

**T.C.
MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES IN
PURE AND APPLIED SCIENCES**

**REENGINEERING OF MATERIALS MANAGEMENT
SYSTEM IN A PLANT MEETING BOTH PROBABILISTIC
DEMAND AND CONTRACTED ORDERS**

**Mehmet KARAASLAN
(Mechanical Engineering, MSc.)**

**DISSERTATION
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
ENGINEERING MANAGEMENT PROGRAMME**

**SUPERVISOR
Asst. Prof. Dr. Serol BULKAN**

ISTANBUL 2005

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ACCEPTANCE AND APPROVAL DOCUMENT

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DEMAND AND CONTRACTED ORDERS**

Established committee listed below, on 27.07.2005 and 2005/16-17 by the INSTITUTE FOR GRADUATE STUDIES IN PURE AND APPLIED SCIENCES' Executive Committee, have accepted Mr. Mehmet KARAASLAN's Doctor of Philosophy dissertation, titled as "Reengineering Of Materials Management System In A Plant Meeting Both Probabilistic Demand And Contracted Orders" in Engineering Management Programme.

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APPROVAL

Mr. Mehmet KARAASLAN has satisfactorily completed the requirements for the degree of Doctor of Philosophy in Engineering Management at Marmara University. Mr. Mehmet KARAASLAN is eligible to have the degree awarded at our convocation on Diploma and transcripts so noted will be available after that date.

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June 2005

Mehmet KARAASLAN

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ÖZET

PROBABİLİSTİK TALEP VE SÖZLEŞMELİ SİPARİŞLERİ BİR ARADA KARŞILAYAN BİR TESİSİN MALZEME YÖNETİM SİSTEMİNİN YENİDEN YAPILANDIRILMASI

Bu çalışma, önerdiği Değişim Yönetimi Modelinin, özel bir tesisin malzeme yönetim sisteminin yeniden yapılandırılması için uygulamasını içermektedir.

Literatür araştırması kısmında, yeniden tasarlama, malzeme yönetimi, talep çeşitleri ve lojistik konularında özetlenmiş bilgilerin derlemesi yer almaktadır.

Tez çalışmaları kısmı, üzerinde çalışılan tesis, malzeme yönetim sistemi ve şirket organizasyonu hakkında kısa bir bilgilendirme ile başlamıştır. Daha sonra Değişim Yönetimi Modeli önerilmiş ve her adımı detaylı olarak anlatılmıştır.

Daha sonra başarılı bir uygulama yapabilmek için ihtiyaç duyulan çalışmalar, bir yol haritası üzerinde verilmiş ve uygulaması anlatılmıştır. Önerilen ve izlenen yol haritası esas itibarıyla, Yeniden Yapılandırma Master Planı'nı oluşturmaya yarayan bir grup matrisin doldurulmasıdır.

Yeniden Yapılandırma Master Planı'nın hazırlanmasının ardından malzeme yönetim sistemi üzerindeki uygulamaların geniş bir şekilde detayları verilmiştir.

Bu çalışmada, birçoğu karmaşık ve birimlerarası konuları kapsayan 20 kadar süreç önerilen değişim yönetimi modeli yoluyla yeniden yapılandırılmıştır. Bu modelin içerdiği Değişim Yönetimi Takımı, hem koordinatör hem de üst yönetim ve Uzman Çalışma Ekipleri arasında uzlaştırıcı olarak etkin bir şekilde kullanılmıştır.

Yeniden yapılandırma sonrası performansı izlemek amacıyla bir grup performans göstergeleri oluşturulmuş ve bu göstergelerde ortalama % 88 iyileşme

elde edilmiştir. Ayrıca, yapılan uygulama ile, çalışılan süreçlerde katma değeri olmayan zamanın % 55'i elimine edilmiştir. Dolayısıyla, önerilen değişim yönetimi modeli, özel bir şirket (farklı talep şekilleri olan, departmantal ve merkezci yönetimli) üzerinde başarıyla uygulanmıştır.

Bunlara ek olarak, çalışma ile 1,8 milyon USD civarında direkt yıllık finansal getiri ve 400.000 USD kadar dolaylı yıllık finansal getiri elde edilmiştir.

Çalışma boyunca, rol alan personelin bilinçlendirme/eğitimi, liderlik ve adanmışlığı ile proseslerin birimlerarası olmasının, önerilen model ile yeniden yapılandırma faaliyetlerinin başarılı olmasında en önemli faktörler oldukları tespit edilmiştir.

Haziran 2005

Mehmet KARAASLAN

ABSTRACT

REENGINEERING OF MATERIALS MANAGEMENT SYSTEM IN A PLANT MEETING BOTH PROBABILISTIC DEMAND AND CONTRACTED ORDERS

This study is a reengineering implementation on materials management system of a plant, through a proposed Change Management Model.

The general background is based on summarized literature about reengineering, materials management, demand patterns and logistics.

The dissertation work starts with a brief information about the plant, its materials management system and company organization. Then, the change management system is proposed, and every step of the model is explained in detail.

The necessary work to conduct a successful implementation is given with a road map, which, in fact, is a set of matrices to be filled in to prepare a Reengineering Master Plan.

After the explanation of how the Reengineering Master Plan is prepared, a detailed explanation of the implementation on materials management system is given.

In this study, about 20 processes most of which are very complex and cross-functional, are reengineered by the proposed change model which introduces a Change Management Team as a coordinator and mediator between Specialized Work Teams and top-level management.

A group of performance indicators were identified to follow performance after reengineering processes and an average of 88 % improvement was obtained. Besides, 55 % of the non-value added time of considered processes was eliminated by the

implementation. Therefore, the proposed change management model was successfully applied on a specific type of company (with different demand patterns, strict functions and centralized management).

In addition, about 1,8 million USD direct annual financial benefit and 400.000 USD indirect annual financial benefit was obtained.

During the study, awareness/training, leadership, commitment of the active personnel and cross-functionality of processes are found to be important factors effecting the success of reengineering studies through the proposed change model.

June 2005

Mehmet KARAASLAN

CLAIM FOR ORIGINALITY

The dissertation work proposes a Change Management Model for Reengineering, applied on Materials Management System of a plant which very recently merged with the plant next to it. The merged company is a fully fragmented functional one, with a very centralized management. The company culture is effected from military discipline since the Turkish Armed Forces have been one of the major customers of the company for about 20 years.

The model was applied on materials management system since it is a combination of processes including actions of different functions in a sencronized manner and the characteristics of the problems are complex and cross-functional. So, reengineering solutions should be consistent with the complexity of the materials management system and ‘the company structure’ at the same time.

This study is unique since it defines a model of change management through reengineering of materials management system of a plant having various ordering policies, in a highly fragmented functional and centralized company.

In addition, this is especially an important case study for it is applied in a company after merger. In cases of mergers, reengineering is an important tool to redefine work flows of the new company after merger and the way reengineering is applied is vital for the success of the merger.

The results of this dissertation work will add to the literature by proposing a systematic change management model and a reengineering implementation on a specific type of company, namely having a variety of products with different demand types, having a strictly functional organization and centralized management and being just after merger.

The study also introduces a new matrix of reengineering success level calculation considering a weighted measure of process indicator performances and

elimination of non-value added times. It also considers the financial benefits and relation between success level and identified related parameters.

June 2005

Asst. Prof. Dr. Serol BULKAN

Mehmet KARAASLAN

LIST OF SYMBOLS

a(t)	: Time Dependent Error Accumulation Function
B	: Reorder Point
c	: Rating of Critical Parameter
C	: Order / Setup Cost
e(t)	: Time Dependent Total System Error Function
E	: Maximum Inventory Level
F	: Annual Holding Cost as a Fraction of Unit Cost
h	: Holding Cost Fraction per Period
H	: Holding Cost
L	: Lead Time
m	: Number of Orders
M	: Lead Time Demand
N	: Operating Days per Year
p	: Production Rate
P	: Unit Purchase Cost
Q	: Order Quantity
Q_o	: Economic Order Quantity
r	: Demand Rate
R	: Annual Demand
$\bar{R}$	: Average Demand Rate per Period
t	: Time
T	: Time Interval
w	: Weight of Critical Parameter
α	: Percent Error Accumulated
β	: Percent Error Corrected or Prevented
σ	: Standard Deviation

ABBREVIATIONS

ABC	: Activity-Based Costing
AC	: Accounting
APL	: Advanced Product List
AS	: After Sales
BNR	: Business Network Redesign
BOM	: Bill of Materials
BPR	: Business Process Reengineering
CEO	: Chief Executive Officer
CL	: Critical Level,
CR	: Continuous Replenishment
CRP	: Capacity Requirements Planning
CSF	: Critical Success Factors
DRP	: Distribution Requirements Planning
EDI	: Electronic Data Interchange
EOC	: Economic Order Quantity
EOI	: Economic Order Interval
EPQ	: Economic Production Quantity
HR	: Human Resources
HRM	: Human Resource Management
IT	: Information Technology
JIT	: Just in Time
LFL	: Lot-For-Lot
MH	: Materials Handling
MPS	: Master Production Schedule
MRO	: Maintenance, Repair & Operating Supplies

MRP	: Material Requirements Planning
MRP II	: Manufacturing Resource Planning
MTT	: Material Tracking Team
NGT	: Nominal Group Technique
OM	: Organizational Management
PE	: Product Engineering
PET	: Process Evaluation Team
PF	: Production Facilities
PL	: Planning
PO	: Purchase Orders
POQ	: Periodic Order Quantity
PP	: Production Plan
PR	: Production
PU	: Purchasing
QR	: Quick Response
QU	: Quality
RCCP	: Rough-cut Capacity Planning
RD	: Research and Development
RN	: Reschedule Notices
RRP	: Resource Requirements Planning
SM	: Sales and Marketing
SP	: Spare Parts
SPCT	: Subassembly Parts Counting Team
TC	: Total Cost
TQM	: Total Quality Management
US	: United States
WIP	: Work in Process
WIPCT	: Work-In-Process Counting Team
WO	: Work Orders

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PART I

INTRODUCTION AND OBJECTIVES

I.1. INTRODUCTION

Business process innovation, despite its promise of radical competitive benefit, is still a rare phenomenon in the corporate world. Growing numbers of executives are aware of it, but very few have undertaken serious process innovation initiatives. The reason for this is simple-business process innovation requires abandoning comfortable old ways of doing business.

It necessitates thinking about organizations and organizational boundaries in new ways that involve major, large-scale organizational change. In short, business process innovation involves radical change, and individuals and organizations cannot always be expected to embrace such change.

Organizational, not technical, barriers present the major challenges in process innovation efforts. Successful implementation of process innovation depends on consciously managing behavioral as well as structural change, with both a sensitivity to employee attitudes and perceptions and a tough-minded concern for results. This combination is difficult to come by.

Many firms are well-known to have readily identified new processes that promise radical performance improvement, but have been unable to implement them because they could not effect the required organizational change.

Managers who perceive the need for change, but are blocked by one of a number of common pitfalls of change management, are likely to become frustrated, having seen the possibility of company-saving process innovation and been unable to realize it [1]*.

I.2. OBJECTIVES

This dissertation work is a case study to apply a change management model for reengineering of materials management processes of a plant after merger. The model will be evaluated regarding the company culture, which is very centralized and employee attitudes, which widely differs after merging two neighbouring plants.

Materials management system is taken into consideration because it has a tremendous influence on the ultimate cost of a product because it handles the total flow of materials in an organization. The total flow includes many interrelated processes and can extend from suppliers to production and subsequently through distribution centers to customers. Encompassed in the management of the material flow is the responsibility for planning, acquisition, storage, movement and control of materials and final products [2].

Before any changes are considered, the various objectives of the inventory system should be delineated. It is essential to define what objectives are sought and their relative importance. The relative importance of various objectives may change over time or as dictated by economic conditions. It is practically impossible to design an effective system without a thorough understanding of the purposes it will serve.

When considering a change in a materials management system, a good starting point is to review the existing system, so as to determine whether or not to change it, in what way it should be changed, and to what extend. *The evaluation of the existing system may begin by examining customer demand patterns, replenishment policies, replenishment lead times and the status of existing stocks [3].

The plant suffers from a high amount of excess of incoming inventory, which has to be deeply analysed before making any decisions to solve the problem. In

* Numbers represent references.

addition to that, the inventory is occupying a valuable space and as it grows, handling and supervision costs increase.

This excess stock accumulation is a result of many processes to plan, acquire, store, move and control inventory (raw materials, purchased parts, work-in-process), so to find a solution to this problem all of those processes had to be filtered and restructured if necessary. That is why the top-level management approved a reengineering study on all of materials management processes to solve the problems and the study includes these reengineering efforts.

PART II

GENERAL BACKGROUND

II.1. REENGINEERING AS A TOOL FOR CHANGE MANAGEMENT

II.1.1. Process Innovation

Defined simply, innovation is, of course, the introduction of something new. The purpose of introducing something new into a process is to bring about major, radical change. Process innovation combines a structure for doing work with an orientation to visible and dramatic results. It involves stepping back from a process to inquire into its overall business objective, and then effecting creative and radical change to realize order-of-magnitude improvements in the way that objective is accomplished [1].

Process innovation can be distinguished from *process improvement*, which seeks a lower level of change. If process innovation means performing a work activity in a radically new way, process improvement involves performing the same business process with slightly increased efficiency or effectiveness. The actual level of benefit derived from operational betterment initiatives falls, of course, across a continuum, but in practice most firms seek either incremental or radical change. It is possible that process innovation might yield only incremental benefit, in which case we would classify it as an improvement [4]. We are also familiar with at least one instance in which a process improvement initiative yielded radical benefit, albeit in a narrowly defined process [5].

There are other important differences between process improvement and process innovation, among them, the locus of participation in organizational change, the importance of process stabilization and statistical measurement, the enablers and

nature of change, and the degree of organizational risk. These are summarized in Table II.1.

Process innovation initiatives start with a relatively clean slate, rather than from the existing process. The fundamental business objectives for the process may be predetermined, but the means of accomplishing them is not. Whereas process improvement initiatives are often continuous in frequency, the goal being ongoing and simultaneous improvement across multiple processes, it is difficult to conceive of continuous process innovation. Process innovation is generally a discrete initiative. As suggested below, it is best combined with improvement programs, both concurrently across different processes and in a cycle of alternation for a single process.

Table II.1. Process Improvement Versus Process Innovation [1]

	<i>Improvement</i>	<i>Innovation</i>
Level of Change	Incremental	Radical
Starting Point	Existing process	Clean slate
Frequency of Change	One-time/continuous	One-time
Time Required	Short	Long
Participation	Bottom-up	Top-down
Typical Scope	Narrow, within Functions	Broad, cross-functional
Risk	Moderate	High
Primary Enabler	Statistical control	Information technology
Type of Change	Cultural	Cultural/structural

Process improvement can begin soon after changes in a process are identified, and incremental benefits can be achieved within months. Because of the magnitude of organizational change involved, process innovation often takes a much longer time. We know of no large organization that has fully identified and implemented a major process innovation in less than two years. Ford's widely reported elimination of three-quarters of its accounts payable staff, achieved by paying on receipt of goods and eliminating invoices, took five years from design to full implementation [6]. This implementation cycle was long despite the fact that the process Ford

adopted was already operational within Mazda, its Japanese subsidiary, and was a relatively narrow process. In this situation, managing the changes required in accounts payable took longer than it should have, but process innovation champions should be prepared for a change cycle measured in years.

Bottom-up participation is a hallmark of continuous quality improvement programs [7]; employees are urged to examine and recommend changes in the work processes in which they participate. Visitors to quality-oriented companies frequently see banners, posters, and newsletters bearing quality-related slogans and progress measurements. Some quality-driven firms boast that every member of the organization is a member of a quality circle.

Process innovation is typically much more top down, requiring strong direction from senior management. Because large firms' structures do not reflect their cross-functional processes, only those in positions overlooking multiple functions may be able to see opportunities for innovation. A clerk in the shipping department is unlikely to conceive a radical redesign of the entire order management process. Ideas from workers and lower-level managers, though they should be solicited, are likely to target incremental improvement. Just like workers, lower/middle managers are as likely to resist as to propose major change, implementers of process innovation must strive to gain commitment and buy-in at all levels of the organization. Encouraging participation in the process design activity can certainly facilitate this.

Process improvement programs, including those initiated under the quality banner, are generally applied to existing organizational structures and thus involve change in narrowly defined functional or subfunctional processes. Process innovation, on the other hand, involves definition of and innovation in broad, cross-functional processes. Just the identification of such processes, often for the first time, can lead to innovative ways of structuring work [8].

II.1.1.1. Enablers Of Process Innovation

The idea of focusing on enablers of innovation as potential drivers of change is perhaps radical. Hayes, observing that abstract planning only rarely anticipates how a firm will address its environment with specific initiatives, argues that often the appropriate order is "means, ways, ends" [9]. Providing the tools for change (including financial, technological, and human resources), and the specific directions in which to apply them will become apparent as the environment changes.

Change enablers for process innovation are clearly "means" in Hayes's terminology. Rather than following in some fixed order, ends and means are better viewed as influencing each other. The use of information technology in processes, for example, can strongly influence, and should be influenced by, strategy. Regardless of the order of ends, ways, and means, it is important to consider the means or enablers of process innovation before a process design is solidified.

By virtue of its power and popularity, no single business resource is better positioned than information technology to bring about radical improvement in business processes. There is a well-developed literature suggesting that the primary enablers of change in organizations are technology and organizational/human factors [10]. Process innovation can seldom be achieved in the absence of a carefully considered combination of both technical and human enablers [11].

Possibilities for applying organizational and human factors to process innovation extend over a broad range. For example, creating a more empowered and diversified work force, eliminating levels of hierarchy, creating self-managing work teams, combining jobs and assigning broader responsibilities, and upgrading skills are some organizational and human resource changes that frequently accompany the use of IT.

1.a. Organizational Enablers: Structural and Cultural

Organizational enablers of process innovation fall into two categories: structure and culture.

Structural Enablers: Of the many kinds of structural changes that can facilitate new, process-oriented behaviors, one of the most powerful involves structuring process performance by teams. Since work design was first advanced during the Taylor era, the primary unit of work performance has been the individual. Taylor and others believed that the more isolated the worker, the more efficient the performance of the task. Yet most processes or subprocesses can be performed by teams (or collections of teams). Work teams were studied in terms of the productivity, motivation, and satisfaction of workers by primarily Harvard researchers at the Hawthorne plant of Western Electric as early as the 1930s [12], and analysis of the role of work teams in relation to new technologies and work processes was pioneered by the Tavistock School in the late 1940s [13]. The technologies involved in the latter research were not computers and communications,

but new machines for coal mining. Tavistock researchers found that individual-based work designs combined with new technologies were less productive than work teams with no technology. The rationale for this finding was, to a degree, process-oriented; the teams worked better because they combined multiple functions into one unit, allowing adaptation to changing conditions inside the mine. Subsequent studies of work teams in a variety of settings-white and blue collar, on assembly lines and in less-structured contexts-have found significant benefits to be associated with a shift to teams [14].

Benefits of teams. Cross-functional skills facilitate functional interfaces and parallel design activities. Furthermore, a broad set of skills and perspectives increases the likelihood that output will meet multifunctional requirements. New product development teams, for example, increasingly include representatives from all the functions involved in the product development process. Even teams composed of a number of employees from the same function are likely to have a broader range of skills than any individual. Nonaka has cited the wealth of information created through overlapping roles and memberships on teams as a key source of innovation in Japanese product development [15].

A second benefit sought by companies that employ team structures is improved quality of work life. Most human beings seem to prefer jobs that include social interaction, and work teams provide opportunities for small talk, development of friendships, and empathic reactions from other employees. Such socialization was anathema to Frederick Taylor, but although there may be a trade-off between productivity and socialization on the job, it is also true that alienated, unhappy individual workers are no more productive than overly socialized team workers. It is well known that team structures are common in Japan, whose companies are noted for their productivity levels; process improvement and quality control in Japan, according to Ishikawa, "is a group activity and cannot be done by individuals. It calls for team work." [16].

It should also be noted that the social interactions of team members are not always positive. Particularly when teams are cross-functional, members may lack a shared culture, leading to conflict and misunderstanding. This conflict has been noted, for example, in cross-functional teams for new product development [17], and in teams for creating integration across the design and manufacturing functions [18]. In some cases, these conflicts have significantly decreased the innovativeness and

performance of the team. Therefore, careful attention must be paid to cultural compatibility issues in selection of team members.

Types of teams. Several different types of teams are relevant to process innovation. The most difficult issues that face teams organized to execute processes or subprocesses over the long term revolve around the relationship between team members and the functional structure of the organization. Assuming the functional structure continues to exist, one of these issues is the question of how and by whom the team members are to be evaluated. Issues of team formation and function involve management as well as operational employees. To function effectively as a cross-functional team, a senior management group must be willing and able to look beyond functional allegiances, and even beyond what may benefit their careers. That many today arrive at management positions by way of ambition and political skill does not bode well for team formation or success.

Criteria for team success. Whatever the type of team, one can find research and experience that indicate how it can be successful, both in general and relative to process innovation in particular. Composition, for example, has been shown to be key to team success. Although personality issues may render some productive workers unsuited for teamwork, in general, employees who perform well as individuals tend to perform well as team members. Finding good performers will contribute to productivity, but unless, collectively, they possess the functional background, skills, and experience requisite to the process being innovated, the team is not likely to succeed.

A clear relationship to functional structure- in terms not only of reporting relationships and performance and reward evaluation, but the relative emphases on process versus functional activities- is also key to team success, particularly if a team is temporary. It is difficult to allocate attention to teamwork unless it comprises at least 50 % of their jobs. In other words, a team that meets only one day per week is not likely to succeed.

It is popular today to establish "self-managing" teams, teams that direct their own work and have no formal leader [19]. Although desirable because of its positive effect on motivation, self management can create ambiguity about who really manages a set of activities.

Finally, it must be acknowledged that teams are not the solution to all process design problems. The work of individuals can also be effective, and Taylor's concern

about the efficiency of teams is not unfounded.

Team-oriented information technologies. Emphasizing the synergistic relationship between technological and human/organizational enablers of processes, there are emerging technologies to facilitate work in teams. The technologies that support team structures have spawned wholly new forms of software. One of these, termed "groupware," supports a variety of activities intended to facilitate group work, including:

- group brainstorming, decision making, and structured discussion [20];
- group communication via teleconferencing, electronic mail, and electronic bulletin boards;
- group preparation of documents;
- group scheduling of meetings and facilities;
- group access to database records (e.g., customer files); and
- analysis of group processes (e.g., frequency of participation).

According to one source, these types of groupware functions have many potential benefits, including reducing meeting time and face-to-face meeting frequency, curtailing missed communications, reducing project delays, and enabling increased flow of information and faster decision making. In Balcor, a real estate investment management firm, for example, these benefits added up to a 30% reduction in product development time from the use of groupware [21]. However, neither these researchers nor Johansen and Bullen [22], nor various researchers in Greif [23], treat the use of groupware specifically within a process context. Though there is no research to support conjectures on groupware use in teambased processes, we would suspect that the more structured the process, the more likely groupware use will lead to measurable time reductions or other benefits.

Cultural Enablers: Most recent shifts in organizational culture have been in the direction of greater empowerment and participation in decision making and more open, less hierarchical communications. The resulting participative cultures, which have a structural side in flatter organizational hierarchies or broader spans of control, have been widely documented to lead to both higher productivity and greater employee satisfaction [14].

In a process innovation context, these cultural changes are intended to empower process participants to make decisions about process operations.

Participative cultures may even lead to self design of smaller, restricted processes by employee teams.

Information technology, as we pointed out earlier, can support either culture-control or empowerment. It can supply employees with information that enables them to make their own process decisions or with instructions that dictate precisely how to perform each process step. This dual nature of IT, which enables individuals or teams to manage themselves with information or information to be used to closely monitor individual or team performance, has been noted by Zuboff [11] and Walton [24].

1.b. Organizational Constraints to Process Innovation

Organizational enablers, like IT enablers, have a flip side; they can constrain, as well as enable, process innovation. Most organizational constraints are simply the reverse of the enablers discussed above. They involve an organizational design element that does not fit the process design, for example, a process design that assumes a great degree of frontline empowerment in a control-oriented organizational structure and culture. But some organizational constraints are more general, for example, organizational structures and cultures that support management along individual functions rather than cross-functional processes. The senior executives who observed that their greatest challenge in moving to process management was getting the senior management group to act as a team were speaking of a constraint to multiple types of change, not just to process innovation.

Many of the firms beginning to investigate process innovation are constrained by some aspect of their structures or cultures, which makes it difficult for them to pursue their interest to the point of concerted action. Structural and cultural constraints to process innovation include strict hierarchical structures, cultures unreceptive to innovation, and general organizational rigidity or inability to accommodate change. These constraints are not all hallmarks of failure; in fact, they may be generated by success.

1.c. Human Resource Enablers of Process Innovation

New processes invariably involve new skills. Because process innovation often involves both greater worker empowerment and a broader set of work tasks, the requisite new skills may involve both greater depth of job knowledge and greater breadth of task expertise. A variety of training programs must be undertaken if the

requisite skills are to be available when they are needed. These include specific process training, anticipatory training, and on-the-job training. The most common type of training in a process innovation context is specific process training. When a new process is designed, the process skill requirements must be assessed and workers who will execute the process must be trained in those skills. Though it may seem straightforward, there are several problems with this type of training. One, because skill acquisition often takes longer than process design, the need for workers with new skills may be urgent before their training can be completed. Two, there are likely to be few employees with sufficient experience and knowledge to train others. If the process is truly innovative, no one will be qualified to train anyone else. Three, unless workers are overqualified for their jobs, it may be difficult to find employees with enough raw intelligence and generic job skills to execute the new process.

The problems inherent in specific process training have led a number of companies to undertake anticipatory training aimed at better preparing managers and workers for process innovation or the IT and other enablers associated with it. A number of manufacturing firms, for example, have established education programs that deal with the ideas behind concurrent engineering, design for manufacturing, integrated logistics, and so forth. Although these programs are frequently offered in association with quality management, their message is often radical rather than incremental change.

Other large companies such as Du Pont and Aetna have undertaken broad programs to familiarize senior and middle managers with the capabilities of information technology. Although not created in an explicit process innovation context, these programs have been cited by those who sponsored and delivered them as having stimulated IT enablement of process innovation. Of course, process innovation is not a simple by-product of this education; many other factors must be present. In Japan, broad worker training in various aspects of manufacturing processes has been discussed as an enabler of so-called flexible manufacturing systems, which are certainly a process innovation [25]. An overall organizational culture that emphasizes skill enhancement and job rotation has also been cited as a key factor in the flexibility and innovativeness inherent in Japanese manufacturing processes [26].

On-the-job training, long known and appreciated, has sometimes been used as an excuse for neglecting other types of training. In the context of process innovation,

on-the-job training takes two forms. One of these relates to the notion of process prototyping, as a means of refining process designs. Process prototyping also has application to the acquisition of process skills. If there is no expert to train workers in the execution of a process, the obvious alternative is to teach the process and its associated skills to a number of flexible, adaptive employees and have them impart their new knowledge and skills to others.

Another approach to on-the-job process skills training, because it makes use of workstations, is particularly relevant to IT enabled process innovation [27]. The value of this approach is that it enables complex educational materials to be delivered when they are required by the process worker. IBM's internal information-systems function, for example, is attempting to speed processes for developing new computer systems by embedding interactive training materials in the systems developers' workstations. Programmers who encounter aspects of a problem or tool that they do not understand can call up a quick training session that employs videodisk images.

In addition, motivation levels of employees are a key determinant of process performance. Employee motivation results from a combination of factors, some determined by individuals' personalities. Companies can set as an objective the hiring of workers with high motivation levels, but they can also design motivation into their processes. The consensus model in studies of work organization suggests that work motivation derives from five key aspects of the job, or process [28]:

- skill variety (the variety of skills necessary to complete the job),
- task identity (the degree to which a job involves completion of an entire activity),
- task significance (the perceived importance and impact of the job),
- autonomy (the freedom and discretion with which the job is performed), and
- feedback (the extent to which information about the performance of the job is provided to the worker).

A number of other human resource policies can be viewed as process innovation enablers when combined with technological and other organizational changes.

Compensation. Since the 1930s, when Joseph Scanlon began to advocate the sharing of productivity gains in the steel mill where he was a labor leader, companies have experimented with approaches to compensating workers on the basis of operational improvements [29]. This approach, now usually called "gainsharing," is

widely referenced in the quality literature. Obviously, given the strong measurement orientation of a process approach, it would be relatively straightforward to compensate process workers on the basis of process performance. Just as obviously, doing so would probably be an effective motivational technique for these employees. At the management or process owner level, compensation-oriented enablers might include giving managers a financial stake in the performance of the process, perhaps even ownership in the literal sense.

Career paths. A process view of the organization usually implies career paths different from those found in the typical functional, hierarchical organization. Career movement is likely to be more lateral than upward; titles may no longer reflect the importance of the role. We are aware of several firms in which new processes already seem to involve fewer options for upward advancement. Companies that can figure out how to motivate employees under these new career conditions will have a long term advantage in process innovation over those that cannot.

Work role rotation. Because processes are typically collections of functions, a process worker should know as much as possible about other functions and activities in order to be able to effectively integrate across them. One way to ensure broad process knowledge is to rotate workers through the various jobs in the process or in related processes. This, like process-oriented career paths, is a long-term enabler of process innovation that should be established broadly throughout a company rather than for a specific process.

Lifetime employment. A lifetime employment policy greatly facilitates process innovation. Employees who feel that they have a job for life are much less worried about designing or performing their jobs out of existence. IBM is one of the few large companies headquartered in the United States that still maintains a lifetime employment policy (and its policy is weakening rapidly under economic pressures), but many firms around the world do so, particularly in Japan. Large Japanese firms' employment of this policy is often credited for the process flexibility and grass-roots innovativeness of their employees [26].

The absence of these human resource enablers could be considered constraints to process innovation. In fact, most change management methodologies of which we are aware focus on identifying and removing organizational and human resource constraints. The positive tone of enablement may spur more enthusiasm for innovation.

II.1.2. Managing Human Resources and Organizational Change

The primary lesson to be learned from extensive sociotechnical research is that social and technical change must be managed jointly. Any approach to embedding the enablers should be a joint method, with concurrent consideration of all the enablers necessary for a specific process design.

Richard Walton has proposed that all major systems changes be accompanied by an "organizational impact statement" that lays out the simultaneous development of the information system and the organization [24]. Although he offers other options- "anticipatory development of the organization" (which may be appropriate for some of the broader and longer-term human enablers described above) and "reactive development of the organization"- he argues most strongly for simultaneous development.

What form simultaneous development should take depends on how an organization plans to implement technical and organizational change. For example, a firm using a systems-development lifecycle methodology to structure the development of new information systems that support a process should manage human change along with the systems change. The company should plan the organizational and human resource changes as it plans the system, design the human change in detail as it designs the system, and construct the new organizational structures, cultures, and human resource procedures as it constructs the system [30].

II.1.2.1. Designing and Implementing the New Process and Organization

The design activity is largely a matter of having a group of intelligent, creative people review the information collected in earlier phases of the initiative and synthesize it into a new process. There are techniques for facilitating the review process, but the success or failure of the effort will turn on the particular people who are gathered together.

The choice of participants for a new process design team should be governed by both design and implementation considerations. A balance must be struck between team members who can deliver the most creative and innovative process solutions and those who can help to ensure that they are implemented.

Although in most organizations, the same individuals who participated in the process selection and visioning phases will participate in the design phase, it is

particularly important that key process stakeholders feel their interests are represented during the latter phase. Stakeholders who should participate on the team during the design phase include heads of key functions intersected by the process, key general managers with operational responsibility for the process, suppliers of important change resources (e.g., the IT, human resource, and financial functions), and process customers and suppliers, both internal and external.

The implementation of new process designs, including requisite intermediate steps, and the implementation of new organizational structures and systems designed to reinforce and support new ways of working will be covered below. Key activities in the design phase are listed in Figure II.1.

- Brainstorm design alternatives
- Assess feasibility, risk, and benefit of design alternatives and select the preferred process design
- Prototype the new process design
- Develop a migration strategy
- Implement new organizational structures and systems

Figure II.1. Key Activities in Designing and Prototyping a New Process [1]

2.a. Brainstorming Design Alternatives

Design innovation is best accomplished in a series of workshops, and brainstorming is an effective means of surfacing creative process designs [31]. Any group facilitation technique or practice that encourages participation from all group members, regardless of their roles and relationships within the organization is referred to by brainstorming. Emphasis during brainstorming sessions should be on creativity and idea generation, and a nonjudgmental atmosphere is essential. Participants must feel certain that they can share their thoughts without risk. The objective of brainstorming sessions is to develop creative, but pragmatic new process designs, taking as input the process vision, change enabler, and benchmark knowledge developed in the earlier phases of process innovation.

It is often useful to define the new process in an iterative fashion, with greater detail at each successive level (see Figure II.2). To begin with, a high-level flow of the overall process should be created. This should not be difficult, given a well-articulated process vision: At the next level of detail, each subprocess can be

described with roughly the same thoroughness as was used in describing the general process in the first iteration. Finally, each major activity should be described in terms of such factors as who will perform it, the information needed to carry it out, and so forth. For the sake of coherence and consistency, different graphic icons should be used to portray each level.

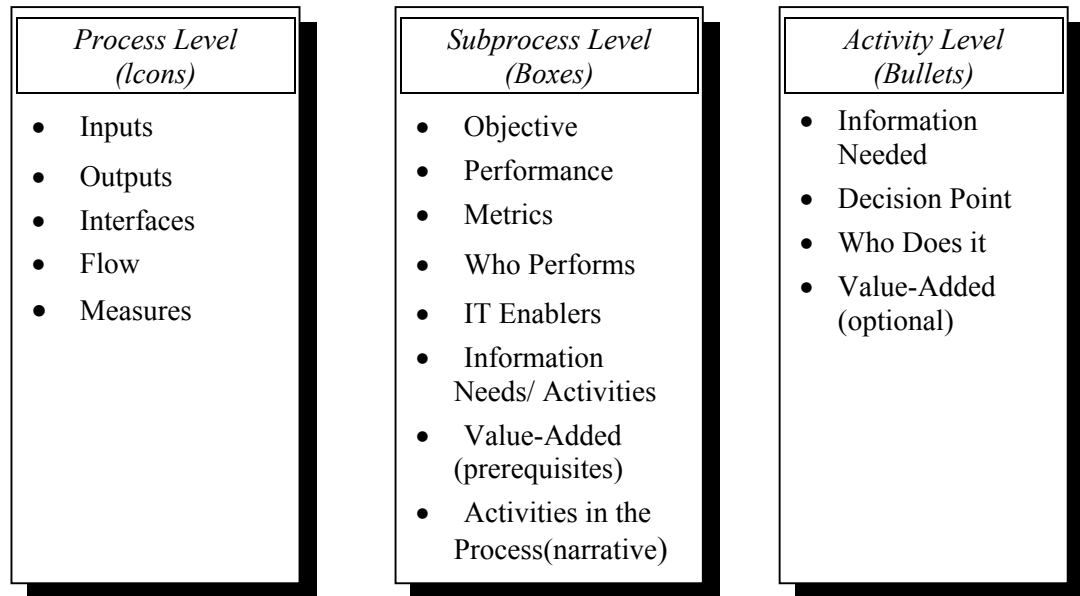


Figure II.2. Levels of Process Design [1]

2.b. Assessing Feasibility, Risk, And Benefits

The minds of design team participants should be full of information as the design activity begins. Participants should be well versed in the high-level vision for the process, including performance objectives and attributes, and be aware of opportunities and constraints presented by likely enablers, both technological and human/organizational, of the target process. They should be familiar at least with the broad performance parameters of the current process.

Brainstorming sessions usually produce a number of design alternatives, which must be submitted to feasibility analyses to evaluate their relative benefits, costs, risks, and time frames. The new design and current state must be compared in terms of structure, technology, and organization to fully understand the implications of each alternative. The results of these analyses provide the basis for selecting the optimum design.

2.c. Prototyping The New Process

Developing a prototype is a way to simulate and test the operation of a new process. It is an iterative process in which the fit between new process structure,

information technology, and organization is refined. A prototype might be considered the analog of a scientific experiment performed in a laboratory setting. Our definition is a small-scale, quasi-operational version of a new process that can be used to test various aspects of its design. This kind of prototype is known as an organizational prototype [32].

There is no way to predict the organizational impact of a redesigned process and associated information technology with complete accuracy. The goal of the prototyping is to gradually shape the organizational environment or, alternatively, to revise the technology. Prototyping can itself be viewed as a series of phases that yield increasing degrees of tangibility (see Figure II.3). Computer simulation is a kind of limited process prototyping, beyond which it may be reasonable to create a paper-based information test of the process. In subsequent phases, the prototype might be taken to a stand-alone process test, using personal computers for information support, and interfaces to other processes and existing information systems might then be added to it. The ultimate prototype would include all enabling technologies, skills, and organizational structures. Each phase helps refine the process design and the information required to support it; taken together, these phases help reduce implementation risk.

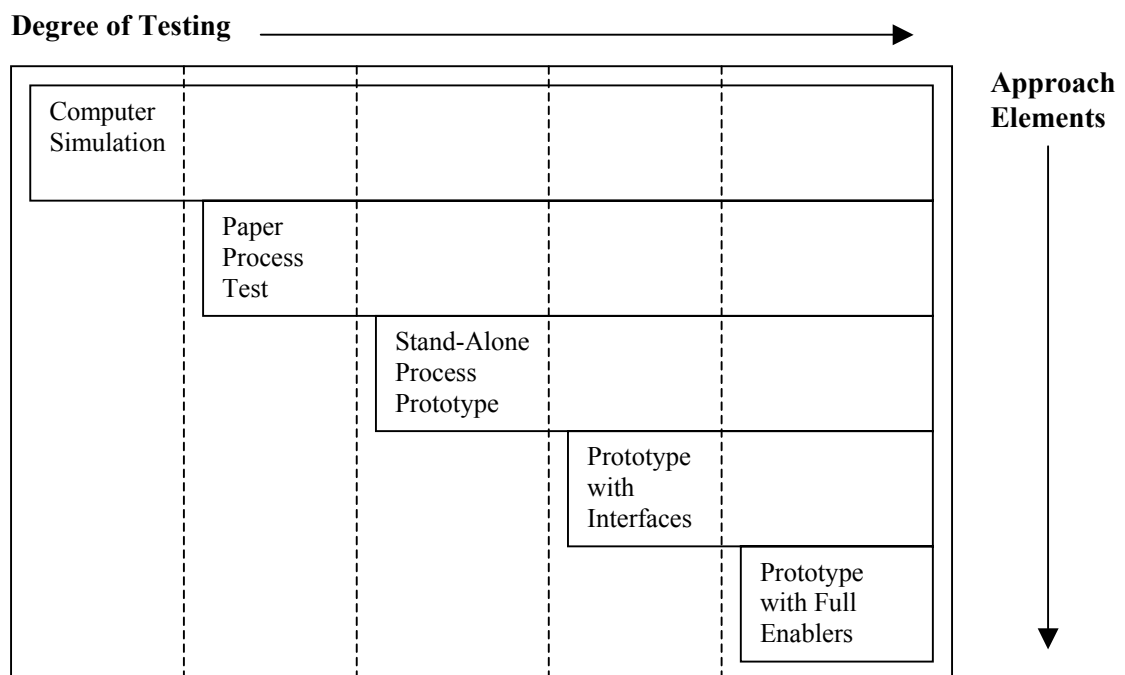


Figure II.3. Levels of Process Prototyping Degree of Testing [1].

2.d. Migrating To A New Process

Having designed and tested a prototype process, an organization faces the considerable challenge of migrating from the current process environment to the radically new design. A full "cutover" may be difficult or impossible. If the new process involves customers, revenues, or valued employees, or if the process change will be highly visible internally or externally, the firm may not want to risk an abrupt transition. Alternatives to full cutover include phased introduction, creating a pilot, or creating an entirely new business unit.

A pilot is a smaller scale, but fully operational, implementation of a new process in a relatively small unit of the organization based on a particular geography, product, or set of customers. Although pilots are often viewed as a means of testing a new process (or other type of intervention), the goal should be to achieve success rather than merely objectively test. Thus, the unit selected should be the one most capable of achieving successful change.

If constraints within the existing environment are too great, it may be desirable to create a new organization for the new process.

2.e. Implementing New Organizational Structures And Systems

Firms and organizations today tend to be structured in a way that works against the success of their new process designs. Most organizational structures are based either on function or product, with little or no process orientation. Functionally organized firms have difficulty meeting customer needs seamlessly across different functions because no one "owns" the issue of how long it takes or how much it costs to fulfill customer requests.

Although the problem of rigid functional organizations is widely recognized, the proposed solution-to abandon any form of structure beyond the self-managing team-is frequently worse than the problem, or at least much less well defined [33].

A more process-based, rather than post-structural, organization offers a powerful compromise between the need to maintain structure and the desire to adopt a flexible approach to the way work is done. Until a process-based organization is established, a new design for work cannot be considered fully implemented.

II.1.3. Understanding Process Innovation As Organizational Change

As a form of organizational change, process innovation is characterized by simultaneous dramatic change in many structures and systems. To manage successfully across all these fronts, managers must be aware of the nature of process innovation as organizational change, the likely sources of problems and resistance, and the areas in which their attention is likely to be required. Specifically, process innovation-oriented change must be understood in terms of five characteristics: the overall magnitude of change required, the level of uncertainty about change outcomes, the breadth of the change across and between organizations, the required depth of penetration of individual attitudes and behaviors, and the duration of the change process.

Process innovation and the organizational change are equivalent to radical surgery. They are the triple bypass operation, the removal of a large malignancy, the transplanted organ. Given the magnitude of the risk and reward, process innovation should be undertaken when more moderate business improvement approaches have failed or will clearly fall short of the need. Process innovation can only be accomplished when the leaders of an organization believe and can demonstrate that current modes of operation are a threat to the survival of the company.

Pain, hope, and uncertainty. The pain of the current state must be visible not only to outsiders, but widely accepted by senior managers within an organization. Often, consultants, the business press, and a handful of executives are aware that problems with key processes threaten a firm's long-term survival, but are unable to convince the majority of the firm's managers that radical corrective action is required.

The sense of organizational "pain" can be manipulated to some degree by senior management, but unless such pain is widely felt and acknowledged by key members of the executive team, any process innovation initiative is likely to be sandbagged or sabotaged. The trick, of course, is to convince an organization of the need for change before a crisis occurs while there is still time to do something about it. The pain associated with maintaining the status quo must be seen to exceed the inevitable and very considerable pain associated with the transformation to a new way of operating.

On the other side of the motivational coin are hope and positive expectations.

Some process innovation initiatives are motivated by hope alone, but most involve a combination of pain and hope. Hope for greatly improved operational and economic performance must be held out to the organization by its leader in the form of a vision. To hold the attention of management, and thus the rest of the organization over the long term, this vision must describe changes in ways of operating as inarguably strategic imperatives. Statements about the objectives and attributes of the future process state are inherent in our definition of a vision.

Uncertainty about the end state is as characteristic of process innovation change as it is of other types of major change in corporations [34]. It is neither possible nor desirable for a leader or anyone else to define at the outset precisely how a transformed company will operate. Process objectives and attributes must be stated in advance, but the process that emerges and the benefit that accrues to it cannot be anticipated. Second- and third-order effects of a given change or set of changes will inevitably lead to further unforeseeable insights and adaptations.

Major change of any kind, even change perceived to be positive, produces anxiety and resistance. Uncertainty about the end state heightens this reaction. To quell anxiety and overcome resistance, a successful change leader must not only foster awareness of the need to change, but also create realistic, positive expectations about the outcome. The manager must draw a bold outline of a compelling future state and be able to fill in enough detail to convince others that to follow is to gain higher ground.

Coordination and cooperation. Process innovation, by definition, spans traditional organizational boundaries. Propelled by mounting competitive pressures and a need to reach new levels of organizational performance, leading companies have realized that functional management and incremental functional improvement are no longer sufficient; in fact, process changes occurring today span inter- as well as intraorganizational boundaries.

Major changes that have occurred in many firms' manufacturing processes over the past decade illustrate the requirements for new levels of internal and external coordination and cooperation. Just-in-time (JIT) inventory management is a case in point. To speed the flow of goods through their factories, manufacturers have reduced the work-in-process (WIP) inventories that buffered different parts of the manufacturing process, obscuring process imbalances and quality problems and clogging the flow of goods. Maintaining a steady flow of goods in a bufferless state

requires tighter coupling not only across the steps in the manufacturing process, but also with the production and materials planning organizations. To provide scheduling stability, the linkage between forecasting and production planning must be tightened and their respective cycle times reduced. This tearing down of internal functional walls is known as "internal JIT," or "continuous flow manufacturing."

Cultural and paradigm shifts. Creating tighter internal linkages between functions entails not only changing structure, but also bridging cultural differences and upsetting traditional power balances. In order management processes, for example, the field sales personnel also become credit checkers, manufacturing expeditors, and logistics analysts. Functional managers must trust that employees have the capacity to gain the experience needed to perform their tasks. Interfunctional and interorganizational trust are desirable generally, but they are only essential in the context of process innovation.

Change incurred by process innovation is not only broad, but deep, extending from the visions of managers to the attitudes and behaviors of the lowest-level workers. As with other types of major organizational change, the behavioral aspects of process innovation equal the structural aspects in magnitude and importance, and often are more difficult to address. Its significant behavioral component makes process innovation-based change qualitatively different from other forms of large-scale restructuring; it runs deeper than even major acquisitions or asset liquidation. Organizational charts come and go, but changes in the way a business and its employees operate on a daily basis cannot be prescribed on paper.

Behavioral change. Successful leaders of transformational restructuring understand that changes in mental models, attitudes, values, and, ultimately, behavior are the foundation for successful implementation of these changes in operational and management structures and systems. They also understand that changes in mental models must precede changes in behavior. Greater cooperation between functional groups is an example of the kind of behavior that is almost always required to improve the performance of major organizational processes.

Companies usually underrate the importance of developing new behavioral competencies and fail to devote sufficient time, effort, and resources to the task. Successful process innovation leaders see new behavior as an integral part of the vision of the way their organization will operate in the future. Recognizing that change in the behavior of individuals and groups is the foundation for successful

institutionalization of structural process changes, they devote explicit attention to developing new behavioral competencies. Training to promote, and constant reinforcement of and informal rewards for, new behaviors are essential during the period of initial organizational learning.

Duration of change. A final aspect of process innovation as organizational change that must be understood is the duration of the change. Change of the magnitude we are describing usually requires a minimum of two years to plan and implement in a given business unit, and we have seen it take as much as five years. The multidimensional scope of transformational change is an obvious driver of the time requirement. It is simply not possible to plan and implement major changes in multiple organizational systems and structures overnight. Moreover, successful implementation of transformational structural change is dependent on changes in beliefs and behaviors, which take time to cultivate.

II.1.4. The Structure Of Process-Oriented Organizational Change

Given the risks and rewards inherent in process innovation, a firm must establish a change structure within which specific initiatives can be successful. Such a structure specifies key roles and responsibilities for change tasks, the types of teams necessary to design and implement new processes, and the composition and skills of the individuals and teams who will participate. The establishment of this structure is, of course, most difficult for the first process initiative; subsequent initiatives can benefit both from the established structure and from learning about how it performed the first time.

II.1.4.1. Roles and Responsibilities

Executive participation is important for communicating management support for and belief in an innovation project to the entire organization. Organizational change associated with process innovation can only be driven top-down. It requires the commitment and involvement of the entire executive team, but ultimately it must be driven by a dynamic executive who serves as the focal point throughout the change process [35].

Three qualities characterize successful transformational leaders: commitment and the ability to inspire, conceptual skills, and impatience for results, the last being

coupled with an ability to deal with the "softer" behavioral aspects of change.

Commitment is an essential ingredient in all leaders. The executive sponsor's degree of commitment-commitment based on utter dissatisfaction with the status quo and a passionate belief in the new ways of operating articulated in the strategic vision-is the single greatest determinant of change management success.

Associated with this deeply felt commitment to a new operational vision is the capacity to inspire and incite. The words "charismatic" and "magic," used by David Nadler, are often associated with individuals who have this ability. Although researchers have tended to focus on the emotional qualities of transformational leaders, major change efforts require more than commitment and emotional impact. The transformational leader is the initial owner, if not creator and primary proponent, of a change vision, and hence must be able to conceptualize and articulate totally new ways of structuring and operating a business [36].

Successful business-unit change leaders are hard-headed, results-oriented executives who set high standards and remain dogmatic and insistent about business results. At the same time, they understand the importance of organizational change and have an ability to deal with its softer dimensions. Impatience for results and a realization of the conscious effort and time that is required to nurture new attitudes and behaviors in groups and individuals are hallmarks of successful transformational leaders. Process innovation leaders, especially at the business unit level, often must modify their own attitudes and behaviors to be consistent with the evolving norms.

But process innovation requires more than a single, charismatic leader. Because the requisite leadership functions range from originating a process innovation initiative, to making it acceptable and necessary, to managing it through to completion, most major change situations involve some type of division of leadership labor. Four major change roles defined are as follows:

- the change advocate, who proposes change but lacks sponsorship;
- the change sponsor, who legitimizes the change;
- the change target, namely, the individuals or groups that must undergo change;
- the change agent, namely, the individuals or groups that must implement the change.

Ensuring that the right people fill each role is crucial. One of the most common mistakes made by companies embarking on process innovation is choosing the

wrong sponsor. The sponsor of process innovation activities plays a pivotal role in defining and driving change within a business unit. The individual of choice must possess the commitment and abilities of the transformational leader. But the political and organizational positioning of the process innovation sponsor is also of critical importance. Executive sponsors should be among the most senior managers in a company.

The sponsorship of change must usually be broader than a single executive. Only when it perceives a unified front on the part of the executive team will the rest of an organization take a process innovation initiative seriously. It is also important that an innovation initiative in a business unit have at least the tacit support of corporate executives.

Functional executives may also be advocates of change. In order to perform this role successfully, they must help introduce the concept of process innovation to the organization and persuade other senior managers of its merits.

Ultimately, it falls to the change leader or sponsor to create and maintain strong commitment and consensus among the executive team members with respect to the need and vision for change and the plans for creating radical improvement in strategic processes. Failure to achieve executive team consensus can prevent a business unit's process-innovation efforts from ever getting off the ground, and failure to maintain commitment and consensus will diminish the degree of change that is achievable and delay progress and the realization of benefits.

II.1.4.2. Types of Teams

The objective of process innovation is to optimize the performance of the business unit as a whole. This is often accomplished by creating new team structures that span traditional boundaries. The teams formed may be at two levels, executive teams and process innovation teams. Executive teams within a business unit make key decisions about process innovation initiatives and review results. Their work might include selecting processes for redesign, forming the process innovation team, supplying strategic direction to a vision effort, and selecting from alternative designs. They may be composed of change sponsors, agents, targets, and advocates-all at the senior-most level.

Process innovation teams do the detailed work of process innovation, including gathering information for process selection, searching for benchmarks, identifying

enablers, creating more detailed visions, defining process flows, and creating prototypes and transition plans. As noted, some firms create a single team with all these functions. Other firms have achieved good results by creating separate teams, with minimal overlap, one to analyze the current process and another to design the future process. Given the importance of change management concerns, some firms have established a third, usually somewhat smaller, team specifically devoted to organizational change-management issues. Unless such a group is created, a process innovation initiative risks starting change tasks too late, or neglecting some change topics completely. Again, overlap of change-management team members should be minimized to prevent overload. Although such a multiplicity of teams is expensive, the cost is quite low when compared to the potential rewards.

Given the rationale for such teams-to "increase coordination across functions and activities so that the performance of the whole is greater than the sum of its parts"-it is not surprising that they almost invariably remain important ongoing structures after process design efforts have concluded. In addition to being a mechanism for developing implementable recommendations, well-functioning process-innovation teams model the way the enterprise as a whole will operate in the future. At the same time, they are an important mechanism for developing the new behavioral competencies needed to make the process innovation succeed.

Ancona and Nadler have identified three important team management processes-work management, relationship management, and external boundary management-that need to be explicitly mastered by executive and process innovation teams [37]. Work management and relationship management processes are essential because of the high degree of interdependence among process-innovation team members. Work management deals with how the group makes decisions, shares information, and coordinates activities, relationship management with issues related to degree of openness and cohesiveness, conflict resolution, and levels of trust.

II.1.4.3. Composition and Skills

Several criteria should be applied when forming a process innovation team. First, there must be a stakeholder analysis. A stakeholder is anyone with a vested interest in the process-a customer, a department manager, an employee involved in one of the process activities. Stakeholder analysis identifies individuals who are likely to be affected by a process innovation. Whenever possible, key stakeholders

should be assigned to project teams.

Managers and other employees who are likely to "lose out" as process innovation redefines and reconfigures activities and responsibilities must be involved in the project to foster commitment to its goals. To the extent that it is logistically impossible for all stakeholders to participate on the project team, other avenues must be found for allowing individuals who are left out to contribute. Data gathering comes to mind. Whatever the avenue, the activity must be at a level that ensures support.

Cross-functional representation on project teams is essential to ensure that a variety of perspectives is brought to bear on innovation efforts. One manufacturer attempting to reduce cycle time for new product development, for example, assembled a team that comprised individuals from sales, product engineering, manufacturing engineering, and the affected plants.

Finally, a process innovation consultant can play a key role in innovation efforts. Such consultants, who may be either internal or external, will possess experience in improving and redesigning processes. In many companies that have formed business units dedicated to assisting with business process innovation- - CIGNA, Continental Bank, and IBM for example- the responsibilities of the information systems function have been expanded to include business process redesign. Other enterprises have established entirely new groups to provide process innovation expertise and facilitate and guide the change process. Such groups also typically provide training in the data-gathering and problem-solving techniques that will be employed in the change effort, and are candidates for managing process interfaces and facilitating interprocess project communications. Firms hiring external consultants often ask them to train internal personnel so that process innovation work can eventually be brought in-house.

Just as sponsors must exercise care in assembling their executive teams, so process owners and executive sponsors must carefully configure each process innovation team. Organizational representation is a primary factor. Clear articulation of the scope of the target process will help define the appropriate make-up of process innovation teams. All change targets must be represented directly, both for their functional knowledge and to ensure buy-in.

Team candidates' characteristics and skills must be carefully weighed against the functional knowledge they bring to the table. Ideally, creativity and openness will

be blended with sound business judgment and the ability to synthesize information from multiple sources. Team members must grasp strategic realities and possess an operational understanding of the business. In today's organizations this combination will most often be found in the middle to upper-middle ranks of a business unit.

II.1.5. Managing Organizational Change in Process Innovation

Even with a high level of awareness of change issues in process innovation and a structure of teams and team members, change must still be managed carefully. Among the factors to be emphasized in the change management process are the timing of change, the creation of a sense of meaning and mission, the management of scope, communications about the change process, and the avoidance of common pitfalls.

