LEVELING THE WORKLOAD
AT THE INTERFACE BETWEEN
INTERNAL AND EXTERNAL
SUPPLY CHAINS

By
TRENT M. GUERRERO

Bachelor of Science in Electrical Engineering
University of Texas (1988)

Masters of International Management
University of Maryland (1996)

Submitted To The Sloan School Of Management and the Department Of Electrical Engineering And Computer Science in partial fulfillment of the requirements for the degrees of

M.B.A. Masters of Science in Management and
Masters of Science in Electrical Engineering and Computer Science

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Signature of Author

Sloan School of Management
Department Of Electrical Engineering And Computer Science
April 8, 2001

Certified By
Don Rosenfield
Senior Lecturer
Thesis Supervisor

Certified By
Stanley Gershwin
Senior Research Scientist
Thesis Supervisor

Accepted By
Margaret Andrews
Director of Master's Program
Sloan School of Management

Accepted By
Arthur C. Smith
Chairman, Committee on Graduate Students
Department of Electrical Engineering And Computer Science
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ABSTRACT

In 1994, Ford's European vehicle assembly operations began implementing lean production techniques under the auspices of the Ford Production System. The Ford Production System includes an initiative called Synchronous Material Flow.

The charter of Synchronous Material Flow is to devise a level process for material receipt and handling. Both external (from component suppliers to Ford's receiving docks) and internal (from receiving dock to marketplace, and from marketplace to point of fit) supply chains are involved.

This thesis focuses on potential throughput increases, workforce flexibility improvements, and cost savings made possible by a leveled material flow. Revised scheduling procedures, material handling processes, and marketplace configurations are proposed. The impact of these revisions on scheduling of inbound material shipments, and material handling resources, both personnel and machinery, is evaluated.

This project was designed to enable a level workload at the interface between external and internal supply chains. The most obvious manifestation of this interface is the assembly plant's receiving docks, where external logistics and internal logistics must mesh seamlessly to enable a smooth, timely flow of material.

Management Thesis Advisor:
Stanley B. Gershwin, Senior Research Scientist, Department of Mechanical Engineering

Engineering Thesis Advisor:
Donald B. Rosenfield, Senior Lecturer, Sloan School of Management
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Chapter 1-INTRODUCTION AND OVERVIEW

1.1 Statement of Problem

The past decade has brought substantial consolidation to the automobile manufacturing industry. As this trend continues, a shrinking number of manufacturers are struggling to grow, or at least retain, market share in a fiercely competitive industry. Even those auto manufacturers currently doing well are feeling the effects of intensifying competitive pressure.

In the past decade, Ford has suffered substantial erosion of its European market share. In the first eight months of 2000, Ford ranked fifth among automakers in terms of market share in the top five European markets, with 10.7% of the market. Volkswagen, PSA, General Motors, and Renault held the top four positions, in that order. Including Fiat, the sixth largest manufacturer, these few firms control a combined 74.2% of the market [Ford Motor Company (2000a)].

![Figure 1-1 European Market Share by Manufacturer](Image)
Manufacturing a modern automobile is a difficult task. Cars have become more complex as features like turbocharging, air conditioning, automatic transmission, cruise control, and improved passenger amenities are designed into modern vehicles. Managing the supply chain for the thousands of components comprising a modern vehicle is a major challenge.

The difficulty of supply chain management is exacerbated by a large number of different model configurations. The two models manufactured in Niehl, Fiesta and Puma, include five different engines: four gasoline and one diesel. Right- or left-side drive, sunroofs, air conditioning, number of doors, cruise control, paint color and type, and interior configuration are all variable features. The multitude of different possible configurations and the inherent complexity of modern vehicles demand that the supply chain at Niehl be capable of managing nearly 4000 different parts.

The logistics challenges associated with qualifying, purchasing, shipping, receiving, handling, storing, and assembling these thousands of different parts is daunting. A logistics management system must be capable of meeting current requirements. It must also be sufficiently flexible to accommodate substantial changes as new models and options are introduced and as consumer demand for various options fluctuates. The compelling need to minimize inventory levels and the resources dedicated to material processing add to the challenge of logistics management.

1.2 Project Description

Ford’s logistics organizational structure includes a director of material planning and logistics, a global logistics manager, and managers of both inbound and outbound logistics. A simplified diagram of this organizational structure is shown in Figure 1-2.
This project includes an analysis of the logistics systems in use at Ford's vehicle assembly facility in Niehl. Ford's operations in Valencia, Genk, and Saarlouis were also examined. The goal of this project is to evaluate material receiving activities and to develop recommendations on how to level the receiving process. A leveled process is one in which the flow of material is balanced from hour to hour, shift to shift, and day to day while supporting production objectives. Perhaps as important is the need to balance the workload associated with that flow of material. Workload is not a simple function of either the number of incoming shipments or the cubic volume of incoming material. Factors such as load complexity, packaging type, and distance from receiving dock to marketplace location(s) must also be considered. (A marketplace is a permanent storage location where inventory is temporarily stored. Inventory in a marketplace serves as a buffer between the downstream assembly processes that consume it and the upstream logistics processes that replenish it.)

Project deliverables include a pilot proposal that can be implemented at one or more of Ford's sites in Niehl, Saarlouis, and Valencia. The proposal is consistent with Ford's efforts to implement a "lean" supply pipeline and is expected to generate savings in terms of total cost.
The bulk of this internship was spent at Ford's assembly operations in Niehl. Several visits were made to other Ford sites, however, including those at Valencia, Saarlouis, and Genk. Although the majority of the specific analysis performed in the conduct of this internship applies most directly to operations at Niehl, the overall approach, learnings, and recommendations are broadly applicable to other assembly sites.

The goals and objectives for this internship were initially quite broad. The first portion of the internship period was spent developing contacts with individuals responsible for Ford's supply chain, and to observing and documenting the processes in use. After those processes were well understood, a meeting with the Material Planning and Logistics (MP&L) manager was conducted to further refine the project objectives and scope.

Ultimately, the scope of the project was defined as “the interface between external and internal supply chains.” The external supply chain includes all activities outside Ford’s facilities, including purchasing, manufacture of components, packaging, and shipping. The internal supply chain refers to processes that occur once material arrives on-site, including receipt, unloading, storage, and transport inside the assembly hall.

Project boundaries were established to include scheduling of incoming material shipments, receipt and processing of those shipments at the receiving dock(s), and movement of material from the receiving dock(s) to storage locations in the various marketplaces. Although project efforts focused on these activities, the impact of proposed changes on up- and down-stream processes, such as line feeding activities, remained a consideration.
A thorough current state analysis identified several key issues limiting logistics performance at Niehl. Revised processes for receipt, unloading, transport, and storage of material were developed to address these issues. The revised processes enable a lean, leveled supply chain, the overall goal of Ford’s Synchronous Material Flow initiative.

1.3 Approach and Methodology

The portion of the supply chain “inside” the project boundaries can be separated into three distinct segments. The first segment, scheduling of incoming material shipments, is the direct connection between external and internal supply chains. Scheduling and route design activities in Niehl are performed with the assistance of Ford’s lead logistics partner (LLP), TNT Logistics. Through extensive interaction with the Ford/TNT logistics team a clear understanding of the scheduling and route design processes was developed.

The second supply chain segment comprises "receiving activities." This segment encompasses all activities performed by Ford personnel between arrival of incoming shipments on site and the complete unloading of incoming conveyances.

The third supply chain segment involves movement of incoming material from the receiving dock to its storage locations in the assembly hall. Included in this segment is the physical location and configuration of those storage locations and the procedures used to place material in them.
This project includes an analysis of the three supply chain segments and the interactions between them. Empirical data captured on information systems at the receiving dock was combined with direct observation and measurement. Interviews were conducted with numerous salaried and hourly personnel engaged in logistics-related tasks, including MP&L managers and machinery operators.

Significant interaction exists among the various segments of this project. The interdependence of activities performed in these segments plays a critical role in overall performance of the larger supply chain. The line feeding activity is immediately "downstream" of the supply chain activities studied.
Line feeding involves transport of components from storage locations to appropriate points of fit (POFs) on the production line, where they are fitted onto vehicles being assembled. The close interdependence of various supply chain activities mandates that any change to one portion of the process take into account the effects of that change on all other portions.

1.4 Performance Metrics

A number of metrics can be used to evaluate the performance of the overall supply chain. These metrics include cube utilization (the ratio of cargo space used to available cargo space) of incoming trucks, overall freight costs, premium freight costs, demurrage fees, number and duration of assembly line stoppages due to material issues, unloading and turnaround time for incoming material shipments, and resources required at the loading dock (both personnel and machinery). More difficult to quantify metrics include robustness and repeatability of the receiving and material handling processes, the ability of those processes to accommodate and quickly adapt to changes in operations, and the throughput capability for a given level of resources.

The extant level of performance, as measured by current metrics, is documented wherever possible. The theoretical maximum performance achievable with the revised processes developed in this project is also included. Unfortunately, the absence of data reflecting actual performance of the proposed processes prevents an “apples to apples” comparison with existing processes. However, the theoretical performance data should prove useful in estimating the resources necessary to support future logistics operations.
Development of modified receiving and material handling processes was conducted with the objective of crafting broadly applicable techniques and procedures. This was particularly important as the Niehl assembly facility was undergoing extensive refurbishment and reconfiguration to support the launch of a new vehicle. Many of the attributes of current operations will be substantially modified when production of the new vehicle begins. Thus, a solution that improves current operations but is not viable in the new logistics environment will provide at best a short-term benefit.
Chapter 2- BACKGROUND

2.1 Ford Motor Company Overview

Ford Motor Company is among the world's largest manufacturers of cars and trucks. In 1999, Ford produced over 7.2 million cars and trucks worldwide. Net income from all activities was $7.24 billion [Ford Motor Company (1999a)].

In Europe, Ford operates a number of production facilities, including those at Dagenham, U.K.; Genk, Belgium; Valencia, Spain; and in Germany at Saarlouis and Niehl [Ford Motor Company (1999b)]. These facilities vary in size and degree of integration. The typical manufacturing site, however, is large, complex, and expensive. A high degree of vertical integration is evident at many of these facilities, where engines, transmissions, and auto bodies are manufactured and those components are assembled into completed vehicles.

Ford has been an active participant in the automobile industry’s accelerating consolidation. The “Ford Family” of nameplates now includes Volvo, Mazda, Lincoln, Mercury, Jaguar, Aston-Martin, and Land Rover.

Ford has also been an active participant in another industry-wide trend: the effort to gain competitive advantage through implementation of lean production techniques. In this context, “lean” is commonly understood to mean “a way to do more and more with less and less” [Womack and Jones (1996)]. Ford's efforts to implement lean production techniques are evident at several of the assembly facilities visited in the course of this project, most notably at Saarlouis and Valencia.
2.2 Operations at Niehl, Germany

Ford operates a large facility at Niehl, Germany. The site, located a few miles north of Cologne, is adjacent to the Rhine River. It is serviced by both train and truck logistics support. The Niehl site is Ford's European headquarters and includes extensive manufacturing operations. Engineering, executive, and administrative activities are all located there, along with an engine plant, transmission plant, body stamping plant, and assembly operations. Roughly 7500 personnel are employed in the body and assembly plants in Niehl, which began operation in 1930. In 1998, 269,370 vehicles were assembled at the site [Ford Motor Company (1999b)].

In Niehl, Ford assembles two vehicles: Fiesta and Puma. Both of these vehicles are sold into the European market. In late 2000, Niehl's assembly operations were producing roughly 1100 cars per day, of which approximately 150 were Pumas. Assembly operations are conducted on two shifts: a first shift running from 0630 to 1430, and a second shift from 1430 to 2230. Each eight-hour shift includes a thirty-minute lunch period and a fifteen-minute break. Thus, there is a total of 14.5 hours' production time in each day's assembly operations. The plant operates Monday through Friday.

The vehicle assembly hall, or Y-Hall, is a very large building occupying nearly one million square feet. It is serviced by three receiving docks. Of the three docks, the south dock is by far the largest and processes the majority of material shipments. Unpainted auto bodies enter the assembly hall via overhead conveyor from the adjacent body shop, and are painted in the centrally located paint shop.

