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Development of a Software Tool to Improve Performance of Packaging Operations through Short Interval Scheduling

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A manufacturer of precision extruded aluminum parts needed to improve productivity and scheduling in its packaging department. Because of the non-standard, irregular nature of the department's work, this market leader chose short interval scheduling (SIS) as the solution. However, in order for SIS to be effective, the company needed to create labour and material standards for the packaging process. Personnel from the Enterprise Systems Center (ESC) at Lehigh University collaborated with the company and, using a standard methodology for process analysis and change, created those standards. Information derived from the implementation of those standards permitted ESC personnel to develop a decision support tool that could more accurately calculate the cost of the packaging and shipping operation. This tool also provided the information necessary to effectively implement SIS. The theory of SIS is described, along with a brief summary of the pertinent literature. The current system is analysed and the desired performance improvements are identified. The development of the decision support tool, the results achieved through its usage, and final conclusions are reviewed. Copyright © 2003 John Wiley & Sons, Ltd.

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INTRODUCTION

In recent times, many companies have abandoned or neglected various production supports, as a means to save or reduce costs, only to find that they later experience difficulties when trying to bring order to their daily operations, which are running poorly or out of control. Such was the case at XYZ Inc., a manufacturer of precision extruded aluminum parts. Due to a reduction in staff, there was no one available to maintain or develop production standards. As a result, they were using cost and labour standards that had become obsolete for their packaging process. Because of the inaccuracy of this information, they were unable to calculate the true operating costs for this opera-

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tion. Since packaging and shipping costs were billed back to the customer, in the absence of a more accurate method, XYZ based their customer quotes on a per pound metric, which was a best-guess estimate with no detail or validity to support it. Not only were the standards outdated, but the prescribed methodology for packaging had also been neglected. Therefore, they did not have consistent packaging processes that defined appropriate material utilization and reasonable expectations of the time required to complete the packaging. Without these standardized processes, it was impossible to develop an effective scheduling method, resulting in insufficient throughput and excessive requests to expedite orders.

Lehigh University's Enterprise Systems Center (ESC), in cooperation with the Ben Franklin Technology Partners of Northeastern Pennsylvania, a state-funded organization that promotes partnerships between universities and industries to improve the competitiveness of Pennsylvania manufacturers, collaborated with XYZ in an improvement project designed to accomplish the following:

1. Create a method to establish accurate baseline estimates for labor and material costs in the packaging process.
2. Improve workflow and scheduling.
3. Minimize the need to expedite orders.
4. Eliminate non-value-added activities and improve packaging productivity.

Short interval scheduling (SIS) was chosen as the scheduling and production control system. To utilize SIS effectively, XYZ needed to establish standardized packaging processes. In addition, XYZ needed a tool that would accurately calculate the costs of those standardized processes. These steps would result in XYZ improving its understanding of the final packaging process in relation to the amount of resources needed to optimize it for greatest efficiency. It would also have the capability to accurately recover the costs of the packaging operation from its customers. This paper describes the steps followed to develop the tool and implement the system.

PROBLEM STATEMENT

In any production environment, time is one of the most important resources under management's control. Lack of scheduling in a manufacturing process makes it extremely difficult for subsequent operations, such as packaging and shipping, to meet completion dates. While examining the packaging process of different orders for XYZ, it was observed that orders were packed using various methods. The same parts packed by two different teams would produce completely different results.

At XYZ, orders in the packaging department were assigned to packing teams when all the finished parts for an order became available. Availability was determined by the supervisor taking a manual count of finished staged production parts. There were no schedules used for prioritizing orders or time standards communicated to, or used by, the workers for packing.

Each packing team was responsible for determining what packaging supplies were needed and obtaining those materials. Because there were no standard packing methods communicated to the individual packing teams, they were largely responsible for using their own judgment on how to pack. This created a lack of expected efficiency in material usage and packing rates, which in turn created the need for overtime work to pack orders that were late. In addition, because priorities were not keyed to customer commitments, many orders needed to be expedited.

Because the level of overtime had become unacceptable, XYZ's management concluded that improved operational procedures were the key to cost reduction and increased throughput. In order to optimize the packaging process, it was necessary to standardize it. This task required the definition and development of standard methods and times for each order (job) and uniform material usage. This necessitated a tool able to plan material usage and generate estimates of times for packaging different types of orders.

