little more time to go through all eight categories to get within 10% of the actual price.

The equipment cost includes two major factors: The base cost, which includes the drive unit; and a total length cost. To get the two, you first multiply the "per-ft. of length" cost by the length of the proposed conveyor in feet. Then you add that figure to the "per conveyor" cost, which is the base cost. Use the tables, or curves, shown here for the specific type of package-handling or unit-load conveyor considered.

Usually, there are one or more extras which add to the cost of the conveyor equipment. These are listed in the tables and include: turns, curves, vertical conveyors, transfers, turntables, pallet loaders, safety railings, and catwalks for conveyors mounted overhead.

We are dealing with powered conveyors here, not gravity flow.

All costs are 1983 first half costs, from then index-up for inflation by Industrial Wholesale Indices or an average of these three product codes usually listed by the U.S. Department of Labor Wholesale Price Index: 3097, Fabricated Structural Metal Products; 3106, Electrical Machinery and Equipment; and 3104, General Purpose Machinery and Equipment. Average the increase in all three of these codes to get your inflation multiplier.

Package-Handling Conveyors (Loads 500 lbs. or less)

Type of Conveyor or Equipment	(1)(2) Cost	Installation Time (Hrs.)	Weight (Lbs.)
Level belt conveyors or incline/decline belt conveyors not exceeding a 2 ft. rise in 10 ft.			
Per conveyor...........	$1,200.00	6	380
Per ft. of length......	50.00	0.3	27
Incline/decline belt conveyors or metering and spacing belts.			
Per conveyor...........	2,200.00	12	700
Per ft. of horizontal length................	60.00	0.4	31
Belt driven live roller conveyor or accumulation conveyor.			
Per conveyor...........	1,500.00	9	470
Per ft. of length......	70.00	0.4	35
Gravity conveyor, roller or skate wheel.			
Per ft. of length......	25.00	0.2	23
Each merge or divert.			
Powered................	2,500.00	16	700
Gravity................	600.00	6	250
Each horizontal turn.			
Powered................	2,200.00	8	500
Gravity................	600.00	5	230
Chain driven live roller conveyor.			
Per conveyor...........	1,000.00	-	400
Per ft. of length......	120.00	0.5	175
Chain drive live roller curve....................	1,800.00	8	800
Vertical conveyor, reciprocating or continuous.	40,000.00	24	2,000
Automatic pallet loader/ unitizer			
Simple line feed.......	88,000.00	48	10,000
Multiple line feed.....	120,000.00	48	17,000

(1) F.O.B. Supplier's factory
(2) Equipment costs are based on 24-inch wide conveyors. For narrower conveyors, deduct 10% (0.90 multiplier). For wider conveyors, add 12% (1.12 multiplier).

[1]Hanelt, Henry. "Conveyors and Related Equipment." Paper presented at Advance Institute (MHI) for Material Handling Teachers Conference, Auburn University, June 1983.

Unit-Load Conveyors (Loads 500 to 4,000 lbs.)

Type of Conveyor or Equipment	(1)(2) Cost	Installation Time (Hrs.)	Weight (Lbs.)
Two strand chain conveyor			
Per conveyor..........	$3,500.00	11	1,200
Per ft. of conveyor....	160.00	0.7	61
Three strand chain conveyor			
Per conveyor..........	4,500.00	15	1,700
Per ft. of conveyor....	130.00	1.0	85
Chain driven live roller conveyor			
Per conveyor..........	2,300.00	-	500
Per ft. of conveyor....	200.00	0.5	235
Heavy-duty gravity roller conveyor			
Per ft. of conveyor....	80.00	0.3	200
Accumulation zone, per unit load..............	1,200.00	3	260
Vertical conveyor, 12 to 15 ft. average			
Per conveyor..........	42,000.00	220	15,000
Per conveyor with fire doors................	39,000.00	240	16,000
Transfer car, with powered conveyor........	8,000.00	40	3,500
Turntable, with powered conveyor..............	8,000.00	24	3,000
Chain driven live roller curve..................	6,000.00	16	2,000
Each merge or divert.....	4,000.00	5	800
Pallet dispenser/collector	12,000.00	24	1,800
Other equipment			
Conveyor walk-over.......	1,000.00	4	200
Fork truck bumper........	300.00	1	150
Safety railing, per ft...	50.00	0.2	6
30-inch catwalk			
Guide rail, one side, per ft...............	120.00	0.4	30
Guide rail, both sides, per ft...............	200.00	0.4	25
Screen guards (spill guard), per ft..........	30.00	0.4	10

(1) F.O.B. Supplier's factory
(2) Costs are based on conveying a 40 by 48 inch pallet. If the loads are 60 inches wide or more, add 10% (1.10 multiplier) to the price. There is no price reduction for smaller conveyors.

2. FREIGHT CHARGES

Freight charges are based on the total weight of the conveyor equipment, given in the tables for equipment costs.

Use 20,000 lbs. as a typical truck load, and get the freight rate, from the expected supplier's plant, from your traffic department.

In general, freight rates will go as high as $15.00 hundred-weight (cwt), or up to $3,000 for a load weighing 20,000 lbs.

3. MECHANICAL INSTALLATION

This factor can account for as much as 25% of the total system cost. It depends on the number of transfer cars, turntables, and other types of equipment required in the system.

Typical installation times are given in the Equipment Cost Tables. The hourly figure given is for both the "per conveyor" listing and the "per ft. of conveyor." Multiply the "per ft. of conveyor" time by the length of the conveyor. Then add that figure to the "per conveyor" time.

You also have to include the time required to unload the conveyor equipment on your dock and move it to the point of installation in the plant. A typical figure for this is 36 manhours per truck, or about 4 manhours per ton of equipment. A labor rate of $35.00 an hour will suffice.

Three trades are involved in most mechanical conveyor installations: Millwrights, iron workers, and pipe fitters. You should check with a local installer for crew sizes, special requirements such as whether or not a non-working supervisor is needed, and hourly labor rates. For estimating purposes, the $35.00 per manhour rate can be used here, too.

It costs significantly more to suspend a conveyor overhead than it does to mount it on legs on the floor, especially when a superstructure and trusses are needed. Usually a forktruck is needed to lift the conveyor sections into place. Multiply overhead installation by 1.5 x floormounted equipment.

Remember, a separate truck operator will be needed if the millwrights are not qualified to operate the truck. And if the truck is not available in the plant, you should add the cost of renting one. A typical truck rental cost is $750.00 a month.

4. AIR PIPING

Installing compressed-air lines brings three costs into consideration: The cost of each feeder-line tap from the main air line that's mounted overhead, each subsystem drop from the overhead tap to the conveyor, and the air line which runs along the conveyor to each air-operated device.

You must consider both the equipment cost and the cost of installation time. Both costs are given in the Air-Line Equipment Cost table.

The cost of a feeder-line tap from the overhead main line includes the use of black iron pipe with welded fittings. There's a base cost for both equipment and installation time. To the base cost, you add the "per ft. of length" figure multiplied times the length in feet.

The cost of a subsystem drop is a one-time figure, per drop. Each drop is made of copper tubing with soldered fittings. Included in the cost is a main shut-off valve, a drain down with bleed-off valve, a filter with automatic drain, a pressure regulator, and a low air pressure safety switch.

The air-supply line which runs along the conveyor to each air-operated device also has a base equipment cost and a "per ft. of length" cost. Again, you multiply the "per ft. of length" figure by the length in feet and add the result to the base figure.

Air-line runs along the conveyor are made of copper tubing with soldered fittings. Straps are included to attach the tubing to the conveyor supports in practical locations. Hose or piping from the main "T" are coupled to the valves of the air devices by push-lock fittings, with support clamps.

Compressed-Air-Line Costs and Installation Time

Equipment	$	Install Time (Hrs.)
Feeder Line Tap		
Base Cost...............	650.00	21
Per ft. of length.......	20.00	.5
Subsystem Drop, each......	650.00	22
Air Supply Line,		
Each Air Device.........	550.00	3
Per ft. of length.......	10.00	.5

5. CONTROL COSTS

Controls represent one-time costs which apply to both package-handling and unit-load conveyors. If a unit-load conveyor is to be used with a high-rise storage system, a programmable controller will be required to control the movement of the loads. The quoted cost, in the Typical Controls Costs table, of $22,000.00 for a programmable controller includes both programming and installation as well as equipment cost.

Typical Controls Costs - Installed, Not Wired

Portion of System Controlled	$
Flat rate for total system...........	10,000.00
Each Conveyor in system, add-on......	800.00
Each Transfer, add-on................	2,000.00
Each Pushbutton, Lanyard, etc., add-on............................	600.00
Each Programmable Controller, add-on.	22,000.00

6. FIELD WIRING COST

Field wiring, on the average, accounts for 16% of the cost of the total system. For rough estimating purposes, you can simply sum up the costs in categories 1 through 5 and add a figure equal to 16% of the total. For best accuracy, however, you should do it again after you have added in the cost of categories 7 and 8. The costs of 7 and 8 are also represented by percentages of the total system cost.

7. ENGINEERING

Under engineering, two costs are involved. One is mechanical engineering, and is based on the conveyor equipment cost, as a percentage. The percentage is 6% of the conveyor equipment cost F.O.B. the supplier's plant.

The second cost is electrical engineering, and is a function of the controls cost: 25%. The two costs are calculated and added to the total system cost.

8. TUNE AND TEST

This last category can be pinned down simply by adding a figure equal to 2% of the total system cost to that total system cost. And that's it: You're done with the job.

......except, if you are your own project manager or hire an outside firm......

add-on 15% Project Management to properly manage the project. Do this same, if you are your own, as you will indeed incur this cost.

REMEMBER, this is a BALLPARK ONLY, for project evaluation only. A qualified supplier will have to propose your system as a firm fixed price proposal, yet.

To compare alternate transport equipment described in previous chapters, use the following, or obtain pricing from vendors, if you find these prices disagreeable.

AGVS (Smart Vehicle):

Basic Vehicle - Lift-Lower Deck	= $ 50,000/unit
Guidepath	= $ 45/ft.
Basic Computer Control System, incl. Hardware & Software	= $120,000/ea. system
Deposit Stands with L.S. & Wiring	= $ 1,200

Forklift Trucks:

Base Vehicle, El. with Battery & Charger	= $ 42,000/unit
COST OF OPERATOR, all burdens incl.	= $ 32,000/yr.

DSB-Monorail:

Basic Vehicle	= $ 3,600/each
Guidepath with own Support Steel from appropriate Ceiling, incl. Netting	= $ 150/ft.
Lift/Lower Device to Place/Pick-Up Loads	= $ 14,000/each
Pick-Up and Delivery Stands with L.S. and Wiring	= $ 1,200/each
Base Computer Control System	= $120,000/ea. system

Additional Explanation

Computer Control Hardware and Software may be an add-on to conveyor systems if complex functions such as sortation are incorporated. See also Controls Section XIV.

Most of these justification topics apply to any single transport system, especially when that system is part of an integrated Storage and Distribution or flexible manufacturing system.

CASE 3

DIECASTERS

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I. NOTES TO THE INSTRUCTOR

OVERVIEW

At the onset of a project, an industrial engineer usually has only a general understanding of the system and the problem to be studied. He frequently does not have any required information provided to him. Therefore, he must decide what data should be collected. In order to identify this information, he must develop an approach to solving the problem, "a plan of action." Even though the required information is identified, the information may not be in the format preferred.

Therefore, a realistic problem solving process is two-fold. First, the analyst must develop an approach to solving the problem and identify what information is needed. Second, the analyst must utilize the available information obtained to construct a viable solution to the problem.

The Diecaster case study tries to expose students to this two-fold problem solving process. The case study first introduces the general description of the production system. It then forces the students to develop a plan of action for solving the problem. Through this process, the required information can be identified. Following the plan of action, the students "discover" the need for particular information.

Students utilize an Information Request Form (see Statement of Problem, Exhibit F) to request specific information throughout their analysis. When the instructor is convinced that the student have proved a reasonable need to know, the information requested (or related information in a different format) should be provided from the general collection of data (provided with the case).

INFORMATION TO THE INSTRUCTOR

Before using this case study, the instructor should be aware that students would benefit if they were at least familiar with general manufacturing processes. A glossary is used to introduce unfamiliar terms as well as problem specific terminology (shop talk). However, a basic understanding of forecasting is needed in this case study.

In order for an effective learning experience to take place, the instructor must be prudent in releasing the provided collection of data. The instructor should release the information only when convinced the students need this information as exemplified by their plan of action.

There are two reasons for developing this case study with the requirement that students must prove a need for data. First, the alternative of providing all data to the students at the beginning not only tends to overwhelm and confuse them, it limits or otherwise hinders their creative approach to the problem ("if this is the only data we have, then we can only do this"). Second, data is seldom readily available since industrial data cost both time and money to collect.

The following section, Statement of the Problem, is intended to be handed out to the student (or student groups) as the "Assignment."

II. STATEMENT OF THE PROBLEM

INTRODUCTION

Diecaster Inc., a manufacturer of zinc, magnesium, and aluminum automotive diecastings, operates three plants in a small community. The magnesium plant, the first plant built, is near the center of town while the other two plants, aluminum and zinc, are located on the edge of town. A warehouse containing both finished goods and general supplies is also located at a separate location. A sketch of the general location of each facility is provided in Exhibit A.

In the zinc and magnesium plants, the manufacturing process is basically composed of the following operations: diecasting, trim or tumble, inspection, secondary machining, and packing. Secondary machining operations are required to finish the castings to the desired work specifications and quality. Examples of these operations are buffing, deburring, washing, drilling, and reaming.

In contrast, the aluminum plant does not have a basic material flow pattern since different parts require a wide variety of machining operations. Therefore, secondary machining dominates the material flow pattern.

The current site of the aluminum and zinc plants is shown in Exhibit B. Exhibits C, D, and E show the detail layouts of the aluminum, zinc, and magnesium plants respectively.

