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TECHNICAL REPORT NO. 1076

November 1993
Revised February 1996

NOVA INCORPORATED: D-CASE THE EXPERIMENT

by

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NOVA MANUFACTURING COMPANY: D-CASE
THE EXPERIMENT

Background

During the past eight months, Fisher's management team has had time to react to Market Opinion Associates' recommendations. The MOA report highlighted three marketing areas that needed improvement: **delivery reliability** - promised shipments were often late; **technical support** - customers in some regions would need more technical support if market share was to increase; **product breadth** - product variations were required to penetrate new market segments. Based on these findings Nova's Chief Information Officer, Julia Anderson, led a task force that recommended several changes to Nova's manufacturing, logistics and information systems. Once the task force proposal was modified and accepted, Anderson would be given the task of implementing the plan.

The plan was to be executed in two phases. In the first phase, temporary changes would be enacted to see if the market would actually respond to improved service to the extent forecast by the MOA study. In the second phase, permanent resources would be committed to increase manufacturing capacity, to build new software for controlling material flow, and to restructure company operations. The exact nature and extent of these investments would depend upon the results of the first phase experiment.

To ensure an adequate test of MOA's market conjectures, the management team decided to run the first phase experiment for six months. There were three major components to the experiment. First, the market study clearly showed that customers wanted products delivered both faster and more reliably than Nova had in the past. To satisfy this requirement, the task force recommended cutting delivery lead times significantly and guaranteeing that Nova would "ship on-time or the product is free." Since on-time delivery was then running at 73%, this commitment represented a substantial potential risk to Nova. Three immediate actions were proposed to meet this target in the short-run. First, additional

finished goods would be placed at each warehouse to cover demand during their reorder lead time. Second, ample raw material would be kept at each factory so that the chance of running out would be minimal, and purchasing preference would be given to suppliers who guaranteed delivery dates and agreed to incur Nova's "product is free" expenses if they caused a missed shipment. Finally, manufacturing was authorized to "keep the pipeline full" by working overtime if needed to respond to variations in product demand.

Anderson's experiment with an on-line, real-time, world-wide, order receipt and shipping system would also be put into operation. The system gave factory production planners visibility of daily sales and shipments so that they could release production only to replenish inventories depleted by actual customer sales. Rather than focusing on the factory operating efficiency, they were instructed to keep lot sizes small so that cycle stock would be low. In addition, electronic receipt of orders from customers was expected to allow Nova to smooth production and build anticipation stocks when appropriate. Key customers had committed to pay for materials and labor for any order canceled within two weeks of planned delivery. Because of this, Nova's financial risk in stocking high volume products was small.

The distribution task force previously established that both demand variability and delivery lead time could be reduced substantially by changing the practices which govern the flow of materials from the central warehouse to the regional distribution centers. The existing communications system induces a full day delay in the picking cycle at both the Cincinnati and London warehouses. Then once picked, 75% of all orders remain in the warehouses for a full day before they are packed for shipment. Finally, when orders are received at a regional warehouse, they typically wait a day or more before product is available for shipment to a customer. In combination, these delays are significant. By using improved software and operational practices, and by working closely with their transportation provider through EDI, Anderson predicted that Nova's lead times could be reduced to the levels given in Table 1.

Revised Lead Time From Central To Regional Warehouses

			From Central Warehouse			
			North America		**Europe**	
			Min. (Days)	Max. (Days)	Min. (Days)	Max. (Days)
To Regions	**N. America**	regular	2	2	2	4
		expedite	1	1	1	2
	Europe	regular	2	4	2	2
		expedite	1	2	2	3
	Eastern Bloc	regular	2	4	2	3
		expedite	2	2	1	1
	S. America	regular	2	4	3	5
		expedite	1	2	2	2
	Asia/Pacific	regular	3	4	3	4
		expedite	1	2	2	2

Table 1.

The second component to the phase-one experiment was to improve the technical support provided to customers. Anderson's staff had developed a prototype software system to allow both OEM and distribution customers to select appropriate products to meet their functional requirements. This PC based system is easily operated by a computer novice. It is menu driven with a graphical user interface and extensive on-line help. If required, Anderson had committed to create multi-lingual versions of this system, and to train Nova personnel and customers in the use of this software. In addition, technical marketing staff in each region could be trained to join with an IS staff member to provide "hot line" and on-site assistance in the use of the software.

The last component of the six-month experiment was an ingenious proposal by Engineering to increase the breadth of the product line. By changing the design of each of the current products in a relatively minor way, it was possible to present hundreds of product variations to the market. With the change, the plants continued to make 10 base products,

but each regional warehouse could then quickly and cheaply customize the product for their local needs. Typically, customer's installation costs were reduced by the design change.

There were some reservations about the plan in the management team. Larry Judge, the Chief Financial Officer, was concerned that profitability would suffer. He predicted that with the growth of inventory, holding costs would increase. Furthermore, with reduced lot sizes and increased overtime, operating costs could rise dramatically. Finally, he was most alarmed by the financial exposure of the "on-time-or-free" guarantee.

