Methodology for the Synchronization of Material Flow in an Assembly Plant

by

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B.S. Mechanical Engineering, Rutgers University (1992)

Submitted to the Sloan School of Management and
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and

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ABSTRACT

General Motors Corporation recognizes that competition will only continue to increase and has begun numerous lean manufacturing initiatives as a response to these challenges. In particular, there is an effort to improve the efficiency of the supply chain and reduce material inventories at plants within the system.

This thesis is based on work that took place in the cab shop of a General Motors assembly plant in Linden, New Jersey. The objective of this thesis is to provide a methodology for the development and implementation of a material delivery system (MDS) which people can use as a guide to develop and implement similar systems in other areas of the plant as well as in other manufacturing settings. The MDS is fundamentally based on the kanban system, a pillar of the Toyota Production System. The goals of the MDS are to reduce inventory, improve the utilization of floor space, increase efficiencies and productivity, and improve the overall ergonomics and attitudes of the work force.

The methodology uses a framework based on ten steps which fall into three phases: understanding, developing, and implementing. The first phase involves: understanding the overall scope of the intended MDS, defining the key dynamic components of the MDS, and identifying key aspects of the original material flow system. Phase two involves: establishing key supplier logistics, improving the operator station workplace organization, and developing the central pull system supermarket. In the final phase, roles and responsibilities are established, education and communication training is conducted, monitoring and maintenance programs are initiated, and the impact of the new system is evaluated.

This thesis describes the development and implementation of a methodology which took place in cab shop of the Linden plant. This allows the author to draw upon specific examples. It also permits the reader to gain a clear understanding of the significant benefits that are possible. In the cab shop alone, savings due to inventory reductions, productivity increases, and efficiency improvements exceeded $250,000, with a possible additional savings of $750,000 if the progress of the system is continued. Finally, the cab shop savings represent less than 25% of the savings potential if the methodology were expanded plant wide.

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Special thanks go to General Motors for its support of my internship and this paper. Many people played an important role in making my experience at Linden, New Jersey a very rewarding one. In particular, several key individuals provided much appreciated personal time, support, and encouragement during my internship: Ric Monkaba, Jim Deluca, Rick Spina, Bob Vrancken, Bob Ziarko, Brian Normant, Diane Fort, Bill Geronimo, Ron Chrobocinski, John Petruska, and Mike Worringer. I also received helpful cooperation from many of the hourly operators and skilled labor and a tremendous amount of direction and encouragement from my company supervisor, Bill Fonte.

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I would also like to extend a warm thank you to my family - Mom, Dad, and Janet. Mom and Dad, you have always been there with support and encouragement during my two years and I am fortunate and grateful. Janet, I thank you for your talks and for helping me to maintain the right perspective when I needed it most. And, without the love and support of my fiancée, Karen, none of this would have been possible. Karen, I thank you for your patience, encouragement, and love - we have finally made it.

Finally, I give thanks to my Lord for blessing me with the opportunity to experience the last two years and for providing me with guidance, direction, and protection each and every day of my life. Thank you.

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Chapter 1. Overview of Problem

1.1 Describing the Environment

History

The General Motors Linden Truck Assembly Plant has a very long history. In 1942, the plant was commissioned by the U.S. Government to make the Grumman Wildcat, a Navy fighter plane, for World War II and since then it has been used to produce a variety of different car and truck models. Thus, it is easy to understand why this plant has a long history and subsequently a strong culture. Many of the operators have been working in the plant for thirty or more years and in general are "quite comfortable with the status quo."

The Product

The GM Linden Plant is part of the GM North American Truck Group (NATG). It is one of three plants that make the Chevrolet and GMC small utility and pickup vehicles. The Linden Plant produces both pickup and utility vehicles for the domestic and international markets. Some of the options include two and four wheel drive utility vehicles and standard/extended cabs on regular and long bed pickup trucks. All of the options increase the general complexity of every production system used in the Linden plant.

The Process

The Linden Plant produces approximately 800 vehicles per day over two shifts. All vehicles pass through five different departments in the plant:

Cab Shop	- the metal body of the vehicle is welded together.
Paint	- the metal body is cleaned, primed, and painted.

Chassis - the structural frame of the vehicle is assembled with the axles and engine.

General Assembly - the body is attached to the chassis and the main accessories are installed (carpeting, seats, etc.).

Final Line - the remaining accessories are installed and the vehicle is tested.

While it is true that all the departments are dependent on one another, they function fairly autonomously. Additional support departments include Supplier Quality Assurance, Finance, Engineering, Material, Purchasing, and Human Resources.

The plant labor force includes both union and management employees. Hourly workers, belonging to a strong union, consist of production operators and skilled tradesmen (electricians, millwrights, pipe fitters, etc.). The salaried portion of the employee base, including supervisors, superintendents, and area managers, hold management responsibility for all of the daily production activities.

1.2 Problem Statement

In the last 10 years, sales of utility vehicles has been growing significantly. During this time the Big Three U.S. manufacturers have captured a large share of the market. While U.S. companies have been fighting intense foreign competition in the automobile market, they have had relatively little competition in the utility and truck business ... until lately. Nissan (Pathfinder), Toyota (Fore Runner and Land Rover), Honda (Passport), Mitsubishi (Montero), and Izuzu (Rodeo) have recently made a strong surge into this lucrative market segment.

Corporate Objectives

Increased competition has moved companies like General Motors to quicken its drive for improved manufacturing methods. They recognize that they must devote resources to initiatives that will help them to improve their position as an industry leader. For the last several years GM has been working on just such an initiative, called Synchronous (i.e. Lean Manufacturing). This is an initiative to improve all facets of how GM produces vehicles, including shorter product development cycles, improved startup processes, reduced production cycle times, increased quality, and better supplier relations.

Another key element of this initiative involves inventory management. GM is seeking ways to improve the efficiency with which it handles the movement of material into and through their plants. To do this, they are working to develop systems that will provide improved overall management and control of production material.

Project Objectives

GM is specifically looking to develop systems that target improvements to many of the material handling processes that exist within a plant. Efforts must be made with suppliers to reduce the volume but increase the frequency of shipments. Once material enters the plant, unnecessary handling must be minimized and tracking control must be maximized. In addition, emphasis must be made to improve ergonomics and overall labor productivity. Throughout all parts of a material delivery system, increased efficiency and reduced variability is of critical importance. Finally, as with any program, care must be taken to continue working towards improvement and progress for the future.

The purpose of the internship was to develop and implement a material delivery system that would bring the plant closer to achieving the above goals. The internship was focused on the cab shop department of the Linden Truck Assembly Plant. In successfully implementing the material delivery system, several important goals were met. First, inventory was reduced which saved holding costs and valuable floor space became available for important process changes. Productivity of material handlers and operators dramatically improved, while increases to efficiencies and inventory control were significant. Finally, an effective tool was developed to continue driving process improvements in the future. Overall, consensus was that the project was a success.

This thesis is intended to provide the reader with a clear but effective methodology which can serve as a guideline for the development and implementation of similar systems in other manufacturing applications. While the internship for this thesis was focused on the cab shop of the Linden plant, this author believes that the same principles can be applied to other areas of the plant and certainly to other plants or facilities in general. As the application of the methodology is expanded to larger areas, the resulting benefits will also increase. Thus, the possible implications associated with the adoption and expansion of this methodology are substantial.

1.3 Thesis Structure

As stated earlier, this thesis presents a structured methodology for the development and implementation of a robust material delivery system in a variety of manufacturing settings. It is intended that the reader of this thesis may be able to use it as a guideline to develop and implement a similar or expanded system with similar or improved results.

Hopefully the preceding overview provided a general sense of the environment in which this methodology was developed and implemented. Next, the bulk of the thesis will provide a detailed description and explanation of this methodology. Figure 1 provides an overview of the entire methodology.

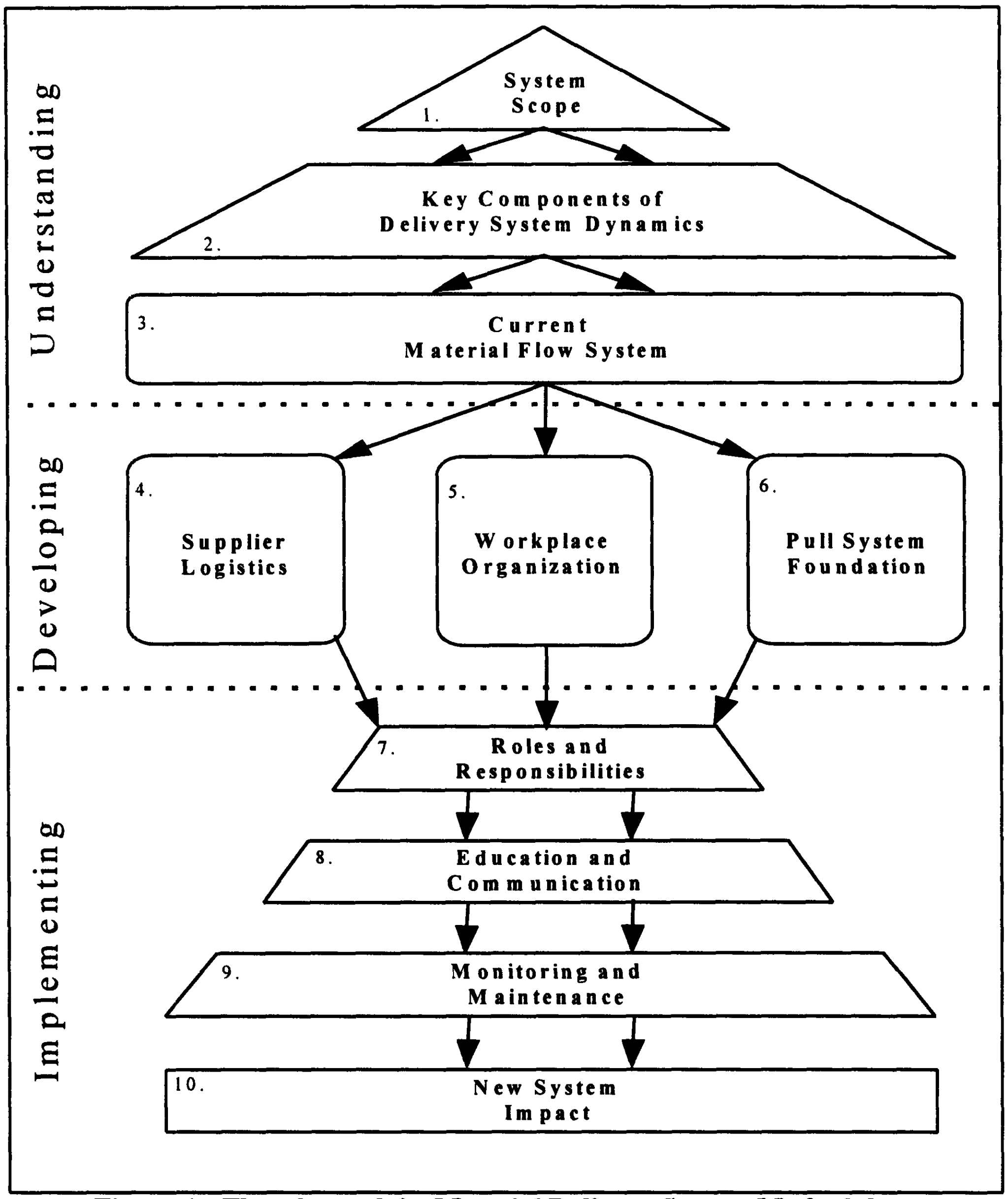

Figure 1 - Flowchart of the Material Delivery System Methodology.