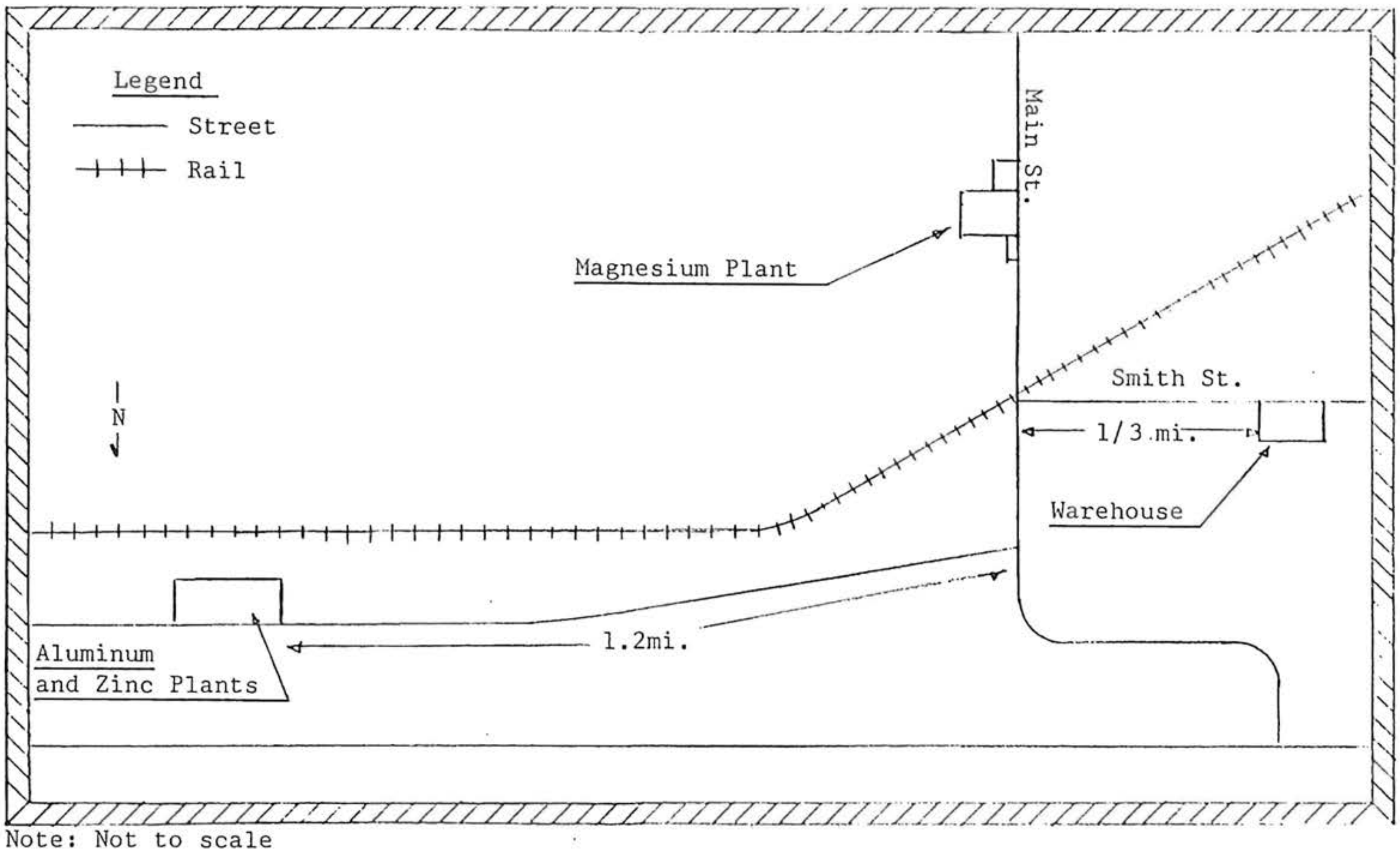


EXHIBIT A: DIECASTER'S FACILITIES

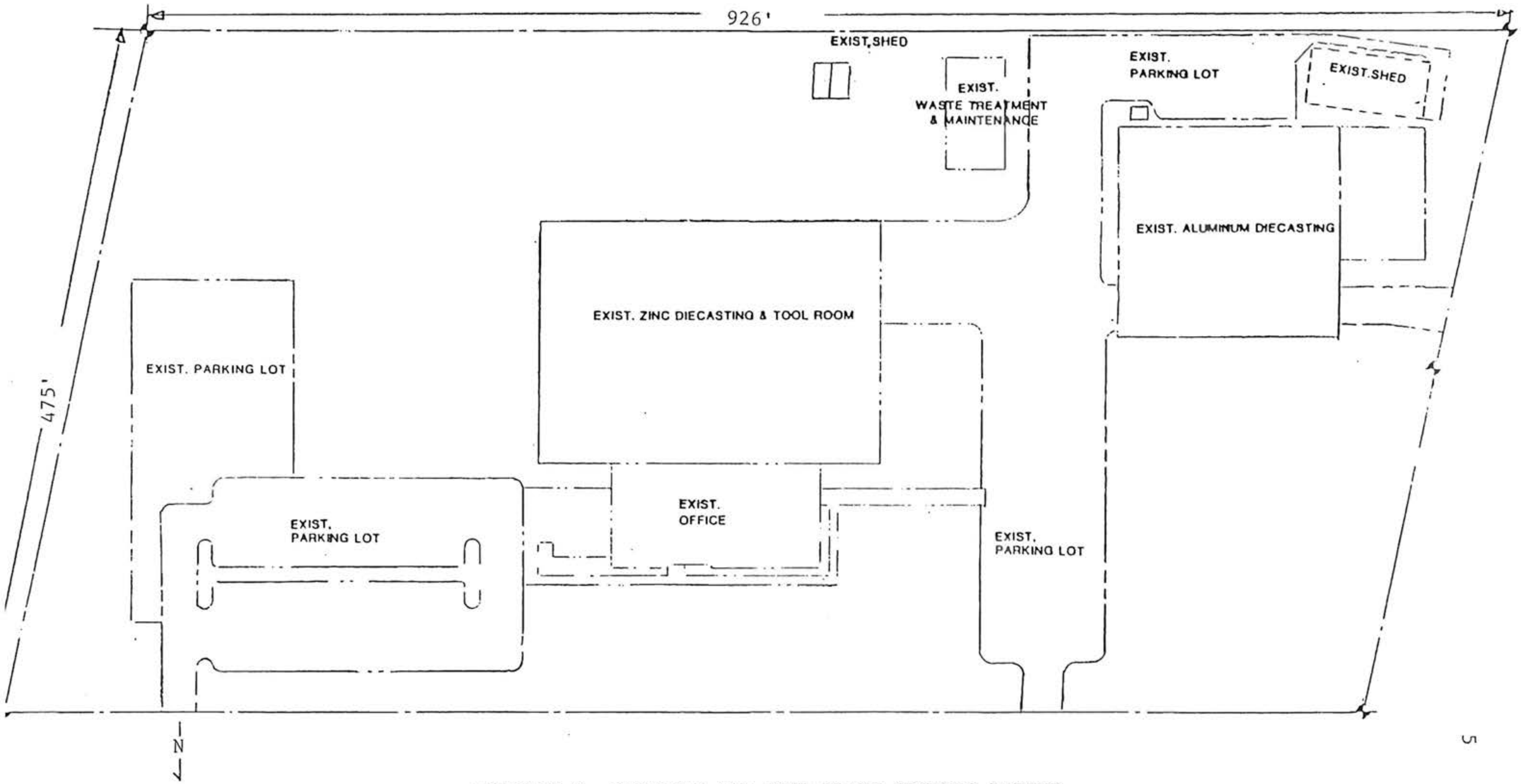
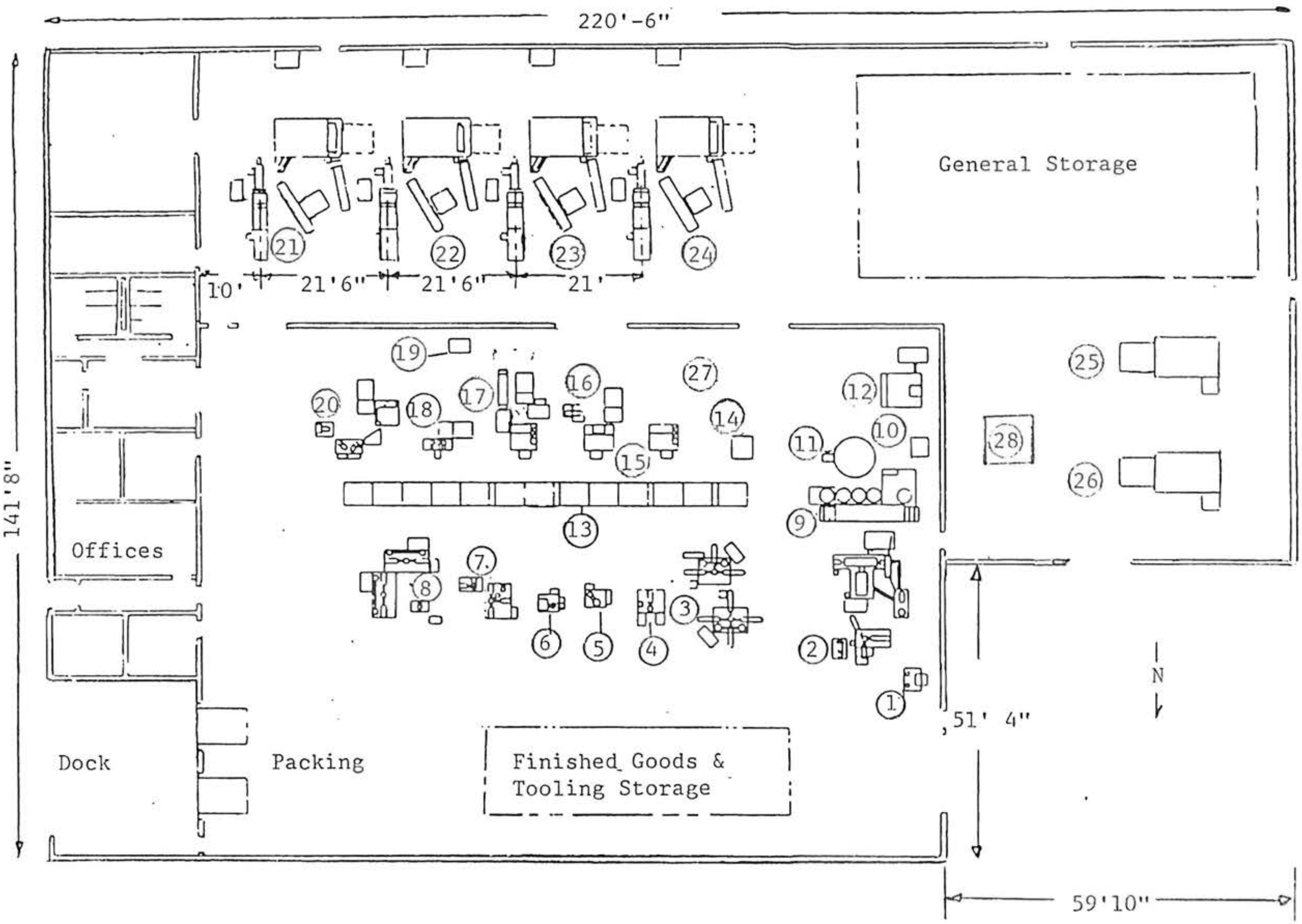


EXHIBIT B: ALUMINUM AND ZINC PLANT GROUNDS LAYOUT

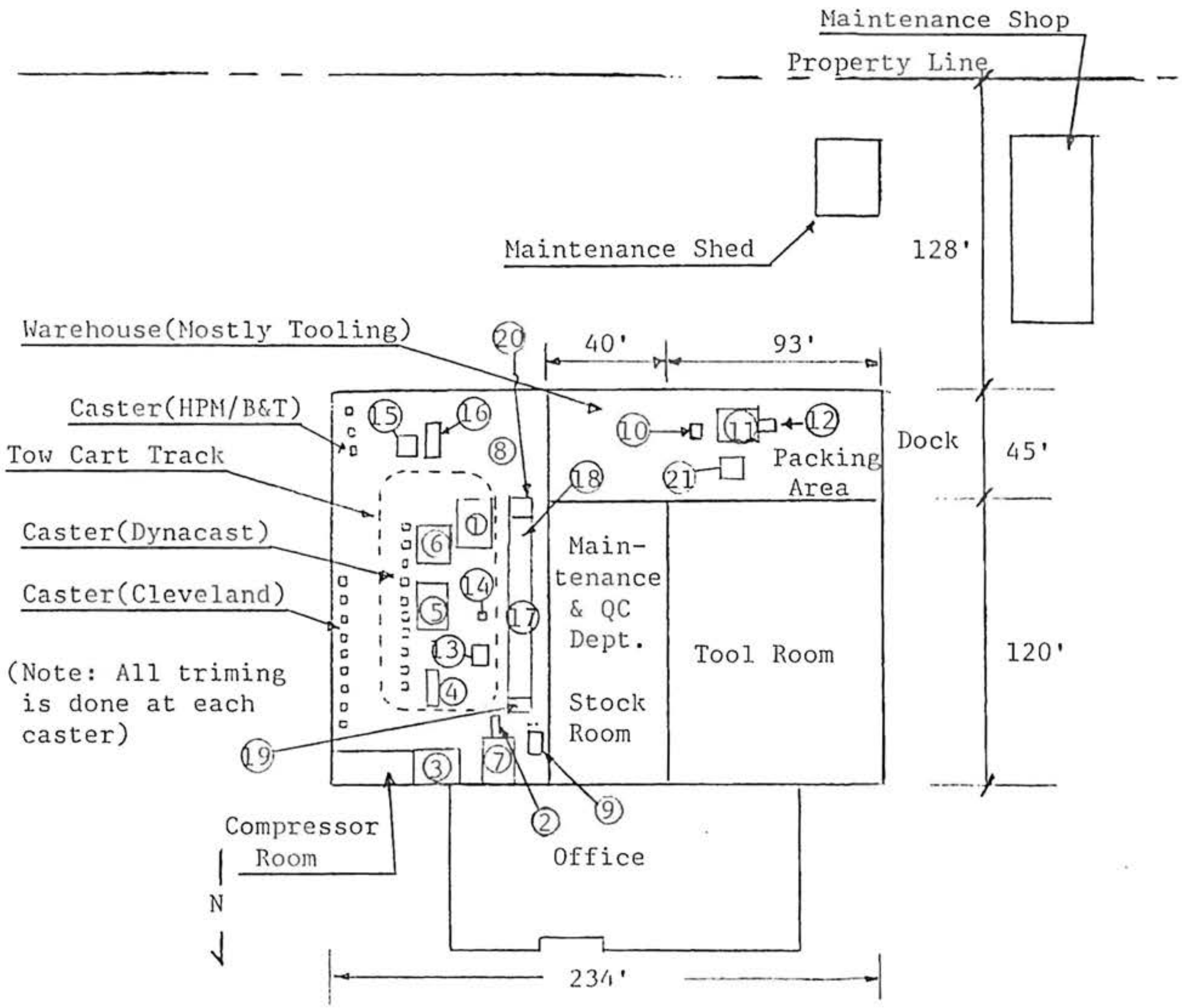


Legend

1. Leak Test (4857)
2. Roch. Ded. Drill (4857)
3. Versa-mate(4857)
4. Drill(4860)
5. Drill(4813)
6. Drill(4843)
7. Drill/Tap(4838,41)
8. Drill/Tap(Putting In Inserts) (4841)
9. Impregnator
10. Tumbler
11. Vibra- Deburr (Vibrating & Deburring)
12. Rotoblast
13. Chromate, Wash, & Dry
14. 3-Way Ecco Drill (4873,75)
15. J & L Lathe (includes Threading & 4865 Reaming)
16. Lathe/Drill/4862 Ream
17. Lathe/Drill/Dry (4830)
18. Drill(4803)
19. Bagger(4840,41)
20. Burnish Operation (4827)
21. Diecast Machine
22. Diecast Machine
23. Diecast Machine
24. Diecast Machine
25. Diecast Machine (Magnesium Caster)
26. Diecast Machine (Magnesium Caster)
27. All Inspections
28. 6067 Machining (For Magnesium Part)

(----)- Production No.

EXHIBIT C: ALUMINUM PLANT LAYOUT

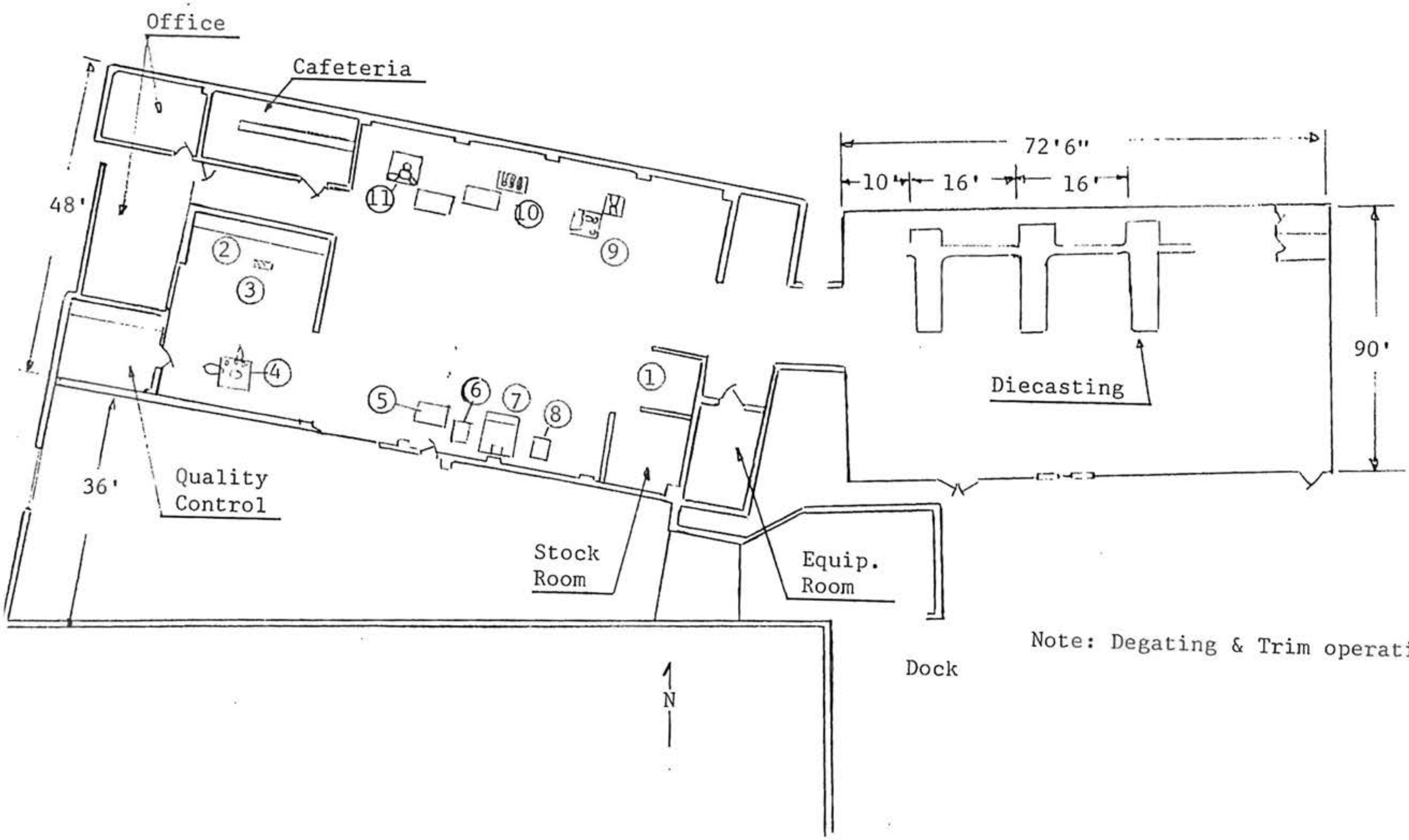


Legend

1. Key Product (Special Machine Oper. (4531)
2. Tapper
3. Waste Area
4. Key Product (Special Machine Oper. (4534)
5. Machine Center (Special Machine Oper.) (4481)
6. Versa-Mate(On Order)
7. Machine Center (Special Machine Oper.) (4564,4465)
8. Inspection & Sorting (for all Inspections)
9. Tapper (4452)
10. Pin & Rivet Press(4408)
11. Buffer
12. Oven
13. Drill(4451)
14. Press(4474)
15. Press(4229)
16. Reamer
17. Chromate,Wash, & Dry
18. Tumbler
19. Deburr
20. Rotoblast
21. 3-M Bonding Machine

(----)- Production No.

EXHIBIT D: ZINC PLANT LAYOUT



Legend

1. Sorting or Inspections
2. Chromate
3. Wash & Dry
4. Rotary
5. Buffer
6. Vibrator
7. Tumbler(deburring operation)
8. Rotoblast
9. Ettco Drill(6053)
10. Drill Roc.(6017)
11. Machine Center (6027)

(----)- Production No.

Note: Degating & Trim operation are done at caster.

EXHIBIT E: MAGNESIUM PLANT LAYOUT

CURRENT SYSTEM PROBLEMS

Because of recent business growth, the present area, expecially secondary machining, is inadequate. Although both zinc and magnesium plants secondary machining has increased, the aluminum plant's secondary machining growth has been more prominent. Along with secondary machining, all production and non-production (finished goods warehouse, office, personnel) space requirements are expected to increase in the future.

In relation to the above problem, management has both short-term and long-term concerns. The short term problem focuses on the immediate inadequacy of secondary machining space, while the long-term concern deals with the actions required periodically to assure adequate facilities to the year 2000.

ASSIGNMENT

Based upon the limited description provided, you are to develop a plan of action for approaching both management concerns (see Current System Problems). Through this effort, specific information which you feel is necessary to solve the problem is to be identified.

To ascertain if this information is available or not, you should complete an Information Request Form (see Exhibit F) and submit it to your instructor. As indicated on the form, you are to relate how the data you request conforms to your plan of action. This is done to justify your perceived need for this type of information consistent with your analysis (as evidenced by your plan of action.)

It is suggested that you do not request a large amount of information at once, but rather, submit your requests on an "as you go" basis while performing your analysis.

EXHIBIT F - INFORMATION REQUEST FORM

DIECASTERS

Request Date ______________ Date Provided ______________________

Team No. _________________ Comments: _________________________

State what information you seek:

Describe how this information relates to your plan of action:

When convinced that your request is justified, the instructor will release to you the information he has. There is no assurance that the data available is what you specifically requested. However, you will be provided with related information, if it is available.

Therefore, the challenge is two-fold. First, you must develop an approach to solving the problem and identify what information is needed. Second, you must utilize the available information obtained to construct a solution to the stated problem.

You are to prepare a report which includes your analysis and recommendations. Your report should be presented in a professional manner. Your instructor will provide you with a set of guidelines for report preparation.

III. PROBLEM ANALYSIS

KNOWN INFORMATION

Presently, only general information is known about Diecaster. This includes:

1. the general location of each plant,
2. the principal products manufactured,
3. the layout of each plant, and
4. the two management concerns.

UNKNOWN INFORMATION

The unknown information includes the following:

1. production figures (historical, present, and predicted),
2. where expansions can be made,
3. the type material handling used,
4. production capacities of the casters, and
5. routings of the material.

PLAN OF ACTION

Based upon the limited description provided, a plan of action for approaching management concerns must be developed. Since the process of determining a feasible solution depends directly on the information available, the plan of action is constructed in flow chart form as shown in Figure 1.