Sensitive to these concerns, the team proposed that Nova extend the guarantee only to customers in the United States and Europe. Customers elsewhere were promised that on time delivery would improve to 95%, and guaranteed that product would be free if it were more than 5 days late. With this modification, the management team had agreed to execute all three components of **The Experiment**.

Fisher Ponders The Results Of Phase-1 Of The Experiment

The Experiment has just now completed its sixth month. As John Fisher reviewed the results, he realized that he must act quickly to regain control of operating expenses, while sustaining the substantial growth in sales that had been achieved. As he examined the progress report, he made four observations. First, the market had indeed responded to the improvements in supply, service and product range. There were important new accounts, and sales to established accounts had grown as well. The greatest improvement occurred in the United States and Europe where sales increased by 41% and 39%, respectively. On time delivery had improved in these regions to 98% and 97% of unit sales. Elsewhere, demand had increased between 18% to 34%. Overall, sales had increased by 33% and were still climbing.

Second, as Larry Judge had feared operating expenses had risen at a faster rate than revenues. Costs were up in four areas:

a. The United States factory was now running at about 125% of capacity and the resulting overtime had increased labor costs by almost 50% over the past 6 months. A similar situation existed in Europe where the factory was running at about 122% of its rated capacity. Sales forecasts based on marketing data project that within 6 months both factories will need to operate at over 200% of capacity.

b. Scrap rates were approaching the disastrous levels of 18 months ago, in spite of an ongoing Quality Improvement Program. The workforce was showing signs of wear, and an alarming increase in scrap rate was driving both material and labor cost variances at both plants.

c. Inventories in all locations for all products had risen substantially to achieve the improved fill rates; finished goods had almost tripled. Fisher believed that inventory levels could be reduced while the high service levels were maintained. But to do this he knew that plant capacity would have to be increased, scheduling procedures revised, quality problems eliminated, workload reallocated between factories, and new inventory policies developed and implemented.

d. Transportation costs had also risen. Because of demand variation, it was often necessary to ship by air to fulfill the on-time promise. Trans-shipments between stocking locations also increased and premium freight was often used to ship products between Europe and the United States. Fisher realized that new transportation partnerships and a revised production strategy were needed to control these increased operating costs.

Fisher's third observation pertained to the tactical and strategic value of his information systems initiative. The new software to support the technical sales had been a major contributor to revenue growth in South America and in Eastern Europe. A major new customer was signed in South America and three others in Poland because of the design assistance available through the software. The information system that supported production planners with real time inventory data was critical in producing the right products and allocating them to the right regional warehouses. Nevertheless, while more product was sold and better production decisions were made with these new information systems, production

costs were increasing in unanticipated ways. Thus, Fisher realized that to take full advantage of new information technologies, the manufacturing equipment and factory procedures would have to be modified.

Fisher's final observation related to changes in product design and assembly. The new design that allows product customization to occur at a regional warehouse helped increase sales without raising production costs. Fisher realized that the product-family-modular-design concept would be an important one to exploit both now and in the future.

Judge's Reflections On Phase-1 Of The Experiment

Larry Judge also reviewed the results of the experiment. He too was pleased with the revenue results but was deeply concerned by the increase in operating expenses. Accounting reports showed that system inventory had grown substantially, primarily due to increases in safety stock levels at each warehouse. While this new inventory was motivated by the marketing decision to improve delivery reliability, Judge felt that the increased revenue could not justify the expense of the additional inventory.

Three years ago, Judge had pressed hard with a detailed financial analysis to convince Nova's board to close 8 of Nova's the 13 regional warehouses. Judge argued that maintaining these warehouses was just too expensive. The incremental revenues derived from a local inventory response could not justify the high fixed costs (space, labor, management, insurance and information system costs) and inventory investments. The marketing and sales staffs had been outraged by that decision and predicted that customer service would suffer significantly. They argued that without local supply it would be impossible to meet the customers needs in a timely manner. History proved that both Judge and the Marketing department were right. Costs did drop and customer service did deteriorate.

In the results of the current experiment, Judge saw a possibility to once again reduce costs, but this time to maintain the new improved service levels. Before presenting his ideas

to Fisher, he asked Eric Reynolds, a senior auditor, to gather additional facts from the MOA survey. Specifically, he wanted to know what the widget buyers' real lead time requirements were. He conjectured that next day service was needed in only a very small number of cases and that 2 to 5 day lead times would be adequate for most if not all customers. Reynolds was asked to establish the validity of Judge's conjecture.

After a week of work by several staff members, the joint marketing and auditors team concluded that Judge was right. They also concluded that customers primarily wanted their deliveries to arrive on the promised date. Relatively short lead times coupled with reliable service was really what the marketplace was demanding. Emergency or next day service actually accounted for only a few percent of total demand.

Judge was now prepared to propose to Fisher that they think about the distribution system in a very different manner. Presently, sales and marketing activities were co-located with logistics activities in each region. If they could separate these functions, Nova could maintain marketing and sales offices in each region, but could virtually eliminate logistics activities without impacting total customer service.

An earlier study proved that by centralizing inventories, required safety stock in the system could be reduced significantly. Thus Judge reasoned that by eliminating all regional warehousing activities he could both reduce costs and improve customer service. Given current transportation costs, he conjectured that even if premium freight was required to meet some customer orders, total freight costs would still be lower if he supplied customers directly from the factory warehouses.