The first phase, which includes three sections, emphasizes the importance of understanding the current system before development of the new system begins. (Throughout the rest of this thesis, the term client will be used to refer to the individual or team that is working through the methodology). The client must gain an overview of the system and how the different components fit together as well as outline goals for the new system. In addition, the client must understand the key drivers for the new system and how a robust material delivery system is part of a larger improvement initiative. Finally, it is necessary for the client to identify the mechanics and processes of the current system and gather critical data.

The second phase centers on development and also includes three sections. Now the client must begin to focus on the details of the new system. Work must be done with the suppliers to improve the logistics of orders and delivery. The foundation of the pull system must be developed, including the operator stations, the supermarket, and the connection between the two.

Finally, the last phase involves implementation and consists of four sections. The various key roles must be identified along with the associated responsibilities. While communication is always important, during the education and training programs, it is critical. Also, systems must be set in place to monitor and maintain the system once it begins. Lastly, the client needs to identify and evaluate the impact of the new material delivery system.

After explanation of the methodology is completed, the thesis ends with conclusions and recommendations for future improvements along with their potential impact.

1.4 Literature Review

The underlying theme of this thesis is based on the Just-In-Time manufacturing principles or the Toyota Production System. The literature search will briefly review some of the key elements of JIT principles as they relate to the work in this thesis. I will describe some of the concepts and ideas on this topic that are held by respected and experienced individuals in this field. Using these findings as a basis, I then develop some of my own ideas which are presented in this paper. As the reader will find in reading through this thesis, much of my work confirms the beliefs put forth by the individuals discussed in this review and included in the bibliography.

The review will take the reader through four areas. First, from the founder of the Toyota Production System, Taiichi Ohno, I will provide an overview of the fundamental concepts that must exist for any JIT system to be successful. Then I will review some of the key aspects that one author feels are critical for successful implementation of a JIT system. I will conclude with insights on important aspects of the JIT system which are relevant to this project - the kanban system and the importance of visual controls.

JIT System

Although the concept of Just-In-Time has been part of the manufacturing language in the U.S. since the early 1980's, there are some fundamental ideas that are central to this system. As Ohno [10] describes, the driver of the Toyota Production System is the elimination of total waste. Rather than producing in mass quantities, focus is placed on producing what is needed when it is needed. However, attaining the goals of JIT requires difficult change and Ohno [10] explains that the success achieved is directly related to the degree to which management commits and dedicates itself to change. This demands full commitment throughout the organization. Accomplishing such change is extremely challenging because the new systems are often in conflict with the methods with which people are most comfortable. Yet, in order to maintain a competitive position in the marketplace, these preconceptions must be broken down and new practices adopted. Thus, in order for a JIT system to be successful, the leaders must recognize, understand, and commit to the underlying goals of a true JIT system.

JIT Implementation

While it is important to understand the philosophy of a JIT system, it is equally important to be able to implement such a system. Many organizations have attempted to introduce a JIT system, but have met with frustration and disappointment. There are several important aspects to achieving a successful JIT program. Hay [3] states that the organization must view JIT as a means to transforming their manufacturing system into a strategic weapon. This helps to create a positive environment where everyone can become involved in the process.

There must also be a structured approach, which Hay [3] describes with a three phase plan. The first phase, described as preparation, requires that top management help the company to understand why the JIT system is being embraced. The company leaders need to also create an overall vision of where the company will be in the near and long term, including physical and cultural changes. The second phase, which involves establishing an organized plan for the needed changes, focuses on four key elements. A steering committee of top management must work to convert the vision into projects that can be implemented with measurable results. Next, facilitators must be empowered to initiate the JIT projects and ensure that the projects have the necessary resources and people. Teams must be formed with middle and lower management as well as floor operators. These teams must jointly define the vision and goal of their specific project. Finally, these teams must adopt team leaders that can direct activities, contribute to the team, and help it to progress. The final phase involves putting the plan into action. The upper management must guide the efforts of the change rather than direct them. The responsibility for achieving results must be delegated to the lower levels where the change is taking place and must be accompanied by appropriate training and incentives.

At the heart of this approach are a few key ideas. First, Hay [3] explains that the approach is a process. The final goal is the institutionalization of the JIT concepts, which will hopefully lead to future cycles through the same approach. Over time the process will evolve and be improved, but one must recognize that it all begins with an organized and well thought out approach. Finally, the top management plays a vital role in the whole process. Everything begins with the senior leader(s) who must provide the initial energy and drive to overcome the inertia of change and who must serve as the model for how the others should embrace the change. Much of the structure and key ideas emphasized by Hay are captured in the methodology that is presented in Chapter 2.

Kanban System

Next I will discuss one of the pillars of the Toyota Production System and this project - the kanban. It is interesting to note that the inspiration for the idea of the kanban was simply the local supermarket - where people shop for what they want when they want. As described in Nahmias [8], kanban means card or ticket in Japanese. The kanban, typically protected in a plastic sleeve, serves as the signal or information flow between two adjacent processes. In this pull system, the subsequent process retrieves exactly what it wants when it wants it from the preceding process. Some of the key functions that the kanban provides are described by Ohno [10] as follows: it provides withdrawal information, prevents overproduction, serves as a work order, and becomes an important tool for inventory control.

Maruyama [7] explains that the kanban system is a pull system rather than the traditional push system. The kanban system works off of demand, as opposed to historical demand behavior and forecasts. The philosophy behind the kanban is not a zero inventory system, but instead a focus on providing control and flexibility within a manufacturing process. As Maruyama [7] points out, the kanban system works best in a multistage production environment where the processes are repetitive. The kanban approach does not focus on economies of scale but uses smaller lot sizes to generate level production.

In addition, one of the main benefits of a kanban system is the resulting reduction of variation in the manufacturing process. The utilization of machine time is improved as the work load is balanced. The work of the operators and delivery persons levels out during the day as the work flowing through the stations becomes more stable. Finally, the variation of the inventory control system decreases as inventory level fluctuations are reduced and ordering patterns become consistent. The drivers behind the use of the kanban described in the above paragraphs also serve as the drivers for the use of the kanban in the cab shop environment of this thesis.

Visual Controls

The final area of discussion about JIT involves visual controls. In his book, The Visual Factory, Michel Greif defines the core concepts of visual communication and outlines some of the important elements of a well designed visual communications program. Grief [2] believes that "employees are intelligent individuals who are motivated by work that keeps them informed about how their efforts affect the outcome and gives them the power and responsibility to reach their goals." Therefore, a visual communication system is based on the sharing of information and trust. It is not only sharing facts and data, but also a sharing of power and control. This view respects the wisdom and experience that employees possess and encourages them to use it to contribute to continuous improvement. The sharing of information allows employees to feel involved and encourages them to work with one another and participate independently in problem solving and process improvement. However, this notion of sharing is clearly a cultural change. Therefore, the pursuit of an effective visual communications system must be in conjunction with the pursuit for significant changes in the management and organization.

Grief [2] also discusses several key success factors required for the development of a visual system. The program requires input and discussion from many people and training for everyone involved. The visual communication should provide "self-service information"; the information should be relevant, clear, and easily attainable at a glance for all those who see it. Additionally, a team needs a place that it can identify uniquely as its own, where it can meet, discuss work, and share information. Yet it should be an open area that visually allows the team to be a part of the larger organization.

The visual controls should be simple and clear and utilize pictures and color to convey information quickly and accurately. Displays should define the goals and rules for the organization as well as convey the progress and results. Communication should also include visual production control such as kanban tickets and visual quality control such as statistical process control charts. Finally, in trying to implement such tools, the organization must define the needs, establish the goals, and recognize that the a culture built on visual communication takes time to create - thus it is best to start with small victories. When a program is implemented successfully the benefits can be significant - errors and variability will be reduced, efficiency will be increased, and quality will be improved; all of which help a company to attain a more competitive position in the market place.

The preceding review captures many important views regarding the successful development and implementation of a JIT system. I have used these ideas as the basis for the methodology which follows in Chapter 2. While the work of this thesis does not incorporate all of the concepts presented above, the overall conclusions confirm much of these findings.

Chapter 2. Development of a Material Delivery System

Understanding

2.1 System Scope

The first step in developing a material delivery system (MDS) is to identify and review the material supply chain, shown in Figure 2 below.

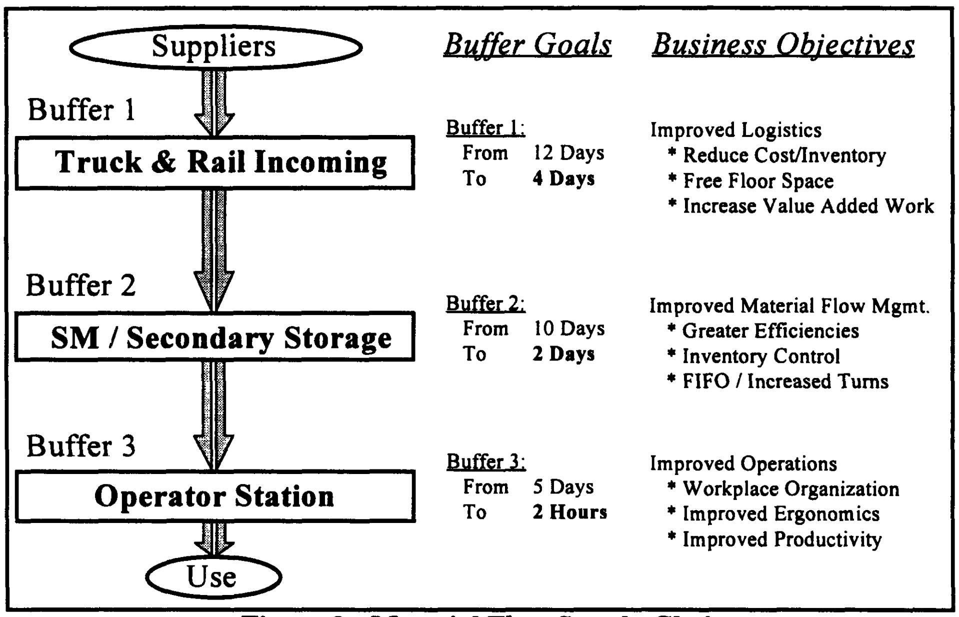

Figure 2 - Material Flow Supply Chain.