The project team believed that SIS would provide the effective time management necessary to meet operational goals. Because the SIS methodology permits management to plan and control work activity of an irregular nature, it avoids the problems associated with relying on traditional production standards that may not be accurate for the variety of work encountered. With SIS, the supervisor uses a systematic approach, reviewing the output of every group, using SIS to assign more work, and looking for ways to improve the flow.

LITERATURE REVIEW AND BACKGROUND ON SIS

SIS uses the same basis as regular scheduling in determining work output. Richardson (1976) defines scheduling as a process for allocating resources to perform specific tasks in a given period of time. Normally, the given task or work unit is regular and predictable. When that is not the case, broader work classifications must be used and work units that are considered similar may in fact require different times and resources to complete. As with regular scheduling, standard data is developed using time studies or predetermined times. While not a work measurement technique, SIS is closely aligned with work measurement. It is used to develop standard times where the determination of such is difficult, due to non-repetitive, irregular work elements and activities. Once these standards are developed, supervisors are able to develop work schedules at the point of effort, allowing them to forecast and control work over relatively short time spans. This increases output in areas that previously were difficult to monitor and evaluate.

Zweben (1994) established that SIS could be used to solve scheduling problems for either the next hour or the next few weeks. According to Smith (1981), successful SIS programs have been implemented for such diverse functions as production, materials handling, quality assurance, maintenance, engineering, and assembly operations. SIS has been mainly used for high-volume situations and for the assignment of pre-measured and pre-defined work, with immediate follow-up and correction when tasks are running late.

Since a variety of groups share responsibility for scheduling decisions, using SIS allows teams to coordinate and couple their activities. In situations where orders can only be processed when the right tools, workers and raw material are available, scheduling over a long time interval may allow a backlog to build. Production time lost can never be regained, and the only recourse is to work overtime or hire additional people. As Li (1996) mentions, the idea that using SIS to solve major cycle-time issues without worrying about the basic behavior of the system is very dangerous. Therefore, while implementing SIS it is necessary to keep alert for other areas of improvement. Input from employees throughout the process may provide valuable information on potential problem areas.

Schmahl (1996) states that SIS can be used to support continuous improvement efforts in production operations. Her studies of decision support systems outline the types of data necessary to plan and control manufacturing operations. The information generated by the decision support system needs to be communicated to shop management and production control to assist personnel in meeting shop performance goals.

Close supervision of operations is required to obtain the benefits of SIS. This brings immediate attention and control to conditions such as backlogs that could decrease total manufacturing output. With short intervals of time allotted for production, supervisors are forced to address and resolve non-value-added work elements. SIS enables supervisors to prevent lost production due to a lack of work, non-standard materials or slow problem intervention by workers. Employees work to a standard that discourages the inclination to stretch out work to fill time and reduce the number of assignments. In utilizing SIS, work units should be developed using the following guidelines:

1. The work output is easy to count.
2. The work is consistent with existing information systems.
3. The work is or can be substantiated with historical data.
4. Other work can be associated with these units.
5. The effort accounts for most of the work input for the person or group.

It is important in developing these work units not to add blanket amounts of extra time to allow for unusual cases or to guarantee a smooth operation due to a time cushion. These practices will only hide work problems and make difficulties harder to correct. Any type of scheduling requires knowledge of the time needed to complete a job. Since SIS is associated with irregular work, less precise time standards are used. The degree of precision depends upon the nature of the work. Initially, one may use pooled estimates of time from the supervisor, the workers and an industrial engineer. This can be supplemented with normal standards development efforts to arrive at a thorough

database of activities and corresponding standard times.

Once this database has been established, workers need to be informed of its purpose and application. They need to be made aware that each task has an allotted time for completion and that they will be expected to complete their work within a specified time frame. New work assignments will then be given. Their performance will be monitored and problems will be addressed immediately. Once this has been completed, the system can be implemented. Implementation requires determining what work needs to be completed, the activities associated with that task, and the time required both individually and as a whole to complete the effort. This can be done either manually or through a computer routine that has been developed. It is now incumbent on the supervisor to establish how much work to assign to each worker or group at a time and to keep track of their performance in completing those efforts. Any significant deviation from the time standard should be addressed and corrected immediately, just as would be the case with regular work efforts. As the work is completed, new work can be assigned. Management now has an effective tool that can be used to improve productivity, eliminate overtime and improve customer service. However, this does not relieve the supervisor of his/her responsibility to manage the people and the work properly. SIS is only a tool to help in that process.