Based on these ideas, Judge prepared a memo to Fisher detailing a plan for closing warehouses, using premium freight when needed, placing emergency stocks in key customer locations in each region, increasing the use of EDI with customers, and using third party logistics providers to manage and expedite the flow of materials.

Fisher's Memo To His Staff

After reviewing Judge's recommendations and combining them with his own observations, Fisher sent a memo to his staff outlining key tasks that needed to be completed to assure Nova's success. The memo assigned responsibility for additional analysis to be presented at next week's meeting.

A key portion of the analysis was assigned to Jerry Jackson, the Cincinnati plant manager. Fisher asked Jackson to evaluate the investment implications and service impact of producing all products in each plant. Currently Cincinnati produces products 1, 2, 3, 6, 8 and 9, while London supplies products 1, 2, 4, 5, 7 and 10. Although tooling costs and operating efficiencies are improved with this arrangement, customer service suffers and transportation costs and inventory costs are higher than they could be. Fisher was considering manufacturing all products required to meet North American and South American demand in the Cincinnati plant, while servicing all other demand out of London. Table 2 provides estimates of the present daily sales rates by product type for North America and South America.

Current Estimated Daily Demand Rates (Units)

Part Numbers	North America	South America	Total
1	50.07	15.58	65.65
2	27.6	7.8	35.4
3	5.18	4.85	10.03
4	7.09	2.33	9.42
5	1.12	1.07	2.19
6	0.64	2.46	3.1
7	1.44	7.73	9.17
8	0.24	0.99	1.23
9	0.09	0.47	0.56
10	0	0.22	0.22
Total	93.47	43.5	136.97

Table 2

For some time Jackson had wanted to improve the Cincinnati operating environment. First, he believed that too large a fraction of total time was currently consumed by set-up due to the new smaller lot sizes. In addition, he knew that if run rates could be increased, then overtime could be reduced. He had investigated new equipment. One type had significantly faster set-up times than currently achieved in Sector 2; but, it also had slower run rates. Another type had much longer set-up times, but considerably higher run rates. Operating data on the current Cincinnati equipment are given in Tables 3.1 through 3.3. Comparable data on the new equipment are given in Tables 4.1 through 4.5. Cost and financial data for all machines are found in Table 5.

Data from the past six months revealed that Sector 1 processes were out of control. The scrap problems arose from a difficulty in positioning the components precisely. The labor utilization rate was lower than expected because of an imbalance in the workload between sectors. Bill Cochran, the plant's chief manufacturing engineer, has proposed to fix the problems by buying a robot to replace the manually operated machine in Sector 1. The highly precise robot would reduce the daily manpower costs by $300 (the equivalent of 2 full-time positions), but would require additional operating expenses for tooling and maintenance. Data describing to this robot are found in Tables 4d and 5.

A significant increase in operating expense was traced to a rather aggressive preventive maintenance program, and Judge's audit staff had recommended cutting back the program in order to reduce labor cost. Jackson's data, however, showed that while maintenance costs had increased, scrap rates and random equipment failure rates had declined because of the program. Cochran was adamant that PM activities be increased rather than be eliminated. Data on the costs and benefits of the preventive maintenance program are given in Table 7.

Cochran has also proposed to replace the current machine in Sector 3. While it is not now a bottleneck, he believes it will become one in the near future if the plant output is increased. Operational data on both machines are found in Tables 3 and 4.

Jackson's material planner, who recently completed a course on production scheduling and inventory planning, has proposed to modify Nova's just-in-time production process. He is urging Jackson to make better use of information available through the new EDI system to build inventories that they can "see" the customers will need prior to the receipt of firm orders. With customers' demands for better service, Nova's just-in-time, small lot size production philosophy creates highly variable work loads at the plant with a resulting need for substantial overtime. The material planner proposes to maintain finished goods inventories in the Central Warehouse in some high volume products in order to smooth workloads and reduce operating costs.

Finally, Jackson was troubled by an alarming increase in scrap rates during the experiment. He had been keeping careful records of scrap rates at each operation, and performed a thorough analysis of all scraped parts. The analysis revealed that while scrap due to machine failure had increased slightly, the major source of the problem could be traced back to defects in raw materials, and in particular one of his suppliers. As part of the experiment, Jackson had reduced the number of suppliers to just two. And in concern over cost, his procurement staff was now recommending that all purchases be made from a single supplier. Unfortunately, the quality problems were arising from the low-price supplier (Supplier 1). In addition, Supplier 1's lead times were significantly higher than those of Supplier 2. Supplier 1's lead time varied between 3 days and 10 days with an average of 5 days, while Supplier 2's lead time varied between 2 days and 4 days, with an average of 3 days. Table 6 summarizes the prices and scrap rates for both suppliers.

To prepare his report for Fisher on the manufacturing capacity required to service all demand from North America and South America, Jackson felt that he needed to analyze the capacity and demand data further. Specifically, he must model and evaluate the operational and cost consequences of various production and equipment plans. He also wants to study the impact of the new production control and inventory planning concepts advocated by his materials manager.