The flow chart includes decision points (diamond symbols)

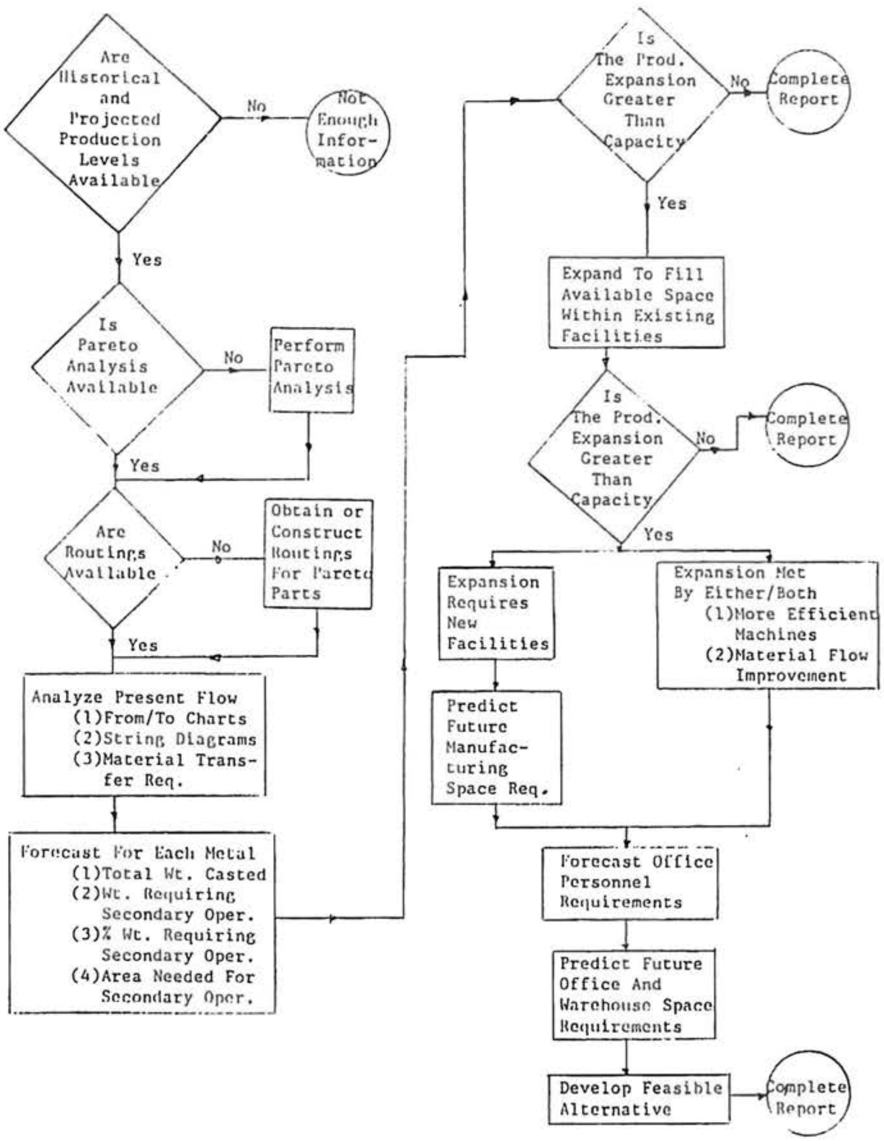


FIGURE 1: PLAN OF ACTION

concerning unknown information or limitations to the system. In order to make a decision, a request for related unknown information is made (Information Request Form is submitted.)

IV. POSSIBLE SOLUTION

PRESENT SYSTEM ANALYSIS

In determining a solution to management's short term concerns, the present material flow is analyzed. The requested information which will be used is:

1. Pareto Analysis of Production (Appendix A),
2. Production Routings (Appendix B),
3. Unit Load Data (Appendix D), and
4. Material Transfer Distances (Appendix E).

Production Routings

This analysis begins with the determination of the production flow through each plant. To facilitate this process, string diagrams are developed for each production routing (see Appendix B).

First, Figure B-1 (Appendix B) illustrates zinc's production flow is principally from casting to trim or tumble, to inspection, and to pack. The production routings of each type of zinc caster are depicted in Figures B-2, B-3, and B-4. Dynacast part's (Figure B-2) primary production flow is from casting to tumble, to inspection, and to pack. The Cleveland parts (Figure B-3) flow from casting to trim, to inspection, and to pack with a large variety of secondary operations. B&T/HPM parts (Figure B-4) flow primarily from casting, to trim, to inspect, and to pack.

The major production flow for magnesium as shown in Figure B-5 is from casting to trim, to inspection, and to pack. Also, the major secondary operation flow is from rotoblast to chromate/wash/dry and to inspection.

In Figure B-6, aluminum parts do not have a specific production flow. Along with wash/dry and inspection, the secondary operations dominate the flow.

In summary, three classes of production flow are present.

1. Primarily direct flow (zinc dynacast, zinc HPM/B&T, magnesium)
2. Moderate machining requirements (zinc cleveland)
3. Diverse production flow (aluminum).

Material Handling Analysis

Using the pareto analysis, production routings, unit load data (Appendix D), and the material transfer distances (Appendix E); the present material transfer requirements can be estimated as shown in Table 1 (see calculations in Appendix F).

The second half of 1984 and the second half of 1986 for magnesium and aluminum illustrate the short term increases in material transfer. In contrast, only 1985 is shown for zinc (pareto parts) because of the limited change in material transfer requirements.

From the above analysis, aluminum shows the largest increase in production volume and material transfer requirements. Also magnesium shows a significant increase. Therefore the management's short term concern is valid.

If the current trend continues, management's long term concern will be valid. To confirm this, the future production volumes and other measures should be forecasted to the year 2000.

TABLE 1. MATERIAL TRANSFER REQUIREMENTS SUMMARY

	Half Year Used in Analysis	Pareto Weight	Avg. # Transfers Per Part	Avg. #Transfers By Conveyor	Avg. #Transfers By Forktruck	Avg. Transfer Distance Conveyor	Avg. Transfer Distance Forktruck	Annual Transfer Requirements (Base Year) Box	Annual Transfer Requirements (Base Year) Pallet
Zinc-Dynacast	'85*	283,182	5.35	3.62	1.63	139'	92'	191,638	2,749
Zinc-Cleveland	'85	1,220,609	5.28	2.52	2.76	142'	133'	203,413	9,163
Zinc-HPM/B&T	'85	358,097	6.39	0.74	5.65	259'	112'	29,851	9,092
TOTAL ZINC								424,902	21,004
MAGNESIUM	'84 '86	485,625 906,398	4.69 4.29	--	4.68 4.29	--	80' 78'	--	8,188 16,504
ALUMINUM	'84 '86	361,916 1,252,170	5.52 3.91	--	5.52 3.91	--	76' 68'	--	5,496 12,383

*85-86 have same results for pareto parts.

FUTURE SYSTEM ANALYSIS

Forecasting Model Development

The measures for the forecasting models are:

1. total weight cast,
2. weight requiring secondary operations,
3. percent of weight requiring secondary operations, and
4. area needed for secondary operations.

These measures are shown in Table 2 with respective historical and short term projected values (see Appendix G). The short term projected values are found by adjusting the pareto projections to reflect total production projections (pareto projections /% of total production making up pareto parts).

Two forecasting models are being considered: linear and exponential. The linear model is based on

Forecast = a + bt (where a is intercept, b is slope, and t is time)

while the exponential is based on

Forecast = $e^{(a + bt)}$ (where a, b, are best fit parameters and t is time).

In Table 3, both models are fitted to the data in Table 2. The "goodness of fit" of each set of data is calculated by a correlation coefficient (R^2). The exponential model is observed to be marginly better than the linear model.

Forecasting

In Tables 4-7, both models (linear and exponential) are used to

TABLE 2: MODEL DATA SUMMARY**

	Historical Data				Projected Data		
	'80	'81	'82	'83	'84*	'85	'86
Total Weight Poured							
Zinc	--	3,923,893	3,777,901	4,026,080	5,087,581	5,374,193	5,905,828
Magnesium	--	532,162	734,770	999,691	1,002,780	1,394,103	2,246,062
Aluminum	--	520,634	409,424	427,177	671,635	1,747,389	2,675,670
TOTAL WEIGHT		4,976,689	4,972,095	5,452,948	6,761,996	8,515,685	10,394,294
Weight Requiring Secondary Machining							
Zinc	1,807,897	649,216	707,011	940,096	2,158,030	2,468,030	2,468,030
Magnesium	144,135	117,262	112,689	162,734	139,344	181,448	213,368
Aluminum	230,539	264,489	261,812	325,516	602,132	1,058,323	1,419,816
Percent of Total Weight Requiring Secondary Operations							
Zinc	--	16.5	18.7	23.3	42.4	45.4	41.7
Magnesium	--	22.0	14.3	16.2	13.9	13.0	11.8
Aluminum	--	50.8	63.9	76.2	89.7	60.5	53.1
Square Feet for Secondary Operations							
Zinc	806	1,178	1,178	1,178	2,286	2,541	2,541
Magnesium	180	180	180	180	349	604	604
Aluminum	275	617	1,760	1,760	3,265	3,634	4,018

*First half is historical and second half predicted
**From Appendix G

TABLE 3. COEFFICIENTS FOR DESCRIPTIVE MODELS

Model	Type	a	b	Base Year (t=0)	R^2	Better Fit
		Total Weight Model				
Zinc	Linear	3,106,574	450,287.2	'80	.8952	
	Expon.	15,011	0.0953	'80		✓
Magnesium	Linear	264,291.2	235,264.5	'80	.9359	
	Expon.	13.0394	0.22444	'80	.9578	✓
Aluminum	Linear	- 428,031.8	429,529.5	'80	.7427	
	Expon.	12.3078	0.37115	'80	.7716	✓
		Weight Requiring Secondary Machining				
Zinc	Linear	1,732,467.1	97,322.9	'79		
	Expon.	14.3798	0.0451	'79		
Magnesium	Linear	101,179.1	12,954.50	'79	.6090	✓
	Expon.	11.5921	0.08079	'79	.5776	
Aluminum	Linear	- 190,456	196,279.3	'79	.8167	
	Expon.	11.7556	0.3236	'79	.9001	✓
		Percent of Weight Requiring Secondary				
Zinc	Linear	56.25	-2.649	'80		
	Expon.	4.0354	-0.05480	'80		
Magnesium	Linear	20.92	-1.634	'80	.7067	
	Expon.	3.0555	-0.10153	'80	.7569	
Aluminum	Linear	64.22	0.4229	'80	.0029	
	Expon.	4.1429	0.0063	'80	.0029	
		Area for Secondary Operations (Footprint)				
Zinc	Linear	1,352.71	172.821	'79		
	Expon.	7.2720	0.0836	'79		
Magnesium	Linear	-1.7143	81.75	'80	.7785	
	Expon.	4.6741	0.2398	'80	.8007	
	Expon.-Drop First Two Points	4.7201	0.3632	'82	.8994	✓
Aluminum	Linear	-382.00	624.75	'80	.9489	✓
	Expon.	5.6528	0.4238	'80	.8642	

TABLE 4. TOTAL WEIGHT PREDICTIONS

	Zinc			Magnesium			Aluminum		
	Actual	Linear Model	Expon. Model	Actual	Linear Model	Expon. Model	Actual	Linear Model	Expon. Model
'81	3,923,893	3,556,861	3,635,655	532,162	499,555	575,986	520,634	1,497.7	320,920
'82	3,777,901	4,007,148	3,999,180	734,770	734,819	720,917	409,424	431,027	465,514
'83	4,026,080	4,457,435	4,399,054	999,691	970,083	903,316	427,177	860,556	674,178
'84	5,087,581	4,907,723	4,838,909	1,002,780	1,205,347	1,129,358	671,635	1,290,086	977,154
'85	5,374,193	5,358,010	5,322,746	1,394,103	1,440,611	1,413,529	1,747,389	1,719,615	1,416,288
'86	5,905,828	5,808,297	5,854,186	1,812,796	1,675,878	1,769,133	2,675,670	2,149,145	2,052,768
'88	--	6,708,871	7,083,463	--	2,146,407	2,771,557	--	3,008,204	4,312,377
'90	--	7,609,445	8,570,869	--	2,616,936	4,341,802	--	3,867,263	9,059,278
'92	--	8,510,020	10,370,602	--	3,087,746	6,801,678	--	4,726,322	19,031,384
2000	--	12,112,317	22,229,034	--	4,969,867	40,963,828	--	8,162,558	37,066,615

TABLE 5. WEIGHT REQUIRING SECONDARY OPERATIONS

	Zinc			Magnesium			Aluminum		
	Actual	Linear Model	Expon. Model	Actual	Linear Model	Expon. Model	Actual	Linear Model	Expon. Model
'80	1,807,897	614,023	1,758,190	144,135	114,133	117,350	230,539	5,773	176,169
'81	2,163,216	1,015,288	1,839,249	117,262	129,088	127,225	264,489	202,002	243,482
'82	2,023,014	1,416,552	1,924,045	112,689	140,042	137,931	261,812	398,231	336,515
'83	1,764,096	1,817,817	2,012,750	162,734	152,997	149,537	325,516	594,461	465,096
'84	2,158,030	2,219,082	2,105,545	139,344	165,951	162,121	602,132	790,690	642,807
'85	2,468,030	2,620,346	2,202,618	181,448	178,906	175,763	1,058,323	986,919	888,420
'86	2,468,030	3,021,611	2,304,167	213,368	191,861	190,553	1,419,816	1,183,149	1,227,880
'88	--	3,824,140	2,521,525	--	217,770	223,972	--	1,575,607	2,345,478
'90	--	4,626,669	2,759,389	--	243,678	263,250	--	1,968,066	4,480,297
'92	--	5,429,198	3,019,688	--	269,581	309,418	--	2,360,524	8,558,196
2000	--	8,639,315	4,330,714	--	373,218	590,546	--	3,930,359	113,941,988

TABLE 6. ACTUAL VS MODEL PREDICTIONS FOR PERCENT OF TOTAL WEIGHT THAT WILL REQUIRE SECONDARY OPERATIONS

	Zinc			Magnesium			Aluminum		
	Actual	Linear Model	Expon. Model	Actual	Linear Model	Expon. Model	Actual	Linear Model	Expon. Model
'80	--	--	--	--	--	--	--	--	--
'81	55.1	53.6	53.5	22	19.2	19.1	50.8	64.6	63.3
'82	53.5	51.0	50.7	14.3	17.7	17.3	63.9	65.1	63.7
'83	43.8	48.3	48.0	16.2	16.0	15.7	76.2	65.5	64.1
'84	42.4	45.7	45.4	13.9	14.3	14.1	89.7	65.9	64.6
'85	45.4	43.0	43.0	13.0	12.7	12.8	60.5	66.3	65.0
'86	41.7	40.4	40.71	11.8	11.1	11.5	53.1	66.8	65.4
'88	--	35.0	36.5	--	7.8	9.4	--	67.6	66.2
'90	--	29.8	32.7	--	4.6	7.6	--	68.4	67.1
'92	--	24.4	29.3	--	1.3	6.3	--	69.3	67.9
2000	--	3.28	18.4	--	<0	2.5	--	73.1	71.9

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TABLE 7. PREDICTIONS FOR SECONDARY MACHINING FOOTPRINTS

	Zinc			Magnesium			Aluminum		
	Actual	Linear Model	Expon. Model	Actual	Linear Model	Expon. Model	Actual	Linear Model	Expon. Model
'80*	1,606	1,526	1,565	180	80	136	275	242	435
'81*	1,778	1,698	1,702	180	161	173	617	867	665
'82*	1,778	1,871	1,850	180	243	220	1,760	1,492	1,016
'83*	1,778	2,044	2,011	180	325	280	1,760	2,117	1,553
'84	2,286	2,217	2,187	349	407	355	3,265	2,741	2,372
'85	2,541	2,390	2,378	604	489	452	3,634	3,367	3,624
'86	2,541	2,564	2,585	604	570	574	4,018	3,991	5,538
'88	--	2,908	3,055	--	734	927	--	5,241	12,926
'90	--	3,254	3,612	--	897	1,498	--	6,490	30,169
'92	--	3,600	4,270	--	1,061	2,419	--	7,739	70,417
2000	--	4,982	8,337	--	1,715	16,479	--	12,737	2,089,844

forecast the measures to year 2000. In the examination of the forecasted data, the exponential model exhibits the characteristic of rapidly increasing in latter forecasting periods. Because of this characteristic, the linear model is chosen as the appropriate forecasting model.

PRODUCTION EXPANSION ALTERNATIVE DEVELOPMENT

Capacity Analysis

The present production capacity can be compared to the future capacities by comparing the number of casters and secondary machining space required. This is illustrated in Table 8.

Aluminum's and zinc's secondary machining will increase very rapidly causing short term space inadequacies. All three plants will have insufficient space for the long term production expansion (refer to Exhibits C-E).

Selection of Production Expansion Alternative

To alleviate the future production space inadequacies, there are four possible alternatives:

1. plant expansion

2. increase productivity through technology improvement (obtain more efficient machines and casters)

3. increase productivity through material flow improvements

4. increase productivity, through technology and material flow improvements.

Since the available general information eliminates alternatives two

TABLE 8: CAPACITY COMPARISON

Metal	Production Measures	Present	Forecasted (Yrs.) 1985	1986	1988	1990	1992	2000
Aluminum	No. of Casters*	4	6	8	11	14	17	29
	Secondary Machining Footprints (ft^2)**	4,230	3,637	3,991	5,421	6,490	7,739	12,737
Zinc	No. of Casters*	23	23	24	29	33	37	52
	Secondary Machining Footprints (ft^2)**	2,400	2,390	2,564	2,098	3,254	3,600	4,982
Magnesium	No. of Casters*	5	5	6	7	9	10	16
	Secondary Machining Footprints (ft^2)**	604	489	570	734	897	1,061	1,715

*No. of Casters = wt. casted per yr. (Table 4)/Annual Caster Capacity (Appendix H)
**Table 7

through four, the plant expansion option is considered. Therefore, the future space requirements must be predicted.

Manufacturing Space Requirements

Assuming the production volume is proportional to the diecasting space in use, the forecasted data (Tables 4-7) along with a set of developed ratios (Table 9) can be used to predict future manufacturing space requirements. These space requirements are shown in Tables 10, 11, and 12.

SUPPORT FACILITIES DEVELOPMENT

By similar forecasting models, the support facilities (offices, finish goods warehouse, and general warehouse) can be predicted through the year 2000. Each support facility is considered below.

Office Area

Future office space needs are predicted by first forecasting future staff requirements. Then the office space requirements of each year are calculated in proportion to the present staff to space ratio.