While SIS has proved successful in many applications, it is not always the right choice. There are certain conditions that must be considered before deciding whether or not the use of SIS is appropriate. SIS is more likely to succeed in situations where:

1. The desired workflow is difficult to forecast with respect to time or required processes.
2. It is hard to develop accurate standards.
3. The work patterns are irregular.
4. Scheduled completion dates are missed because orders are held up in large queues.
5. It has been difficult to reach the desired levels of throughput.

In addition, SIS is more effective in a company in which the first-line supervisor or the operator can be delegated a fair amount of discretion for his/her operation. The existence of a number of these characteristics at XYZ Inc. suggested that SIS would be an appropriate choice. In particular, the following conditions existed:

1. The packaging department did not know in advance which products were going to be available for packaging or when they would be available. Thus, they were not in a position to do any long-term scheduling.
2. Since XYZ knew that their packaging process standards were lacking, no production targets were given to the workers. Thus, they did not how much they were expected to produce over any given period of time.
3. Throughput levels were unacceptably low and deadlines were compromised due to minimal supervision of workers' progress.

PACKAGING IMPROVEMENT METHODOLOGY

A standard methodology for process analysis was used to improve XYZ's Packaging Department performance. As shown in Figure 1, the current situation was modelled to establish a baseline from which to make improvements. This is described as the 'As-Is' environment. Next, the 'As-Is' environment was analysed to identify and prioritize areas for short-term and long-term improvement. Based on this analysis, an improved system was designed to eliminate the current shortcomings and to establish best methods from which to develop standards. This was identified as the 'To-Be' environment, which was then implemented.

'As-Is' environment

Before the process could be improved, it was necessary to understand and document it. To model the 'as-is' environment, extensive information was gathered relative to the physical layout, material flow, labour operations, existing costs, throughput levels, various packaging materials/methods in use, and shipping activities. To facilitate the analysis, the process was divided into two components – labour requirements and materials requirements.

The packaging process was analysed to identify what caused inefficiencies, inconsistencies of styles and the constant use of overtime. Irregularities in