In late 2000, much of Y-Hall was being refurbished. A large portion of the building had been unused for several years following the termination of the Scorpio model. This section was being refurbished and equipped with production lines to support a new vehicle. Preparations for the new vehicle had a
substantial impact on this project. Readying the factory for new equipment installation imposed constraints and demands upon the MP&L organization. As a result, it was not possible to establish a marketplace configured for implementation of modified material handling processes.

2.3 The Ford Production System (FPS)

Intensifying competition among automobile manufacturers has led to a number of initiatives designed to bolster Ford's competitiveness. One such initiative is Ford's adaptation of the Toyota Production System. This system, called the Ford Production System (FPS), was begun in 1994. The FPS program mission statement is:

"We will teach, engage and inspire people and organizations across Ford Motor Company to understand and apply lean behaviors, principles and methods—that continuously improve safety, quality, speed and total cost—and deliver consumer value."

The FPS vision is:

"To have a lean, flexible and disciplined common production system that is defined by a set of principles and processes that employs groups of capable and empowered people who are learning and working safely together to produce and deliver products that consistently exceed customers' expectations in quality, cost and time."

Five principles comprise the rules and code of conduct under the FPS system. Those principles are:

- Effective Work Groups
- Zero Waste/Zero Defects
- Aligning Capacity with Market Demand
- Optimizing Production Throughput
- Using Total Cost to Drive Performance [Ford Motor Company (2000c)]
Ford has employed a staggered schedule in implementing FPS. As a result, Ford’s production facilities, all of which have begun implementing FPS, are at different stages in their respective implementations. In Niehl, implementation of FPS is still ongoing. Some of the assembly line operations, including a door assembly line, are now using FPS production techniques such as team-based work.

Among the FPS initiatives is Synchronous Material Flow (SMF). SMF embodies the attributes of a lean logistics system and is intended for broad implementation—at all of Ford’s manufacturing plants. The charter for SMF lists two major goals:

- Develop a process to deliver material from suppliers’ dock to point of use at the total lowest costs
- Develop a common end item leveled scheduling process [Ford Motor Company (1999c)].

The FPS and SMF initiatives have been recognized throughout the industry. *Sloan Management Review* credits the FPS system with aggressively moving toward frequent, small-lot deliveries [Liker & Yu (2000)].

FPS and SMF are germane to this project. These company-wide initiatives shape the processes Ford uses to produce vehicles. Thus, the techniques and processes designed in the course of this project were developed in accordance with FPS and SMF principles.

### 2.4 New Vehicle Launch Preparations

Ford segments its passenger vehicle offerings into three classes: B, C, and D. These class divisions are not based upon any specific metric, like wheelbase or gross vehicle weight rating (GVWR), but, rather,
are made on the basis of general vehicle size, with "B" class vehicles being the smallest, and "D" class vehicles the largest. To put these classes into perspective consider Ford's current European car offerings, shown in Figure 2-1.

<table>
<thead>
<tr>
<th>CLASS</th>
<th>VEHICLE</th>
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<tr>
<td>B</td>
<td>Ka, Fiesta, Puma</td>
</tr>
<tr>
<td>C</td>
<td>Focus, Mondeo</td>
</tr>
<tr>
<td>D</td>
<td>Mondeo</td>
</tr>
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</table>

*Figure 2-1 Ford Vehicles and Their Classifications*

Mondeo is considered a C/D class vehicle. The Ka, while listed with the other "B" class offerings, is sometimes considered a "sub-B" platform.

The two vehicles produced in Niehl at the time of this project, Fiesta and Puma, are both "B" class vehicles. The Fiesta was originally launched in 1976. More than nine million Fiestas have been sold in over fifty different countries [Ford Motor Company (2000d)]. Although the Fiesta has undergone several revisions, including a facelift in 1999, Ford recognizes the need for a newer B-car offering.

The new B-car is scheduled for launch in November 2001. It will be produced at several of Ford's European manufacturing facilities, including Niehl. Production of the new B-car at Niehl requires substantial reconfiguration of the assembly plant there.

Much of the space in Y-Hall ultimately destined for production of the new B-car was being used as a parts marketplace when this project began. Preparations for the new B-car included tearing up
and repouring the concrete flooring in this area. As a result, entire marketplaces had to be relocated to other portions of the assembly hall.

Preparations for the new B-car launch at Niehl, although disruptive of current production, were seen as both a challenge and an opportunity to effect Ford's first "ground up" implementation of FPS and SMF initiatives. Achieving the lean manufacturing principles of FPS and SMF will depend critically on the efficient transport and delivery of parts [Liker & Yu (2000)].

Fortunately, launch of a new model build is the most convenient time to incorporate new operating and manufacturing processes such as the use of optimally-sized packages in a reusable container program [Witt (2000)]. The new B-car will be the first Ford vehicle produced in Europe for which all supply chain and assembly operations were constructed in accordance with these initiatives.
Chapter 3-THE MATERIAL RECEIVING PROCESS

3.1 Material Planning and Logistics Organization

Ford's organization in Niehl includes a group tasked with Material Planning and Logistics. The (German) acronym for this group is "FNL." Figure 3-1 illustrates the structure of the FNL organization.

![Diagram of FNL Organizational Structure at Niehl]

FNL-5, Industry Park and External Logistics, is a relatively new portion of the organization. An industry park is a facility, adjacent to but outside the boundary of a production site. Industry parks enable components suppliers to co-locate their receiving, shipping, and subassembly facilities with the assembly site they support. Industry parks are becoming commonplace in the automotive industry. "Automotive Manufacture and Production" recently termed Ford's implementation of industry parks at plants in Genk, Saarlouis, and Valencia a "full-blown strategy" [Sabatini (2000)].

At the time this project was conducted, Ford's facility in Niehl did not include an industrial park. However, concurrent with the on-site preparations for the new B-car launch, plans were underway for the construction of an industrial park.
Establishment of this park will have an enormous impact on plant logistics. At the Valencia assembly plant, for example, roughly 50% of the volume of incoming material originates at the industrial park. Much of this material is delivered via conveyor directly to the ultimate points of fit. Conveyor delivery greatly reduces the workload associated with receipt and internal transport of material, and completely eliminates the need to temporarily store that material in marketplaces within the assembly hall. Even assembly plants with nearby suppliers benefit from industry parks since those parks reduce the internal logistics workload via delivery directly to the points of fit.

This project, with its focus upon scheduling, receiving, material handling, and material storage, was primarily conducted under the auspices of FNL-4, the structure of which is indicated in Figure 3-2. FNL-4 is tasked with the logistics processes that most closely support ongoing assembly operations. While other portions of the FNL organization address future operations, including the establishment of an industry park, FNL-4 focuses primarily on supporting ongoing assembly operations.

![Figure 3-2 Organizational Structure of FNL-4]

3.2 Scale, Scope, and Performance of Process

Material receiving and logistics operations comprise an essential part of Ford's vehicle assembly process. These operations involve scheduling, receiving, transporting, storing, and inventorying an enormous amount of material. In order to assemble the 1100 cars per day produced at Niehl during...
this project, roughly one hundred inbound deliveries comprising several thousand unique parts and approximately 4500 cubic meters were processed at the assembly hall each production day. Production stoppages can result if the logistics system fails to make available to the hundreds of points of use these thousands of parts, at the right time, in the right quantity. The cost of unplanned production stoppage due to part(s) unavailability is sometimes called penalty cost [Nahmias (1997)]. In the high fixed-cost environment of automobile assembly, penalty costs are very large. The high cost of a parts stock-out on the assembly line places a premium on a stable, repeatable, transparent supply chain design capable of consistently providing the necessary parts to the proper assembly line stations.

Ford's widely distributed supplier base adds greatly to the difficulty and complexity of designing and scheduling incoming material shipments. Over 300 different component suppliers provide material in support of Ford's assembly operations at Niehl. These suppliers are located in nearly two dozen different countries on five different continents. Lead times and variability of lead times for these many different suppliers span a wide range.

Incoming shipments vary greatly in terms of complexity, which exacerbates the already complex logistics operation. Some shipments are relatively simple, made up of only a dozen or so different parts packaged in identical, large containers. Other shipments, however, such as those delivered from one of ten depot centers located throughout Germany, can be very complex, with literally hundreds of different parts and dozens of different package shapes and sizes. The work necessary to receive and process a given delivery varies greatly due in part to this broad range of complexity. Figure 3-3 shows an extremely “simple” full delivery, a trailer of seventy-eight large, reusable packages called FLCs.
Ford, and the automotive industry in general, is a strong proponent of such standardized, reusable packaging. According to a recent article in “Material Handling Management,” reusable containers, and in particular hand held reusable containers, are a key enabler to lean manufacturing in the automotive industry [Witt (2000)].

Receiving activities at Niehl are governed by a well-documented process specified in BP01_20, "Receiving of Assembly Parts." This document provides directions for individuals tasked with processing incoming material shipments. It specifies the flow of information and the sequence of actions to be taken in processing incoming shipments.

Several different metrics are used to evaluate the performance of receiving activities at Niehl. Among those metrics are: freight cost, premium freight cost, demurrage fees, cube utilization of incoming conveyances, unloading and turnaround times for incoming shipments, and on-time arrival of
incoming shipments. Premium freight costs reflect the higher fees paid to carriers for transporting material on a "rush" basis.

Not measured directly, but perhaps more important, are the following metrics: frequency and duration of line stoppages due to unavailability of parts, resources consumed in performance of receiving activities, and stability, repeatability, and robustness of material receiving processes. In the year following completion of this project, materials handling operations at Niehl will change greatly. Launch of the new B-car, establishment of an industrial park, and implementation of Ford's SMF initiative will substantially alter the workload and the processes now in use.

SMF techniques have already been implemented at Niehl for a subset of the components used on the assembly line. One of the goals of SMF is to maximize the percentage of parts delivered to the assembly line without the use of forklifts or other heavy equipment. Parts delivered by hand are designated “card” parts, while those that require heavy equipment are “call” parts [Ford Motor Company (1999c)].

“Card” parts at Niehl are handled using a kanban system. This system, known as the SMART system, has a dedicated marketplace and operates alongside, but largely independently of, the system for handling call parts. This project, particularly the portions concerning marketplace configuration, deals primarily with call parts.

Full implementation of the SMF vision will require Ford to greatly increase delivery frequency from many of its suppliers. The overall vision calls for deliveries of most parts twice per shift, or six times per day (Ford is planning for three shifts per day operation following launch of the new B-car). This represents an enormous departure from operations today, in which the vast majority of parts are
delivered at most once per day. Raising delivery frequencies will likely result either in smaller 
individual shipments or in shipments of greater complexity if a cross-docking center is established. A 
cross-docking center would consolidate several small deliveries into one larger delivery of greater 
complexity. In either case, a greater need for efficient processing of incoming shipments will result.

Ford expects to achieve substantial reduction in parts inventories as a result of SMF implementation. 
While reducing inventory frees capital otherwise tied up in stocks of parts on hand, it also results in 
greater operational risk, as it results in a smaller safety stock of parts.

Perhaps the most obvious metrics with which to evaluate the performance of receiving, material 
handling, and storage operations are unloading time and turnaround time. Unloading time is the period 
between when a vehicle is classified as "arrived at the dock" and as "unloaded." Turnaround time is 
the duration between the scheduled arrival time (time window) of the vehicle and classification of that 
vehicle as "unloaded."

A vehicle is classified as "unloaded" when all material has been removed from it and the driver of the 
vehicle is free to depart the receiving dock. Ford's SMF initiative has established a goal of no more 
than thirty minutes for unloading time. Ideally, turnaround time and unloading time will be identical. 
(In order for this to be so, the vehicle must arrive at the site early enough to reach the receiving dock 
on schedule, and the facilities at the receiving dock must be capable of processing that vehicle when it 
arrives.)

Analysis of actual material receiving performance indicates that substantial improvement must be 
realized in order to reach the target average unloading time of thirty minutes. Average unloading time 
has remained relatively constant between fifty-five and sixty-five minutes. Further, there has been a
consistent offset of at least thirty minutes between unloading and turnaround time. Part of this offset is due to the late arrival of vehicles, and part to delays in processing newly arrived shipments. Appendix 1 contains several months' performance results.