The timing of process innovation, involves a delicate balance between acting early, when the need for change may not be widely appreciated, and acting late, when the organization is desperate. Waiting too long will put management in a reactive mode and necessitate drastic measures. Such forcible imposition of change might rupture the trust between management and employees and thus make it impossible to achieve common objectives of corporate renewal such as a highly motivated work force. It is better to time the initiation of large-scale change efforts to accommodate a more proactive and positive approach [34].

Duration. A number of other factors influence the duration of transformational change in a business unit. One, varying degrees of readiness among the leadership in various groups within a business unit will influence the pace, and thus duration, of the change effort; a group's leadership must buy into the need for change before any progress can be made. Two, building commitment to and encouraging involvement in a change effort takes time; the make-up of a group at different levels and the need for individuals to adapt or be replaced must be managed with a balance between urgency and sensitivity. Three, change programs need to coexist with ongoing business operations; the pace and duration of change will be driven by the amount of change individuals and groups can absorb and still continue to function productively. No manager should expect that process innovation for a broad process can be fully designed and implemented in less than 18 months to two years.

Scope. Scope management is important because the larger and more diverse the

entity to be changed, and the greater the change sought, the more difficult the process of effecting and managing it. The difficulty of managing strategic change in large, diverse entities has implications for the way change efforts are bounded. In corporate settings, strategic business units tend to be viewed as logical boundaries for change efforts. Getting functions within a business unit to cooperate is difficult; broadening the scope of change makes it even more so. When these units are themselves large and diverse, it may be desirable to carve off smaller, discrete organizational units.

Given the risks associated with transformational initiatives, starting on the periphery makes sense, assuming that a company's competitive situation accommodates this luxury and that managers of other businesses will not discount successful results. Starting on the periphery enables a company to mitigate its risk by testing and refining concepts in order to gain experience with managing process change, including the development of executives and managers. This is consistent with Beer et al.'s findings about the difficulty of managing radical change across large, diverse organizations, and that corporate revitalization typically starts in discrete organizational units such as divisions or business units, plants, or branches and 'depends on successful renewal in many organizational units' [36].

Values, attitudes, and behavior. Changes in values, attitudes, and behavior cannot be effected by a decision taken in the boardroom or mandated in a memo. New process designs must come from the top down, but implementation of these changes is best likened to cultivating a garden. The ground must be prepared row by row. Gains on the behavioral front must be made group by group, person by person, including the leaders themselves. Successful change efforts attend explicitly to the development of new attitudes and behaviors. Extensive training is often provided to all employees, from executives on down, on topics including teamwork, group dynamics, and valuing differences.

Communications and commitment building. Given that achieving organizational change is perhaps the most difficult aspect of process innovation, a concerted effort must be made to communicate throughout an initiative about the change program and to build commitment to the new design. The team that is leading change cannot wait until the design is complete to become concerned about change management. At each step of the approach, there must be consideration of how best to communicate the activities and of what steps can be taken to ensure organizational acceptance. Communication and commitment building must occur at all levels and

for all types of audiences. Certainly senior management must exhibit positive attitudes toward the initiative and be receptive to the new design, but even the lowest level employees whose work is affected by the changes must be prepared to alter their behavior.

Although the details of communication and commitment building programs will vary with the organization and processes involved, regular communication must be established between the executive and process innovation teams and those who will be affected by the new process. Sensitive issues, such as the level and type of personnel reductions to result from the initiative, must be addressed honestly and openly. The selection of teams should be done in a way that maximizes acceptance of change by the rest of the organization.

Equally important to change communications is the creation and maintenance of a sustained sense of meaning in the process innovation effort. People want to be part of something meaningful, greater than themselves [38]. A vision that galvanizes an organization to action will include an emotional call to join in the taking of the moral high ground. Visions almost always begin with calls for "Excellence" and "Quality" in an organization's products and processes, but this appeal to emotions must be combined with a bold outline of what excellence will look and feel like and how it will be measured.

Communication to the organization as a whole needs to start well before implementation begins. Once the business unit head has built commitment within the executive ranks, he or she needs to begin to send signals to and energize the rest of the business unit. The sponsor must use public events, including speeches and meetings, and other communications media to prepare and rally the troops for the changes to come. All employees need to understand the competitive threats and the vision that is taking shape, and they need reassurance about the organization's ability to improve its processes and business results successfully. The announcement of process owners and teams is an obvious example of an occasion that should be exploited by the sponsor to get these messages out.

Measures. A successful change vision also includes the setting of clear strategic goals. Establishing measures of strategic success and setting parameters for these measures is part of the conceptualization of the vision and an important means of communicating how the organization of the future will differ from the organization of today. It is important that statements of objectives be specific and

measures operational. For those who must make it happen, stating that a division will reduce the cycle time for introducing new products by 50% by 1993 is much more meaningful and helpful than stating that the division will increase revenue by 15%.

A vision can also be communicated through a shift in the focus of existing, or through newly created, measures. New operating visions have turned some traditional measures on their ear. Until recently, most companies set goals and measured shipping and service delivery performance on the basis of a ship data committed to very late in the order/delivery cycle. Leading companies that have switched from producer time to customer time are measuring themselves on their ability to meet a delivery data requested by the customer very early in the order/delivery cycle.

Post-implementation interventions. Even after successful change efforts, organizations can not remain in radical change mode forever. At the appropriate time, the behavioral and operational changes must be solidified. Two "hard" management interventions are needed to maximize gains and prevent backsliding. The first is replacing resisters and/or individuals who have failed to adapt to the new environment, the second, making permanent changes in the organization's formal control mechanisms. Timing of these powerful interventions is critical; to achieve maximum benefit from a process innovation initiative, these interventions must occur neither too soon nor too late.

Leaders of successful process change replace resisters and those who cannot adapt to the new environment only after providing education, training, and coaching and allowing them ample time to adapt. Key executives and managers tend to be replaced during the planning phase, others during the implementation phase. Whenever replacement occurs, it sends a strong message to those who remain in the organization. But unless the replacement is perceived to be fair, there will be negative consequences. Poor timing of either set of interventions-people replacement or establishment of formal control systems and structures will yield suboptimal results. Replacing key individuals before they have been given adequate opportunity to grow and adapt will lead to demoralization and passive or suppressed resistance; waiting too long will delay progress and benefits; not replacing resisters at all will increase and institutionalize resistance because management will not be perceived as being serious [1].

II.1.6. Principles of Reengineering

Creating new rules tailored to the modern environment ultimately requires a new conceptualization of the business processes. In fact, some of the principles that companies have already discovered while reengineering their business processes can help jump start the effort for others.

- Organize around outcomes, not tasks.
- Have those who use the output of the process perform the process.
- Subsume information-processing work into the real work that produces the information.
- Treat geographically dispersed resources as though they were centralized.
- Link parallel activities instead of integrating their results.
- Put the decision point where the work is performed, and build control into the process.
- Capture information once and at the source.

Here's the radical manifesto of business process reengineering, 1) All activity that matters to customers can be described as a set of interrelated business processes. 2) Excellence in business processes and their continuous improvement is the secret formula for meeting the customer requirements. 3) Business process teams will displace functional disciplines as the critical organizational unit of world-class companies.

Business process redesign across a wide range of industries is uncovering new ways to organize work that, in turn, is creating breakthrough improvements. A process approach to organizational performance has produced a number of innovations: Quick response logistics systems; invoiceless accounts payable systems; "six sigma" quality achievements; accelerated new product development cycles; and the one-day accounting close [39].

II.1.7. A New Analytic Framework

New team concepts, tools, and methodologies are emerging to support process analysis, improvement, and management:

- Cross-functional teams, organized around processes, are rethinking traditional, functional perspectives of the business; eliminating departmental red tape; and taking charge of overall process performance.

- Rapidly improving computer economics and more flexible data communications are changing ideas of what is possible. Electronic models are replacing new product mock-ups and pilot projects and creating innovative ways of streamlining new product development. Dispersed processing is enabling team collaboration by making information and expertise available anywhere, anytime. Database technology is eradicating traditional territorial attitudes toward data, broadening access, reducing waiting times, and lowering costs.
- For the past decade, process analysis methodologies have been helping us satisfy customers more effectively. Quality function deployment helps embed the “voice of the customer” into products and services. Process design of experiments helps isolate defects or variations that have the most impact on quality and customer satisfaction. Design for manufacturing helps reduce manufacturing costs and cycle times by standardizing parts and tools, simplifying designs, and selecting product features to facilitate factory operations [39].

II.1.8. New Ways To Organize Work

The new analytic framework is helping to challenge traditional thinking on how businesses operate and inspiring management teams to find new ways to organize work:

- ***Extended Enterprise Concepts.*** World-class companies are managing business processes beyond conventional organizational boundaries. Car makers are improving product design by including suppliers’ experts on product development teams. Retailers are sharing demand information among channel partners to improve forecasting accuracy and to accelerate replenishment. Manufacturers are forming supplier alliances to shorten manufacturing cycle times.
- ***Concurrency.*** Process steps that have traditionally been sequential are being performed concurrently. The best new product design organizations are multidisciplinary teams working concurrently. World-class order entry processes permit order specification, inventory commitment, production scheduling, packaging, labeling, documentation and routing to be resolved in a

single telephone call from a customer. Production process flows are being rationalized by integrating equipment, tools, materials handling, and maintenance into multifunction manufacturing cells.

- ***Displacement.*** Information technologies and software, coupled with process reengineering, can displace specialized functions, reducing costs and improving cycle time. For example, quality inspection is being replaced by quality validation during product development; receiving inspection is being displaced by supplier quality certification; and traditional order-entry functions are being displaced by direct customer order placement through electronic data interchange.
- ***Simplification.*** Creative business process redesign teams are challenging the need for traditional activities and functions and eliminating those that are no longer necessary. By linking vendors into production-scheduling systems, Ford has eliminated parts ordering. Another innovative firm has eliminated invoice processing for minor purchases by mailing the payment with the order.

II.1.9. Transforming The Organization

While functional organizations and accountabilities will be with us for some time, crossfunctional organizations and teams are becoming a common organizational characteristic. The best organizations are assigning clear accountability for process performance and realigning functional objectives and performance measures to support process performance goals.

New, more malleable information technologies are being built into process designs. Information systems used to be considered an adjunct to the business process, but now they are being embedded in process designs. Old, rigid, centralized architectures are being replaced by flexible, dispersed networks that enable process improvements that enhance performance.

A successful transformation program needs a clearly defined organizational structure, roles, and accountabilities. Our experience suggests that four groups play a key role in successful change (see Figure II.4):

- ***Executive Steering Committee.*** The CEO and the senior management team champion the change process, set the goals, assign the resources, expedite progress, support change and remove barriers.

Executive Steering Committee • Champion the process • Set overall improvement targets • Select initial process evaluation teams • Provide high profile to need for change • Monitor results and expedite progress • Support changes • Remove barriers • Integrate with other company initiatives	Line Management • Participate in executive workshops • Help define <i>value</i> in their role of internal customers • Provide customer input to teams • Contribute resources to teams and committees • Support implementation of change • Reorganize and redeploy resources
Process Evaluation Teams • Conduct <i>value</i> assessments • Develop process improvements • Develop process measurements and targets • Monitor process improvement • Conduct continuous process improvement activities • Change processes • Evaluate organization and manpower deployment	Consultants/Facilitators • Help define objectives, scope and approach • Provide technical assistance and training • Coach teams • Help ensure conformance with company goals, objectives, and directional inputs • Facilitate workshops and team meetings • Provide an external reality check on conclusions • Monitor the process and keep it going

Figure II.4. Organizing for Change [40].

- ***Process Evaluation Teams (PETs).*** Cross-functional teams provide the baseline, benchmark the existing process, construct the vision of the future process, design the improvements, and oversee implementation. Subteams-created by the PETs when needed-resolve complex problems or capitalize on high-potential opportunities.
- ***Line Management.*** The line organization provides resources to the change effort, then implements the agreed changes. Because implementation is the most

difficult hurdle in any change program, line management involvement is a critical ingredient for success.

- **Consultants/Facilitators.** External consultants assist in the design of the programs, train and facilitate the teams, provide tools and methodologies, import industry and technical knowledge, provide an external reality check, and challenge the thinking.

II.1.10. Executing A Methodology For Structured Change

Sometimes business processes can't be redesigned with a clean sheet of paper; the methods already in place may be tied to physical assets or other constraints that can't practically be overlooked. In such cases, process reengineering starts with the existing framework and focuses on improving it.

On the other hand, some business processes are so bound up in antiquated thinking or outmoded technology that they defy repair. The only solution is to completely replace them. In these cases, process reengineering deemphasizes analysis of the existing process and focuses on creating the vision of the future process. But whether we are improving an existing process or designing a replacement, our goal is always for breakthrough, not incremental improvement.

Typically, the point of departure for the change initiative occurs when the chief executive officer articulates the strategic context and mandate for change. The CEO typically chooses an internal forum, such as the executive committee, as an arena for debating and agreeing upon the business imperative (see Figure II.5). The methodology for supporting this change is:

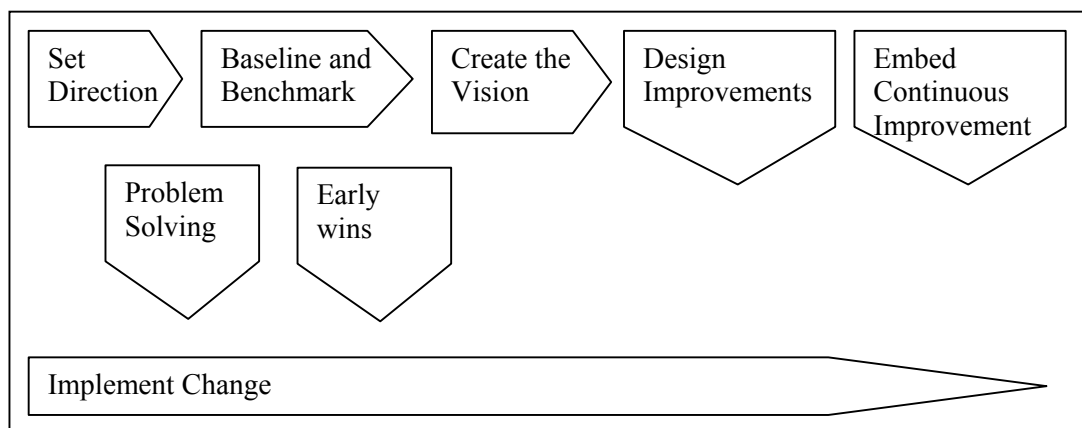


Figure II.5. A Structured Methodology for Process Change [40].

Step One: Set Direction. During an initial 2-to-4 week planning period, the steering committee decides which business processes will be redesigned, in what sequence, and by what teams. The members of the steering committee set macro targets for overall performance improvement. They identify the processes most critical to competitiveness and those offering the greatest opportunity for improvement.

Because thinking in terms of processes may encounter powerful resistance in many organizations, the steering committee may need to spend some time defining the scope of each process and articulating specific process-improvement goals. This sets the stage for deciding which functions need to be represented on each cross-functional PET. Next comes the selection of the leader and members of each team, while also taking steps to ensure that the organization continues to function in the absence of several key people.

The steering committee then designs and launches a communications program to announce the change initiative and to disseminate ongoing information on the process.

Step Two: Baseline and Benchmark. Next, the process-evaluation teams may spend up to 6 weeks learning all the ins and outs of the existing process. The PETs articulate the business process mission and objectives. They identify the customers for the process outputs. And then they conduct surveys of customers to understand their requirements, the current levels of customer satisfaction and value criteria.

The PETs then map the "as is" process flows, activities, and technologies. They establish a baseline for transaction volumes, cycle times, defect rates, and costs. They benchmark the practices and performance of comparable organizations in order to set their own aggressive but achievable goals. They identify or reevaluate performance metrics and begin to shape the steering committee's macro targets into process-specific objectives.

"Early wins" invariably surface from the baseline analysis. These are opportunities to make immediate improvements, and line management is responsible for implementing them. Early wins are critical because they increase cash flow and demonstrate the value of the methodology. They also provide a shakedown cruise for the various teams- they discover first hand the difficulties of implementing real-world change.

Step Three: Create the Vision. While they scrutinize the existing process, the PETs also begin to visualize the future process. This requires PET members to break out of the conventional thinking about how their organization works and launches them into the broader world of possibilities.

Because breakthrough thinking can only originate outside the organization, the PETs need to spend time interpreting benchmarking results, understanding market-place and industry trends, and familiarizing themselves with emerging information technologies. Consultants can contribute significantly to broadening the PETs perspective, and so can suppliers and customers invited into key team meetings.

PET members also need to spend time off-site in visioning workshops to help them shift mindset. These workshops can be exciting events filled with truly creative thinking. They often result in new ways of organizing processes for breakthrough results. Once the vision has been created, the PETs document their new ideas, then communicate and explain the future process to the steering committee and line management. The result of the visioning process is not just an idea. To be truly successful it requires total organizational buy-in.

Step Four. Launch Problem-solving Projects. At the same time that the baseline and visioning steps are proceeding, the PETs initiate projects to investigate detailed problems or capitalize on high-potential opportunities. Such projects typically deal with a wide range of issues- for example, changing product identification codes, changing account-management practices, or implementing a measurement system.

The detailed problem-solving projects are assigned to temporary subteams or sub-PETs under the leadership of a PET member. This approach enables people close to the problem, or to the opportunity, to be included on the team. This, in turn, expands the resources available to the PETs, involves a broader cross-section of the organization in the change process, and allows the PETs to stay focused on overall process issues.

Step Five: Design Improvements. The baseline and vision steps generally draw to a close 12 to 14 weeks into the change initiative. At this stage each PET has both assessed the priority opportunities for improving the existing process and established a vision for what the future process should look like. The PETs have probably set a number of early-win opportunities in motion, and are also managing four to six sub-PETs undertaking detailed improvement projects. By continually

measuring performance improvement on a regular basis, the PETs have a clear grasp of their impact on business results so far.

At this point the PETs begin to consolidate their analyses and develop a comprehensive plan for process improvement. They prepare a blueprint that outlines the future process and a supporting technology architecture that describes the supporting information systems at the design criteria level. Taken together, the process blueprint and technology architecture form a road map that integrates major process and supporting systems changes. This road map then becomes the primary vehicle for communicating the intended changes across the organization.

In addition, the PETs prepare an integrated action plan showing how the blueprint and architecture will be implemented. The action plan describes future changes to the organization structure and staffing levels in support of, or resulting from, process redesign. The PETs establish process performance measures and targets; set the implementation agenda for line management; and scope out the necessary information technology projects. Included in the action plan documentation is the business justification for any capital investments or significant operating expenditures needed to change the business process.

Step Six: Implement Change. Implementation begins up front with the early wins and continues as the PETs spin off problem-solving projects. The full-scale improvement program builds on these initiatives and elevates the activity level to a point where virtually the entire organization is involved in the change process.

Pilot or demonstration processes are established to demonstrate and validate the process changes and new technologies before the full-scale rollout. Training programs are initiated to teach employees needed skills. PETs also track and report achievements against targets, and communicate and celebrate performance-improvement successes.

Step Seven: Embed Continuous Improvement. The ultimate step is to embed teamwork behavior throughout the organization in place of traditional management methods. Teamwork is a well-defined and observable set of behaviors in the day-to-day management of the business. These behaviors include upward, downward, and lateral communication; ongoing measurement and team review of performance against clearly defined targets; feedback from and reinforcement of team members; and continuous improvement of performance through performance-tracking systems and problem-solving skills.

This methodology does not have an end point- the change process is ongoing. The PETs become permanent organizational groups, the custodians of their respective processes. Once the process blueprint and information architecture are in place, the PETs regularly monitor process performance, benchmark emerging best practices, and make continuing recommendations for process improvement. After the line organization has been trained and coached in teamwork behaviors, continuous improvement becomes an ongoing feature of the day-to-day management of the company.

II.1.11. Business Process Reengineering

Business Process Reengineering (BPR) is the most recent in a long line of management innovations adopted by corporations across the industry and commerce in Britain and the US [41-43]. Not only do management practitioners have widely different perceptions as to what BPR means, but also a growing academic literature is challenging the claims and promises that are made on its behalf [44-46].

BPR can be viewed as a compilation of a well-known set of techniques repackaged to respond to, and meet, the anxieties and concerns of contemporary business and management. Although none of its components is completely new, three key features differentiate it from other recipes for business transformation.

1. **From function to process.** The claim that BPR can or should produce radical or revolutionary, quantum-leap change that secures competitive advantage by reorienting businesses around key processes. This involves a complete replacement of traditional bureaucratic and functional divisions by units organized around delivering customer orientated outputs. It is also promoted by the use of exceptionally blunt, colourful and violent language.
2. **Entrepreneurialism.** The belief in the “free market” and “entrepreneurialism”. This involves transforming organizations so that everyone is driven by a competitive desire to provide the 'best' and most profitable customer service.
3. **Information technology.** An emphasis upon the use of computer technologies combined with a veneer of HRM-type ideas about empowerment, team working etc.

Others have located BPR in a trajectory of change determined by the development and application of technology. Notably, Vankatraman [47] has argued

that BPR is but one of a number of stages in the revolution transformation of business and organization through the application of information technology (IT).

As seen from Figure II.6, prior to the development of BPR there are two evolutionary stages in the use of IT. First, there are localized exploitations of IT applications that are fragmented and unrelated to one another. Second, there is an attempt to integrate these applications through a single integrated IT platform. This has major implications for business processes, thus rendering BPR immediately resonant with the problems identified in seeking to integrate a diverse range of IT applications. Once BPR has been successfully established, as an internal system, the concept of redesign can be exported to the network of organizations with which the company interacts, stimulating a fourth stage of development that Vankatraman terms Business Network Redesign, leading to the creation of a Virtual Organization. The final stage is Business Scope Redefinition, where IT is used to expand the networks and business activities through which a reengineered organization operates. The latter three stages are seen as revolutionary. However, it is difficult to discern any feature that renders them revolutionary rather than evolutionary.

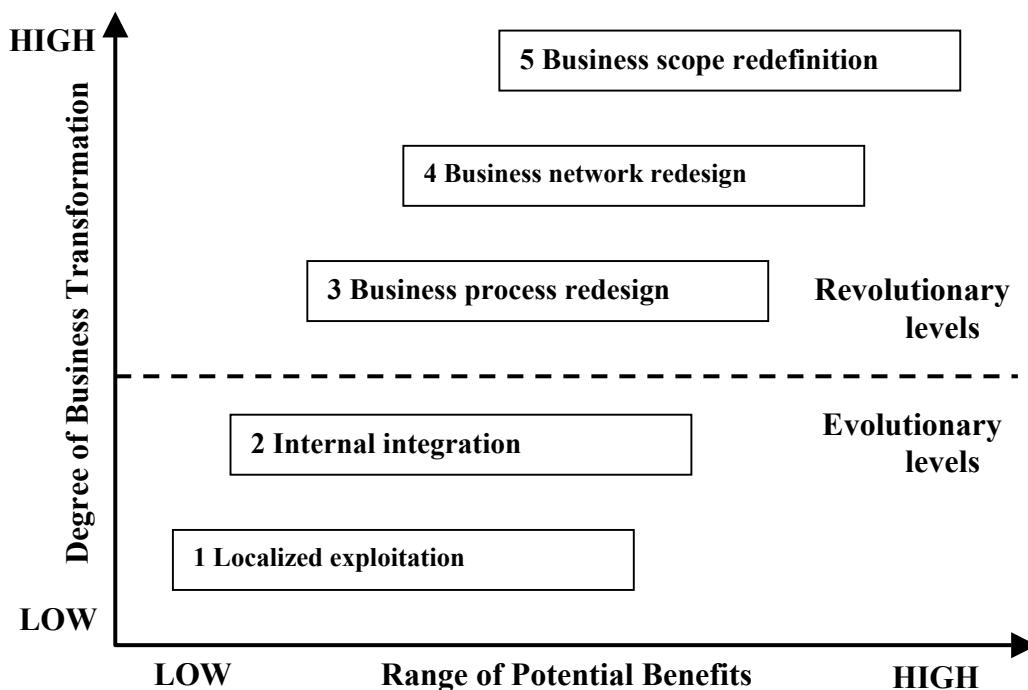


Figure II.6. Business Transformation Levels [47]

Certainly, the promise of BPR is to achieve revolutionary organizational change. It aspires to realize vision by reintegrating and compressing work that is

currently fragmented by a specialized, bureaucratic division of labour. According to its leading proponents, BPR heralds a 'new beginning'. Reengineering is not just another short-lived management fad nor is it a continuation of historically rooted industrial practice [48-49]. Rather, it is the 'radical', 'fundamental' and 'dramatic' solution to corporate under-competitiveness. The challenges facing work organizations are so demanding, it is argued that an incremental approach is simply insufficient. Indeed, it may be counter-productive: Objectives of 5 % or 10 % improvement in all business processes each year must give way to efforts to achieve 50 %, 100 %, or even higher improvement levels in some key processes [1]. BPR, in common with other management techniques, requires active promotion. Its introduction cannot be left to an allegedly irresistible process of technological change.

Reengineering is an attempt, usually by people at the top, to impose new structure over old - to take one set of rigid rules and guidelines and impose them on the rest of the organization [50].

The reengineering process strongly reinforces hierarchy. But, at the same time, it is assumed that the outcome of this process will not simply be 'flatter' hierarchies but also work processes in which people are working more or less autonomously with the guidance of their coaches [49].

When understood in the context of an employment relationship that is at once interdependent and conflictual, BPR can be interpreted as the latest wave in a series of initiatives developed by owners/managers to increase the cooperation/productivity and adaptability of staff. BPR identifies organizational and human resource change as necessary for reengineered designs to be effectively implemented, but it also presents reengineered work as the means of securing employee commitment, flexibility, responsiveness etc. [51].

Unlike previous change programs, BPR also requires us to forget about analytic boundaries and partial resolutions to today's holistic problems and redraw the map to include everything.

Although each individual aspect of reengineering can be seen as merely a restatement of previous deliberations, there is a case for asserting that the novelty of reengineering lies in the total package not the individual elements. Reengineering, in this account, is successful because of its *sui generis* nature: its holistic differentiation from, and superiority over, the analytic elements, which have come before. This is

plausible to the extent that the whole is greater than the sum of the parts. Indeed, one could argue that it is the radical extent of the change required that explains both the success and the failure of reengineering. That is, that the high degree of uncertainty and risk involved unhinges the nerves of those attempting to reengineer and induces them to remember the penalties for radical failure so that they seek more conservative and instrumental approaches to change that appear both less risky and more plausible [52]. These incisive critiques of rational decision-making imply that decision-makers do not approach organizational problems with a clean sheet of paper and an ideal, but with a pre-folded piece of paper and in the light of existing structures and policies. In short, BPR attempts to cleanse organizations of all institutional memories to facilitate the new beginning. Day-to-day management is only concerned with incremental change, that is, change at the margin, small modifications to existing policies, procedures and methods, the bulk of the operation remaining the same.

According to Hammer, reengineering 'cannot be planned meticulously and accomplished in small and cautious steps. It's an all-or-nothing proposition with an uncertain result' [39]. No methodology is offered by Hammer for this 'all-or-nothing' endeavour. In fact, Hammer and Champy do not even provide any techniques for reunifying tasks into coherent business processes. They simply present the reader with some 'principles' and some illustrative and anecdotal descriptions of successful accomplishments of reengineering by US firms. In this respect there appears to be a significant difference between the approach of Hammer and Champy and the approach of Davenport and Short [6], as the latter authors do suggest an approach to proceed with an engineering effort:

1. Develop business vision and process objectives. Prioritize objectives according to strategic objectives, and specify targets that will 'stretch' the organization.
2. Identify processes to be redesigned, that is, critical or bottleneck processes.
3. Understand and measure existing processes. Identify current problems and set baseline.
4. Identify IT levers and brainstorm new process approaches.
5. Design and build a prototype of the process and implement organizational and technical aspects. Successive iterations should be expected and managed.

According to this 'reengineering algorithm', organizational transformation is a manageable, goal-directed and top-down controlled process, perhaps with an element

of trial-and-error, but eventually leading to the desired (planned) end state.

II.1.11.1. Broadening Visions Of BPR

BPR is a "theme" which has been around since the late 1980s. It is still receiving great attention from both the academic community and the popular management press. A recent study reported that 69 percent of U.S. companies and 75 percent of European companies have at least one reengineering initiative and it is also gaining impetus in Japan [53,54].

At the heart of BPR is the notion of discontinuous thinking-of recognizing and breaking from the outdated rules and fundamental assumptions that underlie the design of organizations. Proponents stress that breakthroughs in performance cannot be achieved by cutting fat or automating existing processes but by challenging old assumptions and shedding old rules that made business underperform in the first place. While this may sound logical, by the end of 1994 BPR was attracting a good deal of criticism. Indeed Hammer, perhaps BPR's most charismatic proponent felt the need to defend the concept [55]. He argued that most of the criticism is misplaced and is based "on a misconception of what reengineering really is, and much of the rest reflects a limited assessment of its significance.

The traditional business school functional areas of strategy, information systems, accounting and finance, operations management, human resources, and marketing are all studying the impact which the debate BPR is provoking has on their disciplines and also what they can contribute to the debate.

While BPR, with its doctrine of radical performance improvement, is a powerful message, the initial conceptualization, as detailed in the seminal writings, is giving way to a broader perspective. BPR is broadening in perspective, moving from its narrow, internal and analytic focus, and examines developments which are contributing to a new conceptualization.

Recent research has yielded valuable insights. There have also been many substantial case studies written which highlight different aspects and experiences with BPR, all of which contribute to a body of work from which lessons and best practices can be drawn [1,56-61].

All these studies agree that through the redesign of business processes significant performance improvements can be achieved. While experiences with BPR

among the companies studied have been varied, most of the research attempts to highlight lessons and determine the critical factors which lead to success. What is clear is that BPR is contextual. It offers no prescriptions for the way organizations should work day-to-day but rather is concerned with how organizations can get shifts in performance based on moving from one way of working to another [62,63].

Given the attention now devoted to this philosophy, it is likely that usage of the phrase BPR, which captures the essence of the philosophy may fade [64]. Yet, the fundamental forces driving towards this reappraisal of organizing for work are here to remain. Already, many companies are beginning to use their own labels to describe their performance improvement initiatives with similar objectives to BPR. Regarding BPR's future, Davenport and Stoddard [65] suggest three options. First, another synthesis of ideas will emerge that includes the precepts of reengineering with others. Second, reengineering will be absorbed into existing change methods. Third, reengineering will be combined with quality and other process-oriented improvement approaches into an integrated process management approach.

Whatever the final outcome, evidence from the literature would suggest that BPR is shifting ground from its original manifestations as espoused in the early literature. The initial focus on reengineering work is broadening and in this section these movements are charted and explored. Figure II.7 summarizes these key shifts.

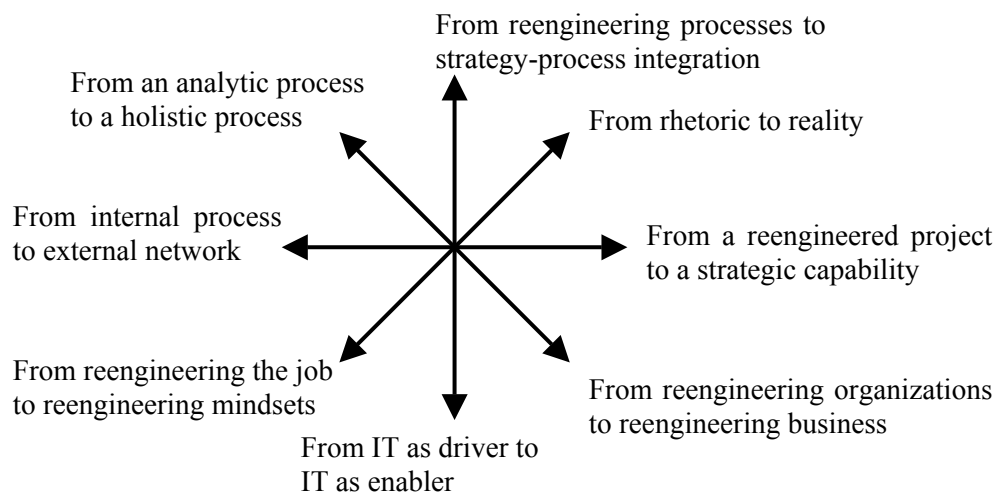


Figure II.7. Broadening Visions of Business Process Reengineering [64]

From Rhetoric to Reality. The language used in relation to BPR is undoubtedly revolutionary in tone, particularly if one examines the seminal writings. The words and phrases are specifically chosen to reflect the radical connotation of the theme. Words like transformation, radical, violent, aggressive, innovation, and obliterate are

central in the vocabulary of BPR. Yet in reality, while most reengineering initiatives may have radical performance improvement as an objective, the route that has been taken is much more incremental.

This duality between radical performance and radical change is not a simple matter of being necessarily bound up together. Radical organizational change, particularly if not managed, can have devastating consequences. The reality, which is supported by research, findings, is that while radical performance improvement is sought through BPR programs, it is usually not through big-bang changes, but rather through a much more incremental approach. Change is a *continuous process* rather than a *static event* as suggested by proponents of the radical view. Since the publication of their book Hammer and Champy have been reported as differing on this issue with Hammer continuing to espouse how violent the reengineering process needs to be.

Japanese experiences of Just In Time, an improvement philosophy centered around the notion of process, clearly shows that the improvements which Japanese companies have achieved have been over an extended period of time. Shiego Shingo has pointed out that it took Toyota 20 years to develop JIT fully, and others will require at least 10 years to obtain satisfactory results [66].

Perhaps what this highlights is that organizations have different capacities to encourage and support change. It has been suggested that organizations who have a TQM or customer care program in place are more likely to succeed at BPR [67] although it is important to recognize that these programs themselves have often resulted in disillusionment, particularly if abandoned for no other reason than to jump on the next "wave." Other organizations may already have a culture which fosters and supports teamworking and empowerment. Readiness for change is therefore clearly an important consideration, and frameworks have been developed to help in assessing an organization capacity for BPR.

From IT as Driver to IT as Enabler. BPR as a phenomenon was observed and labelled at the Massachusetts Institute of Technology (MIT) *Management in the 1990s Research Program*, which focused on examining the role which IT would play in organizations during the 1990s. The MIT researchers used the term quite precisely to describe the use of IT to transform the way in which an organization works internally rather than simply to automate the way it already worked.

Perhaps predictably, surveys of the role of IT in BPR initiatives have reported

that IT plays an important, if not central, role in each stage of an engineering effort. These roles include educating other members of the reengineering team about leading edge information technology and how it can be appropriately applied to business processes, selection and use of business process and data modelling tools [68], simulating alternative process designs, [69] providing technical vision, leadership and project management [70] and to build the systems that are envisioned by the reengineering team.

From an Analytic Process to a Holistic Process. Figure II.8 attempts to position BPR in relation to the dominant eras in organization and management theory in order to identify its intellectual inheritance [62]. This figure also maps these eras against organizational metaphors as articulated by Morgan [71].

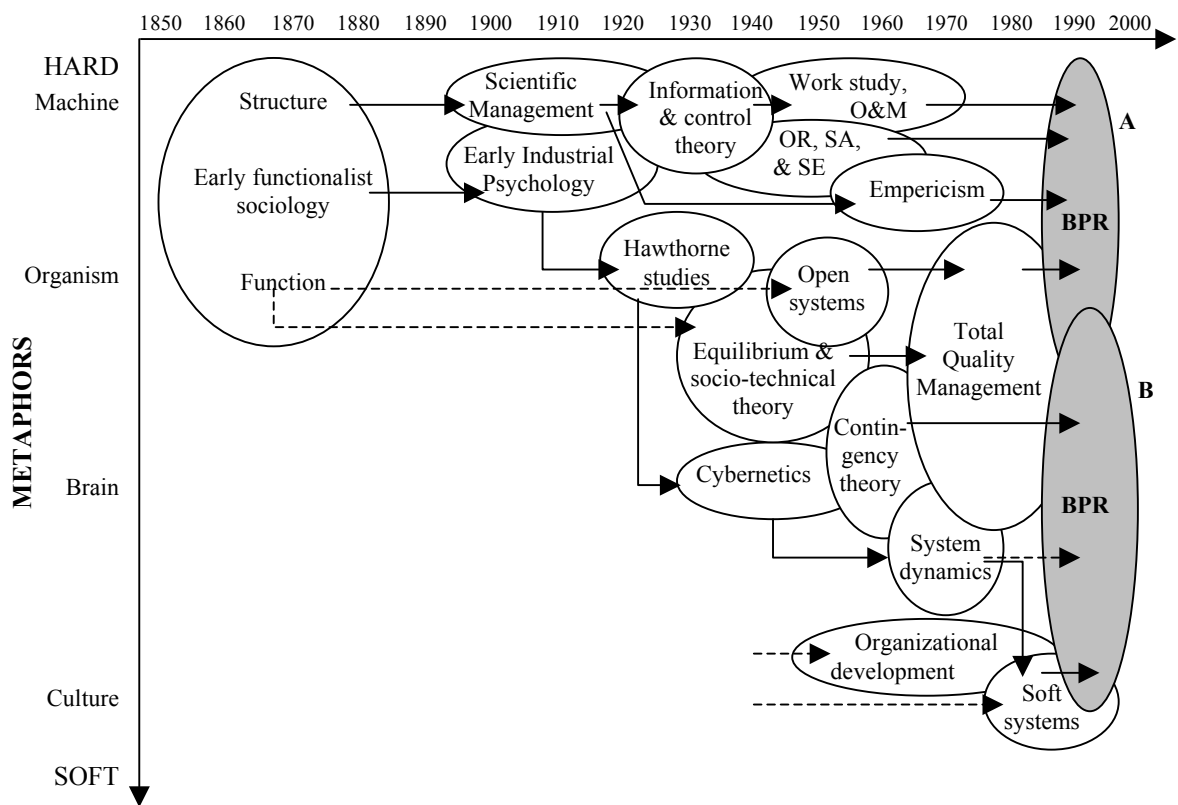


Figure II.8. The Intellectual Inheritance of BPR [62]

As this figure illustrates, early manifestations of the concept were clearly drawn from mechanistic thinking on organizational engineering, chiefly centered around IT and industrial engineering (A). It is not surprising that it drew on these areas for guidance, subscribing to the structured and mechanical philosophies underpinning systems analysis and OM. The focus on IT-enabled business process reengineering meant an implicit inheritance of the tools and methods used to develop IT which were then used to redesign business processes. The organization is thus portrayed as

a machine whose components can be changed to achieve the desired result: in this case radical performance improvement. The laws of mechanics govern the operation of the "machine" and are predictable: reengineer processes and the benefits will automatically flow.

The lessons of implementation have clearly shown that consideration must also be given to the softer "human centered" issues [72]. While the redesign process itself may be treated as a mechanical exercise (and even this is not without its softer influences), implementation is dependent on both harder (for example, design of IT-based systems) and softer (for example, changing work practices and remuneration) aspects. In effect, BPR is now drawing on a breadth of thinking and practice for guidance. The lessons from research strongly suggest that a more holistic view of BPR must be adopted if initiatives are to have a chance of success. Such a perspective draws on antecedents in both hard and soft disciplines (B).

Lessons from research into organizational change, and BPR will undoubtedly involve considerable amounts of change, and have clearly highlighted its political nature. Indeed, the act of redesign itself will often be subject to political wrangling, with interest groups influencing the design process in order to maximize the likelihood of securing decisions, outcomes and resources which are compatible with their goals. Such activity can result in selecting a suboptimal design or adversely affecting the implementation of what might be considered a more effective process. Few organizations have developed approaches to manage the political dimensions of BPR. [73]

From Reengineering the Job to Reengineering Mindsets. The BPR literature is clear in stating that those who will operate in the new process oriented organization will work in teams, be empowered, be multiskilled, and have their compensation tied to customer satisfaction. This shift has implications beyond reengineering and challenges the traditional concept of designing organizations around job structures. Willmott [74] laments the lack of consideration given by the BPR literature to the human aspects of organizing. Focusing on the reengineering of human resources, he argues that the transition from specialist function-based to business process-oriented organizing practices necessarily depends up on "human resources" who enact, and are also (re)constituted by, BPR.

Yet to work in this new organization requires changes in motivations, attitudes, skills, knowledge, and work practices. Such changes can have profound implications

for the individual: change can be intensely personal, and reengineering usually fails because people resist change. In an analysis of 5 years of reengineering activity at CIGNA insurance, Caron et al. [75] highlight the criticality of changing mindsets. They state that it is crucial to acknowledge that "all employees will have to participate in a mindset change to enable the success of the initiative".

From Internal Process Perspective to External Network Perspective. A legacy of MIT's "Management in the 1990s" research project is that a clear distinction now exists between BPR and what is usually referred to as business network redesign (BNR). While BPR was clearly focused on the redesign of internal organizational processes, BNR is concerned with the wider business network. The underlying premise is that the firm is just one entity in an industry value system. Business network processes are those processes, which extend beyond the boundaries of the organization into suppliers, customers, regulators and alliance partners. Such processes may also cross national boundaries.

In reality this distinction is not as clear. Electronic data interchange (EDI) is often looked to automate the link between buyers and suppliers. Yet, this practice of automating existing work practices, which are incorporated within interorganizational processes is exactly what the BPR movement is challenging. Reengineering the process rather than merely automating the data exchange usually demands significant reengineering of internal processes.

McHugh et al. [76] have proposed the concept of the holonic business system as a natural extension of BPR. The holon concept refers to processes within processes, with the holonic network seen as a set of companies that act integratedly and organically. Each company in the network provides a different process capability and the network is constantly reconfigured to manage each business opportunity a customer presents. In fact, they see the customer moving from their traditional passive role to becoming a prosumer, i.e., a proactive customer, working closely with sellers to define the products and services they are buying. They argue that the concept allows businesses continually to deinvent and reinvent themselves as they face increasingly ambiguous markets. A critical challenge, however, becomes identifying how the reengineered core business processes can contribute to a strategic repositioning of the business.

From Reengineering Organizations to Reengineering Business. The inward-looking focus of BPR has clouded the profound influence which IT and new

management strategies are having on the nature of business itself. By reducing the costs of coordination, IT is leading to an overall shift towards proportionately more use of markets-rather than hierarchies-to coordinate economic activity. Illustrative is the implication which automation of the London Stock Exchange had in the extinction of the traditional role of the market maker. The “marketspace” denotes the transformation in business activity as moving from the physical marketplace with fixed locations, inventories, and products to an information defined transaction space.

This shift has profound consequences. The *content* of the transaction is different (information about the product replaces the products themselves); the *context* within which the transaction takes place is redefined (on-screen interaction replaces face-to face contact); and the *infrastructure* that enables the transaction is different (computers and communications replaces physical locations).

Through a variety of strategies the dominant logic of business is being redefined. Traditional business networks are being reconfigured through organizations focusing on core competencies, by forming strategic alliances and by outsourcing. For example, Nike Inc., the largest supplier of athletic shoes in the world, concentrates on its core competencies of research and design of high-tech sports footwear and the marketing and distribution of these to customers [77]. The actual manufacturing process is outsourced to mainly Asian subcontractors.

Commenting on this manifestation, Normann and Ramirez [78] argue that a sequential value system, together with a fixed set of activities, is no longer appropriate to today's business. They suggest that the key strategic task is the reconfiguration of roles and relationships among this constellation of actors in order to mobilize the creation of value in new forms and by new players.

The implication of this is that instead of looking to reengineer their organizations, organizations should first look for opportunities to reconfigure the business network within which they compete. For example, there is not much point in a record company reengineering its manufacturing process if its future competitor is a cable company downloading selections on cable, effectively bypassing them in the value system.

Davidson [79] sees BPR as the first of a three-phase transformation process that starts with structured automation and reengineering efforts, building on new infrastructure and capabilities to enhance and extend the original business, and then rede-

fines it to create new business.

From Reengineering Processes to Strategy-Process Integration. The seminal literature on BPR is clearly centered on the process of reengineering business processes, adopting an operational view of improvement, in particular the redesign of product and service delivery processes. While this still remains the focus, the linkage between reengineering and business strategy is becoming increasingly recognized. Many reengineering initiatives are undertaken without any regard to the organization's strategic direction.

The successful reengineering of Ford's accounts payable process, possibly the most widely quoted example of BPR, illustrates the case of reengineering a process without having any significant impact on the bottom line. Similar sentiments have been expressed by Womack and Jones [80] in relation to the implementation of lean production. The implication is that reported benefits of BPR must be seen in the light of the scale and scope of the process being redesigned.

Hammer [55] sees reengineering offering "an alternative perspective on formulating strategy, one based on operating processes rather than on products and markets". Johansson et al. [81] look to BPR to redress the balance between operational excellence (how to compete) and the usual strategic focus on what products to sell, to whom they should be sold, and where they should be sold. Without all these elements, however, the search for sustainable competitive advantage is likely to be a fruitless one. Strategy, whether implicit or explicit, sets the direction for the enterprise but it is through processes, people and technology that the strategy lives for customers, suppliers and staff alike.

This perspective analyzes firms from the resource side rather than from the product side, (in which traditional strategy approaches are grounded), and is perhaps best captured by the notion of core competencies. It proposes that what sustains competitiveness is not a firm's endowments, but its competencies. Competencies are combinations of resources (physical assets, people, brands, reputation), systems (codified means of deploying or activating the resources, e.g., the manufacturing system), and know-how (a non-imitable capability enabling the firm to deliver a competency). The difference, however, between Hammer's view of reengineering and that of those who subscribe to core competencies is Hammer's lack of strategic context and the criticality of linking BPR with business strategy. As a first step in articulating this link a distinction between business reengineering and business

process reengineering can be made [67]. Illustrated in Table II.2, business reengineering involves the development of an organizational architecture and it entails identifying and linking the strategy of the business with the required organizational processes to ensure that this strategy is actually delivered. With this perspective, the organization engages in a fundamental rethinking and redesign of the business and its underlying processes.

Table II.2. Business Reengineering vs Business Process Reengineering [67]

Business reengineering	aligning processes to the business strategy identify process configuration to provide process capability high-level view of the organization and its underlying processes defines the business architecture
Business process redesign/ reengineering	redesign of individual processes for step improvement in performance usually relates to high-level processes although principles apply to all processes

BPR, on the other hand, refers to the redesign of any organizational process. This can include anything from a total supply chain process to a single process within an individual function or department.

While many scholars have become disillusioned and are concerned about the direction of strategy research and practice, strategy, whether explicitly or implicitly expressed, is vitally important. Prahalad and Hamel [82] have called for strategy paradigms to be reexamined, suggesting that the concepts and tools of analysis may need a basic reevaluation. They suggest that many of the assumptions embedded in traditional strategy models may be incomplete and/or outdated as we approach the new competitive milieu.

From a Reengineering Project to a Reengineering Capability. Many organizations treat their reengineering initiative as a project after whose completion the organization can "get back to normal." Such complacency is to be avoided. In the words of Hammer and Stanton, BPR "must become a core competence of the twenty-first century corporation, one of its defining strengths" [83].

Many managers have expressed concerns regarding managing in the post-BPR organization. They have to find answers to the questions like how organizations would manage the result of a reengineering initiative, how to begin to manage processes as opposed to functions and what comes after reengineering.

II.1.11.2. Process Reengineering Or Business Reengineering

From the basic concept have emerged two major categories of reengineering initiatives. The first and most common category is *process reengineering*. The emphasis is on identifying one or more "core processes" (Figure II.9), analyzing them and then radically rethinking and redesigning their execution. While such initiatives may be supported by the chief executive, they are typically "owned" by a senior manager or possibly a board member.

The second category-and focus is *business reengineering*. This approach involves a strategy-driven, top-down reappraisal and redesign of the total business. Clearly, such initiatives have to be supported and driven by the Chief Executive and demand the commitment and active participation of the entire board [84].

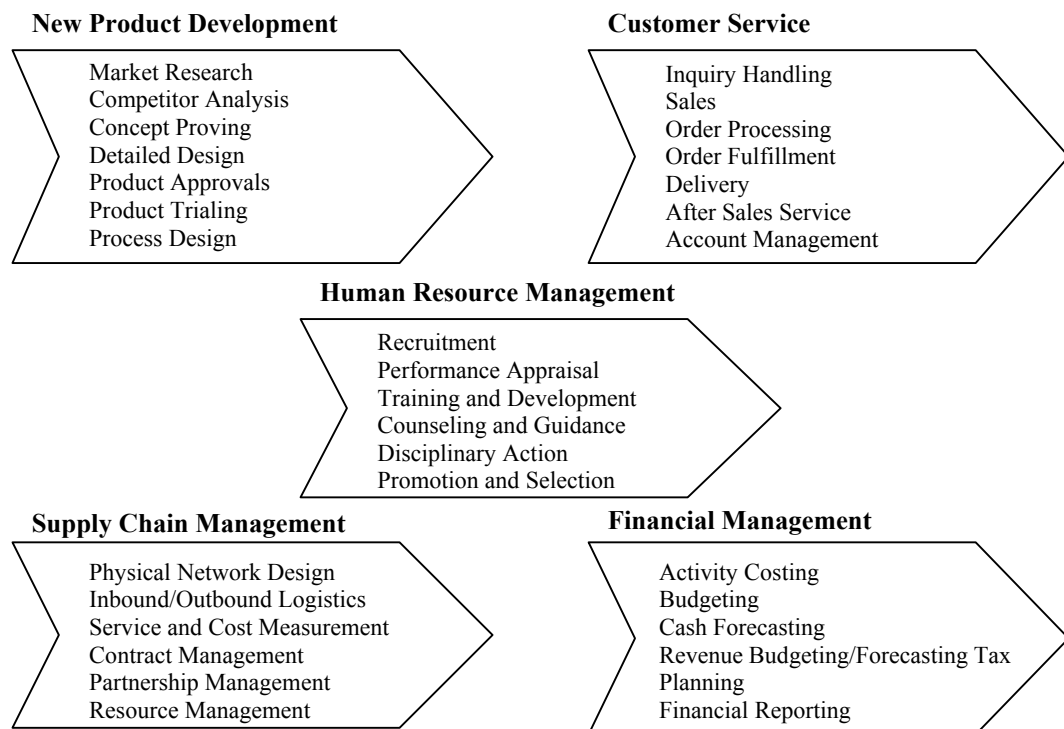


Figure II.9. Core Business Processes [84]

The more wide ranging and fundamental the rethink, the greater the impact on cross-functional activities, working practices, management systems, organization structures, motivation and reward systems, performance monitoring systems, and staff training and development (See Figure II.10).

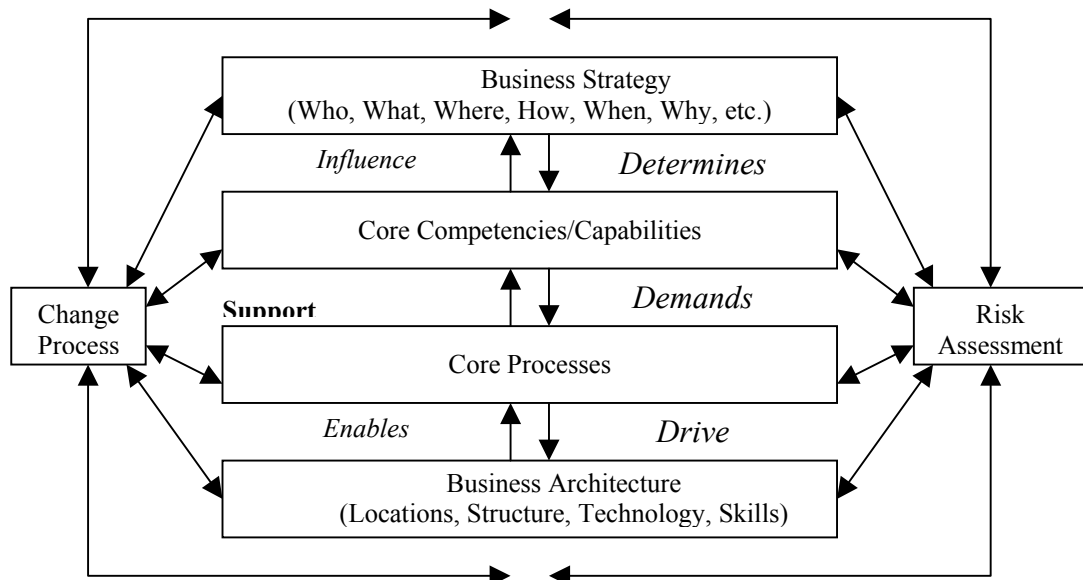


Figure II.10. A Strategy Driven Approach to Business Reengineering [84]

This approach builds on the premise that future competitive success is based upon a strong linkage between strategy, competence, core processes and architecture.

2.a. A Framework For Business Reengineering

Most business reengineering exercises involve six key steps (Figure II.11):

- Building the vision of the reengineered organization,
- Planning how the vision will be realized,
- Analyzing the current structure and processes.
- Redesigning the "business architecture"
- Implementing the redesigned organization and processes.
- Measuring the benefits and sharing the learning.

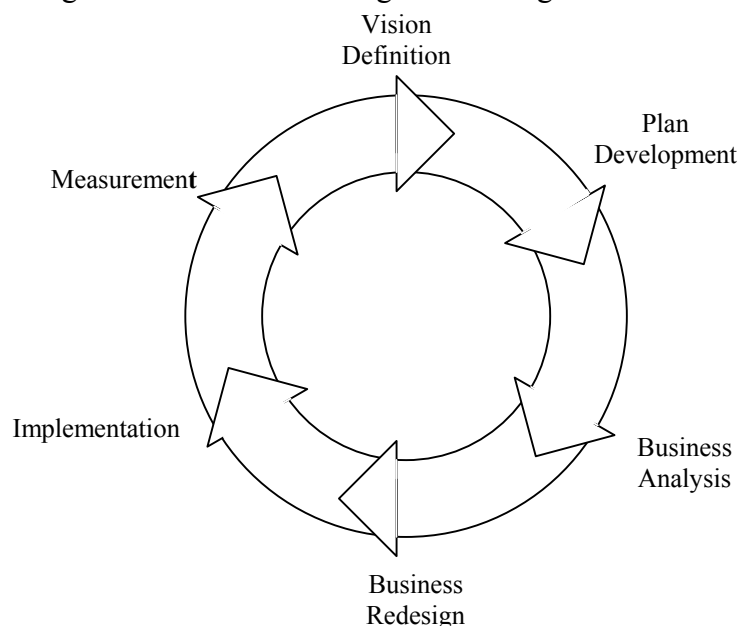


Figure II.11. Six Key Steps in the Reengineering Process [84]

Vision Definition: At this stage (Figure II.12), the aim is to ensure a clear focus on the products and services, competencies and processes around which the business is to be built. Organizations generally have a range of ad hoc and formal techniques for undertaking strategic analysis stage. The search for competence involves analysis of:

- the underlying features of the most successful products and services,
- the capabilities in which a worthwhile and defensible edge is believed to exist,
- the customer requirements and hence capabilities on which the market dominance is believed to occur,
- the results of past approaches to defining and building capability.