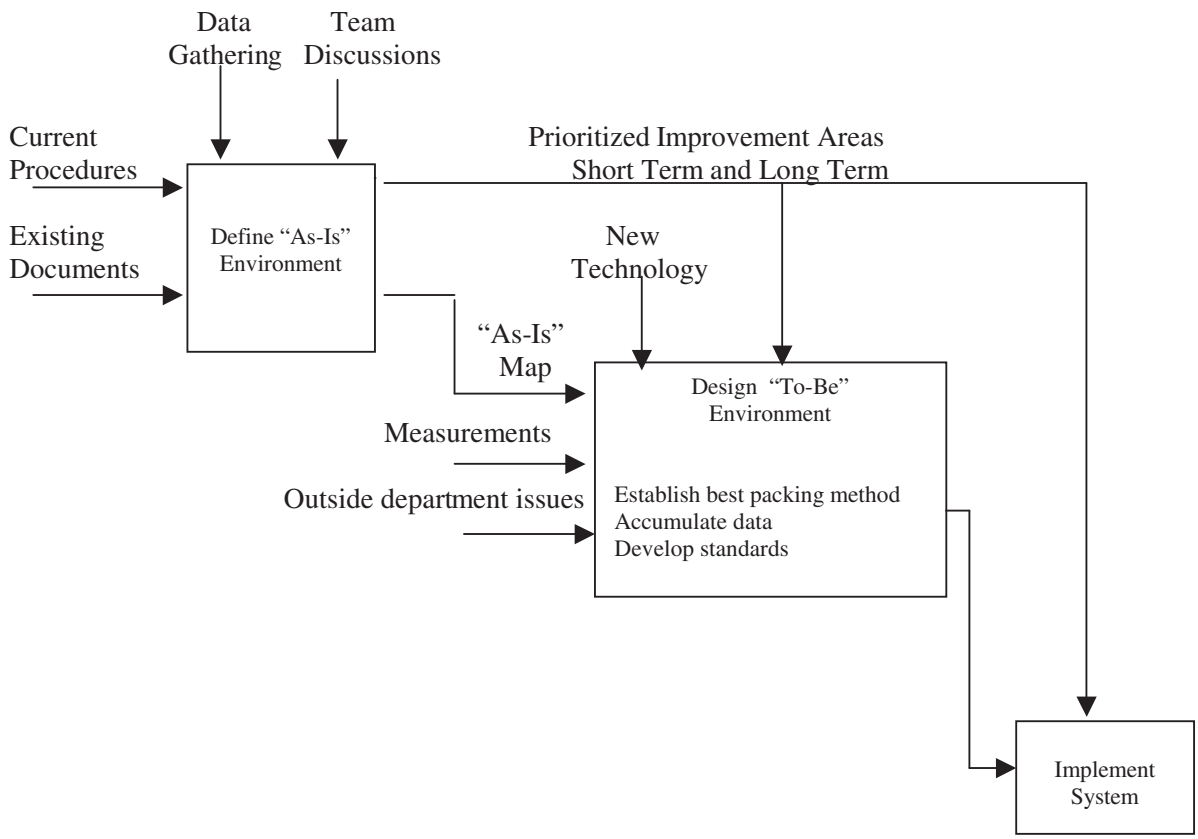

Figure 1. Packaging improvement map.

the packaging process were identified from shift to shift and from order to order. The sales department defined the packaging instructions for each order when the order was received from customers. A system printout conveyed that information to the two-person packaging team assigned that order. However, the printout often did not have accurate or sufficient information to fully specify the packaging.

Additionally, not all employees had the same level of expertise, even within the two-person packaging team. If there was insufficient information on the printout, each team had to make assumptions based on its own experience and level of expertise to compensate. This caused significant variations in packaging style, procedures and the time required to complete each job. Teams also made their own changes to packaging orders, deviating from the instructions by, for example, changing the number of pieces in a bundle or ignoring the allowed weight of the bundle.

In order to determine the 'As-Is' environment for packaging materials, a material usage study was conducted. The Enterprise Systems Center (ESC) team selected the top 20 customers, which accounted for 80% of the total sales. Observations were recorded, and materials and methods were measured on 40–50 orders.

'To-Be' environment

Upon completion of the data-gathering phase and the construction of the 'as-is' model, ESC personnel were ready to analyse the information and establish production standards. Performing time studies proved difficult at first, since there was no set method that employees followed for the packaging operation. Each team had developed its own

Group: Limited Corrugated			
Steps	**Description**	**Units of Measure (per)**	**Family ID**
1	Print out work order	Bundle	Standard
2	Fill out paperwork	Rack	Standard
3	Pick up parts	Move pieces	Sub-bundle amount
4	Place the parts interleaved	Sub-bundle	Sub-bundle amount
5	Get tape	Sub-bundle	No. of taping pieces req'd
6	Pick up a layering paper and place the bundle in it	Sub-bundle	Standard
7	Tape the bundle	Sub-bundle	No. of taping pieces req'd.
8	Move the sub-bundle	Sub-bundle	Standard
9	Tape the bundle using cardboard pieces	Bundle	No. of taping pieces req'd.
10	Go and get the wood for strapping and mark the bundle	Bundle	Standard
11	Place wood on strap locations and strap bundle	Bundle	No. of straps req'd
12	Print label and stick it on	Bundle	Standard
13	Remove Kevlar slats	Rack layer amt	Standard
14	Move the old rack and bring in a full one	Rack	Standard
15	Roll paper for layering and interleaving	Bundle	Standard

Figure 2. Standard process for Limited Corrugated Group.

procedures, based on either habit or preference. As a result, it was necessary to identify the methods for packaging as well as to conduct time studies, in order to have accurate data from which to develop the packaging standards. From this information, a labour-calculating tool was developed that provided estimated labour costs based on a chosen family of work elements and packaging requirements.

No single method could accommodate the range of differences among customers' packaging requests in terms of the materials used. Instead, standardization of the process was agreed upon for the following five different packaging categories or groups: limited corrugated; full corrugated; wood; tube; and triple-wall corrugated. For each group, a different method was created. Since the packaging steps were different for each group of orders, each step was identified and time studies were performed to determine the estimated amount of time required. In addition, a formula was created for each group to calculate the estimated time to pack and the associated cost of the labour involved. Figure 2 shows an example of the standardized process for one of the groups.