Current Operating Characteristics
Sector 1 Manual

Part Numbers	Run Times	Setup Times	Scrap Rates
1	0.7	1.3	0.10%
2	0.8	1.3	0.10%
3	0.8	3	0.20%
4	1.2	3.8	0.20%
5	1.3	3.8	0.50%
6	0.9	3.8	0.40%
7	1.4	4	0.50%
8	0.9	3.8	0.40%
9	1	3.8	0.40%
10	1.7	1.7	0.50%

MTBF	MTTR
1,000	10

Table 3.1

Current Operating Characteristics
Sector 2 Machine 1

Part Numbers	Run Times	Setup Times	Scrap Rates
1	2.9	15	0.68%
2	3.1	15	0.68%
3	3.1	18	2.02%
4	3.5	18	2.42%
5	3.5	21	2.30%
6	3.4	21	2.70%
7	3.8	21	2.70%
8	3.7	23	2.70%
9	4	23	2.70%
10	4	23	4.04%

MTBF	MTTR
900	60

Table 3.2

Current Operating Characteristics
Sector 3 Machine 1

Part Numbers	Run Times	Setup Times	Scrap Rates
1	1.1	1.9	0.14%
2	1.2	1.9	0.14%
3	1.2	4.5	0.32%
4	1.8	5.6	0.32%
5	2	5.6	0.76%
6	1.3	5.6	0.60%
7	2	6	0.76%
8	1.4	5.6	0.60%
9	1.5	5.6	0.60%
10	2.5	6.4	0.76%

MTBF	MTTR
1,000	60

Table 3.3

Available Equipment Operating Characteristics
Sector 1 Robot

Part Numbers	Run Times	Setup Times	Scrap Rates
1	0.1	0.3	0.02%
2	0.2	0.3	0.02%
3	0.2	0.6	0.04%
4	0.2	0.8	0.04%
5	0.3	0.8	0.10%
6	0.2	0.8	0.08%
7	0.3	0.8	0.10%
8	0.2	0.8	0.08%
9	0.2	0.8	0.08%
10	0.3	0.9	0.10%

MTBF	MTTR
10,000	75

Table 4.1

Available Equipment Operating Characteristics
Sector 2 Machine 2

Part Numbers	Run Times	Setup Times	Scrap Rates
1	2.76	18	0.64%
2	2.85	18	0.64%
3	2.87	24	1.90%
4	3.22	26	2.26%
5	3.25	28	2.14%
6	3.21	30	2.52%
7	3.4	30	2.52%
8	3.5	30	2.52%
9	3.8	30	2.52%
10	3.8	30	3.76%

MTBF	MTTR
600	62

Table 4.2

Available Equipment Operating Characteristics
Sector 2 Machine 3

Part Numbers	Run Times	Setup Times	Scrap Rates
1	4.4	2	0.14%
2	4.5	2	0.14%
3	5	2	0.44%
4	5.1	2.5	0.54%
5	5.1	2.5	0.50%
6	5.4	2.5	0.60%
7	5.5	3	0.60%
8	5.7	3	0.60%
9	6	3	0.60%
10	6	3	0.90%

MTBF	MTTR
3,000	50

Table 4.3

Available Equipment Operating Characteristics
Sector 2 Machine 4

Part Numbers	Run Times	Setup Times	Scrap Rates
1	2	27	0.50%
2	2.1	27	0.50%
3	2.1	33	1.48%
4	2.5	33	1.76%
5	2.5	40	1.68%
6	2.4	40	1.98%
7	2.7	40	1.98%
8	2.7	40	1.98%
9	2.9	40	1.98%
10	2.9	40	2.96%

MTBF	MTTR
750	65

Table 4.4

Available Equipment Operating Characteristics
Sector 3 Machine 2

Part Numbers	Run Times	Setup Times	Scrap Rates
1	0.2	0.4	0.04%
2	0.2	0.4	0.04%
3	0.2	0.9	0.06%
4	0.4	1.1	0.06%
5	0.4	1.1	0.14%
6	0.3	1.1	0.14%
7	0.4	1.2	0.14%
8	0.3	1.1	0.14%
9	0.3	1.1	0.14%
10	0.5	1.3	0.14%

MTBF	MTTR
4,000	35

Table 4.5

Equipment Costs And Financial Data

			Last Year's Book Value	Purchase Price	Salvage Value	This Year's Monthly Depreciation	Monthly Maintenance Costs	Initial Tooling Costs	Ongoing Monthly Tooling Costs
Sector 1	Manual	*	51,055	78,000	26,000	945	180	10,400	610
	Robot			96,000		1,636	240	12,000	800
Sector 2	Machine 1	*	1,178,182	1,800,000	1,450,000	21,818	4,700	161,000	14,500
	Machine 2			1,900,000		31,288	3,900	165,000	14,000
	Machine 3			1,050,000		16,712	2,300	53,000	9,500
	Machine 4			2,400,000		38,939	4,900	170,000	10,500
Sector 3	Machine 1	*	399,273	610,000	400,000	7,394	2,100	45,000	5,200
	Machine 2			780,000		12,500	800	45,000	4,800

* Currently installed
- Book Value pertains only to equipment currently installed.
- Initial Tooling Costs for currently installed equipment reflect the costs to initiate production of products 4, 5, 7, and 10 in Cincinnati.
- Monthly Maintenance costs assume no Preventive Maintenance is performed.

