INTEGRATING ENVIRONMENTAL ISSUES INTO MATERIAL PLANNING: 'GREEN' MRP

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Environmental issues are becoming increasingly important to manufacturing managers, employees, investors, and researchers. This importance is the result of factors such as governmental regulations, international certification standards (most notably ISO 14000), changing consumer demands, and managerial awareness of pollution as waste [15, 16]. Managers are now being asked to develop and produce goods and services that are better (higher quality), less expensive (i.e., lower cost), and more flexible, and to do so in less time. The products should also be more environmentally responsible, that is, generate less waste during their use, production, and disposal. Meeting those additional demands has created a new challenge as well as a new requirement, which managers are now struggling to meet.

In the past most research has been focused on product/process design [1, 7]. That attention correctly recognized the importance of product design to overall performance. Decisions made during the design stage, after all, have a significant impact on environmental performance. Fabrycky [6], for example, estimated that up to 85% of life cycle costs are committed by the end of the preliminary design stages. In a field research study Ulrich and Pearson [23] found that at least 50% of the costs (for a class of mature products) are design determined and that up to 70% are affected by manufacturing process decisions. Overlooked for the most part has been the role of materials planning and master scheduling in the management of environmental waste and its reduction and elimination.

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It is important to recognize that a master production schedule not only generates a time-phased flow of completed products and various supporting component schedules, but it can also be used to generate an associated "schedule" of waste and pollution. This waste schedule reflects the activities of the production system in meeting the master schedules. Included in this waste schedule are items such as packaging waste, operations waste, processing waste, and disposal waste. Since these wastes are not tracked or identified at the beginning, when the master schedule is generated, they ultimately take the form of "end-of-pipe" waste. Typically, these streams are addressed when they are encountered on the shop floor, but at that point it is too late. We are forced to remedy the problem (to address the outcomes) rather than eliminate the problem (i.e., prevent it from occurring in the first place). One reason for this situation is that managers lack the necessary tools. They do not have procedures that can flag potential waste problems when the schedules are still being formed and evaluated. This article attempts to address that shortcoming by proposing a new procedure that effectively integrates environmental concerns with materials planning.

Specifically, this article introduces a new planning procedure—"green" MRP. It is essentially a conventional material requirements planning system that has been modified to include environmental considerations when converting the master production schedule into the various component schedules. The result, as we will show, is a system that can flag not only potential component problems but also environmentally related problems. More important, this system is able to convert these environmental impacts into monetary terms—an important consideration if management is to be given a compelling reason for addressing this problem. By making these environmental problems both highly visible and urgent (since the impacts are expressed in both quantitative and monetary terms) and by focusing these activities at the planning stage, we hope to give planners and schedulers a new tool that will enable them to manage pollution in a proactive rather than a reactive manner.

Green MRP is an important element of environmentally responsible manufacturing (ERM). Melnyk and Handfield [11], who use ERM to describe the integration of environmental issues into the decision-making process, define ERM as follows:

> a system which integrates product and process design issues with issues of manufacturing production planning and control in such a manner as to identify, quantify, assess, and manage the flow of environmental waste with the goal of reducing and ultimately minimizing its impact on the environment while also trying to maximize resource efficiency.

This article describes the process of modifying conventional MRP logic to include environmental considerations during planning. In addition, it lays out the traits for an acceptable green MRP system. Finally, the initial results obtained when this new approach to planning was applied to a "real" production problem are described.

One of the objectives of the approach is to integrate two systems into one. The first system is used for manufacturing planning; the second, to identify and manage environmental waste streams. By integrating the two, we allow the people who are best positioned to manage the waste (the schedulers and the planners) to recognize the presence of waste in the schedules and to take the appropriate actions. In a sense, we are applying the concept of "quality at the source" to the problem of pollution prevention and management.