While working to standardize methods within each group, it was determined that some steps could not be fully standardized because of differences in the weight, length, width and/or shape of certain pieces being packaged. Since XYZ did not want to establish formulae for every packaging variation, the solution was to create families within each group to accommodate the differences. Four families were established within each group to cover all the packaging processes, allowing for 20 different procedures that covered the 5000 packaging variations. Figure 3 shows an example of how a family within each group was created.

System refinement and results

As the families within each category were developed, differences in the steps required to pack an order were noted among them. To account for these differences, the labour-calculating tool was revised. For each step, a completion time was calculated, based upon time values determined from the time studies. Adding together the completion times for each step of the packing process resulted in the total time required to pack an order. Figure 4 shows an example of the new formulation for one family.

Group: Limited Corrugated			
Steps	**Description**	**Units of Measure**	**Family ID**
		(per)	
5	Get tape	Sub-bundle	No. of taping pieces req'd
7	Tape the bundle	Sub-bundle	No. of taping pieces req'd
9	Tape the bundle using cardboard pieces	Bundle	No. of taping pieces req'd
11	Place wood on strap locations and strap bundle	Bundle	No. of straps req'd
3	Pick up parts	Piece	Standard
4	Place the parts interleaved	Piece	Standard
1	Print out work order	Bundle	Standard
2	Fill out paper work	Rack	Standard
6	Pick up a layering paper and place the bundle in it	Sub-bundle	Standard
8	Move the sub-bundle	Sub-bundle	Standard
10	Go and get the wood for strapping and mark the bundle	Bundle	Standard
12	Print label and stick it on	Bundle	Standard
13	Remove Kevlar slats	Rack layer amt	Standard
14	Move the old rack and bring in a full one	Rack	Standard
15	Roll paper for layering and interleaving	Bundle	Standard

Figure 3. Family example in Limited Corrugated Group.

The following steps were necessary for the tool to work:

1. Identify the packaging group (choice of five groups).
2. Identify the family within the group (choice of four families).
3. Enter the variable values of pieces per order, pieces per bundle, and pieces per sub-bundle (if necessary).

By using the tool to calculate total packing time for a specific number of orders, supervisors could create daily production schedules for each team using the SIS approach. The tool was also able to calculate the labour cost per order and could be used to provide the following information about each order:

1. Time allocations for each step of the process.
2. Costs associated with each step of the process.

By using the standards that were developed through the labour-calculating tool, the company was able to generate a packaging schedule. Adhering to the schedule produced significant results. Productivity increased by an average of 16.4% over a sampling of eight shifts (see Table 1). This productivity gain translated into an additional five orders per shift per team. The resultant decrease in overtime costs represented an annual labour savings of $800,000.

Material

The type and the amount of packing material were the other critical components of the total cost. While analysing the data from the material usage study, inconsistencies in the amounts and types of materials used were identified. Since there were no standard methods for the packaging process, different teams would pack the same order using very different amounts and types of materials, based upon their judgment. This resulted in a wide range of packaging costs for similar orders. The ESC team developed a program on an Excel spreadsheet to specify the materials to be used. Using cost coefficients incorporated in the spreadsheet, the sheet could then calculate total material cost by packaging order. As shown in Figure 5, the computation of the material cost provided the following information:

1. Costs of the various materials used.
2. Overall cost of packaging materials.
3. Cost per product piece and per product pound.

Steps	Description	Units of Measure (per)	Family ID	Formulation
5	Get tape	Sub-bundle	No. of taping pieces	[(PCS/ORDER) / **(PCS/SUBBUNDLE)**) * **(TAPING PCS/BUNDLE)]** * *(TIME/TAPING LOC)*
7	Tape the bundle	Sub-bundle	No. of taping pieces	
9	Tape the bundle using cardboard pieces	Bundle	No. of taping pieces	CS/ORDER) / **(PCS/SUBBUNDLE)**) **(STRAPS /BUNDLE)]** * *(TIME/STRAP)*
11	Place wood on strap locations and strap bundle from locations	Bundle	No. of straps	
3	Pick up parts	Piece	Standard	(PCS/ORDER)/* *(TIME/SUBBUNDLE)*
4	Place the parts interleaved	Piece	Standard	
1	Print out work order	Bundle	Standard	[(PCS/ORDER)* **(PCS/BUNDLE)]*** *(TIME/BUNDLE)*
2	Fill out paper work	Rack	Standard	
6	Pick up a layering paper and place the bundle in it	Sub-bundle	Standard	
8	Move the sub-bundle	Sub-bundle	Standard	
10	Go and get the wood for strapping and mark the bundle	Bundle	Standard	
12	Print label and stick it on	Bundle	Standard	
13	Remove Kevlar slats	Rack layer amount	Standard	
14	Move the old rack and bring in a full one	Rack	Standard	
15	Roll paper for layering and interleafing	Bundle	Standard	