Specifically the client must understand each element of the supply chain and the mechanisms and systems by which material flows through each link. The client can then begin to outline and plan initiatives to reduce inventory and variation throughout the system. By pursuing these goals, non valued added work can be reduced and efficiencies can be improved. The client can then pursue the key objective by beginning at the operator stations and driving inventory and variation reduction back through the system.

In the above supply chain for the assembly plant, three key buffers are identified along with the initial and target inventory levels for each. Also, the business objectives for reducing inventory and variation in each buffer are also identified on the right. Suppliers receive orders for material and then ship material via rail cars and/or trucks to the plant (noted as Buffer 1). Once received at the plant, the material is unloaded and delivered to secondary staging areas (noted as Buffer 2), also called supermarkets (SM). From here, dedicated delivery men retrieve material and bring it to an operator's station (noted as Buffer 3) on the assembly line. Finally, an operator will install material onto a vehicle.

Specifically, the MDS will target buffer inventory level reductions to achieve improved logistics, material flow management, and operator working conditions. The MDS will then investigate the ordering of material from suppliers as well as the logistics associated with delivering the material to the plant. Finally, the MDS will improve the organization of the staging area as well as the operator work stations and increase the effectiveness and efficiency with which the material transitions between these areas.

2.2 Key Components of Delivery System Dynamics

In this step the client must review the longer term dynamic issues associated with the MDS. The overall goal is not simply the development of a MDS but rather the development of a system that will serve as a foundation and provide the support for other initiatives, as pointed out by Ohno [10]. The MDS is only one part of continuous improvement effort. Thus it is important to understand the key components that make the MDS part of a dynamic manufacturing system.

Flexibility

The MDS must be designed with the flexibility needed to easily adapt to future changes. In the short term, there will likely be line rate changes, mid-model design changes, and model mix changes that will impact the system. In the longer term, there will be full model changes and/or completely new product introductions. If designed with sufficient flexibility, the MDS will be able to accommodate such changes with minor adjustments.

Basic Principles

There are several key principles that serve as the basis for the development of MDS:

- There must be a specific plan for the delivery for every part.
- All wasteful activities must be eliminated.
- Every function/activity must somehow add value to the product/process.
- Delivery of material to the line must be comprehensive, consistent, and efficient.
- Every part must have a unique storage location in each holding area it passes through during the material delivery process (i.e. at the supermarket and the operator stations).
- Visual controls must provide simple, clear, and essential information.
- Orderliness and cleanliness is a must.
- Pride must be created and maintained.
- The general philosophy is to provide the Right part in the Right amount in the Right place at the Right time, Every Time (R4ET).

A Foundation for the Future

The implementation of a robust MDS based on the above principles will reduce the chaos and non value added work of the previous system. With an increase in the productivity of the material and production personnel, line rates can be increased and new model changes can be introduced more smoothly. The inventory reductions will lead to an increase in free floor space which will enable new operations and equipment to be brought into the plant.

There will also be other changes. It may become feasible to move processes performed by outside vendors in-house. In addition, efforts for "rightsizing" will be increased which will have a direct impact on manpower loading for the material delivery persons. All of these changes result in bottom line cost saving.

In this second step of the process, it is important for the client to understand how the MDS fits into a larger picture. The new MDS allows the Cab Shop to handle greater build complexity while providing the end user with reliable service. In this way, the level of variation as seen by the end user is reduced. A properly implemented MDS provides the foundation and flexibility for future changes that could have a large impact on the overall production process. However, these types of future changes are merely part of continuous improvements that will only be successful with the firm commitment and dedication of all team members involved.

A final element that has a dynamic effect on the successful implementation of a MDS involves top management support. It is critical that the leaders of the organization provide top down support for the work, resources, and energy that is required to make the project a reality, as described by Hay [3]. Furthermore, the support must be frequent and public so that the people involved in the daily activities recognize that the upper management holds a vested interest in seeing the MDS implementation become a success.

2.3 Current Material Flow System

The third and final step in this phase (understanding) involves conducting a thorough investigation and analysis of the current material flow system.

Part Details

By taking time to carefully investigate the entire manufacturing process on the floor, the client can gather important information for each part. Some key points are provided below:

- The floor location(s) where every part is used and the layout of the station in which it is used.
- The number of parts that are used for each different model type.
- The quantity and dimensions of the standard pack.

The following spreadsheet contains a representative example of some of the information that was gathered for each part. It is only intended to provide a sample.

Prt. Ord.	Part Number	Mix/ Std.	D/wk	Box/ Spmt.	Uloc Prime	Trans. Time	Box Qunt.	Box Dim. L	W	H	Pt./ Job	Jobs /hr.	Prt. /hr.	Boxes / 1 hr.	Boxes / 1 sft.	Zone	Part Name
1	15993842	STD	5	12	T41A01B	48	72	31	15	6	1	72.00	72.00	1.00	7.23	A	BRACKET AS
2	15955256	STD	2,3	20	T41A01B	50	60	11	10	9	1	72.00	72.00	1.20	8.68	A	REINFORCEM
3	15657615	MIX	5	1-5	T41A01B	53	200	12	12	10	1	72.00	72.00	0.36	2.60	A	DASHSUPPORT
4	15672315	MIX	5	1,2	T41A01B	53	425	12	12	10	1	72.00	72.00	0.17	1.22	A	SUPPORT
5	15647843	MIX	5	4-8	T41A01C	53	100	11	12	10	1	72.00	72.00	0.72	5.21	A	BRACE ASM
6	15647839	MIX	5	2,3	T41A01C	53	250	16	15	10	1	72.00	72.00	0.29	2.08	A	BRACKET AS
7	15647840	MIX	5	2-5	T41A01C	53	175	16	15	10	1	72.00	72.00	0.41	2.97	A	BRACKET AS
8	15685541	STD	1	16	T41A01C	37	200	12	12	12	1	72.00	72.00	0.36	2.60	A	REINFBRACE
9	15653613	MIX	5	3-5	T42A04A	53	225	11	12	10	1	72.00	72.00	0.32	2.31	A	REINFORCEM
10	15981718	MIX	5	7,8	T42A04A	53	180	11	12	10	1	72.00	72.00	0.40	2.89	A	REINFORCEM
11	15669148	MIX	1	8	T42A04A	53	475	15	16	8	1	72.00	72.00	0.15	1.10	A	BRACKET
12	15685054	MIX	5	1-3	T42A04A	53	500	15	16	6	1	72.00	72.00	0.14	1.04	A	DASHBRACKT
13	15992716	STD	1	16	T42A04A	28	150	12	24	10	1	72.00	72.00	0.48	3.47	A	BRACKET AS
14	15992715	STD	1	16	T42A04A	28	150	12	24	10	1	72.00	72.00	0.48	3.47	A	BRACKET AS
15	15658547	STD	1,2	12	U42A12A	53	725	16	16	8	4	72.00	288.00	0.40	2.87	A	BRACKET
16	15672316	MIX	5	1,2	U42A12A	53	1130	12	12	10	2	72.00	144.00	0.13	0.92	A	BRACKET
17	15672317	MIX	3,4	1,2	U42A12A	53	1000	12	12	10	1	72.00	72.00	0.07	0.52	A	BRACKET
18	15958630	MIX	5	2-5	U42A12A	53	190	15	17	10	1	72.00	72.00	0.38	2.74	A	REINFPLATE
19	15647844	MIX	5	4,5	U43A012	53	150	16	16	10	1	72.00	72.00	0.48	3.47	A	BRACE ASM
20	15723947	MIX	5	2-8	U43A012	53	200	15	15	8	2	72.00	144.00	0.72	5.21	A	SEALER
21	11515679	MIX	5	2-4	R43B002	96	550	10	10	8	2	72.00	144.00	0.26	1.89	B	STUD
22	11515602	MIX	4	1,3	R43B002	96	1500	10	10	8	1	72.00	72.00	0.05	0.35	B	STUD
23	15999714	STD	5	10	R43B002	53	115	12	12	10	1	72.00	72.00	0.63	4.53	B	PLATE ASM
24	15999714	STD			R42B03B		115	12	12	10	1	72.00	72.00	0.63	4.53	B	PLATE ASM
25	11515602	MIX			R42B03A		1500	10	10	8	2	72.00	144.00	0.10	0.69	B	STUD
26	15685512	MIX	5	5,6	R42B03A	53	80	12	12	10	1	72.00	72.00	0.90	6.51	B	PLATE ASM
27	15685511	MIX	5	5,6	R42B03A	53	80	12	12	10	1	72.00	72.00	0.90	6.51	B	PLATE ASM
28	15647805	MIX	5	1,2	R42B03A	53	255	12	12	10	2	47.02	94.04	0.37	2.67	B	REINFORCEM
29	15647799	STD	1	15	R42B03A	120	76	16	24	10	2	47.02	94.04	1.24	8.95	B	REINFPLASM
30	11515679	MIX			R42B03B		550	10	10	8	2	72.00	144.00	0.26	1.89	B	STUD
31	14051613	STD	0.333	66	R42B03B	50	100	12	11	8	2	72.00	144.00	1.44	10.41	B	PLATE ASM
32	15678952	MIX	5	1-3	R41B004	28	30	12	12	10	1	47.02	47.02	1.57	11.33	B	PLATE ASM
33	15678951	MIX	5	2,3	R41B004	53	360	10	10	8	1	72.00	72.00	0.20	1.45	B	PLATE ASM
34	376659	STD	1,2	15-25	S42B006	48	200	10	10	8	2	47.02	94.04	0.47	3.40	B	PLATE
35	376659	STD			S42B007		200	10	10	8	2	4.41	8.82	0.04	0.32	B	PLATE
36	15981716	MIX	5	4,5	T32D004	53	150	5	7	21	1	72.00	72.00	0.48	3.47	D	SEALER
37	15647821	MIX	5	1-6	T32D004	53	35	5	7	41	1	72.00	72.00	2.06	14.87	D	ROOF BOW
38	471084	MIX			U34EL01		350	10	10	6	1	4.41	4.41	0.01	0.09	EL	BIG NUTS
39	15672191	STD	0.25	12	U35EL02	120	16	32	41	9	1	4.41	4.41	0.28	1.99	EL	PANEL
40	15685193	STD			U35EL02		66	15	33	8	2	4.41	8.82	0.13	0.97	EL	DRINGSEALE

Figure 3 - Sample Spreadsheet of Part Information.

Most of the information contained in the spreadsheet is straight forward. However, the following descriptions will provide further clarification for most categories:

- Mix/Std: defines whether a part is shipped by itself on a pallet (STD = one part number per pallet) or with other part numbers (MIX = two or more part numbers per pallet).