In Table 13, two models, linear and exponential, are developed using historical data (see Appendix I). Both models have a high correlation, however, in Table 14 the exponential model increases too rapidly in future periods. Therefore, the linear model is chosen as the appropriate forecasting model.

By using the present space to employee ratio (225 $ft.^2$/employee) the predicted office space required can be calculated. This is presented in Table 15.

TABLE 9: SUMMARY OF CONVERSION RATIOS

	Base Year	Weight Cast	Casters	Area/ Caster***	Wt. Cast/ Caster**	Expected Number of Box Transfers	Expected**** Number of Pallet Transfers	Secondary*** Footprint Area	Total Area Secondary Operations*	Secondary Area/ Footprint
Zinc	('85)	5,374,193	23	425	233,660	424,902	21,004	2,541	12,475	4.91
Magnesium	('86)	1,675,878	6	800	320,866	--	16,504	604	3,838	6.35
Aluminum	('86)	2,149,145	9	800	289,785	--	12,383	4,018	11,950	2.97

*Including chromate and inspect/pack.
**See Appendix H
***See Appendix G
****See Table 1

TABLE 10. ZINC MANUFACTURING REQUIREMENTS PROJECTION

Weight	'86	'88	'90	'92	2000
(1) Weight Cast*	5,808,297	6,708,871	7,609,446	8,510,020	12,112,317
(2) Weight Requiring Secondary**** Machining	2,304,167	2,521,525	2,759,389	3,019,688	4,330,714
(3) % Weight Requiring Secondary* Using (1)/(2)	39.7	37.6	36.2	35.4	35.7
Area					
(4) Machine Footprint	2,564	2,908	3,254	3,600	4,982
(5) Secondary Area Required**	12,102	13,726	15,359	16,992	23,515
(6) Number of Diecasters**	24	29	33	37	52
(7) Diecasting Area**	10,200	12,325	14,025	15,725	22,100
Material Handling Requirements* **					
(8) Total Boxes Transferred**	459,223	530,426	601,629	672,831	957,641
(9) Pallet Transfers**	22,701	26,220	29,740	33,260	47,339

*Using best fit model as predictor.

**Using ratios in Table 9.

***Assuming same set-up as present manufacturing.

****Using best fit exponential model.

TABLE 11. MAGNESIUM MANUFACTURING REQUIREMENTS PROJECTION

Weight	'86	'88	'90	'92	2000
(1) Weight Cast*	1,675,878	2,146,407	2,616,936	3,087,746	4,969,862
(2) Weight Requiring Secondary Machining	191,861	217,770	243,678	269,581	373,218
(3) % Weight Requiring Secondary* Using (1)/(2)	11.4	10.1	9.3	8.7	7.5
Area					
(4) Machine Footprints*	570	734	897	1,061	1,715
(5) Secondary Area Required**	3,619	4,660	5,695	6,737	10,890
(6) Number of Diecasters*	6	7	9	10	16
(7) Diecasting Area**	4,800	5,600	7,200	8,000	12,800
Material Handling Requirements					
(8) Pallet Transfers**	16,504	21,138	25,772	30,408	48,943

*Using best fit linear model.

**Using ratios in Table 9.

TABLE 12. ALUMINUM MANUFACTURING REQUIREMENTS PROJECTION

Weight	'86	'88	'90	'92	2000
(1) Weight Cast*	2,149,145	3,008,704	3,867,263	4,726,322	8,162,558
(2) Weight Requiring Secondary* Machining	1,183,149	1,575,607	1,968,066	2,360,524	3,930,359
(3) % Weight Requiring Secondary	55.1	52.3	50.8	49.9	48.2
Area					
(4) Machine Footprint*	3,991	5,241	6,490	7,739	12,737
(5) Secondary Area Required**	11,853	15,565	19,275	22,984	37,828
(6) Number of Diecasters**	8	11	14	17	29
(7) Diecasting Area**	6,400	8,800	11,700	13,600	23,200
Material Handling Requirements					
(8) Pallet Transfers**	12,383	17,336	22,282	27,232	47,031

*Using best fit linear model.

**Using ratios in Table 9.

TABLE 13. COEFFICIENTS FOR PERSONNEL DESCRIPTIVE MODELS

	Type	a	b	Base Year t=0	R^2
Corporate Staff - Corp. Admin. Sales, Finance, and Services (excl. tool & die)	Linear	59.5	2.6	'80	.279
	Expon.	4.09	.039	'80	.261
Zinc Management	Linear	9	.800	'80	.800
	Expon.	2.21	.0729	'80	.800
Magnesium Management	Linear	5	0	'80	1.000
	Expon.	5	0	'80	1.000
Aluminum Management	Linear	2	.600	'80	.600
	Expon.	.8432	.1532	'80	.600

TABLE 14. PERSONNEL PREDICTIONS

	Corporate Staff			Zinc Management			Magnesium Management			Aluminum Management		
	Actual	Linear Model	Expon. Model	Actual	Linear Model	Expon. Model	Actual	Linear Model	Expon. Model	Actual	Linear Model	Expon. Model
'81	62	62.1	62.1	10	9.8	9.8	5	5	5	3	2.6	2.7
'82	65	64.7	64.6	10	10.6	10.6	5	5	5	3	3.2	3.2
'83	67	67.3	67.2	12	11.4	11.4	5	5	5	3	4.4	3.7
'84	70	69.9	69.9	12	12.2	12.2	5	5	5	5	5.0	4.3
'86		75.1	75.6		13.8	14.1		5	5		5.6	5.8
'88		80.3	81.9		15.4	16.4		5	5		6.8	7.9
'90		85.5	88.6		17	18.9		5	5		8.0	10.8
'92		90.7	95.9		18.6	21.9		5	5		9.2	14.6
2000		111.5	131.4		25	39.3		5	5		14	49.8

TABLE 15: OFFICE SPACE REQUIRED PREDICTIONS

	'86	'88	'90	'92	2000
Total Management Staff*	100	108	116	124	159
Office Space Required (225 sq.ft./employee)**	22,500	24,300	26,100	27,900	35,775

*From Table 14.

**Estimated.

Finished Goods Warehouse

Since historical warehousing data is not available, the production volume is assumed proportional to warehousing needs. From given information, Smith street warehouse stores approximately 5 percent of annual production. Therefore, the predictions are estimated in Table 16.

General Warehouse

The space needed for the general warehouse is also assumed to be proportional to production volume. With the given ratio (10,355 lbs./pallet), Table 17 is constructed.

RECOMMENDATIONS DEVELOPMENT

In developing a feasible plant expansion proposal, the following criteria are considered.

1. The zinc and aluminum plants can be expanded to the east by 15

TABLE 16. FINISHED GOODS WAREHOUSE SPACE REQUIREMENTS

	'84*	'86	'88	'90	'92	2000
Zinc Weight to be Cast**	5,087,581	5,808,297	6,708,871	7,609,445	8,510,020	12,112,317
Number of Pallets @ 1000 lbs.	5,087	5,808	6,708	7,609	8,510	12,112
Magnesium Weight to be Cast**	1,002,780	1,675,878	2,146,407	2,616,936	3,087,746	4,969,867
Number of Pallets @ 583 lbs.	1,720	2,875	3,682	4,489	5,296	8,525
Aluminum Weight to be Cast**	427,177	1,183,149	1,575,607	1,968,066	2,360,524	3,930,359
Number of Pallets @ 797 lbs.	536	1,484	1,977	2,469	2,962	4,931
(1) TOTAL PALLETS/YR	7,343	10,167	12,367	14,567	16,768	25,568
Warehouse Skid Requirements***	324	448	545	642	739	1,126

*Actual (1984)(ref. Table 4)

**Using best fit linear model.

***Total Pallets/22.7.

TABLE 17. GENERAL WAREHOUSE SPACE REQUIREMENTS

	'84*	'86	'88	'90	'92	2000
Total Weight to be cast**	6,761,996	8,667,324	10,430,885	12,194,417	13,958,290	21,012,543
'Static' Skids	653	837	1,007	1,177	1,348	2,029

*Actual.

**Using best fit linear model.

acres.

2. The current magnesium plant cannot be expanded.

3. Material handling should be minimized.

4. Machine duplication should be kept to a minimum.

With total space requirements summarized in Table 18, a feasible expansion can be now developed.

The proposed design shown in Exhibit G, expands both the aluminum and zinc plants while building a new magnesium plant, general warehouse (not shown), and finished goods warehouse. With the use of a tow-line or an AGV system, the castings could flow from each plant toward the finished goods warehouse. The aluminum and zinc plants will share similar secondary machines when possible.

TABLE 18. TIME PHASE SPACE REQUIREMENTS

	Current Plant & General Whse.	'86 Casting	'86 Secondary	'88 Casting	'88 Secondary	'90 Casting	'90 Secondary	'92 Casting	'92 Secondary	2000 Casting	2000 Secondary
Zinc	27,400*	10,200	12,102	12,325	13,726	14,025	15,359	15,725	16,992	22,100	23,515
Magnesium		4,800	3,619	5,600	4,660	7,800	5,695	8,000	6,737	12,800	10,890
Aluminum	23,200**	6,400	11,853	8,800	15,565	11,700	19,275	13,600	22,984	23,200	37,828
Combined Zinc and Aluminum		16,600	23,955	21,125	29,291	25,725	34,634	29,325	39,976	45,300	61,343
Offices	--	22,500		24,300		26,100		27,900		35,775	
Finished Goods (Pallets)	324	448		545		642		739		1,126	
Static Goods (Pallets)	653	837		1,007		1,177		1,348		2,029	

*Current zinc plant tool and die (10,000 sq. ft.)

**Assuming static warehouse relocated

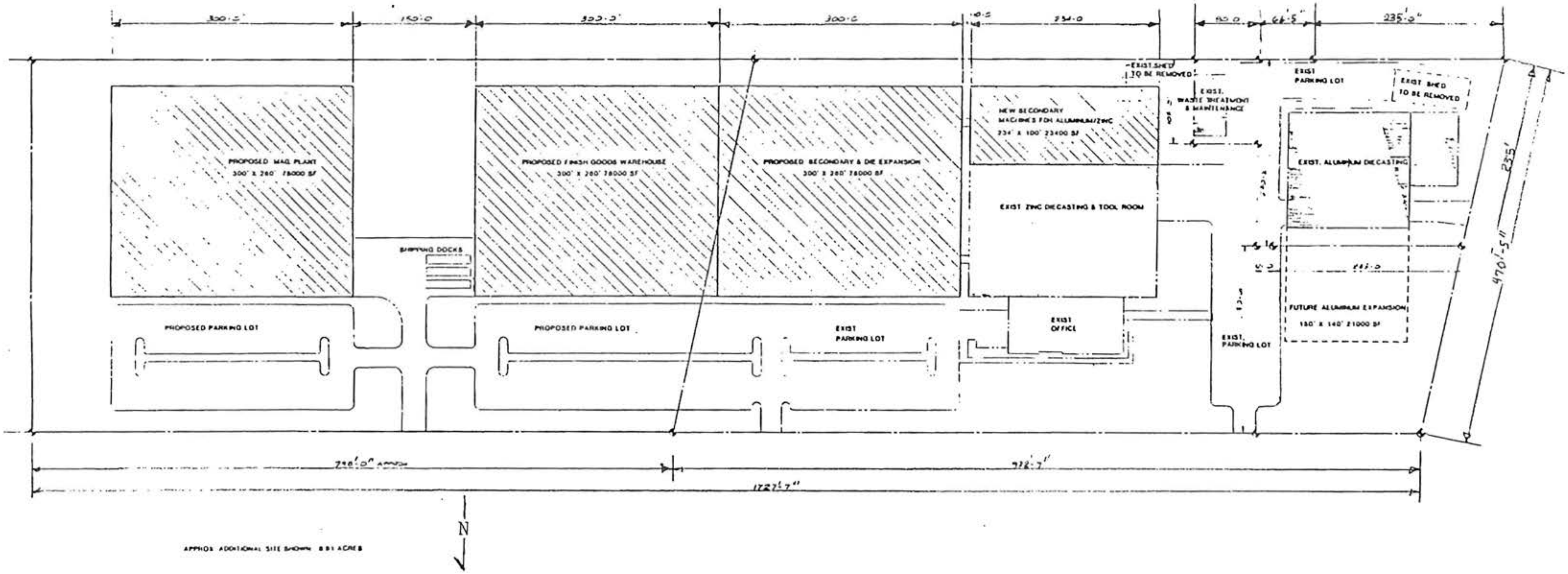


EXHIBIT G: PLANT REDESIGN

V. OTHER POSSIBLE SOLUTIONS

As discussed previously, management's concerns must be solved by plant expansion. However, the design of the expansion will vary among individuals.

There are many expansion possibilities for this problem. However, the expansion should be designed to limit material handling between the plants, as well as, to the finished goods warehouse. Further, the relative expansion cost and the elimination of machine duplication should also be considered in the design process.

APPENDIXES

APPENDIX A

PARETO ANALYSIS

TABLE A-1: PARETO ANALYSIS - ZINC

Part Number	84 - 2nd Half %*	84 - 2nd Half Weight	85 - 1st Half %	85 - 1st Half Weight	85 - 2nd Half %	85 - 2nd Half Weight	86 - 1st Half %	86 - 1st Half Weight	86 - 2nd Half %	86 - 2nd Half Weight
4531	15.8	377,676	14.4	377,676	14.6	377,676	14.6	377,676	14.6	377,676
4464	10.6	252,244	9.7	252,244	9.8	252,244	9.8	252,244	9.8	252,244
4534	7.5	179,907	6.9	179,907	7.0	179,907	7.0	179,907	7.0	179,507
4584	0.0	0	5.9	155,000	6.0	155,000	6.0	155,000	6.0	155,000
4465	6.0	142,692	5.5	142,692	5.5	142,692	5.5	142,692	5.5	142,692
4408	3.3	78,629	3.0	78,629	3.0	78,629	3.0	78,629	3.0	78,629
4451	3.3	77,648	3.0	77,648	3.0	77,648	3.0	77,648	3.0	77,648
4426	3.1	74,690	2.9	74,690	2.9	74,690	2.9	74,690	2.9	74,690
4537	2.7	64,665	2.5	64,655	2.5	64,655	2.5	64,655	2.5	64,655
4389	2.2	51,707	2.0	51,707	2.0	51,707	2.0	51,707	2.0	51,707
4586	2.1	50,000	1.9	50,000	1.9	50,000	1.9	50,000	1.9	50,000
4204	1.9	45,162	1.7	45,162	1.8	45,162	1.8	45,162	1.8	45,162
4229	1.9	44,585	1.7	44,585	1.7	44,585	1.7	44,585	1.7	44,585
4481	1.6	38,835	1.5	38,835	1.5	38,835	1.5	38,835	1.5	38,835
4458	1.6	37,692	1.4	37,692	1.5	37,692	1.5	37,692	1.5	37,692
4288	1.6	38,346	1.5	38,346	1.5	38,346	1.5	38,346	1.5	38,346
4341	1.2	29,061	1.1	29,061	1.1	29,061	1.5	29,061	1.5	29,061
4570	1.1	27,000	1.0	27,000	1.0	27,000	1.0	27,000	1.0	27,000
4407	0.8	19,803	0.8	19,803	0.8	19,803	1.0	19,803	1.0	25,146
4270	1.1	25,146	1.0	25,146	1.0	25,146	1.0	25,146	1.0	25,146
4485	0.9	22,175	0.8	22,175	0.9	22,175	0.9	22,175	0.9	22,175
4393	0.9	21,828	0.8	21,828	0.8	21,828	0.8	21,828	0.8	21,828
4585	1.1	27,200	1.0	27,200	1.0	27,200	1.0	27,200	1.0	27,200
TOTAL	72.3	1,726,691	72.0	1,881,691	72.8	1,881,691	72.8	1,881,691	72.8	1,881,691
Total Metal Incl. New Business		2,387,588		2,613,679		2,760,514		2,952,914		2,952,914
Total Metal Excl. New Business		2,387,588		2,613,679		2,576,314		2,576,314		2,576,314

*Percent of total zinc to be poured

TABLE A-1-1: ZINC-PARETO ANALYSIS - Summary by Caster Type

	'84*	'84**	'85*	'86	'87
	Weight Represented in Pareto				
Dynacast	283,182	283,182	283.182	283,182	283,182
Cleveland	1,085,412	1,240,412	1,240,412	1,240,412	1,240,412
HPM/B&T	358,097	358,097	358,097	358,097	358,097
	Total Weight to be Cast (Incl. New Business)				
Dynacast	707,815	712,720	781,871	826,232	226,232
Cleveland	1,328,003	1,657,106	1,648,571	1,783,671	1,785,671
HPM/B&T	375,438	375,438	394,738	414,038	414,038
	% Total Weight to be Cast in Pareto				
Dynacast	.40	.397	.362	.342	.342
Cleveland	.817	.748	.752	.695	.695
HPM/B&T	.953	.953	.907	.864	.864

*First half of year.

