For the Instructor: Teaching Note on "Incorporating Pollution Prevention in Facilities Planning"

Purpose

When designing new facilities, planners must ask themselves, "Can this facility's environmental impact be reduced?" The accompanying article and exercise are designed to help future facilities planners address this question.

"Pollution Prevention and Facilities Planning" discusses the need for facility planners to consciously include environmental considerations when locating and designing facilities. The first section discusses pollution prevention considerations in the design process; the second examines modeling environmental variables into the facilities location problem.

These articles were designed for an introductory Facilities Planning course. The material requires 50 minutes of class time for discussion; the questions can be assigned as a homework. Students should be familiar with the basic concepts of both facilities design and facilities planning prior to the class. For those courses that do not teach facilities location, the facilities design component can be assigned alone.

Before assigning the accompanying article and exercises, you may want to have your students read this compendium's introduction, "A Logical Role for the Industrial Engineer." It discusses the inherent and critical role industrial engineers must play in developing successful pollution prevention programs, explains regulatory and market factors, and outlines a framework for preventing pollution within a firm.

Answers

1. Wastes are usually generated by productive use of an activity's components. Production waste has traditionally been seen as a necessary, if unwanted, by-product of an activity. Pollution prevention questions the necessity of waste and calls for activities to *prevent* it wherever possible (rather than merely controlling it as is common today).

2. As a facilities planner involved in *product design* review, apply value analysis techniques to the choice of materials or the method of manufacture to determine if pollution can be prevented.

   The *process selection* procedure offers significant opportunities to prevent pollution. Interacting with the process planner, the facilities planner can call for pollution prevention to be evaluated along with cost, flexibility, efficiency, reliability and maintainability.

   Good *schedule design* lends itself to pollution prevention — correct volume determinations will minimize excess inventory and possible waste. The same point applies to scrap estimates and machine fractions. When determining these values, minimizing waste is naturally a goal.

3. x-axis

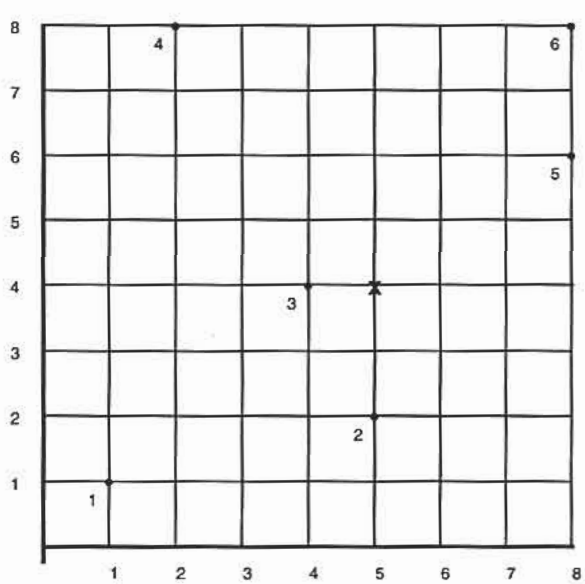
Location	a_i	w_i	Σw_i	
1	1	10	10	
4	2	4	14	
3	4	8	22	
2	5	12	34	> 56/2
5	8	16	50	
6	8	6	56	

$x^* = a^2 = 5$

y-axis

Location	b_i	w_i	Σw_i	
1	1	10	10	
2	2	12	22	
3	4	8	30	> 56/2
5	6	16	46	
4	8	4	50	
6	8	6	56	

$y^* = b^3 = 4$



4. x-axis

Location	a_i	w_i	Σw_i	
1	1	5	5	
4	2	4	9	
3	4	4	13	
2	5	6	19	
5	8	16	35	> 41/2
6	8	6	41	

$xe^* = a^5 = 8$

y-axis

Location	b_i	w_i	Σw_i	
1	1	5	5	
2	2	6	11	
3	4	4	15	
5	6	16	31	> 41/2
4	8	4	35	
6	8	6	41	