3.3 Lead Logistics Partner and Processes

In Niehl, as at all of its European assembly facilities, Ford employs a lead logistics partner, or LLP, tasked with the following:

- Design and implement an optimized route network
- Manage exceptions
- Manage carriers
- Shipment tracking and tracing (ETA's)
- Provide contingency planning
- Process and monitor releases
- Manage parts follow-up
- Continuous improvement
- Validating advance shipping notices (ASNs)
- Monitor and report key process measurables [Ford Motor Company (2000e)]

At the time this project was conducted, the LLP in Niehl was a firm called TNT. However, during the course of the project, Ford announced that two other firms, UPS and Exel, working as a partnership, would be Ford's European LLP of the future. The transition from TNT to the new LLP organization was in progress during the last several months of this project. The new LLP organization assumed responsibilities beginning in early 2001.

This project's focus on the interface between external and internal logistics led to extensive interaction with LLP personnel and their Ford counterparts. The LLP-designed processes for route planning and carrier management are summarized in the following paragraphs.
Ford's supplier base for assembly operations at Niehl is very dispersed. Figure 3-4 illustrates the dispersion of European suppliers supporting Niehl.

In order to manage incoming shipments TNT has designed routes. Each route corresponds to specific supplier(s), carrier(s), and part numbers. The tools used by TNT to coordinate these routes include the Direct Call In (DCI), the Trip Sheet, and the Pickup Sheet. Each of these documents is described below.

An example of each of these documents is included as Appendix 2.

The DCI informs components suppliers of the number of units of each part that Ford will require each day over the next two weeks. Thus, suppliers are provided two weeks' advance notice of Ford's requirements.
For many parts, demand is "lumpy"—that is, it varies significantly from day to day. Much of this variability is due to the packaging used by Ford and its suppliers. Ford has placed in service a wide
variety of standardized, reusable shipping containers. In many cases, each standardized container constitutes more than a full day’s production requirement for the part it contains. The example DCI shown in Figure 3-5 illustrates this point.

The demand for the first part listed in Figure 3-5, part number 90FB B04100 ACYRA5, “toggles” from 480 to zero to 960 units. The “lumpiness” of this demand is primarily driven by the large package size used. For the ten (production) days included on the DCI, an average of 288 parts per day are required. Use of a smaller package size would facilitate a far smoother flow of material.

Ford’s standardized packaging offers the advantages of reusability, stackability, and high cubic utilization of transport vehicles. However, these advantages must be balanced against the disadvantages of overly large packaging. Packaging which places an entire day’s production requirement (or more) in a single container is inimical to a lean, synchronous, leveled logistics pipeline. Pictures of Ford’s standardized reusable shipping containers are included as Appendix 3.

Appendix 2.2, Trip Sheet, is the LLP document used to communicate instructions to the various carriers that service Niehl’s operations. The example trip sheet in Appendix 2 directs the carrier, Hamann International, to pick up components at four different locations. The fourth location, listed
as "Depot Irun," is one of Ford's ten depot facilities in Germany. At Depot Irun, on this particular
day, the carrier will be picking up material from five different suppliers. That material had been
aggregated at the depot by a "milk run" route in which one vehicle traveled from supplier to supplier
collecting the material requested from each by the effective DCI. Milk runs are an effective technique
used to ameliorate the effects of distant suppliers [Liker & Yu (2000)].

Each trip sheet contains further information and instructions for the carrier including an arrival time at
each supplier, the number of containers to be loaded at each location, and the weight and cubic
volume of all containers to be collected and delivered to Ford. Further, the trip sheet includes the date
and time window when that shipment is expected to arrive at Niehl, contact information for Ford
personnel, the building and unloading dock (Y-Hall South, or Sud, Dock in this example), and the side
of the truck from which unloading will be conducted (Right, or Derecha).

The LLP sends a daily Pickup Sheet (example included as Appendix 2.3) to each components supplier
that provides parts via an LLP-controlled route. Pickup sheets list all the parts that a supplier provides
Ford, along with the quantity of each part in that day's order. Also included are the date and time the
shipper will arrive to collect the ordered material, the truck orientation (loading aspect) and vehicle
type.

As the ordered material is loaded on the carrier's truck, the supplier's representative and the carrier's
driver verify that all material on the pickup sheet, and only that material, is being loaded. Both parties
then sign the pickup sheet, which was previously endorsed by an LLP representative. *Thus, the material
on each delivery vehicle has been verified and signed for by two separate parties (supplier and carrier) before it ever reaches*
the receiving dock at Niehl. Upon arrival of the vehicle at the receiving dock, the driver provides the trip sheet, associated pickup sheets, and other paperwork to Ford receiving personnel.

3.4 Scheduling Process

In 1998, in order to establish a more structured material receiving environment, the Niehl site implemented a time window scheduling process for incoming material shipments. Prior to implementation of this system, incoming deliveries (trucks) were simply directed to a large holding area from which they were "called in" to the receiving dock as facilities became available to unload them.

The time window process produced a far greater degree of predictability in the material receiving process. Knowing what time of day a particular shipment of material will arrive enables the plant to substantially reduce the amount of safety stock material held in inventory. Currently, a safety stock of no more than 0.9 day's production is held for most parts. Ford determines the size of its component safety stocks at a high level in the organizational hierarchy. While 0.9 day's stock is quite low given the widely dispersed supplier base at Niehl, a larger safety stock of selected parts is sometimes authorized to provide greater buffer inventory.

A more sophisticated treatment of inventory safety stock can be developed through application of the base stock model. This model identifies appropriate inventory levels based upon supplier lead time, variability of delivery time, service level, and variability in demand [Smith (1999)]. The widely dispersed supplier base utilized by Ford in Niehl complicates application of the base stock model. Although outside the bounds of this project, determination of appropriate safety stock levels warrants further investigation.
The time window system assigns incoming shipments a route number and a thirty-minute time window for unloading of that delivery. A status board located on the receiving dock and maintained by Ford personnel indicates the current and subsequent day’s scheduled deliveries. The status of each incoming shipment is tracked on this status board. Individual shipments are represented by laminated strips of paper on which the route number, carrier, and supplier names are printed.

The scheduling process is complicated by a number of constraints. For example, incoming shipments may be delivered to more than one location at the Ford site. One truck may bring material destined for both the assembly hall and the engine plant. The need to meet multiple time windows reduces scheduling flexibility. Further, a single late truck can negatively impact receiving schedules in multiple operations. Yet another constraint is imposed by the carriers themselves. Many carriers are reluctant to accept a time window other than one early in the morning, since early morning deliveries make available the truck for subsequent deliveries that day.
Chapter 4 - MATERIAL HANDLING AND STORAGE PROCESSES

4.1 Scale, Scope, and Performance of Processes

After an incoming shipment has arrived at the receiving dock and had its paperwork processed, the driver prepares his vehicle for unloading. This process can take a substantial amount of time, depending upon the configuration of the vehicle.

Figure 4-1 Y-Hall South Receiving Dock
Some vehicles require that the driver loosen numerous fasteners in order to "desheet," or open the protective curtain along the side of the trailer. Some vehicle designs also require the driver to remove (and, after unloading is completed, replace) wooden slats running the length of the trailer.

The assembly hall in Niehl processes approximately one hundred deliveries of inbound material each day. Of that number, roughly 80% are assigned time windows by the LLP. An additional five to ten deliveries are premium freight, and the remainder are routes not yet under LLP control. Deliveries are
processed through three receiving docks: South, East, and North. Approximately 4000 different parts are used, comprising a daily delivery volume of roughly 4500 cubic meters.

![Assembly Hall (Y-Hall) Receiving Docks](image)

For the purpose of this project, "Material Handling and Storage" is defined as the activities that take place after a delivery has arrived at the proper receiving dock. These activities include unloading of the material, confirmation that the ordered material has been delivered, and transport of that material to its proper storage locations.

Limited data are available to directly measure the performance of these processes. One metric that can be evaluated, however, is "unload time," which was defined in section 3.2 as "the period between when a vehicle is classified as 'arrived at the dock' and as 'unloaded.'" Less easily captured is a measure of the accuracy rate with which material is stored in its proper locations, adherence to a first-in-first-out (FIFO) inventory process, and the amount of time and effort expended in "searching" the receiving
dock and marketplaces for critically-needed parts that cannot be found in their assigned locations. In short, "robustness, stability, and repeatability" of the processes lack a simple evaluation metric.

The task of unloading, transporting, and storing incoming material is accomplished by MP&L members, each of whom is assigned to carry out a particular portion of the process. These individuals are NOT organized into teams. Instead, they perform their tasks largely independent of each other, with the sole exception that a “checker” typically works with each receiving dock forklift driver to assist in sorting incoming material according to its storage destinations.

In order to understand fully the performance of the system now in place, a representative data set was selected and analyzed. The data selected represents one production week’s worth of incoming shipments, from 5 June to 9 June 2000. Data from this period, Production Week 23, was then "groomed," a process which included correction and/or elimination of clearly erroneous data and exclusion of all shipments to locations other than the assembly hall south dock. This resulted in a data set of 240 entries, a small portion of which is shown in Figure 4-4.

<table>
<thead>
<tr>
<th>COUNT</th>
<th>TRAILER</th>
<th>CODE</th>
<th>CARRIER</th>
<th>DOCK</th>
<th>ARRIVED</th>
<th>UNLOADED</th>
<th>UNLD DUR</th>
<th>SLUPL</th>
<th>COMP</th>
<th>DAY ARR</th>
<th>DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>U963</td>
<td>C1TR</td>
<td></td>
<td>2</td>
<td>6:30:43</td>
<td>4:45:22</td>
<td>0:14:39</td>
<td>AJMA</td>
<td>AUTOCLIV</td>
<td>5/9/00</td>
<td>F</td>
</tr>
<tr>
<td>2</td>
<td>U963</td>
<td>C1TR</td>
<td></td>
<td>2</td>
<td>4:35:18</td>
<td>4:45:54</td>
<td>0:10:36</td>
<td>C56LA</td>
<td>AUTOCLIVGMBH</td>
<td>5/8/00</td>
<td>Th</td>
</tr>
<tr>
<td>3</td>
<td>B1443OR</td>
<td>VEND</td>
<td>VENDOR</td>
<td>2</td>
<td>4:21:49</td>
<td>4:46:08</td>
<td>0:25:19</td>
<td>CJ2A</td>
<td>CASTELLOSA</td>
<td>5/9/00</td>
<td>F</td>
</tr>
<tr>
<td>4</td>
<td>V4265R</td>
<td>DTV7</td>
<td>HAMANN</td>
<td>2</td>
<td>4:25:14</td>
<td>4:53:01</td>
<td>0:27:47</td>
<td>CMHSA</td>
<td>DR FRANZ SCHNEIDER SA</td>
<td>5/8/00</td>
<td>Th</td>
</tr>
<tr>
<td>5</td>
<td>K1250</td>
<td>U963</td>
<td>C1TR</td>
<td>2</td>
<td>4:28:17</td>
<td>4:54:39</td>
<td>0:26:22</td>
<td>DIY7A</td>
<td>AUTOCLIVGMBH</td>
<td>5/7/00</td>
<td>W</td>
</tr>
<tr>
<td>6</td>
<td>TUIV911</td>
<td>U963</td>
<td>C1TR</td>
<td>2</td>
<td>4:31:56</td>
<td>4:55:17</td>
<td>0:23:21</td>
<td>C84A</td>
<td>DICOMS HOHMANN GMBH</td>
<td>5/7/00</td>
<td>W</td>
</tr>
<tr>
<td>7</td>
<td>80360P4</td>
<td>DTV7</td>
<td>HAMANN</td>
<td>2</td>
<td>4:32:57</td>
<td>4:56:10</td>
<td>0:25:13</td>
<td>R3GA</td>
<td>SCTIRASA</td>
<td>5/7/00</td>
<td>W</td>
</tr>
<tr>
<td>8</td>
<td>MX555R</td>
<td>DTV7</td>
<td>HAMANN</td>
<td>2</td>
<td>4:24:23</td>
<td>4:56:50</td>
<td>0:32:27</td>
<td>CMHSA</td>
<td>DR FRANZ SCHNEIDER SA</td>
<td>5/7/00</td>
<td>W</td>
</tr>
<tr>
<td>9</td>
<td>MXL901</td>
<td>DTV7</td>
<td>HAMANN</td>
<td>2</td>
<td>4:22:17</td>
<td>4:56:52</td>
<td>0:34:35</td>
<td>CJ9MB</td>
<td>DALPHA METAL ESPANASA</td>
<td>5/6/00</td>
<td>F</td>
</tr>
<tr>
<td>10</td>
<td>V8256R</td>
<td>DTV7</td>
<td>HAMANN</td>
<td>2</td>
<td>4:21:53</td>
<td>4:57:48</td>
<td>0:35:55</td>
<td>CMHSA</td>
<td>DR FRANZ SCHNEIDER SA</td>
<td>5/6/00</td>
<td>Tu</td>
</tr>
<tr>
<td>11</td>
<td>BATN33</td>
<td>VOK2</td>
<td>ASTRA</td>
<td>2</td>
<td>4:34:07</td>
<td>4:58:00</td>
<td>0:23:53</td>
<td>SOMMA</td>
<td>CONTINENTAL AROSA</td>
<td>5/6/00</td>
<td>Tu</td>
</tr>
<tr>
<td>12</td>
<td>ACK288</td>
<td>U963</td>
<td>C1TR</td>
<td>2</td>
<td>4:38:02</td>
<td>5:02:36</td>
<td>0:24:34</td>
<td>BHUDA</td>
<td>EATON CONTROLS</td>
<td>5/9/00</td>
<td>F</td>
</tr>
</tbody>
</table>

Figure 4-4  Production Week 23 Data (partial)
Analysis of this data resulted in several key findings, the first of which, extreme variability of unloading performance, is illustrated in Figure 4-5. While mean unloading time is approximately fifty-five minutes, the standard deviation is thirty-six minutes. This is a critical issue. The standard deviation for unloading time is greater than the target maximum for that process. The huge variation in unloading performance makes nearly impossible the formulation of a delivery schedule that consistently levels the workload associated with processing incoming shipments.