GREEN MRP—MERGING ENVIRONMENTAL CONCERNS WITH MATERIALS PLANNING

Before the concept of green MRP is introduced, it is important to explain the premises underlying this new technique:

- The definition of ERM implies an integrated system. The challenge facing companies is that environmental data usually reside in parallel information systems apart from corporate data [8]. ERM is ultimately a cross-functional undertaking, and affects all the functional areas of a business enterprise [9, 10, 14, 22]. It is here in the manufacturing process that firms put into place the actions that ultimately create the waste streams encountered in the transformation system. Production scheduling determines what items will be produced, where they will be produced, and in what quantities. These decisions, in turn, cause the consumption of resources and the creation of waste (through the discarding of packaging, the operation of equipment, and the types of material used). One way of controlling and reducing environmental waste streams is to make those responsible for production scheduling aware of the environmental impact of production schedules and the associated costs.
- When dealing with wastes, managers are interested in three major attributes [13]—the type of waste generated, the quantity generated, and the timing of the waste flows. These three elements collectively define a schedule of waste generation. Ideally, management wants to deal with such schedules because of the allocation of resources necessary to control, monitor, store, and remove wastes. Because information is presented in a familiar way, that is, MRP software output, management will be more receptive to this approach.
- Potential environmental problems should be conveyed to planners in a form that they are comfortable with and that they understand. Furthermore, these problems should be identified by a process or logic that the planners readily understand and accept.

These premises and objectives are explicitly addressed by the creation of a green MRP logic. However, to understand the operation of green MRP, we must understand material requirements planning (MRP), the basis for green MRP.

MRP is one of the most widely used manufacturing planning and control systems in industry [5, 19]. There are several reasons for its widespread acceptance. A major factor is that MRP works and that its use has generated real, sizable benefits. These include improved customer service, better production scheduling, and reduced manufacturing costs [2, 3, 18]. Another reason for MRP's acceptance lies in its inherent flexibility. The logic underlying MRP can and has been modified to meet a wide range of needs and operating conditions. In the past, for example, MRP has been modified to accommodate tool planning and scheduling [21]. In green MRP, we are modifying the underlying MRP logic to create greater pollution visibility and to provide a tool for assessing pollution problems and for evaluating alternative schedules aimed at reducing them.

TRAITS OF AN EFFECTIVE GREEN MRP SYSTEM

For green MRP to be judged effective, certain requirements have to be met. Namely, green MRP has to:

- Be implemented as an addition or "add-on" to an existing MRP system. This requirement reflects the assumption made by the research team that few firms (and managers) would be willing to buy and implement a new MRP system with the environmental waste schedule features built in. The procedure would be most attractive if it were to be presented as an add-on.
- Be able to show the impact of environmental waste issues on both costs and production requirements. That is, the user should be able to use the procedure to identify the impact of environmental problems on costs (per unit) and on the amount of production needed to meet the requirements set down in the schedule (after adjusting for environmental waste streams).
- Cope with *process* waste (waste incurred in making the product), *operation* waste (waste generated during the operation of certain equipment and processes), *product* waste (e.g., cardboard discarded when unpacking a part or component), *scrap*, and *found* material.
- Identify or recognize the impact of recycled material on production and cost. That is, during the production of a part, if there was a usable or salable by-product created, then the costs of production for the original part should be adjusted to reflect the offsetting benefit.

Using these requirements, the research team chose MAGI/MFG from MAGI of Grand Rapids, Michigan, as the basis for the development of the green MRP system. The package, which runs on an IBM-compatible system in the DOS (as compared to the Windows) environment, was selected because it embodied an MRP logic that was highly conventional. Also, the company agreed to provide support (software and programming) to the research team.