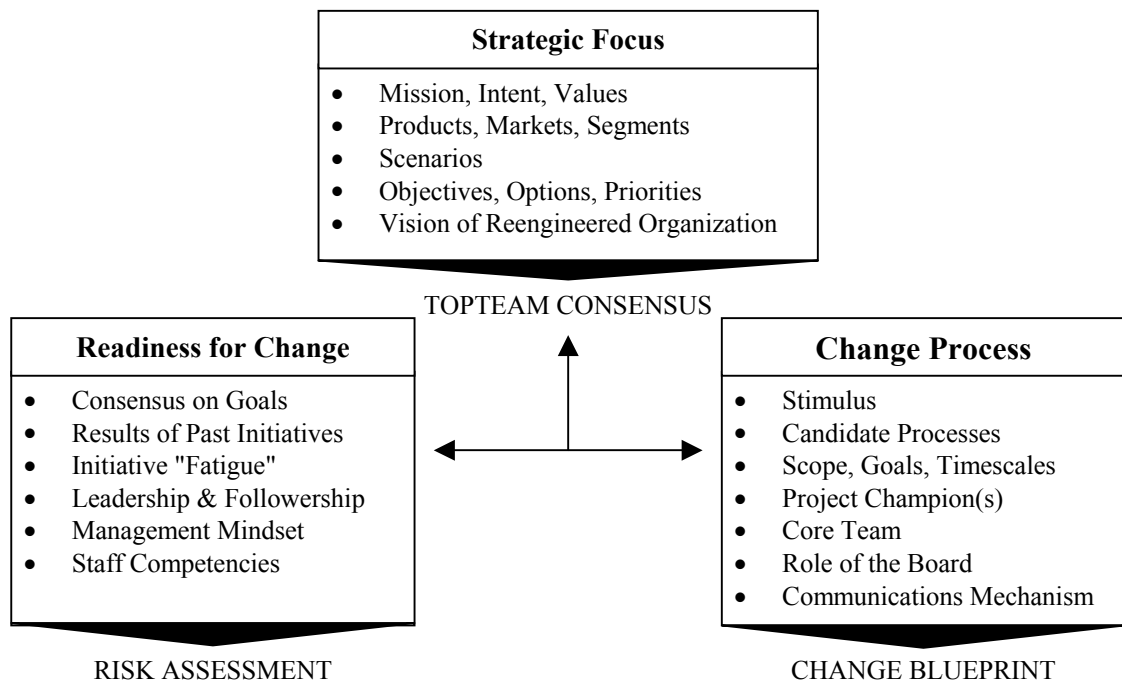


Figure II.12. Building a Vision of the Reengineered Organization [84]

Much has already been said about the components of the change process. A key element though is clearly the selection of candidate processes. One approach to assessing process capability is to rank its performance against the needs of both customers and shareholders (Figure II.13).

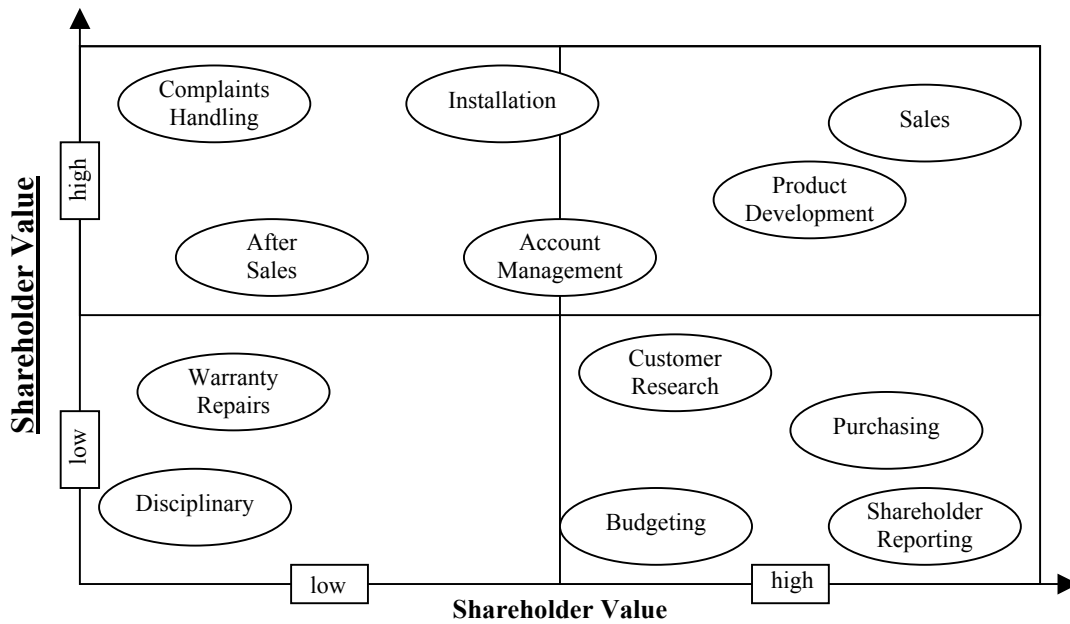


Figure II.13. Assessing the Value of a Process-An Example [84]

A weighted ranking of performance against key criteria can be used to determine the individual value scores. For example, the evaluation of the customer value created by each process could be based on the contribution they made against such factors as helping the customer to identify, evaluate, buy and use the product.

The resulting value index (Figure II.14) can then be compared to the cost of process ownership to determine the appropriate treatment for each process in the reengineering exercise. Experience suggests that those, which fall in the central region are typically the ones which will benefit most from redesign.

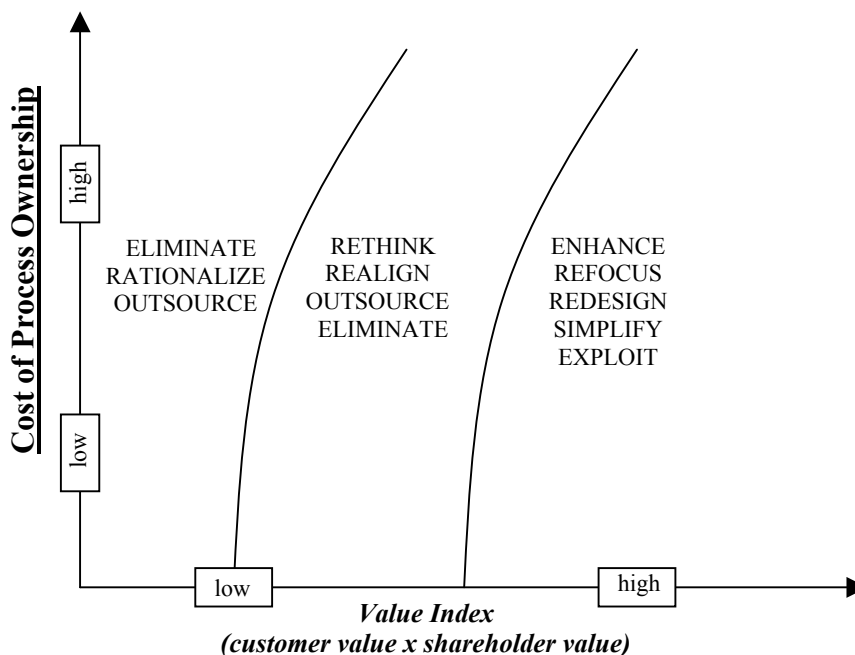


Figure II.14. Comparing Value and Cost [84]

Plan Development: The quality of the overall plan is a key determinant of the eventual success of the initiative. The wide ranging nature of the exercise means that those managing it must have a good understanding of the "system" or "business model." The only aspect of planning that requires further discussion is the notion of planning incremental performance improvements. Experience suggests that those who have tried to reengineer often fail if they focus all their attentions in one area alone such as technology or even staff capability.

Similarly, organizations which choose a balanced approach but then set targets far beyond the sights of those involved have also found the exercise failing. The problems are generally the absence of an internal reference point and a lack of belief in the organization's ability to achieve such dramatic improvements. These barriers can typically be overcome if each successive round of reengineering has more demanding targets than the last based on a demonstrated ability to deliver.

Business Analysis: The objective is to understand and build a high level model of the business as currently structured by:

- Analyzing customer requirements,
- Modelling target processes,
- Assessing organizational issues,
- Reviewing IT infrastructure,
- Identifying candidates for improvement, elimination, outsourcing, and redesign,
- Consolidating the reengineering options.

The underlying objective is to free the firm from the shackles of past behaviour and practice. Hence the analysis phase questions why a business entity such as a process or structure exists. Next question is how much of a process the customer sees and what value is added by each process step.

In justifying and dismantling every process, the aim is to avoid doing things just because *"it has always been done"* and eliminate duplication of effort and remove wasteful activities.

There are a number of genuine benefits to be gained from understanding the current operation, including:

- defining a baseline model of existing processes with which future changes can be planned and tested,
- identifying candidates for improvement,

- spotting current and potential problems,
- identifying improvements that can be made immediately by the process owner,
- building consensus on the steps in and problems of the current process,
- confirming interfaces to other functions, processes and organizations,
- creating the stimulus for change.

A variety of tools and techniques exist to support the modelling phase. These start with simple and easily understood pen and paper based techniques and they then increase in complexity and the amount of training required. At this stage the organization must decide how it will use the tools. The more sophisticated and expensive tools can be of value if key requirements are process simulation and/or the ability to support the physical enactment of the process once the business has been reengineered.

Business Redesign: The redesign stage is the most difficult part of the whole initiative. The objective is to create and cost the design for the reengineered business (Figure II.15). There is no single technique which is guaranteed to give the optimal business design.

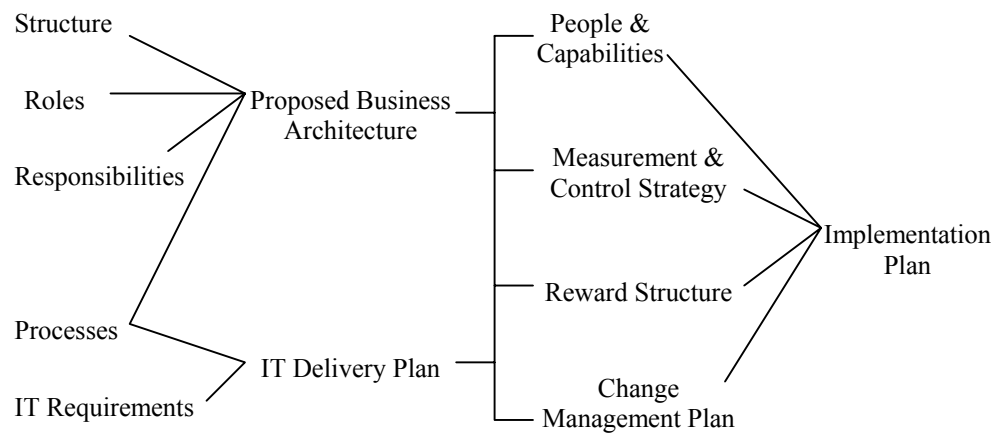


Figure II.15. Designing the Reengineered Business [84]

A number of variations on the basic concept of brainstorming are put forward. Most have the same basic elements-to allow participants the freedom to come up with a range of options of how the business processes and supporting architecture should be structured. Two rules of thumb are useful when defining new processes:

- *completeness*- a well-drawn process is not necessarily well defined or complete
- *conformance-specifying* a process completely does not guarantee that it will be executed that way.

Implementation: The implementation plan typically needs to address three key areas:

- Changes affecting parts of the current structure that will remain largely unchanged,
- Putting in place those elements of the structure that have undergone substantial change,
- Identifying changes to be made in future rounds of reengineering.

This stage also requires a phase of bedding in and refinement:

- Assessing the initial performance of the new architecture,
- Making initial refinements,
- Initiating a continuous review process.

Measuring Performance Gains: A rigorous assessment of the results of reengineering is vital (Figure II.16).

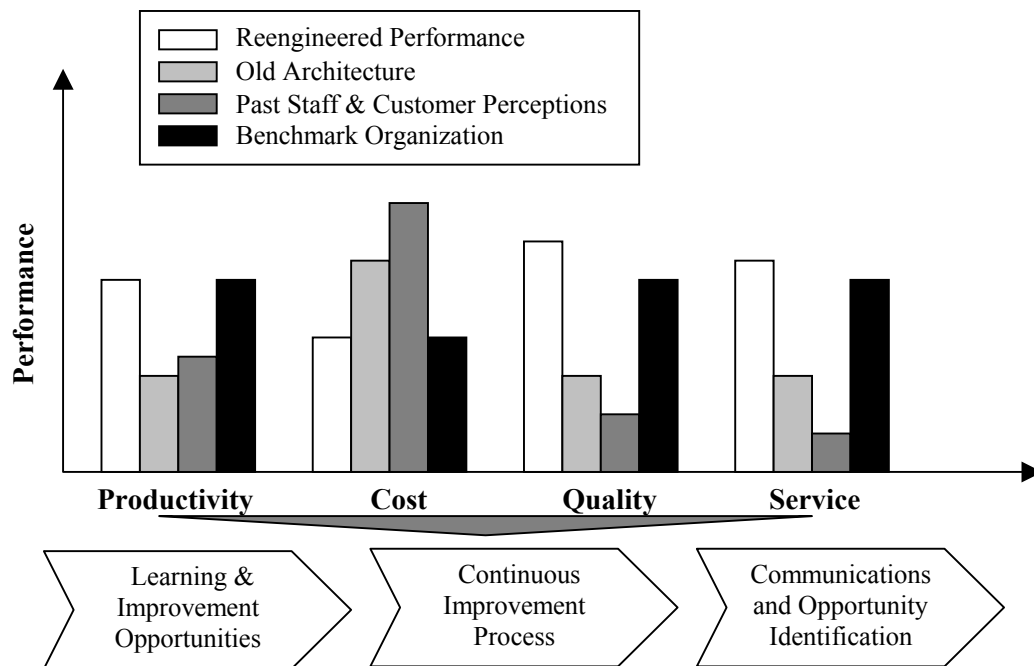


Figure II.16. Measuring Performance Gains [84]

Again, measuring against a balanced scorecard of both hard and soft measures is essential. The objectives are to:

- identify and share the learning on what worked and what could be improved,
- help process owners create a continuous improvement process to support ongoing refinement,
- communicate the overall results and encourage others to spot further opportunities to be addressed in subsequent rounds of reengineering.

II.2. MATERIALS MANAGEMENT SYSTEMS

II.2.1. Inventory Management

II.2.1.1. Inventory Control

The purpose of the inventory control function in supporting business activities is to optimise three targets:

- Customer service,
- Inventory costs,
- Operating costs.

Optimising the balance between these three objectives is the focus of stock control. The better the balance the greater the profits provided for the company. The improvement in stock control has been slow and gradual, created by new technology, financial need and competitive pressure. Those companies who can tighten their control faster than the average will flourish, but those, which do not keep up with the average, even if they are improving, will gradually dwindle.

One of the dichotomies of inventory control is that at item level, the more stock the better the availability. However for the whole inventory, experience has shown that the businesses with the highest stock are often those, which have the worst availability. High stock levels arise because too much stock has been purchased through bad forecasting, monitoring or controls. High stock and poor availability are caused simultaneously as a result of poor control. The problem rests with the inventory controller and the solution is in improved techniques [85].

1.a. Reasons for the current stock

It is easy to assess the effectiveness of inventory control in a company. All that is required is a visit to the stores. The stock level is a result of the effectiveness of the stock control, but what is held there is probably not ideal. Instead of considering the detailed ordering history for each item (and there are some interesting causes for stockholdings) the inventory can be classified according to why it is now in stock. An examination of the factors, which give rise to the stock in a typical store reveals causes: Purchase order quantity, safety stocks, market changes, stock obsolescence,

poorly defined responsibility, planned inventories, layout/location of stores, company strategies and control systems are important ones.

Analysis will show that actual stock is not held in the right balance to meet marketing and financial targets in the most effective way. By establishing a reason for this, a plan can be devised and action taken to ensure the lowest stockholding levels necessary to meet company targets.

Initially, the reason for stockholding has to be determined. It could be to achieve good customer service, cheap purchase, bulk discount, security or a large number of other reasons. The stockholding strategy depends directly on the company objectives and policy. Company policy defines the service, which it intends to provide to customers, what investment to make in stock, how orders are placed on manufacturers or other principles on which to base supply plans. This is the first ground rule of stock control to have a policy worked out by top management to guide the operation [85].

1.b. Meeting Customer Requirements

Customer service is a complex subject of its own, but there are two main aspects, namely customer relations and availability of service or items.

Customer relations requires interpersonal skills to ensure that the customers have the correct level of expectation of supply and that they are happy with their purchase so that there is potential for repeat business and wider sales.

This aspect of customer service has gradually emerged because it is the differentiating factor between many companies. The product can be similar from a wide variety of vendors, the vendor which is most successful is the one where the quality of customer relations is best.

The second aspect of customer service, availability, is a key target for stock control. It requires technical management.

1.c. Measuring Availability

Availability: The entire reason for stockholding is to have items available, but despite the key nature of customer service to the success of the business, some companies do not quantify proper stockholding, only taking notice of complaints or other oblique assessments of service. To manage professionally there is a need for solid facts.

For each item in stock the risk of stockout can be reduced by increasing the stockholding. The larger the investment in inventory for an item, the better the service. This is shown in Figure II.17 for an individual stock item.

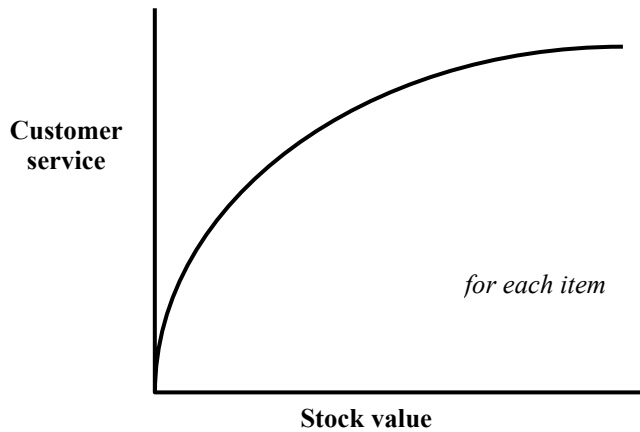


Figure II.17. Availability of a Stock Item [85].

This is the criterion, which should be applied to all areas of inventory to monitor how well the investment in inventory is doing.

When the whole range of stock items is considered, the minimum stock levels result from all the items being under control at their optimum service level. Basically, each item should be on the same curve in Figure 17. The only way to reduce the stock beyond this balance, while maintaining service, is to improve the total control method. After all, the aim is towards the top left corner of the graph - high service with low stock across the whole of the inventory.

Availability policy: Customer service can be structured or focused on a particular group of customers or market sector using alternative availability policies. Options, which could be used are:

- The same availability across all the products,
- Minimising the total cost of service,
- Concentrating on the most valuable customers,
- Enhancing service on the most sensitive products,
- Greatest availability of the most profitable products, or
- Better service on the major turnover items, reduced service on slow movers.

These alternatives will provide different availabilities for different products, with a management decision setting availability levels.

1.d. Demand Management

Demand management consists of a series of steps:

1. Order receipt,
2. Order processing,
3. Estimating delivery times to customers,
4. Production of despatch information,
5. Customer feedback.

Order receipt is the initial compilation of orders into a form which can be used to despatch the goods at the right time to the customer. Order processing is the entry of the order into the system. Next step is estimating delivery times which causes a high level of customer confidence to be gained or lost. Despatch information consists of two stages: 1) picking and delivery note production, 2) customer invoicing.

A delivery note can be prepared as soon as the order is processed, as long as the stock records are accurate as shown in Figure II.18.b. Where records are suspect, a safer procedure is the one shown in Figure II.18.a. This usually causes extra paperwork.

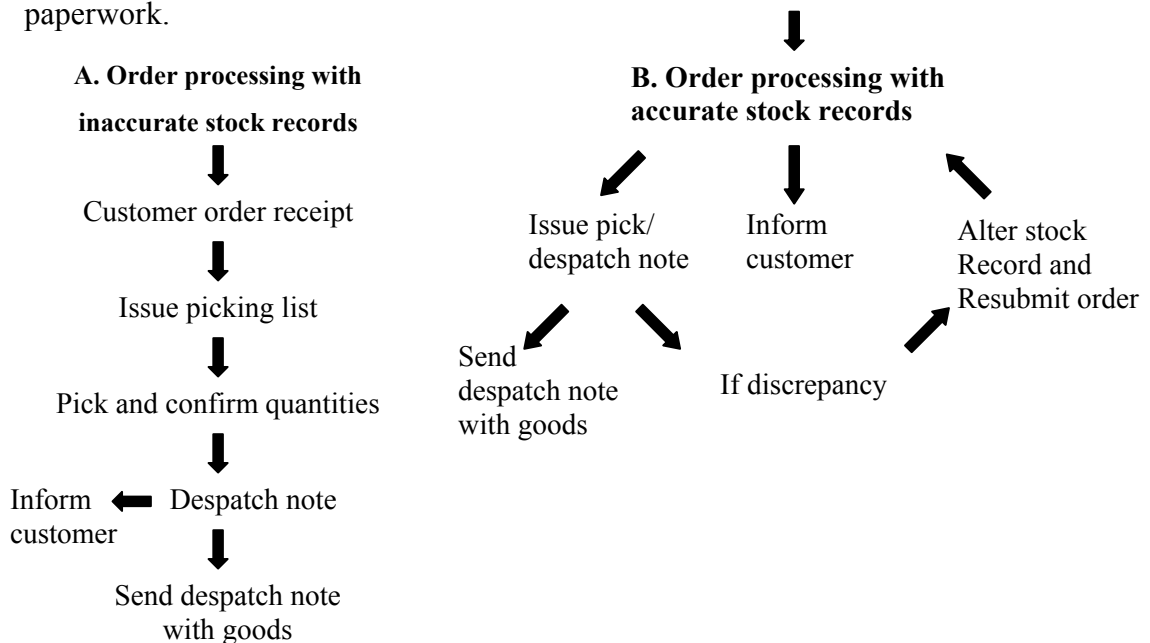


Figure II.18. Stock Item Order Processing [85].

Customer feedback: To report on progress and to keep the customer feeling involved in the supply is very important from a customer relations standpoint. Customers often require acknowledgement of order and confirmation of price as well as a despatch note and invoice. This confirmation should form part of the normal information processing procedures.

1.e. Consuming Forecast Demand

In almost all situations business works to a forecast until the real orders arrive. However, real orders rarely match the forecast and the question is raised as to whether an actual order received is really part of the forecast.

The ideal situation is when a company accurately forecasts demand and makes that quantity available. As customer orders arrive, available quantity is allocated and despatched.

When the quantity for the current period has all been allocated, customers are provided with items in the next period. This situation is shown in Figure II.19.

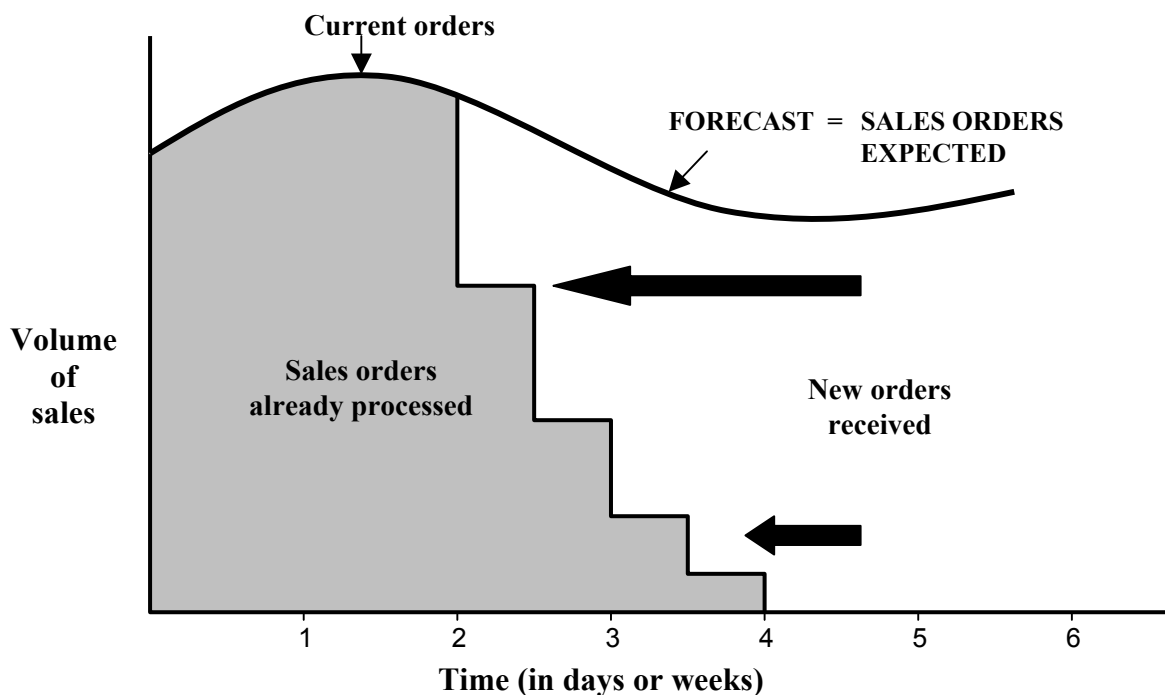


Figure II.19. Consuming the forecast [85].

Here the forecast in periods 1 and 2 (shown as the curve) is fully allocated and there are orders for periods 3 and 4 which have already been received. The demand in periods 5 and 6 is all forecast as no orders have been received which need satisfying so far ahead. Orders are constantly being received and product is allocated to these customers. This consumes the forecast quantity and builds up the allocations. This approach ensures that a company does not allocate more than has been provisioned through the forecast.

Applying effective control: Pareto analysis is the technique which forms the basis of inventory control thinking and is an important management principle which

can be applied to minimise effort and to obtain best results. The Pareto curve (see Figure II.20) is often called the ‘80/20 rule’, but the values can be read off at any convenient point.

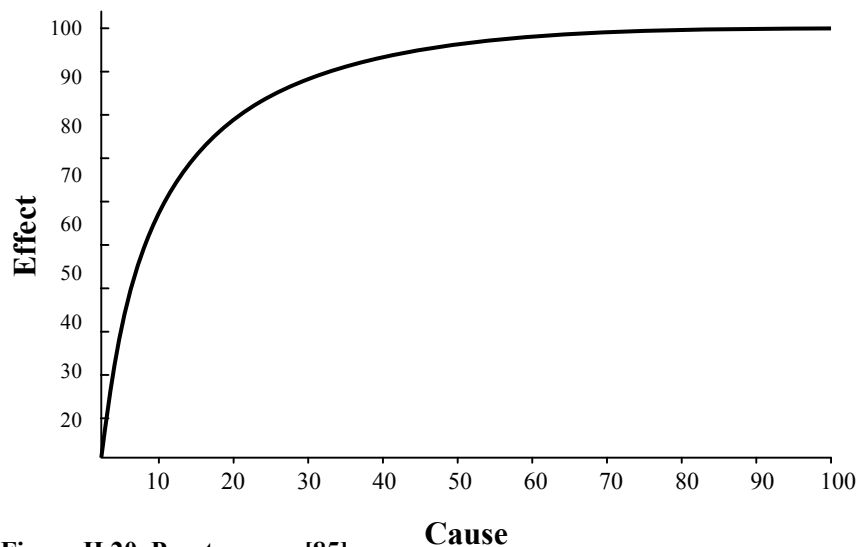


Figure II.20. Pareto curve [85].

To use Pareto analysis properly requires classification of stock by issue value and the simplest way is to use ABC classes. These can be defined as:

- A = 10% of stock numbers, giving 65% of turnover
- B = 20% of stock numbers, giving 25% of turnover
- C = 70% of stock numbers, giving 10% of turnover.

This is illustrated in Figure II.21. It is important to ensure that ABC analysis is based on turnover, but less important that the exact percentages are adhered to. In some instances a further classification (D) is useful to include a large number of very low turnover items.

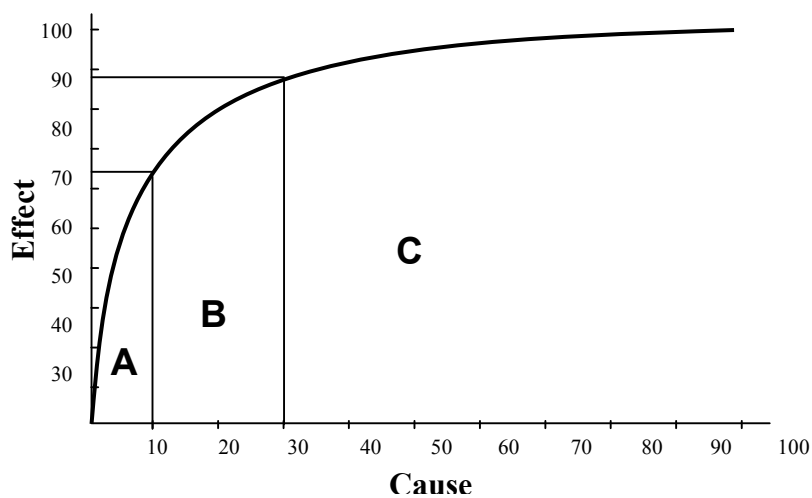


Figure II.21. ABC analysis [85].

The purpose of ABC analysis is not to provide different types of service but to provide service with the least amount of cost and effort. Different systems of control are used for the three categories of stock. As the A items carry the most value, accurate systems are required to control them. On the other hand, the C items are low turnover value but form the bulk of the inventory. For these the main requirement is to ensure that stock is available to meet demand.

The control requirements for each category are shown in Table II.3. Category A items have a disproportionate amount of time and effort used on them and have to be controlled tightly using systems in conjunction with market expertise and product knowledge to maintain stock at the lowest appropriate level.

For category B items computerised techniques are most appropriate. The number of items involved and the lower values make it a waste of time to use specialist skill which could be working on category A. The computer can maintain control through statistics and deal with the complex calculations using the computer forecasting models which are most important for B items. The use of management by exception is also important for the B class.

Table II.3. ABC inventory control [85].

Characteristics	Policy	Methods
<i>A Items</i>		
Few items	Tight control	Frequent monitoring
Most of turnover	Personal supervision	Accurate Records
	Communication	Sophisticated forecasting
	JIT approach - balanced safety stock	Service level policy
<i>B Items</i>		
Important items	Lean stock policy	Rely on sophisticated system
Significant turnover	Use classic stock control	Calculated safety stocks
	Fast appraisal methods	Limit order value
	Manage by exception	Computerised Management & exception reporting
<i>C Items</i>		
Many items	Minimum supervision	Simple system
Low turnover value	Supply to order where possible	Avoid stockouts and excess
(Few movements or low value items)	'Large' orders	Infrequent ordering
	Zero or high safety stock policy	Automatic system

The minor sales items, category C, should be controlled by a simple system which enables supply to be obtained with a minimum of administration. However the control system for C items must be reliable and not result in stockouts or large

excesses. An investment in extra stock of C class items is inexpensive but can greatly simplify the problems of controlling large numbers of stock lines [85].

II.2.1.2. Types Of Inventory

Inventory may consist of supplies, raw materials, in-process goods, and finished goods. *Supplies* are inventory items consumed in the normal functioning of an organization that are not a part of the final product. Typical supplies are pencils, paper, light bulbs, typewriter ribbons, and facility maintenance items. (Factory supplies are called MRO, for maintenance, repair, and operating supplies.) *Raw materials* are items purchased from suppliers to be used as inputs into the production process. They will be modified or transformed into finished goods. *In-process goods* are partially completed final products that are still in the production process. They represent both the accumulation of partially completed work and the queue of material awaiting further processing. *Finished goods* are the final product, available for sale, distribution, or storage.

The assignment of inventory to any of these categories is dependent on the entity under study. This is because the finished product of one entity may be the raw material of another.

II.2.1.3. Organizational Categories And Inventory Problems

Different types of organizations have different inventory problems. By classifying organizations as retail, wholesale/ distribution, and manufacturing/assembly, the extent of inventory problems can be generally delineated. In traversing from retail systems to wholesale/distribution systems to manufacturing/assembly systems, the problems of inventory increase in magnitude and complexity. Table II.4 indicates the organizational category and the types of inventory encountered in each.

Table II.4. Organizational Categories and the Types of Inventory [2].

Type of Organization	Type of Inventory			
	Supplies	Raw Materials	In-Process Goods	Finished Goods
A. Retail systems				
1. Sale of goods	*			*
2. Sale of services	*			
B. Wholesale/distribution systems	*			*
C. Manufacturing/assembly systems				
1. Continuous production system	*	*	*	*
2. Intermittent production system				
a. Open job shop	*	*	*	
b. Closed job shop	*	*	*	
3. Special projects	*	*	*	

Manufacturing/assembly systems comprise organizations that purchase raw materials and change their form to create a well-defined finished good. These systems have the most difficult and complex inventory problems. Manufacturing/assembly systems can be subdivided into continuous production systems, intermittent production systems, and special projects.

II.2.1.4. Inventory Problem Classifications

Inventory problems can be classified in many ways. They can be organized according to the repetitiveness of the inventory decision, the source of supply, the knowledge of demand, the knowledge of lead time, and the type of inventory system.

1. Repetitiveness (a. Single order, b. Repeat order)
2. Supply source (a. Outside supply, b. Inside supply)
3. Knowledge of demand (a. Constant demand / Variable demand, b. Independent demand / Dependent demand)
4. Knowledge of lead time (a. Constant lead time, b. Variable lead time)
5. Inventory system (a. Perpetual, b. Periodic, c. Material requirements planning, d. Distribution requirements planning, e. Single order quantity)

II.2.1.5. Properties Of Inventory

In viewing the properties of inventory systems, several components are universal. Demands, replenishments, constraints, and costs are the most commonly cited. *Demands* can be categorized according to their size, rate, and pattern. *Demand*

size refers to the magnitude of demand and has the dimension of quantity. When the demand size is known, the system is referred to as deterministic. When the demand size is not known, it is possible in some cases to ascertain its probability distribution, so that the system is probabilistic: Probability distributions can be discrete or continuous. Discrete distributions can only take on certain values, whereas continuous distributions can take on any value. Standard probability distributions such as the normal, Poisson, and binomial are frequently assumed for demand. The *demand rate* is simply the demand size per unit of time. *Demand patterns* refer to how units are withdrawn from inventory. Units may be withdrawn at the beginning of the period, at the end of the period, uniformly throughout the period, or in some other apparent pattern (e.g., seasonally).

Replenishments can be categorized according to size, pattern, and lead time. *Replenishment size* refers to the quantity or size of the order to be received into inventory. The size may be constant or variable, depending on the type of inventory system. When a replenishment order is received, it usually goes into storage and becomes part of the organization's inventory. It is carried on the balance sheet as an asset until it is sold to a customer or consumed by the organization. The *replenishment pattern* refers to how the units are added to inventory. Replenishment patterns are usually instantaneous, uniform, or batch. Instantaneous receipt indicates that the entire lot is received into stock at the same time. *Replenishment lead time* is the length of time between the decision to replenish an item and its actual addition to stock and can be constant or variable. Probability distributions are used in describing variable lead time, much the same as they are in describing variable demand. The major components of lead time are shown below in Figure II.22:

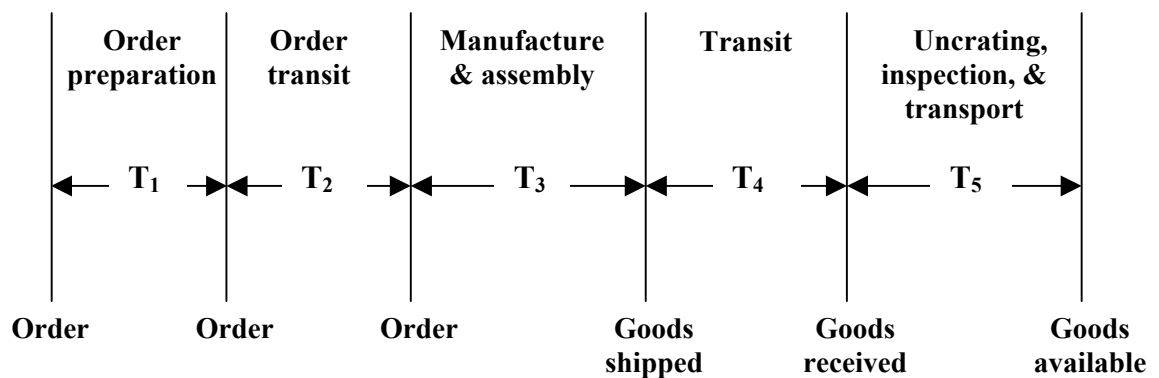


Figure II.22. Major Components of Lead Time [2].

Mathematically, it can be stated as;

$$L = T_1 + T_2 + T_3 + T_4 + T_5 = \text{lead time}, \quad (\text{II.1})$$

where

T_1 = in-house order preparation time,

T_2 = order transmittal time to supplier,

T_3 = manufacture and assembly time,

T_4 = goods transit time from supplier,

T_5 = in-house goods preparation time.

Observe that the variables T_2 , T_3 , and T_4 are governed by factors outside the ordering organization, rendering them largely uncontrollable. In contrast, the variables T_1 and T_5 correspond to internal activities controllable by the ordering organization. When an organization moves from external to internal manufacturing and assembly of its items, it acquires more control over its replenishment lead time.

Constraints are limitations placed on the inventory system. Space constraints may limit the amount of inventory held; capital constraints the amount of money invested in inventories; and facility, equipment, or personnel constraints the supply capability and operating level of an organization. Management policies (such as never being out of stock on certain items) and administrative decisions (such as reciprocal purchasing agreements) can confine an inventory system in innumerable ways.

II.2.1.6. Inventory Costs

The objective of inventory management is to have the appropriate amounts of raw materials, supplies, and finished goods in the right place, at the right time, and at low cost. Inventory costs are associated with the operation of an inventory system and result from action or lack of action on the part of management in establishing the system. They are the basic economic parameters to any inventory decision model, and the more relevant ones to most systems are itemized as follows: 1) purchase cost, 2) order/setup cost, 3) holding cost, 4) stockout cost [86].

II.2.1.7. Cost Accumulation Profile

Organizations that manufacture products accumulate costs as manufacturing takes place. Until raw materials are released, no labor or labor-related costs are incurred. But once manufacturing begins, those materials acquire more and more value (cost) as labor and factory overhead are added. Ultimately, completed items

reach peak value as they go into finished goods inventory and await shipment to the customer.

Assume an intermittent manufacturing process where material is routed through a series of steps (stages). Value is added at each step, and time is consumed between steps (in queue, transfer, or storage). Assume the product is manufactured in discrete, equal-sized batches. The inventory cost accumulation profile is illustrated in Figure II.23. At the beginning of the process, the cost is that of the raw materials; each step (incline) adds additional cost. The horizontal line segments indicate that materials do not change value while in a raw material, storage, or finished goods state. The slope of the line at each step represents the rate at which labor cost is being added. The final vertical rise is the addition of factory overhead to the batch to obtain the total manufacturing cost.

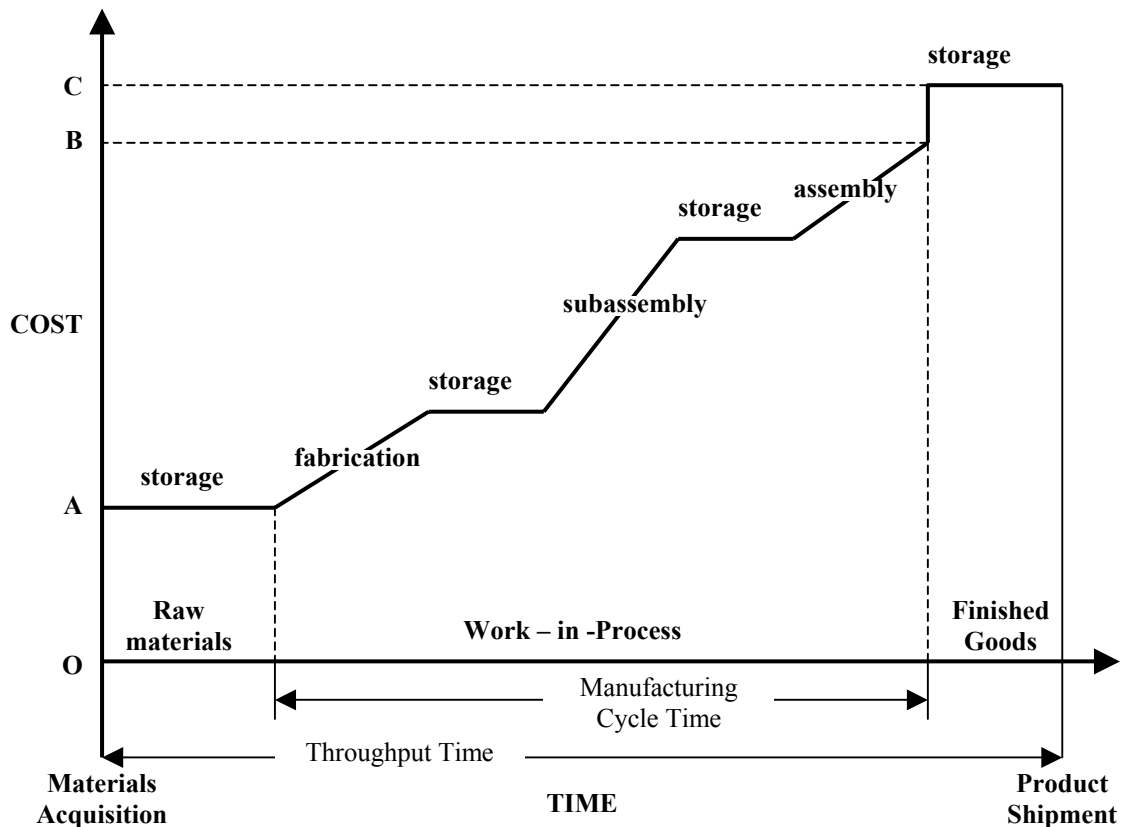


Figure II.23. Inventory Cost Accumulation Profile [2]. (OA = material cost, AB = labor cost, BC = factory overhead, OC = total product cost.)

II.2.2. Demand Systems

II.2.2.1 Independent Demand Systems: Deterministic Models

In deterministic models, all of the parameters and variables are known or can be calculated with certainty. The rate of demand for units and the appropriate inventory costs are assumed to be known with assurance. The replenishment lead time also is presumed constant and independent of demand. The real world is seldom as well behaved as described by deterministic models but is more reasonably depicted in probabilistic terms (i.e. in stochastic models, where some or all of the variables are probabilistic). However, deterministic models are frequently excellent approximations, or at least, good starting points for describing inventory phenomena.

It usually is easier to work analytically with inventory models if the variables can be treated as continuous rather than discrete. In cases where inventory demand is sufficiently high, variables can be considered continuous, and it is possible to take derivatives instead of having to work with differences. This collection of models assumes continuous properties and thereby simplifies the task of finding optimizing inventory policies.

1.a. Fixed Order Size Systems

The two fundamental questions posed to any inventory system are how many and when to order. The answers depend on the nature of inventory demand and the parameters used to define the system. As previously described, demand in a deterministic fixed order size system is assumed to be known or able to be calculated with certainty and presumed to be continuous. Therefore, the same number of units (how many) always is ordered, and the time between orders (when) is not expected to vary. The stock level is reviewed continuously, and whenever the inventory position reaches a predetermined point, an order for a fixed number of units is placed. Thus, the two defining parameters of the system are the reorder point (B) and the size of the order (Q).

The fixed order size system also is termed a Q-system, since the size of the order (Q) is fixed for each replenishment. A typical example is depicted in Figure II.24.

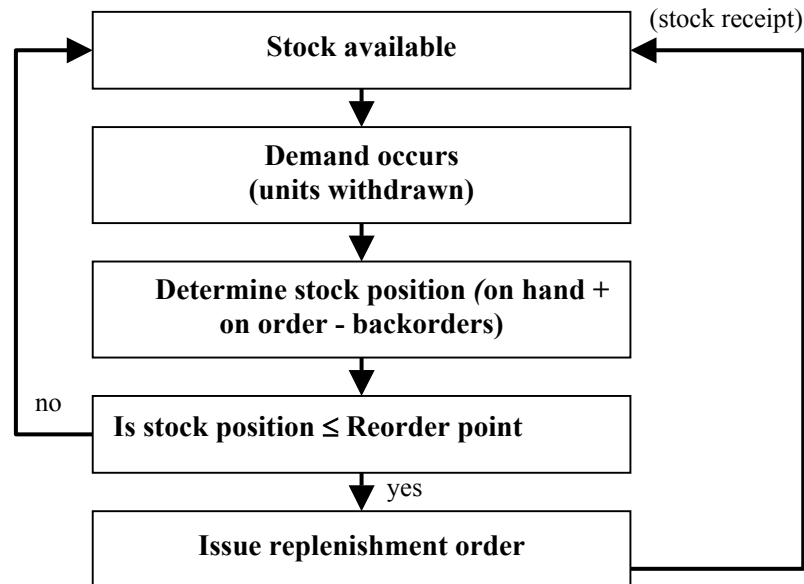


Figure II.24. Fixed Order Size System [2].

Economic Order Quantity (EOQ)-Single Items: The size of an order that minimizes the total inventory cost is known as the economic order quantity (EOQ). The classical inventory model assumes the idealized situations shown in Figure II.25, where Q is the order size. Upon receipt of an order, the inventory level is Q units. Units are withdrawn from inventory at a constant demand rate, which is represented by the negative sloping lines. When the inventory reaches the reorder point B , a new order is placed for Q units.

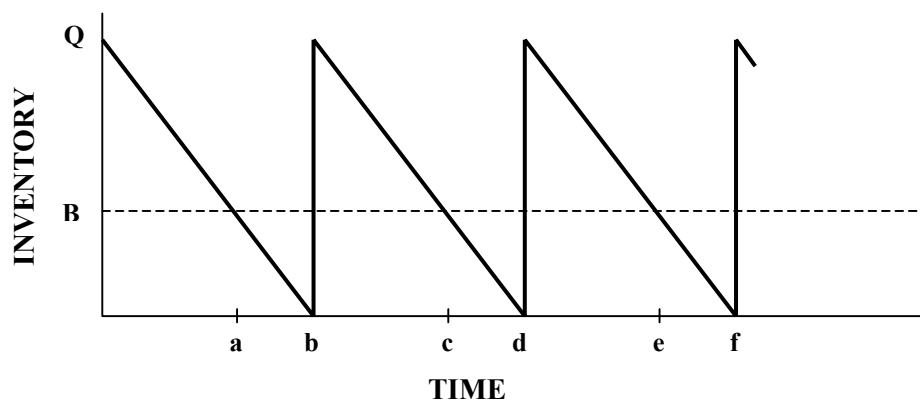


Figure II.25. Classical Inventory Model [2].(Key: Q = Lot Size; $Q/2$ = Average Inventory; B = Reorder Point; $ac = ce$ = Interval Between Orders; $ab = cd = ef$ = Lead Time.)

After a fixed time period, the order is received all at once and placed into inventory. The vertical lines indicate the receipt of a lot into inventory. The new lot is received just as the inventory level reaches zero, so the average inventory is $(Q + 0)/2$ or $Q/2$. If stockouts are not permitted, the total inventory cost per year is graphically depicted by Figure II.26 and by the following formula:

$$\text{total annual cost} = (\text{purchase cost}) + (\text{order cost}) + (\text{holding cost}), \quad (\text{II.2})$$

$$TC = RP + \frac{RC}{Q} + \frac{QH}{2}, \quad (\text{II.3})$$

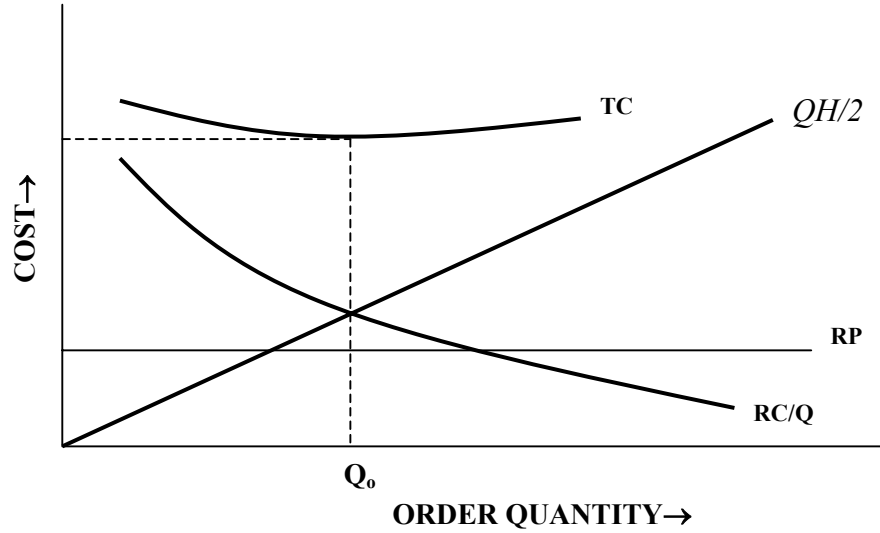


Figure II.26. Annual Inventory Costs [2].

where

R = annual demand in units,

P = purchase cost of an item,

C = ordering cost per order,

H = PF = holding cost per unit per year,

Q = lot size or order quantity in units,

F = annual holding cost as a fraction of unit cost.

In effect, the total annual cost equation determines the annual purchase cost, which is the annual demand times the purchase cost per unit. The annual order cost is obtained as the number of orders per year (R/Q) times the cost to place an order (C). The annual holding cost is the average inventory ($Q/2$) times the annual unit holding cost (H). The sum of the three costs (purchase, order, and holding) is the total inventory cost per year for any given purchased item.

To obtain the minimum cost lot size (EOQ), take the first derivative of total annual cost with respect to the lot size (Q) and set it equal to zero:

$$\frac{dTC}{dQ} = \frac{H}{2} - \frac{CR}{Q^2} = 0. \quad (\text{II.4})$$

Solving the equation for Q , we get the EOQ formula:

$$Q_o = \sqrt{\frac{2CR}{H}} = \sqrt{\frac{2CR}{PF}} = \text{economic order quantity.} \quad (\text{II.5})$$

Once the economic order quantity is known, the expected number of orders placed during the year, m , and the average time between orders, T , can be determined:

$$\text{expected number of orders during year} = m = \frac{R}{Q_o} = \sqrt{\frac{HR}{2C}}, \quad (\text{II.6})$$

$$\text{average order interval} = T = \frac{1}{m} = \frac{Q_o}{R} = \sqrt{\frac{2C}{RH}}. \quad (\text{II.7})$$

The reorder point is obtained by determining the demand that will occur during the lead time period. When the stock position [(on hand) + (on order) - (backorders)] reaches the reorder point, an order will be placed for Q_o units, the economic order quantity. The following formula gives the reorder point when the lead time L is expressed in months:

$$B = \frac{RL}{12} = \text{reorder point in units.} \quad (\text{II.8})$$

if the lead time L is expressed in weeks, the reorder point is expressed as

$$B = \frac{RL}{52} = \text{reorder point in units.} \quad (\text{II.9})$$

The minimum total cost per year is obtained by substituting Q_o for Q in the total annual cost equation. A simplified formula for the minimum total cost per year results:

$$TC_o = RP + HQ_o. \quad (\text{II.10})$$

The classical EOQ model is based on the following assumptions:

1. The demand rate is known and constant.
2. The lead time is known and constant.
3. The entire lot size is added to inventory at the same time.
4. No stockouts are permitted; since demand and lead time are known, stockouts can be avoided.
5. The cost structure is fixed; order/setup costs are the same regardless of lot size, holding cost is a linear function based on average inventory, and no quantity discounts are given on large purchases.

6. There is sufficient space, capacity, and capital to procure the desired quantity.
7. The item is a single product; it does not interact with any other inventory items (there are no joint orders).

1.b. Batch-Type Production Systems

In batch-type production systems, products are often made to stock in lot sizes (batches). In most cases, multiple products are produced on the same equipment; these products share and even compete for common production capacity as individual items and/or as members of a product family. Planning batch production may involve the determination of the optimum number of units to include in each production run to minimize total annual costs. It also may require coordinating production runs through batch scheduling- that is, determining the order of production and the number of each item to produce before production is changed over to the next product in the sequence. Thus, it may not seek optimum production levels, but allocate production capacity to items in relation to their demands, production rates, and existing inventory levels.

Economic Production Quantity (EPQ)-Single Items: The EOQ formulation assumes that the entire order for an item is received into inventory at a given time. This assumption applies whether the item is purchased externally or produced in-house. If a firm produces a product that has a constant demand and that product is entered into inventory instantaneously, the production order quantity should be determined by the EOQ model. In this case, the order cost will be replaced by a setup cost.

The assumption that the entire order is received into inventory at one time is often not true for in-house production runs. Frequently, replenishment is continuous, and the stock of inventory is being depleted even while the production of an order takes place (finished goods go into inventory gradually). Thus, the EOQ model must be revised to take account of this change in its assumptions. The economic production quantity (EPQ) accommodates this change. Whereas the EOQ assumes discrete instantaneous additions to stock, the EPQ implicitly assumes continuous gradual additions to stock over the production period. Therefore, the EPQ is more suitable to situations where consumption and replenishment simultaneously decrease and increase the stock level.

In gradual replenishment situations, the major decision involves the

determination of the size of the production run (order). The production run that minimizes the total inventory cost is the economic production quantity (EPQ). Figure II.27 depicts a typical cycle for the gradual replenishment of inventory over the time period t_p .

Production starts at time zero and ends at time t_p . During the time period from t_p to t , no production occurs and the inventory stock is depleted. At time t , a new production run is started. If there had been no demand during the period zero to t_p , inventories would have risen at a rate p . Hence, $t_p = Q/p$. Since there is a demand at rate r , inventories will increase at a rate $p - r$, where p is greater than r .