Table 5

Component Costs And Purities

Component Number	Supplier 1		Supplier 2	
	Price	Purity	Price	Purity
1	$98.92	98.63%	$102.06	99.50%
2	$122.46	98.49%	$127.36	99.50%
3	$160.14	97.82%	$163.34	99.50%
4	$34.54	98.72%	$38.00	99.50%
5	$44.90	99.37%	$49.40	99.50%
6	$58.72	98.74%	$64.58	99.50%
7	$12.56	98.39%	$13.18	99.50%
8	$16.32	97.17%	$16.98	99.50%
9	$15.70	98.59%	$17.12	99.50%
10	$17.28	97.44%	$18.82	99.50%

Table 6

Costs And Benefits Of Preventive Maintenance (PM)

		Without PM			With Preventive Maintenance (PM)					
		MTBF (Minutes)	MTTR (Minutes)	Scrap Rates **	MTBF (Minutes)	MTTR (Minutes)	Scrap Rates **	Minutes Between Scheduled PM	Duration of PM Activity (Minutes)	Incremental Annual Cost ***
Sector 1	Manual *	1,000	10	0.001-> 0.005	5,540	10	0.0004-> 0.0032	2,000	15	(150)
	Robot	10,000	75	0.0002-> 0.001	50,400	75	0.0001-> 0.0005	2,000	50	4,100
Sector 2	Machine 1 *	900	60	0.0068-> 0.0404	3,380	60	0.0036-> 0.0214	2,000	30	3,000
	Machine 2	600	62	0.0064-> 0.0376	3,490	50	0.0032-> 0.0206	2,000	30	(900)
	Machine 3	3,000	50	0.0014-> 0.009	13,700	50	0.0008-> 0.0048	2,000	30	(1,000)
	Machine 4	750	65	0.005-> 0.0296	4,120	50	0.0026-> 0.0152	2,000	30	4,500
Sector 3	Machine 1 *	1,000	60	0.0014-> 0.0076	5,200	60	0.0008-> 0.0042	2,000	30	1,000
	Machine 2	4,000	35	0.0004-> 0.0014	15,840	35	0.0002-> 0.0008	2,000	30	2,300

* Currently Installed.

** In general, scrap rates under a preventive maintenance policy are between 50% and 60% of the no-PM case.

*** Does not include the effect on cost of scrap rate reduction.

Table 7

Assignment 1. Analysis Of Customer Demand Data

Demand for Nova's products increased substantially during the six-month experiment. New customers were a major source of this growth in demand in each region; some existing customers also increased their purchases. To understand the changes in demand patterns, analyze the demand data for the past 6 months for customers in North and South America. Specifically, conduct appropriate Pareto and time series analyses. Examine demand patterns for individual customers. What do you observe? What impact does the variability in demand due to ordering patterns have on the need for production capacity? With which customers would it be beneficial to establish an EDI forecasting relationship? In general, what value would accurate forecast information from these customers have on inventory requirements, the use of production capacity, and customer service?

Assignment 2. Capital Appropriations Request

Select the equipment plan for each sector, the supplier plan for each component, and the preventive maintenance plan that you would recommend to Fisher for the Cincinnati factory to meet the current and future market requirements. Justify your selection. Use the spreadsheet provided to you to assist in making your selection. When examining the spreadsheet, observe that it is possible to put a second shift into operation only after the next six months. Management feels that it would take six months to hire and properly train the people required to operate a second shift. If you choose to operate a second shift, corresponding startup costs are included in the spreadsheet in the labor and operating costs for the period preceding the one during which the second shift commences operation.

Prepare a presentation for Fisher summarizing your recommendations and their consequences.

Assignment 3. Evaluating Your Operational Strategy

Fisher is concerned that your analysis has not considered how the Cincinnati facility will operate during the next several months. He observed that the basic logic used in the financial analysis largely ignored the operational implications of your plan. Fisher understands that variability is present and that it can affect both cost and customer service.

Fisher wants you to verify your plan through an operational test. To do this, first develop a comprehensive production scheduling procedure and an inventory policy. Next, test your plans and policies using the provided simulation software. Use the "Decisions" menu to set up the factory according to your equipment plan and to select suppliers for components. Then run the simulator for 10 days and record

- consolidated net income,
- fill rates at each location,
- average inventory levels at each location, and
- average machine utilizations at the end of day 10.

Assignment 4. A New Marketing Opportunity

Nova's improved customer service has been no secret in the industry. The dramatic improvement in fill rates and reliability of supply has been evident to both competitors and customers. This improvement has also become a central theme of Nova's push to increase its market penetration. As a consequence of this improved performance and several weeks of lengthy discussions, Nova's marketing group has been able to conditionally convince the R. Cardinal Company to purchase all its widgets from Nova. Cardinal is a major consumer of widgets in both the United States and in South America, and obtaining this account will dramatically increase Nova's sales.