- D/wk: defines how many days per week a shipment is received at the plant. This number sometimes varies.

- Box/Spmt.: defines how many boxes are typically included in a shipment.

- Uloc Prime: defines an address (unique within the plant) where the part is used.

- Trans. Time: defines the typical transit time (hours) from the supplier to the plant.

- Box Dim.: defines the dimensions (inches) of the box in which the material is shipped.

- Pt./Job: defines the quantity of a given part number that are used on each vehicle (job) that passes through a given operation.

- Jobs/hr.: defines the number of vehicles that pass through a given station per hour.

- Zone: defines a region of the cab shop and usually contains several related stations.

Once this information was gathered, several pieces of critical data became accessible:

- The initial inventory level and buffer size for each part.
- The initial quantity of floor space used for storage of inventory.
- The usage level and inventory turns for each part.

It is critical to identify the key information that is needed and then to obtain it early in the overall process. This and other information will be used later in development of the MDS.

Operator Methods

It is very important to learn how each production operator performs his/her task. By spending ample time, the client can learn about any manipulations that the operator must do to the part before it is placed on the assembly line - any special procedures or flexibility constraints that are required for each operator station. This will provide valuable ergonomic information that will be used to design the operator stations in a later step.

Other important information can be obtained by working with the material delivery persons. The client can learn the difficulties of opening and lifting boxes, short cuts for delivery routes, and methods for recognizing when stations need replenishing. The client should also conduct a time study of the delivery stockpersons to gain an understanding of the duration of each task performed. This data will be used later to balance the work load of each driver. The time study that was conducted for this project is presented below in Figure 4.

		Trials (minutes)					**Avg**
#	**Action**	**1**	**2**	**3**	**4**	**5**	**/box**
1	Stocking Parts, from pallets to racks:						
	a - removing packaging (shrink rap).	.20	.21	.24			.22
	b - loading cartons.	.15	.16	.16	.15		.16
	c - removing dunage.	.08	.10	.11	.12		.10
2	Load cartons from racks to cart.	.11	.19	.18	.13	.21	.16
3	Picking/Placing cards:						
	a - picking up cards from mail box,	.09	.06	.09	.07	.09	.08
	b - placing cards in new cartons.	.02	.04	.02	.02	.01	.02
4	Cutting cartons open.	.26	.17	.24	.40	.36	.29
5	Load cartons from cart to station	.21	.08	.18	.44	.17	.22
6	Getting off cart.	.03	.02	.04	.03	.04	.03
7	Getting on cart.	.03	.02	.04	.03	.04	.03
8	Removing empty cartons:						
	a - empties from station to cart.	.12	.10	.07	.10		.10
	b - empties from cart to dumpster.	.03	.04	.04			.04
9	Counting parts. Note - Timed Activity - 2.25min/pt. Standard (Kukan) - 2.00 min/pt. Expected (Synchronous) - .5 *used in calc.* Only 10% of parts counted per						.05
	Total (without travel) =						**1.49**
10	Travel speed (note distance traveled - Note - 200ft /.346 min = 578 ft/min or **.346 / 200 = .00173 min/ft.**	.32	.32	.38	.37	.34	.001
	Note: Above data from June 29, 1995 time study by Don						

Figure 4 - Material Driver Time Study.

Material System Process

Lastly, the client must learn how the "front office" material department functions. Several key questions must be answered - What system is used to order parts and how does it work? How is material transported from the suppliers to the plant? What are some of the statistics of delivery for each part such as delivery frequency and volume? (some of this information was included in Fig 3).

Some facts about the truck assembly plant material delivery system provide insight into the type of information needed. The Linden assembly plant uses over 550 suppliers to provide more than 4,300 parts (roughly 54 suppliers for the material used in the cab shop). The end product which emerges from the cab shop, called a "Body-in-White", contains roughly 330 parts. This equates to a material flow in excess of 250,000 pieces per day in the cab shop alone.

All material is ordered via an automatic computer network system. This system ties together all plants and suppliers, as some suppliers ship to multiple plants. The system works on a "Freeze and Slide" process, see Figure 5 below. Three week production forecasts are input into the computer system. Then from this forecast, along with data on the current quantities of material in the plant, a schedule is developed for each supplier. This shipping schedule tells the supplier exactly how much and when to ship material. It is "frozen" or locked for the upcoming three week period. When week 1 is complete, weeks 2 and 3 "slide" forward to become the new weeks 1 and 2 along with a newly calculated week 3, and so on.

All material is shipped via railcar or truck from the suppliers. While most suppliers of bulk material ship directly to the plant, 15% of the bulk suppliers and 95% of the small carton suppliers route their material through seven Regional Distribution Centers (RDC's). For example, suppliers ship material bound for several plants on one truck to a local RDC. At the RDC, this material is unloaded. All material destined to one plant from each supplier is then consolidated

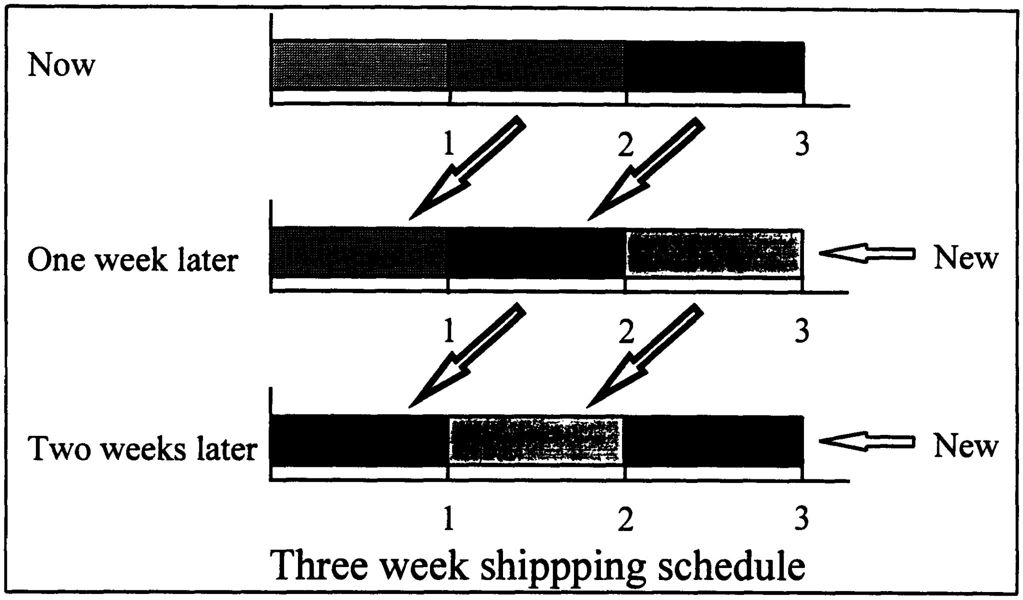

Figure 5 - Visual Depiction of "Freeze and Slide".

onto one truck bound for that plant. This has greatly reduced transportation costs and time.

Finally, roughly 70% of the parts for the cab shop are shipped daily in quantities equivalent to one day's worth of production. However, the other 30% arrive to the plant less frequently: 1, 2, 3 days per week, or even every other week. With regard to shipment quantities, suppliers ship from 1 day's worth to more than a week's worth at one time. It was found that this range of shipment frequencies and volumes was due in part to incorrect information in the computer system and less then optimal shipment schedules from the plant. The rest was due to suppliers that did not honor the scheduled shipping requests of the plant.

In all cases, it is critical for the client to learn as much as possible about parts that are used in production, how they are delivered, and how they are handled. This will make the next phase of the ten step process (developing) much more effective.

Developing

The second phase of the MDS involves developing the plans and making the physical preparations so that the system can later be implemented. There are three key areas of focus: adjusting the supplier logistics to improve the manner in which material arrives in the plant, preparing the production operator stations to receive material in a synchronous fashion, and preparing the supermarket area to store material so it can be retrieved in a synchronous manner. The underlying theme for this preparation phase of the process is to develop "a plan for every part." The next section discusses the first step.

2.4 Supplier Logistics

At this point the client should have a firm understanding of the current system for obtaining material from suppliers and the logistics that are associated with this process. In this stage, the client can work to improve these logistics by focusing on several key targets. The ideal system would be to have one day's worth of material shipped everyday from each supplier. However, other information and facts require tradeoffs to be made regarding shipping quantity and frequency. The assembly plant experience will be used as an example.

Accurate Information

It is important to first make sure that the correct information is input to the automated computer system (or other ordering system). In the case of the assembly plant:

- The quantities for the standard packs were reviewed and corrected. (If a 100 count standard pack is incorrectly set to 1000, the system will not place an order until at least 1,000 pieces are needed - a mistake on the part of the plant, not the supplier.)

- The delivery location addresses for the secondary storage areas as well as the usage locations at the operator stations must be correct and present in the system database.
- The desired banks must be set correctly. The bank is the amount of "safety stock" material to be "in house" at any given time. The ideal situation is one day, since one day's worth of material would be used during production and that same amount would arrive during that day's deliveries. This assumes the general understanding that deliveries to the plant arrive at most once per day. However, I started with a bank of two days with a plan to reduce this level over the next year. Some bank is necessary as it allows the plant to continue running in the event of bad weather, delivery accidents, or other reasons. In the long run, the holding cost of a small amount of material is less than the stockout cost if there is not enough material to run production.
- In selecting the metric to use when setting the bank levels, it is important to use a quantity of pieces rather than a number of hours worth of production. The model mix of vehicle types per hour can vary due to changes internal and external to the plant. As the model mix changes, so do the hours of stock needed for various parts particular to different models. Thus, hours will quickly become a poor metric.

Supplier Selection and Routing

Once the data in the ordering system is correct, the client should review the suppliers that are providing material for the plant. While changes to the supplier base were not made in conjunction with this project due to time limitations, such changes should be investigated. It may be possible to receive material from a new supplier in less time and/or at a lower cost. Also, one or two suppliers may be able to supply the same material that three or four suppliers are currently supplying and thus lead to savings through supplier consolidation.

Next, look for ways to improve the efficiency of the transportation routing. GM recognizes that substantial efficiency gains can be obtained through the use of multiple hub logistics. I tried to leverage the strengths of the RDC system that the plant was currently using. I reviewed the locations of all suppliers and searched for situations in which rerouting a supplier through an RDC would lead to a cost savings. In some cases I recommended investigating the possibility of opening an additional RDC to further improve logistics.

Shipment Size

I also studied the shipping practices of some of the bulk material suppliers using rail cars. It is most economical to ship full rail cars. Thus suppliers would ship more than the requested quantities of material to obtain full rail cars, but would only fill the cars with two or three part numbers. When the material arrived at the plant, several railcar loads of unneeded material would have to be unloaded to reach one or two specific part numbers that were needed.