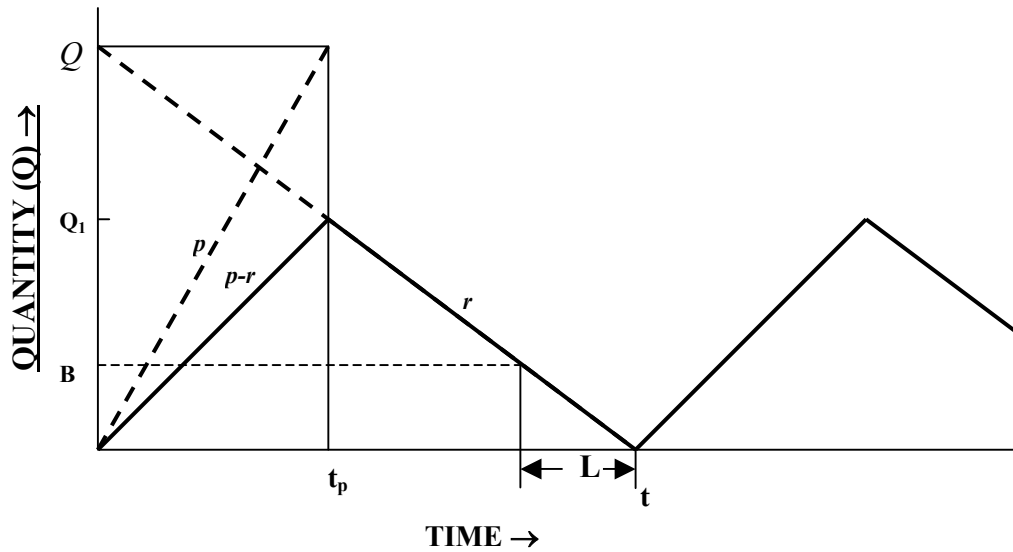


Figure II.27. Production Order Quantity [2]. (Key: p = production rate; r = demand rate ($r < p$); t_p = production time period; t = time between production runs; $Q_1 = t_p (p - r)$ = maximum inventory; $Q = t_p p$ = production run quantity; $Q_1/2 = t_p (p - r)/2 = [Q(p - r)]/2p$ = average inventory; $p - r$ = inventory buildup rate; B = reorder point; L = lead time.)

During the production period, zero to t_p , inventories accumulate at a rate equal to the production rate minus the demand rate, $p - r$. The maximum inventory level is $t_p (p - r)$, or the time of production times the rate of inventory buildup. The average inventory is one-half the maximum inventory, or $t_p [(p - r)/2]$. Since $t_p = Q/p$, the average inventory is given by the following formula:

$$\text{average inventory} = \frac{Q(p - r)}{2p}. \quad (\text{II.11})$$

The average inventory is not just $Q/2$, but is $Q(p - r)/2p$. The factor r/p represents the fractional amount of the lot size withdrawn from stock during the time the item is being produced. The factor $(p - r)/p$ represents the fractional amount of the lot size remaining in stock at the end of the production period. Since the stock

level ranges between a minimum of zero and a maximum of $Q(p - r)/p$, the average inventory is simply one-half of the maximum inventory. If stockouts are not permitted, the total annual inventory cost is as follows:

$$\text{total annual cost} = (\text{production cost}) + (\text{setup cost}) + (\text{holding cost}), \quad (\text{II.12})$$

$$TC = RP + \frac{RC}{Q} + \frac{Q(p - r)H}{P}, \quad (\text{II.13})$$

where

R = annual demand in units,

P = unit production cost,

Q = size of production run or production order quantity,

p = production rate,

r = demand rate,

C = setup cost per production run,

H = holding cost per unit per year.

To obtain the minimum cost production order quantity (EPQ), take the first derivative of total annual cost with respect to the production order quantity Q and set it equal to zero:

$$\frac{dTC}{dQ} = -\frac{RC}{Q^2} + \frac{(p - r)H}{2p} = 0. \quad (\text{II.14})$$

Solving the equation for Q , the EPQ formula is obtained:

$$Q_o = \sqrt{\frac{2CRp}{(H)(p - r)}} = \text{economic production quantity}. \quad (\text{II.15})$$

Once the economic production quantity is known, the optimum length of the production run can be obtained as well as the production reorder point. If it is assumed that there are N operating days per year, the following relationships apply:

$$\text{optimum length of production run} = \frac{Q_o}{p}, \quad (\text{II.16})$$

$$\text{production reorder point in units} = B \quad (\text{II.17})$$

$$= \frac{RL}{N} = rL, \quad (\text{II.18})$$

where L is the scheduling and production setup time in days and r is the daily demand rate. The EPQ is somewhat larger than the ordinary EOQ, because the factor $p/(p - r)$ is greater than one.

Replacing Q in the total annual cost formula by Q_o , the following formula for the minimum total annual cost results:

$$TC_o = RP + \frac{(p - r)HQ_o}{p} . \quad (II.19)$$

1.c. Fixed Order Interval Systems

The fixed order interval system, also called a periodic inventory system, is based on a periodic rather than a continuous review of the inventory stock position. It is a time based inventory system in which orders are placed at equally spaced predetermined points in time (when to order). The order quantity (how many to order) is dependent upon the usage (demand) between order review periods.

A maximum inventory level for the item is developed, based on usage during both the lead time and the order interval. After a fixed period of time (T) has passed, the stock position of the item is determined. An order is placed to replenish the stock, and the size of the order is sufficient to bring the present stock level up to the maximum inventory level. Thus, the size of the order is the difference between the maximum inventory level and the inventory position at the time of the review. In deterministic fixed order interval systems, the order size is not expected to vary, because usage (demand) is assumed to be both known with certainty and continuous.

The system, therefore, contains only two parameters to be chosen: the fixed review period T and the maximum inventory level E . From these, all replenishment orders can be found. The fixed order interval system is termed a T-system, since the order interval (when to order) is constant. Occasionally, the order interval is rounded to a weekly, monthly, or some other convenient time basis. A typical fixed order interval system is shown in Figures II.28 and II.29.

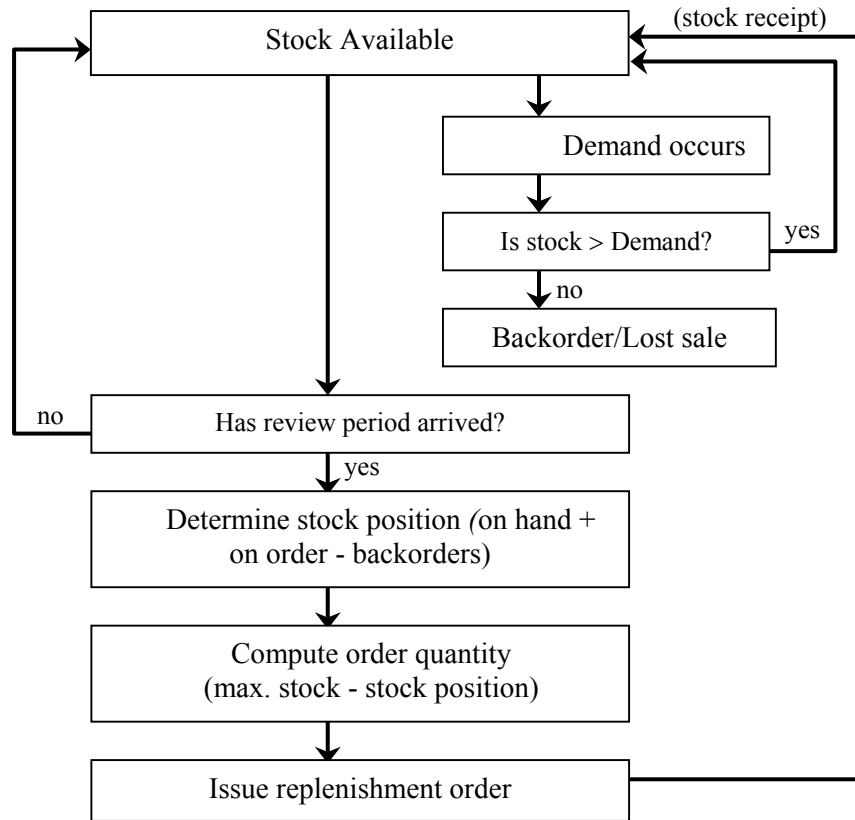


Figure II.28. Fixed Order Interval System [2].

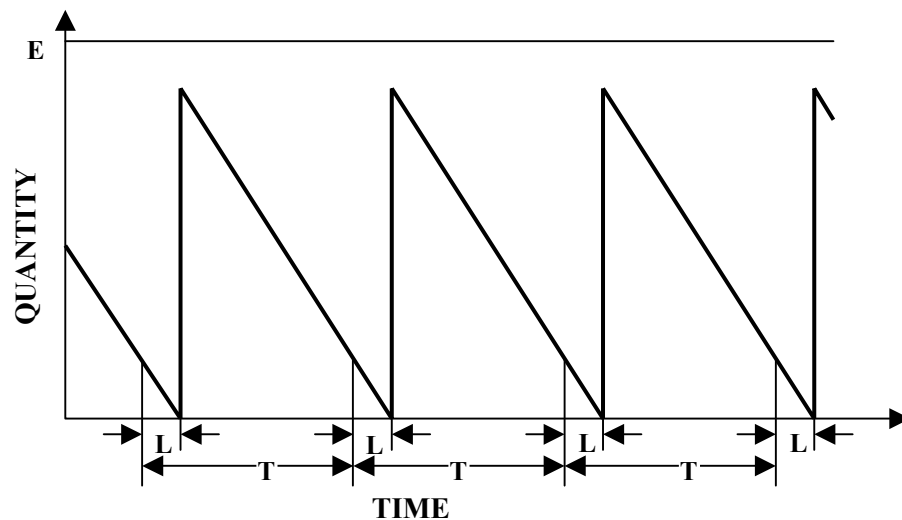


Figure II.29. Fixed Order Interval System [2].

Economic Order Interval (EOI)-Single Items: The basic problem in this system is determining the order interval T and the desired maximum inventory level E . The economic order interval can be obtained by the minimization of the total annual cost. If stockouts are not permitted, the total annual inventory cost is given by Figure II.30 and the following formula:

$$\text{total annual cost} = (\text{purchase cost}) + (\text{order cost}) + (\text{holding cost}), \quad (\text{II.20})$$

$$TC = RP + mC + \frac{RFP}{2m} = RP + \frac{C}{T} + \frac{RFPT}{2}, \quad (\text{II.21})$$

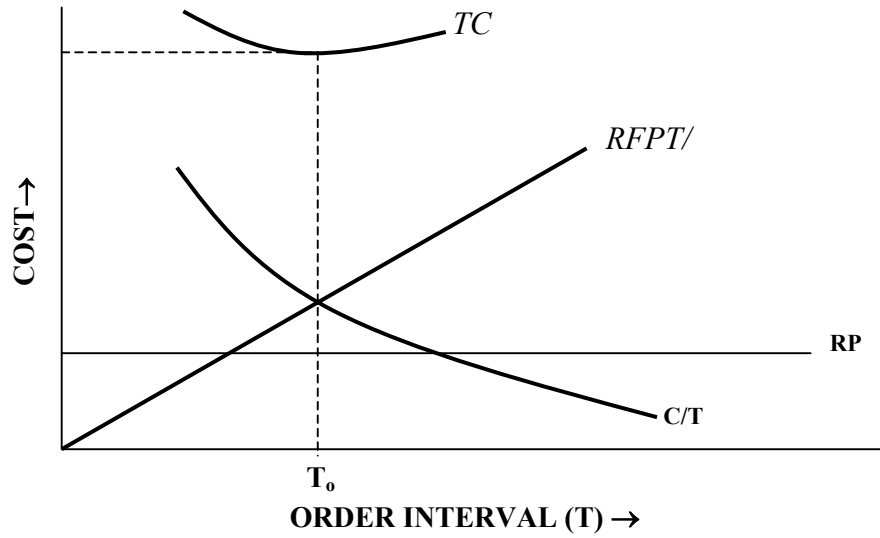


Figure II.30. Annual Inventory Costs [2].

where

$$m = \frac{1}{T} = \text{number of orders or reviews per year}, \quad (\text{II.22})$$

$$\frac{R}{2m} = \frac{RT}{2} = \text{average inventory in units}, \quad (\text{II.23})$$

$$T = \frac{1}{m} = \text{order interval in years}. \quad (\text{II.24})$$

To obtain the minimum cost order interval, the first derivative of the total annual cost with respect to the order interval T is set equal to zero:

$$\frac{dTC}{dT} = \frac{-C}{T^2} + \frac{RFP}{2} = 0. \quad (\text{II.25})$$

Solving the equation for T , the following formula results:

$$T_o = \sqrt{\frac{2C}{RFP}} = \text{economic order interval (EOI) in years}. \quad (\text{II.26})$$

The minimum cost number of reviews per year (m) is simply the reciprocal of T_o , or

$$m_o = \frac{1}{T_o} = \sqrt{\frac{RFP}{2C}}. \quad (\text{II.27})$$

In deterministic situations, there is no difference between the fixed order size system and the fixed order interval system. The order quantity for the fixed order interval is simply $Q = RT$, or

$$Q_o = RT_o = R \sqrt{\frac{2C}{RFP}} = \sqrt{\frac{2CR}{FP}} = \sqrt{\frac{2CR}{H}} \quad (\text{II.28})$$

The maximum inventory level E must be large enough to satisfy demand during the subsequent order interval T and also during the lead time L . The following formula gives the maximum inventory level when the order interval and lead time are expressed in years:

$$E = RT + RL = R(T + L) = Q + B = \text{maximum inventory level.} \quad (\text{II.29})$$

The following formula gives the maximum inventory level when the order interval and lead time are expressed in days and there are N operating days in the year:

$$E = \frac{RT}{N} + \frac{RL}{N} = \frac{R(T + L)}{N} = Q + B. \quad (\text{II.30})$$

The minimum total cost per year is obtained by putting T_o for T in the total annual cost equation. The following formula for the minimum total cost per year results:

$$TC_o = RP + RHT_o. \quad (\text{II.31})$$

II.2.2.2. Discrete Demand Systems: Deterministic Models

The lot sizing techniques developed for continuous and independent demand items (EOQ, EPQ, and EOI) assume that demand occurs with certainty at a constant rate. Although the static EOQs, EPQs, and EOIs are insensitive (robust) to variations from their underlying assumptions (including demand variations), there are situations where time variations in demand are so pronounced that the constant demand rate assumption is seriously violated. Even though demand may be deterministic or known with certainty, its pattern may vary so drastically over time that it cannot appropriately be addressed by techniques that approximate average inventory by a repeating sawtooth pattern.

Demand which exhibits time varying patterns is characterized as discrete. Discrete demand patterns can occur in either independent or dependent demand items, and hence represent another departure from the applications associated with the lot sizing techniques suitable to continuous, independent demand situations. The emphasis is on lot sizing models for items exhibiting deterministic, time varying demand, whether that demand is independent or dependent. Such is the case for components with lumpiness of demand in an MRP system, as well as for end items with a pronounced trend and/or seasonal effect.

When the demand rate varies with time, an exact analysis is more burdensome than the fixed order sizes used with continuous demand items. It is necessary to analyze demand over a finite period from the present to a specified planning horizon where the length of the planning horizon can have a substantial effect on the lot size decisions. Furthermore, a dynamic rather than a static lot sizing policy must be put into effect, and it is often necessary to adopt a rolling schedule. Replenishment quantities are computed over the entire planning horizon, but only the imminent (immediate) decision is implemented. As the schedule rolls forward in time, new demand information is appended so that the constant length of the planning horizon is maintained.

Various approaches have been devised to handle varying demand rates. A simplistic approach is to ignore the variation and apply the EOQ formulation with an average demand rate. In lot-for-lot ordering, the order for each period is the exact quantity in that period. Wagner and Whitin developed a dynamic programming procedure to determine the optimum varying order size [87]. Silver and Meal developed a heuristic algorithm for order size determination [88]. Groff also developed a marginal cost algorithm for lot sizing [89].

2.a. Lot -For-Lot Ordering

Lot-for-lot (LFL) ordering is the simplest approach of all. Items are purchased in the exact quantities required for each period. There is no forward buying beyond the immediate period. This approach minimizes the inventory holding cost, since no items are ever held over from period to period. However, it ignores the costs of placing an order. It is suitable for very expensive items or items with a highly discontinuous demand where excellent inventory control must be maintained. It is also well suited to high-volume, continuous production (assembly lines).

2.b. Periodic Order Quantity

A periodic order quantity (POQ) approach to discrete demand results in varying lot sizes which each encompass the demand for a fixed period of time. The fixed time period is given as an economic order interval (EOI) or economic order quantity (EOQ) expressed as a time supply. The EOI is calculated using an average demand rate, instead of a constant demand rate per period as with continuous models. The calculated economic order interval is rounded to the nearest integer greater than zero, so the lot sizes obtained from its use will cover exactly the requirements for an integer number of periods. The EOI is found as follows:

$$EOI = \frac{EOQ}{\bar{R}} = \sqrt{\frac{2C}{\bar{R}Ph}}, \quad (\text{II.32})$$

where

EOI = economic order interval in periods,

C = ordering cost per order,

h = holding cost fraction per period,

P = unit purchase cost,

$\bar{R}$ = average demand rate per period.

The lot sizes are simply the accumulated demand for the rounded EOI time supply. Order receipts are only planned for periods with a positive demand. If zero demand exists for an order receipt period, the order receipt is moved forward to the first subsequent period with a positive demand.

II.2.2.3. Independent Demand Systems: Probabilistic Models

If demand and lead time are treated as *constants*, they are called deterministic; if they are treated as *random variables*, they are called probabilistic or stochastic. The models in this chapter assume that the average demand remains approximately constant with time and that it is possible to state the probability distribution of the demand. In particular, since the lead time is the usual period of concern, attention is focused on the distribution of demand during the lead time. Lead time demand is a random variable if at least one of its primary components (demand and/or lead time) is a random variable.

Inventory of independent demand items can be divided into working stock and safety stock. Working stock is what is expected to be used during a given time period. The average working stock is one-half the order quantity (lot size), which may be determined by the EOQ formula or some variant of it. The working stock varies with the square root of annual usage. Safety stock, unlike working stock, does not usually depend on lot sizes. It is not held because an organization expects to use it, but because it might. It is held because an organization believes in the long run it is more efficient (it will generate more revenue or reduce costs).

3.a. Safety Stock

Risk and uncertainty enter the inventory analysis through many variables, but the most prevalent are variations in demand and lead time. Such variations are absorbed by provision for safety stocks, also referred to as buffer stocks or fluctuation stocks. Safety stocks are extra inventory kept on hand as a cushion against stockouts due to random perturbations of nature or the environment. They are needed to cover the demand during the replenishment lead time in case actual demand exceeds expected demand, or the lead time exceeds the expected lead time. Safety stock has two effects on a firm's cost: it decreases the cost of stockouts, but it increases holding costs.

Under the fixed order size system (*Q-system*), there is a fixed order quantity that is ordered every time the reorder point is reached as shown in Figure II.31.

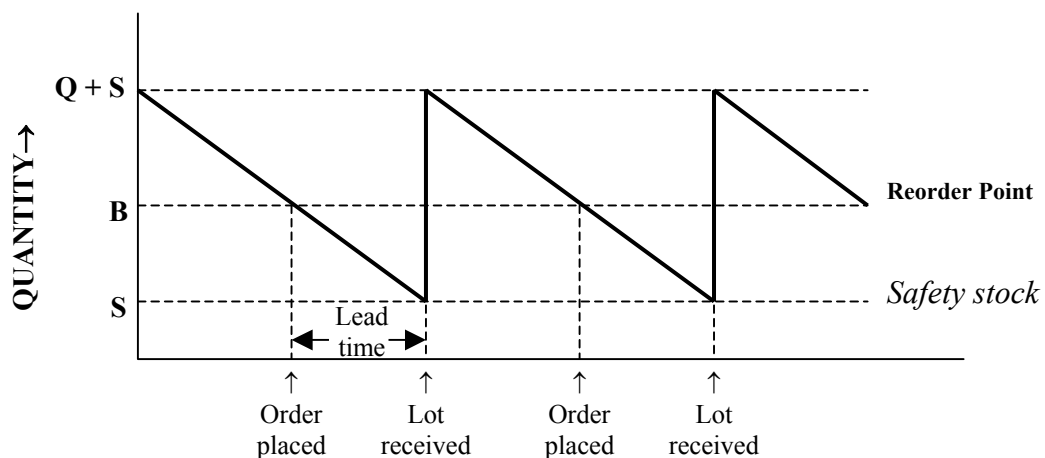


Figure II.31. Ideal Inventory Model [2].

Safety stock is needed to protect against a stockout after the reorder point is reached and prior to receipt of an order. This time period during which a stockout could occur is known as the lead time. The fixed order quantity Q and the reorder

point B completely define the fixed order size system. Safety stock is an important constituent of the reorder point. In fixed order size systems, the reorder point B is composed of the mean lead time demand M plus the safety stock S .

Safety stocks are needed because forecasts or estimations are less than perfect and suppliers sometimes fail to deliver goods on time. There should be some protection against these two unfavorable contingencies:

1. a higher rate of use than was forecasted,
2. a late delivery of goods.

Safety stock can be considered a fairly permanent investment in inventory. On an average, safety stock is always on hand-similar to a fixed asset. In deterministic fixed order size models, the average inventory is approximated as $Q/2$. When safety stock is held, the approximate average inventory becomes $S + Q/2$, where S is the safety stock quantity and Q is the order quantity.

The relationship between safety stock and service level is shown in Figure II.32. It shows safety stock or investment along the vertical axis and service level along the horizontal axis. For a single item, the relationship is straightforward: the curve slopes upward throughout, indicating that additional safety stock (investment) will always increase the level of customer service. The curve gives no indication of what the level of service or investment should be. Management must decide if the additional expenditure is justified in a particular case.

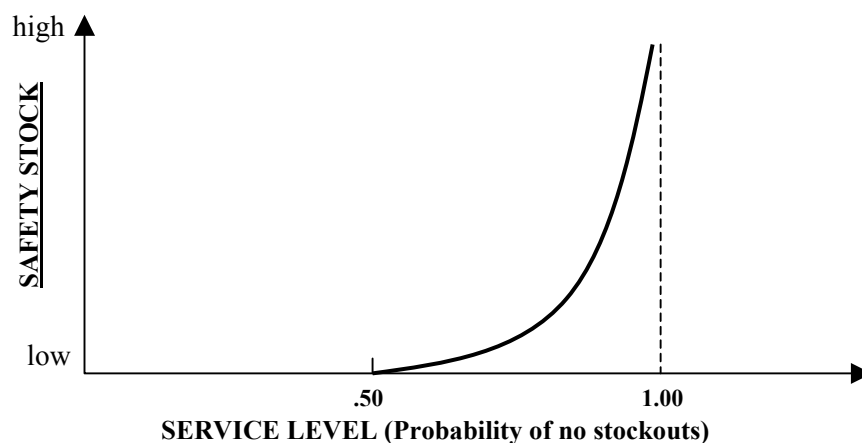


Figure II.32. Safety Stock vs. Service Level [2].

There is no fixed formula or rigid procedure to follow in determining the safety stock. The calculations of different methods available are based on demand, lead time, and stockout costs. The information known about these variables determines the complexity of the calculations. The safety stock is simply the difference between

the stock available for the replenishment period (reorder point) and the average demand during the replenishment period. The reorder point is defined as the stock position at which an order is triggered.

3.b. Statistical Considerations

When the demand is probabilistic (not deterministic), rather than minimize cost, it is necessary to minimize the expected cost. If the demand distribution is discrete, the expected cost is obtained by summing the different costs for each strategy weighted (multiplied) by their respective probabilities and then selecting the strategy (demand level) with the lowest expected cost. If the demand distribution is continuous, the minimum expected cost expression is obtained by taking the derivative of expected cost with respect to the variable and then setting it equal to zero.

Two of the best-known and most widely used statistics for describing distributions are the arithmetic mean and the standard deviation. The arithmetic mean is a measure of central tendency, while the standard deviation is a measure of dispersion of a distribution. The arithmetic mean $\overline{M}$ for a continuous distribution is

$$\overline{M} = \int_0^{\infty} Mf(M)dM = \text{mean lead time demand}, \quad (\text{II.33})$$

and the standard deviation σ is the square root of the variance,

$$\sigma^2 = \int_0^{\infty} (M - \overline{M})^2 f(M)dM = \text{variance of lead time demand}. \quad (\text{II.34})$$

For discrete data, the following formulas apply:

$$\overline{M} = \sum_{M=0}^{M_{\max}} MP(M) = \text{mean lead time demand}, \quad (\text{II.35})$$

$$\sigma^2 = \sum_{M=0}^{M_{\max}} (M - \overline{M})^2 P(M) = \text{variance of lead time demand}, \quad (\text{II.36})$$

where

M = lead time demand in units (a random variable),

$f(M)$ = probability density function of lead time demand,

σ = standard deviation of lead time demand,

$P(M)$ = probability of a lead time demand of M units,

M_{max} = maximum lead time demand in units.

The probability of a stockout for a given item is simply the probability that the demand during the lead time will exceed the reorder point. When continuous distributions are employed, the stockout probability is the first definite integral of the probability density function of demand during the lead time from the reorder point to infinity, or

$$P(M > B) = \int_B^{\infty} f(M) dM . \quad (\text{II.37})$$

The expected stockout quantity during the lead time is the second definite integral of the probability density function of demand during the lead time from the reorder point to infinity, or

$$E(M > B) = \int_B^{\infty} \left[\int_M^{\infty} f(M) dM \right] dM = \int_B^{\infty} (M - B) f(M) dM . \quad (\text{II.38})$$

For discrete data, the following formulas apply:

$$P(M > B) = \sum_{M=B+1}^{M_{max}} P(M) , \quad (\text{II.39})$$

$$E(M > B) = \sum_{M=B+1}^{M_{max}} (M - B) P(M) \quad (\text{II.40})$$

where

$P(M > B)$ = probability of a stockout,

B = reorder point in units,

$f(M)$ = probability density function of demand during the lead time,

$E(M > B)$ = expected stockout in units during lead time.

A summary of the relevant statistical measures outlined in this section is contained in Table II.5 for both continuous and discrete distributions.

The normal, Poisson, and negative exponential distributions have been found to be of considerable value in describing demand functions. The normal distribution has been found to describe many demand functions at the factory level; the Poisson, at the retail level; and the negative exponential, at the wholesale and retail levels.

Of course, these distributions should not be automatically applied to any demand situation. Statistical tests should establish the basis for any standard distribution assumption concerning a demand function.

Table II.5. Statistical Considerations [2].

Variable	Continuous Distributions	Discrete Distributions
Mean lead time demand, $\bar{M}$	$\int_0^{\infty} Mf(M)dM$	$\sum_{M=0}^{M_{\max}} MP(M)$
Lead time demand variance, σ^2	$\int_0^{\infty} (M - \bar{M})^2 f(M)dM$	$\sum_{M=0}^{M_{\max}} (M - \bar{M})^2 P(M)$
Probability of a stockout, $P(M > B)$	$\int_B^{\infty} f(M)dM$	$\sum_{M=B+1}^{M_{\max}} P(M)$
Expected stockout quantity, $E(M > B)$	$\int_B^{\infty} (M - B)f(M)dM$	$\sum_{M=B+1}^{M_{\max}} (M - B)P(M)$

Normal Distribution. When demand is treated as continuous, the most frequently used distribution is the normal (also called the Gaussian) distribution. The normal distribution is easy to work with, and it is well tabulated. More importantly, the normal distribution tends to reasonably approximate phenomena encountered in practice. It has two defining parameters, the mean and standard deviation.

The general formula for the normal distribution is cumbersome and difficult to use. When demand is normally distributed, the reorder point can be obtained from the following formula:

$$B = \bar{M} + S = \bar{M} + Z\sigma = \text{reorder point in units}, \quad (\text{II.41})$$

where

$\bar{M}$ = average lead time demand in units,

S = safety stock in units,

Z = standard normal deviate,

σ = standard deviation of lead time demand.

Poisson Distribution. The normal distribution is restrictive because of its symmetrical form. A further disadvantage is that the range of the distribution includes negative values. For items of low demand the discrete Poisson distribution is a very likely candidate for the demand distribution. The Poisson distribution is defined by a single parameter, the mean. The mean rate of demand can be determined by dividing the total number of units demanded over the relevant

historical period by the length of the time interval. The standard deviation of the Poisson distribution is simply the square root of the mean ($\sigma = \sqrt{M}$).

Negative Exponential Distribution. The negative exponential distribution has been found to describe demand for some retail and wholesale situations. This continuous distribution is a single-parameter distribution, being completely defined by its mean. The standard deviation of the negative exponential distribution is the same as its mean ($\sigma = \overline{M}$).

II.2.3. Material Requirements Planning (MRP)

The distinctions between independent and dependent demands are important both in classifying inventory items and in developing systems to manage items within each classification. Because the demand for work-in-process and raw materials is dependent on the production of independent demand items, a different basis should be used for planning their usage. Material requirements planning (MRP) systems were developed to help manufacturing and fabrication organizations cope better with their dependent demand items than they could with previous systems built upon inappropriate demand assumptions. MRP is a computer-based system. It is designed to release production and purchase orders to regulate the flow of raw materials and in-process inventories necessary to meet the production schedules for finished products. It enables manufacturing organizations to maintain minimum levels of dependent demand items, yet assures that production schedules for the independent items can be met. It does so through the proper timing of order placement, and thus also is known as "time-phased requirements planning."

II.2.3.1. Closed-Loop MRP

Material requirements planning (MRP), as an information processing system, has made possible planning and controlling both the materials and the capacity required to manufacture end items. A "closed-loop" MRP system is flow diagrammed in Figure II.33. This general overview is one of a broad, integrated information system which goes beyond the simpler order launch inventory control systems which first applied materials planning logic. Supported by numerous files, it enables organizations to develop realistic plans and to coordinate resources to:

1. ensure the availability of materials, components, and products for planned production and for customer delivery,
2. maintain the lowest possible level of inventory, and
3. plan manufacturing activities, delivery schedules, and purchasing activities.

Figure II.33 shows that a master production schedule is determined from customer orders, forecasts, and an aggregate production plan. (The master production schedule (MPS) stipulates the products that are to be produced in specific time periods. MRP's role is to schedule all the dependent components that are required to meet the master production schedule through a materials "explosion" process. Referring to the product structure records and the inventory status records, MRP determines what components will be required and when they will be required.

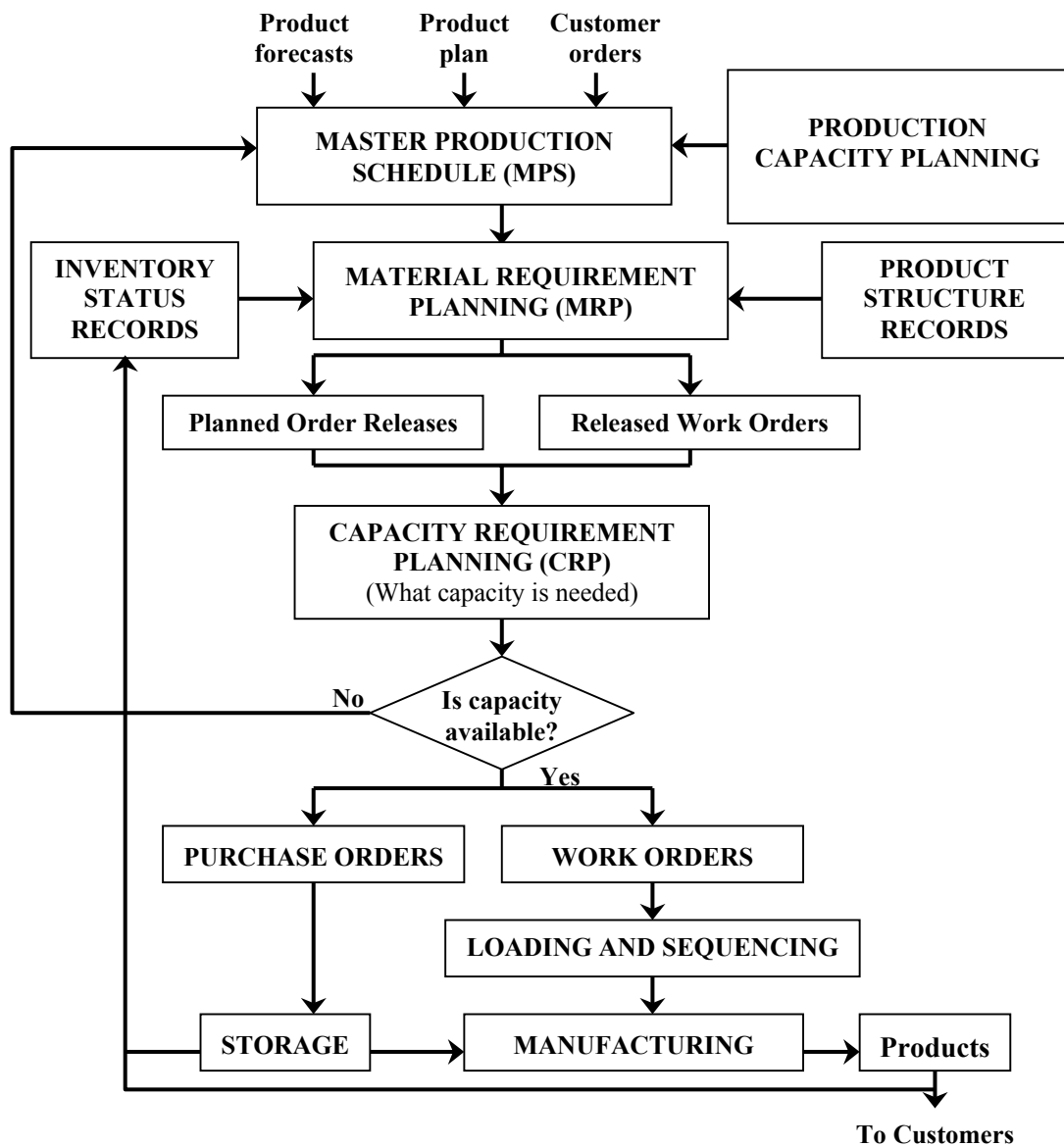


Figure II.33. A Closed-Loop MRP System [2].

II.2.3.2. MRP Inputs

The three major inputs of an MRP system are the master production schedule (MPS), the inventory status records, and the product structure records. These are diagrammed in Figure II.34, and each is explained further in this section. The *master production schedule* (MPS) outlines the production plan for all end items; it expresses how much of each item is planned and when it is wanted.

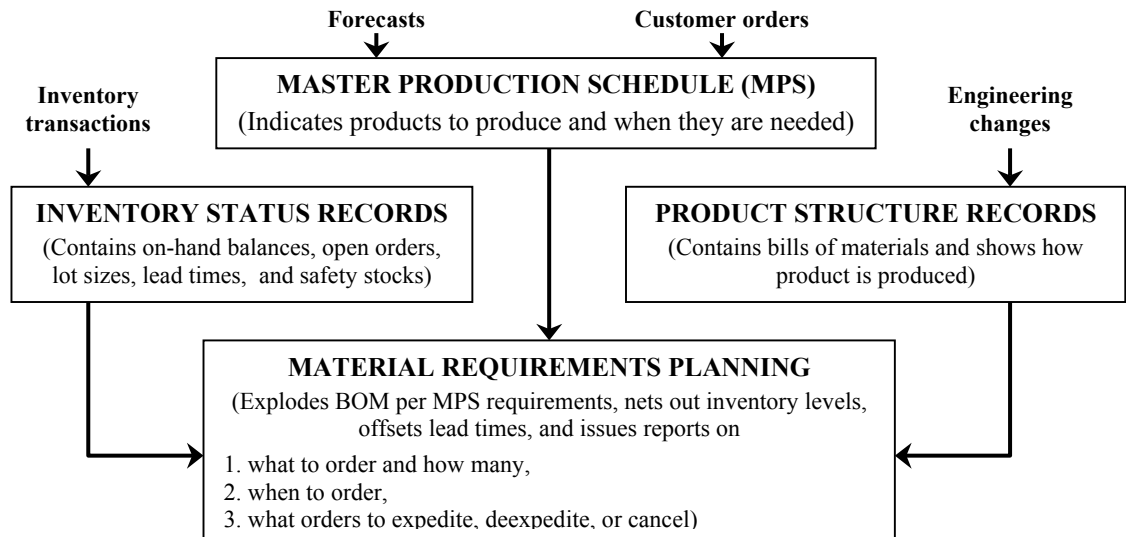


Figure II.34. MRP Inputs [2].

II.2.3.3. MRP Outputs

As suited previously, MRP takes the master production schedule for end items and determines the gross quantities of components according to the requirements given in the product structure records. Gross requirements are obtained by "exploding" the end item product structure record into its lower level requirements. MRP outputs are diagrammed in Figure II.35.

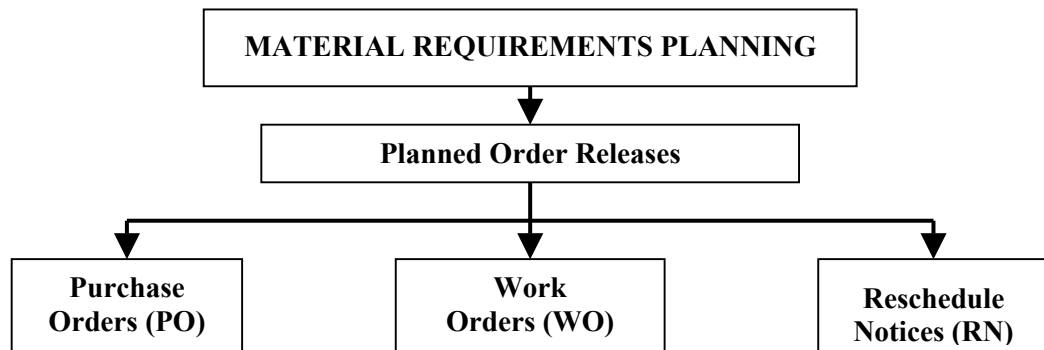


Figure II.35. MRP Outputs [2].

II.2.3.4. MRP Computations

The computations and steps required in the MRP process are shown in Figure II.36. The format for a typical MRP matrix is shown in Table II.6 along with a description of the meaning of each term.

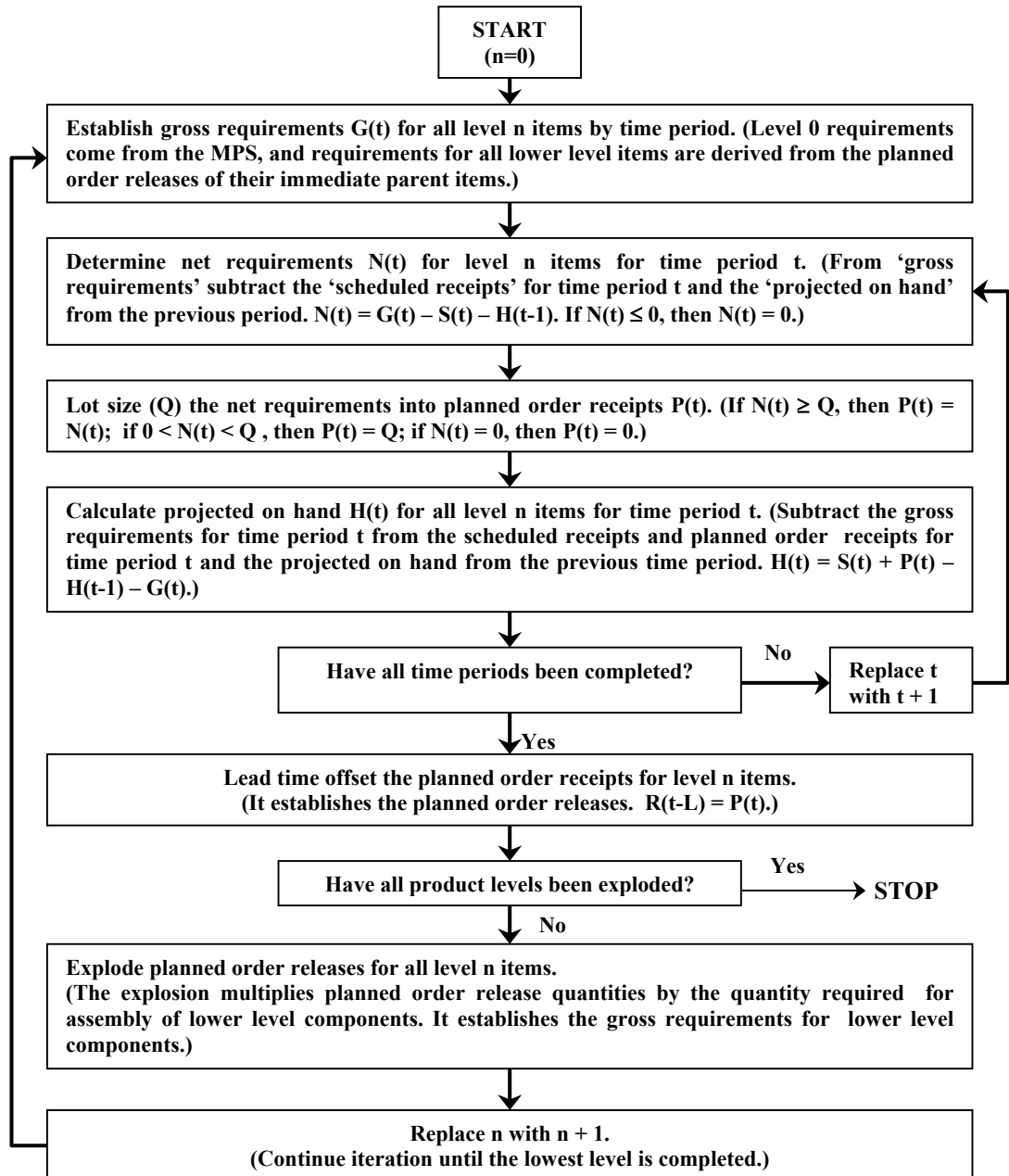


Figure II.36. The MRP Process [2].

Table II.6. Typical MRP Matrix [2].

Lot size	Lead time	On hand	Safety stock	Allocated	Low level code	Item		Period								
								PD	1	2	3	4	5	6	7	8
							Gross requirements									
							Scheduled receipts									
							Projected on hand									
							Net requirements									
							Planned order receipts									
							Planned order releases									

II.2.4. Manufacturing Resource Planning

MRP originally was seen as a superior method of ordering inventory. As it evolved, its major emphasis shifted to scheduling (establishing and maintaining valid due dates on orders). Today, it has been expanded further into manufacturing resource planning (MRP II) to include the effective planning of all the resources of a manufacturing organization. As illustrated in Figure II.37, manufacturing resource planning is a much more sophisticated system, which incorporates information from manufacturing, marketing, engineering, and finance into a total operations plan for the organization.

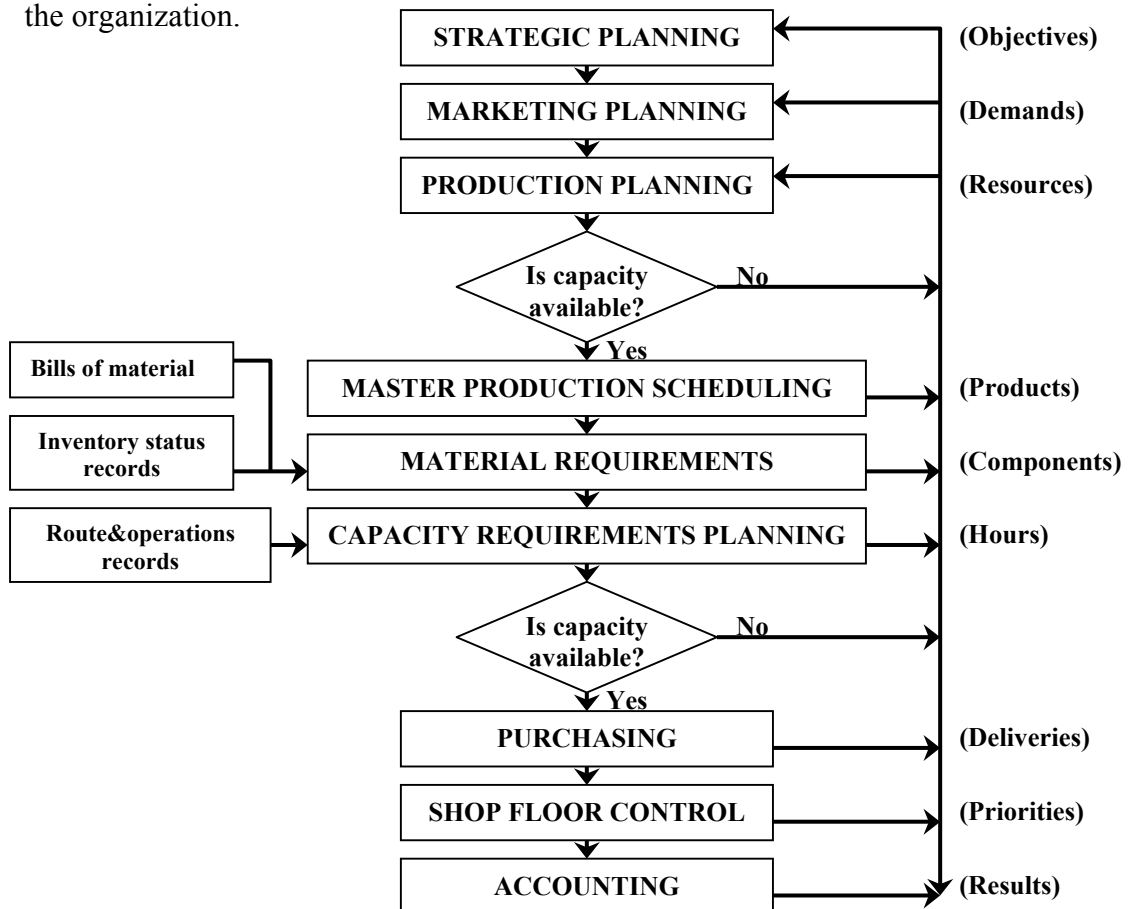


Figure II.37. Manufacturing Resource Planning [2].

Thus, the term MRP has meant different things to different people at different times. Some think of it as an inventory system, others as a scheduling system, and still others as a complete closed-loop production system. It can be all of these things, depending on the organization and the stage of its development with MRP. Most would agree that MRP fosters systems thinking and tends to become the cornerstone of the production system. Within the limits of its methodology, it will reveal (1) what is needed, (2) how many are needed, (3) when they will be needed, and (4) when they should be ordered.

II.2.5. Capacity Planning And Control

Capacity planning determines how many persons, machines, and physical resources are required to accomplish the tasks of production. It defines, measures, and adjusts the levels of capacity so they are consistent with the needs of production. There are many factors that affect capacity. Some factors are completely under management control, while others are not. The management controlled factors include; land, labor, facilities, machines, tooling, shifts worked per day, days worked per week, overtime, subcontracting, preventive maintenance. Other, less controllable factors include; absenteeism, personnel turnover, labor performance, equipment breakdown, scrap and rework. Capacity can be affected by a change in any of the above factors.

Capacity refers to the production capability of a work center, department, or facility. It is important because (1) sufficient capacity is needed to provide the output for current and future customer demand, (2) it directly influences the efficiency (cost) of operations, and (3) it represents a sizable investment by the organization.

It is necessary to plan and control both priority and capacity. Priority is the ranking by due date of an order relative to other orders. It determines what material is required and when it is required. MRP is a form of priority planning. Capacity is the quantity of work that can be performed at a work center and is frequently expressed in hours.

Within the framework of MRP II, capacity management validates the feasibility of manufacturing plans with respect to capacity in each stage of the planning process (production plan, master production schedule, and MRP) so major problems can be anticipated and avoided. As illustrated in Figure II.38 and Table II.7, the three levels of capacity planning are resource requirements planning (RRP),

rough-cut capacity planning (RCCP), and capacity requirements planning (CRP). All three are time-phased predictions of resources required, but each differs in the amount of detail produced.

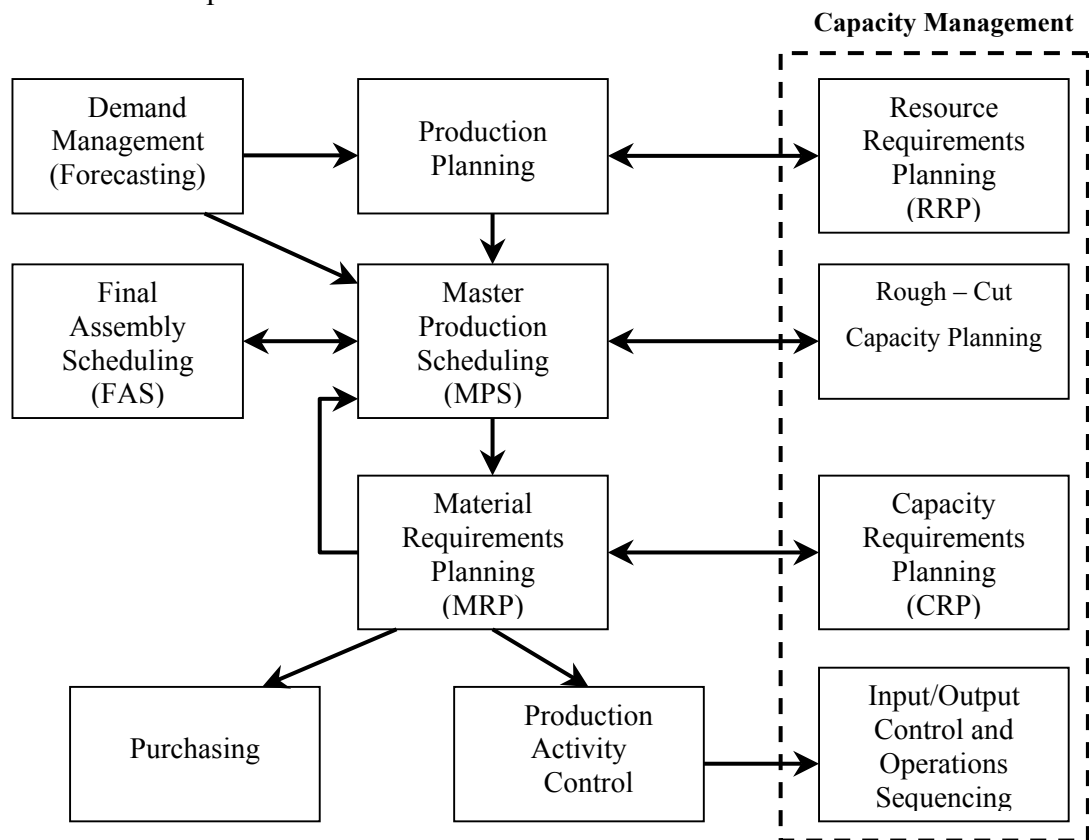


Figure II.38. Capacity Planning and Control [2].

Table II.7. Capacity Planning [2].

Capacity Tool	Time Horizon	Plan	Change Options
Resource requirements planning (RRP)	Long range	Production plan (PP)	Land, facilities, equipment, work force
Rough-cut capacity planning (RCCP)	Medium/long range	Master production schedule (MPS)	Work force, routings, make/buy, tooling, subcontract
Capacity requirements planning (CRP)	Short/medium range	Material requirements planning (MRP)	Work force, routings, overtime, subcontract

Capacity decisions really start with the production plan, which establishes the output for each time period in aggregate terms. The production plan should be leveled so it is realizable within capacity constraints. The time horizon of the production plan is usually long enough that capacity can be changed (expanded or contracted) to meet expected demand. While the production plan deals in aggregate

terms, the master schedule, which is derived from it, contains more specific detail on products and product modules.

The objective of *resource requirements planning* is to identify the aggregate level of major resources required to meet the production plan. Resource profiles are developed to indicate the usage of key resources at the product family level. Resource profiles (also known as capacity bills, time-phased bills of capacity, load profiles, capacity planning factors, and bills of labor or resources) contain three data: (1) identification of the resource, (2) estimated capacity impact of each product family, and (3) time estimates to predict when resources will be required.

The objective of *rough-cut capacity planning* is to identify the resources required to meet the master production schedule. It converts the MPS to a prediction of the load on the factory. Resource profiles are constructed for each master scheduled item, similar to those in RRP but in more detail. By extending the master scheduled quantities over the resource profiles, management has an estimate of the requirements for critical resources over the master production schedule horizon. Thus, RCCP is used to verify that the MPS is realistic in terms of gross capacity.

Capacity requirements planning (CRP) is the tool used to validate the material plan generated by material requirements planning (MRP). CRP determines the amount of specific labor and equipment resources required to meet the material plan over the short- to medium-range horizon. The required capacity is then compared with the available capacity to identify potential overloads or underloads.

The output from MRP will be planned order releases and released (open) orders, which are the inputs into capacity requirements planning (CRP). As shown in Figure II.39, the combination of planned orders and released orders will be converted into their capacity requirements by time period. From route sheets, the operations required and their standard time can be ascertained. The capacity requirements plan will calculate the standard hours of production by work center and time period required to satisfy the master schedule. The objective is to indicate if existing capacity is adequate to support the master schedule.

MRP is an input to capacity requirements planning, which must assess the workload at work centers and determine if capacity is sufficient. MRP systems assume that the master production schedule is feasible and adequate capacity exists to meet its requirements.

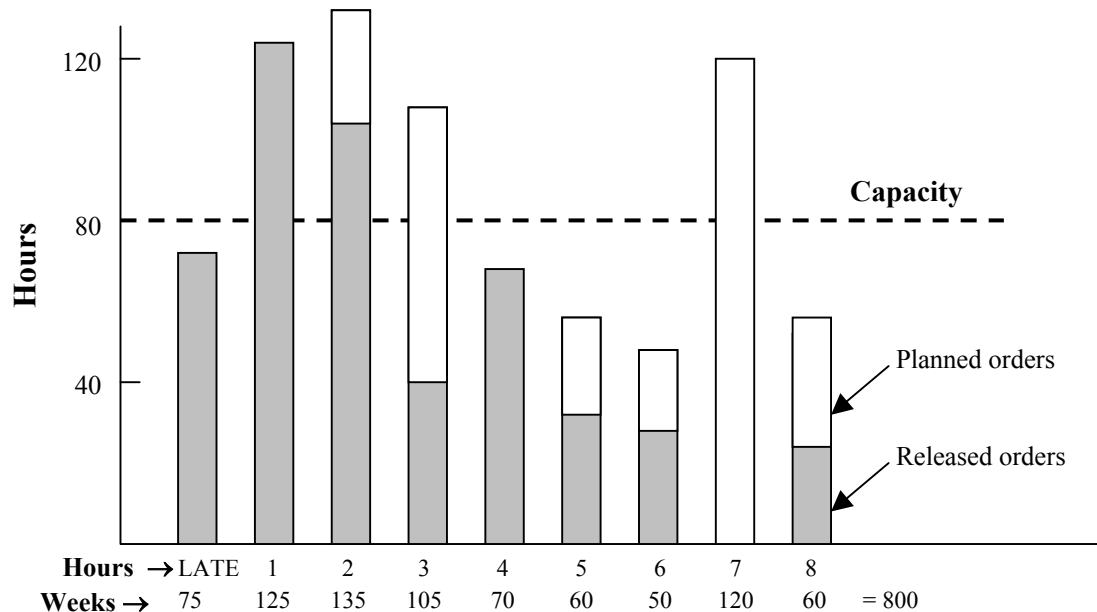


Figure II.39. Capacity Requirements Plan [2].