When combined with a mean unload time of nearly twice the thirty minute goal, the variability of unloading performance results in only 27% of incoming shipments being processed within the allotted time. Actual system performance may be even worse than suggested by these numbers. "Unload time" measures only that amount of time between recognition of the truck's arrival at the receiving...
dock and completion of unloading. The process now in use frequently requires that material being unloaded be placed on the dock floor. Therefore, even after a particular delivery is classified as "unloaded," much or all of the material from that shipment is often simply sitting on the receiving dock floor. In short, "unloading time" does not reflect completion of the entire task of unloading, transporting, and properly storing incoming material.

Investigation of the surprisingly high variability in unloading performance revealed three primary culprits: "friction" from one delivery to its successors, the tremendous variance in complexity of incoming shipments, and the extreme fragmentation of marketplace locations. Each of these issues is addressed below.

"Friction" refers to the effect of one incoming shipment upon the shipment(s) that follow it. In Niehl, this effect is magnified by the design of facilities and processes in use. Ideally, each arriving shipment would "see" essentially the same initial state upon arrival at the receiving dock. The bay designated to receive that particular shipment would be cleared and ready for use. The following resources would be assigned to that shipment: one 3.5 ton forklift with driver, one tow motor with driver, and some number of trolleys configured into "trains." A checker would be standing by, ready to assist the forklift driver in verifying and sorting the material as it was unloaded.

In reality, there are often more trucks present at the south dock than can be processed at one time. The dock has bays for as many as seven trucks, in addition to rails for boxcar deliveries. With a maximum of three forklifts operating on the dock at any one time, it is impossible to unload more than three vehicles concurrently. Further, unstructured work processes allow individual receiving bay personnel to work in an uncoordinated fashion, and to begin processing a shipment while material
from the preceding shipment(s) remains piled on the receiving dock floor. These factors cause arriving shipments to "see" greatly different initial conditions.

Extensive observation of receiving dock operations indicates that often no empty trolleys are available on the dock while unloading is in progress. When this occurs, material being unloaded is simply placed on the receiving dock floor.

Figure 4-6 illustrates this situation. Unfortunately, the practice of placing material on the floor both obstructs movement of forklifts and tow carts on the dock and necessitates a second "touch" of each
of those packages by the forklift driver, essentially doubling his workload. This practice is expressly proscribed at Ford's Valencia facility.

Complexity, and the wide disparity in load-to-load complexity, is also a major contributor to variability in unloading performance. Generally, incoming shipments arriving at the receiving dock are one of three types:

- **Direct shipment**: From supplier to assembly hall
- **Milk run**: Truck loaded at several suppliers, then proceeds to assembly hall
- **Depot**: Material from multiple suppliers consolidated at depot. Truck is loaded at depot, then proceeds to assembly hall. (A depot pickup is sometimes incorporated into a milk run)

The amount of work necessary to process a particular incoming shipment varies with the composition of that shipment. In general, direct shipments contain a relatively small number of unique parts. These parts tend to be large, and are packed in standardized containers. Milk runs tend to be somewhat more complex, and shipments received from depots may contain literally hundreds of different types of parts, in many different package types.

Processing a complex shipment involves a great deal of effort. A checker is required to verify the presence and quantity of each unique part ordered, and to write on each package's label the marketplace destination for that package. In addition, unloading and transporting a shipment of small, palletized packages is more labor-intensive than is similar processing of larger containers like the FLCs shown in Appendix 3.1.

The amount of sorting that complex loads require further complicates processing of those loads. The internal logistics system is highly fragmented, with over twenty different distinct storage locations in
Fragmentation of storage locations has an enormous impact on the receiving dock, where material is sorted based upon its storage location. Several incoming deliveries, chosen for their relative simplicity, contained material bound for as many as ten different marketplaces!

General practice on the receiving dock involves staging empty trolley trains bound for individual marketplaces. As a result, a forklift unloading a truck in one bay may be forced to carry material to trolley trains staged near other bays on the receiving dock. This is no small matter on a receiving dock over 150 meters long—it places greater burden upon the forklift operators, results in excessive vehicular traffic along the length of the dock, and raises the likelihood of misprocessing.

To summarize: performance at the receiving dock does not meet expectations. Average unload time is nearly twice the thirty minute target, and variability of unload time is enormous—with a thirty-six minute standard deviation. The lack of structured teams, the extreme fragmentation of marketplace locations, the excessively large receiving area, and the wide complexity variation among incoming shipments all contribute to this performance shortfall.

4.2 Personnel, Equipment, and Facilities

Logistics operations at the Niehl site include a substantial number of workers and a large amount of machinery and other equipment. Like the upstream receiving operations, material handling and storage operations are conducted on two shifts per production day (Monday through Friday). Each shift is eight hours long and includes 7.25 hours of actual production. First shift runs from 0630 to 1430, and second shift from 1430 to 2230. Total manning for each shift is reflected in Figure 4-7.
Equipment used in material handling includes trolleys towed in trains of three behind the electric tow motors.

<table>
<thead>
<tr>
<th>Number of Personnel</th>
<th>Position</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Forklift Driver (3.5 ton) on receiving dock (Bays 1-6)</td>
<td>Unload incoming trucks and boxcars. Can lift/move up to four standard FLC containers at once.</td>
</tr>
<tr>
<td>1</td>
<td>Forklift driver (2.5 ton) on receiving dock (Bays 1-3)</td>
<td>Unload smaller parts and containers from incoming trucks. Used in Bays 1-3.</td>
</tr>
<tr>
<td>3 or 4</td>
<td>Tow Motor Drivers</td>
<td>Move material from dock to marketplaces using electric tow motor and trolleys. Return empty trolleys from marketplaces to receiving dock.</td>
</tr>
<tr>
<td>4</td>
<td>Checker</td>
<td>Verify proper material is received. Write on package labels the proper storage location and date of receipt.</td>
</tr>
<tr>
<td>3 / 1</td>
<td>Receiving clerks (3 on 1st shift, 1 on 2nd shift)</td>
<td>Deal with documentation, address supplier complaints.</td>
</tr>
<tr>
<td>4 / 3</td>
<td>Administration (4 on 1st shift, 3 on 2nd shift)</td>
<td>Perform initial receipt of incoming shipments at site. Process trip and pickup sheets. Update inventory system.</td>
</tr>
</tbody>
</table>

*Figure 4-7 Material Handling Staffing and Job Descriptions*
Figure 4-8 Full Trolley Train

Figure 4-8 depicts a train of trolleys with a full load of FLC containers. There are reputedly 240 of these trolleys available for use in the assembly hall, though obtaining an accurate count is somewhat problematic. Since there is not a "closed loop" process in use to transport material from the receiving dock to the marketplaces, trolley trains, both laden and unloaded, often sit inside the marketplaces for extended periods. Individual trolleys can occasionally be found in other areas of the assembly hall. Many of these trolleys were being used for purposes other than material handling (e.g., for collection of rubbish or construction materials.)
A closed loop process would prevent the accumulation of trolleys in the marketplaces (or elsewhere) by providing a mechanism to ensure that unloaded trolleys are returned from the marketplace to the receiving dock at the same rate as laden trolleys are transported from the receiving dock to the marketplace. This can be accomplished simply by requiring that tow motors do not travel from one location to another without either a full or unloaded trolley train.

4.2 Marketplace Philosophy and Design

The lean manufacturing movement has resulted in increased recognition of the important role played by material storage in a manufacturing process. In the words of one expert, “Storage today should be planned to be part of the materials flow process, rather than being a stationary, off-path break in an operation” [“Make Storage Part,” (1997)].

Ford's SMF Handbook describes a marketplace in the following fashion: "The marketplace is a permanent storage area where the inventory is only temporary. This area is your buffer between lineside and your transportation system, your suppliers' reliability and manufacturing stability" [Ford Motor Company (1999c)]. The handbook provides guidelines on marketplace location, design, and operation. It states that a marketplace should be close to the points-of-use for the materials stored in that marketplace, and, secondarily, should be close to the dock at which those materials are received. It further notes that the conveyance system, transportation frequency, packaging, and buffer stocks determine the size and type of storage areas required.

Figure 4-9 is an example of a marketplace with the attributes necessary to support a lean material supply pipeline.
Note the following attributes of this theoretical marketplace:

- Designated, clearly-marked locations for each part
- FIFO-compliance (via push-through method)
- Proximity to points of use
- Clear labels with minimum and maximum number of packages allowed
- Designated material overflow area
While the SMF methodology provides fairly detailed guidance on the proper construction and operation of a marketplace, only one of the marketplaces in use at the time of this project had incorporated any of the SMF principles.

Figure 4-10 Existing Marketplace

Figure 4-10 depicts one of the larger marketplaces in use. A brief examination of figure 4-10 reveals some of the existing marketplaces' shortcomings: there is not a designated location for each part, or indication of the minimum and maximum inventory for those parts. There is no designated overflow area for excess material. There is no provision for FIFO, as material is both stored and retrieved from
the same aisle. Although the marketplace is very large, space utilization is poor, and material is stacked high enough to obstruct the view of forklift and tow motor operators working in the aisles.

Extensive observation of current operations suggests that the shortcomings noted above greatly reduce the overall performance of the internal supply chain at Niehl. Forklift drivers often drive up and down marketplace aisles, searching for needed parts. On several instances, different versions of a particular part were found in a single stack of containers. Mixing parts in this fashion greatly increases the difficulty of finding a particular version of a part when it is needed at the assembly line.

During the performance of this project the SMF team designed and implemented a new marketplace by aggregating several old marketplaces. The new marketplace, designated number 50, is very different from all of the others. Figure 4-11 indicates that in marketplace 50, most of the shortcomings cited above have been corrected.
Figure 4-11 Marketplace 50

Figure 4-12 highlights the location of marketplace 50 in the assembly hall. Unfortunately, this location is problematic. The parts stored there are used on nearby final assembly lines. Thus, the "proximity to point of use" criterion is satisfied. However, the round trip route from the south receiving dock, where marketplace 50 material is received, to marketplace 50 itself, is a distance of over 1300 meters. The circuitous route shown in Figure 4-12 is required to skirt the final assembly lines. The significance of this enormous distance will be explored in the following chapter.
Figure 4-12 Location of Marketplace 50 in Assembly Hall
5.1 Analysis of Current Delivery Scheduling

Ford's objective in scheduling incoming deliveries of material is to achieve a leveled flow of material. By leveling the amount of material delivered over a period of production, (e.g., a week) a stable, predictable flow of material can be established and processed with maximum efficiency and minimum resources. This efficiency is essential to achieving the vision for material flow in support of the new B-car. That vision requires most parts be delivered twice per shift. Deliveries as frequent as six times per day will require highly efficient and repeatable processes for receiving, transporting, and storing the incoming material.