The material department began to work with the suppliers to improve this problem. The agreement was to have the railcars fully loaded by the supplier, but with more part numbers per car. Thus, the material department was required to unload half the number of railcars in order to receive one day's worth of material. The level of in-house inventory was dramatically reduced.

In any case, a thorough analysis must be completed to determine where the benefits of more frequent shipments outweigh the increased handling costs. Since transportation costs are a large portion of the handling costs, the goal is to work with full or "cubed out" trucks and railcars. Thus, in order to maintain minimal safety stock levels and provide the needed material to the line, the focus must be on reducing the quantity of each part number shipped while simultaneously increasing the amount of different part numbers shipped per load. The optimal goal is to use the fewest number of trucks and railcars to supply the plant with the daily requirements for each part.

Shipment Frequency

After investigating possible areas for change, the material department and I moved forward with several changes where the cost analysis showed it to be financially beneficial. Changes were driven by the goals to reduce the order quantities and increase the inventory turns. Some small carton suppliers began shipping more frequently with less per shipment. This was accomplished by revising the data in the computer system to reduce the standard size of a shipment and to increase the standard frequency for the shipment.

In addition, through the strong efforts of the plant material department, some bulk suppliers began packing "JIT" cars as described above with a day's worth of material of several parts on one railcar. This dramatically reduced the amount of material double handling that had been necessary in the past and moved the plant one step closer to the goal described earlier.

Labeling

Finally, I found that the suppliers could provide a valuable service at no additional cost. Every box of material that passes through an RDC receives a label which contains various information for every shipment package. The information on the labels is pulled from the database in the central network computer system and is automatically printed and placed on the shipment (pallet of cartons or large box or basket). With some simple changes and adjustments, I was able to have the in-plant delivery location printed on the shipping label automatically. Thus, when the material arrives at the plant, the delivery drivers need only look at the label to know where that particular material is to be stored.

In addition to the printed delivery labels, color was also used to improve the material loading and delivery process. Colored dots helped the delivery persons distinguish between the two separate routes used in the cab shop as well as between mixed and standard parts. The dots, one inch circles, were affixed to each pull card. Together with the labels, the colored dots helped to reduce the confusion and increase the efficiency associated with the handling of material by the delivery persons.

Support

In order for such changes to be successful, the plant must provide support to the suppliers. First, the plant must provide a clear explanation for the changes and then work with the suppliers to make the desired adjustments. Compromises were often found to work best.

The client must also be clear with all suppliers as to expectations. The suppliers must be expected to follow the shipment schedule as issued by the plant. Rather than punishment for nonconformance, the client should consider an incentive system for 100% conformance, which may often produce better results.

2.5 Workplace Organization

Outline Needs for the Operator Stations

The key to making an operator's station an efficient and effective part of a synchronous material system is to focus directly on the operator. The client must look for ways to improve ergonomics - reduce excess walking, bending, and/or double handling. The goal is to make the operator as productive as possible by making as much of his/her work content valued added as possible.

In assuring that the production operator's needs are met, the client must insure that several criteria are addressed for every small parts:

1 - A standard place is needed for the part to be delivered in a FIFO manner, be it a table, rack, or stand. This location must be for one part only and used for nothing else, such as a newspaper holder, shoe rack, or lunch tray.

2 - A location is needed for the operator to place empty containers.

3 - A location is needed for the operator to deposit the pull cards (a mail box or chute).

Next, the client must review the above points and develop an outline or recommendation for the changes needed to prepare each station for synchronous delivery. It is very important to involve the operators when considering the necessary adjustments, as they can often provide some valuable insights.

Review of Proposal

Once the client completes an outline of the needed changes, it must be reviewed for consensus and acceptance. I used a simple table format (shown in Figure 6 below) to outline the needed changes for each station. Next, formal meetings were held with key individuals to gain acceptance: first and second shift production operators, production supervisors, the material delivery driver responsible for that station, material supervisors, and the union representative. The overall concept of the MDS was explained to everyone and the changes for the individual stations were reviewed. One by one, questions and concerns were addressed and resolved through compromise, persuasion, or decree. The outline was then adjusted with any changes and the document was signed for acceptance by all parties involved.

		Sign Off	
Stn.	Need	1st S	2nd S
1B & 1C	1. Get part #15993842 on pull card. 2. Install one roller rack (6'W by 4'D) to the south side of the maintenance panel. The panel will have to be moved to the north approx. 1 foot. 3. Install one roller rack (5'W by 3'D) to the north side of the maintenance panel. [Note - could also go with a roller rack (3'W by 3'D) with two shelves. The operator does not work from the table, but rather has stands on the machine which hold the boxes of parts.] 4. Both roller racks must have front extended 15" tables and chutes (north side of 1B and south side of 1C) for the card return.		
4A	5. Move panel view from east side of station to west side. 6. Remove current work table. Install one roller rack with front extended 15" table (7'W by 4'D) to east side of station. Rack will have a chute on the east side. [Note - part #'s 716 and 715 will be loaded onto the rack with their long direction running north/south. The operator doesn't need to work directly out of boxes as he places the boxes on the station equipment.]		
12	7. Remove both current stands. 8. The north side of the station gets a stand with two (2) lower shelves for the sealer strips (first shelf at 11", second shelf at 22", top at 34"). **(TAF)** 9. The south side of the station gets a stand with two (2) lower shelves for the brace assemblies (first shelf at 5", second shelf at 20", top at 34"). **(TAF)** 10. A special location for the pull card mail box must be established in a location that the stock person can see from the cart (maybe go with a light switch).		

Figure 6 - Operator Station Recommendation/Signoff Sheet.

Purchase and Install

This phase will generally take the longest time. The recommendation is to spend as much time as needed up front to find a vendor that satisfies everyone's needs and then use that vendor as a standard. Make this standard known throughout the plant to save others the hassle and effort of trying to find an appropriate vendor in the future. Work closely with the selected vendor up front to insure that what is ordered is what is received. Next, make the necessary arrangements to have the equipment correctly installed.

Visual Controls

Finally, visual controls must be developed and installed for all the operations. The important elements are as follows:

1 - Every delivery location must be clearly labeled with an easily understandable address. We used column location, the zone letter, and the station number. Anyone must be able to follow the system and the signs must be very visible (black lettering on a yellow background was used).

2 - The part number must be clearly visible at each part destination location for the delivery person and the operator. Thus, if the part is stored on a table with shelves below, only one number on the front of the table is adequate. However, if a FIFO roller rack is used, the part number must be on the front and the back of the rack.

    The system must be clearly visible and flexible. We used 2.5" high numbers (black lettering on yellow background). Also, each number was individual. It slid into a bracket that had a locking screw clamp on each end. Thus, if the part number changed, the clamp could be loosened and the new number inserted.

3 - Finally, the triggering mechanisms must be clearly marked. The pull card chutes and mail boxes must have labels indicating their purpose. Also, the mail boxes used were white with cut-away openings in the center. This made it very easy to see if there were any bright yellow cards to be picked up.

2.6 Pull System Foundation

The secondary storage areas are where material is brought to when it arrives into the plant. It is stored here in an organized and efficient manner until it is delivered to the line where the parts are installed onto the vehicle.

Small parts - Supermarket System

The second stage of preparation involves the secondary storage area for the small parts, referred to as the supermarket or buffer 2 in Figure 2 earlier. This area represents an intermediate staging area for parts that will later be delivered on an hourly basis to the production line.

Determine location

The first step is to determine how many supermarkets will be used and where they will be located. Based on the constraints of the client's situation, there will be varying degrees of flexibility in this choice. In most cases, the ideal set up is one location as centrally located as possible.

Determine space needed

The next step is to carefully determine the amount of space needed in the supermarket. The goal is to have enough space to hold the desired buffer but not too much space to allow people to hide problems with excess inventory. Finally, there must be some "contingency" space to provide the needed flexibility for future changes and adjustments.

1 - Determine how many boxes are needed on the line. In the assembly plant, our project team agreed to have 2 hours of inventory "on the line". Although this was a larger buffer than was needed to allow the delivery person enough time to make his/her round, it was a starting point which was targeted to be reduced gradually over time. Using the usage rates from the spreadsheet in Figure 3 and the desired line buffer, the client can determine how many boxes of each part are needed on the line. For example, for a given part, the number of boxes in the on-line buffer: = usage (parts/hr.) * 2hr. ÷ box size (parts/box)

The resulting quantity above must be rounded up to the nearest whole box. It is important to note that this number is also the number of pull cards that are needed to operate the synchronous system.

2 - Determine the size of the buffer for the supermarket; we chose to have between one and two day's worth of material kept in the supermarket. Again, using the usage numbers from the spreadsheet, the client can determine the number of boxes to be stored in the supermarket for each part.

3 - Decide upon the manner in which the material will be stored and retrieved (by pallet or carton). Specifically, the material department must decide which parts will be picked directly from the pallet on which they are shipped and which parts will be loaded from the pallet onto a rack and then picked from the rack. The rule of thumb is: if a pallet holds less than 1.5 days of material, the material should be left on the pallet, which will reduce a great deal of non value added double handling. Otherwise the boxes on the pallet should be loaded onto the racks.

4 - Determine the square footage needed. For parts to be stored by pallet, count on using a 4' wide by 4' high by 8' deep volume of space. For carton flow racks, use the number of boxes calculated in step 2 above and the dimensions of the boxes (from the spreadsheet in Figure 3) to determine the square footage needed.

5 - Determine how each individual rack will be laid out - how many levels will the rack have, how wide will it be, how deep will it be, will there be a top level for extra storage space.

Determine Rack Specifications

Once the above information has been gathered, the client is now ready to start laying out the supermarket area. Figure 7 below shows a layout of the assembly plant supermarket.

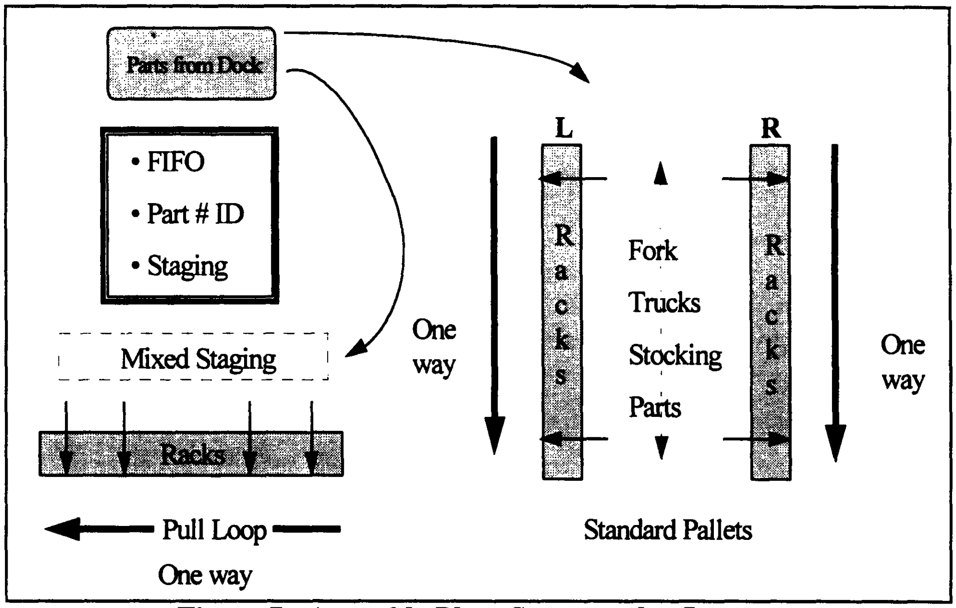

Figure 7 - Assembly Plant Supermarket Layout.