If capacity is insufficient, changes must be made. Usually, capacities in key work centers are continuously monitored, for they indicate capacity limitations. Adjustments to labor and machine utilization may be necessary in critical work centers. The major modules in a production planning and control system are outlined in Figure II.40.

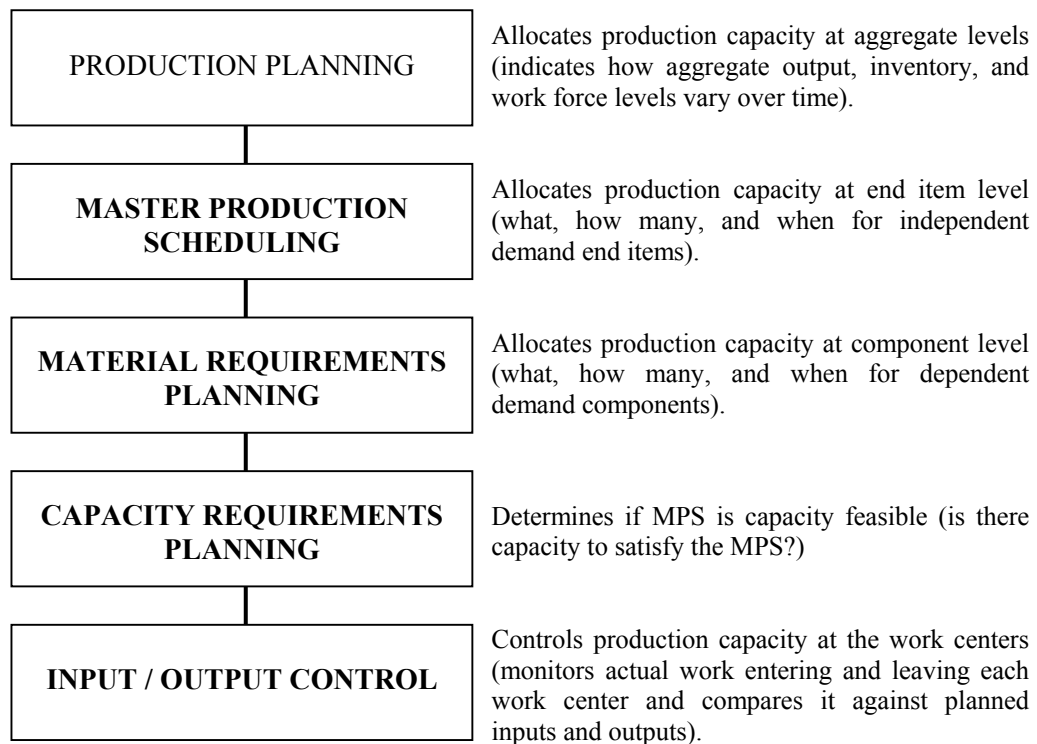


Figure II.40. Production Planning and Control Systems [2].

II.3. LOGISTICAL OPERATIONS

II.3.1. The Work Of Logistics

Logistical competency is achieved by coordinating (1) network design, (2) information, (3) transportation, (4) inventory, and (5) warehousing, material handling, and packaging. Work related to these functional areas is combined to create the capabilities needed to achieve logistical requirements. Attention is directed to an introductory discussion of each facet of logistical work and how they interact in a typical business.

Two qualifications are important when discussing logistical work. First, all firms require the support and cooperation of many other businesses to complete their overall logistical process. Such cooperation unites the firms in terms of common goals, policies, and programs. From the perspective of the total supply chain, efficiency is improved by eliminating duplication and waste. However, cross-organizational coordination requires joint planning and relationship management.

Second, there are service firms that perform logistical work on behalf of their customers such as transportation carriers or warehouse firms. Such specialists are supplemental to or may be substitutes for a customer's employees performing the involved work. When outside specialists are used in a logistical system, they must be willing to accept reasonable managerial direction and control from their customers. Therefore, while the performance of a specific task may be outsourced to specialists, the contracting firm's management remains responsible for successful performance of the required work [90].

II.3.1.1. Network Design

Classical economics neglected the importance of facility location and overall network design. When economists originally discussed supply-and-demand relationships, facility location and transportation cost differentials were assumed to be either nonexistent or equal among competitors. However, the number, size, and geographical relationship of facilities used to perform logistical operations directly affect customer service capabilities and cost. Network design is a primary responsibility of logistical management since a firm's facility structure is used to provide

products and materials to customers. Typical logistics facilities are manufacturing plants, warehouses, cross-dock operations, and retail stores. Determining how many of each type of facility are needed, their geographic locations, and the work to be performed at each is a significant part of network design. In specific situations, facility operation may be outsourced to service specialists. Regardless of who does the actual work, all facilities must be managed as an integral part of a firm's logistical network.

II.3.1.2. Information

The importance of information to logistical performance has historically not been highlighted. This neglect resulted from the lack of suitable technology to generate desired information. Management also lacked full appreciation and in-depth understanding of how fast and accurate communication could improve logistical performance. Both of these historical deficiencies have been eliminated. Current technology is capable of handling the most demanding information requirements. If desired, information can be obtained on a real-time basis. Managers are learning how to use such information technology to devise new and unique logistical solutions.

However, the technology is only as good as the quality of information. Deficiencies in the quality of information can create countless operational problems. Typical deficiencies fall into two broad categories. First of all, information received may be incorrect with respect to trends and events. Because a great deal of logistics takes place in anticipation of future requirements, an inaccurate appraisal or forecast can cause inventory shortage or overcommitment. Overly optimistic forecasts may result in improper inventory positioning. Second, information related to order processing may be inaccurate with respect to a specific customer's requirements. The processing of an incorrect order creates all the cost of logistics but typically does not result in a sale. Indeed, logistics costs are often increased by the expense of inventory return and, if the sales opportunity still exists, the cost of once again trying to provide the desired service. Each error in the composition of information requirements creates potential disturbance for the total supply chain.

Forecasting and order management are two areas of logistical work that depend on information. The logistics forecast is an effort to estimate future requirements. The forecast is used to guide the positioning of inventory to satisfy anticipated customer requirements. One of the main reasons managers use information to

achieve positive control of logistical operations is their desire to replace forecasting inaccuracy with faster response to customer requirements. Control concepts such as just-in-time (JIT), quick response (QR), and continuous replenishment (CR) represent approaches to positive logistical control made possible by the application of recently developed information technology. One of the main jobs of logistics managers is to plan and implement their firm's strategy regarding the desired combination of forecasting and operational control.

II.3.1.3. Transportation

Given a facility network and information capability, transportation is the operational area of logistics that geographically positions inventory. Because of its fundamental importance and visible cost, transportation has received considerable managerial attention over the years. Almost all enterprises, big and small, have managers responsible for transportation.

Transportation requirements can be accomplished in three basic ways. First of all, a private fleet of equipment may be operated. Second, contracts may be arranged with transport specialists. Third, an enterprise may engage the services of a wide variety of carriers that provide different transportation services on an individual shipment basis. These three forms of transport are typically referred to as *private*, *contract*, and *common carriage*. From the logistical system viewpoint, three factors are fundamental to transportation performance: cost, speed, and consistency.

II.3.1.4. Inventory

The inventory requirements of a firm depend on the network structure and the desired level of customer service. Theoretically, a firm could stock every item sold in a facility dedicated to service each customer, but the objective is to achieve the desired customer service with the minimum inventory commitment, consistent with lowest total cost. Excessive inventories may compensate for deficiencies in basic design of a logistics network and to some degree inferior management. However, excessive inventory used as a crutch will ultimately result in higher than necessary total logistics cost.

Logistical strategies are designed to maintain the lowest possible financial assets in inventory. The basic goal of inventory management is to achieve maximum turnover while satisfying customer commitments.

II.3.1.5. Warehousing, Material Handling, and Packaging

Four of the functional areas of logistics- network design, information, transportation, and inventory- can be engineered into a variety of different operational arrangements. Each arrangement will have the potential to achieve a level of customer service at an associated total cost. In essence, these four functions combine to create a system solution for integrated logistics. The final functions of logistics-warehousing, material handling, and packaging-also represent an integral part of an operating solution. However, these functions do not have the independent status of the four previously discussed. Warehousing, material handling, and packaging are an integral part of other logistics areas.

When warehouses are required in a logistical system, a firm can choose between obtaining the services of a specialist or operating its own facility. The decision is broader than simply selecting a facility to store inventory, since many activities essential to the overall logistical process are typically performed while products are warehoused. Examples of such activities are sorting, sequencing, order selection, transportation consolidation, and, in some cases, product modification and assembly.

Within the warehouse, material handling is an important activity. Products must be received, moved, sorted, and assembled to meet customer order requirements. The direct labor and capital invested in material-handling equipment are a major part of total logistics cost. When performed in an inferior manner, material handling can result in substantial product damage. It stands to reason that the fewer times a product is handled, the less potential exists for product damage, and the overall efficiency of the warehouse is increased. A variety of mechanized and automated devices exist to assist in material handling. In essence, each warehouse and its material-handling capability represent a minisystem within the overall logistical process.

To facilitate handling efficiency, products in the form of cans, bottles, or boxes are typically combined into larger units. The initial unit, the *master carton*, provides two important features. First of all, it serves to protect the product during the logistical process. Second, the master carton facilitates ease of handling by creating one large package rather than a multitude of small, individual products. For efficient handling and transport, master cartons are typically consolidated into larger units.

The most common units for master carton consolidation are pallets, slip sheets, and various types of containers.

When effectively integrated into an enterprise's logistical operations, warehousing, material handling, and packaging facilitate the speed and overall ease of product flow throughout the logistical system. In fact, several firms have engineered devices to move broad product assortments from manufacturing plants directly to retail stores without intermediate handling.

II.3.2. Integrated Logistics

The conceptualization of integrated logistics is illustrated in the shaded area of Figure II.41. Logistics is viewed as the competency that links an enterprise with its customers and suppliers. Information from and about customers flows through the enterprise in the form of sales activity, forecasts, and orders. The information is refined into specific manufacturing and purchasing plans. As products and materials are procured, a value-added inventory flow is initiated that ultimately results in ownership transfer of finished products to customers. Thus, the process is viewed in terms of two interrelated efforts, inventory flow and information flow.

Viewing internal operations (the shaded area of Figure 41) in isolation is useful to elaborate the fundamental importance of integrating all functions and work involved in logistics. While such integration is prerequisite to success, it is not sufficient to guarantee that a firm will achieve its performance goals. To be fully effective in today's competitive environment, firms must expand their integrated behavior to incorporate customers and suppliers. This extension, through external integration, is referred to as *supply chain management*.

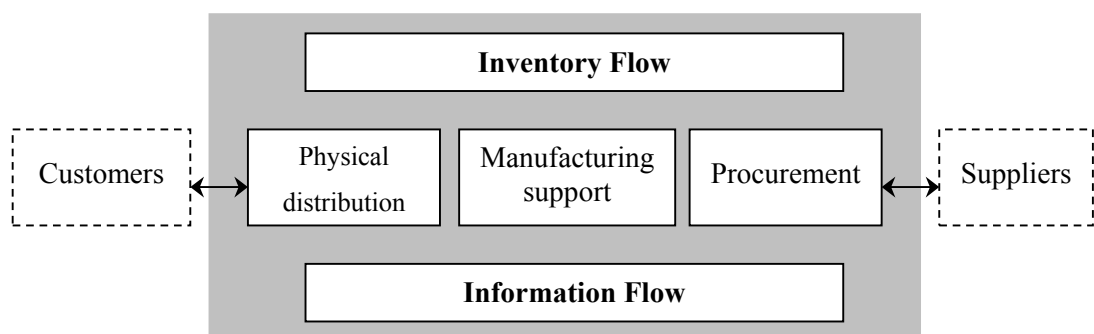


Figure II.41. Logistical Integration [90].

II.3.2.1. Logistical Information Flow

Logistical information involves two major types of flows: coordination flows and operational flows. The overall relationship between the two logistical information flows is illustrated in Figure II.42.

1.a. Planning and Coordination Flows

Coordination is the backbone of overall information system architecture among value chain participants. Coordination results in plans specifying (1) strategic objectives, (2) capacity constraints, (3) logistical requirements, (4) inventory deployment, (5) manufacturing requirements, (6) procurement requirements, and (7) forecasting.

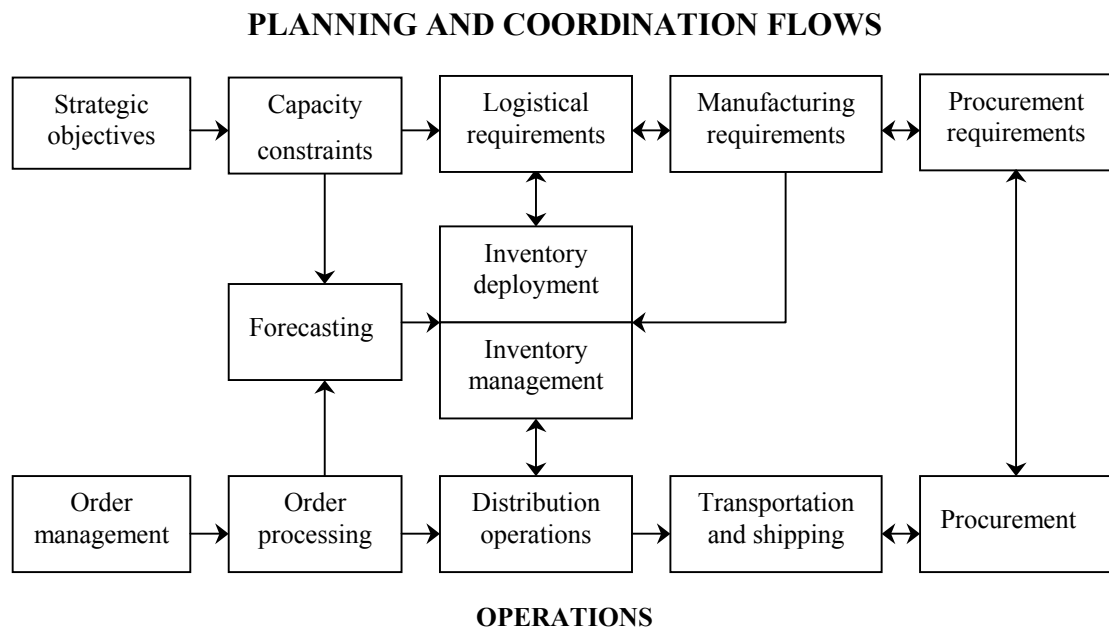


Figure II.42. Logistics Information Requirements [90].

1.b. Operational Requirements

The second aspect of information requirements is concerned with directing operations to receive, process, and ship inventory as required to support customer and purchase orders. Operational information requirements deal with (1) order management, (2) order processing, (3) distribution operations, (4) inventory management, (5) transportation and shipping, (6) procurement. Especially the impact of information technology on order management is extensive [91,92].

II.3.2.2. Applications Of New Information Technologies

Logistics managers see information technologies a major source of improved productivity and competitiveness. Unlike most other resources, information technology is increasing in both speed and capacity while declining in cost. While new capabilities are identified daily, live specific technologies have demonstrated widespread logistics applications. These include electronic data interchange (EDI), personal computers, artificial intelligence/expert systems, communications, and bar coding and scanning. Among them, EDI is considered as a critical transformation that needs to be focused on.

EDI is identified as intercompany computer-to-computer exchange of business documents in standard formats. EDI describes both the capability and practice of communicating information between two organizations electronically instead of via the traditional forms of mail, courier, or even fax. The practice refers to the ability of the two organizations to effectively utilize the information exchanged.

Logistics information consists of real-time data on company operations-inbound material flows, production status, product inventories, customer shipments and incoming orders. From an external perspective, companies need to communicate order shipment and billing information with vendors or suppliers, financial institutions, transportation carriers and customers. Internal functions exchange information on production schedule and control data.

Direct EDI benefits include (1) increased internal productivity, (2) improved channel relationships, (3) increased external productivity, (4) increased ability to compete internationally, and (5) decreased operating cost [93]. EDI improves productivity through faster information transmission as well as reduced information entry redundancy. Accuracy is improved by reducing the number of times and individuals involved in data entry. EDI impacts logistics operating cost through (1) reduced labor and material cost associated with printing, mailing, and handling paper-based transactions; (2) reduced telephone, fax, and telex communication; and (3) reduced clerical cost [94].

II.4. WAREHOUSE MANAGEMENT

II.4.1. Warehouse Operating Principles

Warehouse design criteria address physical facility characteristics and product movement. Three factors to be considered in the design process are the number of stories in the facility, height utilization, and product flow.

The ideal warehouse design is limited to a single story so that product does not have to be moved up and down. The use of elevators to move product from one floor to the next requires time and energy. The elevator is also often a bottleneck in product flow since many material handlers are usually competing for a limited number of elevators. While it is not always possible, particularly in central business districts where land is restricted or expensive, warehouses should be limited to a single story.

Regardless of facility size, the design should maximize the usage of the available cubic space by allowing for the greatest use of height on each floor. Through the use of racking or other hardware, it should be possible to store products up to the building's ceiling. Maximum effective warehouse height is limited by the safe lifting capabilities of material-handling equipment, such as forklifts, and fire safety regulations imposed by overhead sprinkler systems.

Warehouse design should also allow for straight product flow through the facility whether items are stored or not. In general, this means that product should be received at one end of the building, stored in the middle, and then shipped from the other end. Figure II.43 illustrates this flow principle. Straight-line product flow minimizes congestion and confusion.

The second principle focuses on the effectiveness and efficiency of material-handling technology: The elements of this principle concern movement continuity and movement scale economies.

Movement continuity means that it is better for a material handler or piece of handling equipment to make a longer move than to have a number of handlers make numerous, individual, short segments of the same move. Exchanging the product between handlers or moving it from one piece of equipment to another wastes time and increases the potential for damage. Thus, as a general rule, fewer longer

movements in the warehouse are preferred.

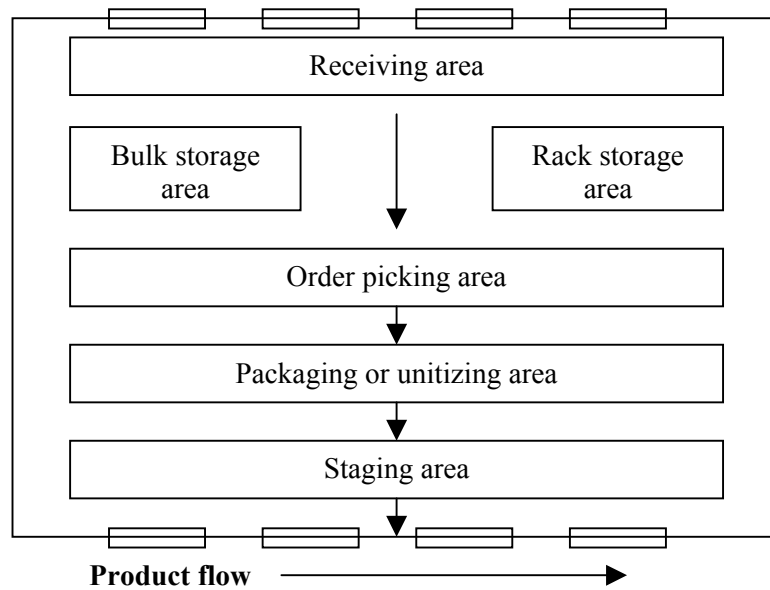


Figure II.43. Typical Warehouse Design [90].

Movement scale economies imply that all warehouse activities should handle or move the largest quantities possible. Instead of moving individual cases, warehouse activities should be designed to move groups of cases such as pallets or containers. This grouping or batching might mean that multiple products or orders must be moved or selected at the same time. While this might increase the complexity of an individual's activities since multiple products or orders must be considered, the principle reduces the number of activities and the resulting cost.

According to the third principle, a warehouse design should consider product characteristics, particularly those pertaining to volume, weight, and storage.

Product volume is the major concern when defining a warehouse storage plan. High-volume sales or throughput product should be stored in a location that minimizes the distance it is moved, such as near primary aisles and in low storage racks. Such a location minimizes travel distance and the need for extended lifting. Conversely, low-volume product can be assigned locations that are distant from primary aisles or higher up in storage racks. Figure II.44 illustrates a storage plan based on product movement.

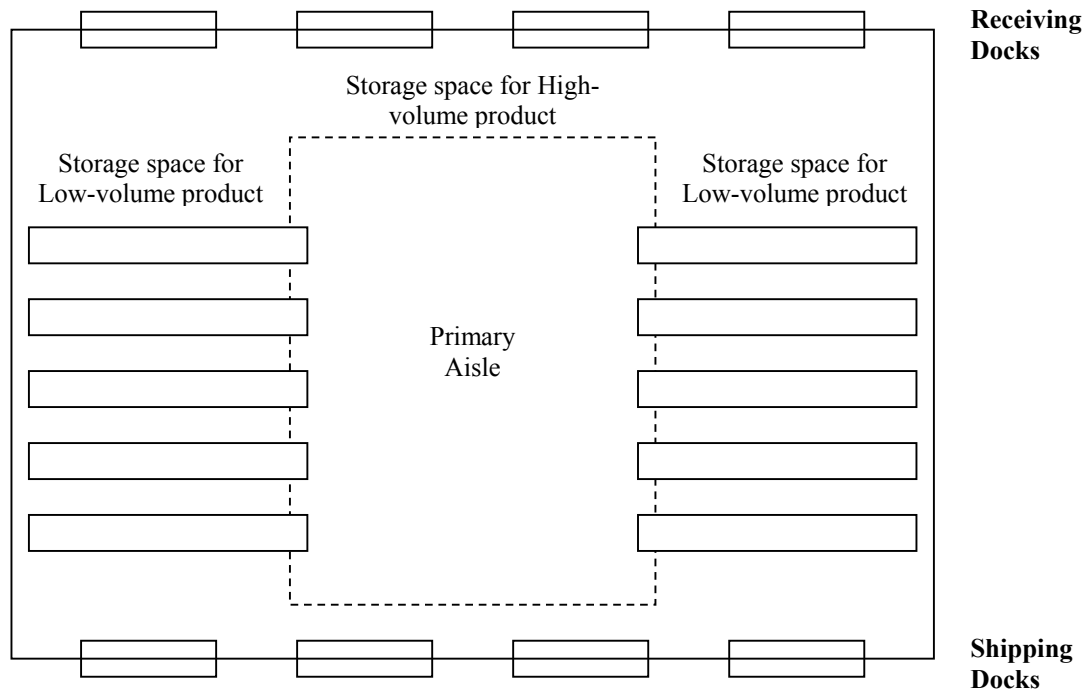


Figure II.44. Storage Plan Based on Product Movement [90].

Similarly, the plan should include a specific strategy for products dependent on weight and storage characteristics. Relatively heavy items should be assigned to locations low to the ground to minimize the effort and risk of heavy lifting. Bulky or low-density products require extensive storage volume, so open floor space or high-level racks can be used for them. On the other hand, smaller items may require storage shelves or drawers. The integrated storage plan must consider and address the specific characteristics of each product.

II.4.2. Material Handling

II.4.2.1. Basic Handling Considerations

Over the years a variety of guidelines have been suggested to assist management in the design of material-handling systems. These are representative:

1. Equipment for handling and storage should be as standardized as possible,
2. When in motion, the system should be designed to provide maximum continuous product flow,
3. Investment should be in handling rather than stationary equipment,
4. Handling equipment should be utilized to the maximum extent possible,
5. In handling equipment selection, the ratio of deadweight to payload should be minimized,

6. Whenever practical, gravity flow should be incorporated in system design.

Handling systems are classified as mechanized, semiautomated, automated, and information-directed.

II.4.2.2. Mechanized Systems

Mechanized systems employ a wide range of handling equipment. The types of equipment most commonly used are forklift trucks, walkie-rider, pallet trucks, towlines, tractor-trailer devices, conveyors, and carousels.

II.4.2.3. Semiautomated Handling

The semiautomated system supplements a mechanized system by automating specific handling requirements. Thus, the semiautomated warehouse is a mixture of mechanized and automated handling. Typical equipment utilized in semiautomated warehouses are automated-guided vehicle systems, computerized sortation, robotics, and various forms of live racks.

II.4.2.4. Automated-Guided Vehicle Systems

The automated-guided vehicle system (AGVS) performs the same type of handling function as a mechanized tow tractor with trailer or rider pallet truck. The essential difference is that an AGVS does not require an operator. It is automatically routed and positioned at the destination without operator intervention.

II.4.2.5. Sortations

Automated sortation devices are typically used in combination with conveyors. As products are selected in the warehouse and conveyORIZED out, they must be sorted to specific shipment docks. In order for automated sortation systems to operate, the master carton must have a distinguishing code. These codes are read by optical scanning devices and automatically routed to the desired location.

II.4.2.6. Robotics

The appeal of robotics lies in the ability to program the robot to function as an expert system capable of implementing decision logic in the handling process. The popularity of robotics resulted from their widespread adoption in the automotive

industry during the early 1980s to replace selected manual tasks. The primary use of robotics in warehousing is to break down and build unit loads. In the breakdown process, the robot is programmed to recognize stocking patterns and place products in the desired position on a conveyor belt. The use of robots to build unit loads is essentially the reverse operation.

Another prime potential use of robotics in warehousing occurs in environments where humans find it difficult to function. Examples include high noise areas and extreme temperature environments like cold-storage freezers.

II.4.2.7. ASRS Systems

The concept of automated unit-load handling using high-rise storage has received considerable attention recently. The high-rise concept of handling is fully automated from receiving to shipping. Four main components constitute the basic system: storage racks, storage and retrieval equipment, input/output systems, and control systems.

II.4.2.8. Information-Directed Systems

The concept of information-directed handling is relatively new and is still in the testing process. The idea is appealing because it combines the control of automated handling with the operational flexibility of mechanized systems.

The information-directed system uses mechanized handling equipment. The typical source of power is the forklift truck. In layout and design, the warehouse facility is essentially the same as any mechanized operation. The difference is, forklift movements are directed and monitored by the command of a microprocessor.

II.4.2.9. Storage Guidelines for the Warehouse

The managerial question to consider is whether a specific handling system should be designed on a mechanized, semiautomated, or information-directed basis. Table II.8 suggests guidelines and considerations for specific types of manual and automated warehouse storage systems.

Table II.8. Storage Guidelines for the Warehouse [90].

Equipment	Type of Materials	Benefits	Other Considerations
Manual			
Conventional pallet rack	Pallet loads	Good storage density, good product security	Storage density increased further by storing loads two deep
Drive-in racks	Pallet loads	Fork trucks can access loads, good storage density	Fork truck access is from one direction only
Drive-through racks	Pallet loads	Fork trucks can access loads, good storage density	Fork truck access is from two directions
High-rise racks	Pallet loads	Very high storage density	Often used in ASRS and may offer tax advantages when used in rack-supported building
Cantilever racks	Long loads or rolls	Designed to store difficult shapes	Each different SKU can be stored on a separate shell
Pallet stacking frames	Odd-shaped or crushable parts	Allow otherwise unstackable loads to be stacked, saving floor space	Can be disassembled when not in use
Stacking racks	Odd-shaped or crushable parts	Allow otherwise unstackable loads to be stacked, saving floor space	Can be stacked flat when not in use
Gravity-flow racks	Unit loads	High density storage, gravity moves loads	FIFO or LIFO flow of loads
Shelving	Small, loose loads and cases	Inexpensive	Can be combined with drawers for flexibility
Drawers	Small parts and tools	All parts are easily accessed, good security	Can be compartmentalized for many SKUs
Mobile racking or shelving	Pallet loads, loose materials, and cases	Can reduce required floor space by half	Can be equipped with safety devices
Automated			
Unit-Load ASRS	Pallet loads, and a wide variety of sizes and shapes	Very high storage density, computer-controlled	May offer tax advantages when rack-supported
Car-in-lane	Pallet loads/other unit loads	High storage density	Best used where there are large quantities of only a few SKUs
Miniload ASRS	Small parts	High storage density, computer-controlled	For flexibility, can be installed in several different configurations
Horizontal carousels	Small parts	Easy access to parts, relatively inexpensive	Can be stacked on top of each other
Vertical carousels	Small parts and tools	High storage density	Can serve dual role as storage and delivery system in multifloor facilities
Man-ride machines	Small parts	Very flexible	Can be used with high-rise shelving or modular drawers

The initial cost of an automated system will be higher than for one that is mechanized. An automated system will require less building space, but the equipment investment will be greater. The key benefit from automation is reduced operating cost. An automated handling system, if properly designed and controlled, should outperform a mechanized system in terms of labor, damage, accuracy, product protection, and rotation. In the final analysis, the design to be used must be evaluated on the basis of return on investment.

II.4.3. Logistics System Design

II.4.3.1. Logistics Reengineering

The popular framework for implementing system integration principles is through a procedure referred to as process reengineering. The basic idea is to identify and study the steps required to perform specific work in order to increase the likelihood of integrating performance. No rules or laws exist concerning what constitutes the ideal or even the minimal focus for a reengineering initiative. The appropriate scope is determined by management. Near identical procedures can be followed to redefine how a specific job, task, resource, functional area, or even the overall logistics competency is performed.

Four factors are common to all logistical reengineering initiatives. First, the objective is to increase integration of some or all aspects of the activities under review. The analytical foundations for integration draw on principles of systems analysis. Second, benchmarking is a critical part of reengineering. Third, the activities under review need to be decomposed or de-averaged to achieve effective integration. Such decomposition can be achieved only by developing activity-based metrics. Finally, reengineering is continuous and aiming for higher quality.

1.a. Systems Integration

The foundation for logistics reengineering is based on the logic of systems analysis. The exact origin of systems analysis is difficult to trace since the concept is closely related to all forms of organized activity. Faced with unprecedented challenges, scientists during World War II developed an organized methodology to guide research and development of complex physical and organizational problems [95,96]. This approach is now commonly referred to as *system integration*. A basic understanding of the systems concept is desirable for a full appreciation of integrated logistics. Early articles describing the potential of integrated logistics relied heavily on systems analysis to overcome the shortfalls of treating logistical functions as isolated work [97,98].

The systems concept stresses total integrated effort toward the accomplishment of predetermined objectives. Systems analysis is a proven methodology to view how specific functions can be combined to create a whole that is greater than the sum of

the individual parts or functions. Such a "holistic" approach seeks to stimulate a synergistic relationship between the individual parts of a system for the good of the overall effort. In terms of systems methodology, functional excellence is defined as contribution to the process as contrasted to individual area performance. Until the last few decades such process thinking was foreign to managers, who had been trained to perform a specific function to the best of their ability.

1.b. Benchmarking

A critical step in process reengineering is benchmarking. The technique has gained popularity as a way to help managers gauge how well their organization performs a specific task or specialization. A formal definition of benchmarking is that it consists of a systematic procedure for identifying the best practice and modifying actual knowledge to achieve superior performance [99].

Benchmarking is supported by two basic beliefs. First, progressive firms must seek to continuously improve all facets of their operations. Therefore, their attitude should be one of fixing or improving a work method before it breaks. Second, best practice should be identified and studied, which typically means searching outside one's own enterprise.

It is important that managers who undertake reengineering develop approaches to incorporate benchmarking into their initiative.

1.c. Activity-Based Costing

A critical aspect for improving a process is the development of meaningful metrics to measure existing practice and evaluate the relative attractiveness of alternatives. Most accounting practices generate averages that hide the time costs of performing specific activities or of providing a unique service to specified customers. The challenges of "de-averaging" and developing activity-based costs (ABC) that reflect the metrics are critical to reengineering.

1.d. Quality Initiatives

The commitment to operational quality was highlighted as a fundamental objective of integrated logistics. It is important to note that reengineering is the procedure that enables firms to improve quality on a continuous basis. Regardless of the scope of the reengineering effort, the idea of seeking continuous improvement is consistent with a total quality management philosophy.

II.4.3.2. Reengineering Procedure

Table II.9 details a standard six-step procedure to guide a firm's reengineering initiative. Each step is briefly discussed.

Table II.9. A Standard Six-Step Reengineering Procedure.

	<i>Reengineering Steps</i>
<i>1</i>	Identifying Targets
<i>2</i>	Understanding the Work Sequence Being Evaluated
<i>3</i>	Modelling the Activity Under Consideration
<i>4</i>	External Benchmarking to Seek Improved Alternative Approaches
<i>5</i>	Evaluation of Modifications to the Activity Being Reviewed
<i>6</i>	Implementation

Step 1 of reengineering is target identification. This initial step is the most important aspect of the overall reengineering procedure. It is essential to identify exactly which work is the candidate for potential change. It is equally important to identify the known range of potential improvements. While it is exciting to envision major breakthroughs in customer service or cost reduction, it must be kept in mind that quantum leaps are not necessary to justify reengineering. Small, continuous steps can aggregate to significantly improved performance.

The second step in reengineering is to fully understand the work sequence being evaluated. The traditional way to evaluate a work stream is to develop a detailed flowchart or process map of the steps required to complete the activity. This is the point in reengineering where it is essential to de-average and apply meaningful metrics. Regardless of the scope of the reengineering effort, potential improvements will be meaningless without the capability to ultimately measure and evaluate alternatives. In situations that require capital commitment, the metrics will need to incorporate alternative investment strategies and return-on-investment calculations.

Steps 3 and 4 of reengineering involve the creative aspect of the exercise. One approach to identifying improvement is to model the activity under consideration in an effort to identify the best possible design. Simultaneously, a firm should initiate external benchmarking to seek improved alternative approaches. The final result should be a combination of internal and external perspectives.

The fifth step of reengineering is to evaluate modifications to the activity being reviewed. Care should be taken to judge and creatively adapt ideas generated during the benchmarking exercise. The primary focus of an evaluation is the accurate

assessment of expected benefits from implementation of a modified activity. While the activity under consideration may not be totally changed, it is likely that improvement will result from careful completion of the initial steps in the reengineering procedure. The key is to quantify and justify all potential changes on a cost-benefit basis.

The final step of reengineering involves implementation. Identification of a better way to perform a process falls short of having the improvement in place and working. Depending on the scope of the proposed change, it may be necessary to undertake significant testing and employee training. The appropriate rate and comprehensiveness of implementation will depend on the risk involved and the magnitude of the change that must be managed.

In conclusion, it is important to stress that reengineering in logistics is a technique that is equally applicable for all levels of potential change [90].

II.4.4. Logistical Organizational Development

Prior to the 1950s, functions now accepted as logistics were generally viewed as facilitating or support work. Organizational responsibility for logistics was dispersed throughout the firm. In time managers recognizing the need for total-cost control began to reorganize and combine logistics functions into a single managerial group. Then the emphasis shifted from function to process. Firms began to examine the role logistical competency could play in the overall process of creating customer value. This ushered in new thinking regarding how to best achieve integrated logistical performance.

The mission of logistics is to position inventory when and where it is required to facilitate profitable sales. The ideal structure for logistics would be an organization that performs essential work as part of the processes it supports while achieving the synergism of cross-functional integration.

Information technology introduced the potential of electronic integration as contrasted to physically combining logistics functions. Using information technology to coordinate or orchestrate integrated performance allows the responsibility for work itself to be distributed throughout the overall organization. Integration requires that logistics combine with other areas such as marketing and manufacturing. For example, rather than focusing on how to relate transportation and inventory, the real challenge is to integrate transportation, inventory, new-product development, flexible

manufacturing, and customer service. In order to achieve overall organizational integration, a firm must combine a wide variety of capabilities into new organizational units. This means that the traditional single-function department must be assimilated into a process. Such assimilation often requires that traditional organization structures be disaggregated and then recombined in new and unique ways. In one sense, such functional disaggregation may appear to come full circle back to the early days of fragmented single-function departments. However, the critical difference in the emerging organizational model is the widespread availability of unbridled information. The new organization format is characterized by an extremely different culture concerning how information is managed and shared.

Logistics managers can benefit from understanding the organization development process. Such understanding permits them to evaluate their firm's current state of organization and plan changes that can be accommodated. To fully understand structural positioning and change management, it is useful to have an application concerning how traditional bureaucratic organizations evolved. Research suggests that managers initially stabilized logistics through functional aggregation. Such aggregation was essential prior to embarking on the use of information networking to facilitate process integration. Figure II.45 illustrates live stages of organizational development based on the relative balance of functional aggregation and information integration.

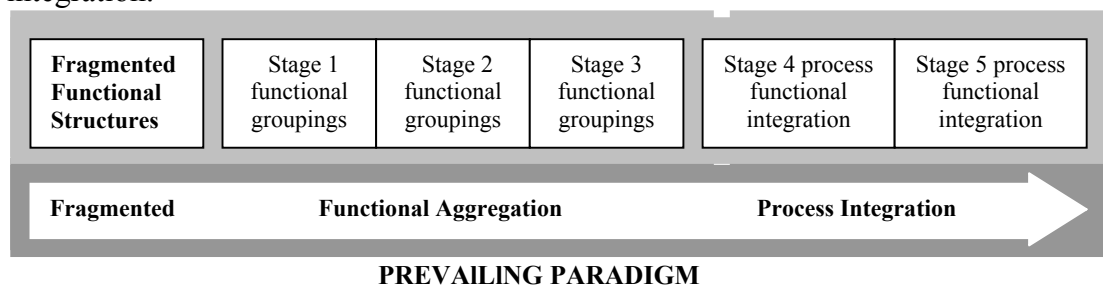


Figure II.45. Logistical Organization Development Cycle [90].

The challenge for managers is to be able to assess how their particular organization should be structured given current competency to best exploit logistics.

II.5. AN IMPLEMENTATION OF BPR ON MATERIALS MANAGEMENT

During the decade of 1990s, BPR has captured the imagination of many industry leaders across the globe. Reengineering has been used by many companies for the pursuit of organisational efficiency through automation, labour saving and streamlining systems and procedures and the management reforms through business, market, technology and organisational development. BPR has been accepted in industry as a strategic initiative for managing change and the efforts for directing the change are steered in multiple dimensions such as: structure, people, management, and system. BPR has been considered as a multidimensional problem solving approach, emphasising on very significant improvements in the organisational performance in terms of multiple parameters such as quality, cost, delivery, service level, etc. to gain competitive advantage. BPR in principle, concentrates on the generic transformation of business processes and thus focuses on various work systems within the enterprise. BPR enables to restructure various management systems and procedures with an ultimate purpose of inside-in value innovations [100].

Many companies which have successfully implemented BPR projects have indicated a number of benefits [101-103], such as: improved financial performance, enhanced customer satisfaction, cost reduction, improved product/service quality, improved delivery performance, improvement in productivity, enhancement in flexibility / responsiveness, reduction in process times, faster rate of innovation, organisational restructuring/reengineering work systems. Although reengineering is important for business organisations it is complex to implement. A total systems intervention is needed to redesign the existing business processes by focusing upon competition, customers and change.

II.5.1. BPR Model

When BPR literature [49, 104-106] is scanned, a well-defined framework reported in literature which can easily be adopted and used, can not be found. An attempt to formulate a framework for BPR is depicted in Figure II.46. The salient features of the proposed framework are: (a) a step-by-step logical approach which is easy to follow, (b) incorporation of the feed back to evaluate the results of BPR and to take corrective actions, (c) team-based implementation process and thereby increasing the chances of successful implementation process, and (d) OD-based

intervention which involves team formation and extensive learning support to the team members, thereby creating a greater awareness among members who in turn would act as catalysts in the change process [107].

The implementation is through OD, which is a structured intervention process that helps organisations to improve themselves through facilitation. The theoretical foundation of OD and reengineering can be thought of as opposite ends of a spectrum of business management science [108].

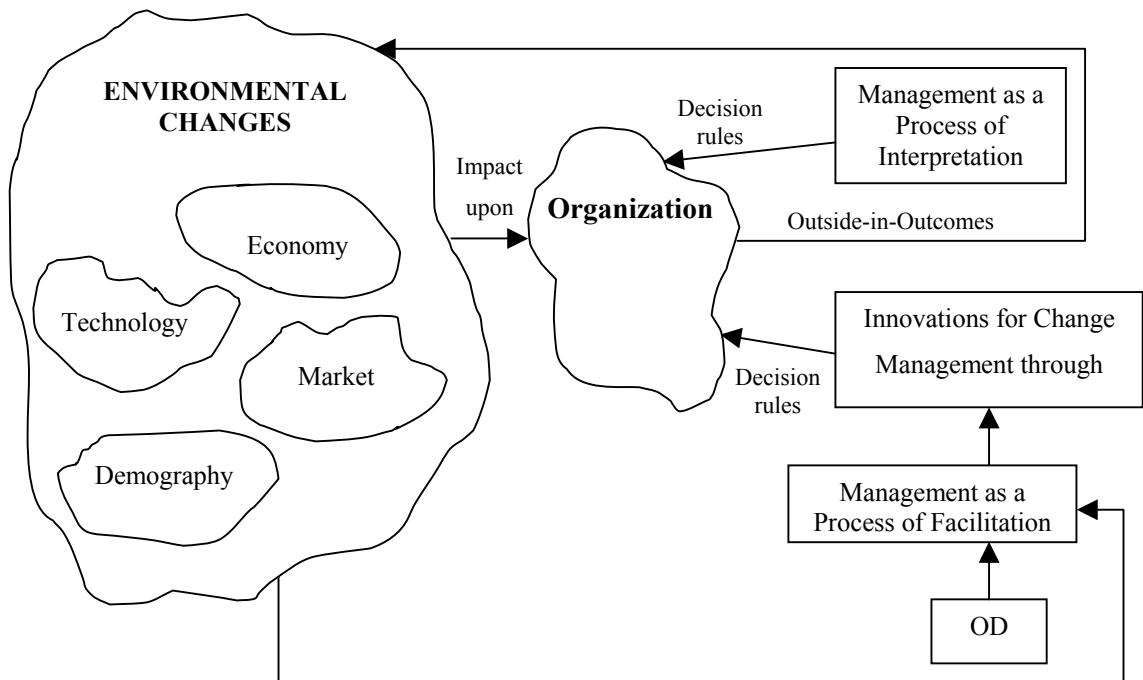


Figure II.46. A model for BPR implementation [107].

However, the two meet and co-operate very well when the change management paradigm is annexed to reengineering. For reengineering, the ability to determine the results of projects, assess its impact across the organisation, and provide support, such as information technology (IT), must be preserved. From OD, the commitment of the workforce, enhanced individual performance, and teamwork are to be gained. This ability of reengineering and OD to co-operate has been a motivation to use OD interventions as one of the tools on which reengineering can be carried out. The general approach to combining reengineering is consistent with the widely accepted philosophy that recommends plan from top down, implement from bottom up. The reengineering design is carried out to a sufficient detail and then OD takes over the implementation of workflow. The selection of OD interventions is highly dependent on the circumstances. In this sample study, team building and training techniques as OD interventions have been used. This was required for effective implementation of

the reengineering project. In this context, it was felt that OD intervention such as group based participatory decision-making approaches be evolved which may further be reinforced through qualitative decision-making models. Nominal group technique (NGT) is a very useful participatory decision making approach [109] for such situations. NGT is a structured methodology, where ideas and judgements of knowledgeable individuals need to be tapped and a group consensus is aimed at as the desired outcome. The primary value of NGT lies in its capacity as a methodology to develop involvement, commitment and other behavioural outcomes that spur action due to large efforts extended by the participating members. An iterative feedback is implicit in NGT. The outcomes of the NGT may provide a prioritised list of strategic initiatives. It may be noted that inquiry systems such as NGT are integrated into the reengineering model as proposed here. This naturally enhances the implementation chances of group decisions as members actively participate in the process. NGT process stimulates the exchange of ideas and help in opening up conflicting interfaces and boundaries. This ensures a fresh flow of ideas and a better chance to consider competing perspectives on the problems of strategic importance such as reengineering.

Management can act as an interpreter of the business environment and then manage the process of change through structured decision rules. Alternatively, the management of an enterprise can be viewed as a process of facilitation in which the participants of the organisation can steer the changes in the various domains of business. The facilitation brings an organic transformation across many dimensions of a work system. The following steps for facilitation are outlined:

1. *Induce*: Employees and the interested/affected people are induced and impressed upon for the importance of BPR.
2. *Engage individuals*: The individuals are identified based on their level of enthusiasm, commitment and potential. These people are engaged as champions to spread the message of reengineering across the organisation not merely through formal forums but more often through on-the-job and informal socialisation.
3. *Reinforce and use multiple value sets*: Participants are reinforced through diagnostic, analytical, and behavioural skills, and are provided with data and information and are shared through experiences. Such multiple value sets are used to enhance capability to use knowledge.

4. *Realisation*: After extensive training spread across the entire organisation, the employees understand and appreciate the need and mechanisms for effecting BPR. This results in the realisation of the process of BPR.
5. *Empowerment*: Once the employees are aware of the needs, they are also empowered to take decisions, to identify themselves the non-value adding activities. This helps in getting the acceptance from various quarters for effective implementation.

II.5.2. The BPR Implementation Framework

The authors have demonstrated a BPR framework in managing a supply chain network [110] in a large engineering goods manufacturing company, which was used also for implementation. This framework has the following phases.

II.5.2.1. Diagnostic Phase

The objective of this phase was to critically analyse the materials management system in its totality. The tasks involved in this phase included: definition of materials management system, identification of the problems associated with various sub systems, and their qualifications and quantification. The materials management is defined as a coordinating function responsible to: plan for, acquire, store, move, and control inventory (raw material, work-in-process, and finished goods) so as to optimise: usage of physical facilities; usage of personnel, and usage of capital funds in line with corporate goals of maximising profit, and growth [111]. This definition is used to bring a total system perspective so as to eventuate; functional integration, process orientation and value adding working pattern.

The management of the case company realised that to remain in competition, they need to:

- reduce lead times,
- enhance customer service, and
- optimise operations.

To achieve these, it was necessary to identify and structure the problems. Through critical success factors (CSF), one can identify what problems are important to an organisation. CSFs are the vital and critical few where things must go right if the business is to flourish. For any organisation, there exist a limited number of areas

in which results, if they are satisfactory, will ensure competitive performance. Executives drawn from stores, purchase, inspection, engineering, production, and accounts, etc. were involved to identify CSFs. After an intensive workshop, the team members identified the following set of CSFs:

- balanced inventory position,
- enhanced service to internal and external customers,
- good relations with vendors,
- streamlined procedures.

After a detailed analysis of the current operating system, the following problems were diagnosed.

- *High inventory levels*
- *High lead times of store items and spares*
- *The relations with large vendor base*

II.5.2.2. Process Analysis Phase

In this phase, various processes were enumerated in relation to the CSFs identified earlier by the team members. These processes were modelled through flow charts and other visual aids. The idea was to get the entire team involved in understanding the process, its inputs, outputs and control points.

Generally, there are three types of BPR efforts a company normally undertakes:

Type 1: Cost improvement

Type 2: To achieve "Best in Class"

Type 3: To effect a Breakpoint

A BPR effort can be driven by one of the three different business goals. They are:

1. Process improvement can lead to dramatic cost reduction in non-core processes far beyond what can be accomplished through traditional costcutting efforts.
2. Within the core business process, the reengineering effort is usually aimed at reaching the "best in class". Attaining competitive level of those who have set standards and rules of the competition in the past.
3. The attempt is made to find and implement the Breakpoints, to change the rules

and create the new definition of the best in class for all others to try to emulate.

It is important for management to look at all of these business goals when determining the direction of BPR effort for a number of reasons. First, not all the companies will find Breakpoint opportunities in operation, even if they are achieving them. Second, not all companies will feel it is appropriate to put in time, effort and the cost of trying to achieve the Breakpoint. And third, there are almost always opportunities for cost reduction in improving non-core process and usually big opportunities to increase competitiveness by improving core business process.

In the present case, the motivation for BPR was to cut down the costs, improve the service, cutdown the lead-time and streamline the operations within an integrated Materials Management set up. After clearly identifying the need for BPR, it is important to identify which processes need to be reengineered.

A process consists of an activity, or a set of interrelated activities, intended to transform one or more inputs -at least one of which represent customer requirements - into one or more outputs. Reengineering represent solution from the internal or external customer's point of view. These are often cross-functional and involve flow of information. However, it is not an easy task to identify processes requiring immediate attention for such an exercise. Going through the literature, it seems that no authors or consultant who have sold BPR solutions have reported any kind of structured systems approach for BPR, even if it is client-specific. After identifying CSFs, a cost-value matrix (Figure II.47) to identify the processes requiring attention is adopted. Generally, in any reengineering exercise, it is difficult to start with any activity. Because of the limited resources and management time, it was worthwhile to classify the processes identified into various categories based on their contribution to value and the cost they consume.

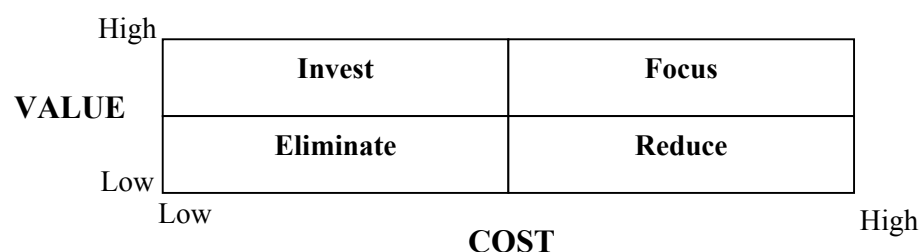


Figure II.47. Value-Cost Evaluation for Activities [107].

Most of the current work processes in companies are often the result of a series of unplanned decisions made in time by their functional units. The existing processes have not been systematically analysed and measured with regard to their

effectiveness across their entire domain and/or the organisation as a whole. Often the individual departments or sections of a company focus on optimising their own performance. This, in fact, can result in sub-optimal outcomes from the organisational viewpoint.

The specific objectives of this phase were to identify and analyse key processes. The approach is to break up the entire procedure into processes. These processes can then be redesigned or even be eliminated. The idea is to get quantum benefits, which may be of the order of 100% improvements over the existing processes. The procedure used for reengineering depends on the complexities and structures of the processes involved. The group consisted of people from purchase, stores, shop floor, accounts/finance, and inspection. Based on the NGT sessions, the following reasons were identified for high inventory: Procedural delays; uncertain and unreliable delivery; high lead time; poor multi-user co-ordination; poor documentation of spares parts; poor inspection system; lack of responsibility; delay in getting the imported components; poor vendor appraisal; poor vendor registration system, and poor treatment to vendors. Further analysis revealed that these reasons were responsible for the maximum inventory build-up. It is clear that high lead-time and poor vendor development are among the major reasons for high inventory.

The source of enterprise wide change may come from top management, as happened in the present case, or, it could also be guided by the corporate strategic plans. These changes would guide the selection of processes for redesign effort. In the present case, the responsibility of selecting the process was vested with various teams. The objective here was to identify those key processes that require change/redesign and which have maximum value innovations effect on the entire system.

II.5.2.3. Process Design Phase

After selecting the processes, the critical processes requiring attention are simplified. This was done with a view of eliminating non-value adding activities, taking support from IT and focusing on the core processes.

II.5.2.4. Evaluation Phase

The objectives of this phase were to quantify various attributes related to a process before and after the redesign. The activities of a process can have many

metrics. Basically: a process is analysed in its full detail by partitioning it into value adding and non-value adding activities. By elimination of the non-value adding activities, the process is redesigned.

II.5.2.5. Appraisal Phase

The objectives of this phase are to appraise the BPR efforts through the benefits visualised so that the team members and top management can be convinced about the utility of such effort. These were mainly due to the elimination of certain processes and in some cases by improvements in the current procedures.

II.5.3. Results and Remarks

With objectives to streamline management processes and formalise communications and eliminate unproductive activities in materials management processes, reengineering project resulted in the following quantitative benefits: faster and more effective learning of skill set; better utilisation of physical assets and human resources; developing knowledge base for all functional areas to address common problems; developing infrastructure to support increased decentralisation and networking of individual work systems for working autonomously.

A cross-functional team based and focused approach through OD intervention was used to create a learning organisation and bring transformation in the work systems. The group participatory approaches such as NGT made the implementation process quite involved. The confidence generated in the exercise was commendable. Everybody felt as a part of the exercise. In today's context, it is necessary for an organisation to have a learning focus in proper perspective. Reengineering exercise indeed presented an opportunity to learn the organisational procedures, to identify the bottlenecks in the system and areas requiring change, which are essential to remain competitive. The reengineering exercise involved two important elements of the value delivery process, namely, the internal customers (various groups and functional people involved) and vendors (external customers). While there is no sure-shot solution as to how to carry out a reengineering study, attempts such as the presented one, definitely have the potential of being applied on a larger scale elsewhere in the organisation. The reengineering exercise has implications for processes, people (management and employees), and technology [112].

PART III

IMPLEMENTATION OF THE MODEL

III.1. GENERAL

In this study, a change management model for reengineering studies on materials management system of a plant is proposed and implemented after the merger of the plant with another plant next to it. First a general information about the plant, and materials management system will be given and then the studies will be detailed.

III.2. THE PLANT

The company was established in early 1960's in İstanbul, Turkey and the facilities of the company moved to Adapazarı, Turkey in 1997. The plant was located on 90.000 m² total and 25.000 m² closed area. The plant layout as it was established in 1997 is given in Figure III.1. As shown in the figure, building 1 was the administrative building. The armoured vehicle production unit (building no.2) was a separate one and the light commercial vehicles and light tactical vehicles were mounted on assembly lines in one building (building no.3). The Main Stock Area was also in building no.3.

Building no.4 was the final control unit for both commercial and military vehicles and field no.5 was the finished product storage area. Field no.6 was used for excess or early deliveries of incoming materials and field no.7 was the test field for military products.

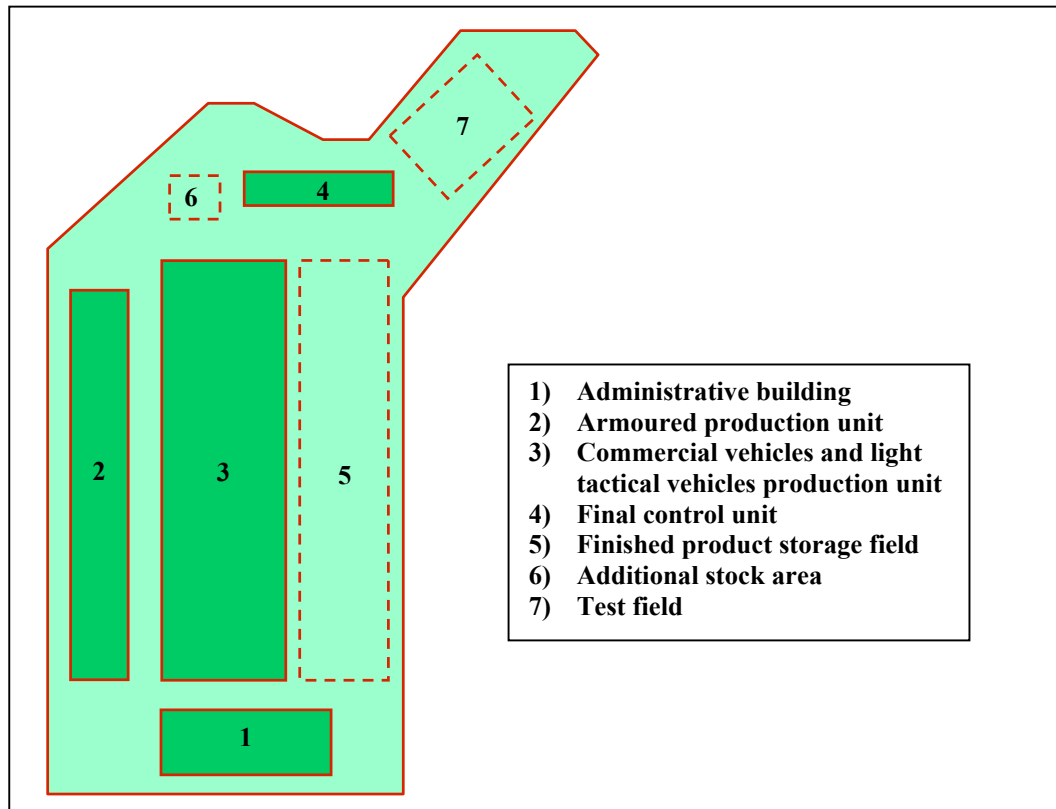


Figure III.1. The Plant Lay-out Before Merger.