The LLP in Niehl is responsible for scheduling incoming shipments. At the assembly hall, the majority of those shipments are delivered to the south dock. For that reason, the following analysis deals primarily with the processes and resources in use at that dock.
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**Figure 5-1 LLP Master Receiving Schedule for Y-Hall South Dock**
Figure 5-1 is the LLP master schedule for incoming shipments to the south dock of the assembly hall. The schedule includes fifty-four different routes. In addition to these regularly scheduled deliveries, roughly a dozen premium freight (emergent) deliveries and one half dozen non-LLP controlled deliveries arrive at the south dock and must be processed every day. In order to understand operations under the current scheduling process, we created a graphic depiction of the master schedule in Figure 5-1. The graphical schedule is included as Appendix 4.

Appendix 4 displays along a timeline the scheduled deliveries to the south dock. Lunch and rest breaks are annotated along with the six receiving bays of the south dock. A seventh bay, used for drop-and-carry processing, is not reflected. Drop-and-carry occurs when an incoming truck simply positions its trailer in the designated (bay 7) location, then detaches that trailer and departs. These shipments, along with one rail delivery (of six trucks' capacity) are processed each day whenever time allows. Interestingly, one of the motivations for implementing drop-and-carry routes was the inability to rapidly process incoming shipments. Several inbound delivery routes involve extended driving time and in order to meet shippers' specifications for driver rest time, rapid processing at the receiving dock is required. Ford's inability to consistently meet this requirement led to the establishment of drop-and-carry routes.

As depicted in Appendix 4, each incoming delivery occupies one receiving bay for sixty minutes (closely approximating actual unload performance.) A ten minute "changeover period" is included between deliveries to reflect the time necessary for the just-unloaded truck to depart and the newly-arriving truck to park, complete exchange of paperwork, and prepare for unloading.
The results of this analysis were quite surprising. They reveal a schedule that is far from leveled over the course of a production day. For example, during the period between 0700 and 0800, there are consistently six trucks in the receiving dock awaiting unloading. In contrast, during the period from 1530 to 1630 at most three daily deliveries are scheduled to be unloaded. (The Hamann route, number 122, is a once per week delivery).

In addition to the uneven material flow across the course of a production day, incoming shipments also vary significantly over the course of the production week.

![Figure 5-2 Day-to-Day Imbalance in Incoming Shipments](image)

Figure 5-2 reflects this pattern. Several months' data show the same pattern being repeated each week: the number of deliveries peaks on Monday, then declines over the week to a low on Friday. Figure 5-2 reveals that over 15% more deliveries were processed on Monday than on Friday. Nominal staffing at
the receiving dock remains constant over the course of the week, suggesting that the receiving area may be staffed to meet the requirements of peak rather than average workload.

In order to schedule incoming shipments so that a level workload is achieved from day-to-day and hour-to-hour, it is essential to understand the actual workload embodied in each incoming shipment. The current scheduling system has allocated identical thirty-minute time windows to all incoming shipments. Analysis of empirical data, however, indicates that the actual work necessary to process a given shipment is a function (among other things) of the complexity of that shipment.

![Figure 5-3 Average Unload Time (by Carrier)](image)

*Figure 5-3 Average Unload Time (by Carrier)*

Figure 5-3 illustrates this point. Each of the entries on this chart represents a unique route. On average, processing of deliveries by Hays (a very complex, consolidated route that can include material
from as many as twenty suppliers) took over ninety minutes, while processing of deliveries from Cotrans, a far simpler route involving three or fewer suppliers, took only thirty minutes.

The factor of three disparity in processing time for the two routes cited suggests that those routes cannot be treated as "identical" for purposes of scheduling. In order to best level the workload associated with processing incoming deliveries, more complex deliveries must be assigned greater unload durations and/or greater processing resources.

5.2 Analysis of Current Marketplace Configuration

In October 2000 the assembly hall included twenty-one different storage areas. Most of these locations are marketplaces, though several are "bahnhofs," or train stations, where loaded trolleys are staged.

Marketplace fragmentation is one of the primary causes of failure to meet material handling performance targets. Extreme fragmentation, with over twenty distinct storage areas, imposes an unacceptably complex and inefficient sorting burden upon material receipt and handling personnel.

The current system may be an outgrowth of the structure that preceded implementation of marketplaces several years ago. Prior to implementation of marketplaces, material was stored lineside in huge racks. The current configuration, in which many small marketplaces are scattered throughout the assembly hall, may be evidence of a "keep the inventory close to the point of use" mentality. The processes now in use, including marketplace design, simplify line feeding. However, they greatly increase the receiving dock workload.
Marketplace location within the assembly hall is also an important consideration. The location of marketplace 50, for example, imposes an unacceptable penalty. Figure 4-12 highlights the path used to transport material from the south receiving dock to marketplace 50. A single round-trip from the south receiving dock to marketplace 50 and back requires a journey of over 1300 meters.

On-site experiments conducted with material handling equipment (electric tow motor and fully-loaded trolley train) generated an average travel time of 10.4 minutes for a round trip between the south dock and marketplace 50. This figure reflects only the time required to pick up a fully-laden trolley train on the south receiving dock, tow it to marketplace 50, drop it off, pick up an empty trolley train and return with it to the dock. This best case scenario assumes no waiting for other activities like loading or unloading of the trolleys. Under these ideal conditions, the time needed to process the "simple" full trailer of material shown in Figure 3-3 is over seventy-two minutes, or 2.4 times the target of thirty minutes. Clearly, the distance between receiving dock and marketplace(s) must be far less than that for marketplace 50 to enable an average unloading time of thirty minutes or less. The ability to unload in thirty minutes or less will become even more important as delivery frequency is increased and inventory is reduced.

5.3 The Marketplace / Line feeding Interface

Call part marketplaces are (theoretically—many exceptions were observed) organized so that the parts stored in them are a "mirror image" of the points of use for those parts. This configuration simplifies the task of providing parts to the assembly line (line feeding).
Line feeding is conducted using forklifts, tow motors, and trolleys, just like the upstream processes used to transport material from the receiving dock to the marketplaces. Prior to the start of first shift production at 0630, an inventory is taken of the parts remaining lineside from the previous day's production. The results of this inventory are recorded on "order forms," each of which corresponds to a particular portion of the assembly line. Figure 5-4 shows one of these order forms, each of which has entries for somewhere between eighteen and seventy parts. In the cells atop the four rightmost columns of Figure 5-4, "Früh/Spät," simply means Early/Late. Thus, for the scheduled deliveries of the first column, one will occur at 0900, and one at 1700.

The filled-out order forms are then delivered from the assembly line to the line feeding operators. These individuals use forklifts to load needed materials from their storage locations in the marketplaces onto trains of trolleys.

Laden trolley trains are then transported to the appropriate portions of the assembly line, where other forklifts transfer material from them to the designated lineside locations. Trolleys are arranged in trains of three or fewer trolleys. Each trolley can carry a maximum of four FLCs, in two stacks of two. Therefore, a maximum of twelve FLCs (or other large containers) can be delivered per tow motor round trip. Most standard call part containers can be stacked two high during transportation.
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*Figure 5-4 Line feeding Order Form*
The line feeding crew replenishes the assembly line with call parts three times per shift. Each call part route uses one order form per shift, with a separate column of the form used for each successive delivery.

The current marketplace organization, by “mirroring” the organization of the assembly line, enables line feeding crews to resupply a contiguous section of the assembly line by picking material from a contiguous section of marketplace. In other words, no "sorting," or picking from dispersed storage locations, need be performed by line feeding operators.

Ford’s assembly operations in Valencia and Saarlouis use a very different system for replenishment of call parts. The call board system, shown in simplified form in Figure 5-5, operates as a pull system, rather than the “scheduled push” type system in use at Niehl. Rather than transporting material from the marketplaces to lineside on a prearranged schedule, and in a forecasted amount, material is provided to lineside assembly stations one part number at a time, and only in response to demand from the “calling” assembly station. At the end of the project period, Niehl was installing equipment for a pilot implementation of this system. The pilot will operate in conjunction with the newly established marketplace 50 for selected portions of the final assembly lines.

The call board system operates as follows:

- Lineside operator identifies requirement for a call part, and pushes button corresponding to that part.
- Light on call board corresponding to needed part illuminates. If more than one part has an “unanswered” request, the light corresponding to the oldest, or first-received, request will flash.
One light and one card associated with each unique part

(5) Driver returns card to proper slot. Awaits next call from assembly line.

(2) Forklift driver acknowledges call by pushing illuminated button on call board. Picks up associated card.

(3) Driver picks up part from marketplace and delivers it to appropriate lineside station.

(4) Empty parts containers are aggregated for transport.

(1) Line worker calls for parts replenishment by pushing button.
- Forklift driver presses button associated with flashing (if present) or illuminated light, then removes the associated part card. The card contains part number, package type, storage location, and the part's assembly line point of fit (destination).

- Forklift driver proceeds to indicated storage location, procures container of parts, and delivers it to the calling station. Empty container is removed from lineside rack and placed in designated location for eventual transport to empty containers area.

- Forklift driver returns to call board, replaces part card in appropriate slot, and awaits next part request.

The call board system is being used with great success in Valencia and Saarlouis. It has several advantages. First, it is a true pull system. Parts are not transported from the marketplace to the assembly line until they are needed. Thus, lineside inventory is maintained at an optimal level.

Secondly, rather than operating in a relatively unstructured "free work" environment, forklift drivers are provided a consistent and immediately understandable priority: the lit (or flashing, if present) button. This eliminates the problem of drivers "cruising," or driving unproductively through the plant, which they are prone to do when not provided a clear task prioritization. A team of line feeding forklift drivers is assigned to each call board-supported area. Individual drivers are therefore held responsible by their peers for unproductive activities. Shirking is both more easily detected (i.e., if a button is lit or flashing, driver(s) should be responding to it) and discouraged at a peer level.

Thirdly, since individual containers of parts are transported by forklifts directly from the marketplace to the assembly line, tow motors, trolleys, and tow motor drivers are removed from the system, eliminating the need for coordination between these operators, and freeing the operators and equipment for use elsewhere in the system. Lastly, and most significantly for the recommendations made in this project, there is no longer any incentive to configure marketplaces to "mirror" a section of the assembly line. The significance of this last observation will be discussed more fully in the following chapters.
5.4 Bottlenecks and Resource Allocation

In *The Goal*, Goldratt prescribes a very simple means of identifying bottlenecks—find the station where material tends to accumulate, and the process immediately downstream is likely a bottleneck [Goldratt (1992)]. Applying this simple approach to the logistics operations in the Niehl assembly hall suggests that processes on the receiving dock itself are an obvious bottleneck. On any given day, particularly in the morning, the receiving dock is typically piled high with material, on trolleys and on the floor, awaiting processing. Some of this material need be checked, some sorted, and some transported to its proper storage locations. Some material is on the dock simply because the individuals tasked with processing it have turned to the next incoming shipment in an attempt to "stay on schedule."

The receiving dock, then, and the processes that drive it—scheduling, unloading, checking, sorting, and transporting material from the dock to the marketplaces—is the apparent bottleneck in material flow through the supply chain. Several factors contribute to the less-than-desired performance at the receiving dock, including a substantial imbalance in scheduling of incoming shipments, the onerous material sorting required, and "friction" between one incoming shipment and those that succeed it. In addition, the "free work" processes in use fail to properly group and focus the personnel and equipment needed to efficiently perform the required tasks.

A leveled supply chain requires that a nearly constant amount of work be completed per unit time. In order to create such a system, incoming shipments of materials must be scheduled so that the work required to process those shipments remains roughly constant. The workload must be less than the maximum capacity of the system and nearly constant over the course of the day, and from one day to
the next. Inventory in the marketplace(s) serves as a buffer that enables a leveled demand of parts from upstream components suppliers. This philosophy is used in the Toyota Production System, where it is called heijunka [Liker, (1999)].