GREEN MRP—BENEFITS

If successful, green MRP can provide a firm with a number of important benefits:

- *Identification of potential problems in advance.* Porter and van der Linde [16] claim that companies must improve their ability to collect environmental cost and savings information. In most manufacturing systems, the people who do the planning of production are unaware of the impact of their plans on the level and timing of environmental waste. As a result, any problems relating to waste levels are often flagged by others operating outside the manufacturing planning system. Often this means that plans previously generated through extensive work have to be revisited and revised, which is an extensive, time-consuming, and often less than effective exercise. By integrating the manufacturing planning process with the waste management process, we can provide manufacturing planners with the tools needed to identify potential problems while they are still in the process of developing production plans. Given past experience with product design systems, such as simultaneous engineering, we know that early introduction of such issues results in better products being designed and developed in less time [12].
- *Improved waste management planning.* A company's ability to accurately reflect the costs associated with current or proposed products and processes is the most critical information required for an ERM initiative to be given serious consideration [17]. Whenever a stream of waste is generated, there are a number of issues that must be resolved. It has been commonly accepted that there are great benefits in eliminating pollution at its source rather than reacting to the situation with end-of-pipe controls [4]. Capacity for waste management must be proactive and planned. This capacity consists of people who are trained in the handling, management, and disposition of waste. It also consists of waste-moving equipment and waste storage locations. A green MRP system can provide the planner with the necessary tools to determine the schedule of waste and to formally plan the capacity necessary to manage this waste. That should result in better management of waste-related costs and, ultimately, a reduction in the overall level of overhead assigned to this area.
- *Improved ability to ensure compliance with government regulations and requirements.* At a minimum, manufacturing firms must be in compliance with the appropriate governmental regulations. Often this compliance is attained by a series of short-term, reactive actions [20]. The result is that firms often scramble and take actions aimed at bringing the situation back under control. In some cases, this may mean accepting the situation and paying the increased costs (due to fines or the purchase of pollution credits from other firms). In other cases, the schedule and/or the product mix may have been changed to something that will help bring down the waste levels. In some cases, the firm may even decide to shut down production until the problem is resolved. By planning for waste flows in advance with green MRP, the resulting flows of waste can be analyzed to determine whether or not they are in compliance with government regulations. If they are not, then the firm will have sufficient time available in which to evaluate other plans or actions through a series of "what if"

simulations (a major feature of most MRP systems). The results will help ensure compliance.

- *Generation of formal documentation for government requirements.* Ultimately, the waste schedules generated by a green MRP system can be used to generate the formal documentation many government agencies require. The result should be an overall reduction in the amount of activity needed to meet these requirements since one system (green MRP) will be used to meet and satisfy those various needs. This documentation also parallels the environmental management systems proposed by ISO 14000.

GREEN MRP—A CASE STUDY IN IMPLEMENTATION

The green MRP system was developed and evaluated through a case study. In this study, the implementation consisted of two elements carried out simultaneously. The first was selecting a prototype to be used in building and testing the operation of the modified MRP system. The second was the modification of the MRP logic.

The part studied for this project—a taillight for a pickup truck—was chosen for several reasons. First, the taillight involves purchased components, recycled material, and "virgin" material. Second, during the manufacture of the taillight, all four types of waste (scrap, product, process, and operation) were observed. Third, the taillight assembly involves a relatively shallow bill of materials and a very short lead time (i.e., all production issued during a shift is completed during that shift).

The taillight assembly consists primarily of two plastic parts, one manufactured (the black plastic metallized body), the other purchased (the red and white plastic lens). The two parts are glued together, metal studs are inserted in the back for fit on the truck, and bulbs are snapped into the body.

Using a mass balance approach to the inputs and outputs of the system, if we have an order for 3600 parts and we have scrap factors at different levels and at different routings, then the system will identify the need to produce more than 3600 parts to fulfill the master production schedule. We want to capture the difference between what was produced and what was used to fill the order for the shift. This difference will yield the amount of waste and, if minimized, will help to recover lost profits. The following three approaches for doing so were assessed:

- *Modified BOM approach.* This approach, which meant changing the BOM to include waste products generated at each level, is not very parsimonious. Each part will not only have the original subassemblies and inputs, but will now also have additional components that capture the waste associated with each component.
- *Bill of waste approach.* For this approach, a bill of waste is created to exist parallel to the BOM, focusing on the waste products created. For each product a separate but parallel BOM will identify and accumulate the wastes associated with a specific part. Again, this is not a very parsimonious approach.
- *Scrap factor approach.* In this approach, the scrap factors in the software are used to account for wastes. Depending on the software used, this can be a much simpler approach to capturing relevant waste information. Existing scrap factors for the routings and for the BOM can be used to capture the waste involved with the component. The scrap factors for the BOM account for components themselves that are going to be wasted and for which the MRP system should plan. The scrap factor in the routings is used to plan for the cost of the waste in the cost rollout worksheets. This routing scrap factor is not used in the planning of the MRP system.

While all three approaches have their merits, the third one was selected because it is intuitive in nature. As such, it was felt that it would be the one most easily understood by managers. Further, it required the least amount of change to the computer programs. That is, it required the least amount of change to the database fields, and was easily incorporated into any new reports that managers might want.

INITIAL EXPERIENCES WITH GREEN MRP

To make the research as realistic as possible, actual production data pertaining to the assembly and manufacture of the taillight assembly were obtained (thanks to the active participation of the manufacturer). One of the difficulties noted during the data collection process was the firm's lack of reliable statistics on waste. Through the course of numerous interviews with company personnel, it became apparent that, while the firm did a good job of collecting data on the amount of government-regulated pollution produced, there was limited understanding of how much material was going to waste during the production process. It was not unusual to have a situation in which two people who worked with the process and the product (and could be assumed to be knowledgeable about the product) gave two different estimates for the level of waste being generated. Care was taken to ensure that the values used in the green MRP system were well supported and that they were set conservatively. As a result, while

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PART NUMBER		U/M	ACCOUNT NUMBER	COMM	TYPE-M/B	ANNUAL FORECAST	COSTED LOT SIZE
A1-F75X-13440-CC	BODY LH RR METAL BODY	EACH			S-M	0	3600

Frozen Matl - Labor - Overhead Rates with the Standard Routing.

OPERATION NUMBER 01	Work Center	Work Center Rates: Labor	Fxd Ohd	Var Ohd		
injection molding	3 Plastics	18.75	0.0000	0.0000	DLHR	Opn Scrap - 5.000

Bill of Material		U/M	Type M/B	Qty Per	Material	Labor	Fxd Ohd	Var Ohd	Total
F1-RESF-M4D373	RM ABS HIGH HEAT BLA	OZ	Std B	1.0000	1.000	0.000	0.000	0.000	1.000
Material ====>					1.000	0.000	0.000	0.000	1.000

Labor & Overhead	LT	SU Hr	Pcs/Hr	Material	Labor	Fxd Ohd	Var Ohd	Total
		0.3	205.76	0.000	0.093	0.000	0.000	0.093

Note: Setup cost per piece (std lot size) is 0.0016

	Material	Labor	Fxd Ohd	Var Ohd	Total
BOM Waste in this operation ====>	0.050	0.000	0.000	0.000	0.050
RTG Waste in this operation ====>	0.053	0.005	0.000	0.000	0.058
Total opn cost per piece (incl. scrap) ====>	0.000	0.093	0.000	0.000	0.093
Running Total ====>	1.053	0.098	0.000	0.000	1.150

OPERATION NUMBER 02	Work Center	Work Center Rates: Labor	Fxd Ohd	Var Ohd		
metalization	2 Metalization	18.75	0.0000	0.0000	DLHR	Opn Scrap - 2.000

Bill of Material		U/M	Type M/B	Qty Per	Material	Labor	Fxd Ohd	Var Ohd	Total
D1-CATHOD-NICR	PP CATHODE NICR 80/20	OZ	Std B	0.0010	0.001	0.000	0.000	0.000	0.001
Material ====>					0.001	0.000	0.000	0.000	0.001