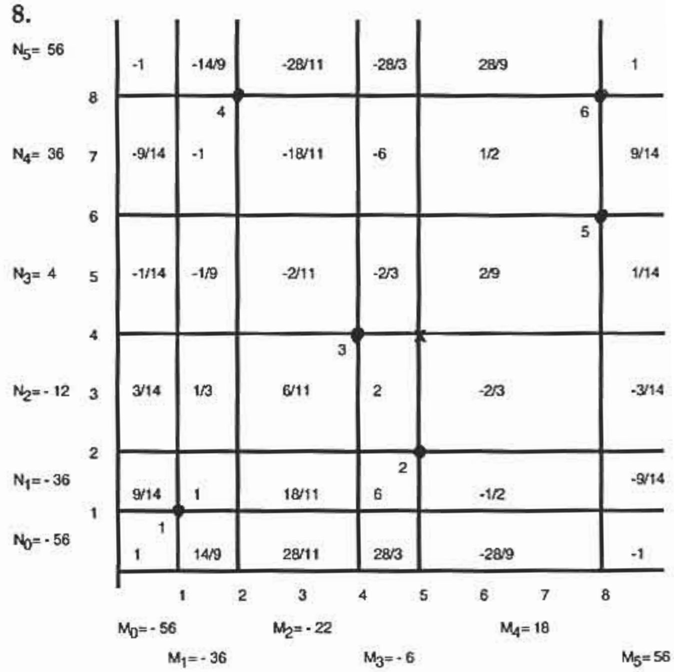
$ye^* = b^5 = 6$

5. The solution in problem #3 tends to "center" the facility with regard to all other facilities. In contrast, #4 tends to place the facility away from the populated areas.

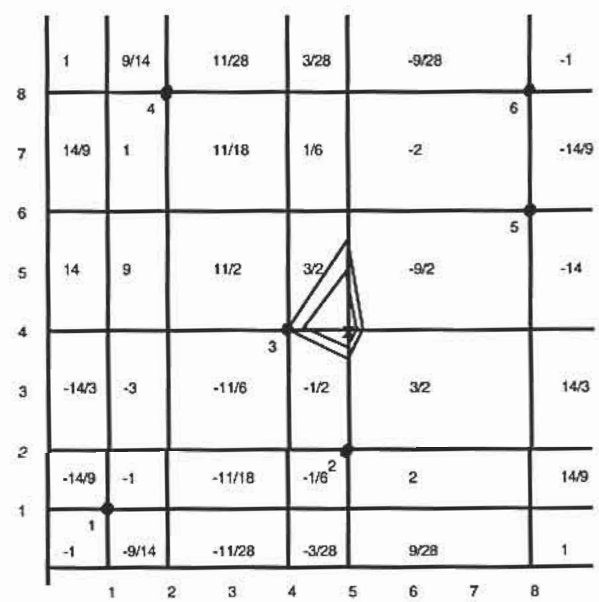
6. The environmental weights take on smaller values to force the model to place the facilities *away* from the populated areas. High positive values would drive the facility closer to the very places that need to be kept apart from the facility. In determining weights, the "costs" associated with the environmental issues should be *subtracted* from the traditional costs to reach the new w_{ei}s.

7. In this example, all the population areas are located in a certain quadrant of the area. If the population areas are more dispersed, the solutions will show a tendency toward the center which might be the worst possible solution.

8.

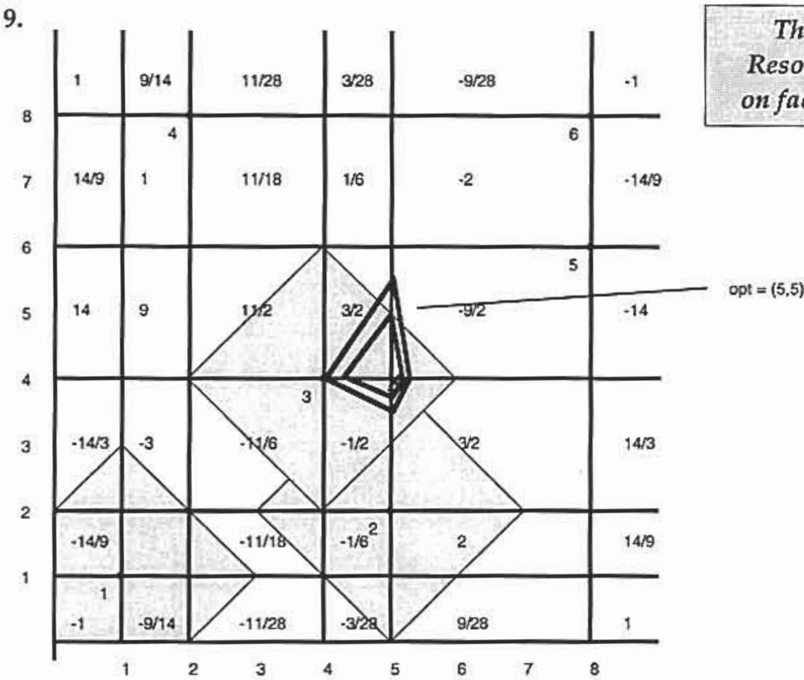


Forces



Contour lines

9.



Contour lines
with constraints

The matrix at the end of this compendium's Resource List indicates eight books and articles on facilities planning and industrial engineering.

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Incorporating Pollution Prevention in Facilities Planning

By Leith Harmon, NPPC Research Rssistant, under the supervision of Yavuz Bozer, Associate Professor of Industrial and Operations Engineering, University of Michigan.