The amount of work required to process the material contained in each LLP-designed route must be quantified before such a schedule can be implemented at Niehl. Analysis of material handling performance indicates that the amount of work required to fully process an incoming shipment is a function of distance between dock and marketplace, and of shipment size and complexity. As the size of a given shipment increases, the workload increases for all material handling personnel. The forklift engaged in unloading the vehicle must perform more lifts, the checker must identify, verify, and sort more containers, and the tow motor drivers must transport more containers to the appropriate marketplaces.

Increasing the complexity of an incoming shipment places a disproportionately large burden upon the checker. For example, rather than confirm that nine containers each of eight different parts have arrived, he may face the task of verifying literally hundreds of different parts, each identified by an (approximately) sixteen-character part code printed on the package label. Often, many small containers of different parts arrive stacked on a common pallet, making identification and sorting very time consuming.

Performance of the overall material handling system is gated by the most limiting component of that system. Unfortunately, due to the effects of "friction," once any component of the system falls behind, the other portions of the system will suffer reduced productivity as a result. For example, if the checker is unable to perform his task as rapidly as the forklift driver unloading material, then
material will simply be piled on the dock until the checker can attend to it. As a result, the overall efficiency of the forklift driver falls, since containers set on the dock will require another “touch” by the forklift. Double handling of containers is cited by Azim as one of the source of inefficiency in material handling [Azim (2000)]. Additionally, the congestion that results from piling material on the dock impedes the movement of both forklifts and tow motors.

Another frequently observed bottleneck is caused by the absence of empty trolleys on the receiving dock. When no trolleys are available, material is placed on the dock floor, causing congestion and reducing efficiency. Direct observation suggests that there are, in fact, sufficient trolleys available. Empty trolleys are not available at the receiving dock because often they are left for extended periods inside the assembly hall.

The bottlenecks caused by shipment complexity and trolley unavailability can be addressed in several ways. One approach is to simply apply more resources in the areas now limiting performance. For example, additional individuals could be hired and assigned as checkers. Alternatively, current resources could be redistributed to increase the ratio of checkers to other workers such as forklift drivers and tow motor drivers. More trolleys could be purchased to improve trolley availability on the receiving dock.

None of these approaches, however, addresses the underlying root causes that limit material handling performance at Niehl: unleveled scheduling of incoming shipments, excessive fragmentation of marketplaces, and inefficient work practices. In order to achieve substantive gains in performance and to enable the leveled supply pipeline essential to successful launch of the new B-car, more fundamental change is required.
Chapter 6 – RATIONALIZATION OF MARKETPLACE DESIGN

The location, organization, and operation of call part marketplaces must be addressed in order to achieve the desired level of logistics performance. The highly integrated nature of supply chain operations demands that packaging, receiving, and line feeding are all considered in identifying an efficient, low-cost solution.

Analysis of current operations at Niehl suggests that the following four factors are very important in configuring a highly efficient marketplace system:

- Distance from receiving dock to marketplace
- Distance from marketplace to point of fit on assembly line
- Total distance traveled in moving material through system
- Degree of fragmentation of storage locations

The total distance traveled in moving material through the system is not simply the algebraic sum of the first two factors. It also depends upon the number of containers transported per trip (up to twelve using tow motors and trolleys, but no more than two using forklifts). Degree of storage location fragmentation determines the amount of effort required to sort incoming material by its marketplace storage locations.

The system currently in use at Niehl does a poor job of addressing these four factors. Distances from the receiving dock to the marketplaces are quite long—requiring a round trip of over a kilometer in one instance. Distances from marketplaces to points of fit vary greatly, but are routinely hundreds of meters.
While improvements must be made in distances traveled, perhaps more important is reducing the extreme fragmentation of storage locations. The sorting task imposed by this fragmentation is excessive, and constitutes a bottleneck.

Ford's assembly operations in Saarolouis and Valencia have done a much better job of addressing the four factors cited above. Distances at those sites have been reduced through utilization of multiple loading docks, and fragmentation is minimized through consolidation of call part storage locations into relatively few (four or five) marketplaces.

Conditions at Saarolouis and Valencia differ from those at Niehl, preventing an “apples-to-apples” comparison. However, the superior logistics performance achieved at those sites is attributable, in part, to their superior marketplace configurations. Valencia, for example, achieves an average “turnaround time” for incoming shipments of approximately thirty minutes, significantly less than half the time needed at Niehl.

6.1 Consolidation of Marketplaces

Chapter Four cited the extreme fragmentation of storage locations as one of the major factors limiting performance of the supply chain at Niehl. The fragmentation present at Niehl, with over twenty storage locations in use, far exceeds that of Ford's facilities in Valencia, Genk, and Saarolouis. Consolidating storage locations will reduce the complexity of sorting the material on the receiving dock.

Judicious location of fewer, larger marketplaces can also reduce the total distance traveled in moving material from the receiving dock to the marketplaces, then, ultimately, to the points of fit on the
assembly line. Following implementation of the call-board system described in Section 5.3, a far greater premium will be placed on proximity between marketplace and assembly line than upon proximity between receiving dock and marketplace.

In a call board system, delivery of each standard large part container from the marketplace to the assembly line will require a separate (forklift) trip, while a single (tow motor) trip can transport twelve large standard parts containers from receiving dock to marketplace. Clearly, once a call board system is established, greater weight need be placed on the marketplace-to-assembly line distance than upon the receiving dock-to-marketplace distance.

However, simply pulling the material now scattered throughout the assembly hall into larger, aggregated locations will not yield the degree of improvement necessary to support the SMF vision for the new B-car. Larger marketplaces will contain many more unique parts. A systematic, intuitive means of locating specific parts must be implemented to prevent excessive “searching” within a marketplace.

6.2 Proposed Marketplace Configuration

Organization of parts within the marketplaces has a profound effect on the operators’ ability to expeditiously place material in and remove material from storage locations. A number of (often conflicting) criteria must be considered in determining the organization of parts in a marketplace. The configuration selected must facilitate rapid location of specific parts. Operators tasked with placing material in the storage locations and operators tasked with removing material from those locations will both benefit from a consistent, intuitive, clearly-labeled system.
Ford's assembly facility in Saarlouis has addressed this issue by posting each storage location (e.g., A1, A2, A3...) in addition to posting the number of the part stored in that location. Thus, rather than searching for a part number, operators need only search for the appropriate marketplace location. The part cards used by linefeed forklift drivers include the marketplace location corresponding to each part number.

The system in use at Saarlouis is a fixed, (rather than a floating), system, since each marketplace location is designated to contain one unique part. A fixed system affords greater ease of use since a given unique part will always be stored in the same location. Fixed systems, however, are relatively inefficient in their use of space. The storage location for each unique part must be sufficiently large to contain the maximum allowed inventory for that part, regardless of the actual amount of inventory present at any given time. Intelligent use of racking, particularly for low-use parts, can mitigate the space-consumptive nature of fixed storage systems.

Operators tasked with transporting parts from the receiving dock to the marketplaces also require the proper marketplace location for each part. The most elegant solution to this issue involves components suppliers. Suppliers already produce and attach to two sides of each (call) part container a label consistent with Ford's specifications. Figure 6-1 is a container label for part YS6F 10849 AG, an instrument panel assembly.
Figure 6-1 Part Container Label

PART NUMBER: 97BG-1000-EC

Part Weight: _______ LB _______ KG

Scale Tolerance: 

Description of Articles Code: 

Stock In-Plant Loc 1: 23 Loc 2: EC35 Loc 3: 

In-Plant Warehouse Indicator: Pkg Indicator: 

Print Zero Quantity on Label: KD Bulk Hardware Part: 

Build Sheet Number: 

Receiving Dock Code: Shipping Dock Code: 

Figure 6-2 Sample CMMS3 Screen (with part location fields)
Ford and its components suppliers communicate through the Common Material Management System (CMMS3). This comprehensive, complex system already includes, for each part, three fields reserved for part locations, as shown in Figure 6-2. Location one (Loc1) is already being used to indicate the marketplace in which a part is stored. This field can be modified to reflect a specific part’s marketplace and its location within that marketplace.

Suppliers would then be instructed to include the contents of the Loc1 field on their part labels. (This step will likely take some effort--preliminary discussions with several suppliers revealed compatibility issues with various CMMS3 implementations.) Once suppliers can reliably reproduce the contents of this field on the labels of incoming parts containers, forklift drivers tasked with placing incoming material into the marketplaces need only read the label of the package they are carrying in order to determine precisely where it need be placed.

Searching for a specific marketplace location is far easier and more intuitive than searching for a specific part number, since storage locations will be labeled in a logical sequence. Locating a particular part by searching for its part number is especially difficult and non-intuitive due to Ford’s lengthy part numbering methodology, shown in Figure 6-3. In this system, the first ten characters of an (up to) sixteen-character part number may be identical for different versions of the same basic part.

Implementation of the new call part line feeding system described in Chapter 5 eliminates any advantage of arranging the marketplace to mirror the assembly line. Since forklifts will deliver only one unique part at a time to assembly stations requesting replenishment, there is no benefit in arranging marketplaces to mirror the assembly line. Instead, marketplaces can be configured to minimize sorting of parts on the receiving dock.
**Prefix**

<table>
<thead>
<tr>
<th>Character</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1-2)</td>
<td>Year (model year part first used)</td>
</tr>
<tr>
<td>(3)</td>
<td>Model (example: F = Fiesta)</td>
</tr>
<tr>
<td>(4)</td>
<td>Region (example: B = Britain)</td>
</tr>
</tbody>
</table>

**Base**

<table>
<thead>
<tr>
<th>Character</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Version (example: B = 3-door)</td>
</tr>
<tr>
<td>(2-5)</td>
<td>Side (even = right, odd = left)</td>
</tr>
</tbody>
</table>

**Suffix**

<table>
<thead>
<tr>
<th>Character</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Version (example: B = no air conditioning)</td>
</tr>
<tr>
<td>(2)</td>
<td>Revision (number of revisions part has undergone)</td>
</tr>
<tr>
<td>(3-5)</td>
<td>Color (example: ZUXW = black)</td>
</tr>
<tr>
<td></td>
<td>if not a colored part, suffix is normally only two characters</td>
</tr>
</tbody>
</table>

*Figure 6-3 Part Numbering Methodology*

Minimizing the sorting task will eliminate one of the most constrictive bottlenecks now limiting supply chain performance. In the ideal case, **no** sorting would be required on the loading dock. A marketplace configured so that **all parts delivered by a particular (LLP-designed) route are stored contiguously** will achieve this goal. Each LLP-designed route can be assigned an area in the marketplace. Every part delivered by that route will be stored in the contiguous marketplace area.
assigned to the route. No sorting would be required on the receiving dock. Material will simply be unloaded from the truck and transported directly to the area designated for that route.

6.3 Benefits of Proposed Marketplace Configuration

Minimizing or eliminating the task of sorting material on the receiving dock will enable more predictable, expeditious, efficient processing of incoming material. It will also produce a second important benefit. Currently, four individuals per shift work as “checkers” on the receiving dock. These individuals are tasked with writing on the label of each container the date of receipt and the marketplace to which that container must be taken. They also verify that the parts received are in fact the parts ordered.

Establishing a marketplace configured as shown in Figure 4-9 will ensure first-in-first-out (FIFO) inventory management, obviating the need to record the date of receipt on each package. Further, since suppliers will automatically produce labels with precise material storage locations for each part, there will no longer be a need for checkers to write anything on container labels.

The remaining aspect of the checkers’ tasks, that of verifying incoming parts, can also be eliminated, or at least substantially reduced. The LLP-designed system described in detail in Chapter 3 includes documentation signed by both supplier and carrier certifying that the parts ordered, and only those parts, have been loaded on the truck. There is industry precedent for requiring drivers of incoming shipments to verify the compliance of those shipments. In Traffic World, Parker describes a system in which drivers are trained to interpret suppliers’ paperwork, and to report volume discrepancies [Parker (1999)].
Discussion of this verification issue with material handling personnel up to and including the MP&L manager revealed that it is exceedingly rare for a checker to identify an error in the identification or quantity of incoming parts. Even a conservative approach of retaining two checkers to assist with particularly complex loads, or to spot check shipments from carriers with the poorest records of compliance, would free two personnel from this non-value added task.