**Second half of year.

TABLE A-2: PARETO ANALYSIS - MAGNESIUM

Part Number	84 - 2nd Half %	84 - 2nd Half Weight	85 - 1st Half %	85 - 1st Half Weight	85 - 2nd Half %	85 - 2nd Half Weight	86 - 1st Half %	86 - 1st Half Weight	86 - 2nd Half %	86 - 2nd Half Weight
6035	49.1	250,560	36.5	250,560	26.6	250,560	22.3	250,560	22.3	250,560
6059	22.1	112,800	16.4	112,800	18.0	169,200	15.1	169,200	15.1	169,200
6052	--	0	10.9	74,775	8.0	74,775	6.7	74,775	6.7	74,775
6046	0.9	4,472	3.1	21,463	2.3	21,463	6.0	67,073	6.0	67,073
6017	12.4	63,120	9.2	63,120	6.7	63,120	5.6	63,120	5.6	63,120
6047	0.8	3,956	2.8	18,986	6.3	59,333	5.3	59,333	5.3	59,333
6045	0.5	2,389	1.7	11,467	1.2	11,467	3.2	35,835	3.2	35,835
6044	0.4	2,224	1.5	10,673	1.1	10,673	3.0	33,353	3.0	33,353
6067	--	0	--	0	3.1	29,000	2.6	29,000	2.6	29,000
6041	4.5	22,800	3.3	22,800	2.4	22,800	2.0	22,800	2.0	22,800
6057	0.6	3,250	0.9	6,500	0.7	6,500	1.7	19,500	1.7	19,500
6063	--	0	1.5	10,230	1.1	10,230	1.4	15,345	1.4	15,345
6053	2.6	13,104	1.9	13,104	1.4	13,104	1.2	13,104	1.2	13,104
6054	0.6	2,950	0.9	5,900	0.6	5,900	1.6	17,700	1.6	17,700
6055	0.4	2,000	0.6	4,000	0.4	4,000	1.1	12,000	1.1	12,000
6056	0.4	2,000	0.6	4,000	0.4	4,000	1.1	12,000	1.1	12,000
6064	--	0	1.1	7,800	0.8	7,800	1.0	11,700	1.0	11,700
TOTALS	95.3	485,625	93.0	634,178	81.4	759,925	80.9	906,398	80.9	906,398
Total to be Poured		509,343		686,058		938,963		1,123,031		1,123,031

TABLE A-3: PARETO ANALYSIS - ALUMINUM

	84 - 2nd Half		85 - 1st Half		85 - 2nd Half		86 - 1st Half		86 - 2nd Half	
Part Number	%	Weight	%	Weight	%	Weight	%	Weight	%	Weight
4870/89	--	0	--	0	20.1	250,800	19.1	250,800	19.1	250,800
4891	--	0	--	0	8.8	110,000	8.9	117,000	9.4	117,000
4882/4	--	0	2.2	10,000	14.0	175,000	13.4	175,000	13.4	
4871	--	0	--	0	8.8	110,400	8.4	110,400	8.4	110,400
4873	10.0	39,680	17.3	79,360	7.5	93,000	7.1	93,000	7.1	93,000
4885	--	0	0.8	3,600	7.2	90,000	6.9	90,000	6.9	90,000
4857	9.4	37,480	16.3	74,960	6.0	74,960	5.7	74,960	5.7	74,960
4881/3	--	0	2.0	9,300	5.6	69,750	5.3	69,750	5.3	69,750
4830	17.5	69,224	15.1	69,224	5.5	69,224	5.3	69,224	5.3	69,224
4803	12.7	50,154	10.9	50,154	4.0	50,154	3.8	50,154	3.8	50,154
4866	7.9	31,300	6.8	31,300	2.5	31,300	2.4	31,300	2.4	31,300
4876	7.0	27,660	6.0	27,660	2.2	27,660	2.1	27,660	2.1	27,660
4894	--	0	--	0	--	0	2.1	26,975	2.1	26,975
4827	8.1	32,138	--	0	--	0	--	0	--	0
4877	5.5	21,850	4.8	21,850	1.8	21,850	1.7	21,850	1.7	21,850
4862	3.3	13,216	2.9	13,216	1.0	13,216	1.0	13,216	1.0	13,216
4865	2.1	8,333	--	0	--	0	--	0	--	0
4813	3.1	12,369	2.7	12,369	1.0	12,369	0.9	12,369	0.9	12,369
4867	2.5	9,800	2.1	9,800	0.8	9,800	0.7	9,800	0.7	9,800
4841	2.2	8,712	1.9	8,712	0.7	8,712	0.7	8,712	0.7	8,712
TOTAL	91.3	361,916	91.8	421,505	97.5	1,218,195	95.5	1,252,170	95.5	1,252,170
Total Metal to be Poured		396,354		458,996		1,247,593		1,299,63		1,308,439

APPENDIX B

PRODUCTION ROUTINGS

TABLE B-1: FROM/TO CHART FOR ZINC

To / From	Trim	Drill	Tumble	1st Insp.	Drill Tap	Sort	Pin & Rivet	Buff	Ream	Bake	Sp. Mach.	Chrom.	2nd Insp.	Wash	Dry	Deburr	Roto.	3-M	3rd Insp.	Pack	4th Insp.
Dynacast Die(1)			**	4389																	
Clev. Die(8)	4464,58 4465,08 4558,51 4393 *			4407							4481										
HPM (15)	4426 4537 4534																				
Trim			4408	4464, 4465 4451, 4426 4458, 4393 4570 4534													4534 4526 4585 4537				
Drill																					
Tumble				4204, 4570 4229 4481 4270 4288 4485									4389				4408				
1st Insp.					4457		4408		4229 4534		4464 4465 4531	4426				4389 4401 4461 4298 4270 4485 4570				***	
Drill/ Tap													4451								
Sort																		4531			4534

* - 4585, 4451
** - 4204, 4485, 4229, 4570, 4288, 4341, 4270
*** - 4584, 4585, 4586, 4537, 4204, 4458, 4341, 4393

TABLE B-1: FROM/TO CHART FOR ZINC(CONTINUED)

From \ To	Trim	Drill	Tumble	1st Insp.	Drill Tap	Sort	Pin & Rivet	Buff	Ream	Bake	Sp. Mach.	Chrom.	2nd Insp.	Wash	Dry	Deburr	Roto.	3-M	3rd Insp.	Pack	4th Insp.
Pin & Rivet													4408								
Ream													4534 4229								
Bake						4534															
Special Mach.			4481									4584	4531		4464 4465				4534		4229
Chrom.				4584 4585 4586						4534					4451 4570 4426 4229 4481 4485						
2nd Insp.						4531					4534	4229		4451			4464 4465	4407		4408 4270 4426 4465 4354 4570 4451 4260 4268	
Wash															4451 4354 4268 4270 4407						
Dry			4389										4464, 4485 4465, 4570 4426, 4457 4461 4248 4220			4451			4451 4229		
Deburr												4451 4481 4485 4570		4389 4288 4270 4407							
Roto				4406 4341 4531 4537							4584	4586 4585							4464 4465		
3-M																			4407		
3rd Insp.											4229	4534								4464 4465 4451 4407 4531	
4th Insp.																				4534 4229	

TABLE B-2: FROM/TO CHART FOR ALUMINUM

From \ To	Trim	Roto-Blast	Vibr/Deburr	Versa-Mate	3-Way Ettco	1st Insp.	Deburr	Drill/Tap	Mach. Bed. Drill	Drill	Tap	Dial Index	Burnish	J & L	Lathe	Thread	Ream	Press-In	Ass'y	Bed. Ass'y	Bed. Ream	Wash	Dry	Tumble	Drill/Ream	Put in Inserts	2nd Insp.	Vibrate	Impregnate	Bag	3rd Insp.	4th Insp.	Leak Test	Pack
Cast	ALL																																	
Trim		4885	4870		4873	*	4881 4882			4877									4876		4894													
Roto-Blast						4885																					4803							
Vibr/Deburr						4870			4857																									
Versa-Mate																						4882 4857												
3-Way Ettco																						4873												
1st Insp.			4857				4841			4830 4803 4862		4891		4865	4827			4866						4813				4865						4872, 82, 71 ← 73, 85, 81, 76, 67, 70
Deburr				4882				4841			4881																							
Drill/Tap																											4841							
Mach. Bed. Drill										4857																								
Drill				4857										4830 4862								4803 4877												
Tap																																		
Dial Index																						4891												
Burnish																	4865					4827												
J & L																4862	4865					4830												
Lathe																	4827																	
Thread																						4862												

*- All but 4885, 4870, 4873, 4877, 4876, 4894, 4881, 4882

TABLE B-2: FROM/TO CHART FOR ALUMINUM(CONTINUED)

From \ To	Trim	Roto-Blast	Vibr/ Deburr	Versa-Mate	3-Way Ettco	1st Insp.	Deburr	Drill/ Tap	Rough. Dod. Drill	Drill	Tap	Diag Index	Burnish	J & L	Lathe	Thread	Ream	Press-In	Ass'y	Dod. Ass'y	Dod. Ream	Wash	Dry	Tumble	Drill/ Ream	Put In Inserts	2nd Insp.	Vibrate	Impregnate	Bag	3rd Insp.	4th Insp.	Leak Test	Pack
Ream													4827 4865														4865							
Press-In																											4866							
Ass'y						4876																												
Dod. Ass'y																																	4894	
Dod. Ream																						4894												
Wash																							*				4857, 30,27 62,91		4827	4891	4865 4813		4877	
Dry		4803				4862, 73, 81														4894														
Tumble																									4813									
Drill/ Ream																											4813							
Put In Inserts																															4891			
2nd Insp.																						4813				4891		4865					4857	4830, 03,66, 27,62, 91
Vibrate																													4865					
Impregnate																						4827 4865												
Bag																																4841		
3rd Insp.																						4891												4865 4813
4th Insp.																																		4841
Leak Test																																		4857 4894 4877
Pack																																		

* 4882, 73, 57, 81, 03, 94, 27, 65, 13, 77, 41,

TABLE B-3: FROM/TO CHART FOR MAGNESIUM

From \ To	Degate	Trim	Tumble	1st Insp.	Roto.	Vibra.	Wash	Deburr	Chrom.	Sort	Drill	Mach.	2nd Insp.	Buff	3rd Insp.	4th Insp.	Pack
Product	6067	ALL BUT 6067															
Degate		6067															
Trim			6041	ALL BUT 6041													
Tumble				6041													
1st Insp.					6045 6041 6044 6055 6064			6035 6052	6059	6054 6057 6046 6047 6063 6053	6017	6067					
Roto.						6053	6056 6055 6064 6045 6044						6041		6017		
Vibra.									6053								
Wash					6017								6056 6055 6064 6045 6044				
Deburr													6052 6035				
Chrom.										6059					6067	6017 6053	
Sort													6054 6046 6059 6057 6063 6047	6053			
Drill													6017		6053		
Mach.													6067				
2nd Insp.							6017				6053			6067			ALL BUT 6067 6017 6053
Buff													6053		6067		
3rd Insp.					6053				6017								6067
4th Insp.																	6017 6053