Introduction

Facilities planning represents a significant economic activity. The U.S. Bureau of Census estimates that U.S. industry spends eight percent of the GNP on new facilities. As environmental concerns continue to grow, new facilities will have to be designed with pollution prevention in mind. It is important that the facilities planner ask the question, "Can this facility's environmental impact be reduced?" By considering pollution prevention, and including environmental variables in analytical models, that impact can indeed be reduced.

Facilities planning involves many disciplines. Civil, electrical, industrial and mechanical engineers; architects; consultants; general contractors; managers; real estate brokers; and urban planners all participate in facilities planning. Although all play an important role, this article will focus on the industrial engineer's role in preventing pollution in facilities planning. Because facilities planning is frequently divided into "facilities design" and "facilities location," this paper addresses pollution prevention in regards to both.

Facilities Design

Tompkins and White define facilities design as "the determination of how the components of an activity support achieving the activity's objectives." [1] These objectives usually take the form of generating profit, providing quality products, and providing quality service. Thus, the components are purchased and utilized to be as efficient and productive as possible. Wastes are usually generated by productive use of an activity's components, and it is then the responsibility of the environmental engineering department to get rid of the waste in a safe and legal manner. The traditional approach to production waste has been to view it as a necessary, if unwanted, by-product of an activity. Pollution prevention questions the necessity of waste and calls for activities to *prevent* pollution wherever possible, rather than merely controlling. Generally, pollution prevention is not explicitly defined as a means to meeting an activity's objectives. Yet, by consciously including pollution prevention in facilities planning, a more efficient and productive facility can result.

Tompkins and White stress that "the success of a firm is dependent on having an efficient production system." [2] Further, "it is essential that product designs, process selections, production schedules and facilities plans be mutually supportive." Thus, before a facility can be adequately designed, these other activities must be performed. While the facilities planner will not be involved in much of the detailed work in product design, process selection, or production scheduling, s/he will have the opportunity to review these functions as they relate to facilities planning *and* pollution prevention.

PRODUCT DESIGN

Within product design, value analysis is employed to determine the interaction between product function and cost. The facilities planner involved in product design review might ask if the choice of materials or the method of manufacturing best prevent product and process waste.

PROCESS SELECTION

The process selection procedure offers significant opportunities to prevent pollution. Interacting with the process planner, the facilities planner can ask that pollution prevention be evaluated along with cost, flexibility, efficiency, reliability and maintainability. Production Scheduling design call for scrap estimates, and it is during the process selection procedure that process and facilities planners must ask if and how much scrap is really necessary.

Step 1: Define elemental operations

Step 2: Identify alternative processes for each operation

Step 3: Analyze alternative processes

Step 4: Standardize processes

Step 5: Evaluate alternative processes

Step 6: Select processes [3]

PRODUCTION SCHEDULING

Good schedule design lends itself to pollution prevention — correct volume determinations will minimize excess inventory and possible waste. The same point applies to scrap estimates and machine fractions. When determining these values, minimizing waste is naturally a goal.

Once the product designs, process selections, and scheduling activities have been completed, the facilities planner can develop requirements for space, material handling, and personnel. Each of these activities provides opportunities for preventing pollution, and will be considered in turn.

SPACE REQUIREMENTS

Good space requirement design inherently prevents pollution. Efficient flow of material and personnel in and out of departments naturally reduces waste by reducing energy consumption and possible work-in-progress (WIP) losses. Within departments, space should be allocated to ensure stable flow of WIP. Too much space may allow WIP to accumulate, causing stress and possible waste for the downstream department. Too little space may cause employees to store WIP outside the department, where it can be lost.

Interdepartmental space allocations are even more important. A good layout minimizes the flow of material and energy through the facility. Not only are costs minimized, but waste is reduced when high-volume departments are in close proximity. As aisles provide the routes by which material is transferred between departments, good aisle arrangement also reduces waste.

MATERIAL HANDLING REQUIREMENTS

Material handling deals with moving raw material, work-in-progress, and finished goods within the facility. When determining "what to move," "where to move it," "how to move it," and "when to move it," good material handling design naturally minimizes waste. Not often asked however, is the question "what to move it in." Many parts and supplies are brought into a facility and moved through it in single-use packaging. This packaging can take the form of cardboard boxes, weak wooden pallets, or shrink-wrap plastic, all of which become waste after one use. Reusable materials, such as metal or plastic bins, can often replace disposable packaging. Ford Motor Company uses this "reusable dunnage" with both internal and external suppliers. When designing material-handling requirements, the facilities planner should investigate reusable dunnage as well.

PERSONNEL REQUIREMENTS

When defining the needs of employees, consider pollution prevention as well. For instance, the facilities planner can encourage alternatives to commuting in single-occupant vehicles. The state of California currently provides tax incentives to employers who develop transportation alternatives; other states may soon follow suit. Parking facilities can have secure, convenient bicycle storage; locker rooms can include showers for employees who cycle long distances to work. Employee shuttle services from home or a common "park-&-ride" area might also be viable. Because parking facilities can tie up large tracts of land, reducing them with these other alternatives might reduce real estate costs as well as gain tax breaks and improve the environment.