Those two (and, ultimately, as many as four) individuals could be reassigned as forklift drivers and/or tow motor drivers. Doing so would increase theoretical maximum throughput by as much as a hundred percent, at no additional cost (assuming that additional equipment is available for them to operate.)
Chapter 7—TEAM-BASED MATERIAL HANDLING PROCESSES

In the current production environment at Niehl the material handling performance consistently falls short of goals. Average unloading time for incoming shipments is roughly twice the thirty minute target, and suffers from tremendous variability—with a standard deviation of thirty-six minutes. During the course of this project, the production line was stopped due to parts outage—while the parts needed at the line were “lost” in the piles of containers piled on the receiving dock. With the new B-car launch in late 2001, lean manufacturing processes will be implemented. Inventory will be reduced and more frequent deliveries of parts will occur, both from external components suppliers and, internally, from marketplaces to the assembly line.

In order to succeed in implementing lean manufacturing at Niehl, the variability now present in material handling processes must be reduced. Among other factors, the use of controlled work environments and standardized procedures can reduce variability [Standard & Davis (2000)]. The processes described in this chapter were developed to reduce variability and improve supply chain performance at Niehl.

7.1 Importance of a Balanced Workload

Figure 4-7 lists the personnel assigned to receive incoming material and transport that material to the marketplaces where it is stored. Ignoring the tasks now performed by “checkers,” the remaining tasks consist of unloading incoming material, transporting it, and placing it into storage locations. Each of these three tasks requires both equipment and an operator. Sustained performance of each task depends upon roughly equivalent progress being made in all three tasks. If the forklift operator
unloading material from trucks and placing it on trolleys falls behind, both of the other tasks are starved for work, and fall idle.

If the operator transporting material from the receiving dock to the marketplaces falls behind, no empty trolleys are available at the dock, which becomes congested with material piled on the floor, impeding the unloading process. Also, the operator unloading material from full trolleys and placing it into storage locations in the marketplace(s) is starved for work, and falls idle.

If the operator unloading material from full trolleys and placing it into storage locations falls behind, trolleys laden with material accumulate in the marketplace(s), further slowing his work. Eventually, no empty trolleys will be available for return to the loading dock, and the unloading forklift operator will be forced to set material on the floor, reducing his efficiency.

Efficient performance of the required tasks demands a balanced workload—one in which individuals, working at a steady, sustainable rate, will generate a smooth flow of material from incoming trucks to the marketplaces. Unfortunately, individuals engaged in the tasks described typically tend to be defined by their function (e.g., tow motor operator) rather than as part of a balanced team identified with the complete task at hand [Vasilash, (2000)].

7.2 Analysis of Individual Tasks

In order to balance the material handling workload, the overall task (defined here as the process of unloading material from one truck, transporting that material to the marketplace(s), and placing it in the proper storage locations) must be broken into clearly defined subtasks. Next, those subtasks must be further divided into their component actions, each with an associated cycle time.
Once the cycle time has been determined for the fundamental actions of a subtask, that information can be combined with standardized procedures to develop cycle times for subtasks, and, ultimately, the overall task. This technique was applied to the task of material handling. The theoretical calculations that follow are based upon the following assumptions:

- Full truckload of standardized packages (78 FLC containers)
- Three FLCs removed from truck with each lift by forklift
- Trains of three trolleys, with four FLCs per trolley (stacked two high)
- No “checker” required on dock
- Marketplace configured as proposed in Chapter 6—no sorting required on dock

7.2.1 *Forklift Operator on Receiving Dock*

This operator is tasked with removing all material from the incoming truck and placing that material onto trolley trains positioned by the tow motor driver. Each “unload” cycle begins with the forklift, unladen, positioned near the trolley train with the forks near the level of the trolleys. The operator performs the following steps, in the order listed:

1) Approach trailer while raising forks to level of trailer bed
2) Insert forks beneath bottom container of three-FLC stack. Lift stack
3) Approach trolley train while lowering forks to level of trolleys
4) Place stack of three containers on trolley
5) Remove forks from beneath containers
Figure 7-1 Complete Unloading Cycle per Trolley Train
Each unload cycle ends just as it began, with the forklift positioned near the trolley train, unladen, forks near the level of the trolleys.

Repeated measurements were taken of actual operations on the receiving dock. Multiple operators were timed, using different forklifts, unloading different types of containers from slightly different configurations of trucks, and traveling an average of roughly ten meters between the truck and trolleys. On average, each five-step unload cycle described above takes thirty seconds to complete.

Four complete unload cycles (performed in accordance with the standardized procedure developed in the course of this project) will result in the condition depicted in stage 1 of Figure 7.1.

In order to position the containers for transport to the marketplace, the forklift driver must perform the actions represented by stages two through five of Figure 7.1. Each “reposition” cycle requires the operator to perform the following steps, in the order listed.

1) Approach stack of three containers on trolley while raising forks to level of third container
2) Insert forks beneath third (uppermost) container on stack. Remove container from top of stack and place it in nearest trolley position with less than two containers
3) Remove forks

Although each of these four reposition cycles involves repositioning of only one container and requires traveling a shorter distance than does each of the unload cycles, they are conservatively estimated to require thirty seconds each.

Completion of four unload cycles (of thirty seconds each) and four reposition cycles (of thirty seconds each), will result in the condition depicted in Stage 5 of Figure 7.1. At this point, the trolley train is full.
and ready for transport to the marketplace. The forklift operator then repeats these same steps, in the same order, transferring containers to an empty trolley train staged at his station. On average, each entire unload-and-reposition cycle will take four minutes to complete.

7.2.2 Tow Motor Operator

This operator is tasked with transporting laden trolley trains from the receiving dock to the staging area in the appropriate marketplace, and with transporting empty trolley trains from the marketplace to the staging area on the receiving dock. Figure 7-2 is a graphical depiction of the task.

Each “transport” cycle begins with the tow motor, unladen, positioned near the trolley train staging area on the receiving dock. The operator performs the following steps, in the order listed:

1) Approach laden trolley train in receiving dock staging area. Connect tow motor hitch to lead trolley of train

2) Transport laden trolley train from staging area on receiving dock to staging area in appropriate marketplace

3) Disengage tow motor hitch from laden trolley train

4) Approach empty trolley train in marketplace staging area. Connect tow motor hitch to lead trolley of train

5) Transport empty trolley train from staging area in marketplace to staging area on receiving dock

6) Disengage tow motor hitch from empty trolley train
TOW MOTOR CYCLE:

Pick up laden trolley train from staging area on receiving dock. Transport to marketplace.

Pick up empty trolley train in marketplace staging area. Transport to receiving dock.
Each transport cycle ends just as it began, with the tow motor on the receiving dock, positioned near the laden trolley train in the staging area.

Measurements were taken of actual material transport from the receiving dock to various marketplaces. Multiple timed runs were conducted. Several individual run time results include delays due to cross traffic on the dock and in the marketplace aisles. All measurements were taken with fully-laden trolley trains. A conservative round trip distance of 400 meters was used in modeling tow motor cycle time. On average, each six-step transport cycle will take 3.4 minutes to complete.

7.2.3 Forklift Operator in Marketplace

This operator is tasked with removing all material from the laden trolley trains and placing that material into the appropriate storage locations. This operation is similar to that performed by the forklift driver on the receiving dock. Each “unload” cycle begins with the forklift, unladen, positioned near a laden trolley train, with the forks near the level of the trolleys. The operator performs the following steps, in the order listed:

1) Approach laden trolley train while positioning forks to level of bottom container
2) Read storage location identifier on label of bottom container, then top container
3) Insert forks beneath bottom container
4) Remove containers from trolley and proceed to storage location for bottom container
5) Place containers in storage location listed on bottom container label. Remove forks
   a. IF the storage locations for the two containers are identical, proceed to step 10
   b. OTHERWISE proceed to step 6
6) Insert forks beneath top container

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7) Lift container and proceed to storage location for container
8) Place container in storage location listed on container label
9) Remove forks
10) Proceed to laden trolley train while positioning forks to level of containers on trolleys

Each unload cycle ends just as it began, with the forklift positioned near the trolley train, unladen, forks near the level of the trolleys.

On average, each six- (or ten)-step unload cycle described above is estimated to take forty-five seconds to complete. Precise estimation of this cycle time is difficult. It depends on whether the two containers are of identical parts, on the distance from the trolley train staging area to the part storage location(s), and on time required by the operator to read the storage locations on the container labels.

Even if the two containers unloaded from the trolley need be placed in different locations, the technique detailed above should result in faster overall unloading performance than that achieved by unloading the trolley train one container at a time. Part storage locations can be assigned so that parts which are loaded near each other on inbound trucks (and, thus, loaded together onto trolley trains), are assigned storage locations near each other.

Judicious siting of marketplace trolley train staging areas near the storage locations of parts with the highest container usage and intelligent loading of incoming shipments will minimize the overall magnitude and variability of this cycle time. The goal in intelligent loading is to maximize instances of identical parts in vertical stacks after they are unloaded from stacks of three on the truck to stacks of two on the trolleys.
Six complete unload cycles (of either six or ten steps each) are required to unload a fully-laden trolley train.

### 7.3 Theoretical Team Performance

Figure 7-3 summarizes tasks and estimated times for each of the three team members.

<table>
<thead>
<tr>
<th>Member</th>
<th>Tasks / Cycle</th>
<th>Time / Cycle</th>
<th>Task Time</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dock Forklift</td>
<td>8 lifts (4 unload cycles and 4 reposition cycles)</td>
<td>8 lifts @ 30 sec each lift</td>
<td>6.5 cycles @ 4 min</td>
<td>Train of 3 trolleys with 4 FLCs per trolley</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= 4 min</td>
<td>= 26 min</td>
<td></td>
</tr>
<tr>
<td>Tow Motor</td>
<td>One 400 meter round trip between receiving dock and marketplace</td>
<td>1 round trip</td>
<td>7 trips @ 3.4 minutes</td>
<td>Based upon 2.5 m/sec (adjusted for turns, stops, p/u and drop of trailers)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= 3.4 min</td>
<td>= 24 min</td>
<td></td>
</tr>
<tr>
<td>MP Forklift</td>
<td>6 unload lifts (unload may require placing two containers in different locations)</td>
<td>6 unloads @ 45 sec each</td>
<td>6.5 cycles @ 4.5 min</td>
<td>Based upon minimal stack sorting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= 4.5 min</td>
<td>= 29 min</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 7-3 Overall Team Task Summary*

In figure 7-3, the “task time” column represents the work (and time) necessary to unload one full truck of seventy-eight containers, transport that material to the marketplace, and store it in the assigned
locations. Thus, the design of this team-based work is consistent with the lean principle of seeing a task through to completion before beginning the subsequent task.

Section 4.1 identified “friction,” or the effect of one shipment upon those that succeed it, as one of the sources of variability in unloading performance. The impact of one shipment upon following shipment(s) is largely due to the unstructured nature of current job designs. Individual operators perform the specific tasks (e.g., checking, unloading, and transporting) they are assigned largely without regard for the status or progress of other portions of the material handling process. Friction will be essentially eliminated by application of this team-based process. Its standardized, structured tasks will ensure that each task (arriving inbound shipment) “sees” the same initial conditions on the receiving dock.

The throughput of this system is expected to be substantially higher than the one now in use. The total work associated with processing a given shipment will be less, since no sorting on the dock, or checking of parts received, will be required. In addition, the individuals now assigned as checkers can be reassigned to drive forklifts, or tow motors. The end result will be the same amount of (human) resources performing less work per task. Average unloading time and variability of unloading time should both be substantially reduced.

The “task time” column of Figure 7-3 indicates that all three team operators can theoretically complete processing of a simple, full shipment in less than thirty minutes. Significantly, the workload placed upon each of the three operators is relatively level, with individual task times between twenty-four minutes (tow motor operator) and twenty-nine minutes (marketplace forklift operator).
Balancing of the work among team members is essential for a team to operate smoothly and efficiently. The inefficiency of the current system is partly due to the absence of this balance.

### 7.4 Material Handling and the New B-car

With the introduction and rapid production ramp planned for the new B-car in late 2001, logistics operations at Niehl will change dramatically. Much of the volume now brought into the assembly hall via forklift and trolley trains will instead be delivered via overhead conveyor directly at the proper points of fit. Far more frequent deliveries will be instituted, and three-shift-per-day operations will commence.