While every situation will be different, there are some key elements to focus on:

1 - Must involve the material personnel (supervisors) in every step. They will be the final users and are thus the customer. The client can make suggestions, but final acceptance must be obtained from the material department.

2 - Try to separate the loading activity from the picking activity as this will reduce interference and delays.

3 - Separate the fork truck loading of the pallet flow racks from the picking operation of the pallet flow racks. This is an important safety issue.

4 - All traffic through the supermarket for picking should be one way travel.

Material Layout on Racks

The material must be loaded according to the way the material is delivered - not by part numerical order (see Figure 8 below). At most, the material is loaded into the supermarket once per day. However, material will be retrieved from the racks up to 16 times per day (hourly deliveries for two 8-hr shifts).

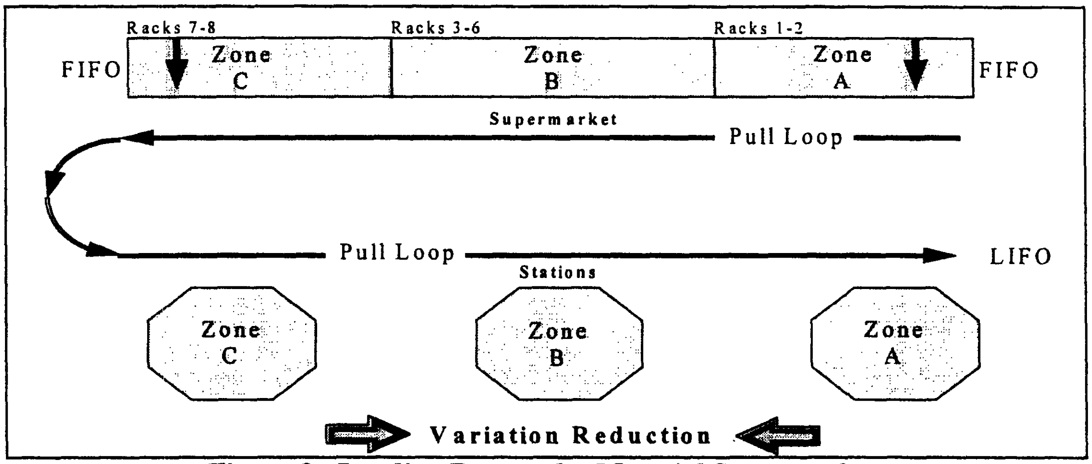

Figure 8 - Loading Pattern for Material Supermarket.

The material should be loaded on the racks by zone in the opposite order in which the material will be delivered (LIFO). Thus, the last box that the material delivery driver loads will be the first box unloaded. This method of part number sequencing in the supermarket racks permits the most efficient pattern for delivery - a one time pass through the supermarket on material pick up leads to a dramatic reduction of material double handling.

Visual Controls

As with the production operator stations, visual controls are an important element of an efficient and well run secondary storage area, which refers to some of the ideas from Greif [2].

1. Every part location storage area is labeled with the part number (black lettering on a yellow background). Similarly to the signage at the operator stations,

brackets with locking end clamps are used for the part numbers; this allows for easy adjustment.

2. The supermarket parts on the roller racks have part number labels on both the load side for the crib attendant and on the pick side for the material delivery persons.
3. On the load side of the racks a max and min sign is provided for every part number. The max and min numbers provide a range of acceptable inventory levels for the individual taking the inventory count. Any counts that fall outside the range should be noted as problem parts and be investigated. The min level is set to one day's worth of inventory. The max level is set to the bank level established by the front office material department. (Note, for this project the max was set to 2 days with the intention of lowering this amount over the next year.)
4. Every rack in the supermarket is labeled with a rack number (1-32) and the level letter (A, B, and/or C) on both the load and pick sides.
5. On the load side, every part number has a pull card attached to the rack (with a magnet) below the part number.
6. At the end of the supermarket racks, there are "red hot" boxes. The material delivery persons deposit the pull card for any part in which there is no material in the rack. The crib attendant is to deposit the pull card for any part in which the inventory level does not fall within the min/max values. The supervisors then have one location to monitor for "hot" items that need immediate attention.
7. On the front end of the racks, there are return boxes (one for each driver). The supervisor or crib attendant deposit cards they retrieved from the hot boxes after

the problem has been addressed and resolved. The drivers can then retrieve their cards from the return boxes and fulfill the pull card delivery order on the next cycle or the crib attendant can retrieve their cards and place them back on the rack in their proper location.

8. On the front of the rack, there is a Stockman Delivery Board. The material delivery persons mark their status with every pass through the supermarket. This allows the material supervisor to always monitor the cycle and loop in which the drivers are delivering.

There are a few important points regarding item number three above. First, the max/min visual controls were used only on the supermarket racks and not on the station racks. The key reason for using the max/min signs was to provide the supermarket crib attendant with guidelines for acceptable material inventory levels. With one look, the attendant knows whether the quantity of material on the rack for a given part number is within the acceptable range. Part numbers falling outside the range can be flagged and addressed quickly. Also, every part number is not replenished daily. If all parts were replenished daily, then there would be no need for max/min controls but rather adjustments to the incoming daily quantities.

In an ideal situation, the max/min signs would not be required, Maruyama [7]. The pull signal should be continued further upstream in the supply chain. Thus, the supplier should receive a signal requesting the shipment of a box of material when a box of that material is removed from the supermarket. In this way, the system would be self replenishing. However, due to constraints that existed during this project, the decision was made use the max/min signs with the intention to eliminate their need as improvements are made in the future.

Review and Adjust

The client must develop a plan to have all of the above changes implemented for the secondary storage areas. The next step is to review the plan with all the parties involved (production, material, and the union). Once consensus has been reached, the equipment must be purchased and installed. The overall process is the same as for reviewing the changes for the operator stations (see section 2.5 above).

Implementing

The next steps of the process (7-10) involve the implementation and operation of the process.

2.7 Roles and Responsibilities

In step 7, the client establishes the roles and responsibilities of the individuals that will run the system.

There are three key individuals involved with the synchronous delivery of small parts. Their positions are as follows.

Supermarket Crib Attendant

The primary responsibility of this individual is to make sure the material is prepared and acceptable for retrieval by the material delivery persons. This means the crib attendant must load all individual cartons into their correct locations on the roller racks. All dunage (cardboard lids, plastic wrap, pallets, or any other debris) must be removed. The crib attendant is also responsible for keeping inventory levels - taking part counts daily and indicating when any part counts are above preset max or below preset min values.

Role of Delivery Stockpersons

The material delivery stockpersons are responsible for keeping the operator stations stocked with the correct amount of inventory. This correct amount of material is based on the number of pull cards for that part. For every card assigned to a part number, there should be a box of material at the operator station.

In the assembly plant, for example, there were two delivery stockmen, each with his own established delivery route. The route for each man has two loops; this is because the flatbed delivery cart used by the drivers is not large enough to accommodate the space that would be needed to deliver the material for one larger loop.

Designing the Routes

The routes were designed in part with the help of the Clark and Wright algorithm. The algorithm provides an optimized routing for a fleet of trucks from a central location to a number of defined delivery points. The procedure begins by identifying the distance between the central depot and each delivery location. Then, delivery locations are grouped into one stop if the required travel distance together is less then the travel distance taken separately, as long as the capacity of the delivery truck is not exceeded. Note that the groupings are based on a rank ordering of the location pairs. For further information on this algorithm, see reference [1] at the end of this paper.

In addition, there were several other aspects to consider:

1 - The work loads for each driver must be balanced. Thus, the client must use the time study conducted earlier to determine the work load for each driver. The work load should be calculated in the metric of hours, as this allows for an accurate comparison (using the metric, for instance, of boxes delivered per hour does not provide reliable results).

2 - As mentioned above, the client must consider the capacity of the delivery cart. The driver must have enough room to maneuver boxes and stack empties.

The Driver's Operation

1 - Driver arrives at the supermarket and records his status (i.e. beginning loop 2 on the fourth cycle of the day) on the schedule board. He also retrieves any cards left for him in the "return" box.

2 - Driver travels through the supermarket and retrieves the correct box for each card he collected on the previous cycle.

3 - The driver retrieves a box, cuts it open if necessary, and then places the card for that box in the opened box. (some boxes have a common pallet lid and thus no individual tops to cut open)

4 - The driver should pass through the supermarket only once, always in the same direction.

5 - The driver then leaves the supermarket and follows the set loop.

6 - The driver deposits any pull cards he could not find material for into the "red hot" boxes.

7 - At each station the driver must load full boxes to the correct locations (which are labeled) at each operation, remove empty boxes, and collect any deposited pull cards from mail boxes or chutes.

In the assembly plant, the floor is divided into regions that are called zones. The drivers deliver parts by zone. For example, a driver will deliver all the parts to A-zone and then deliver all the parts to B-zone. When a driver collects cards for a given zone, he then deposits them in card holders secured to the delivery carts (there is one card deposit location for each zone). This facilitates the later retrieval of material from the supermarket.

Role of Operator

While the operator's role is critical to the success of the system, it is quite simple:

1 - When an operator finishes working from a given box of parts, he/she must dispose of it by placing it on the empty return rack of the roller rack or on the lower shelf of the work stand.

2 - Upon removing this box, a new box will automatically roll forward or the operator must retrieve a full box from a lower shelf of a material work stand.

3 - As soon as the operator uses the first piece from that box, he/she must remove the pull card and deposit it in a mailbox or chute, which is located near the operator.

4 - The operator is to work only from one box at a time and not "build up". As the desire to work ahead will still exist, it will be the responsibility of the supervisors and management to enforce this requirement through explanation and firm, consistent reminders.

2.8 Education and Communication

The most important element of a successful implementation plan is education and communication. The client must work to insure that everyone involved with the project understands what is going to happen and why, as explained by Hay [3]. If people are well informed they will be more willing to cooperate.

Structured Meetings

The first stage of education involves meetings. I found it necessary to have three levels of informative meetings.