The facilities planner should also investigate the waste to be generated by the proposed food service facility. In facilities with less than 200 employees, vending machines are considered sufficient. However, this type of food service often results in a significant amount of packaging waste. As landfill costs soar, the removal of this waste can become a significant expense. The facilities planner should investigate the viability of reusable dishware and utensils — when weighed against disposal costs, they can save the firm money and prevent pollution.

Facilities Location

Traditional facilities location is concerned with placing the facility to best provide for the interactions with customers, suppliers, and other facilities. To determine the "optimal" location of the facility, planners often use analytical models that ignore environmental issues such as pollution prevention. However, simple awareness of environmental factors enable the planner to incorporate these issues into the models. Two commonly used models — minisum and minimax — can be modified to address environmental considerations.

Minisum seeks to find the value of the objective, X, which minimizes the weighted sum of distance traveled, or:

$$\text{Minimize } f(X) = \sum w_i \, d(X,P_i) \quad \text{for } i = 1 \text{ to } n$$

where $d(X,P_i)$ is the distance between X (the new location) and P_i (the existing location), and w_i is the "weight" between the new location and the existing location.

The objective function usually includes the minimization of cost or distance (cost would be assigned as part of the weight, w_i). By default, these values generally prove to benefit (or minimize the impact on) the environment: the shortest distance traveled will require the least amount of energy consumption. Sometimes, however, environmental considerations must be explicitly included in the model.

For example, a facilities planner is responsible for siting a manufacturing facility that generates toxic waste. While developing a process that does not generate the waste at all should be a goal, it might not be technologically or financially feasible at the time. Siting the facility upstream from a town might affect the town more adversely than siting it downstream. These adverse affects can translate into financial liabilities. To address this issue, the environmental consideration can be incorporated into the weights for the minisum model. An industrial engineer probably doesn't have the expertise to assess these weights independently. However, just as accountants provide necessary cost data, environmental experts should be available to provide guidance on environmental issues. The facilities planner should understand how the weights were determined and question the viability of those values before incorporating them into the model. As a facility planner, it is important to ask the questions, even if one is not necessarily able to provide the answers.

The other model, **minimax**, seeks to find the value of the objective, X, which minimizes the maximum distance between the new location and any existing location, or:

$$\text{Minimize } f(X) = \max \; d(X,P_i) \quad \text{for } i = 1 \text{ to } n$$

Minimax models are often used when transaction time cannot exceed a defined value (firehouse siting, for example). A variation — maximin (maximizing the minimum distance between the new location and any existing location) — can be used in certain environmental applications. For example, a hazardous waste facility must be sited. No one can live closer than X miles from the facility. Further, the more remote the facility the better. Thus, the minimum distance is maximized for any neighbor.

Conclusions

Environmental concerns *are here to stay*. Facilities planners will have to take these concerns into account when designing new facilities, now and into the foreseeable future. Again, it is important that a facilities planner ask the question, "Can this facility's environmental impact be reduced?" By considering pollution prevention, and including environmental variables in analytical models, the facilities planner will be addressing these growing environmental concerns.

ENDNOTES

[1] James A. Tompkins and John A. White. *Facilities Planning*. New York: Wiley & Sons, 1984, p 2.

[2] Ibid, p 33.

[3] Ibid, p. 42.

Questions

1. What has been the traditional approach to an activity's waste, and how does pollution prevention change that approach?

2. When interacting with product, process, and schedule design, how can the facilities planner introduce pollution prevention considerations?

3. Consider the location of a manufacturing facility where the costs (w_is) of traveling between the plant and existing suppliers and customers (P_is) are shown below. Solve and graph the minisum facility location problem.

Location	Coordinates	Weights
1	1,1	10
2	5,2	12
3	4,4	8
4	2,8	4
5	8,6	16
6	8,8	6

4. A new weighting table includes the adverse affects of locating the facility closer to populated areas (P_1, P_2, P_3). Solve and graph the minisum facility location problem with the environmental consideration weights.

Location	Coordinates	Weights
1	1,1	5
2	5,2	6
3	4,4	4
4	2,8	4
5	8,6	16
6	8,8	6

5. Discuss the differences between the solutions in #3 and #4.

6. Why do the environmental weightings take on smaller "cost" values?

7. If the population areas are more dispersed how will the model place the manufacturing facility?

8. Using the data from #3, develop and graph minisum contour lines for the rectilinear distance problem.

9. Now assume that a constraint is placed on the new facility whereby its location cannot be within two rectilinear units of locations 1, 2, and 3 (represented populated areas). On the graph developed for #8, show the optimal location.

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