Nate Coleman, Nova's VP for Sales and Marketing, proudly describes this coup to Fisher and his staff in their morning meeting. He explains that this one new account would increase sales in the newly formed North and South American sales region by about 43%. He goes on to state that the reason for Cardinal's shift in suppliers is that they are very unhappy with their current suppliers' delivery performance. He states that they are willing to buy all widgets from Nova, on the condition that deliveries will be on time every time. To test Nova's ability to meet their stringent on-time demand requirement, Cardinal has proposed entering into a six month agreement with Nova. This agreement states that Cardinal normally wants shipments in the United States on the second day after they place their order; a shipment in South America must be received on the third day after order placement. In emergencies, they want the material on the following day.

Fisher is obviously delighted with this news, but is also deeply concerned. He recognizes that this new account would propel Nova into the big league of widget manufacturers. He also recognizes that if they cannot deliver on time, they will lose the Cardinal account and, in all likelihood, face the competitive consequences of a severely damaged image with existing customers. He is reasonably confidant that Nova can meet the increased demand by resorting to heroic efforts on the part of its manufacturing and

distribution team; however, the costs would increase substantially too, so that profitability would be adversely affected.

Since the Company's reorganization, Jackson's Cincinnati plant has taken on the responsibility for satisfying total demand for both the North and South American markets. Consequently, Fisher turns to Jackson and asks whether or not he believes the plant can produce to meet this higher rate of demand. Since Nova has purchased new equipment and modified operational procedures in the Cincinnati plant, capacity has increased greatly. (Specifically they purchased the new robot for Sector 1, kept machine 1 in Sector 2 but also bought machine 3 for that sector, and purchased machine 2 for sector 3. They also instituted a preventive maintenance program throughout the facility. Furthermore, they switched raw material purchases to Supplier 2 from whom they have been receiving excellent on time delivery of virtually defect-free material). Because of these modifications to the plant, Jackson is presently running his bottleneck workcenter, sector 2, at only about 73% of capacity. Apparently he could accommodate the increased load; he is reluctant, however, to state unequivocally that he can meet the increased production requirement. He asks for time to evaluate the consequences.

Coleman is clearly agitated and begins to complain that manufacturing is again not being responsive to the Company's needs. He states clearly that he must get back to Cardinal quickly or the offer will likely be withdrawn. Fisher, too, would like to act quickly; but he recognizes that there are significant risks involved, and asks Jackson to explain his position further.

Jackson explains that the plant presently operates on one shift and that while they have been able to meet demand with no difficulty due to the increased capacity, there is no guarantee that they will be able to meet the increased load. Even though there is apparently enough capacity, he states that variability in demand could cause substantial fluctuations in workload. This, in turn, could increase operating costs, transportation costs and inventory

costs and lower fill rates. He further explains that he cannot add a second shift on short notice, nor can he acquire and install additional equipment within the next 60 days.

Julia Anderson, the head of the Information Systems group, reminds Jackson that the new EDI-based forecasting system is about to be implemented with several large customers. Specifically, she suggests that since customers have agreed to provide timely, accurate forecasts (timing of firm orders should differ by no more than one day from their projected date, and order quantities should vary by no more than 15% from their forecasted values), the manufacturing facility's ability to foresee and respond to dramatic variations in demand should improve substantially. Jackson agrees that the new forecasting system will add value, but argues that his staff needs time to measure the quality of the forecast information, and to develop methods to exploit it.

Fisher agrees that some additional facts must be gathered and analyses be performed. Since he understands that demand must not be allowed to fluctuate wildly and unpredictably, he instructs Coleman to communicate with Cardinal and determine whether they will be able to provide EDI forecasts comparable to those provided by Nova's other major customers. He also tells him to get volume projections, lead time data and demand patterns for all part numbers. Finally, he instructs Jackson to conduct his analysis using the demand projections and lead time data and to give a report at their next staff meeting.

That afternoon, Coleman calls to say that he has confirmed that Cardinal will provide 5 day forecasts for their regular weekly shipment. Coleman reports that Cardinal normally places only one regular order per week. Emergency orders can be placed on any day. According to Cardinal's purchasing manager, they plan to purchase only variations of part numbers 1, 2, 4, 5 and 7. Table 8 contains data provided by Cardinal which represents their average weekly demand rates for both regular and emergency demand over the past 25 weeks.

Fisher thanks Coleman for the speedy response to his request for information, and passes it on to Jackson. Jackson is relieved that Cardinal's emergency orders appear to be small relative to total demand, but regular demand is so large that he is reluctant to commit

on the basis of averages alone. Consequently, he requests detailed data on actual weekly demand, and Coleman reluctantly calls Cardinal again to obtain the desired information. The data for regular demand are shown in Table 9. Emergency demand varied somewhat from week to week, and Jackson feels that a Poisson distribution can be used to represent this emergency demand for each part number.

R. Cardinal Company Average Demand Rates For Past 25 Weeks

	North America					South America				
	Part 1	Part 2	Part 4	Part 5	Part 7	Part 1	Part 2	Part 4	Part 5	Part 7
Regular	60.12	44.8	27.8	28.28	13.8	25.72	18.16	12.48	14	3.04
Emergency	3	4	1	3	1	2	3	2	1	2

Table 8.