Labor & Overhead	LT	SU Hr	Pcs/Hr	Material	Labor	Fxd Ohd	Var Ohd	Total
		0.0	450.05	0.000	0.042	0.000	0.000	0.042

	Material	Labor	Fxd Ohd	Var Ohd	Total
BOM Waste in this operation ====>	0.001	0.000	0.000	0.000	0.001
RTG Waste in this operation ====>	0.020	0.003	0.000	0.000	0.023
Total opn cost per piece (incl. scrap) ====>	0.000	0.042	0.000	0.000	0.042
Running Total ====>	1.074	0.142	0.000	0.000	1.216

GRAND TOTALS

	Material	Labor	Fxd Ohd	Var Ohd	Total
Total from Material ====>	1.001	0.000	0.000	0.000	1.001
Total from Operations ====>	0.000	0.134	0.000	0.000	0.134
Total from BOM Waste ====>	0.051	0.000	0.000	0.000	0.051
Total from RTG Waste ====>	0.073	0.008	0.000	0.000	0.081
Total Cost ====>	1.074	0.142	0.000	0.000	1.216

FIGURE 1: Green MRP report for base or "as is" case

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PART NUMBER		U/M	ACCOUNT NUMBER	COMM	TYPE-M/B	ANNUAL FORECAST	COSTED LOT SIZE
A1-PN96	FORD F150 REAR LAMP STYLESID	EACH	0-000-1305-000	?	S-M	0	3600

BOM Waste in this operation ====>	0.000	0.000	0.000	0.000	0.000
RTG Waste in this operation ====>	0.046	0.002	0.000	0.000	0.048
Total opn cost per piece (incl. scrap) ====>	0.000	0.023	0.000	0.000	0.023
Running Total ====>	9.296	0.392	0.000	0.000	9.688

OPERATION	Work	Work Center Rates				
NUMBER 090	Center	Labor	Fxd Ohd	Var Ohd		
final packing	8 Inspection	18.75	0.0000	0.0000	DLHR	Opn Scrap - 0.000

Bill of Material		U/M	Type M/B	Qty Per	Material	Labor	Fxd Ohd	Var Ohd	Total
Q1-48ZH5830	DU PAD CONTAINER FOR PA	EACH	Std B	1.0000	1.000	0.000	0.000	0.000	1.000
Material ====>					1.000	0.000	0.000	0.000	1.000

Labor & Overhead	LT	SU Hr	Pcs/Hr	Material	Labor	Fxd Ohd	Var Ohd	Total
		0.0	476.19	0.000	0.039	0.000	0.000	0.039

BOM Waste in this operation ====>	0.000	0.000	0.000	0.000	0.000
RTG Waste in this operation ====>	0.000	0.000	0.000	0.000	0.000
Total opn cost per piece (incl. scrap) ====>	0.000	0.039	0.000	0.000	0.039
Running Total ====>	10.296	0.431	0.000	0.000	10.727

GRAND TOTALS

Total from Material ====>	10.074	0.142	0.000	0.000	10.216
Total from Operations ====>	0.000	0.279	0.000	0.000	0.279
Total from BOM Waste ====>	0.697	0.071	0.000	0.000	0.768
Total from RTG Waste ====>	0.222	0.010	0.000	0.000	0.232
Total Cost ====>	10.296	0.431	0.000	0.000	10.727

FIGURE 1—*continued:* **Green MRP report for base or "as is" case**

we had confidence in our data, we recognized that in some cases certain statistics were only estimates.

Working with the firm, we were able to produce a product cost worksheet. The worksheets generated used the scrap factors for the parts and for the routings. These worksheets allowed the cost of the scrap to appear on reports that a production planner could generate before the order is released to the shop floor. This allowed for an "up-front" look at the waste that would be generated, before any potential problems occurred. It also allowed for better planning for waste disposal and an understanding of where the costs of the waste are coming from and what processes or products need to be further developed to minimize their impact on the waste stream.