During the study, the company merged with the plant next to it and both the total plant area and total closed area have increased to 169.000 m² and 45.000 m², respectively. The new layout (starting from late 2001) is given in Figure III.2. Building no.8 was the administrative building of the trailer company before merger and became the second administrative building after the merger. The commercial vehicles welding and BIW(Body-In-White) lines are carried to building no.9 from building no.3. Trailer chassis and body assembly lines are also in building no.9. Building no.10 is trailer service area and no.11 is trailer after sales department.

The merger also changed the product range and total capacity because the plant acquired was a manufacturer of various types of trailers/semi-trailers and trucks. The yearly plant capacity increased to 2.000 minibuses, 2.000 midibuses, 1.500 4x4 tactical vehicles, 500 armoured vehicles and 1.500 trailers/semi-trailers and truck body applications. The total number of personnel is 1.050 with 210 white collars and total turnover for 2003 is 205 million USD.

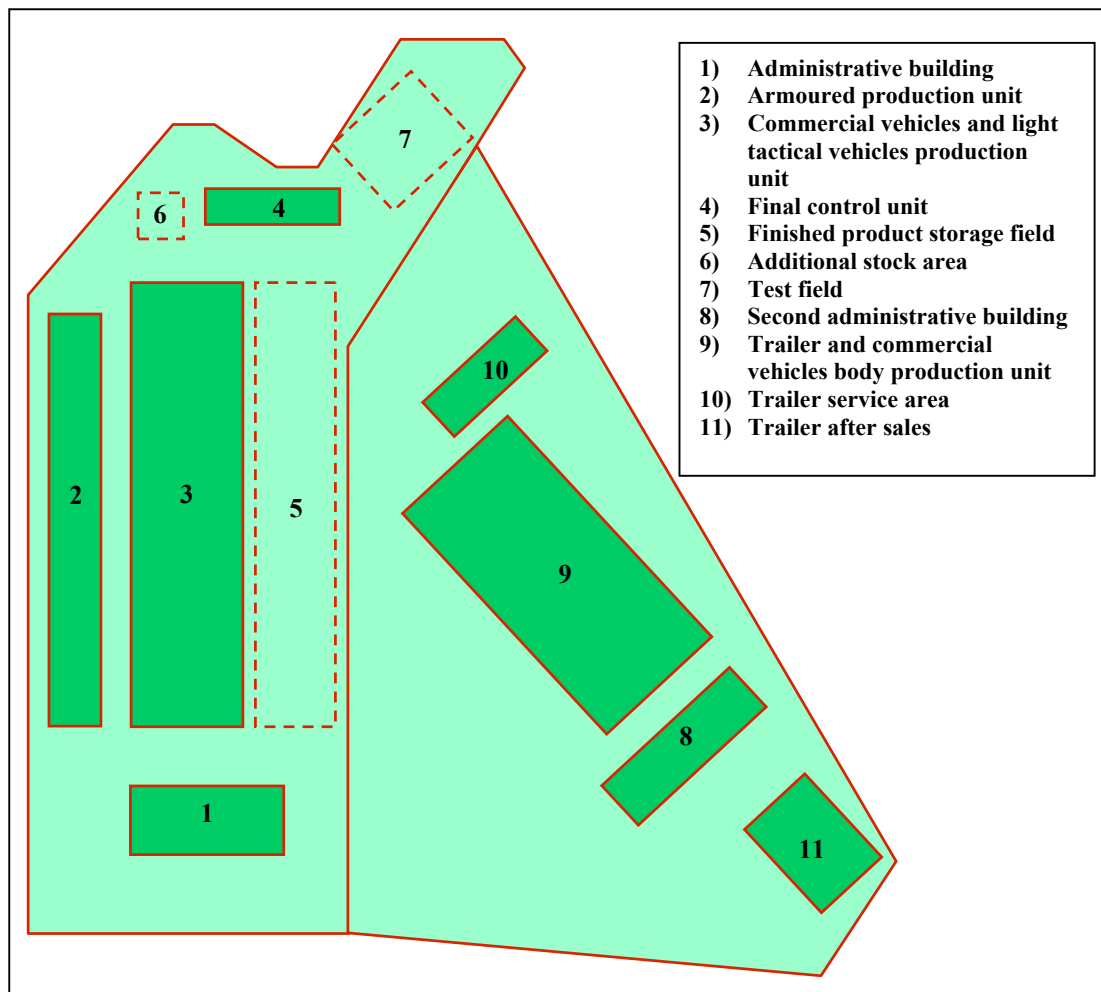


Figure III.2. The Plant Lay-out After Merger.

The organization of the company before the merger is given in Figure III.3. The actual organization of the company is not given deliberately because the changes on the organization were mainly a result of the materials management reengineering study and merger, and will be given in following chapters with all the necessary explanations.

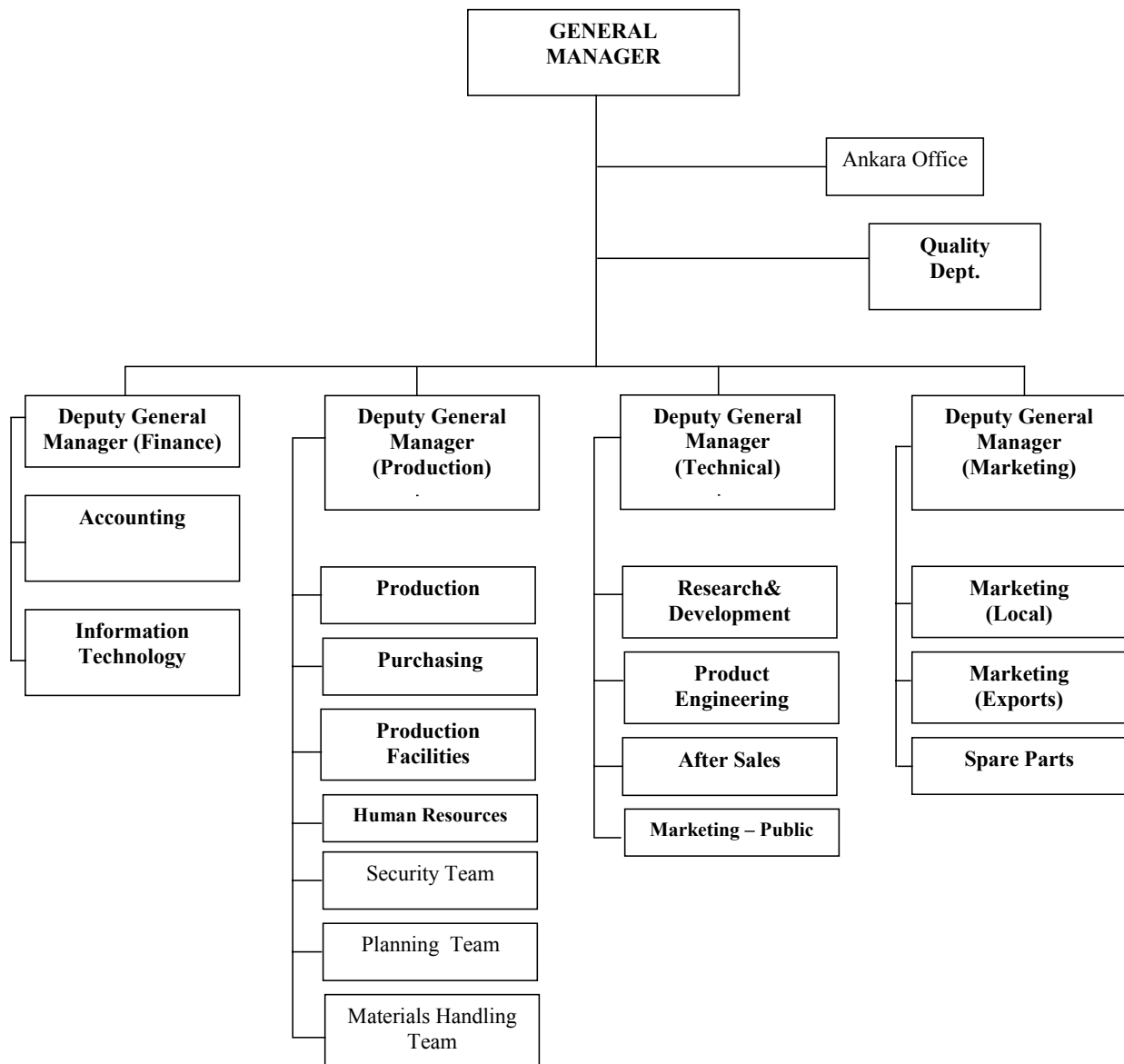


Figure III.3. The Company Organization Before Merger.

III.3. MATERIALS MANAGEMENT SYSTEM

The plant manufactures light-medium weight commercial vehicles and tactical vehicles for defense industry. The demand for the commercial vehicles are easier to forecast and a probabilistic distribution can be assumed, but the demand for tactical vehicles depends on contracts and it is not easy to forecast the contracts the company may be awarded in future. The study is interesting because the material management systems required for the two types of products are quite different from each other and they co-exist in the plant. The inventory policy of the plant is a mixed structure of Materials Requirement Planning and manual orders. This causes many problems to occur on every stage of materials management.

The decision to start this study was the result of some previous work and feedback, which should be included in this dissertation work in order to make the reader understand why such a multidimensional change on organisation, was asked by top-level management. As a result of the economic crisis in Turkish economy, the defence industry orders shrunk at once at the start of year 2001. The company was ready to face this demand change, because the top-level management had foreseen it and had made its plans to recover from the probable negative effects of it. One of the many strategies to overcome the crisis was to introduce new products to commercial vehicles market and research and development work for a new series of midibuses had started in year 1999. In the second half of the year 2001, the products were ready for the market. So, the year 2001 was a year of sharp decrease in some products of defence industry and a start of some new products in commercial market. This change directly effected the inventory levels and some systematic problems which were not an important factor in routine production work, became worth considering. The top-level management asked for a report on inventory levels and this was giving clues about some materials management problems that had to be attacked immediately not to let their negative effects grow. Some important notes from the report which give an idea about the current situation are given below.

The defense industry products have many derivatives and commercial vehicles are comparatively mass production vehicles. Table III.1 shows percent of sales turnover and percent of total stocks for these groups.

Table III.1. Sales Turnover and Total Stocks for Mass Production and Derivative Vehicles.

	% of Sales Turnover	% of Total Stock
Mass Production Vehicles	89	66
Derivative Vehicles	11	34

The plant suffers from a high amount of excess of incoming inventory, which has to be deeply analyzed before making any decisions to solve the problems. Table III.1. shows that the amount of inventory stock for mass production vehicles (constituting 89 % of the sales turnover) is about 66 % of the total inventory in dollars. That implies the remaining 34 % of total inventory are held for vehicles constituting only 11 % of the sales turnover. An item by item evaluation shows that there are approximately 9,100 different items in the inventory and only 3,100 different items are kept for mass production vehicles.

Another interesting point is shown below in Table III.2. About 35 % of the total inventory are older than 6 months (14 % is acceptable as dead stock that is older than 12 months).

Table III.2. Aging for Total Stocks.

	Stock time < 6 months	Stock time 6 – 12 months	Stock time > 12 months
% of Total Stock	65	21	14

When we divide the stock items into groups as raw materials, purchased parts and hardware, we find out that 7 % of the total inventory is hardware. Besides 49 % of the hardware is older than 6 months. In short, the plant is definitely carrying an excessive and old inventory, which has to be focused on. In addition to that, the inventory is occupying a valuable space and as it grows higher and higher handling and supervision costs increase.

This excess stock accumulation is a result of many processes to plan, acquire, store, move and control inventory (raw materials, purchased parts, work-in-process), so to find a solution to this problem all of those processes had to be filtered and restructured if necessary. That is why the top-level management wanted a reengineering study on all of materials management processes to solve the problems and the study includes these reengineering efforts which are implemented in

accordance with the proposed model. It also includes improvements on existing processes to increase the efficiency, if a drastic change is not obtained.

The study includes the materials management system starting from ordering, transportation, inspection, acceptance, storage and handling of materials until they are mounted on vehicles to form a finished product. The processes of finished products are not a subject to this study.

The materials management system is considered as a combination of many processes conducted by different functions. Briefly;

- ◆ Purchasing department sends orders in line with demand from marketing and sales.
- ◆ Purchasing department follows the transportation of materials from suppliers to the plant.
- ◆ Materials Handling team records the incoming materials.
- ◆ Quality department inspects the materials.
- ◆ Materials Handling team stores and transfers the materials to the assembly lines as planned.
- ◆ Production department machines parts to form work in process products and finally mounts components to form finished goods.

This is 'simply' how the system works, but real life is not so easy. For instance, the demand may change at any time, even after the orders are sent to suppliers and the purchasing has to reorganise vendors not to bring excess inventory or not to be short of some parts. Another problem could be the transportation, sometimes they are late for some reason and precautions have to be taken. Or we may consider the material inspection and acceptance; not all the materials brought to the plant are accepted. Even if the right material is brought to the plant at the right time, there is still possibility that it may not be on the assembly line due to many reasons including materials handling problems.

Every step of materials management process is a combination of many processes and any problem on one step may effect all other steps. That is why when a reengineer study is planned on materials management system, all the steps and related processes have to be considered.

III.4. THE BPR CHANGE MANAGEMENT MODEL

When the top-level management asked for a reengineering study on materials management system, a work model so called BPR Change Management Model is constructed. BPR has been considered as a multidimensional problem solving approach in literature and the frameworks defined and used are scanned. The specific BPR model constructed for this case study is given in Figure III.4. in the following page. It is based on the general information given in literature, but is unique for the way it is constructed and implemented during the study. The framework is composed of two parts; A) Actors, B) Steps of BPR Model.

The model is based on company management style, current situation of the work processes, effects of merger and company culture. The company has been serving military customers for decades and a centralized management understanding similar to military discipline is existent. The functions of the company are separated from each other with thick lines and cross-functional communication and collaboration is very weak. In addition to that, after merger almost half of the personnel (from trailer company) had to change the way they are used to doing their work and adapt to the working style of the parent company. They were having serious learning and communication problems at this transition period.

The above mentioned centralized management, fragmented functional structure and after merger situation have been very effective while developing the model.

The reengineering study would definitely be based on team work of both process owners and operators because it requires a full knowledge of problems and details of processes to be able to redefine them. The model introduces Specialized Work Teams to study problems and redefine processes.

An important step of the model is introduction and functioning of a Materials Management Team composed of middle class managers to coordinate and monitor the change process.

The way the model works is a newly defined, standardized road map by generating Decision Matrices to direct the studies, and the model also defines a standardized way to evaluate reengineering achievements and to derive conclusions.

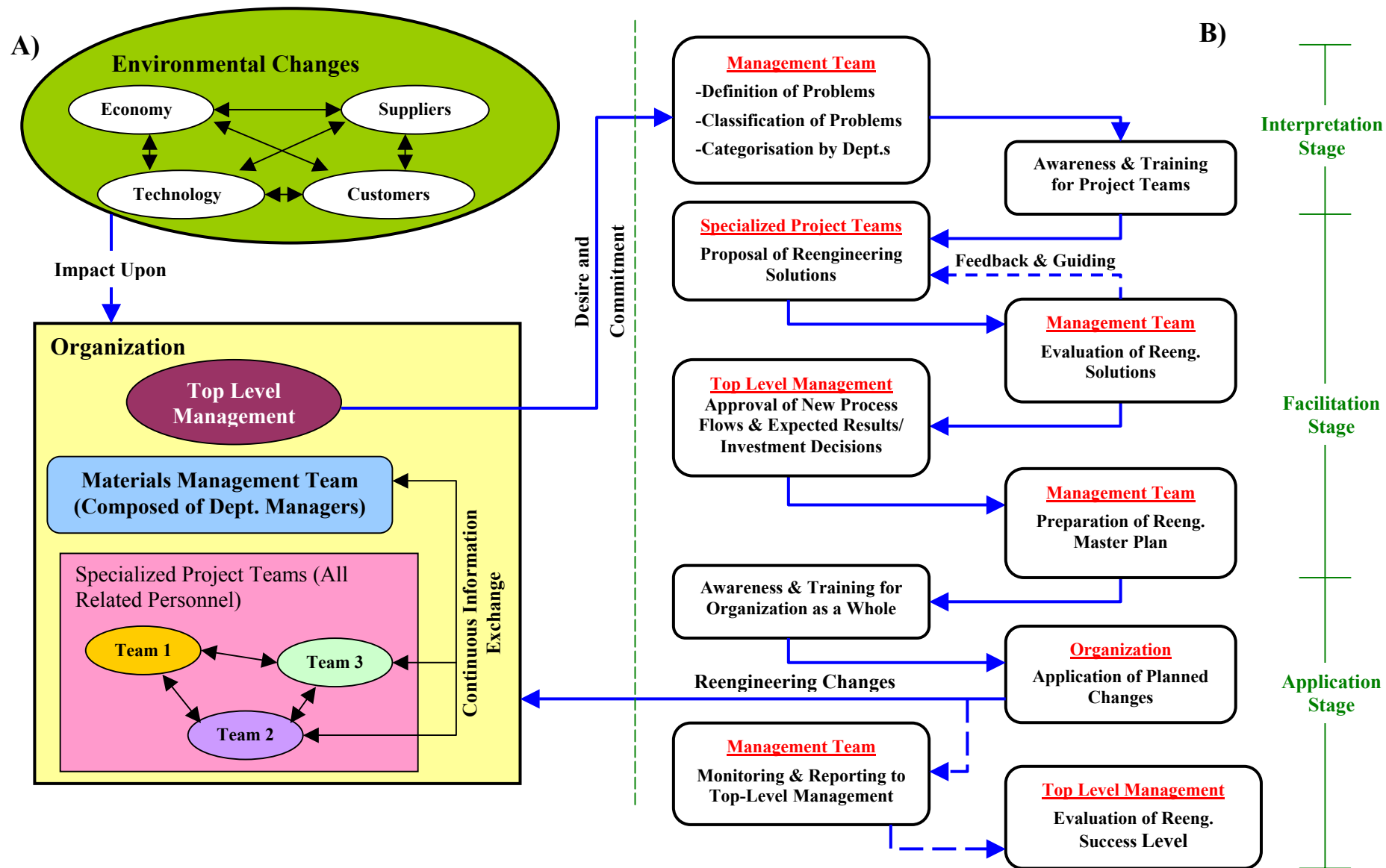


Figure III.4. The BPR Change Management Model Used in Case Study. A)Actors; B)Steps of BPR Model.

The left hand side of Figure III.4 shows the actors as the organization itself and the environment. The environmental factors like the technology, economy, suppliers and customers effect the organization. They may either add to the problems of materials management system or solve some of its problems if they are well-known and appropriately used. Knowing this fact, the top level management decided to apply a reengineering methodology to identify and solve the problems related to materials management processes. The actors in the organization are identified as a result of this initiative.

The model asks the top-level management to assign a group of department managers as a Materials Management Team to identify the problems of the system. The group consisted of managers of Purchasing, Production, Quality, IT, Product Engineering and Materials Handling and Planning team leaders. Below this Management Team, Specialised Project Teams of white/blue collars were established later on to work on the problems identified by the Materials Management Team. Since most of the problems in the materials management system were interrelated, continuous information exchange was vital for the success of the change efforts.

It was mentioned that the study started with the top level management decision and declaration of commitment for change. Later on, during the study it was observed that the top-level management commitment was really a critical factor for the success of the reengineering work.

A series of meetings were held to understand the problems deeply and to take the opinion of operational managers about the subject and as a result, the top-level management made its decision to make a complete reengineering study on the materials management system and declared its commitment for change.

Given the responsibility, the Materials Management Team started to work on materials management system to define the problems and points open to reengineering or improvement. At the end of long meetings and discussions a list of problems was obtained.

The second step of the Management Team was to classify the listed problems through certain priority parameters, and identify which problems are critical to the organisation. It is not possible to solve all of the problems at once, so critical problems that have high priority level are first taken into account. Then working on

this structured list, the Management Team identified the departments effecting or effected by every single problem.

The categorisation by departments was done in order to establish teams by including a member from each related department. After forming the teams, the next BPR step was to explain and educate team members about the aim of the study, the work that has been done, and the single problems they would work on. This was an important milestone, because the performance of the teams was very dependent on awareness and training given to them about what was expected from them.

The definition and classification of problems, categorisation by functions, and awareness / training of Specialized Project Teams altogether formed the Interpretation Stage of the BPR model.

Then, the Specialised Project Teams detailed the problems, found out all the related work flows, analysed every action of the work flows on the basis of their effect to cause the problem of interest. They tried to eliminate or replace both problem causing and non-value adding actions and prepared reengineering or improvement solutions by defining new actions to the work flows.

The next step was the evaluation of the proposed reengineering or improvement solutions by the Management Team. This was the start of a loop because if the proposed solutions are not found feasible to apply, then the management team returned to the project teams explaining them why the solutions could not be applied and guided them to restudy the problem and come to the management team with new solutions. After the re-evaluation of these new solutions by the management team, the next stage was to present all applicable solutions to the Top-Level Management.

Top-Level Management worked on the list of reengineering and improvement changes that were expected to solve the identified problems of the materials management system and made decisions on the proposed new process flows, approved appropriate ones to be realised in a certain period of time, within a given budget and to obtain measurable results. For cases like changes of buildings, machinery and manpower, detailed investment plans were prepared. Only after that step, the scope of the study was clear.

The next step was to form a Reengineering Master Plan according to the Top-Level Management approval of new work-flows proposed to eliminate problem causing and non value adding actions.

The Master Plan included all activities to be done regarding them as single projects one by one with all the resources like manpower, machinery, time and budgets defined. The performance measures of each project were also given in the Reengineering Master Plan.

After the master plan was prepared, the facilitation stage of the BPR model was completed. The next stage was the application stage where all the projects and plans would be realised.

At the beginning of the application stage, an important step was to declare to the organisation that the Reengineering Master Plan for the Materials Management System of the plant, which was an important change plan, would be applied. When such a multidimensional change procedure is applied, individuals who are not well-informed about the purpose of the changes and the scope of reengineering efforts, may have questions in their minds and show resistance to change because of the uncertainty for their careers. For that reason, it is better to let every individual in the organisation know what is going on in the plant, and for what purpose. In addition to that, training may be necessary for some employees depending on the level of process changes and technologies used. This step was done in the case study but not as a separate step from application of planned changes. It was not possible to draw exact borders between the two steps. Of course, awareness and training for organisation as a whole started just after the declaration of the master plan, but it continued during the application of planned changes as well.

During the study the specialised project team members were actively applying the reengineering solutions while The Management Team was monitoring the performance of the change efforts and periodically reporting to the Top-Level Management. As a result, the application stage was the part of the study where all the permanent changes on materials management system of the plant were made.

For the unique study made here, the model includes a step to evaluate the reengineering success level by comparing results of reengineering efforts with reengineering process parameters. This step is added to the model to be able to generate a mathematical measure of success for the reengineering change management model to work in this type of plants (centralized management, strictly functional, recently merged to another plant) and it is vital for the conclusion of the dissertation work.

The BPR model returns the reengineering changes to the organisation and completes the cycle of activities to perform the reengineering study. This model has been used during the study, and in fact is the core of this dissertation work. Model matrices and tables were used to apply the BPR model systematically. The Model Matrices and tables are given below in Figure III.5. In the following chapters, every step of BPR model and every activity done at each stage will be explained in detail. The targets, performances and results of each project will be presented as well and lessons learned from the studies will be discussed.

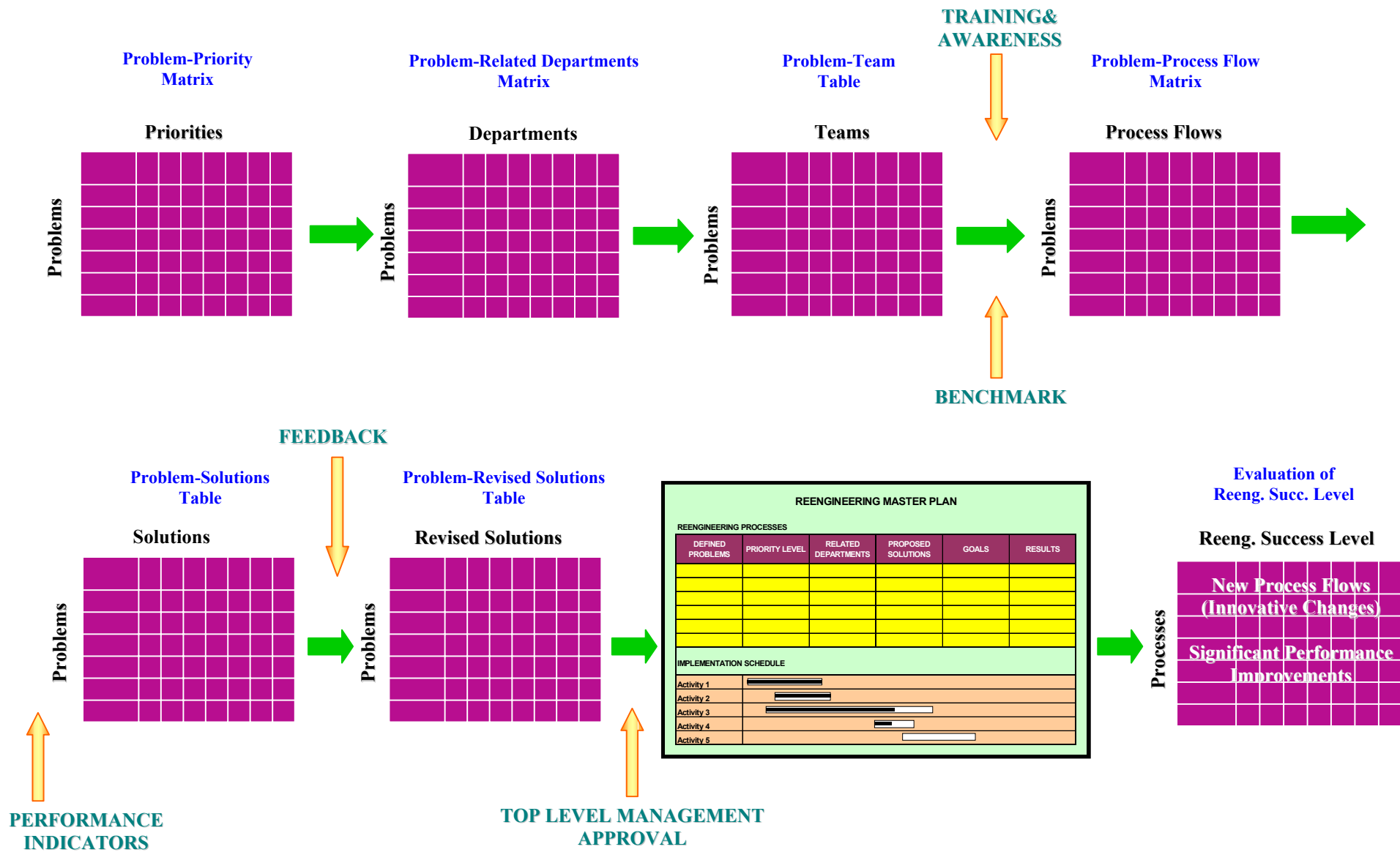


Figure III.5. The BPR Model Implementation Matrices.

III.5. BPR CHANGE MANAGEMENT MODEL IMPLEMENTATION ON MATERIALS MANAGEMENT SYSTEM

In this section, how the Reengineering Master Plan was formed and implemented will be explained. The details of processes considered in the study, problems faced, solutions proposed by work teams and redefined process flows will be given. In addition, the goals of reengineering efforts and applied action plans will be presented.

III.5.1. Decision Matrices and Tables

The step by step implementation can be summarised by formation of necessary background matrices and tables to define the specialized work teams, the actions to be done, relative importance of these actions, related work flows, solutions etc.

The first step was brainstorming on materials management system in light of existing reports and current work flows. A series of meetings were held to understand the problems deeply and a problem list to work on was obtained at the end.

This list was analysed through certain priority parameters, forming the so called Problem-Priority Matrix (Figure III.6) to obtain the priority level of each problem. The critical parameters used were financial impact, customer impact, strategic impact, deployment potential, difficulty and time required.

Each parameter was rated between 1 and 10 and had a weight relative to other parameters. Then the below formula was used to determine the critical level of each problem.

$$CL = \frac{\sum_{i=1}^6 c_i \cdot w_i}{\sum_{i=1}^6 w_i} . \quad (III.1)$$

where

CL = Critical Level,

c = rating of critical parameter,

w = weight of critical parameter.

Using the above calculated critical levels, the priority level for each problem is determined according to the Table III.3 given below.

Table III.3. Conversion Table: Critical Level to Priority Level

Critical Level Range	Priority Level
$8 \leq CL \leq 10$	1
$6 \leq CL < 8$	2
$4,5 \leq CL < 6$	3
$3 \leq CL < 4,5$	4
$2 \leq CL < 3$	5
$1 \leq CL < 2$	6
$0,5 \leq CL < 1$	7
$0 \leq CL < 0,5$	8

	WEIGHTS	25	20	20	15	10	10		
	DEFINED PROBLEMS	FINANCIAL IMPACT	CUSTOMER IMPACT	STRATEGIC IMPACT	DEPLOYMENT POTENTIAL	DIFFICULTY	TIME REQUIRED	CRITICAL LEVEL	PRIORITY LEVEL
1	Formation of Advanced Product Lists for Derivative Military Vehicles	8	8	9	10	9	7	8,50	1
2	Formation of Advanced Product Lists for Derivative Trailers	8	8	9	10	9	6	8,40	1
3	Disorder in Main Stock Area	7	6	7	8	9	8	7,25	2
4	Tracking of engineering changes	9	4	7	8	8	6	7,05	2
5	Sending / Approval time of purchase orders	7	8	6	8	4	4	6,55	2
6	Difficulties of tracking of old & excessive stocks	7	5	5	9	7	7	6,50	2
7	Long lead times	4	7	7	8	4	4	5,80	3
8	Lack of tracking of materials going out of factory for machining and coating	5	7	4	6	7	7	5,75	3
9	Material Handling coordination problems	7	2	6	5	8	7	5,60	3
10	Counting the inventory in wrong codes and unit conflicts (Causing inventory deviations)	5	4	6	6	8	4	5,35	3
11	In-house manufacturing control	6	2	5	6	7	8	5,30	3
12	Poor coordination, evaluation of feed-back from production line	6	2	4	9	6	6	5,25	3
13	Simultaneous transfer of materials (Recorded vs. Physical)	8	1	5	3	6	4	4,65	3
14	Weak control on hardware	4	2	3	8	4	5	4,10	4
15	Difficulties of tracking of hardware materials	4	2	3	8	4	5	4,10	4
16	Material quality inspection problems	2	7	4	3	4	4	3,95	4
17	Incoming material entry (registry out of factory / acceptance criteria)	2	6	2	4	5	3	3,50	4
18	Classification of urgency of demands of inventory from different functions (production vs spare parts)	5	3	4	2	3	2	3,45	4
19	Work - in - process inventory audit problems	4	2	2	2	7	3	3,10	4
20	Subassembly audit problems	4	2	2	2	7	3	3,10	4

Figure III.6. Problem-Priority Matrix.

The problems with an overall rating less than 3 (out of 10) were excluded from the study and the team was left with 20 problems to be considered while reengineering the materials management system.

Then these problems were grouped with respect to higher level processes like ordering problems, planning problems etc. and another matrix is formed presenting the related departments to these problems. The relation is rated 1 to 5, 1 being the weakest and 5 being the strongest relation. This Problem-Related Departments Matrix (Figure III.7) was the base for the identification of Specialized Work Teams and their advisors. The grouping of problems resulted 6 Problem Packages:

1. APL Management
2. Missing Planning Functions
3. Inventory Audit
4. Stock Area
5. Ordering
6. Incoming Material Entry

and members of Specialized Work Teams to work on each package is identified by analysing the Problem-Related Departments Matrix and the main criterion was to include a member from each department with a rating 4 or 5.

1. Rate relation strength between problem and departments (1 to 5)
2. Choose team members from departments with ratings 4 or 5.
3. Make teams with permanent members between 3 to 6 people.

The only limitation to this approach was availability of personnel and in practice this was managed by coordination in cases where permanent team membership was not possible. The Problem-Team Table shows the Problem Packages, Specialized Work Teams and their advisors from the Materials Management Team (Table III.4).

DEFINED PROBLEMS	RELATED DEPARTMENTS													
	PURCHASING	PRODUCT ENGINEERING	MATERIALS HANDLING *	QUALITY	PLANNING *	PRODUCTION	INFORMATION TECHNOLOGY	PRODUCTION FACILITIES	ACCOUNTING	RESEARCH & DEVELOPMENT	AFTER SALES	SPARE PARTS	SALES & MARKETING	HUMAN RESOURCES
Formation of Advanced Product Lists for Derivative Military Vehicles	5	5	2	3	5	4	3	3	1	3	2	2	2	1
Formation of Advanced Product Lists for Derivative Trailers	5	5	2	3	5	4	3	3	1	3	2	2	2	1
Classification of urgency of demands of inventory from different functions (production vs spare parts)	3	1	5	2	4	5	4	1	2	2	3	4	1	1
In-house manufacturing control	1	3	4	3	5	5	3	3	1	3	1	1	1	1
Tracking of engineering changes	4	5	3	4	5	3	4	4	2	3	1	3	1	1
Weak control on hardware	4	2	5	2	3	3	3	1	1	2	2	1	1	1
Material Handling coordination problems	3	4	5	2	5	3	4	2	1	2	1	2	1	1
Simultaneous transfer of materials (Recorded vs. Physical)	3	2	5	3	3	4	3	3	2	2	1	3	1	1
Poor coordination, evaluation of feed-back from production line	3	3	3	2	5	5	3	2	1	3	1	1	1	1
Work - in - process inventory audit problems	2	2	3	3	3	5	5	4	3	2	1	1	1	1
Subassembly audit problems	4	2	4	3	3	3	4	3	3	2	1	2	1	1
Counting the inventory in wrong codes and unit conflicts (Causing inventory deviations)	4	3	5	1	3	2	5	2	3	2	1	1	1	1
Difficulties of tracking of hardware materials	4	3	3	2	5	4	3	2	1	3	2	3	1	1
Disorder in Main Stock Area	3	2	5	3	5	3	3	3	2	3	2	3	1	1
Difficulties of tracking of old & excessive stocks	4	3	5	4	4	3	3	2	2	2	1	2	1	1
Sending / Approval time of purchase orders	5	2	3	4	4	4	3	3	2	3	2	1	1	1
Long lead times	5	2	3	3	3	3	2	2	2	2	1	3	2	1
Incoming material entry (registry out of factory / acceptance criteria)	5	2	5	3	4	3	2	2	3	2	2	2	1	1
Lack of tracking of materials going out of factory for machining and coating	4	2	5	2	4	3	3	3	3	2	1	2	1	1
Material quality inspection problems	4	3	4	5	2	2	4	2	1	2	1	1	1	1

* Materials Handling and Planning were separate teams at the start of the study, during the study they combined to form Planning Department.

Figure III.7. Problem-Related Departments Matrix.

Table III.4. Problem-Team Table.

	PROBLEM PACKAGE	DEFINED PROBLEMS	SPECIALIZED WORK TEAM MEMBERS	ADVISOR
1.1.	APL Management of Derivative Products	Formation of Advanced Product Lists for Derivative Military Vehicles	PE, PU, PL, PR	PE MANAGER
1.2.		Formation of Advanced Product Lists for Derivative Trailers		
2.1.	Missing Planning Functions	Classification of urgency of demands of inventory from different functions (production vs spare parts)	MH, PL, PR, IT	PL, MH TEAM LEADERS
2.2.		In-house manufacturing control		
2.3.		Tracking of engineering changes		
2.4.		Weak control on hardware		
2.5.		Material Handling coordination problems		
2.6.		Simultaneous transfer of materials (Recorded vs. Physical)		
2.7.		Poor coordination, evaluation of feed-back from production line		
3.1.	Inventory Audit	Work - in - process inventory audit problems	PR, PU, MH, IT, PF	IT MANAGER
3.2.		Subassembly audit problems		
3.3.		Counting the inventory in wrong codes and unit conflicts (Causing inventory deviations)		
4.1.	Stock Area	Difficulties of tracking of hardware materials	PL, MH, PU, QU, PR	PR MANAGER
4.2.		Disorder in Main Stock Area		
4.3.		Difficulties of tracking of old & excessive stocks		
5.1.	Ordering	Sending / Approval time of purchase orders	PU, QU, PL, PR	PU MANAGER
5.2.		Long lead times		
6.1.	Incoming Material Entry	Incoming material entry (registry out of factory / acceptance criteria)	PU, PL, MH	QU MANAGER
6.2.		Lack of tracking of materials going out of factory for machining and coating		
6.3.		Material quality inspection problems		

Then the Specialized Work Teams analysed the problems and collected the subprocesses to be reengineered to eliminate these problems on a matrix. All the subprocesses that are involved and somewhat related to problems are taken into account and shown on Problem-Process Flow Matrix in Figure III.8.

The following step was to generate solutions that reengineer the processes to eliminate the identified problems. The work teams used many group study techniques like brainstorming, nominal group technique, 6 sigma tools etc. and formed solution tables for the problems. These solution tables were both evaluated by team supervisors and Materials Management Team as a whole and the proposed solutions were restudied over and over again until the revised list was obtained with the approval of Top-Level Management. The Problem-Revised Solutions Table is given below in Table III.5.

After preparing these matrices and tables the problems were identified, the work teams were ready to work on specified processes and all the information gathered was used to make an overall plan for reengineering, namely the Reengineering Master Plan including the reengineering schedules and goals.

DEFINED PROBLEMS	RELATED PROCESS FLOWS							
	APL Information Flow and Production Process of Derivative Military Vehicles	APL Information Flow and Product Definition Process of Derivative Trailers	Spare Parts and Production Material Handling Process	In-House Manufacturing Process Flow	Engineering Changes Process Flow	Hardware Transfer Process Flow	Line Loading Process Flow	Physical and Registered Motion of Items
Formation of Advanced Product Lists for Derivative Military Vehicles	X			X	X		X	X
Formation of Advanced Product Lists for Derivative Trailers		X		X	X		X	X
Classification of urgency of demands of inventory from different functions (production vs spare parts)			X				X	X
In-house manufacturing control	X		X	X			X	X
Tracking of engineering changes	X	X			X		X	
Weak control on hardware						X		
Material Handling coordination problems	X	X		X		X	X	X
Simultaneous transfer of materials (Recorded vs. Physical)		X		X		X	X	X
Poor coordination, evaluation of feed-back from production line				X	X		X	
Work - in - process inventory audit problems				X				X
Subassembly audit problems		X		X				X
Counting the inventory in wrong codes and unit conflicts (Causing inventory deviations)						X		X
Difficulties of tracking of hardware materials						X	X	X
Disorder in Main Stock Area	X					X	X	X
Difficulties of tracking of old & excessive stocks	X	X			X		X	X
Sending / Approval time of purchase orders			X					
Long lead times			X					
Incoming material entry (registry out of factory / acceptance criteria)							X	
Lack of tracking of materials going out of factory for machining and coating				X	X		X	
Material quality inspection problems	X							

Figure III.8. Problem-Process Flow Matrix (continued next page).

DEFINED PROBLEMS	RELATED PROCESS FLOWS								
	Process Flow of Feedback From Production Line	Inventory Audit Preparation of Work-In-Process Vehicles	Inventory Audit Preparation of Subassemblies	Tracking of Old & Excessive Stocks	Sending/Approval Flow of Purchase Orders	Vendor to Facility Flow of Critical Items	Incoming Material Entry Process Flow	Tracking of Materials Going Out of Factory for Machining and Coating	Incoming Material Inspection Process Flow
Formation of Advanced Product Lists for Derivative Military Vehicles	X			X	X	X			
Formation of Advanced Product Lists for Derivative Trailers			X	X	X				
Classification of urgency of demands of inventory from different functions (production vs spare parts)	X								
In-house manufacturing control									
Tracking of engineering changes	X			X					
Weak control on hardware									
Material Handling coordination problems	X			X				X	X
Importance of registered transfer of materials, at the same time with physical transfer				X			X	X	
Poor coordination, evaluation of feed-back from production line	X			X				X	
Work - in - process inventory audit problems		X							
Subassembly audit problems			X						
Counting the inventory in wrong codes and unit conflicts (Causing inventory deviations)		X	X					X	
Difficulties of tracking of hardware materials									
Disorder in Main Stock Area	X			X			X	X	
Difficulties of tracking of old & excessive stocks	X			X					
Sending / Approval time of purchase orders					X	X			
Long lead times	X				X	X			X
Incoming material entry (registry out of factory / acceptance criteria)							X	X	X
Lack of tracking of materials going out of factory for machining and coating				X			X	X	
Material quality inspection problems	X						X		X

Figure III.8 Problem-Process Flow Matrix.

Table III.5. Problem-Revised Solutions Table.

DEFINED PROBLEMS	REVISED SOLUTIONS			
	SOLUTION 1	SOLUTION 2	SOLUTION 3	SOLUTION 4
Formation of Advanced Product Lists for Derivative Military Vehicles	4 Base Product Definitions + Options System			
Formation of Advanced Product Lists for Derivative Trailers	6 Standard Product Definitions	Description of product definition, purchasing and production process flows		
Classification of urgency of demands of inventory from different functions (Production vs. Spare Parts)	Redesign of delivery labels	Responsibility definition to track such cases	New Spare Parts Stock Area	
In-house manufacturing control	Planning of In-house manufacturing on MRP system	Raw material tracking system		
Tracking of engineering changes	IT Solution for New Product Release & Effectivity	Engineering Change Meetings		
Weak control on hardware	New hardware stock area	New hardware transfer method to production lines		
Material Handling coordination problems	Organizational Change	Line Loading via System Data		
Simultaneous transfer of materials (Recorded vs. Physical)	Definition of responsible personnel in stock area	Definition of coordination between Stock Area and Production line operators		
Poor coordination, evaluation of feed-back from production line	Formation of Work Order Analysis Teams	Continuous inventory auditing using WOAT and material tracking team results		
Work - in - process inventory audit problems	Bringing All Vehicles in One Location to the End of Location Montage Level			
Subassembly audit problems	Bringing All Subassemblies to Completed Form			
Counting the inventory in wrong codes and unit conflicts (Causing inventory deviations)	Review of part codes of trailer company	Review units of part groups (sheet metal, pipes, oils, chemicals etc.)	Inventory Audit preparations (Education, detailed line addressing, personnel planning, equipment planning, consultancy teams)	Fixed addressing and barcoding
Difficulties of tracking of hardware materials	Eliminate redundant codes	Decrease variety of hardware material types	Use single coding system	
Disorder in Main Stock Area	Redesign of stock area on a product basis	Increase total storage area		
Difficulties of tracking of old & excessive stocks	Separate Old & Excessive Stock Area			
Sending / Approval time of purchase orders	Sending order plans on the web	Fax automation for vendors not using EDI	Receiving order approvals on the web	
Long lead times	Nearer vendors	Less vendors	Revised contracts with critical vendors	
Incoming material entry (registry out of factory / acceptance criteria)	IT solution for acceptance criteria	Early registry of trucks out of factory		
Lack of tracking of materials going out of factory for machining and coating	IT solution for part coding and reentry system			
Material quality inspection problems	Pass & Periodic Control Systems	IT solution for recording inspection results		

III.5.2. The Reengineering Master Plan:

As explained earlier, the structure of the BPR model was aiming to form a plan to manage the change. This plan is the major tool for Materials Management Team to monitor the performance of the reengineering efforts. The Reengineering Master Plan is given in Appendix A and the details of the plan will be given item by item in the following pages.

III.5.2.1. Advanced Product List (APL) Management of Derivative Products

1.a. Formation of Advanced Product Lists for Derivative Military Vehicles

4x4 Military products had around 100 different derivatives, that is customised versions to satisfy the specific requirements asked for by the customers. Most of the orders were similar but unique in terms of detailed parts lists (called Advanced Product Lists in the company). That is the reason why it was not possible to keep Advanced Product Lists up to date for all types. For those, which did not have the lists, the custom was to convert the technical specifications of the customers by verbal communication using part names and some specific definitions. Part codes could not always be used and this was a typical reason for wrong parts ordering. Product Engineering and Purchasing departments used to work together to make the product definition from the customer technical specifications and Production department worked separately to form their own material requirement lists. For each new order of derivatives similar processes were done, causing repetitive work and double-duplication of some processes.

While converting the technical specifications into Advanced Product Lists, part names and optional requirements asked for by the customer should be translated to part codes. Usually, only system definitions were given in Product Identification Forms prepared by Product Engineering department and determination of subgroups of parts and identification of codes among similar part codes was causing disorder and a considerable loss of time. Figure III.9 shows an example of Product Identification Forms.

PRODUCT IDENTIFICATION FORM			
DATE		REVISION	PAGE NO
NAME			
CODE			
TYPE			
ENGINE			
GEARBOX			
CHASSIS			
BODY			
COLOUR			
STEERING			
WHEELS			
SEATS			
SEAT BELTS			
ELECTRICAL SYSTEM			
SPARES-TOOLS			
SPECIAL EQUIPMENT			
OTHER PROPERTIES			
DOCUMENTATION			
VEHICLE VIEWS			
			
DELIVERY LIST		INFO.	
PREPARED BY	CONTROLLED BY	APPROVED BY	

Figure III.9. An Example of Product Identification Forms.

In general, all material requirements for products with Advanced Product Lists could be determined from MFG-PRO, the MRP system and all the engineering changes could be updated from the system. For those derivatives without Advanced Product Lists, all the work was done on excel sheets and updating these lists was a point open to manual errors.

Each time these lists were used, the errors on the lists could accumulate and as a result of these incorrect lists, wrong or late orders could be given, late deliveries or inactive inventory accumulation could be observed. The inactive inventory formed this way had to remain in stock area for a long time since it is quite often that the company does not receive orders from the same type of derivative for a couple of years.

On the other hand, the incorrect lists might be a cause of missing parts. The derivatives without Advanced Part Lists sometimes contains special parts with long lead times and if they are not ordered on time, the deliveries would be delayed or transportation costs would drastically increase especially due to air transportation.

The company had efficient control systems to detect any nonconformity and all the problems were solved before delivery to customers. The process needed to be

redefined to get rid of time losses and other inefficiencies. The process flow before the reengineering study is illustrated in Figure III.10.

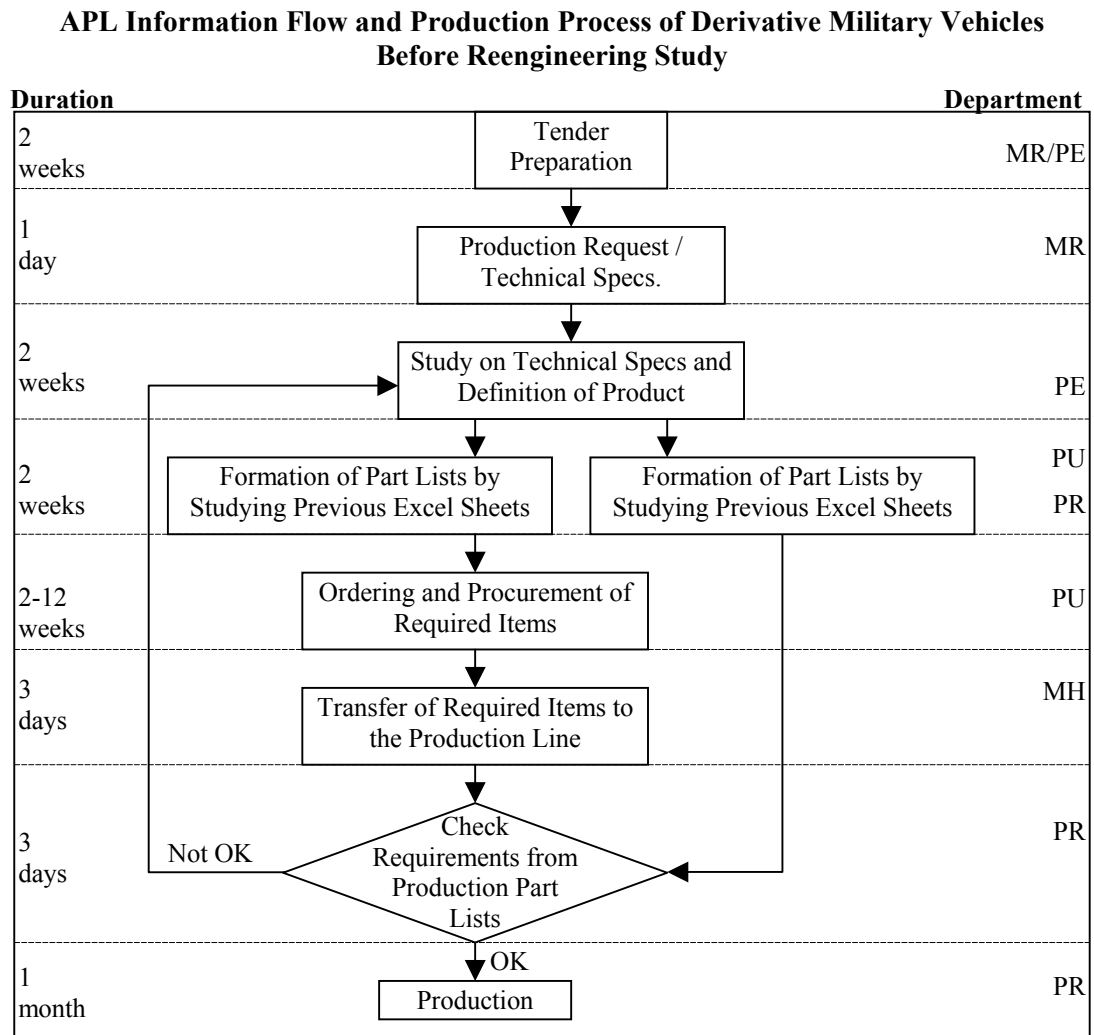


Figure III.10. APL Information Flow and Production Process of Derivative Military Vehicles Before Reengineering Study.

The problems of the process flow before reengineering was explained above and to solve these problems a work team was established. The team studied the process in detail and proposed necessary solutions and an action plan to implement them. The goals of the process changes were also explained to the Materials Management Team and after the approval from the Top Management they were included to the Reengineering Master Plan.

The proposed solution was to define 4 Base Products + Options System. 4 product types would be chosen by the Product Engineering and their Advanced Product Lists would be prepared. Then, most of the possible options (if not all) which the customer might ask for would be defined. When a new order for a derivative product came, Product Engineering would choose the adequate base and

required options to form the Advanced Product List of the new derivative. The Base Product and Option Lists would always be kept up to date on the MFG-PRO system.

Below in Figure III.11 a view of the related page of the Reengineering Master Plan is given.

I. <i>APL Management Problems for Derivative Products</i>		TEAM: PE, PU, PL, PR			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
1.1.	Formation of Advanced Product Lists for Derivative Military Vehicles	1	PE, PU, PL, PR	4 Base Product Definitions + Options System	Decrease the quantity of inactive items after production for base products
					Decrease the quantity of inactive items after production for optional systems
					Time period between marketing request and purchasing order
					Decrease production material transportation cost

Figure III.11. Related Part of the Reengineering Master Plan.(III.5.2.1.a)

The goals of the new system are given on the Master Plan page. They are;

- ◆ To decrease the quantity of inactive items after production for base products
- ◆ To decrease the quantity of inactive items after production for optional systems
- ◆ To decrease time period between marketing request and purchasing order
- ◆ To decrease production material transportation cost

The Action Plan to launch the new system is given below.

Action Plan for Launching 4 Base Products + Options System:

1. The definition of the 4 base products by Product Reengineering.
2. The definition of the options by Product Reengineering.
3. Updating of the documentation.
4. Presentation of the new system.
5. Implementation.

The expected process flow after the completion of the above activities is given in Figure III.12.

APL Information Flow and Production Process of Derivative Military Vehicles After Reengineering Study

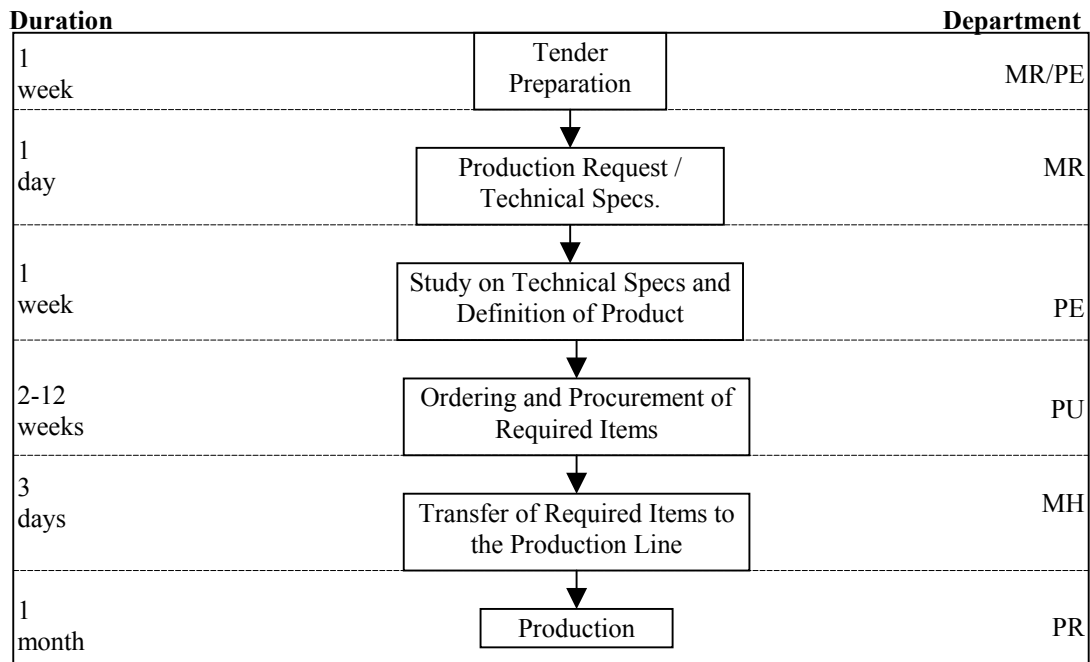


Figure III.12. APL Information Flow and Production Process of Derivative Military Vehicles After Reengineering Study.