Figure 4. Family worksheet.

Table 1. Comparison of packaging times

Schedule No.	Shift	Actual packaging time prior to using the new tool (hours)	Estimated packaging time using the new tool (hours)	Productivity gain (%)
1	2	112	89.9	19.7
2	1	96	99.3	–3.4
3	2	112	95.1	15.1
4	3	112	85.3	23.8
5	1	88	71.3	18.9
6	2	112	89.8	19.9
7	3	112	92.1	17.8
8	1	112	90.1	19.6
				16.4

The spreadsheet program allowed the Packaging Department to evaluate the use of alternative packaging materials within the constraints of customer preferences when the teams believed using alternative materials could reduce costs. Four 'what-if' scenarios were run using the above spreadsheet to show how costs were affected while varying some of the packaging materials for a

Customer Name:

Die Number		Qty (pc)	
Order Number		Qty (lb)	
Order Cost		Qty (ft)	
Packaging Code		Actual (pc)	
Net #		Pc/bundle	
Gross #		Subs/bundle	
Labels		Bundles/order	
Packaging Cost	$0.00000	Clips	
Cost / pc	#DIV/0!	Skids	
Cost / lb	#DIV/0!	Tubes	
		Caps	

Corrugated

Fanfold	Feet	Inches	Cost
2x2			$0.00000
2x4			$0.00000
2x6			$0.00000
2x8			$0.00000
3x4			$0.00000
3x5			$0.00000
3x6			$0.00000
3x8			$0.00000
4x4			$0.00000
4x6			$0.00000
4x8			$0.00000
5x5			$0.00000
5x6			$0.00000
6x6			$0.00000
6x8			$0.00000
7x7			$0.00000
8x8			$0.00000
	Number		
baby 18-5/8x122			$0.00000
baby 20-5/8x122			$0.00000
orig. 28-3/4x122			$0.00000
orig. 26-3/4x122			$0.00000

Corrugated Cost: $0.00000

Paper

40# Heavy	Feet	Inches	Cost	15# Light	Feet	Inches
2.5"			$0.00000			
6"			$0.00000			
9"			$0.00000	9"		
12"			$0.00000	12"		
15"			$0.00000	15"		
18"			$0.00000	18"		
24"			$0.00000	24"		
30"			$0.00000	30"		
36"			$0.00000			

Paper Cost: $0.00000

Lumber

Lumber	Feet	Inches	Cost
1x6x16'			$0.00000
1x3x18'			$0.00000
1x6x122"			$0.00000
2x3x7'			$0.00000
3x4x8'			$0.00000

Lumber Cost: $0.00000

Tape

Tape	Feet	Inches	Cost
3/8"			$0.00000
3/4"			
2"			$0.00000

Tape Cost: $0.00000

Stretch Wrap

Feet	Inches	Cost
		$0.00000

Wrap Cost: $0.00000

Banding

Banding	Feet	Inches	Cost
.023 x 3/4			$0.00000

Banding Cost: $0.00000

Honeycomb

	Number	Cost
Baby		$0.00000
Original		$0.00000

HC Cost: $0.00000

Figure 5. Material cost spreadsheet.

typical order. The results obtained are shown in Table 2.

As shown in the chart, the final packaging cost can be affected by changing the materials used. By varying the type of corrugated and the type/size of lumber, a significant effect is seen on the final packaging cost. The best results were achieved in Scenario 4, where the packaging cost for the same type of order was reduced by 11% compared to the Base Data. The total cost per piece and total cost per pound were also reduced by 11%.