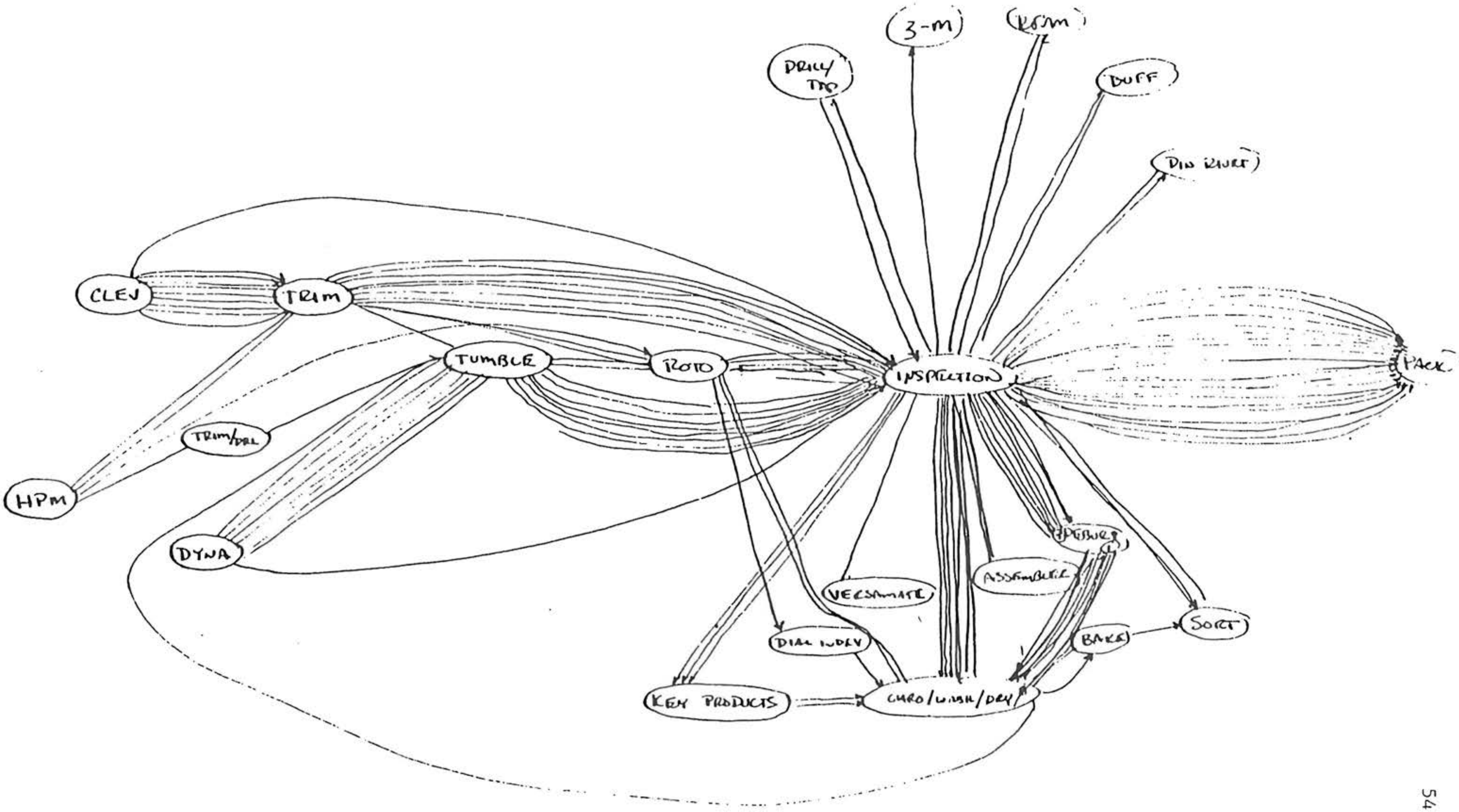


FIGURE B-1: ZINC PARTS- PARTS IN PARETO ANALYSIS

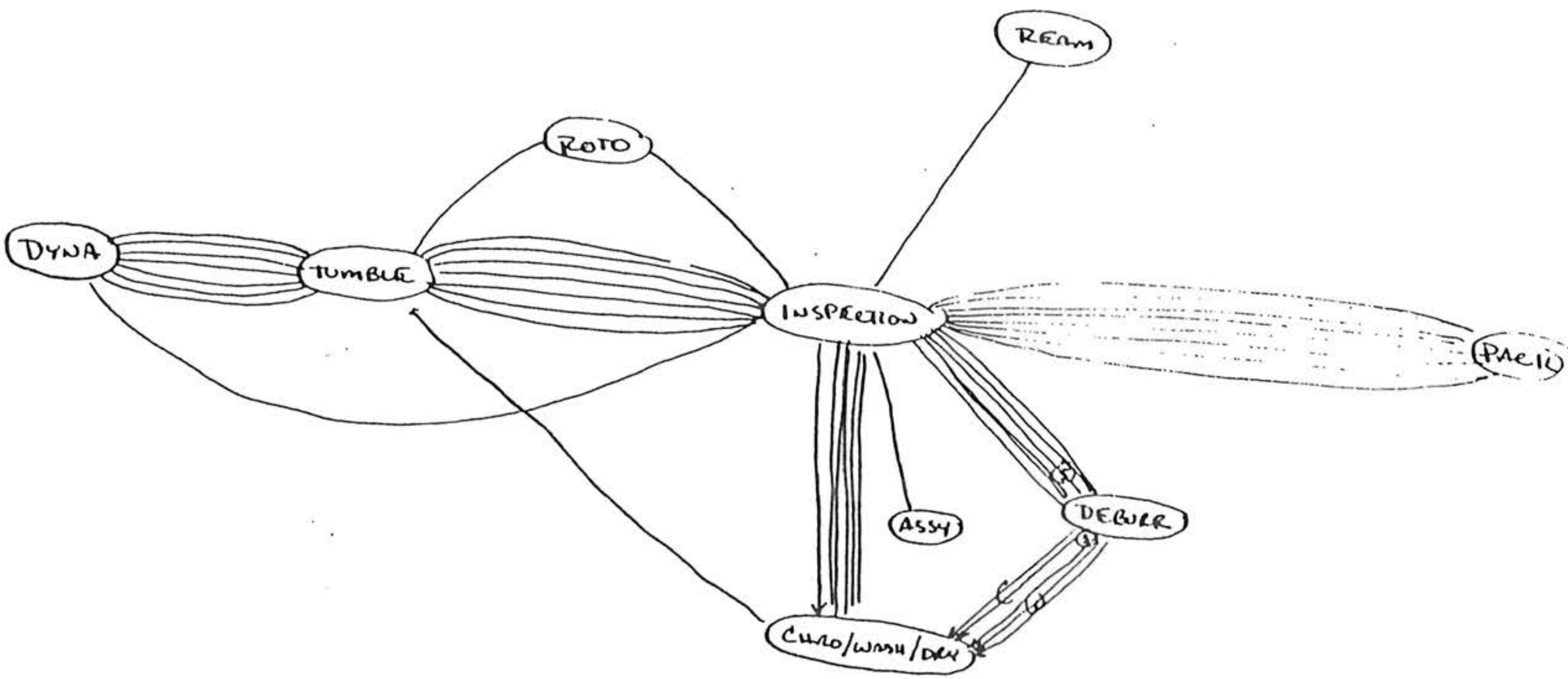


FIGURE B-2: ZINC PARTS - DYNACAST PARTS IN PARETO ANALYSIS

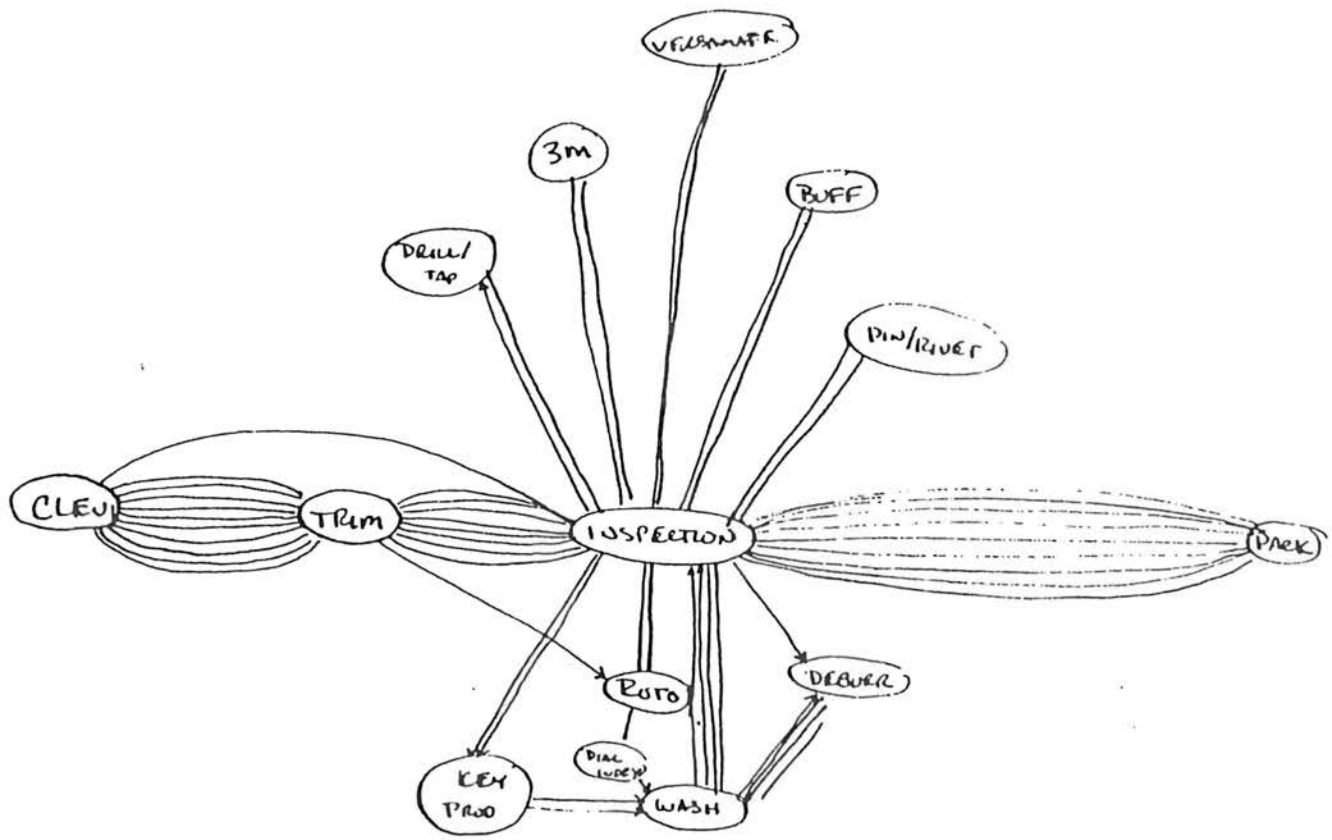


FIGURE B-3: ZINC PARTS - CLEVELAND PARTS IN PARETO ANALYSIS

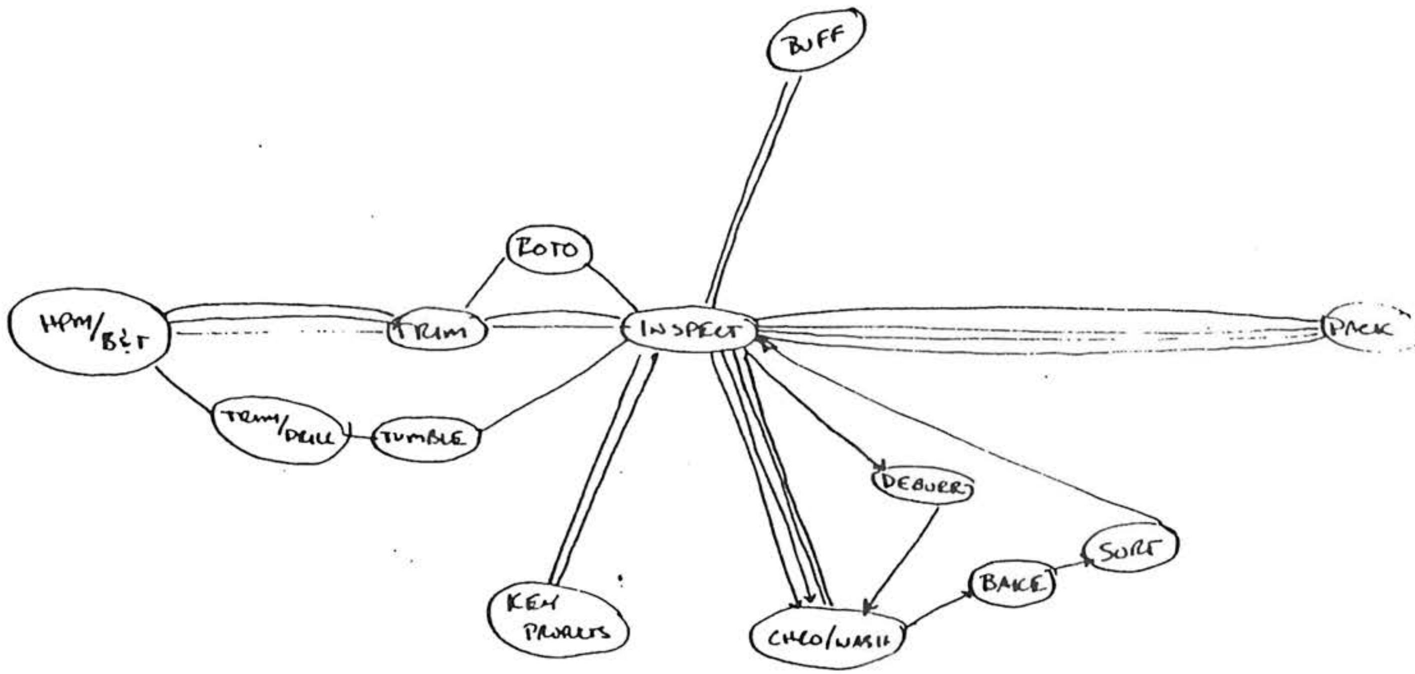


FIGURE B-4: ZINC PARTS - HPM/B&T PARTS IN PARETO ANALYSIS

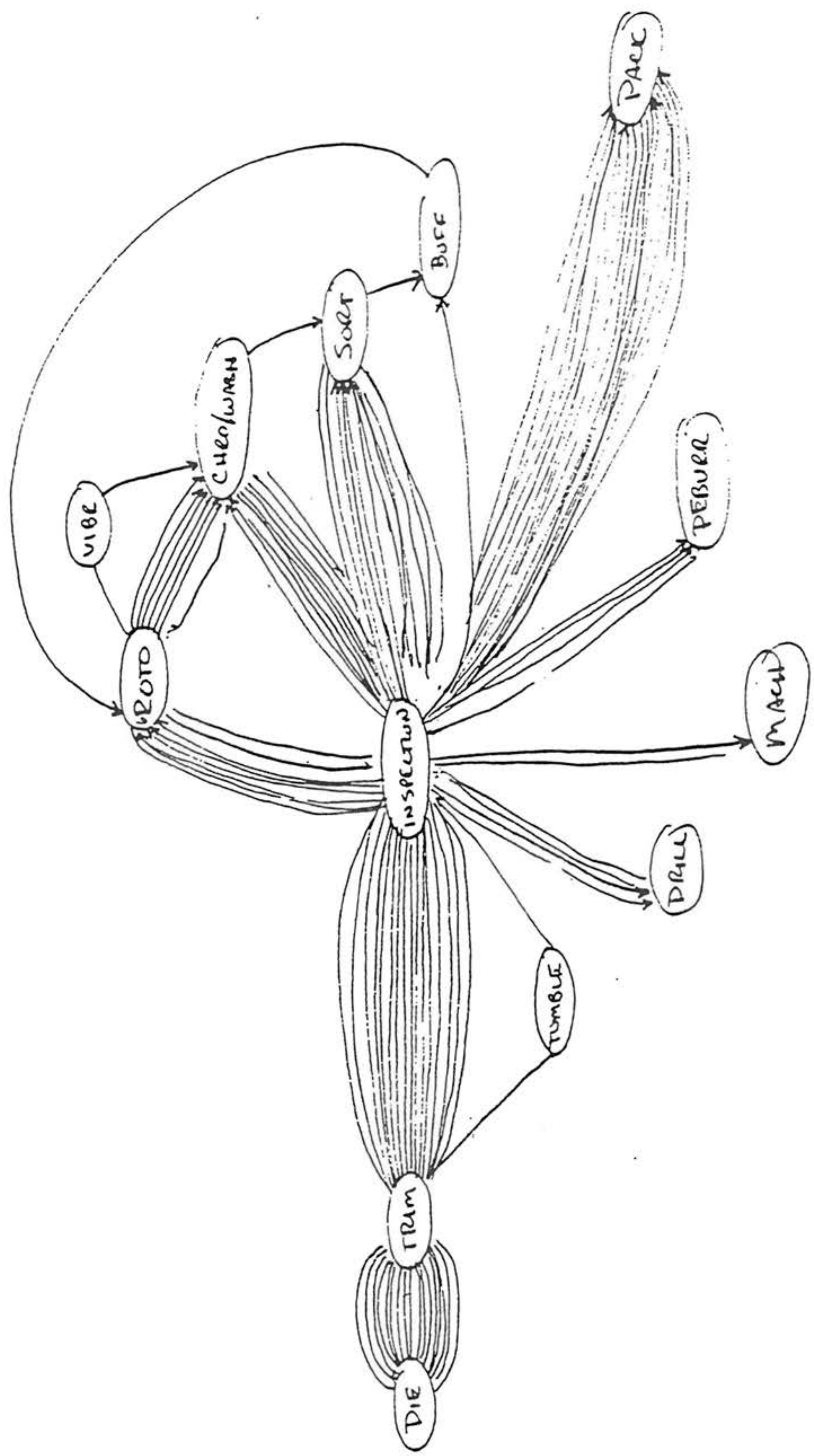


FIGURE B-5: MAGNESIUM PARTS

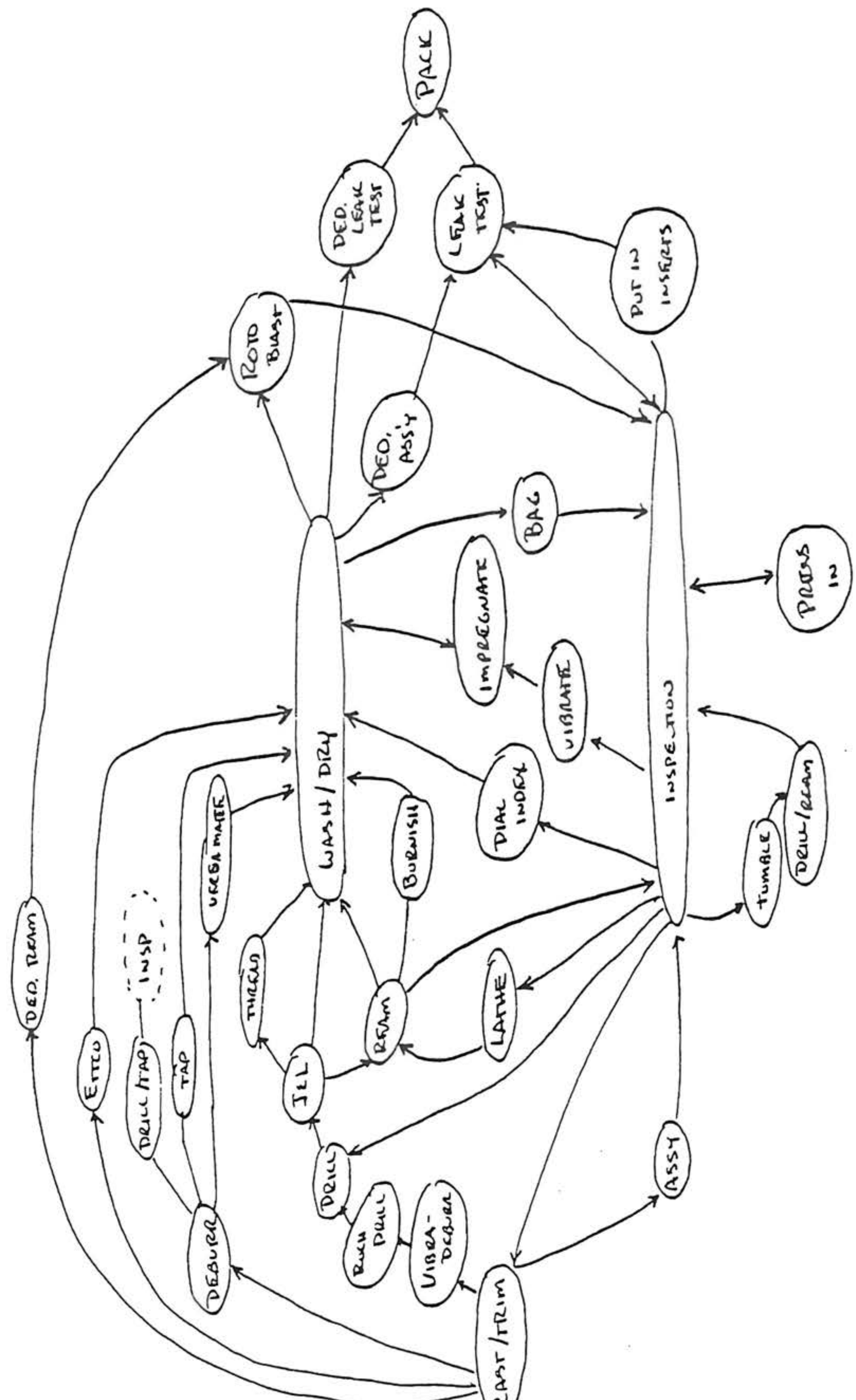


FIGURE B-6: ALUMINUM PARTS

APPENDIX C

AREA AVAILABLE FOR EXPANSION

AREAS AVAILABLE FOR EXPANSION

The magnesium plant cannot be expanded in its present location. The aluminum and zinc plant site can be expanded to the east by extending the present north and south property lines. Fifteen acres are available in this area. Also, management has obtained the option to construct a parking lot on park land owned by a local civic organization immediately to the north of the aluminum and zinc plant site. In return for donating the parking lot, Diecaster would be given use of the lot indefinitely.

APPENDIX D

UNIT LOAD DATA

TABLE D-1: UNIT LOAD DATA - ZINC

Part Number	Caster Type	Box Size* Transfer	Box Size* Final Pack	Wt/Box Transfer	Wt/Box Final Pack	#Box/Skid**
4531	C	Box	8	62.95	62.95	17/skid
4464	C	8	8	48.9	48.9	17/skid
4534	H	Cargo	5	461.3	565	1/skid
4584	C	1	1	53.9	53.9	27/skid
4465	C	#8	#8	48.1	48.1	17/skid
4408	C	1	1	27.2	27.2	27/skid
4451	C	1	2	22.2	57.5	48/skid
4426	H	1	1	26.8	26.8	27/skid
4537	H	2	2	47.9	47.9	48/skid
4389	D	1	1	34.3	37.6	27/skid
4586	C	2	2	18	18	48/skid
4204	D	1	1	28.9	31.4	27/skid
4229	H	Pan	1	38.0	35.4	27/skid
4481	H	1	1	27.7	27.7	27/skid
4458	C	1	1	42.0	42.0	27/skid
4288	D	1	1	32.9	36.5	27/skid
4341	D	1	1	23.0	44.6	27/skid
4570	D	1	1	27.0	29.7	27/skid
4407	C	1	1	25.8	25.8	27/skid
4270	D	1	1	27.0	35.3	27/skid
4485	D	1	1	14.9	30.0	27/skid
4393	C	1	1	23.8	23.8	27/skid
4585	C	2	2	25.8	25.8	48/skid

*Yellow pans were considered equivalent to #1 boxes for material handling estimating purposes.

**Estimated.

TABLE D-2: UNIT LOAD DATA - Magnesium

Part Number	Box Size	Wt./Box	#Boxes/Skid
6035	5	292	1/skid
6054	3	20.65	36/skid
6059	5	188	1/skid
6080			
6052	5	120	1/skid
6075			
6046	5	403	1/skid
6017	Tub,3	34.2, 32.9	36/skid
6047	5,5	403, 403	1/skid
6045	5,5	573, 573	1/skid
6044	5,5	445, 445	1/skid
6067	5	263	1/skid
6027	Tub,2	33.3, 21	48/skid
6041	3,3	42.75, 42.75	17,17/#3 skid
6057	3,5	31.2, 284.7	36,1/skid
6063	#7	36.8	18/skid
6053	5	173	1/skid
6054	3,5	20.6, 194.7	36,1/skid
6055	3,5	27.2, 536	36,1/skid
6056	3,5	27.2, 536	36,1/skid
6064	#7	78	18/skid

TABLE D-3: UNIT LOAD DATA - ALUMINUM

Part Number	Box Size	Wt./Box	#Box/Skid
4870	Tub, #5	65, 666	1/skid
4891	#2, Cargo, #2	22, 463, 22	48/skid
4882/4	Tub, #2	34, 11.5	48/skid
4858	--	--	--
4871	#5	864	1/skid
4873	Tub, #5	65, 440	1/skid
4885	#2	66	48/skid
4857	Red Tub, #4	103, 51.5	16/skid
4881/3	Tub, #2	41, 15	48/skid
4880	#2, #4	27.5,42.5	16/skid
4803	#3	48.22	36/skid
4866	#2, #6	36, 54	30/skid
4876	#5	450	1/skid
4894	#1, #1	44, 40	27/skid
4827	#7	62.5	18/skid
4862	#2, #4	33, 32	16/skid
4865	Tub, Cargo, #7	108, 519, 126	18/skid
4813	#2	19.25	16/skid
4877	#2, #1	65, 25	27/skid
4841	7	30.25	18/skid

APPENDIX E

MATERIAL TRANSFER DISTANCE

TABLE E-1: MATERIAL TRANSFER DISTANCE- ZINC DYNACAST

	Distance		
	Manual	Track	Fork.
Dynacast-Tumble	8'	80'	--
Dynacast-Inspection	8'	84'	--
Tumble-Inspection	16'	10'	--
Tumble-Rotoblast	10'	--	--
Inspection-Ream	--	--	84'
Inspection-Assembly	--	--	78'
Inspection-Chromate/Dry	8'	92'	--
Inspection-Deburr	8'	270'	--
Inspection-Pack	--	--	96'
Ream-Inspection	--	--	88'
Assembly-Inspection	--	--	80'
Deburr-Chromate/Dry	15'	136'	--
Deburr-Wash/Dry	15'	136'	--
Dry-Tumble	6'	240'	--
Dry-Inspection	6'	240'	--
Rotoblast-Inspection	20'	16'	--

TABLE E-2: MATERIAL TRANSFER DISTANCE- ZINC(HPM/B&T)

	Manual	Track	Fork.
Cast-Trim	8'	--	--
Cast-Special Machine	--	--	132'
Trim-Inspection	8'	88'	90'
Trim-Rotoblast	8'	72'	--
Tumble-Inspection	16'	10'	--
Inspection-Buff	--	--	115'
Inspection-Special Mach.	--	--	156'
Inspection-Chromate/Dry	--	--	100'
Inspection-Deburr	8'	220'	--
Inspection-Pack	--	--	96'
Buff-Inspection	--	--	115'
Bake-Inspection	--	--	120'
Special Machine-Tumble	--	--	24'
Special Machine-Insp.	--	--	144'
Chromate-Bake	--	--	120'
Chromate/Dry-Inspection	8'	240'	--
Deburr-Chromate/Dry	15'	136'	--
Rotoblast-Inspection	20'	16'	--

TABLE E-3: MATERIAL TRANSFER DISTANCE- ZINC(CLEVELAND)