1.b. Formation of Advanced Product Lists for Derivative Trailers

As stated before, trailers and semi-trailers were the products of the neighbouring company and after the merger they became a part of the company's product range. The sector was new to the company and all the processes like product definition, ordering and production were quite different. Product definition problems were obvious and they were taken into account as priority subjects to attack.

The old system was to break down products into modules and combine them into new part lists according to customer requirements. In fact the modules system works well for flexible manufacturing lines as long as they are very well coordinated and required engineering time is supplied. Every new batch order included different customer requirements and for each batch Product Engineering had to prepare Advanced Product Lists. Time spent on this module combination was occupying a considerable percent of Product Engineering working time, and because of the volume of the work it was not easy to avoid manual errors during the update processes. As a result, just like 4x4 military derivatives, not updated or late purchasing orders might be given, late deliveries or inactive inventory accumulation might be observed.

Another problem related to this type of product definition was point of design freeze. Product Engineering was usually working on a couple of trailer definitions at the same time and the definition process was continuous, meaning each day they were releasing a portion of the product on Product Definition Forms and sending them to Purchasing Department for orders. While defining the rest of the product, if they found that they had made an inaccurate definition of the released parts, the correction was either impossible or very costly. Items, wrongly ordered as defined and could not be returned, were accumulating in stocks. This problem was also a cause for late product deliveries.

To solve the above mentioned problems a team of related departments was established by the Materials Management Team and the team worked to solve both of the problems at the same time. They worked on all process steps to define a new flow recovering the problems. The process flows before the reengineering study are illustrated in Figure III.13.

**APL Information Flow and Product Definition Process of Derivative Trailers
Before Reengineering Study**

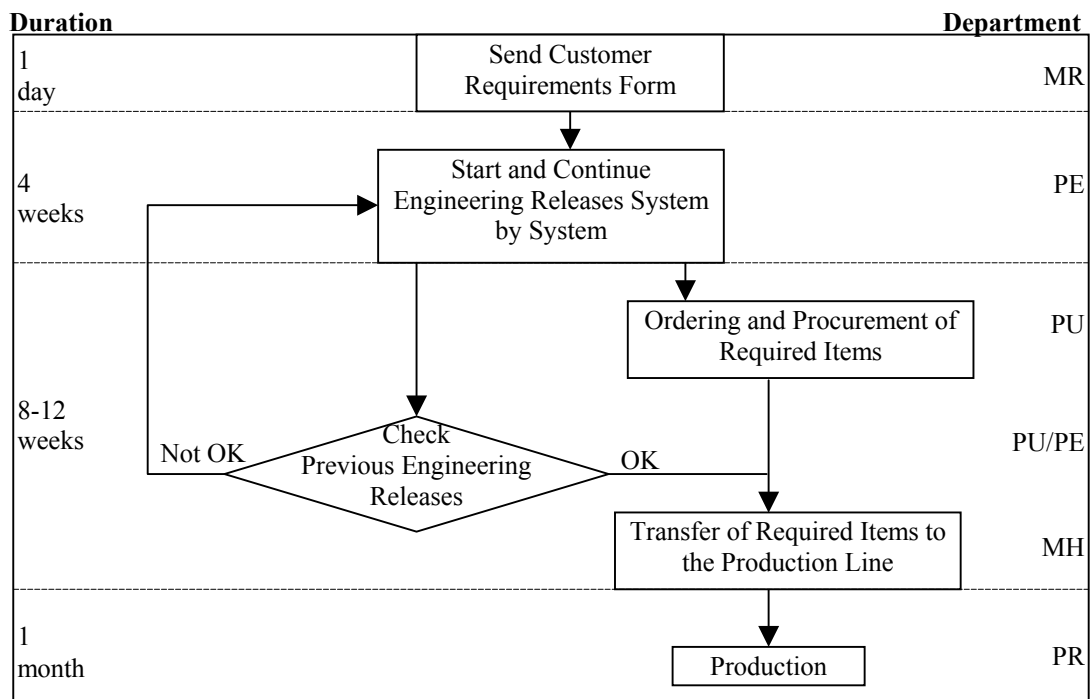


Figure III.13. APL Information Flow and Product Definition Process of Derivative Trailers Before Reengineering Study.

As a result of the process studies, a new process flow was defined and proposed solutions were added to the Reengineering Master Plan as shown below in Figure III.14.

I. <i>APL Management Problems for Derivative Products</i>		TEAM: PE, PU, PL, PR			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
1.2.	Formation of Advanced Product Lists for Derivative Trailers	1	PE, PU, PL, PR	6 Standard Product Definitions	Decrease the quantity of inactive items after production
					Decrease time period between marketing request and production
					Decrease production material transportation cost
				Description of product definition, purchasing and production process flows	Start declared standard time (design freeze) for product definition

Figure III.14. Related Part of the Reengineering Master Plan.(III.5.2.1.b)

First solution was to make 6 Standard Product Definitions and encourage Marketing department to sell these standard types by providing them cheaper and earlier than other customer specific trailers. That would really decrease the engineering time and manual copying-updating errors.

Second solution was to define a predetermined design study period and Design Freeze date. This would solve problems due to continuously changing engineering releases and wrong purchasing orders.

The goals of the new system are given on the Master Plan page. They are;

- ◆ To decrease the quantity of inactive items after production
- ◆ To decrease time period between marketing request and production
- ◆ To decrease production material transportation cost
- ◆ To start declared standard time for product definition (design freeze) implementation

The Action Plans to launch the new system were as follows.

Action Plan for Start of Design Freeze:

1. First meeting – Studies on process flow
2. Determination of empirical work durations
3. Implementation and control
4. Corrections

Action Plan for Standardisation:

1. Definition of Standard Types
 - 1.1. Product 1 Advanced Product List
 - 1.2. Product 2 Advanced Product List
 - 1.3. Product 3 Advanced Product List

- 1.4. Product 4 Advanced Product List
- 1.5. Product 5 Advanced Product List
- 1.6. Product 6 Advanced Product List
2. Updating of the documentation.
3. Presentation of the new system.
4. Implementation.

The expected process flow after the completion of the above activities is given in Figure III.15.

**APL Information Flow and Product Definition Process of Derivative Trailers
After Reengineering Study**

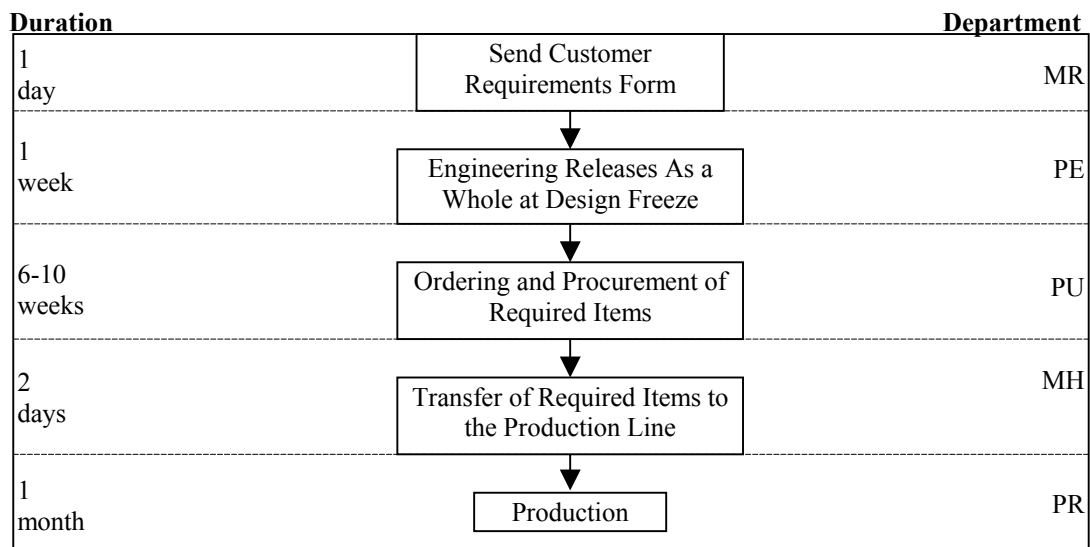


Figure III.15. APL Information Flow and Product Definition Process of Derivative Trailers After Reengineering Study.

III.5.2.2. Missing Planning Functions

2.a. Classification Of Urgency Of Demands Of Inventory From Different Functions (Production vs Spare Parts):

The purchase orders for both production materials and spare parts were given by Purchasing Department but the requirement information for spare parts was supplied by Spare Parts Department. The production materials and spare parts were coming to the company with same type of labels and part codes. In Main Stock Area, there was a group of shelves defined as spare parts storage and if there are Open Orders for spare parts, the first incoming materials were taken to those shelves. Then, they were transferred to spare part stocks on the system.

The first problem was the process was not checking the urgency of demand from production and spare parts. A production part might be urgently needed by production lines although there is an open spare part order for it. Sometimes, it was

possible that the parts ordered for production could be sent to spare parts stocks, and sometimes urgent demands coming to factory as spare parts could be used by production. The result was either shortages due to priority mistakes or customer complaints from services. It was not easy to track which parts were given to which department since there was considerable registration delays and use of different softwares. When there is shortage due to some other reason, it was possible that production personnel could use parts from spare parts shelves without registration resulting a stock deviation.

The second problem was the physical transfer of spare parts to after sales dealers and services. The capacity of the spare parts shelves and packaging space was not enough to satisfy the increasing demand. Especially with the start of new products, the satisfaction of new customers became vital for the company and this type of delay was not acceptable.

A specialized team of related departments was established by the Materials Management Team and team members worked to solve both of the problems at the same time. They worked on all process steps to define reengineering solutions to get rid of the above mentioned problems. The process flow before the reengineering study is shown in Figure III.16.

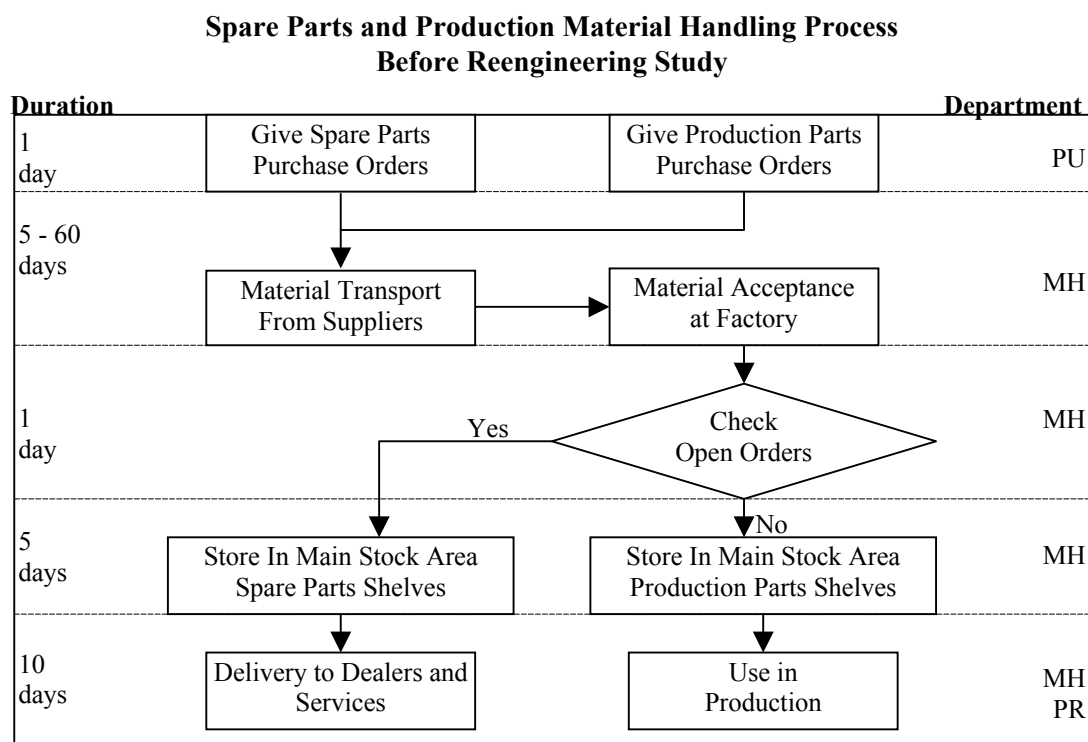


Figure III.16. Spare Parts and Production Material Handling Process Before Reengineering Study.

As stated above, production materials and spare parts were coming to the company with same type of labels and part codes. The first change was to define a new label with a barcode on it, distinguishing materials coming to the factory as spare parts. A sample of new labels is shown below in Figure III.17.



Figure III.17. A Sample of New Labels.

Then, a responsible personnel from Materials Handling department is defined to check Purchasing Approvals for the spare parts. This way, wrong routing of these materials would be prevented.

The above solutions would distinguish the spare parts requirement and supply but would not help physical transfer of spare parts to after sales dealers and services, or the capacity of the spare parts shelves and packaging space if they were stored in Main Stock Area. Besides, their use in production without registration would still be possible. The solution to this problem was to built a new Spare Parts Stock Area and manage spare parts stocks separately. This solution would necessitate an investment and Top-Level Management approval. The team prepared a presentation to clarify the benefits of a new stock area and especially requirement of a higher stock level, control over safety stocks and a higher turnover rate to satisfy the spare part demands for new products. The expected profit increase was found appropriate by the Top-Level Management and the investment was approved. The construction for the new Spare Parts Stock Area started by the end of 2003 and is expected to be completed by mid-summer 2004. The location for the building is shown below in Figure III.18.



Figure III.18. New Spare Parts Stock Area.

The goals of the new system are given on the Master Plan page as shown below in Figure III.19.

2. <i>Missing Planning Functions</i>		TEAM : MH, PL, PR, IT			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
2.1.	Classification of urgency of demands of inventory from different functions (production vs spare parts)	4	MH, PL, PR, SP, IT	Redesign of delivery labels	Control material transfers and take precautions before shortage due to priority mistakes
				Responsibility definition to track the cases	
				New Spare Parts Stock Area	Separate spare parts stock and increase turnover rate Separate spare parts stock and increase control over spare parts safety stocks

Figure III.19. Related Part of the Reengineering Master Plan.(III.5.2.2.a)

They are;

- ◆ To control material transfers and take precautions before shortage due to priority mistakes
- ◆ To separate spare parts stock and increase turnover rate

- ◆ To separate spare parts stock and increase control over spare parts safety stocks

The Action Plans to launch the new system were as follows.

Action Plan for Redesign of Labels:

1. Description of required information on new labels
2. Preparation of digital labels by IT department
3. Integration to the current system
4. Pilot Implementation
5. Deployment

Action Plan for New Spare Parts Stock Area:

1. Investment Planning for New Spare Parts Stock Area
2. Supply of Required Shelves and Equipment
3. Construction & Installation
4. Counting and Transferring the Spare Parts to New Spare Parts Stock Area
5. Definition of Responsibilities for the New Process Flow
6. Implementation

The expected work flow after the above changes is shown in Figure III.20.

**Spare Parts and Production Material Handling Process
After Reengineering Study**

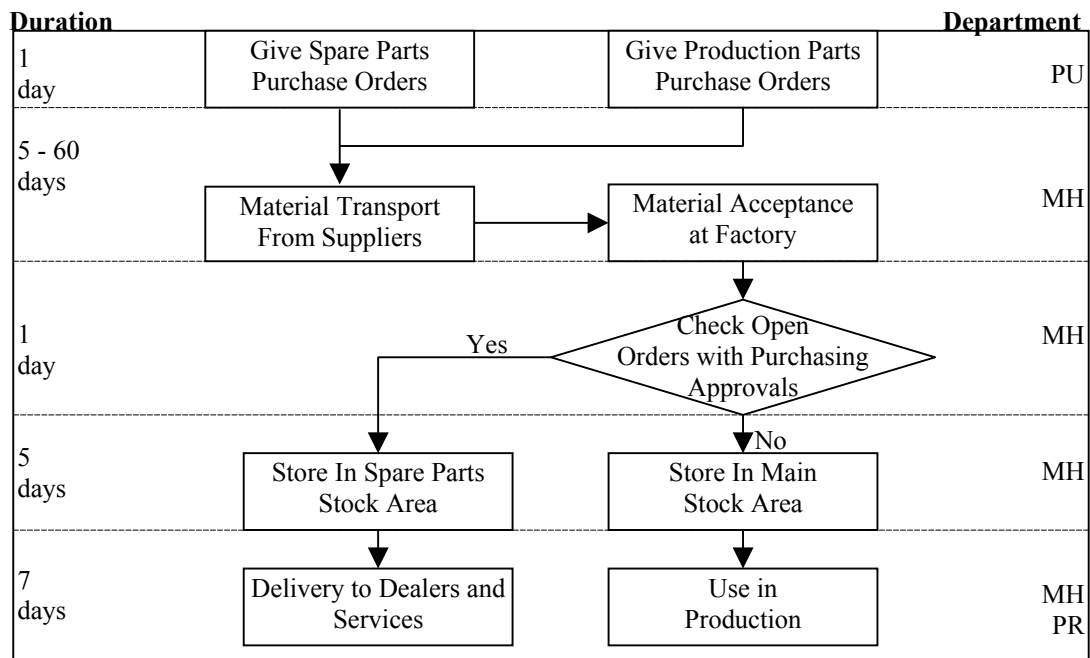


Figure III.20. Spare Parts and Production Material Handling Process After Reengineering Study.

2.b. In-house Manufacturing Control

MFG-Pro, which is the running MRP system of the company, could calculate the requirements for in-house manufactured parts, but the system needed data for machine capacities, standard production times, set-up times, parts operation sequences, part weights, wastage ratios, lot sizes etc. and requirements could not be calculated correctly without them.

For that reason, manual calculation of parts production sequences and lot sizes was very often resulting shortage of some in-house parts and sometimes resulting an excessive stock of some other parts. Even if, work orders were used, for in-house production the manual implementation did not generate any data on the system and manual material reduction to work orders was causing serious stock deviations.

Another problem was that, the unexpected shortages were forcing the facility to keep high raw material stocks.

Because of the above mentioned reasons, the in-house manufacturing processes were generating unexpected problems. The process flow before the reengineering study was as shown in Figure III.21.

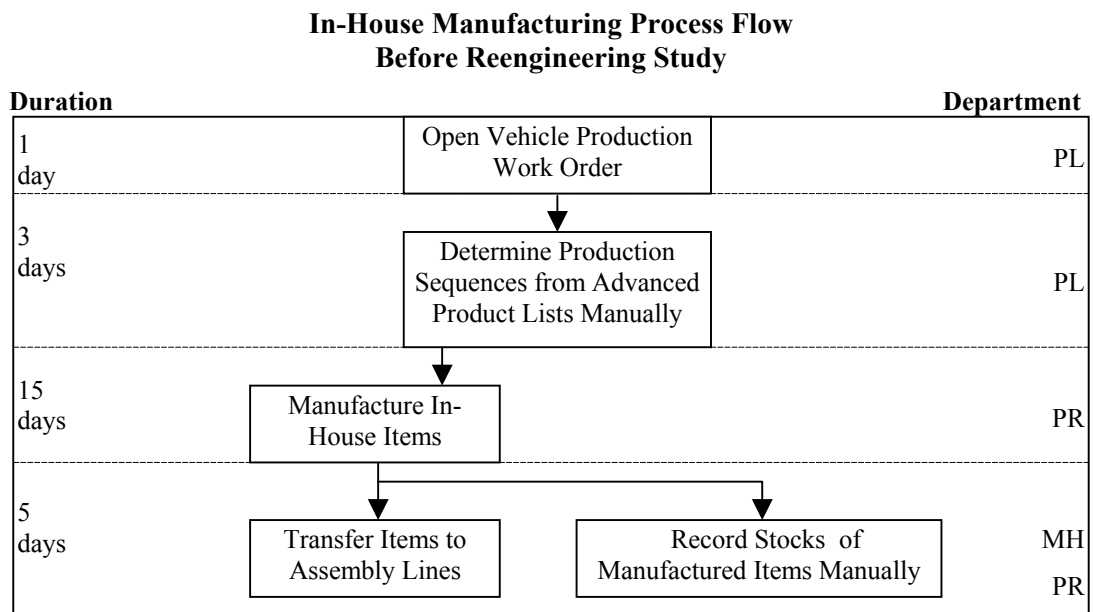


Figure III.21. In-House Manufacturing Process Flow Before Reengineering Study

So the team worked on the flow to change it to satisfy the below goals as shown in related part of the Master Plan in Figure III.22;

- ◆ To decrease the amount of shortages and excess stocks due to planning mistakes
- ◆ To decrease differences between actual and registered stocks
- ◆ To decrease production without work orders

- ◆ To decrease raw material safety stocks

2. <i>Missing Planning Functions</i>		TEAM : MH, PL, PR, IT			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
2.2.	In-house manufacturing control	3	MH, PR, PL	Planning of In-house Manufacturing on MRP system	Decrease the amount of shortages and excess stocks due to planning mistakes
					Decrease differences between actual and recorded stocks
					Decrease production without work orders
				Raw material tracking system	Decrease raw material safety stocks

Figure III.22. Related Part of the Reengineering Master Plan.(III.5.2.2.b)

The solution to the problem of in-house manufacturing was simple in a sense that manual operations should be omitted and all information would flow on MFG-Pro system, but implementation was not so easy. There were a lot of pre-requisites to start the system. They are summarized in the Action Plan below:

Action Plan to Control In-House Manufacturing:

1. Collection of all machine capacities data
2. Time studies for in-house manufactured items
3. Definition of process sequences
4. Determination of lot sizes with respect to Vehicle Production Plan
5. Completion of operation pages
6. Start of work orders for in-house manufacturing items on the system by Planning Department
7. In-house manufacturing depending on MFG-Pro results

After the completion of the above activities the expected flow would be on the MRP system and would look like as given below in Figure III.23.

In-House Manufacturing Process Flow After Reengineering Study

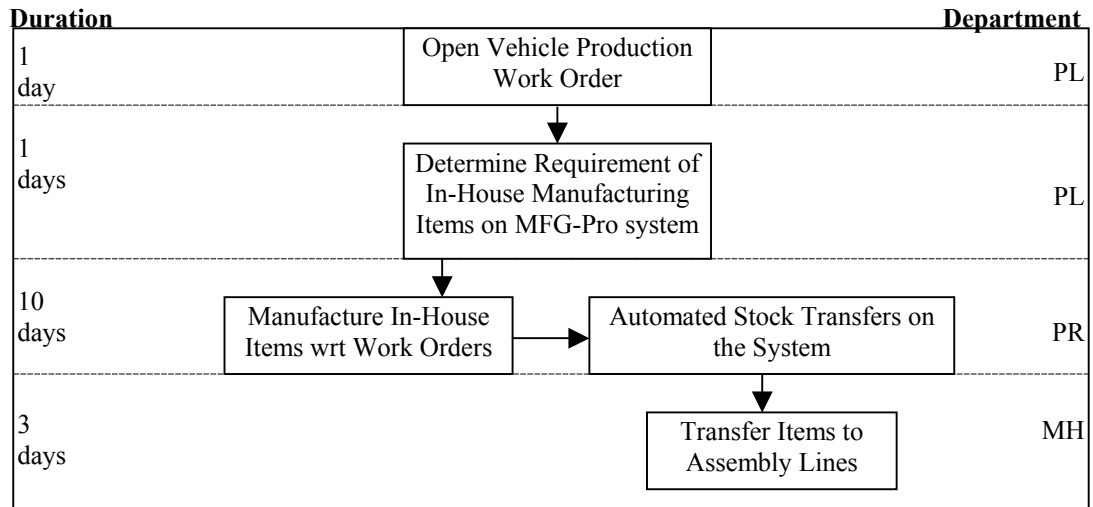


Figure III.23. In-House Manufacturing Process Flow After Reengineering Study

2.c. Tracking of Engineering Changes:

The engineering changes were followed by all departments through an engineering release system prepared by the IT department. When a change was released by Product Engineering or R&D department, the change was automatically forwarded to all related departments to be effective, and Purchasing, Planning and Production were following the changes separately. On release pages, Product Engineering or R&D were defining the effectivity dates for changes, but still there were problems to comply with the defined dates and chassis numbers. Neither Product Engineering nor R&D could know the stocks of the changing parts, the availability of suppliers and fixture requirements and lead times. When Planning department used these defined dates and chassis numbers as reference for assembly lines, very often there was a possibility of using wrong versions of parts or stockouts.

Even if the engineering changes came to effect at defined dates and chassis numbers, the older version parts were remaining at stocks and usually could not be used again (except as spare parts when required). These items were a source of extra cost and cause for quality problems. The only check was the records of Quality department, listing the realisation dates of changes.

The project team worked on the problems and the flow given below in Figure III.24 and defined the possible solutions with reengineering the work flow.

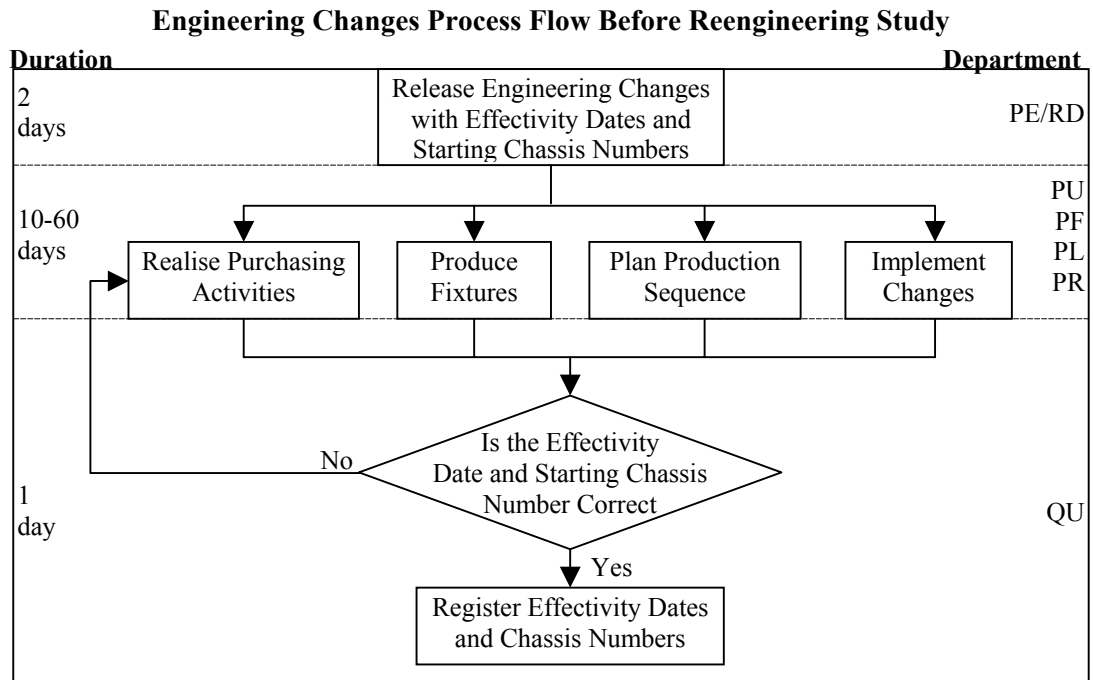


Figure III.24. Engineering Changes Process Flow Before Reengineering Study

The team decided that an IT solution on the engineering release system was necessary, and this solution should be supported by meetings of related departments. The IT solution would be an added module where all releases, all stock positions, purchase orders, fixture lead times could be tracked in a common field by all related departments and under the coordination of Planning department effectivity dates and starting chassis numbers would be determined in short engineering change meetings attended by representatives of Product Engineering, Purchasing, Planning, Production Facilities and Production departments.

Sample forms of the new module are given below in Figure III.25.

In addition the new process flow would allow planning department to control the remaining inactive stock and generate financial value by selling, rework or exchanging the old parts.

Yeni Yayın Devreye Giriş Sistemi - Microsoft Internet Explorer

YENİ YAYIN DEVREYE GİRİŞ SİSTEMİ

Parça Kodu : 12B22-08298-AA Yayın No : 19699
 Parça Adı : ADAPTÖR Yayın Tanımı : ARKA FREH TABLALARI VE SEHSÖR BAĞLAYAK DEĞİŞİK.
 Grup Kodu : 0 Yayın Tarihi : 05/10/2004
 Grup Adı : GENEL Araç Kodu : 12E00 ; 12E01 ; 12E02 ; 12E12 ; 12E50

PLANLAMA **KALİTE** **MALZEME**

Planlanan Devreye Giriş Şasi No : NLR12E00A5A005350 Fikri Devreye Giriş Şasi No : Firma : Lütfen Seçiniz
 Planlanan Devreye Giriş Tarihi : Fikri Devreye Giriş Tarihi : Firma Sorumlusu :
☐ Listede Görünmesin Parça Sorumlusu : Lütfen Seçiniz
 İlk Numune Geliş Tarihi :
 Ön Seri Geliş Tarihi :
 İlk Sipariş Tarihi :
 Seri Sipariş Düzenleme Tarihi :

Araç Kodu :
 Takip Sorumlusu : Lütfen Seçiniz
 Açıklama :
☐ Default

Sorumlu	Açıklama	Birim	Tarih	Kayıd Yapan Statüsü
Aydın Aslan		KALİTE BİRİMİ	21/10/2004 12:45:47	normal
Şamil Seçkin		ÜRETİM ALANI	21/09/2004 23:35:25	Şamil Seçkin default
Volkan Yalçın		ÜR. TES MÜH. BİRİMİ	06/09/2004 06:57:51	Atıl Erel default

1 2 3 4 5

İlot :
 İlotun Kapsamı : ☒ Yayın Bazlı ☐ Parça Bazlı

No	Not	Birim	Tarih	Notu Yazan Yayın Parça
1	ARALIK'04 73.ARAÇ	PLANLAMA BİRİMİ	19-11-2004	Ayhan Kedikli

KAYDET KAPAT

Figure III.25. Sample Forms of the New Module.

Below in Figure III.26 a view of the related page of the Reengineering Master Plan is given.

2. Missing Planning Functions		TEAM : MH, PL, PR, IT			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
2.3.	Tracking of engineering changes	2	PL, PE, PU, QU, PF, IT	IT Solution for New Product Release & Effectivity Engineering Change Meetings	Immediate sharing of correct information between functions Prevent formation of inactive stock Determination of correct effectivity dates and chassis numbers

Figure III.26. Related Part of the Reengineering Master Plan.(III.5.2.2.c)

As described on Master Plan page, the goals of the process flow change was;

- ◆ To share correct information between functions immediately
- ◆ To prevent formation of inactive stock
- ◆ To determine correct effectivity dates and chassis numbers

The Action Plan to launch the new system was as follows;

Action Plan for New Module Definition and Implementation:

1. Meetings to define the new work flow and required module to IT
2. Design of New Module

- 2.1. Design of Data Entry Form for Purchasing
- 2.2. Design of Data Entry form for Production Facilities
- 2.3. Design of Data Entry form for Planning
- 2.4. Design of Data Entry form for Quality
3. Preparation of engineering changes meetings procedure
4. Presentation of new module and flow
5. Implementation

The work flow after the start of new module implementation and engineering change meetings would be as given in Figure III.27.

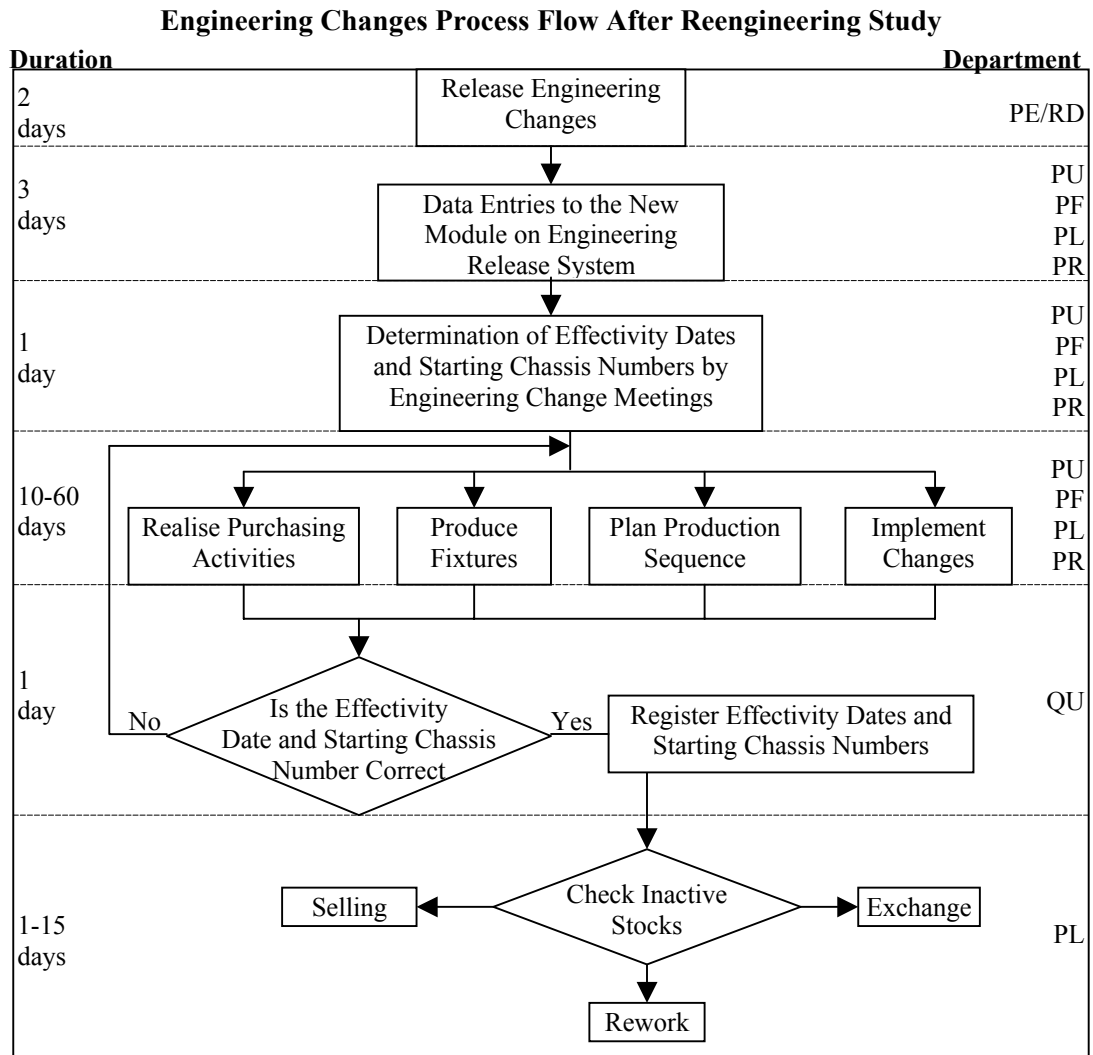


Figure III.27. Engineering Changes Process Flow After Reengineering Study

2.d. Weak Control on Hardware:

Hardware used on assembly lines was stored and distributed from the Main Stock Area. Since the storage system was not based on fixed shelves, hardware

material were stored in various shelves and in time, their motion and addressing could not be tracked correctly on the system. As a result, the hardware materials in the stocks were causing a serious disorder.

In addition to that, usually the items in the stocks could not be found at the addresses given by the system, so they were urgently ordered although they existed somewhere in the main stock area. This situation was resulting an excess stock of these items and high transportation costs.

Even if they could be found in the Main Stock Area, the collection of these items from different shelves to transfer to the assembly line, was a considerable time loss and too much material handling cost.

For the MRP system, the possibility of material losses and on time material transfer problems meant high safety stocks and a serious amount of inactive stock of hardware items.

The flow before the reengineering study was as shown in Figure III.28.

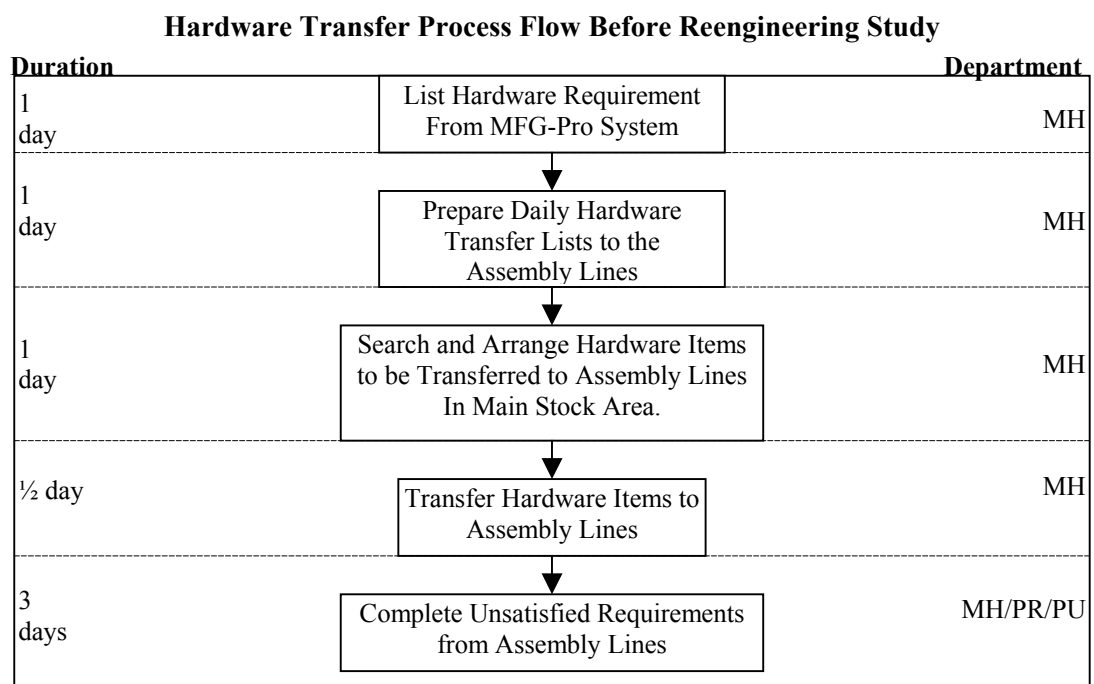


Figure III.28. Hardware Transfer Process Flow Before Reengineering Study

The work team decided that, if the flow of materials from the Main Stock Area continued, most of the problems would not be solved. The reengineering solution would be to start fixed shelf implementation to control locations but this was not possible for the whole Main Stock Area in short term. So, the decision was to define a new Hardware Stock Area with fixed shelves and item groups, and personnel responsible from tracking and distribution of all hardware stocks.

With the realisation of the new Hardware Stock Area, it would be possible to change the transfer method to assembly lines. A pull system of collecting requirement information from the lines every evening and making the required items ready on the assembly lines in the next morning started. After the construction of the Stock Area and installation of the shelves, all the hardware material in the Stock Area were picked, counted and stored in defined shelves of new Hardware Stock Area, and all the system records were corrected. Since the amount and transfer of hardware items were under control it was then possible to decrease the safety stocks.

Below in Figure III.29 a view of the related page of the Reengineering Master Plan is given.

2. <i>Missing Planning Functions</i>		TEAM : MH, PL, PR, IT			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
2.4.	Weak control on hardware	4	MH, PU	New hardware stock area	Speed up hardware materials handling
				New hardware transfer method to production lines	Decrease hardware material safety stocks

Figure III.29. Related Part of the Reengineering Master Plan.(III.5.2.2.d)

The goals of the new system are given on the Master Plan page. They are;

- ◆ To speed up hardware materials handling
- ◆ To decrease hardware material safety stocks

The action plan to implement the new flow is as follows;

Action Plan for New Hardware Stock Area and Transfer Method:

1. Requirement definitions for new hardware stock area
2. Arrangement of shelves and review of part codes
3. Construction and physical arrangement
4. Counting and transfer of hardware materials to the new hardware stock area
5. Definition of responsibilities for the new hardware transfer method to assembly lines
6. Determination of new safety stock levels
7. Implementation

The flow after the study was expected to be as given in Figure III.30 below.

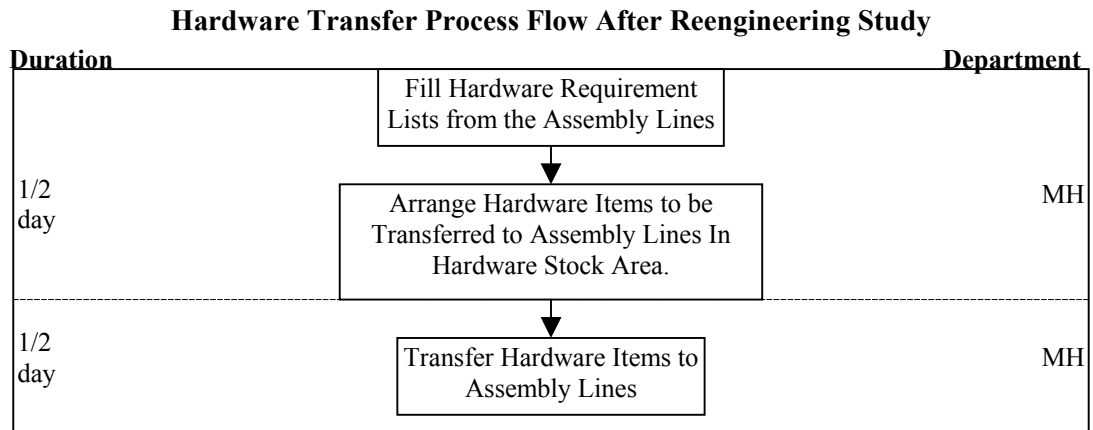


Figure III.30. Hardware Transfer Process Flow After Reengineering Study

2.e. Material Handling Coordination Problems:

The organization of the company before the merger was in Figure III.3. The organisation contained two teams – Planning Team and Materials Handling Team - directly reporting to Deputy General Manager responsible from production, and these two teams were working separately, not in coordination.

Planning Team was preparing the Main Production Plan and releasing the product work orders for the assembly lines. Planning functions like in-house manufacturing control, tracking of engineering changes, level of inactive stocks were not considered.

Materials Handling Team was only responsible from providing the materials demanded by production department. Since Materials Handling Team members were not in coordination with Planning Team, they could only try to determine the requirements from the lines 3 days earlier. Automatic line loading and system data for daily material requirements were not used. So, usually there were manual mistakes in items transferred to assembly lines, especially due to changes in last 3 days.

The line loading process before the study was as shown in Figure III.31.

Line Loading Process Flow Before Reengineering Study

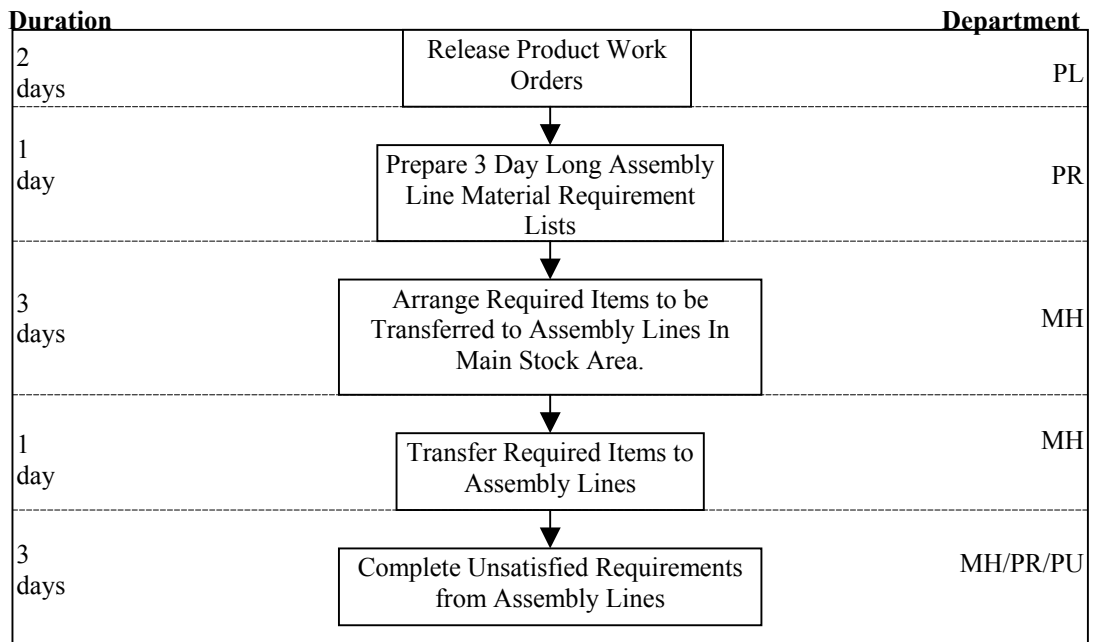


Figure III.31. Line Loading Process Flow Before Reengineering Study

The solution defined for this problem was an organisational change. The idea was to combine the two teams under a Planning Department and define all the missing planning and coordination functions for this department. With the new responsibilities defined, the Planning department would also increase efficiency of coordination between all active manufacturing departments. The old and new organisation charts are given below in Figure III.32. The coordination under Planning Department would mean start of Automatic Line Loading and enable the use of system data for requirements and eliminate manual planning or transfer mistakes.

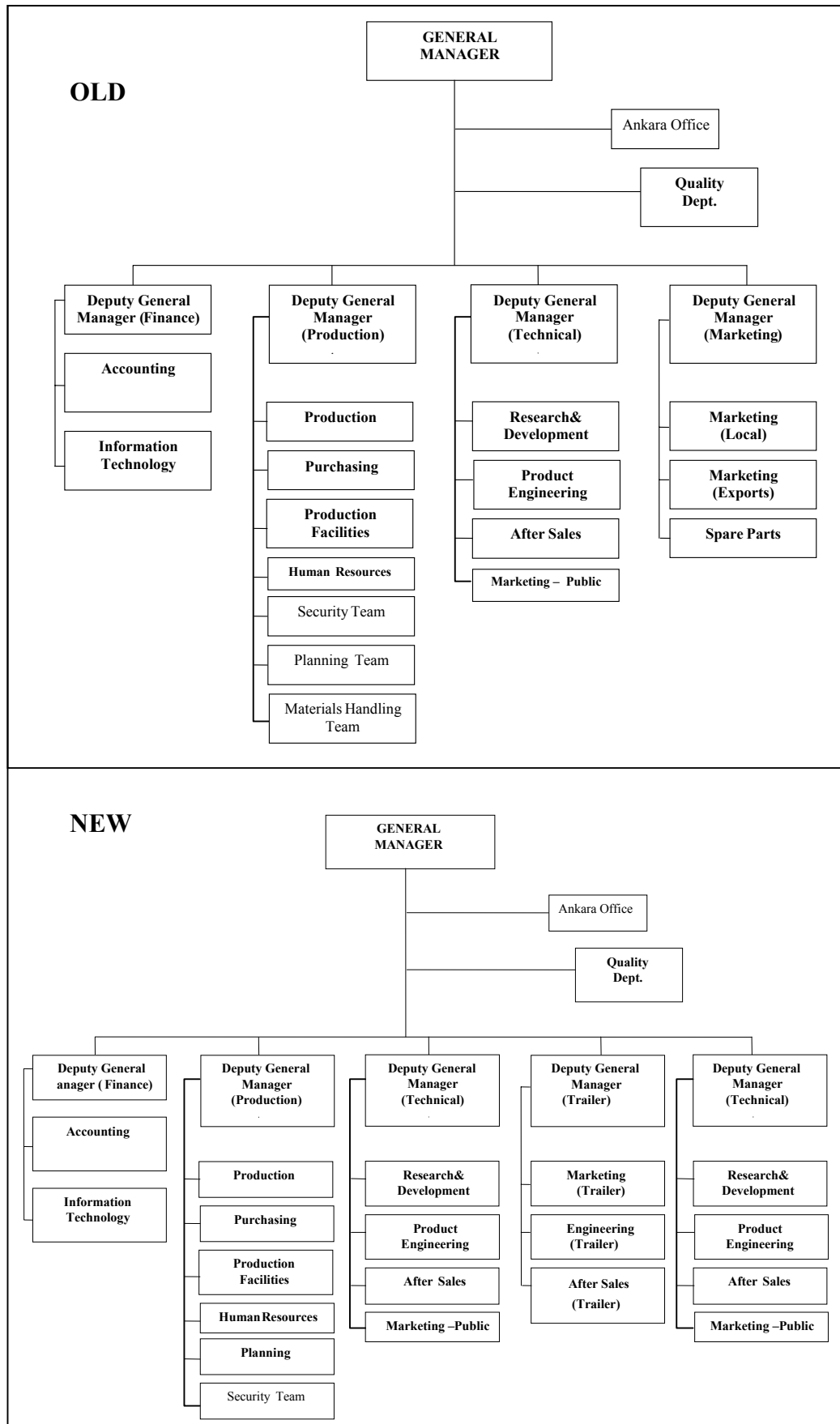


Figure III.32. Organizational Charts a)Old b)New.

A view of the related page of the Reengineering Master Plan is given below in Figure III.33.

2. <i>Missing Planning Functions</i>		TEAM : MH, PL, PR, IT			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
2.5.	Material Handling coordination problems	3	MH, PL, PE, IT	Organizational Change	Increase efficiency of coordination between Material Handling and Planning teams
					Increase efficiency of coordination between active manufacturing departments
					Introduction of lacking planning functions
				Line Loading via System Data	Speed up line loading Prevent production line stockout problems

Figure III.33. Related Part of the Reengineering Master Plan.(III.5.2.2.e)

The goals of the solutions are given on the Master Plan page. They are;

- ◆ To increase efficiency of coordination between Material Handling and Planning teams
- ◆ To increase efficiency of coordination between active manufacturing departments
- ◆ To introduce lacking planning functions
- ◆ To speed up line loading
- ◆ To prevent production line stockout problems

The action plans to implement the solutions are as follows;

Action Plan for Establishment of Planning Department:

1. Preparation of job definitions for Planning Department Personnel
2. Arrangement of offices and equipment
3. Posting required personnel
4. Definition of new process flow on procedures
5. Declaration

Action Plan for Automatic Line Loading:

1. Pilot implementation of listing line requirements using system data
2. Determination of deviations from actual requirements
3. Elimination of Advanced Product Lists and routing errors
4. System establishment to track Advanced Product Lists and routing errors

5. Definition of new process flow on procedures
6. Implementation

The expected line loading process after the study was as shown in Figure III.34.

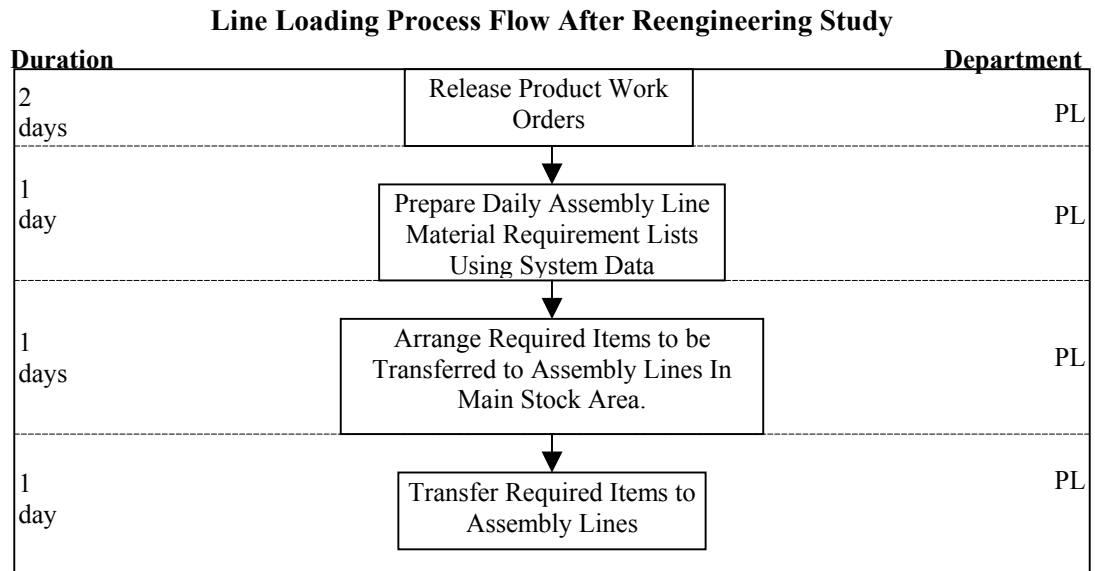


Figure III.34. Line Loading Process Flow After Reengineering Study

2.f. Simultaneous Transfer of Materials (Recorded vs. Physical)

If there is a difference between the physical motion and registry of motion of materials in the facility, system data of stocks and usage are in danger. For instance, an item may be physically transferred to the assembly line and mounted on a vehicle but may not be transferred to the line on the software system. At the same time, the line operator responsible from filling work orders may record mounted items to the work orders on the system. In such a case, that item mounted to the vehicle will not exist in line stocks on the system and will not be recorded to the vehicle. That means the cost of that part will be ignored since the system calculates vehicle costs by calculating the cost of items recorded to every single vehicle. Besides, if that item is transferred to the assembly line on the system later on, a virtual stock of that item will be seen on the system at assembly line location and this stock deviation will mislead the MRP of following order period. In addition to that, while the operator is recording the items to the work order of the following vehicle, since there is a virtual stock of the item, the system will use the virtual stock and will not warn the operator about stockout.

As a result, due to the fact that most of the registry of daily physical material handling was done late in the evening, some problems like the examples above could be faced in the facility.

The flow before the study was as shown in Figure III.35.