R. Cardinal Company Demand For Past 25 Weeks

	North America					South America				
Weeks In The Past	Part 1	Part 2	Part 4	Part 5	Part 7	Part 1	Part 2	Part 4	Part 5	Part 7
25	52	23	10	16	6	13	17	14	25	0
24	48	33	37	11	9	21	14	9	5	0
23	58	34	24	15	20	27	14	18	59	12
22	57	47	24	15	29	12	21	0	0	11
21	70	40	29	22	37	17	18	13	0	37
20	55	37	28	36	8	27	23	7	15	0
19	73	41	27	53	6	9	12	9	0	0
18	77	46	33	12	15	34	15	14	2	1
17	42	61	22	66	34	16	27	8	4	0
16	42	45	25	48	30	22	22	1	10	0
15	58	32	30	28	22	15	20	6	0	1
14	72	55	27	36	19	29	19	21	3	0
13	52	28	27	59	2	27	13	1	32	6
12	57	38	29	16	21	25	13	0	5	0
11	45	46	27	21	25	30	20	3	18	0
10	67	47	22	25	7	28	16	29	3	0
9	62	60	33	19	5	18	11	24	101	4
8	83	48	34	12	1	33	33	8	9	0
7	70	62	27	31	11	22	42	14	3	0
6	59	46	18	15	6	33	16	14	30	0
5	44	44	53	31	0	28	15	4	7	0
4	55	60	36	18	0	35	6	10	18	2
3	65	39	17	39	7	36	23	47	1	1
2	69	46	35	33	4	34	16	18	0	1
1	71	62	21	30	21	52	8	20	0	0
Average	60.12	44.8	27.8	28.28	13.8	25.72	18.16	12.48	14	3.04
Std. Dev.	11.34	10.81	8.22	15.27	11.18	9.56	7.66	10.56	22.85	7.81

Table 9.

Jackson plots these demand patterns for regular orders and performs linear regressions to detect growth. He observes three noteworthy features: first, there seems to be a distinct pattern of growth in several of the parts, second, there is alarmingly high variation in most of the demand patterns, and third, regular demand per week appears to be independent from part to part in both the United States and South America. Two of these plots are shown in Figures 1 and 2. Table 10 summarizes the results for all parts.

Jackson feels he now has a better understanding of the demand process, and is ready to conduct his analysis of manufacturing's ability to meet Cardinal's requirements.

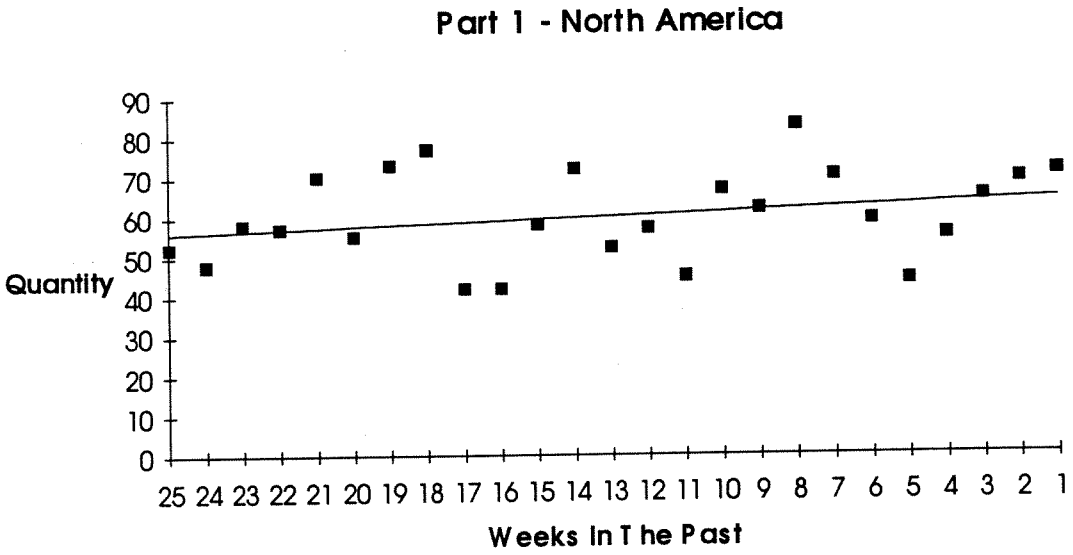

Figure 1.