1. The first meeting took place with the higher level management in the cab shop and material departments - the area managers and superintendents. It was very important that they understood the changes that were going to occur and the role they would need to play in making those changes successful.
2. The second meeting took place with the rest of the management personnel in both departments. Since these individuals would have direct contact with the

hourlies, it was critical that they understood exactly how the system was to work. It is important to note that the client should encourage the individuals who attended the first meeting (the upper management) to take the responsibility for making the presentation in the second meeting. This will help convey support, build ownership, and facilitate acceptance.

3. The third round of meetings took place with all the hourly employees involved (production operators and material delivery drivers). Again, in this case the supervisors from the second meeting should present all aspects of the system to the production operators and the material drivers.

Throughout the implementation phase, there are several key points to keep in mind.

1. While support and commitment must be shared by everyone involved, it is critical to demonstrate clear support from the top down.
2. Everyone involved must absolutely understand what is expected from him/her. Each person must also understand the overall goals of the project as well as the consequences for not fulfilling responsibilities.
3. Meetings should be a time for explanation. They also should be a time to listen carefully to the concerns and issues that may be raised, as there is always room for the evolution and improvement of an idea.

Clear Communication

Although this idea is simple, I feel it is the most important. Communication is the foundation of the process - without it, the project will never succeed. From my experience in the cab shop, I found it very beneficial to talk to as many people as possible as often as possible for several reasons.

1. I was able to meet everyone and they were able to get to know me. This helped me to develop relationships and bonds with certain individuals that were very helpful at various stages of the project.
2. I was able to teach others and at the same time learn from them.
3. I was able to build a positive reputation that was very beneficial in the long run.

The key to successful communication is consistency and clarity. I worked hard to make sure everyone I worked with understood what changes were needed, why they were needed, and when they were needed. I kept everyone informed as to their responsibilities and expectations. It may seem trivial, but effective communication was the key to the success of this project. Finally, although there will always be glitches and difficulties to overcome during the early stages of such a project, following the above steps will lead to a smoother and more effective startup.

2.9 Monitoring and Maintenance

Once the project is implemented and underway, the client must still work to monitor the operation of the system.

Monitor Equipment

Without fail, some pieces of equipment will need to be repaired or updated. Part number brackets, mailboxes, or chutes may get knocked off by a fork truck or cards may become worn through use. On the other hand, some parts may begin arriving to the plant in small boxes due to rightsizing efforts. In this case, the current roller rack may not be large enough; thus some changes may be needed.

Flexibility

In addition to monitoring the physical equipment, the client must also be careful to recognize when other changes are necessary. For example, the part number brackets with locking end clamps where chosen to provide flexibility. Thus, part numbers will need to be updated at the stations, in the supermarket, and on the pull cards.

There may also be adjustments to the production rates. The plant may change the line rates or the model mix. These changes will impact the number of cards needed for each part as well as the max and min quantities. The client can use the spreadsheets to update the changes and then issue new cards (or take cards away) and max/min plates for the supermarket racks.

In addition, the personnel will most likely change frequently. Thus, the client must take the necessary steps, for example, to train new drivers or operators, or adjust a route if new operator stations are added. However, because of the flexibility and simplicity of this system, new personnel should be able to learn the system quickly.

Supplier Inventory Tracking

Once the MDS is up and running, the effort to gain further control over the flow of material and to reduce inventory levels must continue. For the assembly plant project, a system to track supplier performance through the use of control charts was created.

Everyday the central computer system generates data on the current level of material in the plant. This data is automatically downloaded into an excel spreadsheet where macros are run to analyze the data. The result is control charts that can be used by the material and production personnel.

With a simple push of a button, time series control charts are produced for:

1- Total inventory value of the entire cab shop (see Figure 9 below) or selected supplier.

2- Total number of parts that are "out of control" for the entire cab shop (see Figure 10 below) or a given supplier.

3- A complete list of the parts that are "out of control" for the entire cab shop or a given supplier.

A part is considered "out of control" when there are both more than two days of inventory of a part in the plant and more than two standard packs of the same part in the plant. For example, it is possible to have one day's worth of a given part that requires five standard packs. It is also possible to have one standard pack of a given part represent four days worth of inventory of that part. Thus, both criteria (days on hand and standard packs) needed to be two or more for a part to be considered "out of control". While part of the objective of this project was to develop a system that worked to eliminate such parts, there were some cases where "out of control" levels were acceptable for a short time period, such as a strike or bad weather.

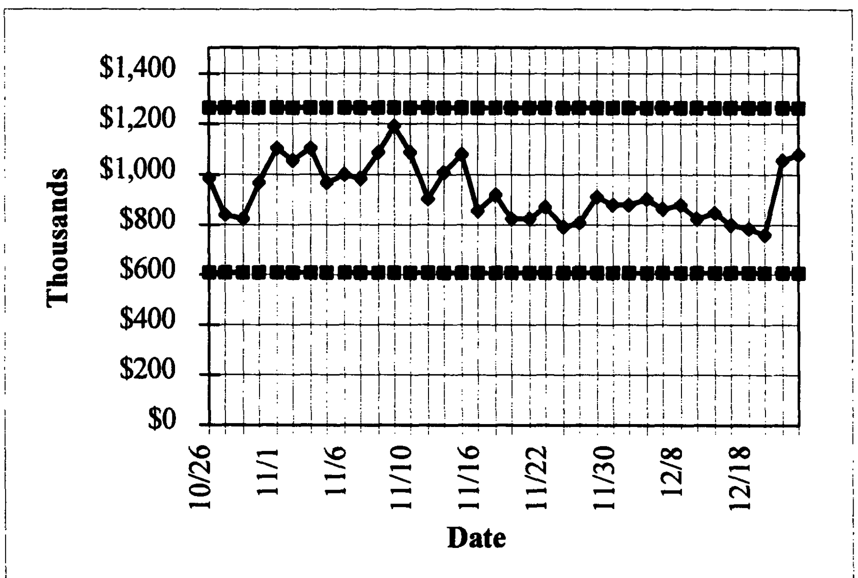

Figure 9 - Control Chart for Total Cab Shop Inventory.

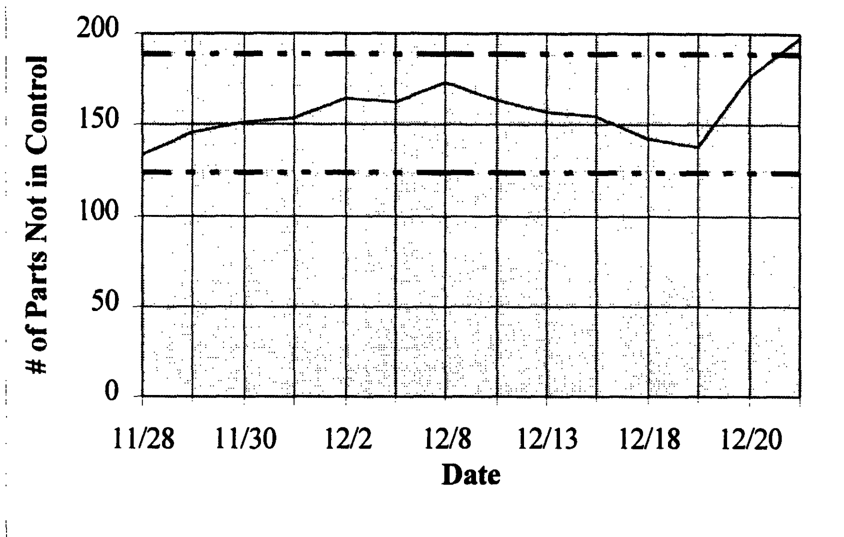

Figure 10 - Control Chart for All "Out of Control" Parts in the Cab Shop.

The key to this system is that it provided people with tangible information and data. Rather than asking people to "reduce inventory", these charts provide the exact supplier and part numbers that are not in conformance. With these charts, the production and material personnel can gradually continue to reduce inventory levels and thereby increase their material handling control.

2.10 New System Impact

System Dynamics View of the Original Process

In order to understand the impact of the MDS, I first analyzed the original state of the material system in the cab shop (see the smaller left loop in Figure 11). As disorganization increases, non-value added work increases. This leads to a reduction in productivity for the material and production personnel. At this point, changes are introduced into the system by the union or management or both. The changes could take many forms: an attempt to reduce the downward trend in productivity, a line rate change, a model mix change, or a new model introduction. Without a robust MDS, these changes lead to only further disorganization.

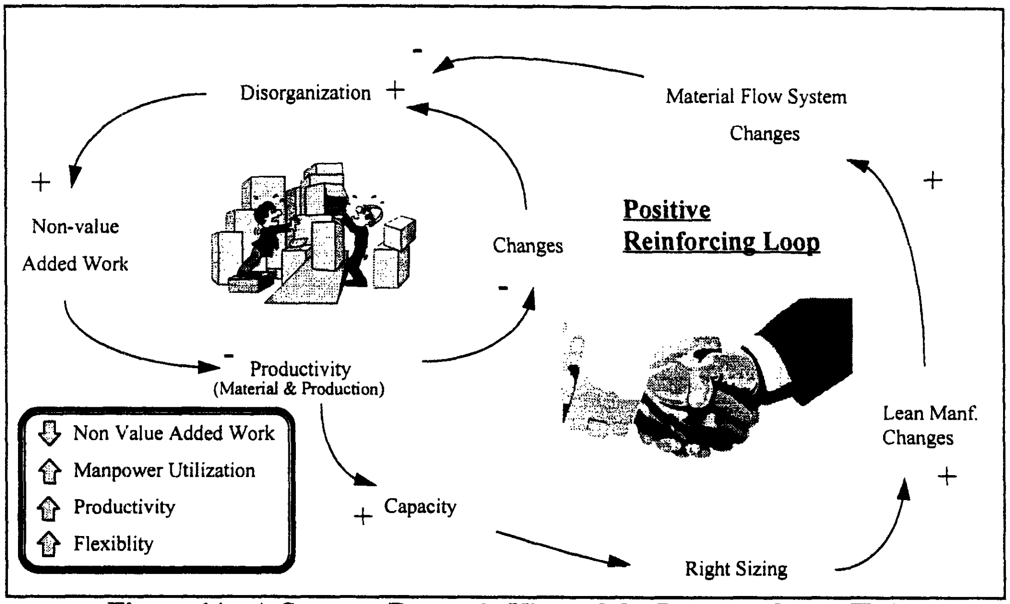

Figure 11 - A Systems Dynamic View of the Impact of the MDS.

System Dynamics View of the New Process

As Figure 11 also shows, the new MDS adds a positive reinforcing loop. The MDS works to reduce disorganization and thus non value added work. This leads to an increase in productivity and also capacity (for the production operators and the material delivery persons). This additional capacity allows other improvement initiatives to begin which lead to other lean manufacturing changes and new material (or other) system improvements. These steps then continue to cycle.