	Distance		
	Manual	Track	Fork
Cleveland-Trim	4'	--	--
Cleveland-Inspection	12'	80'	--
Trim-Tumble	8'	88'	--
Trim-Inspection	8'	88'	90'
Trim-Rotoblast	8'	72'	--
Tumbler-Rotoblast	10'	--	--
Inspection-Drill/Tap	--	--	112'
Inspection-Pin/Rivet	--	--	80'
Inspection-Key Products	--	--	96'
Inspection-Versamatic	--	--	136'
Inspection-Wash/Dry	8'	92'	--
Inspection-Deburr	8'	270'	--
Inspection-Rotoblast	8'	270'	--
Inspection-3-M	--	--	136'
Inspection-Pack	--	--	96'
Drill/Tap-Inspection	--	--	40'
Pin/Rivet-Inspection	--	--	80'
Special Mach.-Chromate/Dry	--	--	136'
Versamatic-Inspection	--	--	136'
Key Products-Inspection	--	--	96'
Chromate/Dry-Inspection	32'	250'	--
Deburr-Chromate/Dry	15'	136'	--
Dry-Deburr	6'	240'	--
Dry-Inspect	8'	240'	--
Deburr-Wash/Dry	15'	136'	--
Rotoblast-Inspection	20'	16'	--
Rotoblast-Special Mach.	--	--	160'
Rotoblast-Chromate/Dry	20'	136'	--
3-M-Inspection	--	--	148'

TABLE E-4: MATERIAL TRANSFER DISTANCE- MAGNESIUM

	Distance	
	Manual	Forktruck
Diecast - Trim	10'	-
Trim - Tumble	-	112'
Tumble - Inspection	-	16'
Trim - Inspection	-	96'
Inspection - Rotoblast	-	55'
Inspection - Deburr	-	120'
Inspection - Chromate/ Dry	-	40'
Inspection - Drill	-	25'
Inspection - Machine	-	56'
Rotoblast - Vibra Finish	-	20'
Rotoblast - Wash/Dry	-	25'
Rotoblast - Chromate/Dry	-	96'
Rotoblast - Inspection	-	40'
Vibra Finish - Chromate	-	100'
Wash/Dry - Rotoblast	-	25'
Wash/Dry - Inspection	-	56'
Deburr - Inspection	-	120'
Chromate - Inspection	-	120'
Inspection - Buff	-	25'
Drill - Inspection	-	25'
Spec. Machine-Insp.	-	40'
Buff - Rotoblast	-	.20'
Buff - Inspection	-	25'
Inspection - Pack	-	65'

TABLE E-5: MATERIAL TRANSFER DISTANCE- ALUMINUM

	Distance	
	Manual	Forktruck
Cast-Trim	8'	-
Trim-Roto Blast	-	56'
Trim-Vibra/Deburr	-	50'
Trim-3-Way Ettco	-	80'
Trim-Inspection	-	160'
Trim-Deburr	-	50'
Trim-Drill	-	50'
Trim-Assembly	-	136'
Trim-Ded. Ream	-	88'
Rotoblast-Inspection	-	172'
Vibr/Deburr-Roch.Drill	-	30'
Versa-Mate-Wash/Dry	-	88'
Versa-Mate-Wash/Dry	-	136'
3-Way Fitted-Wash/Dry	-	24'
Inspect-Vibrator	-	120'
Inspect-Vibra/Deburr	-	120'
Inspect-Deburr	-	120'
Inspect-Drill	-	50'
Inspect-Drill	-	72'
Inspect-Drill	-	40'
Inspect-Dial Index	-	152'
Inspect-J&L	-	40'

	Distance	
	Manual	Forktruck
Inspect-Lathe	-	80'
Inspect-Press-In	-	35'
Inspect-Chromate/Wash	-	44'
Inspect-Tumble	-	136'
Inspect-Put In Insert	-	25'
Inspect-Leak Test	-	[illegible]
Inspect-Pack	-	8'
Deburr-Versa-Mate	-	16'
Deburr-Drill/Tap	-	136'
Deburr-Tap	-	24'
Drill/Tap-Inspect	-	24'
Drill-Wash/Dry	-	25'
Tap-Wash/Dry	-	88'
Dial Index-Wash/Dry	-	72'
Burnish-Wash	-	35'
Ream-Inspect	-	55'
Press-In-Inspect	-	35'
Assembly-Inspect	-	24'
Ded. Ream-Wash	-	40'
Dry-Rotoblast	-	25'
Dry-Inspect	-	112'
Dry-Ded. Assembly	-	90'

	Distance	
	Manual	Forktruck
Dry-Bag	-	120'
Dry-Leak Test	-	72'
Tumble-Drill/Ream	-	35'
Vibrator-Impregnate	-	10'
Impregnate/Wash	-	112'
Bag-Inspect	-	32'
Leak-Test-Pack	-	40'
Leak Test-Pack	-	30'
Leak-Test-Pack	-	50'

APPENDIX F

MATERIAL TRANSFER REQUIREMENTS

The short term material transfer requirements are developed in Tables F-1 through F-5. The following equations are used in the development.

#Boxes Handled = (weight moved between operations (row)/Avg. Wt. per box)

#Pallets Handled = (weight moved between Operators (row)/ (Avg. Wt. per pallet)

Avg. # of Transfers per part = (Total % Cast/100% cast)

Avg. Transfer Distance = [$\sum$(% moved) (Distance)]/ (Avg. # of Transfer per part)

TABLE F-1

MATERIAL TRANSFER REQUIREMENTS* - ZINC DYNACAST

	Weight	%Dynacast	Part Numbers	Distance: Manual	Distance: Track	Distance: Fork.	Container	#Boxes Handled Avg.Box=28.25	# Pallets Handled Avg.Pallet=30 Boxes**
Dynacast-Tumble	231,475	81.7	4204, 4229, 4288, 4341, 4230, 4485, 4570	8'	80'	--	#1	8193	--
Dynacast-Inspection	51,707	18.3	4389	8'	84'	--	#1	1830	--
Tumble-Inspection	202,414	71.5	4204, 4225, 4270, 4288, 4485, 4570, 4389	16'	10'	--	#1	7165	--
Tumble-Rotoblast	29,061	10.3	4341	10'	--	--	#1	- Manual Only -	
Inspection-Ream	44,585	15.7	4229	--	--	84'	Pallet	--	43.8
Inspection-Assembly	44,585	15.7	4229	--	--	78'	Pallet	--	43.8
Inspection-Chromate/Dry	44,585	15.7	4229	8'	92'	--	#1	--	43.8
Inspection-Deburr	137,374	48.5	4389, 4288, 4270, 4485, 4570	8'	270'	--	#1	4863	--
Inspection-Pack	283,182	100	4204, 4341, 4389, 4288, 4220, 4485, 4570, 4229	--	--	96'	Pallet	--	279
Ream-Inspection	44,585	15.7	4229	--	--	88'	Pallet	--	43.8
Assembly-Inspection	44,585	15.7	4229	--	--	80'	Pallet	--	43.8
Deburr-Chromate/Dry	49,175	17.4	4485, 4570	15'	136'	--	#1	1741	--
Deburr-Wash/Dry	115,199	40.7	4389, 4288, 4220	15'	136'	--	#1	4078	--
Dry-Tumble	51,707	18.3	4389	6'	240'	--	#1	1830	--
Dry-Inspection	112,667	39.8	4288, 4270, 4485, 4229	6'	240'	--	#1	3988	--
Rotoblast-Inspection	29,061	10.3	4341	20'	16'	--	#1	1029	--
		534.3						34,717/6mo x2	498 x2
							Transfer Requirements only for Pareto Parts	69,434/yr x2.76***	996 x2.76***
							Transfer Requirements for Dynacast	191,638 Box/yr	2749
							Weighted Average Distance Traveled****	139'	92'

*Parts on '85 Pareto Analysis (6 months)

**Observation with D. Moss.

***Pareto Represents 36.2% of total weight in '85.

****(Percent Dynacast x Distance)/(Avg # Trips)

TABLE F-2

MATERIAL TRANSFER REQUIREMENTS* - ZINC/CLEVELAND CAST

	Weight	%Cleveland	Part Numbers	Distance Manual	Distance Track	Distance Fork	Container	# Boxes Handled #1	# Boxes Handled #2	# Boxes Handled #8	#Pallets Handled (Avg. Pallet = 12 #1 Boxes, 24 #2 Boxes, 16 #8 Boxes)**
Cleveland-Trim	1,170,609	98.4	4464, 4584, 4465, 4408, 4451, 4458, 4393, 4531, 4585	4'	--	--	--	--	Manual	--	
Cleveland-Inspection	19,803	1.6	4407	12'	80'	--	#1	702	--	--	
Trim-Tumble	78,629	6.3	4408	8'	88'	--	#1	2788	--	--	
Trim-Inspection	909,780	73.3	4464, 4465, 4451, 4458, 4393, 4531	8'	88'	90'	#1(137,168) #8(772,612)	4864	--	14,495	
Trim-Rotoblast	182,200	14.7	4585, 4585	8'	72'	--	#1(155,000) #2(27,200)	5496	807	--	
Tumbler-Rotoblast	78,629	6.3	4408	10'	--	--	#1	--	Manual	--	
Inspection-Drill/Tap	77,648	6.3	4451	--	--	112'	Pallet	--	--	--	76
Inspection-Pin/Rivet	78,629	6.3	4408	--	--	80'	Pallet	--	--	--	77
Inspection-Key Products	394,873	31.8	4464, 4465	--	--	96'	Pallet	--	--	--	463
Inspection-Versamatic	377,676	30.4	4531	--	--	136'	Pallet	--	--	--	442
Inspection-Wash/Dry	77,648	6.3	4451	8'	92'	--	#1	2753	--	--	
Inspection-Deburr	19,803	1.6	4407	8'	270'	--	#1	702	--	--	
Inspection-Rotoblast	394,873	31.8	4464, 4465	8'	270'	--	#8	--	--	7408	
Inspection-3-M	19,803	1.6	4407	--	--	136'	Pallet	--	--	--	
Inspection-Pack	1,220,609	100.0	4584, 4586, 4458, 4393, 4585, 4408, 4464, 4465, 4451, 4407, 4531	--	--	96'	Pallet	--	--	--	385 + 95 + 495
Drill/Tap-Inspection	77,648	6.3	4451	--	--	40'	Pallet	--	--	--	76
Pin/Rivet-Inspection	78,629	6.3	4408	--	--	80'	Pallet	--	--	--	77

TABLE E-2 (Continued)

	Weight	%Cleveland	Part Numbers	Distance: Manual	Distance: Track	Distance: Fork	Container	# Boxes Handled: #1	# Boxes Handled: #2	# Boxes Handled: #8	#Pallets Handled (Avg. Pallet = 12 #1 Boxes, 24 #2 Boxes, 16 #8 Boxes)**
Special Mach.-Chromate/ Dry	155,000	12.5	4584	--	--	136'	Pallet	--	--	--	153
Versamatic-Inspection	377,676	30.4	4531	--	--	136'	Pallet	--	--	--	442
Key Products-Inspection	394,873	31.8	4464, 4465	--	--	96'	Pallet	--	--	--	463
Chromate/Dry-Inspection	232,200	18.7	4584, 4586, 4585	32'	250'	--	#1(27,200) #2(205,000)	964	6083	--	
Deburr-Chromate/Dry	77,648	6.3	4451	15'	136'	--	#1	2753	--	--	
Dry-Deburr	77,648	6.3	4457	6'	240'	--	#1	2753	--	--	
Dry-Inspect	492,324	39.7	4464, 4465, 4407, 4451	8'	240'	--	#1(97,451) #8(394,873)	3455	--	7408	
Deburr-Wash/Dry	19,803	1.6	4407	15'	136'	--	#1	702	--	--	
Rotoblast-Inspection	473,502	38.2	4464, 4465, 4408	20'	16'	--	#1(78,629) #8(394,873)	2788	--	7408	
Rotoblast-Special Mach.	155,000	12.5	4584	--	--	160'	#Pallet	--	--	--	153
Rotoblast-Chromate/Dry	72,175	5.8	4586, 4585	20'	136'	--	#2	--	2142	--	
3-M-Inspection	19,803	1.6	4407	--	--	148'	Pallet	--	--	--	20
		528.4						30,720	9,032	36,719	3,437
								x2	x2	x2	x2
								61,440	18,064	73,438	6,874
								x1.33	x1.33	x1.33	x1.33***
Transfer Requirement for Cleveland								81,715 /yr	24,025 /yr	97,673/yr	9,163/yr
# Moves/Part								1.21	0.25	1.07	2.76
Wt. Avg. Distance Per Move								103.7'	207'	166'	108'

*Parts on Pareto Analysis.

**Estimated with D. Moss.

***Pareto Analysis incl. only 75% of metal in '85.

TABLE F-3

MATERIAL TRANSFER REQUIREMENTS* - ZINC (HPM AND B&T)

	Weight	%Cast	Part Numbers	Manual	Track	Fork.	Container	Boxes Handled #1	Boxes Handled #2	Pallets Handled: Cargoes	Pallets Handled: Pallets #2 Box 24/Skid	Pallets Handled: Pallets #1 Box 36/Skid
Cast-Trim	319,262	89.2	4426, 4534, 4537	8'	--	--	Cargo(179,907) #1(74,790) #2(64,665)	- Manual -		340		
Cast-Special Machine	38,835	10.8	4481	--	--	132'	Pallet	--	--			39
Trim-Inspection	254,597	71.1	4426, 4534	8'	88'	90'	Pallet	2788	--	390		
Trim-Rotoblast	64,665	18.0	4537	8'	72'	--	#2	--	1350			
Tumble-Inspection	38,835	10.8	4481	16'	10'	--	#1	1402	--			
Inspection-Buff	179,907	50.2	4534	--	--	115'	Pallet	--	--	390		
Inspection-Special Mach.	179,907	50.2	4534	--	--	156'	Pallet	--	--	390		
Inspection-Chromate/Dry	254,597	71.1	4534	--	--	100'	Pallet	--	--	390		
Inspection-Deburr	38,855	10.8	4481	8'	220'	--	#1	1402	--			
Inspection-Pack	358,097	100.0	4426, 4534, 4537, 4481	--	--	96'	Pallet	--	--	390	56	116
Buff-Inspection	179,907	50.2	4534	--	--	115'	Pallet	--	--	390		
Bake-Inspection	179,907	50.2	4534	--	--	120'	Pallet	--	--	390		
Special Machine-Tumble	38,835	10.8	4481	--	--	24'	Pallet	--	--			39
Special Machine-Insp.	179,907	50.2	4534	--	--	144'	Pallet	--	--	390		
Chromate-Bake	179,907	50.2	4534	--	--	120'	Pallet	--	--	390		
Chromate/Dry-Inspection	113,525	31.7	4426, 4481	8'	240'	--	#1	4190	--			
Deburr-Chromate/Dry	38,835	10.8	4481	15'	136'	--	#1	1402	--			
Rotoblast-Inspection	64,665	2.7	4537	20'	16'	--	#2	--	1350			
		639.0						11,184	2,700		4,228	
								x2	x2		x2	
								22,368	5,400		8,456	
								x1.075**	x1.075**		x1.075**	
Transfers/Year								24,046	5,805		9,092	
# Moves Per Avg. Part								.533	.207		5.65	
Wt. Avg. Distance/Move								170'	64.7'		105'	

*For Parts on Pareto List

**Pareto Analysis includes 93% of metal in '85.

TABLE F-4

MATERIAL TRANSFER REQUIREMENTS* - MAGNESIUM

	Weight		%Magnesium			Distance			# Pallets (583#/skid)	
	'84	'86	'84	'86	Part Numbers	Manual	Forktruck	Container	'84	'86
Diecast - Trim	485,625	906,398			(All)	10'	-	Pallet	- Manual -	
Trim - Tumble	22,800	22,800	4.7	2.5	6041	-	112'	Pallet	39	39
Tumble - Inspection	22,800	22,800	4.7	2.5	6041	-	16'	Pallet	39	39
Trim - Inspection	462,825	883,598	95.3	97.5	(All but 6041)	-	96'	Pallet	794	1516
Inspection - Rotoblast	44,517	140,792	9.2	15.5	6045, 6044, 6041, 6055, 6056, 6064, 6053	-	55'	Pallet	76	241
Inspection - Deburr	250,560	325,295	51.6	35.9	6035, 6052	-	120'	Pallet	430	558
Inspection - Chromate/Dry	175,920	232,320	36.2	25.6	6059, 6017	-	40'	Pallet	302	398
Inspection - Drill	76,224	76,224	15.7	8.4	6017, 6053	-	25'	Pallet	131	131
Inspection - Machine	0	29,000	0	3.2	6067	-	56'	Pallet	0	50
Rotoblast - Vibra Finish	13,104	13,104	2.7	1.4	6053	-	20'	Pallet	22	22
Rotoblast - Wash/Dry	8,613	144,626	1.8	15.9	6056, 6055, 6064, 6045, 6044	-	25'	Pallet	15	248
Rotoblast - Chromate/Dry	0	29,000	0	3.2	6067	-	96'	Pallet	0	50
Rotoblast - Inspection	85,920	85,920	17.7	9.5	6041, 6017	-	40'	Pallet	147	147
Vibra Finish - Chromate	13,104	13,104	2.7	1.4	6053	-	100'	Pallet	22	22
Wash/Dry - Rotoblast	63,120	63,120	13.0	7.0	6017	-	25'	Pallet	108	108
Wash/Dry - Inspection	8,613	144,626	1.8	16.0	6045, 6044, 6056, 6055, 6064	-	56'	Pallet	15	248
Deburr - Inspection	250,560	325,335	51.6	35.9	6052, 6035	-	120'	Pallet	430	558
Chromate - Inspection	189,024	274,424	38.9	30.3	6067, 6017, 6053	-	120'	Pallet	324	471
Inspection - Buff	13,104	13,104	2.7	1.4	6053	-	25'	Pallet	22	22
Drill - Inspection	76,224	76,224	15.7	8.4	6017, 6053	-	25'	Pallet	131	131

TABLE F-4 (Continued)

	Weight '84	Weight '86	%Magnesium '84	%Magnesium '86	Part Numbers	Distance Manual	Distance Forktruck	Container	#Pallets (583#/skid) '84	#Pallets (583#/skid) '86
Spec. Machine-Insp.	0	29,000	0	3.2	6067	-	40'	Pallet	0	50
Buff - Rotoblast	0	29,000	0	3.2	6067	-	20'	Pallet	0	50
Buff - Inspection	13,104	13,104	2.7	1.4	6053	-	25'	Pallet	22	22
Inspection - Pack	485,398	906,398	100	100.0	(All)	-	65'	Pallet	833	1555
			468.7	429.3					3902	6676
									x2	x2
							Pareto Transfer/Yr		7804	13352
									1.04*	1.236*
							Transfer/Yr		8188	16504
							# Moves/Avg		4.68	4.29
							Avg. Distance/Move		80.4'	78.1'

*Adjustment for % metal included in pareto.