Integration of labour and material issues

The next phase of the project was to integrate the data from the labour and the material studies

Table 2. Comparison of total material costs for a typical packaging order

	Cost of material						Total material cost		
	Corrugated ($)	Paper ($)	Lumber ($)	Tape ($)	Stretch wrap ($)	Banding ($)	Per order ($)	Per product piece ($)	Per product pound ($)
Base data	8.064	1.026	53.54	0.125	0.729	1.98	65.467	0.0654	0.0268
Scenario 1	9.984	1.012	48.37	0.228	0.729	1.98	62.372	0.0623	0.0255
Scenario 2	8.832	1.026	56.81	0.125	0.729	1.98	69.502	0.069	0.0284
Scenario 3	7.503	1.035	53.54	0.093	0.729	1.98	64.884	0.064	0.0265
Scenario 4	6.912	1.012	48.36	0.125	0.729	1.98	59.125	0.059	0.0242

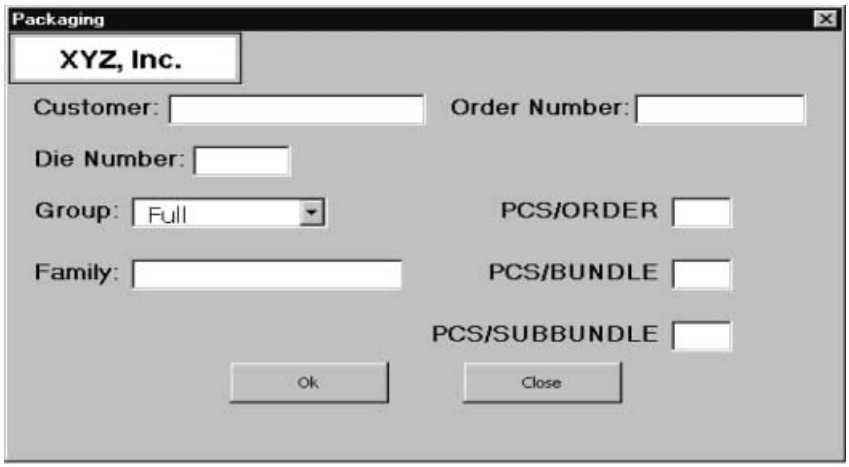

Figure 6. Input Data Form.

into one system that could produce a reasonably accurate estimate for the time and cost to package an order. Such a tool would provide inputs to:

1. The sales department to develop quotes.
2. The logistics department to create schedules.
3. The production supervisors to assign work and evaluate employee performance.

The ESC team created a Visual Basic application that combined the material cost spreadsheet and the labour-calculating tool into one decision support tool. With this application, the user can input key information, such as the customer name, order number, die number, group name, family type, number of pieces, number of bundles, and number of sub-bundles (where applicable) to generate a summary sheet that includes all labour and material costs. Figure 6 shows one of the screens that guide the user through the program.

RESULTS

Using the SIS approach to develop a scheduling and production control system resulted in several process improvements for both labour and materials used in the packaging operation. Labour standards were developed and used to reduce the cycle

times. These standards could then be used to formulate attainable schedules.

A decision support tool was created that merged labour and material usage and estimated costs per order. The tool could be used for quoting, planning and scheduling purposes. By defining specific procedures to be followed uniformly by all of the packaging teams, throughput was estimated to improve by five additional orders per shift per team, while keeping material usage to an acceptable minimum. This helped to reduce costs and eliminate problems arising from excessive or insufficient packaging. The tool also improved the company's ability to provide customers with accurate quotes for packaging and shipping costs and delivery dates, thereby improving customer service. It was estimated that the packing improvement concepts yielded reduced packaging material costs, $800,000 in labour savings, and an average productivity increase of 16.4%.

CONCLUSION

Short Interval Scheduling (SIS) can be a useful tool for improving productivity and scheduling in areas that have non-standard, irregular work processes. In order for SIS to be effective, however, the company must have in place labour standards based on appropriate work units. Using a standard methodology for process analysis and change can facilitate the creation of process standards. As an added benefit, the implementation of those standards can also provide information for more accurate cost calculation. XYZ Inc. used its decision to implement SIS as an opportunity to standardize its packaging operation. The decision support tool developed by ESC personnel then used the improved information from the standardized processes to calculate more accurately the costs of the packaging and shipping operation. Because of this decision, XYZ's management now has an effective tool that can be used to improve productivity, eliminate overtime and improve customer service.

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