Rightsizing

One specific new initiative that has received much attention because of the new MDS is "rightsizing". Rightsizing refers to reducing the standard pack size in which material is shipped from the supplier to the plant. For example, a large box moveable only by forktruck may contain 1000 pieces. After rightsizing, the supplier may ship that same part in small hand deliverable boxes containing 50 pieces each. These types of changes are all in alignment with the goals of a JIT system.

Manpower Changes

The MDS will provide an increase in the capacity and flexibility of small carton delivery. Thus as the rightsizing effort continues, more material will begin arriving in smaller hand held packages. Material personnel manpower loading will shift and work will move from bulk fork truck delivery to small carton hand delivery. Figure 12 below shows the initial increase in manpower during the project startup and then the reduction as the rightsizing initiative continues. It is important to note, as figure 12 shows, that in the long term, the manpower requirements in a new MDS can remain constant or even decrease in some cases.

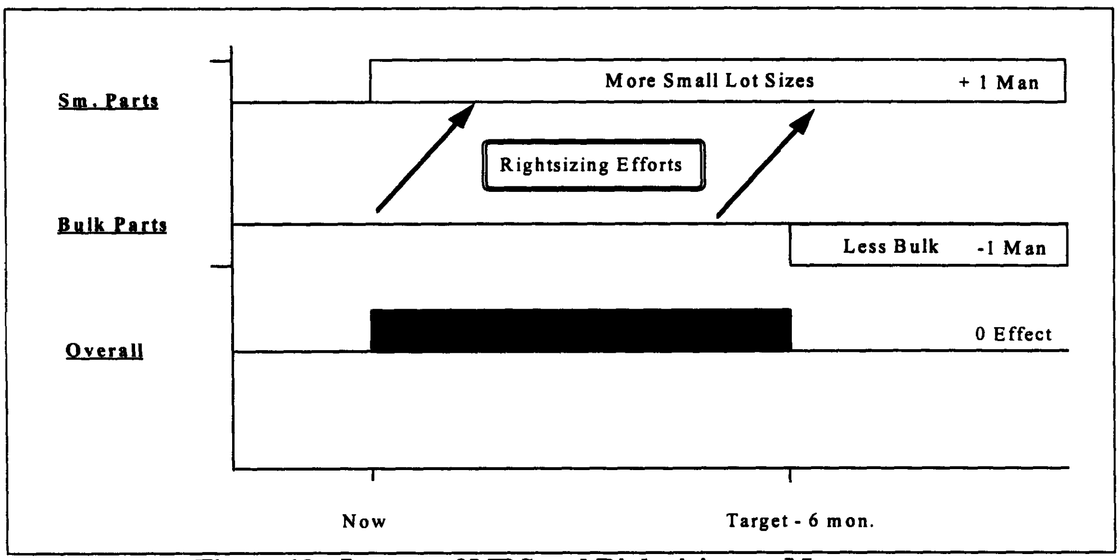

Figure 12 - Impact of MDS and Rightsizing on Manpower.

Beneficial Impact

There were numerous beneficial results of the new MDS. The major items are outlined below.

1. <u>Reduction of inventory - $28,000</u>: By implementing the MDS, I was able to reduce the amount of material inventory that was held in the cab shop. The $28,000 represents the inventory value of the small part material that was eliminated, exclusive of interest savings. It was simply a before and after calculation based on the value of the material eliminated. This

figure will continue to grow as further amounts of small part material are removed. In addition, substantial gains will be made when the levels of bulk material begin to decline, as the per part cost on average is much higher for bulk parts then small parts.

2. Increased floor space - $80,000: This figure is based on the number of small parts boxes that were removed from the cab shop. A value of $90/sqft was used as an approximation since the plant financial department uses this value for the comparable sqft cost of a new building. It is important to recognize that this savings is not an immediate bottom line dollar savings, but rather an opportunity for savings if the new found floor space allows the plant to avoid construction expenditures for needed space in the future.

Floor space reduction is also an important goal for the plant as a whole. There are plans for substantial changes to the cab shop assembly equipment for an upcoming model change. Removing excess material will provide some much needed floor space for the installation of the new equipment.

3. Increased Productivity - $30,000/yr.: The MDS has improved the efficiency for both the production operators and the material delivery persons. Early in the project, I watched a material delivery man take on average 30 minutes to count inventory levels for 15 parts. With the new layout of the supermarket, this task now takes on average 5 minutes. This results in a tremendous time savings and translates into the dollar savings noted above (when using the total hourly cost to the company for a delivery person)

In addition, there is also a savings due to the reduction of non value added work (excess walking, counting, and bending) for both the delivery person and the production operator. A conservative estimate for the increased productivity is 20%.

4. Reduction in lost jobs - $140,000: In the course of a typical production year there are many "lost jobs." A lost job is a vehicle that does not progress routinely through the production

process of the body shop. In many cases the vehicle must be taken out of the production sequence, reworked or repaired, and then reinserted back into the production flow. In other cases, it must be completely scraped. Lost jobs can occur when incorrect or damaged parts are delivered to an operation or are simply not delivered in time.

For every vehicle that does not leave the cab shop, the plant loses an estimated $7,000. It is important to note that this savings is based on variable cost savings and not on opportunity cost savings because unless the plant is at capacity, the opportunity for the sale of the vehicle is not lost. Thus, included in the $7,000 is the wasted material that has already been installed onto the scraped vehicle as well as labor costs. While it is possible to view labor costs in this setting as fixed, for the purposes of this analysis it was considered variable and part of the savings associated with "lost jobs". With the new MDS, it is anticipated that there will be a reduction of at least 20 lost jobs every year.

5. Improved efficiencies/organization - $??: While this bullet describes some of the most important benefits of the MDS, the impact is the most difficult to quantify. The flow of material in the cab shop has been dramatically improved. The material supervisors now have much more accurate information on their inventories and greater control with which to manage these inventories. Also, because of the reduced variation in the delivery system and the improved visual controls, it is much easier for a new person to fill in if one of the regular drivers is out.

Tremendous changes have been made for all the operators involved in the system. The production operators no longer have to bend down to pick up 40+ pound boxes. All material is delivered to them ready to use. The material delivery persons no longer have to get on and off their delivery carts to use fork trucks. They can now retrieve all of their material from roller rack shelves that are roughly waist high. Their responsibilities have been refined and much of the waste from the old system (searching for parts, double handling, emergency calls for parts) has been eliminated.

Finally, very obvious changes have taken place in the plant. The operator stations have been made safer, more organized, ergonomically friendly, and cleaner. The layout of the supermarket is now extremely efficient, organized, and clean. Everyone in the cab shop has seen that management has taken the necessary steps to make improvements. The production and material operators especially, now see the way a well run system functions. They like the new system and have begun to take pride and ownership in its daily operation and maintenance. Furthermore, there has been a noticeable positive change in the attitude of everyone involved in the project, which can only have a positive impact overall.

Chapter 3. Conclusions and Recommendations

Conclusions

1. The formation of strong relationships can be one of the most powerful tools in achieving successful change. Most individuals are very resistant to change. Therefore it is important to take the time to form solid working relationships. Then, through patient but persist effort and reinforcement, the idea of change can be introduced.
2. An organization can increase productivity and efficiency by focusing on the overall philosophy that "there must be a plan for every part". By understanding how every part will be handled and defining were every part will be stored, wasteful non value added work can be eliminated.
3. A manufacturer can reduce its inventory holding costs in part by improving the logistics of how its suppliers provide material, specifically by moving to daily shipments for daily needs where possible.
4. While it is difficult to ignite a movement for change in an organization, the change agent must recognize the importance of early tangible benefits. Once people can see and understand the positive results associated with a change, support and acceptance for the movement becomes contagious and spreads more quickly.
5. In order for an organization to effectively implement a change, it must respectfully seek out the suggestions and inputs from all parties involved at all levels. People have many unique ideas, like to be asked to think, and want to contribute; they just need to be asked.

6. Successful implementation of a MDS requires a detailed and well thought out plan complete with contingencies for the inevitable unknowns. All involved parties must have input to the plan and clearly understand their responsibilities and the expected results.

Recommendations

The following are recommendations that will enable an organization to develop a system as outlined in this paper as well as to improve its effectiveness.

1. The organization must improve its communication. All issues and concerns must be dealt with as early as possible to avoid future delays and additional costs. This could be addressed with a more frequent and mandatory meeting schedule and/or an electronic linkup such as Lotus Notes or simply e-mail.
2. The commitment from upper management must be more vocal and be present earlier in the project to speed up the overall process. This could be accomplished by "Kick Off" meeting called by the plant manager and more frequent status reports or presentations.
3. The client leading the project must have adequate authority to make decisions and enforce them. Thus, the leader should be an individual who is respected, someone with legitimate power as well as referent power. This will help to speed up decision making and shorten the overall project duration.
4. The trigger mechanism could be improved by using an electronic trigger rather than a paper pull card. For example, a bar code reader could be used by the operators to indicate when more material is needed. Then material drivers could simply receive a printout of needed material just as they entered the supermarket to begin a cycle. An electronic trigger would eliminate the possibility of lost

cards, reduce variation, and improve the timing of the delivery signals to the supermarket. This change would lead to an approximate 10% further increase in productivity and efficiency for the material delivery persons.

5. Once the system is functioning properly for a time period in the cab shop, the same concepts for small parts should be expanded to large (bulk) parts and to other areas of the same plant and to other plants. If inventory level in the cab shop was reduced to one day (approximately $520,000), the holding cost savings (see Figure 9) would be on the order of $500,000 and floor space, lost jobs, and productivity impacts would approach $250,000. Finally, recognizing that less than roughly 25% (by dollar value) of all the material flowing through the plant in a given day flows through the cab shop, the potential savings for the rest of the plant, not to mention other plants, is quite notable.
6. The pull system can be expanded one step further up the supply chain to the supplier. When material is removed from the supermarket, an electronic signal could automatically be issued to the supplier for a shipment of replenishment material, thus allowing the plant to hold less inventory. The ideal system would implement the pull system trigger throughout the supply chain. Since roughly $6 million worth of material passes through the plant each day, even a half day's reduction of inventory is significant. Thus, the overall system efficiency and benefit gains are limited by the extent to which the pull system covers the entire supply chain.
7. Relations must be improved with the suppliers. The plant and the suppliers must understand the difficulties and needs of each other and then work together to improve the current system rather than shifting problems onto the other or

pointing fingers. Possible changes include increasing supplier interaction and information sharing to promote commitment and trust. Unless this relation is improved, the benefits of the project described in this paper will be limited.

8. As the system is implemented in other areas, the overall process should be documented. This will allow others to learn from past experiences and pass on ideas to the next team.
9. People must improve the way they interact with each other - focusing on communication, trust, and respect.

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