TABLE F-5

MATERIAL TRANSFER REQUIREMENTS* - ALUMINUM

	Weight		% Aluminum		Part Numbers	Distance		Container	# Pallets	
	'84	'86	'84	'86		Manual	Forktruck		'84	'86
Cast-Trim	361,916	1,252,172	[illegible]		(All)	8'	-	-	- Manual -	
Trim-Roto Blast	0	90,000	0	7.2	4885	-	56'	Pallet	0	113
Trim-Vibra/Deburr	0	250,800	0	20.0	4870	-	50'	Pallet	0	314
Trim-3-Way Ettco	39,680	93,000	11.0	7.4	4873	-	80'	Pallet	50	117
Trim-Inspection	310,206	497,135	85.7	39.7	4870, 4871, 4857, 4830, 4803, 4866, 4827, 4862, 4865, 4813, 4867, 4841, 4891	-	160'	Pallet	389	623
Trim-Deburr	0	244,750	0	19.5	4881, 4882	-	50'	Pallet	0	307
Trim-Drill	21,850	21,850	6.0	1.7	4877	-	50'	Pallet	27	27
Trim-Assembly	27,660	27,660	7.6	2.2	4876	-	136'	Pallet	35	35
Trim-Ded. Ream	0	26,975	0	2.1	4894	-	88'	Pallet	0	34
Rotoblast-Inspection	50,154	140,154	13.9	11.1	4885, 4803	-	172'	Pallet	63	176
Vibr/Deburr-Roch.Drill	74,960	74,960	20.7	6.0	4857	-	30'	Pallet	94	94
Versa-Mate-Wash/Dry	0	175,000	0	14.0	4882	-	88'	Pallet	0	220
Versa-Mate-Wash/Dry	37,480	74,960	10.4	6.0	4857	-	136'	Pallet	47	94
3-Way Fitted-Wash/Dry	39,680	93,000	11.0	7.4	4873	-	24'	Pallet	50	117
Inspect-Vibrator	8,333	0	2.3	0	4865	-	120'	Pallet	10	0
Inspect-Vibra/Deburr	74,960	74,960	20.7	6.0	4857	-	120'	Pallet	94	94
Inspect-Deburr	8,712	8,712	2.4	0.7	4841	-	120'	Pallet	11	11
Inspect-Drill	69,224	69,224	19.1	5.5	4830	-	50'	Pallet	87	87
Inspect-Drill	50,154	50,154	13.9	4.0	4803	-	72'	Pallet	63	63
Inspect-Drill	13,216	13,216	3.7	1.1	4862	-	40'	Pallet	17	17
Inspect-Dial Index	0	117,000	0	9.3	4891	-	152'	Pallet	0	147
Inspect-J&L	8,333	0	2.3	0	4865	-	40'	Pallet	10	0

TABLE F-5 (Continued)

	Weight '84	Weight '86	% Aluminum '84	% Aluminum '86	Part Numbers	Distance Manual	Distance Forktruck	Container	# Pallets '84	# Pallets '86
Inspect-Lathe	32,188	0	8.9	0	4827	-	80'	Pallet	40	.0
Inspect-Press-In	31,300	31,300	8.7	2.5	4866	-	35'	Pallet	39	39
Inspect-Chromate/Wash	21,081	21,081	5.8	1.7	4813, 4841	-	44'	Pallet	26	26
Inspect-Tumble	12,369	12,369	3.4	1.0	4813	-	136'	Pallet	16	16
Inspect-Put In Insert	8,712	8,712	2.4	0.7	4841	-	25'	Pallet	11	11
Inspect-Leak Test	74,960	74,960	20.7	6.0	4857	-	40'	Pallet	94	94
Inspect-Pack	337,024	1,128,385	93.1	90.1	All but 4857, 4894, 4877	-	8'	Pallet	423	1416
Deburr-Versa-Mate	0	175,000	0	14.0	4882	-	16'	Pallet	0	220
Deburr-Drill/Tap	8,712	8,712	2.4	0.7	4841	-	136'	Pallet	11	11
Deburr-Tap	0	67,750	0	5.4	4881	-	24'	Pallet	0	85
Drill/Tap-Inspect	8,712	8,712	2.4	0.7	4841	-	24'	Pallet	11	11
Drill-Wash/Dry	72,004	72,004	19.9	5.8	4803, 4877	-	25'	Pallet	90	90
Tap-Wash/Dry	0	69,750	0	5.6	4881	-	88'	Pallet	0	88
Dial Index-Wash/Dry	0	117,000	0	9.3	4891	-	72'	Pallet	0	147
Burnish-Wash	32,138	0	8.9	0	4827	-	35'	Pallet	40	0
Ream-Inspect	8,333	0	2.3	0	4865	-	55'	Pallet	10	0
Press-In-Inspect	31,300	31,300	8.6	2.5	4866	-	35'	Pallet	39	39
Assembly-Inspect	27,660	27,600	7.6	2.2	4876	-	24'	Pallet	35	35
Ded. Ream-Wash	0	26,975	0	2.2	4894	-	40'	Pallet	0	34
Dry-Rotoblast	50,154	50,154	13.9	4.0	4803	-	25'	Pallet	63	63
Dry-Inspect	249,920	624,519	69.0	49.9	4882, 4873, 4881, 4857, 4830, 4827, 4862, 4891, 4865, 4813	-	112'	Pallet	314	783
Dry-Ded. Assembly	0	26,975	0	2.2	4894	-	90'	Pallet	0	34

TABLE F-5 (Continued)

	Weight '84	Weight '86	% Aluminum '84	% Aluminum '86	Part Numbers	Distance Manual	Distance Forktruck	Container	# Pallets '84	# Pallets '86
Dry-Bag	8,712	8,712	2.4	0.7	4841	-	120'	Pallet	11	11
Dry-Leak Test	21,850	21,850	6.0	1.7	4877	-	72'	Pallet	27	27
Tumble-Drill/Ream	12,369	12,369	3.4	1.0	4813	-	35'	Pallet	16	16
Vibrator-Impregnate	8,333	0	2.3	0	4865	-	10'	Pallet	10	0
Impregnate/Wash	40,471	0	11.2	0	4827, 4865	-	112'	Pallet	51	0
Bag-Inspect	8,712	8,712	2.4	0.7	4841	-	32'	Pallet	11	11
Leak-Test-Pack	37,480	74,960	10.3	5.9	4857	-	40'	Pallet	47	94
Leak Test-Pack	0	26,975	0	2.2	4894	-	30'	Pallet	0	34
Leak-Test-Pack	21,850	21,850	6.0	1.7	4877	-	50'	Pallet	27	27
			552.7	391.3					2509	6152
									x2	x2
									5018	12304
									1.09*	1.05*
Annual Transfer Requirements									5496	12883
Wt. Avg. Distance									76'	68'
# Moves/Part									5.52	3.91

*Adjustment for % metal in pareto.

APPENDIX G

SECONDARY MACHINING EQUIPMENT

TABLE G-1: EQUIPMENT DATA - ZINC

Machine	Foot. Print.	Sq. Ft.	Production No.	Pounds Processed '80	'81	'82	'83	'84*	'85**	'86**
Buffer Oven Key Product	13 x 13 6 x 8 11 x 14	371 Ft^2	4534	0	0	0	0	359,814	359,814	359,814
Press	7 x 8	56 Ft^2	4408	12,769	41,943	70,341	150,864	157,258	157,258	157,258
Press Reamer	10 x 14 8 x 10	220 Ft^2	4229	146,508	135,449	112,986	101,609	89,170	89,170	89,170
Press	6 x 7	42 Ft^2	4474	0	0	0	0	22,954	22,954	22,954
Machine Center	17 x 18	306 Ft^2	4464	0	223,767	311,192	402,037	504,488	504,488	504,488
Key Product Key Product	20 x 24 17 x 19	803 Ft^2	4531	0	0	0	0	755,352	755,352	755,352
J & L Lathe	10 x 11	110 Ft^2	4412	35,508	59,137	0	0	19,202	19,202	19,202
Tapper Trimmer	6 x 11 6 x 7	108 Ft^2	4413	84,600	51,570	42,407	72,241	0	0	0
Tapper	6 x 11	66 Ft^2	4452	0	5,026	14,351	26,792	40,628	40,628	40,628
Drill	8 x 9	72 Ft^2	4451	9,315	7,188	32,146	86,200	155,296	155,296	155,296
Versa-Mate	15 x 17	255 Ft^2	4584	0	0	0	0	0	310,000	310,000
Machine Center	14 x 17	240 Ft^2	6027	19,197	125,136	123,591	100,353	53,268	53,268	53,268
Total Sq. Ft. in use for secondary machining				1,606	1,178	1,178	1,178	2,286	2,541	2,541
Total Pounds Processed Through Secondary				307,897	649,216	707,014	940,096	2,158,030	2,468,030	2,468,030
Sq. Ft./100,000 Pounds Processed				262	181	167	125	106	103	103
Total Weight Processed				--	3,923,893	3,777,901	4,026,080	5,086,581	5,374,193	5,905,828
% of Total Weight Requiring Secondary Operations				--	16.5%	18.7%	23.3%	42.4%	45.9%	41.7%

*First six months actual plus projected metal usage.

**Metal usage projection.

TABLE G-2: EQUIPMENT DATA - MAGNESIUM

Machine	Foot. Print.	Sq. Ft.	Production No.	Pounds Processed '80	'81	'82	'83	'84*	'85**	'86**
Drilling Unit	12 x 15	180	6017	144,135	117,262	112,689	162,734	126,240	126,240	126,240
ETTCO DU300 DU500	13 x 13	169	6053	0	0	0	0	13,104	26,208	26,208
	15 x 17	255	6067 6068							2,920
Total Sq. Ft.		604		180	180	180	180	349	604	604
Total Weight Using Secondary				144,135	117,262	112,689	162,734	139,344	181,448	213,368
Sq. Ft./100,000#				125	154	160	111	250	333	283
Total Weight Packed					532,162	784,776	999,691	1,002,780	1,394,103	1,812,796
% Wt. Require Secondary					22%	14.3%	16.2%	13.9%	13.0%	11.8%

*First six months actual plus projected metal usage.

**Metal usage projection.

TABLE G-3: EQUIPMENT DATA - ALUMINUM

Machine	Foot. Print.	Sq. Ft.	Production No.	Pounds Processed '80	'81	'82	'83	'84*	'85**	'86**
J & L Lathe Reamer & Drill	18 x 17	342 Ft^2	4827	0	142,748	111,549	108,207	83,558	0	0
Drilling Unit	11 x 13	143 Ft^2	4803	227,622	116,220	123,938	118,006	100,308	100,308	100,308
J & L Lathe Ettco Drilling Machine	13 x 19	247 Ft^2	4830	0	0	183	25,615	138,448	138,448	138,448
Ettco DU-300 Drilling Machine	9 x 11	99 Ft^2 (incl. above)	4829 4830	0 0	0 0	0 185	0 25,615	11,000 138,448	11,000 138,448	11,000 138,448
Key Products Rotary Index (retooled)	15 x 16	240 Ft^2	4891	0	0	0	0	0	110,000	234,000
Ettco ATU-5 Tapping Machine	10 x 12	120 Ft^2	4881 4875	0 0	0 0	0 0	0 0	0 0	79,050 2,963	139,500 2,766
J & L Lathe Procunier Tapper	15 x 16	256 Ft^2	4862	0	0	0	0	26,432	26,432	26,432
J & L Lathe	14 x 16	224 Ft^2	4832	0	0	1,809	6,109	12,006	12,006	12,006
Ettco DU-500 Drilling Machine	10 x 12	120 Ft^2	4873 4875	0 0	0 0	0 0	0 0	39,680 0	172,360 2,963	186,000 2,763
Allan Air- Drilling & Tapping Machine	18 x 20	360 Ft^2	4841	0	0	5,886	0	17,424	17,424	17,424

TABLE G-3: EQUIPMENT DATA - ALUMINUM (Continued)

Machine	Foot. Print.	Sq. Ft.	Production No.	Pounds Processed '80	'81	'82	'83	'84*	'85**	'86**
Hypnumat Drill & Procunier Tapping Machines	12 x 16	192 Ft^2	4838 4840	0 0	0 0	1,668 274	1,983 544	2,112 888	2,112 888	2,112 888
Drill	10 x 12	120 Ft^2	4843	0	0	3,068	6,391	8,258	8,258	8,258
Key Products Drilling & Milling Machine	9 x 11	99 Ft^2	4860	0	0	0	0	6,500	6,500	6,500
Machine Research Rotary Index Drill	11 x 12	132 Ft^2	4813	2,917	5,521	13,437	32,446	24,738	24,738	24,738
Drilling & Tapping Versa-mates	17 x 20	340 Ft^2	4857	0	0	0	0	119,920	119,920	119,920
Key Products - Boring & Gun Drill	19 x 21	399 Ft^2	4857	0	0	0	0	119,920	119,920	119,920
Uson leak test	8 x 9	72 Ft^2	4857	0	0	0	0	119,920	119,920	119,920
Key Products (3) way drilling machine	9 x 11	99 Ft^2	4857	0	0	0	0	119,920	119,920	119,920

TABLE G-3: EQUIPMENT DATA - ALUMINUM (Continued)

Machine	Foot. Print.	Sq. Ft.	Production No.	Pounds Processed '80	'81	'82	'83	'84*	'85**	'86**
LeBlond Makino CNC Machining Center	16 x 24	384 Ft^2	4878	0	0	0	0	0	0	8,000
Ettco ATU-5 Tapping Machine	10 x 12	120 Ft^2	4877	0	0	0	0	10,860	42,510	43,700
			4878	0	0	0	0	0	0	8,000
			4880	0	0	0	0	0	0	388
Uson Leak Test Machine	8 x 12	96 Ft^2	4877	0	0	0	0	10,860	42,510	43,700
			4878	0	0	0	0	0	0	8,000
			4879	0	0	0	0	0	0	420
			4880	0	0	0	0	0	0	388
Versa-Mate	15 x 17	255 Ft^2	4882	0	0	0	0	0	175,935	332,850
Total - Sq. Ft.		4360 Ft^2		275	617	1,760	1,760	3,265	3,634	4,018
Total - Pounds Processed through secondary machining				230,539	264,489	261,812	325,516	602,132	1,058,323	1,419,816
Sq. Ft./100,000 lbs. Processed				119	233	672	541	542	283	346
Total Weight Processed				--	520,634	409,424	427,177	671,635	1,747,389	2,625,670
% Total Weight Requiring Secondary Operations				--	50.8%	63.9%	76.2%	89.7%	60.5%	53.1%

*First six months actual plus projected metal usage.

**Metal usage projection.

APPENDIX H

CASTER SPECIFICATIONS

CASTER SPECIFICATIONS

METAL	ANNUAL WT. CAST/CASTER (lbs.) (1985)	AREA/CASTER (ft^2)
Zinc	233,660	425
Magnesium	320,866	800
Aluminum	289,785	800

APPENDIX I

PERSONNEL DATA

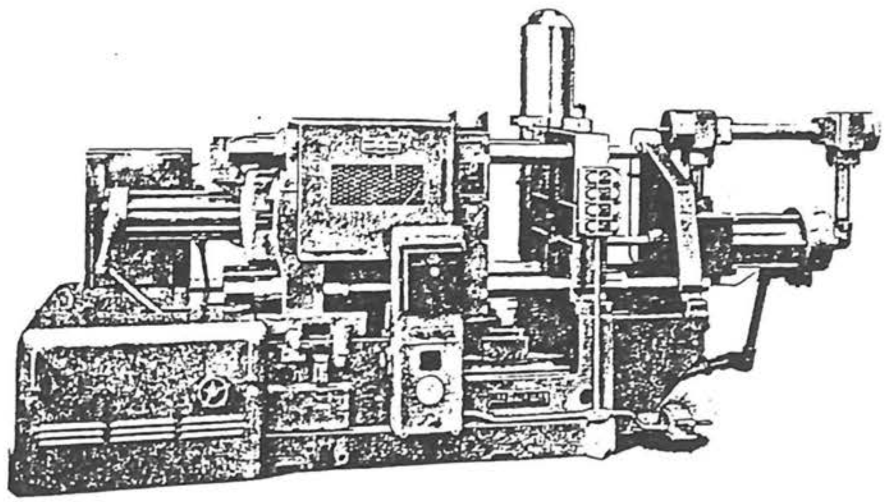
TABLE I-1: PERSONNEL DATA USED TO DETERMINE TRENDS

	81-Dec	82-Dec	83-Dec	84-Aug
Corporate Administration	10	10	10	9
Sales	2	2	2	3
Finance & Control	13	14	14	15
Services: Tool & Die	37	36	38	40
Other	37	40(1)	41	43
Zinc	103(2)	103	105	105
Aluminum	32(2	28		45
Magnesium	17(1)	18	26	36
Trucking	2	5	5	5
TOTAL EMPLOYEES	253(3)	256(1)	274	301
Less Layoff()				11
Zinc Division				
Division Management	10	10	12	12
Diecasting	39	11	42	42
Secondary	33(2)	33	32	32
Inspection	14	14	14	14
Warehouse/Shipping	7	5	5	5
ZINC TOTAL	103	103	105	105
Less Layoff()	(2)			
Aluminum Division				
Division Management	3	3	3	5
Diecasting	17	14	15	18
Secondary	8(1)	8	12	18
Inspection	3	3	3	4
ALUMINUM TOTAL	31	28	33	45
Less Layoff()	(1)			
Magnesium Division				
Division Management	5	5	5	5
Diecasting	8	9	15	21
Secondary	2	2	3	6
Inspection	1	2	3	4
MAGNESIUM TOTAL	17	18	26	36
Less Layoff()	(16)			

OFFICE SPACE PER EMPLOYEE -225 sq. ft.
*Do not have an office

GLOSSARY

Diecasting - A process in which molten metal is forced into a mold by pressure and held under pressure during solidification. Zinc, copper, and aluminum base alloys are suitable for diecasting. A typical die-casting machine is shown below.



Source: Materials and Processes in Manufacturing, E. Paul DeGarmo, MacMillan Publishing.

Dynacast Part - A zinc part that is die casted on a machine whose brand name is "Dynacast."

Cleveland Part - A zinc part that is die casted on a machine whose brand name is "Cleveland."

B&T/HPM part - A zinc part that is diecasted on a machine whose brand name is either B & T or HPM.

Secondary Machining- Operations required to finish a casting to a desired specifications and quality

General Warehouse - A warehouse containing only spare parts, scrap parts, spare equipment, etc.

Production No. - A number(s) assigned to a machine (or process) which identifies that part number(s) routed to the machine or process.

CONCLUSION

The preceding material handling and plant layout case studies illustrate different industrial situations. Each case requires an understanding of material handling concepts and other related Industrial Engineering skills.

These case studies are valuable teaching aids because of their ability to exemplify an industrial situation in the classroom environment. The first two case studies present two common industrial situations while case 3 presents a more realistic situation where only general information about the problem is first provided.

Hopefully, this effort will generate an interest for the development of more case studies. In order to obtain a meaningful learning experience, "new" skills must be practiced. Since visiting a manufacturing plant is not always practical or possible, a learning tool such as a well developed case study is beneficial.