Many of the logistics details for the new B-car are not yet finalized. It is not yet known exactly how many deliveries per day will be scheduled, or how those deliveries will be configured. As a result, it is not possible to identify the material processing takt time. Takt time is defined as “total working time divided by production quantity” [Shingo, (1989)]. For example, if fifty incoming deliveries need be processed in a five hour period, the takt time would be (5 hours / 50 deliveries), or 0.1 hours per delivery.

As planning is finalized, however, a takt time can be calculated. Combined with the theoretical (or empirical) throughput capacity of the material handling team(s), the appropriate amount of material handling resources, both personnel and equipment, can be allocated.
Chapter 8 – CONCLUSIONS AND RECOMMENDATIONS

This project deals with the interface between external and internal supply chains. Although it is based upon vehicle assembly operations at Ford's Niehl plant, the observations and recommendations herein may also be applicable to other Ford sites, including those at Valencia and Saarlouis.

8.1 Summary of Current State Analysis

The material planning and logistics processes now in use at Niehl do not meet performance targets. Average unloading time is nearly twice the thirty minute objective and the standard deviation for unloading time is thirty-six minutes, which represents a large coefficient of variation.

Scheduling of incoming shipments is done using a “one size fits all” approach that fails to take into account the actual workload embodied in each shipment. That workload varies significantly with the size and complexity of the shipment. Further, the schedule is not leveled from day-to-day or from hour-to-hour.

Marketplace location, organization, and operation all detract from logistics performance. Storage locations are extremely fragmented, forcing a complex, time-consuming, and needless sorting task. Call, or large, parts are arranged in the marketplaces to mirror their use on the assembly line(s), a configuration that exacerbates the material sorting task.

The individuals performing material handling tasks operate in a “free work” environment. Operational processes fail to group personnel and equipment and to focus them on the tasks necessary to efficiently process incoming material. Performance of the overall system, while constrained to its
slowest component, erodes as one operation (e.g., unloading) outstrips the others (e.g., transport to marketplaces). Material is then piled on the dock floor, creating the additional work of “multiple touches,” and obstructing movement on the dock. Subsequent incoming shipments are more difficult to process on the obstructed dock, particularly when no free trolleys are available. This phenomenon of “friction,” or effect of one shipment upon subsequent shipments, contributes to the high variability of unloading performance.

Each shift now includes four individuals serving as checkers on the receiving dock. The checker’s tasks consist of work that has either already been done (suppliers and carriers sign for proper load contents), or can be done through more effective use of existing information systems (printing marketplace locations on container labels).

The immensity of the south receiving dock exacerbates the inefficiencies described above. Sufficient personnel and equipment exist to simultaneously process, at most, three shipments. However, the dock has bays for as many as seven trucks and three boxcars, and, at times, all these locations are completely filled.

8.2 Summary of Proposed Changes

The changes described in this section are substantial. Full implementation of these changes will entail a sizeable commitment of time and effort by the entire MP&L organization. The sequence in which these changes are implemented is important. For example, the time required to fully process each incoming route using team-based techniques should be determined prior to leveling the schedule of
incoming shipments. However, determining the processing time required by each shipment can be accomplished only after a rationalization of the marketplace(s) utilized by that shipment.

Wholesale reorganization of marketplaces, implementation of team-based material handling processes, and leveling of incoming shipments will disrupt daily production. In order to minimize this disruption the proposed changes should be implemented in stages. Reducing the scale of change to that necessary for implementation of a pilot, or trial, will also limit disruption while providing valuable empirical data about the performance of the modified processes. A pilot implementation can be achieved using a subset of delivery routes. One team (of three or four) material handling operators can be trained in the revised, team-based processes.

The following sections describe the changes necessary to implement the recommendations of this project. The changes are presented in the recommended order of implementation.

8.2.1 Marketplace Redesign

The revised marketplace configuration will embody many of the SMF principles. In addition to those changes, however, the redesigned marketplace will be organized by incoming route, rather than to mirror the assembly line. All the call parts delivered by a particular incoming route will be stored in one contiguous area. This organization will eliminate the excessive sorting now conducted on the receiving dock.

Each part will have a designated location in the marketplace. Each marketplace location will have two labels. One will identify the marketplace location itself (A1, A2, ...), and the other will identify the
part stored in that location. The part-specific label will contain the part number, minimum and maximum number of containers, the container type, and the number of parts per container.

First-in, first-out (FIFO) discipline will be enforced through the use of one-way aisles. Material will always be placed into a storage location from one side and removed from the opposite side. A designated overflow area will be implemented, and, particularly at corners and intersections, material will not be piled so high that it obstructs the vision of forklift and tow motor operators.

8.2.2 Team-Based Material Handling

Individual material handling operators will be formed into a team. Each team will consist of one forklift driver on the receiving dock, one tow motor driver, and one forklift operator in the marketplace(s). In addition to two forklifts and one tow motor, three trolley trains, comprising a total of nine trolleys, will be assigned to the team.

Each of the team members’ tasks will be accomplished through the use of standardized work processes like those detailed in Chapter 7. Those processes and the time measurements used to evaluate them must be applied to identify best methods. Best methods must then be developed into standard work procedures. The combination of method improvements and operation measurements should be used together [Ishiwata, (1991)].

Forklift drivers will not be allowed to place material on the receiving dock floor, rather than on trolleys. Tow motor operators will not be allowed to drive around the assembly hall without a trolley train (either full or empty) in tow. Routes to and from the various marketplaces will be specified and posted. Careful route design will ensure minimum driving distances and reduced traffic congestion.
Forklift drivers in the marketplace will completely unload one trolley train before beginning on the subsequent train.

Each incoming shipment will be treated as a discrete task. Material processing associated with that task will be completed before the subsequent task is begun. “Friction” between shipments will be eliminated, further reducing the variability of unloading performance.

8.2.3 Scheduling

After the modified marketplace and material handling processes have been implemented (and adjusted as necessary to maximize performance), sufficient data should be collected to determine the average time required to process the material delivered by each route. Two weeks’ data should provide a reasonable sample size of at least ten for each (daily) route. Taking into account the (expected) longer processing times required by complex shipments, a modified receiving schedule can then be constructed.

The modified schedule should balance the workload associated with material processing. Day-to-day and hour-to-hour imbalances that cause peaks on Monday, and in the early mornings, should be smoothed.

Appendix 4, a timeline depiction of the schedule now in use, includes a ten minute “changeover period” between subsequent deliveries at each receiving bay. The changeover period allows a truck driver to position his vehicle and prepare it for unloading. These tasks are “external” since they can be performed without interrupting the unloading process being carried out at another receiving bay. In
World-Class Manufacturing, Todd states that converting “internal” activities to “external” activities is one of three means to reduce changeover time [Todd, (1995)].

Judicious use of the six receiving bays will serve to convert essentially all of the changeover period into an external activity. Procedures which require one shipment be completely processed before processing of the second is begun afford more than enough time for all changeover activities to be conducted without delaying material processing.

8.2.4 Organizational Change

Performance of logistics activities at Niehl will benefit from a system that aligns the incentives of everyone in the system. Improved overall performance will result from a focus on the overall system, rather than upon components of that system.

Currently, the line feeding and receiving groups are distinct. They do not share manpower or first-level supervision. Organizing the marketplaces in a highly-fragmented, assembly-line centric fashion makes easier the tasks of the line feeding group. However, it imposes enormous burdens on the receiving group. The current organization provides little incentive for one group to consider the other when designing processes.

These two groups should be combined so that they draw from a common pool of operators. They should share first-level supervision. They should jointly evaluate the design of processes and procedures. They should be evaluated based upon the overall performance of internal logistics.

Forming a single material handling team will provide long-term benefits. Aligning operators and
supervisors so that they work together to achieve the same organizational goal creates a favorable environment for continuous improvement [Suzaki, (1987)].


APPENDIX 1-RECEIVING PERFORMANCE

A1.1 Receiving Performance for April, 2000
A1.2 Receiving Performance for May, 2000

[Graphs and charts showing data analysis]
A1.3 Receiving Performance for June, 2000
### DCI Nr. 646-22 erstellt am Dienstag, 31. Oktober 2000

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Salvage, please fill up with additional material (if possible)

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Dear Driver,
Please fill out the actual times for each stop and call us if you are late (arrival, departure).
Please give this Trip sheet and the supplier's Pick-up sheets to Ford Cologne's receiving personnel.
### PICKUP SHEET

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- **Route-No.**: CGN 16 A1
- **Transp. Mode**: MR
- **Stop**: 1

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**Signatures**

- **LLP Signature**: [Signature]
- **Driver Signature**: [Signature]
- **Supplier Signature**: [Signature]
- **Ford Receiving Signature**: [Signature]
APPENDIX 3-FORD STANDARD REUSABLE CONTAINERS

A3.1 Standard Containers

KLT 3214

Außenabmessungen: 390 x 260 x 147:mm
Innenabmessungen: 271 x 196 x 115:mm
Tara gewicht: 0.72kg
Fußgewicht für den manuellen Transport: 1.63kg
Anzahl von KLT pro Palette: 60

KLT 4314

Außenabmessungen: 400 x 300 x 147:mm
Innenabmessungen: 334 x 247 x 103:mm
Tara gewicht: 0.50kg
Fußgewicht für den manuellen Transport: 1.54kg
Anzahl von KLT pro Palette: 60

KLT 4328

Außenabmessungen: 400 x 300 x 281:mm
Innenabmessungen: 333 x 247 x 226:mm
Tara gewicht: 2.24kg
Fußgewicht für den manuellen Transport: 1.54kg
Anzahl von KLT pro Palette: 30

KLT 6428

Außenabmessungen: 660 x 400 x 281mm
Innenabmessungen: 532 x 346 x 221:mm
Tara gewicht: 4.4kg
Fußgewicht für den manuellen Transport: 1.54kg
Anzahl von KLT pro Palette: 15

FSC 1206

SPEZIAL CONTAINER

Außenabmessungen auseinandergefahren: 1200 x 1000 x 600mm
gefüllt: 1200 x 1000 x 406:mm
Innenabmessungen: 1115 x 915 x 370:mm
Maximales Nettofüllgewicht: 500kg

FLC 1210

Außenabmessungen auseinandergefahren: 1200 x 1000 x 975:mm
gefüllt: 1200 x 1000 x 406:mm
Innenabmessungen: 1115 x 915 x 755:mm
Maximales Nettofüllgewicht: 500kg
ZE 13 (Y)
1200 x 1000 x 870mm Wgt = 141 Kg

ZE 36 (Q)
1200 x 1200 x 1010mm Wgt = 74 Kg

ZE 15 (K)
1200 x 1000 x 1000mm Wgt = 106 Kg

ZE 38 (X)
1200 x 1000 x 1010mm Wgt = 180 Kg

ZE 35 (Z)
2000 x 1200 x 870mm Wgt = 229 Kg

ZE 29 (L)
2500 x 1200 x 1010mm Wgt = 246 Kg
ZE 39 (M) 2200 x 1200 x 1010mm Wgt = 241 Kg

ZE 49 (MC)
2200 x 1200 x 1010mm Wgt = 270 Kg
FORD SPECIAL CONTAINERS (welded superstructure or non standard size base)
### REceiving Bay (Y) Scheduling

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<tr>
<td>BAY 4: TransOps (717)</td>
<td>11:00 - 12:00</td>
</tr>
<tr>
<td>BAY 5: TransOps (718)</td>
<td>12:00 - 1:00</td>
</tr>
<tr>
<td>BAY 6: TransOps (719)</td>
<td>1:00 - 2:00</td>
</tr>
</tbody>
</table>

### NOTES
- **Truck transition period:**
- **Overlap in unloading schedule:**
- **Overlap AND enable to side favors half of receiving dock:**
- **Tuesday/Thursday:**
- **Does Per Week:**
- **Conflict with Break Period:**
- **Drop & Carry Load:**

### APPENDIX 4: Timeline of LLP Schedule

1. Reflects master time window schedule. Includes 53 LLP-controlled routes.
2. Does not reflect premium or non-controlled routes.
3. Assumes unload time of 60 minutes, and turnaround time of 10 minutes.
4. Bays 1,2,3 are preferred for KLT/Textron, "complicated" loads. Bays 4,5,6 preferred for large parts.