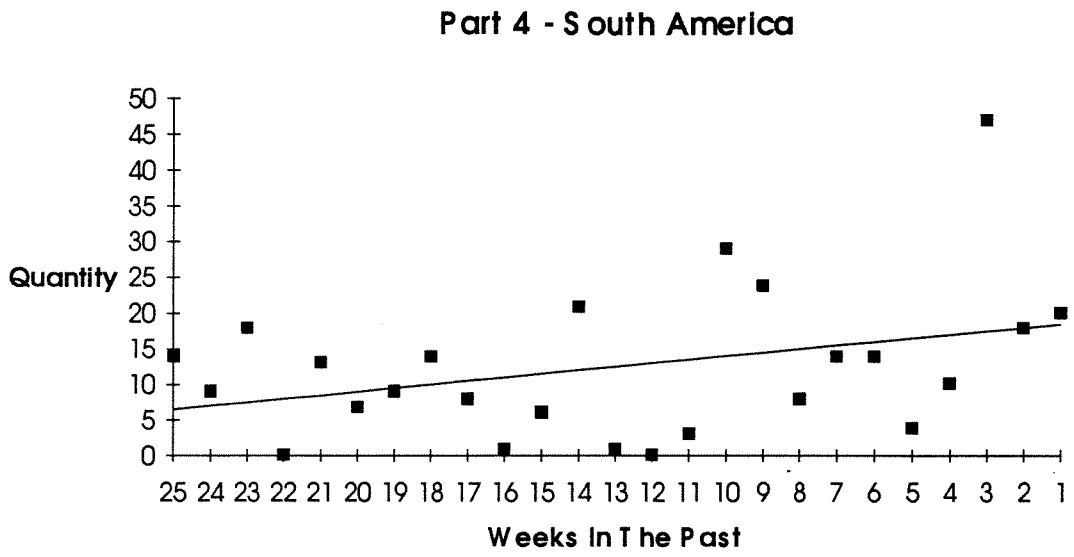

Figure 2.

Fisher has also wanted to test Judge's proposed alternative distribution system configuration. He has avoided implementing it because of its potential risk and its impact on the collegiality of his staff. However, he now realizes that he can no longer avoid considering this potentially profitable alternative. After again reviewing the details of the cost of operating the regional warehouses (see Table 11 for a financial summary) and reflecting on the variability in the demand for more products, Fisher believes that Judge's proposal must be tested. Consequently, in addition to asking Jackson to evaluate his manufacturing capacity, he wants him to also determine the impact of meeting all of the United States and South American demand directly from the Cincinnati warehouse.

Growth Trends For Past 25 Weeks

	North America					South America				
	Part 1	Part 2	Part 4	Part 5	Part 7	Part 1	Part 2	Part 4	Part 5	Part 7
Average	60.12	44.8	27.8	28.28	13.8	25.72	18.16	12.48	14	3.04
Std. Dev.	11.34	10.81	8.22	15.27	11.18	9.56	7.66	10.56	22.85	7.81
First Week	55.55	34.58	24.74	26.49	21.73	14.09	18.38	5.99	15.54	7.71
Growth	0.3515	0.7862	0.2354	0.1377	-0.61	0.8946	-0.0169	0.4992	-0.1185	-0.3592
Last Week	64.338	54.234	30.625	29.932	6.48	36.455	17.957	18.471	12.578	-1.2708

Table 10.

Specifically, he asks Jackson to estimate both the operational and the financial impact of meeting the customer demand through both the current and the proposed distribution systems.

Nova's Annual Fixed Costs

	With North and South American DC's				With North and South American Sales Offices			
	Factory	North American DC	South American DC	Total	Factory	North American Sales Office	South American Sales Office	Total
Central Warehouse Overhead	432,000	0	0	432,000	432,000	0	0	432,000
Depreciation	2,326,560	0	0	2,326,560	2,326,560	0	0	2,326,560
Fixed Overhead	863,760	432,701	256,001	1,552,462	863,760	216,350	128,000	1,208,111
General & Administrative	1,063,680	480,300	432,701	1,976,681	1,063,680	240,150	216,350	1,520,180
Short-Term Interest	11,520	6,494	11,330	29,345	11,520	3,247	5,665	20,432
Long-Term Interest	441,360	49,999	106,001	597,360	441,360	25,000	53,000	519,360
Total	5,138,880	969,494	806,033	6,914,407	5,138,880	484,747	403,016	6,026,644

Nova's Assets

	With North and South American DC's				With North and South American Sales Offices			
	Factory	North American DC	South American DC	Total	Factory	North American Sales Office	South American Sales Office	Total
Property, Plant & Equipment	16,007,000	4,191,000	3,129,000	23,327,000	16,007,000	2,095,500	1,564,500	19,667,000

Table 11.

Use the simulator to conduct your analyses of the system's costs, performance, and policies with and without Distribution Centers. When you start the simulator, select the Distribution Center option that you wish to evaluate, then proceed as follows. First, establish values for the following policy parameters:

- which suppliers supply which components,
- target inventory levels,
- preventive maintenance,
- overtime, and
- sector 2 routings.

The equipment configuration will already reflect the equipment plan described previously, and should not be changed since additional equipment cannot be acquired within the next 60

days. Second, run 20 replications of a simulation of 60 days of operation of the system. For each of the 20 simulation runs, collect performance and profitability statistics and record them as instructed by the software. You may want to run the simulator manually for several days to observe how the system behaves before conducting the large-scale test. This initial analysis will help you understand how the scheduling rules actually work in practice, and how your decisions about suppliers, routing, overtime and target inventory levels influence performance. You may also want to conduct the full experiment a few times using different settings for the policy parameters. Your statistics will change depending on the values you choose - your objective is to find policy parameter settings that work best in each of the two cases (with and without Distribution Centers).

Once you are satisfied that you have selected appropriate values for the policy parameters, present the results of the corresponding simulations using the summary statistics in the software.