Most dramatically, these worksheets clearly illustrated the costs of waste. Using a simple "what-if" analysis, the research team generated product costs for the part "as-is" and for the part assuming that all waste had been eliminated from the production process. These two reports, both generated by the resulting green MRP system, are presented in figures 1 (for "as is") and 2 (for "no waste" case). The comparison between the two scenarios clearly shows a difference of

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No Waste Case
PRODUCT COST WORKSHEET

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PART NUMBER		U/M	ACCOUNT NUMBER	COMM	TYPE-M/B	ANNUAL FORECAST	COSTED LOT SIZE
A1-F75X-13440-CC	BODY LH RR METAL BODY	EACH			S-M	0	3600

Frozen Matl - Labor - Overhead Rates with the Standard Routing.

OPERATION NUMBER 01 injection molding | Work Center 3 Plastics

Work Center Rates: Labor 18.75, Fxd Ohd 0.0000, Var Ohd 0.0000 DLHR Opn Scrap - 0.000

Bill of Material		U/M	Type M/B	Qty Per	Material	Labor	Fxd Ohd	Var Ohd	Total
F1-RESF-M4D373	RM ABS HIGH HEAT BLA	OZ	Std B	1.0000	1.000	0.000	0.000	0.000	1.000
Material →					1.000	0.000	0.000	0.000	1.000

Labor & Overhead	LT	SU Hr	Pcs/Hr	Material	Labor	Fxd Ohd	Var Ohd	Total
		0.3	205.76	0.000	0.093	0.000	0.000	0.093

Note: Setup cost per piece (std lot size) is 0.0016

	Material	Labor	Fxd Ohd	Var Ohd	Total
BOM Waste in this operation →	0.000	0.000	0.000	0.000	0.000
RTG Waste in this operation →	0.000	0.000	0.000	0.000	0.000
Total opn cost per piece (incl. scrap) →	0.000	0.093	0.000	0.000	0.093
Running Total →	1.000	0.093	0.000	0.000	1.093

OPERATION NUMBER 02 metalization | Work Center 2 Metalization

Work Center Rates: Labor 18.75, Fxd Ohd 0.0000, Var Ohd 0.0000 DLHR Opn Scrap - 0.000

Bill of Material		U/M	Type M/B	Qty Per	Material	Labor	Fxd Ohd	Var Ohd	Total
D1-CATHOD-NICR	PP CATHODE NICR 80/20	OZ	Std B	0.0010	0.001	0.000	0.000	0.000	0.001
Material →					0.001	0.000	0.000	0.000	0.001

Labor & Overhead	LT	SU Hr	Pcs/Hr	Material	Labor	Fxd Ohd	Var Ohd	Total
		0.0	450.00	0.000	0.042	0.000	0.000	0.042

	Material	Labor	Fxd Ohd	Var Ohd	Total
BOM Waste in this operation →	0.000	0.000	0.000	0.000	0.000
RTG Waste in this operation →	0.000	0.000	0.000	0.000	0.000
Total opn cost per piece (incl. scrap) →	0.000	0.042	0.000	0.000	0.042
Running Total →	1.001	0.134	0.000	0.000	1.135

GRAND TOTALS

	Material	Labor	Fxd Ohd	Var Ohd	Total
Total from Material →	1.001	0.000	0.000	0.000	1.001
Total from Operations →	0.000	0.134	0.000	0.000	0.134
Total from BOM Waste →	0.000	0.000	0.000	0.000	0.000
Total from RTG Waste →	0.000	0.000	0.000	0.000	0.000
Total Cost →	1.001	0.134	0.000	0.000	1.135

FIGURE 2: Green MRP report for "no waste" case

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PART NUMBER		U/M	ACCOUNT NUMBER	COMM	TYPE-M/B	ANNUAL FORECAST	COSTED LOT SIZE
A1-PN96	FORD F150 REAR LAMP STYLESID	EACH	0-000-1305-000	?	S-M	0	3600

BOM Waste in this operation ====>	0.000	0.000	0.000	0.000	0.000
RTG Waste in this operation ====>	0.000	0.000	0.000	0.000	0.000
Total opn cost per piece (incl. scrap) ====>	0.000	0.023	0.000	0.000	0.023
Running Total ====>	9.001	0.374	0.000	0.000	9.375

OPERATION	Work	Work Center Rates			
NUMBER 090	Center	Labor	Fxd Ohd	Var Ohd	
final packing	8 Inspection	18.75	0.0000	0.0000	DLHR Opn Scrap - 0.000

Bill of Material		U/M	Type M/B	Qty Per	Material	Labor	Fxd Ohd	Var Ohd	Total
Q1-48ZH5830	DU PAD CONTAINER FOR PA	EACH	Std B	1.0000	1.000	0.000	0.000	0.000	1.000
Material ====>					1.000	0.000	0.000	0.000	1.000

Labor & Overhead	LT	SU Hr	Pcs/Hr	Material	Labor	Fxd Ohd	Var Ohd	Total
		0.0	476.19	0.000	0.039	0.000	0.000	0.039

BOM Waste in this operation ====>	0.000	0.000	0.000	0.000	0.000
RTG Waste in this operation ====>	0.000	0.000	0.000	0.000	0.000
Total opn cost per piece (incl. scrap) ====>	0.000	0.039	0.000	0.000	0.039
Running Total ====>	10.001	0.413	0.000	0.000	10.414

GRAND TOTALS

Total from Material ====>	10.001	0.134	0.000	0.000	10.135
Total from Operations ====>	0.000	0.279	0.000	0.000	0.279
Total from BOM Waste ====>	0.000	0.000	0.000	0.000	0.000
Total from RTG Waste ====>	0.000	0.000	0.000	0.000	0.000
Total Cost ====>	10.001	0.413	0.000	0.000	10.414

FIGURE 2—*continued:* Green MRP report for "no waste" case

about $281,700 when summed over one year's worth of production (assuming one shift per day of production). This number was arrived at by taking the difference in costs due to environmental waste ($.313 per piece) and multiplying it by the number of units produced per year (assuming production of 5 days per week and 50 production weeks). By explicitly recognizing the cost of environmental waste in this way, we were able to decompose a large part of the overhead, which is where this firm previously assigned these costs. Nothing had been done because, as part of overhead, the source of the costs could not be easily identified, nor was anyone responsible for managing this cost component. By separating these costs from the rest of overhead, we were able to make the pollution problem highly visible and to provide management with a strong, compelling (cost-reduction based) reason for change. This type of possible cost savings is even more dramatic considering the fact that the truck has thousands of parts; the taillight is just one single part.

At present, the research team is working with the firm to further enhance the capabilities of this green MRP system and to assess user acceptance of the new system.

CONCLUDING COMMENTS

We have described the concepts behind environmentally responsible manufacturing, and a tool for this system, green MRP. As we have shown, green MRP is a relatively easy and intuitive method for managers to use to become aware of waste problems that may exist in the production process.

It is imperative that the MRP system mirror actual shop conditions. Both the physical system and the information system have the ability to capture waste information that has traditionally been overlooked. The wastes associated within the manufacturing processes studied contain valuable cost and quality information about processes and products. This article addresses one approach to capturing relevant waste information that has been overlooked in the assemble-to-order environment.

Our initial results show that a significant amount of waste information can be captured in existing off-the-shelf software. Capturing that information can lead to better cost allocation to components, the identification of potential problems in advance, improved waste management planning, improved documentation, and an improved ability to ensure compliance with government regulations. Additionally, green MRP becomes a tool that helps facilitate integrated resource management. Through the use of green MRP we may see better communication between finance, accounting, purchasing, production, maintenance, environmental health and safety, and logistics. Green MRP can act as a warning system, telling firms where and when a waste problem exists and the costs savings available if they can solve the problem.

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