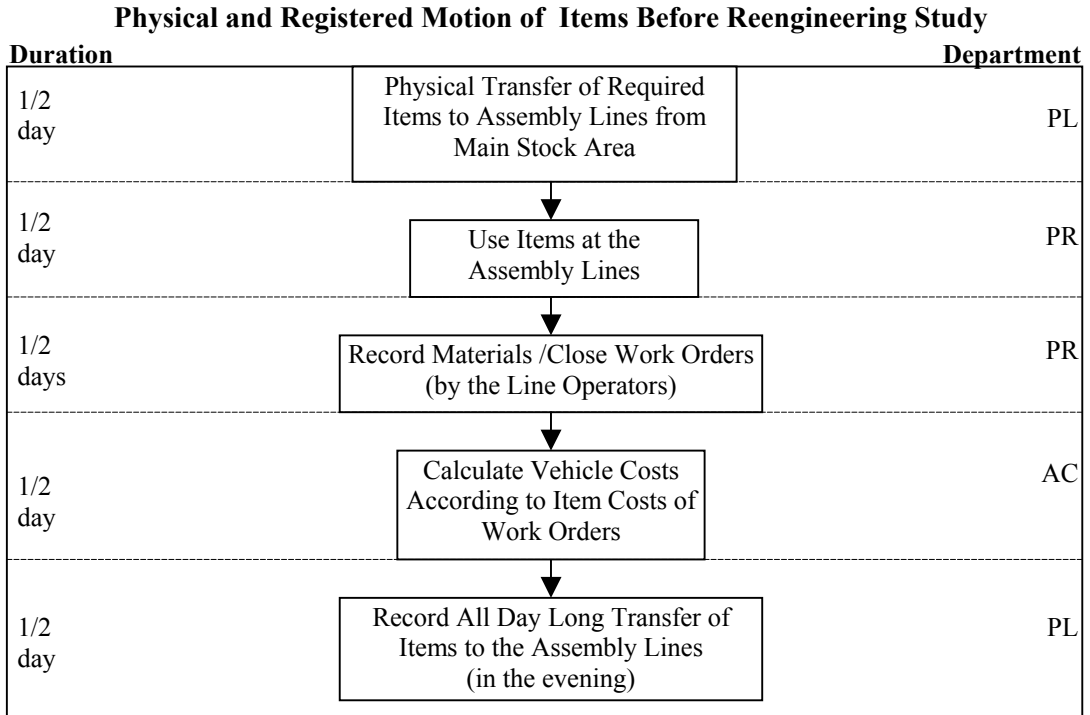


Figure III.35. Physical and Registered Motion of Items Before Reengineering Study

The solution to these problems was easy to predict, but difficult to apply. There should be no difference between the physical motion and registry of motion of materials in the facility. To comply with this requirement a personnel from the stock area was assigned to assure that all physical material transfers were also realised on the system. Besides, the line operators would not record any materials on the vehicles without the approval of this responsible personnel from the stock area.

A view of the related page of the Reengineering Master Plan is given below in Figure III.36.

2.	Missing Planning Functions	TEAM : MH, PL, PR, IT			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
2.6.	Simultaneous transfer of materials (Recorded vs. Physical)	3	MH, PR	Definition of responsible personnel in stock area Definition of coordination between Stock Area and Production line	Decrease number of late material transfer entries to the system Decrease production line stock deviations Prevent product cost errors

Figure III.36. Related Part of the Reengineering Master Plan.(III.5.2.2.f)

The goals of the solutions are listed on the Master Plan page. They are;

- ◆ To decrease number of late material transfer entries to the system
- ◆ To decrease production line stock deviations
- ◆ To prevent product cost errors

The action plan to implement the new flow is as follows;

Action Plan to Control Registered Material Flow:

1. Preparation of job definition for Stock Area Operator
2. Posting required personnel
3. Definition of coordination between Stock Area Operator and Line Operators on procedures
4. Declaration
5. Implementation

After the above changes the new process flow would become as shown below in Figure III.37.

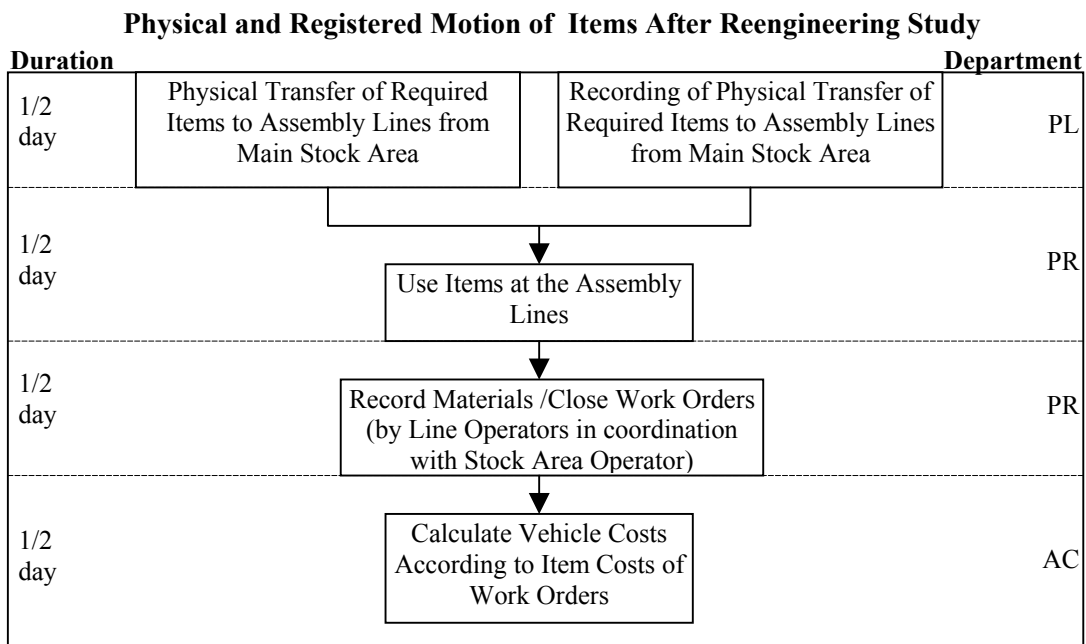


Figure III.37. Physical and Registered Motion of Items After Reengineering Study

2.7. Poor Coordination and Evaluation of Feedback from Production Line

The subject of evaluation of feedback from production line was very important, because product engineering might define wrong quantities, components, units, values or production facilities department might define wrong manufacturing techniques, fixtures, locations, suppliers or this way or that, the system stock values might deviate from physical case in time. The process of production feedback was not formally evaluated in the plant, was only active in dialogues between production

and other departments' personnel. Only in urgent or unsolvable cases the problems were reflected to other departments and the feedback given this way was not in systematic form and was difficult to evaluate. Corrective actions made as a result of the feedback from production line were not recorded or tracked properly.

The process was only the determination and declaration of mistakes to other departments as shown below in Figure III.38.

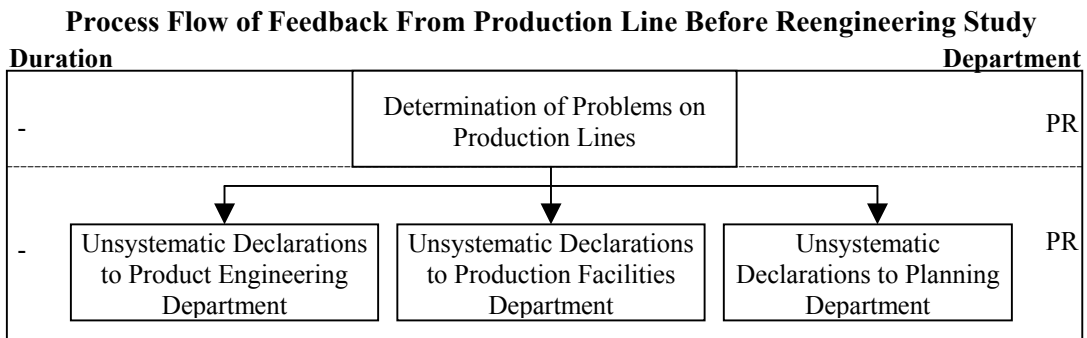


Figure III.38. Process Flow of Feedback from Production Line Before Reengineering Study

The first thing to be done was to find a proper flow which would guarantee a systematic tracking of problem solutions depending on information fed back from production lines. The team decided that the information should be coordinated from one hand, that is Planning Department. All the information from production line would be collected at Planning department and distributed to related departments in recorded form (See Figure III.39). Then, the corrective actions made should be tracked in regular meetings organized by Planning Department.

COMPANY

CORRECTION REQUEST FORM

NO	CHANGE REQUEST DATE	PLANNING CORRECTION DATE	VEHICLE CODE	PART NUMBER	NOT EXIST ON APL	EXISTS ON APL, NOT USED	EXISTS ON APL, QUANTITY WRONG	EXISTS ON APL, ROUTING WRONG	RELATED PARTS	EXPLANATION
1					X					
2					X					
3							X			
4						X				
5						X				
6					X					
7					X				X	
8					X			X		

Figure III.39. Correction Request Forms.

- ◆ To find and eliminate APL errors

2. <i>Missing Planning Functions</i>		TEAM : MH, PL, PR, IT			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
2.7.	Poor coordination, evaluation of feedback from production line	3	PL, PR	Formation of Work Order Analysis Teams	Find and eliminate incorrect inventory data
					Find and eliminate incorrect part routings
					Find and eliminate APL errors
				Continuous inventory auditing using WOAT and material tracking team results	Correction of existing errors on system records

Figure III.41. Related Part of the Reengineering Master Plan.(III.5.2.2.g)

The Action Plan to launch the new system was as follows;

Action Plan for Production Line Feedback Coordination and Evaluation:

1. Examination of the Current Flow
2. Preparation of Procedure for Work Order Analysis Team and Meetings
3. Formation of Infrastructure for Corrective Action Tracking
4. Implementation

The expected process flow would be as given below in Figure III.42.

Process Flow of Feedback From Production Line After Reengineering Study

Duration		Department	
1 day	Determination of Problems on Production Lines	Results of Work Order Analysis	PR PL/PR/PU/QU
1/2 day	Collection of Problems at Planning Department		PL
1/2 day	Systematic Declarations to Product Engineering Department	Systematic Declarations to Production Facilities Department	Systematic Declarations to Planning Department PL
5 days	Systematic Corrective Actions on Product Engineering Problems	Systematic Corrective Actions on Production Facilities Problems	Systematic Corrective Actions on Planning Problems PE PF PL
1/2 day	Tracking of Corrective Actions		PL

Figure III.42. Process Flow of Feedback From Production Line After Reengineering Study

As stated above the mission of Work Order Analysis Team was to determine incorrect inventory data, incorrect part routings and APL errors. The reengineering

team decided that only correction of part routings and APL errors was not enough, and it was necessary to count, justify and correct specified wrong inventory records. A Material Tracking Team (MTT) in Purchasing department also started to specify wrong inventory records from daily purchasing orders. A continuous inventory audit model could be applied regarding the WOAT and purchasing team results and a periodic review of material groups. As a result, a new process of Continuous Auditing was defined as summarised below in Table III.6 to correct existing errors on system records.

Table III.6. Continuous Inventory Audit Guide.

Material Group	Total no. of Items	Audit Frequency	Responsible
A Group Materials (%35 of Vehicle Material Costs)		All items to be reviewed once quarterly	Planning Dept.
B Group Materials (% 35-80 of Vehicle Material Costs)		All items to be reviewed once in 6 months	Planning Dept.
C-D-E Group Materials (%80-100 of Vehicle Material Costs)		All items to be reviewed once in a year	Planning Dept.
WOAT Specified Items	1-20	Daily	Planning Dept.
MTT Specified Items	1-100	Weekly	Planning Dept.
Other Requested Items	As requested	As requested	Planning Dept.

The action plan to start continuous inventory auditing is given below.

Action Plan for Organizing Continuous Inventory Audits:

1. Assignment of a Responsible Personnel for Continuous Auditing
2. Determination of Material Groups and Audit Frequencies
3. Defining the System of Auditing
4. Preparation of Procedures and Declaration
5. Implementation

III.5.2.3. Inventory Audit Problems

3.a. Work-In-Process Inventory Audit Problems

At annual inventory audit, all the physical and on line material transfers would be stopped for the audit and no motion would be possible until all inventory counts were completed and recorded. So, it was important to stop at a point where all

physical and recorded material transfers were correct as a preparation for inventory audit. That meant, all the components mounted to the vehicles on the assembly lines must be recorded on these vehicles, all the parts physically transferred to the assembly lines and all the incoming materials approved by Quality department must be recorded to Stock Area before the inventory audit started.

The assembly lines in general, were arranged as “Locations” composed of 4 to 6 stops. A sample is given below in Figure III.43.

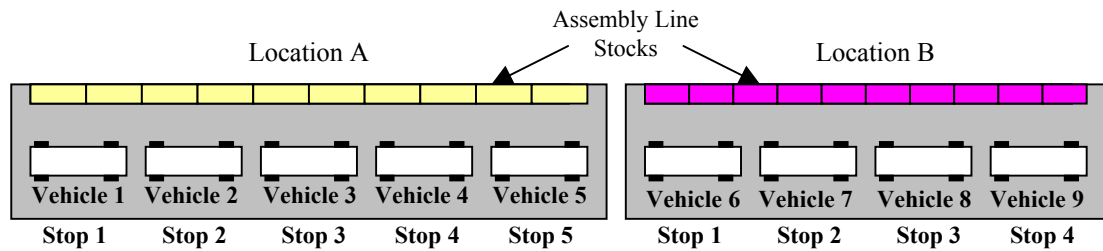


Figure III.43. Assembly Line of Vehicle X.

The work orders were closed as vehicles leave locations. To close a location meant to record all the components mounted on the vehicle in a location from the MFG-Pro system. For the assembly line shown above when Vehicle 5 moved to the Stop 1 of Location B, that is the position of Vehicle 6, the work order of Location A for Vehicle 5 would be closed. When Vehicle 9 moved to the next location, the components mounted on this vehicle would be recorded on the vehicle from the line stocks and they will be included in the vehicle cost later on.

Lets assume that, the above situation is the snapshot position of inventory audit. Then, for all the vehicles of Location B (Vehicles 6 to 9), the work orders of Location A should be closed, that is all the components mounted at Location A should be recorded on them. But for the same vehicles, the components mounted on the vehicles will be different because they are at different stops of Location B, and different components are mounted at each stop as shown in Figure III.44. So, to make a correct counting of stocks, the components mounted at this location must be listed for each vehicle because these components are not recorded on vehicles in Location B since they have not left the location. If they are not separately listed and counted, they will be missed while counting the line stocks. Since the work orders are not closed, the mounted parts are stil known to be line stocks although they are on the vehicles. So, it is necessary to list them and count them not to have stock deviations.

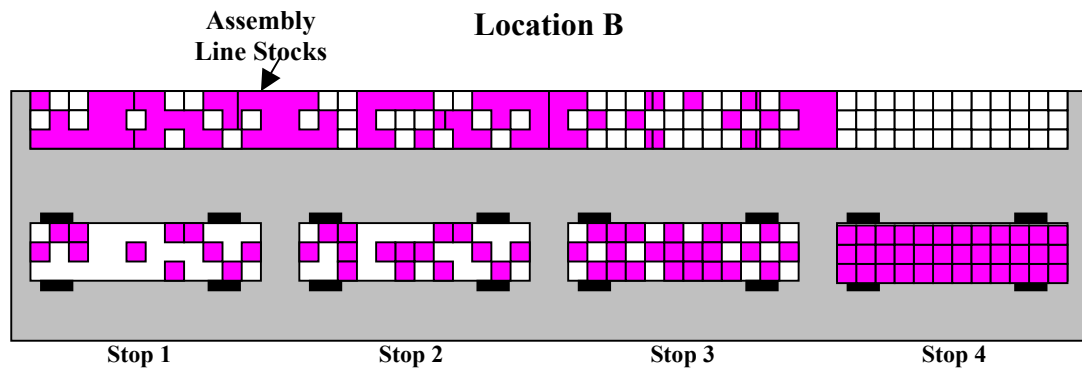


Figure III.44. Mounting Level for Each Vehicle of Location B.

This counting was called Work-In-Process counting in the facility and meant counting of vehicle bodies that were on production lines (with different parts mounted on them, i.e. different completion rates) just at the time of stop for inventory audit.

The experience of last 3 years showed that, this manual work of making WIP vehicles counting lists created considerable amount of errors. Since the computer system stock records were corrected according to the results of inventory audit, the mistakes made during the audit, might corrupt the records causing unnecessary stockouts or excess stocks. The flow before the reengineering team started to work was as shown below in Figure III.45.

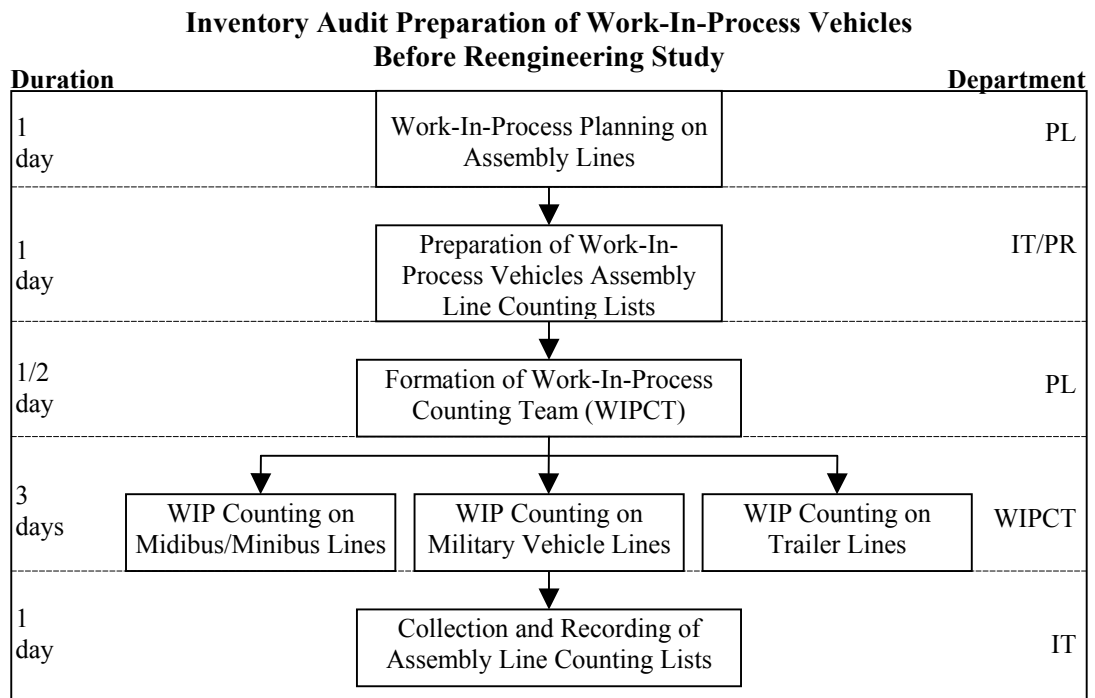


Figure III.45. Inventory Audit Preparation of Work-In-Process Vehicles Before Reengineering Study

The Assembly Line Counting Lists were prepared as a check list including the list of components to be mounted at each Stop position of each Location, so during

the inventory audit, WIPCT had to find out all the components on the vehicles, which is a very hard work and open to error.

After long discussions the study team found a solution which eliminated counting the components mounted on the vehicles. The idea was to make a plan 2 days before the inventory audit and stop moving the vehicles on assembly line half a day before the inventory audit and complete all the vehicles of a location to close all work orders. If the example of Location B is again considered, instead of starting the inventory audit as shown before in Figure III.44, the situation is as shown below in Figure III.46. In the previous example, the idea was to operate the assembly line regularly until the stop for inventory audit but this was a cause for having all the vehicles at different stop positions of location at different levels of montage.

This time, the assembly line would continue to operate regularly until the noon of the day before the inventory audit and on the last half day, the assembly line would work to mount all the missing components to be mounted on vehicles in the Location and bring all of them to the level ready to pass to the next location. The work orders for all these vehicles would be closed and all the components mounted on them would be reduced from the line stocks so there would be no need to make lists and there would be no possibility of counting errors.

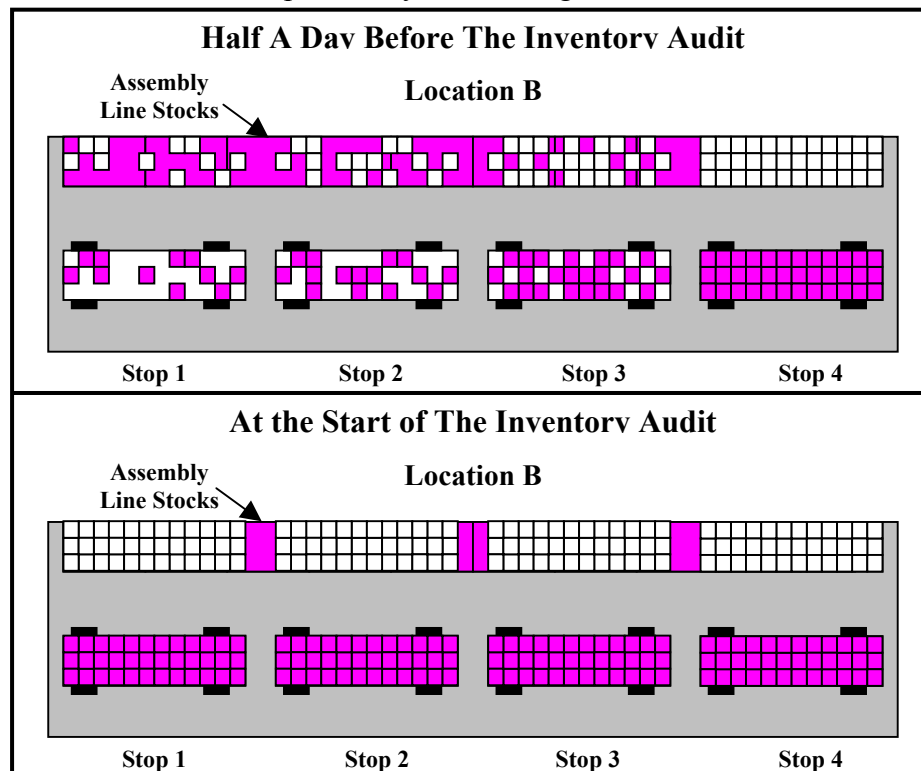


Figure III.46. Components Mounted Half a Day Before and at the Start of Inventory Audit.

The proposed process flow would be as shown below in Figure III.47.

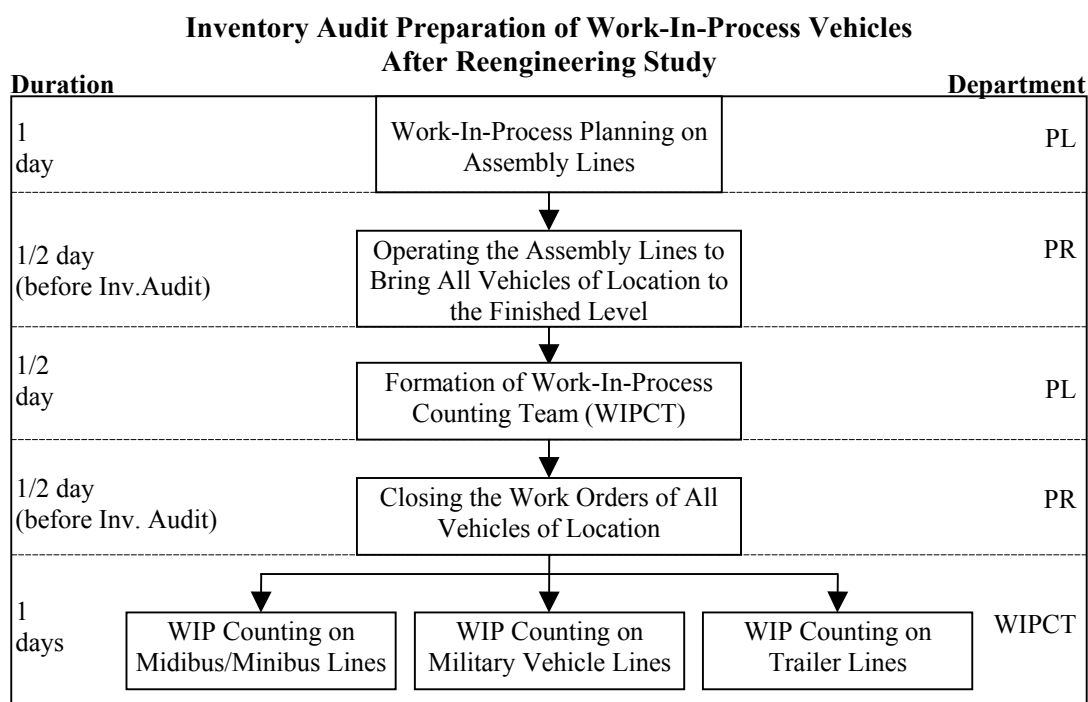


Figure III.47. Inventory Audit Preparation of Work-In-Process Vehicles After Reengineering Study.

The related Master Plan page is shown in Figure III.48.

3.	Inventory Audit Problems	TEAM: PR, PU, MH, IT, PF			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
3.1.	Work - in - process inventory audit problems	4	PF, IT, PR	Bringing All Vehicles in One Location to the End of Location Montage Level	Eliminate WIP listing and decrease WIP counting time Eliminate WIP manual counting errors

Figure III.48. Related Part of the Reengineering Master Plan.(III.5.2.3.a)

The goals of the necessary changes are given above on the Master Plan page;

- ◆ Eliminate WIP listing and decrease WIP counting time
- ◆ Eliminate WIP manual counting errors

The action plan to implement the new flow is as follows;

Action Plan to Change Inventory Audit Preparation of Work-In-Process Vehicles:

1. Study of Necessary Completion Montage Time on Assembly Lines
2. Study of Necessary Materials Handling and Ordering Change
3. Definition of New Work Flow and Responsibilities
4. Declaration

5. Implementation

The solution above was expected to eliminate the Work-In_Process component listing and counting errors, but one problem was that it was causing a production loss since after the audit, in the first day all the vehicles on the line were at the start of locations. So, a better solution was looked for and a good but hard to apply reengineering solution without side effects was proposed to be applied at the end of 2005. That was to define all Stop positions as Locations and close work orders as one vehicle moved from one location to the other.

3.b. Subassembly Audit Problems

The structures of most of the products of the company were made from steel pipes with rectangular cross-sections welded together. So, there was a considerable amount of in-house manufacturing and at the time of inventory auditing, similar to Work-In-Process vehicles, counting of subassemblies was an important problem to be solved. Some subassemblies were made up of several pipes welded together and sometimes covered with sheet metal.

During the inventory audit all components on these subassemblies were counted and this process was causing errors because again subassembly parts listing was necessary and a lot of time had to be spent to find all parts one by one. A similar solution was applied for subassemblies and half a day before the inventory audit, the units worked to complete the subassemblies before the audit. During the audit, only the subassemblies were counted and IT department exploded them to correct the parts stocks.

The flow before the study was as shown below in Figure III.49.

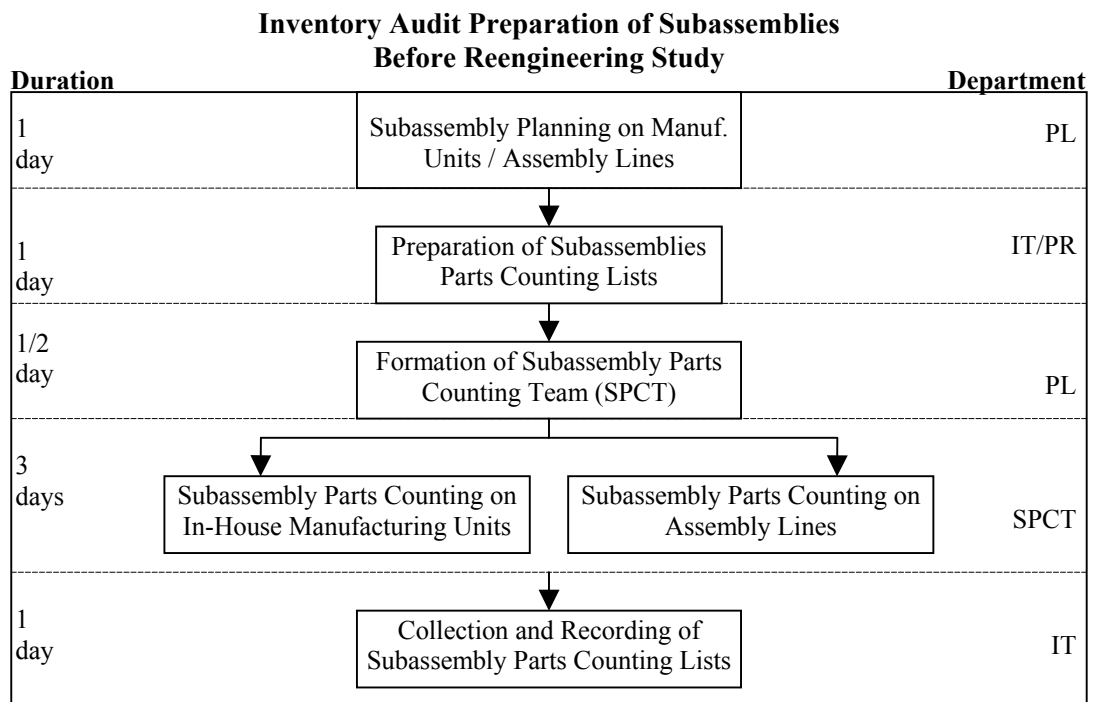


Figure III.49. Inventory Audit Preparation of Subassemblies Before Reengineering Study

The Master Plan page giving the proposed solution is shown below in Figure III.50.

3. Inventory Audit Problems		TEAM: PR, PU, MH, IT, PF			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
3.2.	Subassembly audit problems	4	PU, MH, IT	Bringing All Subassemblies to Completed Form	Eliminate Subassembly listing and decrease Subassembly counting time Eliminate Subassembly manual counting errors

Figure III.50. Related Part of the Reengineering Master Plan.(III.5.2.3.b)

The goals of the proposed process change was;

- ◆ To eliminate subassembly listing and decrease subassembly counting time
- ◆ To eliminate subassembly manual counting errors

The action plan to implement the new flow is as follows;

Action Plan to Change Inventory Audit Preparation of Subassemblies:

1. Study of Necessary Completion Time of Subassemblies
2. Study of Necessary Materials Handling Change
3. Definition of New Work Flow and Responsibilities
4. Declaration
5. Implementation

The above actions would change the flow of audit preparation of subassemblies to the below given Figure III.51.

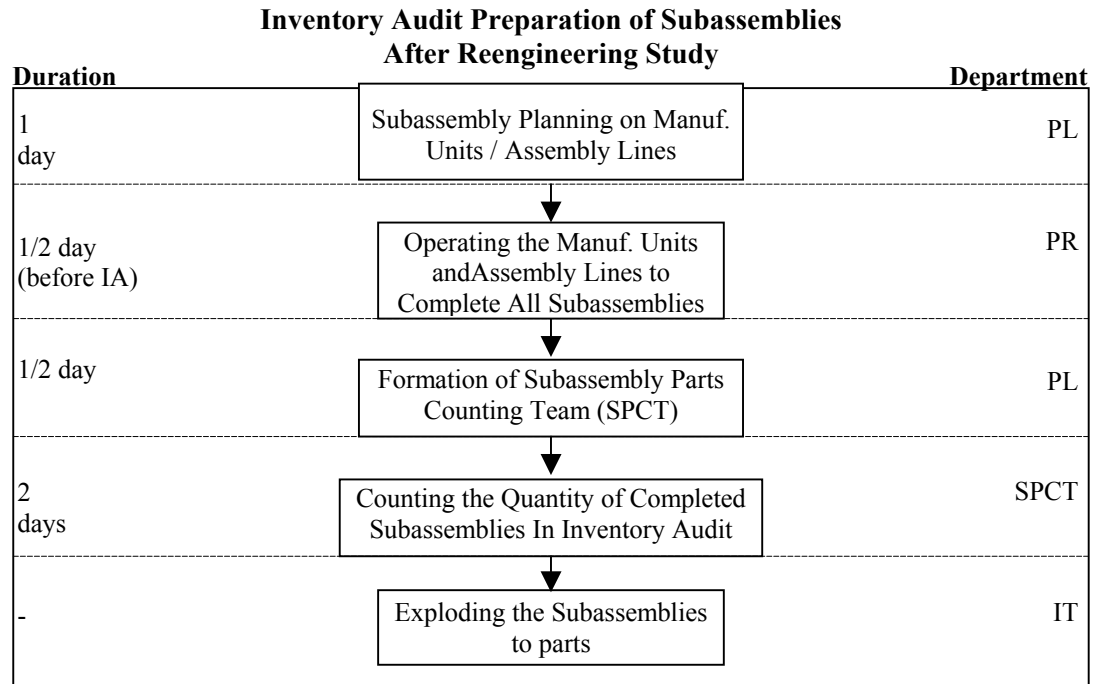


Figure III.51. Inventory Audit Preparation of Subassemblies After Reengineering Study

3.c. Counting the Inventory In Wrong Codes and Unit Conflicts (Causing Inventory Deviations)

The inventory audit experience showed that considerable amount of inventory deviations were a result of counting the inventory in wrong codes or recording wrong units. If all the packages and containers, or the components don't have part codes on them, then the personnel counting the inventory could make mistakes while entering the part codes to the Inventory Audit Cards.

After the merger with the trailer company, it was necessary to convert all of their codes to Product Engineering defined codes and especially for the common materials and parts (hardware, raw materials like sheet metal, pipes, chemicals etc.), it was necessary to eliminate trailer company part codes. This was a very long process including review of about 10,000 part codes, making the necessary changes on computer system and documentation. A team in Product Engineering was defined to complete this task at the end of 2004. During the inventory audits, wrong codes resulting from the above mentioned problem, were still observed.

Another problem was a result of unit conflicts. In general, RD Department designed parts and entered units to the MFG-Pro system. The Operation Pages of Assembly Lines and Records of Stock Areas contained these units, but it was not always possible to bring all the defined parts to the factory from the suppliers, with the units defined by RD Department. For example, the standard definition of oil was litres for RD, while Purchasing Department bought it in kilograms, or some pipes were defined in meters, while Purchasing Department bought them in tonnes. If all necessary conversions were not made then the cost of materials in stocks could be either overvalued or undervalued.

The team tried to solve the above mentioned problems and proposed some solutions for the short run. These solutions were not acceptable as reengineering solutions but were acceptable as improvements to control the code and unit conflicts, so they were approved to degrade the problems. The team members prepared a solution requiring investment to solve the problem completely in 2006.

The related Master Plan page is given below in Figure III.52.

3. <i>Inventory Audit Problems</i>		TEAM: PR, PU, MH, IT, PF			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
3.3.	Counting the inventory in wrong codes and unit conflicts (Causing inventory deviations)	3	PU, MH, IT	Review of part codes of trailer company	Eliminate double codes
				Review units of part groups (sheet metal, pipes, oils, chemicals etc.)	Eliminate R&D defined and purchased unit differences
				Inventory Audit preparations (Education, detailed line addressing, personnel planning, equipment planning, consultancy teams)	Decrease counting in wrong codes and unit conflicts in the short run
				Fixed addressing and barcoding	Eliminate counting in wrong codes and unit conflicts by 2006

Figure III.52. Related Part of the Reengineering Master Plan.(III.5.2.3.c)

The review of part codes and units of part groups are still on and expected to be completed by the end of 2004. This was to eliminate double codes after the merger, and unit differences between design pages and purchase orders.

The improvement would be due to educating people before the audit – explaining them responsibilities, inventory audit program, the structure of part codes, the importance of inventory audit, filling Inventory Audit Cards etc. For that purpose, a briefing was prepared by IT department. Another precaution was to address all assembly line stock areas in detail. Every single shelf for each item was

defined. Personnel and equipment requirements were reviewed. From the experience of recent years, the personnel and equipment needed for every location was revised. For every location, personnel who know that location (and parts) best were assigned for inventory audit. To support the counting personnel about part codes, consultancy teams were formed and equipped with computers where needed, to supply any information related to part codes and stocks.

In addition to the above improvements, the team decided that fixed addressing and barcoding would be the reengineering solution for inventory audit stock deviations. That way complete elimination of wrong codes and unit conflicts might be possible by 2006.

The required activities to change the current flow would be as follows:

Action Plan for Establishment of Fixed Addressing and Barcoding:

1. Preparation of Material Flow Models for Product Groups
2. Benchmarking Fixed Addressing from Companies with Similar Products and Flows
3. Selecting Appropriate Barcoding System
4. Investments for New Shelves and Reorganization of Assembly Lines and Stock Areas
5. Installation of Barcoding Infrastructure
6. Addressing and Labeling of Containers and Shelves
7. Training (Barcode Usage)
8. System Introduction Briefs
9. Implementation (Inventory Audit at the End of 2005)

III.5.2.4. Stock Area Problems

4.a. Difficulties of Tracking of Hardware Materials

The difficulties of storing and distributing hardware materials from Main Stock Area, the necessity of building a new Hardware Stock Area and changing the transfer method to assembly lines to a pull system, was explained in Section III.5.2.d. Even if the above stated solutions were implemented, another problem of tracking the hardware materials still existed and troubled the purchase orders and usage on the assembly lines. Before the merger, both the company and the old trailer company had their own part coding system and after the merger, identically same hardware materials existed in stocks with different part codes. The redundant part codes had to be distinguished and eliminated. Starting such an effort would at the same time mean an opportunity to decrease part variety and eliminate hardware parts from stocks which can be replaced by more common parts without changing functionality.

The team worked on the process flow and an improvement study if not reengineering, started. The team members would work on hardware lists and pick redundant codes and guide materials handling to reorganize shelves in Hardware Stock Area. Another group of team members would work on the lists to distinguish parts that can be superseded. Another effort was to change the part release process of the trailer product engineering to match with the company's part release system and use single coding system as shown in Figure III.53.

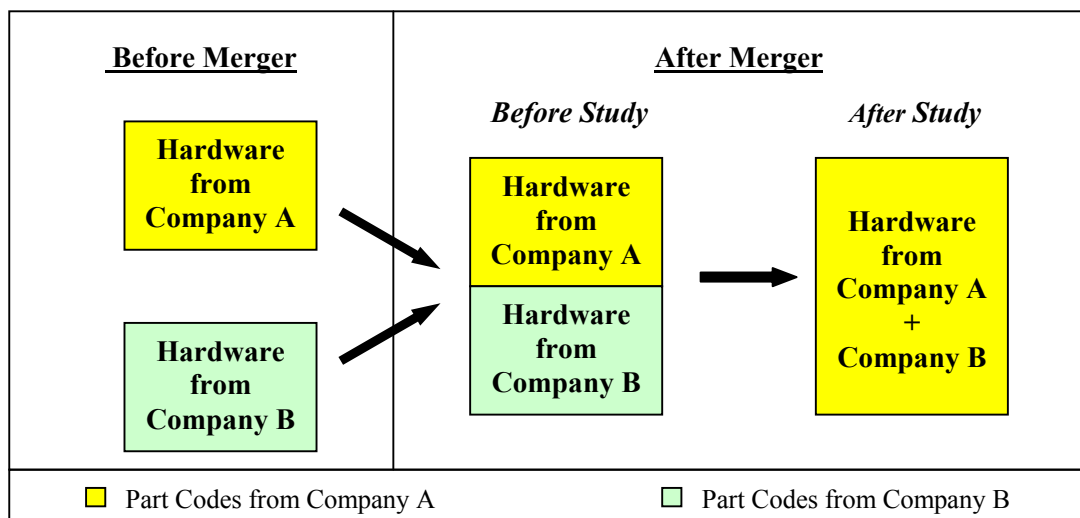


Figure III.53. Process Change for Unification of Part Release Before/After Merger

The related Master Plan page is given below in Figure III.54.

4. <i>Stock Area Problems</i>		TEAM: PL, MH, PU, QU, PR			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
4.1.	Difficulties of tracking of hardware materials	4	PL, PU, PR	Eliminate redundant codes	Decrease total hardware stock
					Decrease redundant shelves in Hardware Stock Area
				Decrease variety of hardware material types	Decrease total hardware stock
					Decrease redundant shelves in Hardware Stock Area & purchasing orders
				Use single coding system	Stop generation of redundant codes

Figure III.54. Related Part of the Reengineering Master Plan.(III.5.2.4.a)

The goals of the study was as follows;

- ◆ To decrease total hardware stock
- ◆ To decrease redundant shelves in Hardware Stock Area
- ◆ To stop generation of redundant codes

The action plan to implement the solutions is as follows;

Action Plan for Hardware Coding Process Improvements:

1. Determination of Work Team
2. Analysis of Hardware Lists to Distinguish Redundant Codes
3. Redefinition of Stock Area Shelves
4. Documentation Changes and Training for Product Engineers (Trailer)
5. Declaration of Unified Hardware Part Release System

4.b. Disorder in Main Stock Area

It was possible to store materials and parts in more than one shelf and in different shelves each time, since fixed addressing was not used in Main Stock Area. As a result, it was hard to find the parts and both handling and transfer to assembly lines were difficult. In addition to that, a couple of parts could be stored in one shelf due to lack of empty space and this was again a cause of disorder and damage of parts. Because of these problems, additional purchase orders were given, and additional costs like transportation and paperwork were generated.



Figure III.55. Disorder in Main Stock Area Shelves

The work team decided on two solutions that would improve the situation. The first one was to expand the Stock Area space as required by the increasing production rate. The expansion would be possible by the use of free space supplied by transferring the hardware to new Hardware Stock Area, transferring chemicals to new Chemicals Stock Area, transferring spare parts to new Spare Parts Stock Area, and transferring old – excessive stock to Inactive Stock Area. Hardware, chemicals, spare parts and old – excessive stocks had better be kept in separate stock areas due to their need for special treatment.

The second solution was to organise the Main Stock Area on a product basis. The remaining parts in the Main Stock Area would be organised as shown in the lay-out below in Figure III.56. The reorganisation will be completed at the end of 2004 after the transfer of spare parts stocks to the new built spare parts stock area.

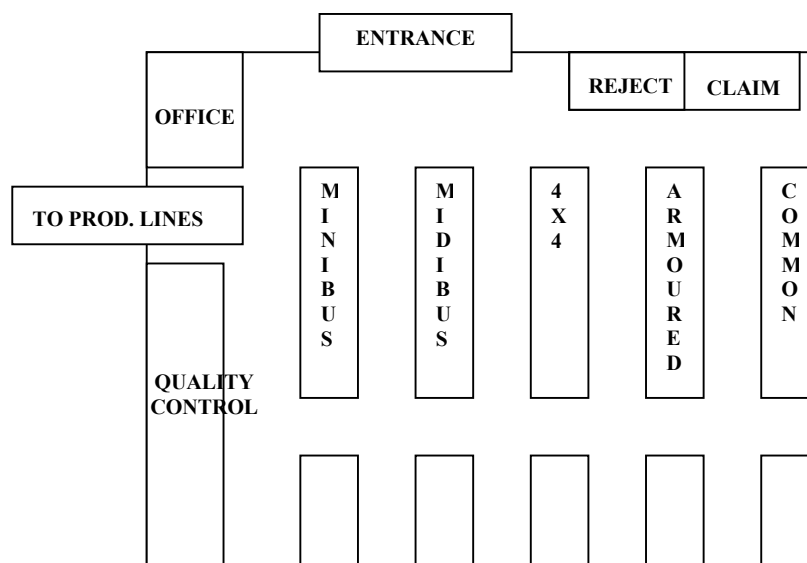


Figure III.56. New Main Stock Area Lay-Out.

The related Master Plan page is given below in Figure III.57.

4. <i>Stock Area Problems</i>		TEAM: PL, MH, PU, QU, PR			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
4.2.	Disorder in Main Stock Area	2	MH, PL	Redesign of stock area on a product basis	Ease of material transfer to assembly lines
				Increase total storage area	Decrease material damage in stock area

Figure III.57. Related Part of the Reengineering Master Plan.(III.5.2.4.b)

The goals are stated as follows;

- ◆ To ease material transfer to assembly lines
- ◆ To decrease material damage in stock area

The action plan to implement the solutions is as follows;

Action Plan for Reorganising Main Stock Area:

1. Transferring the Hardware to New Hardware Stock Area
2. Transferring chemicals to New Chemicals Stock Area
3. Transferring Spare Parts to New Spare Parts Stock Area
4. Transferring Old – Excessive Stocks to Inactive Stock Area
5. Planning of New Shelf Requirements
6. Purchasing and Installation of New Shelves
7. Section Definitions for Part Groups on a Product Basis
8. Arranging the Stocks on a Product Basis Section by Section

4.c. Difficulties of Tracking of Old & Excessive Stocks

As discussed above, at the beginning of the project the situation of old and excessive stocks was one of the major interests for the top management. The company was making its products to satisfy two typical types of demand.

The first one was the contracted orders which was mostly conducted by manual orders depending on quantity and time constraints. This work usually necessitated special parts production at low quantities which was not suitable for most of the vendors, thus resulted deliberate excessive orders that might remain in stock for years to satisfy supplier scale requirements. The second one was the probabilistic demand for commercial vehicles which was mostly conducted through the MFG-Pro system.

The probabilistic demand pattern did not generate stocks due to quantity constraints, but could generate stocks if the effectivity of engineering changes are not managed properly. That way, it was quite often that stocks of cancelled or changed parts might remain in Main Stock Area or in assembly line stocks. Even orders of cancelled or changed parts might be given after effectivity dates of newly defined parts and stocked in Main Stock Area. These items remained in stocks for a long time since they were cancelled from production lists and occupied valuable space and created unnecessary holding costs. Besides, they were a cause of part code errors resulting stock deviations in inventory audits.

The work team decided that the solution was to separate this type of stocks from active stocks. Regular (monthly) stock aging lists would be produced (dividing stocks on a average stocking time basis) and old & excessive stocks should be collected from stock areas and assembly lines to Inactive Stock Area and should be evaluated there. The decisions to sell, rework or exchange of these items would be made and these stocks would be eliminated. Moreover, a responsible personnel from the Planning department would track the issue to find out why these stocks accumulated and would be responsible to establish problem solving teams to find solutions to the problems. A new process would be defined for the explained work.

In addition to that, the Work Flow of Engineering Changes was also studied and the process change for Engineering Changes was given in Section III.5.2.c, so will not be repeated here.

The related Master Plan page is given below in Figure III.58.

4. <i>Stock Area Problems</i>		TEAM: PL, MH, PU, QU, PR			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
4.3.	Difficulties of tracking of old & excessive stocks	2	PL, MH, PU, QU	Separate Old & Excessive Stock Area	Decrease total old&excessive stock
					Increase turnover ratio

Figure III.58. Related Part of the Reengineering Master Plan.(III.5.2.4.c)

The goals are stated as follows;

- ◆ To decrease total old&excessive stock
- ◆ To increase turnover ratio

The action plan to implement the solutions is as follows;

Action Plan for Separating Old & Excessive Stocks:

1. Investment Planning for Inactive Stock Area

2. Supply of Required Shelves and Equipment
3. Construction & Installation
4. Transferring the Old and Excessive Stocks to Inactive Stock Area
5. Responsibility Definition for Planning Personnel
6. Implementation

The expected flow after the implementation of the above action plan is given in Figure III.59.

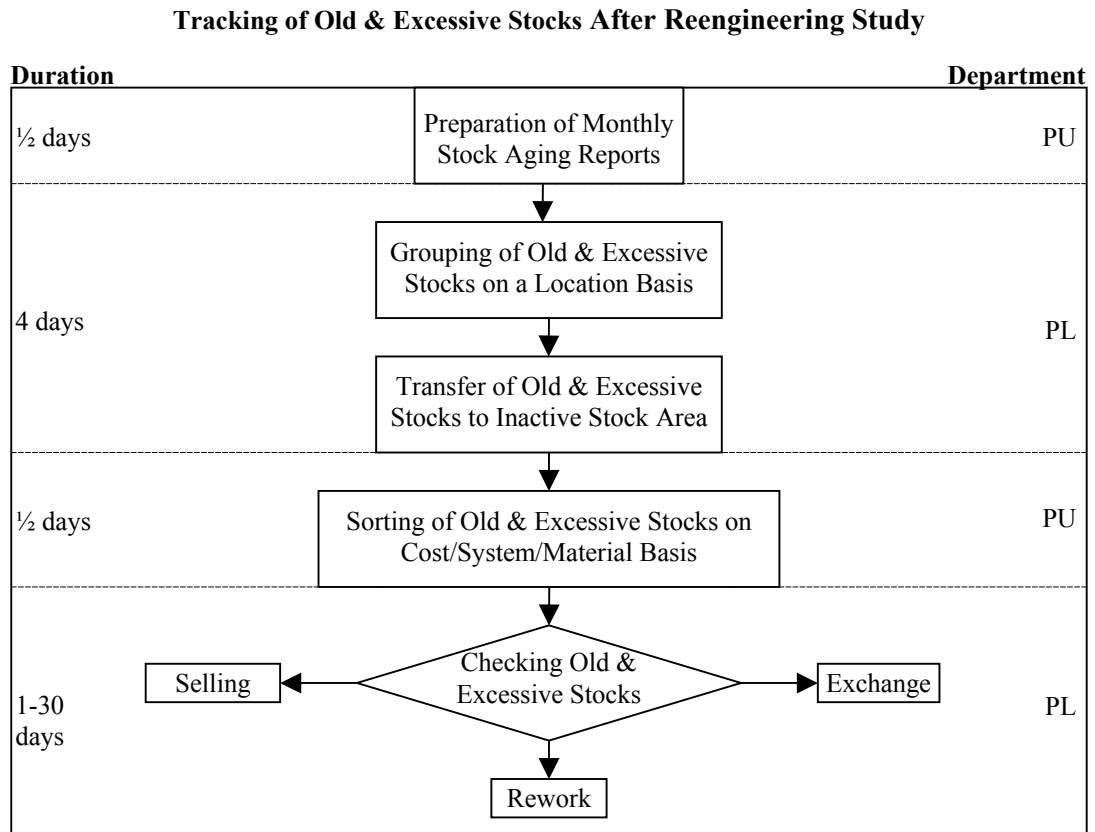


Figure III.59. Tracking of Old & Excessive Stocks After Reengineering Study

III.5.2.5. Ordering Problems

5.a. Sending / Approval Time of Purchase Orders

Before the merger, the company had about 400 local vendors. The MFG-Pro system was run once in every 15 days and the system was preparing purchase orders for about 180-190 vendors at each run. Due to emergency cases or changes in production plan, additional purchase orders for about 40-50 vendors were given some time in the ordering period. After the merger, the total number of vendors and total number of purchase orders given have increased.

Table III.7. Number of Approved Vendors (Before and After Merger)

	End of 2000	End of 2001	End of 2002
Number of Approved Vendors	241	254	442

Before the study, the orders printed out from the MFG-Pro system were sent to the vendors by fax. The Sending Time of Purchase Orders was defined as “the time elapsed between printing of the first purchase order and faxing of the last purchase order”. The average sending time of purchase orders before the study was measured to be 5 days. This long sending time was a serious loss of time and cause of stockouts. In short, it was a considerable cost and a good subject to reengineer.

The Approval Time of Purchase Orders was defined as “the average time elapsed between faxing of a purchase order and receiving the approval from the vendor”. The approval time of purchase orders was measured to be 3,5 days. Like the sending time, approval time of purchase orders was found to be long and taken into consideration in the study.

The sending/approval flow of purchase orders before the study was as shown below in Figure III.60.

Sending/Approval Flow of Purchase Orders Before Reengineering Study

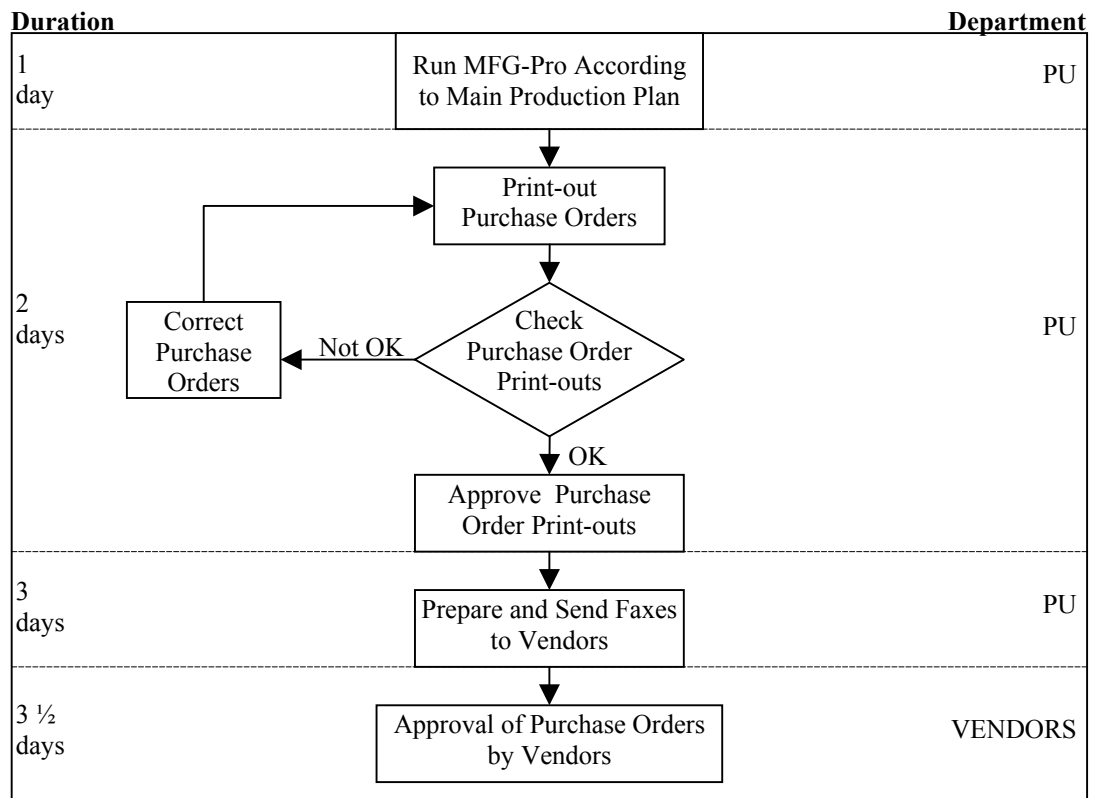


Figure III.60. Sending/Approval Flow of Purchase Orders Before Reengineering Study

The reengineering team working on the subject decided that a valuable improvement on print-out and faxing time could not be realized without implementing an IT solution. IT and Purchasing departments and a consultant company worked on the process in detail. They investigated available systems, software packages and infrastructure of vendors and prepared a report on possible solutions.

The reengineering team decided to establish an EDI (Electronic Data Interchange) system with those vendors that have an appropriate infrastructure (computer hardware, internet connection, skilful personnel etc.) and make it possible to send purchase orders on the web. For companies that did not have an appropriate infrastructure, the team decided to apply a fax automation system to eliminate faxing time and the IT department would buy and customize a software for that purpose. In addition to that, a financial support program for vendors to form necessary infrastructure, called EDI Transformation Plan was activated. The EDI usage was also expected to shorten approval time of purchase orders by vendors.

The related Master Plan Page is given below in Figure III.61.

5. <i>Ordering Problems</i>		TEAM: PU, QU, PL, PR			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
5.1.	Sending / Approval time of purchase orders	2	PU, QU, PL, PR	Sending order plans on the web	Increase number of vendors communicated on the web
					Decrease average sending time
				Fax automation for vendors not using EDI	Decrease average sending time
				Receiving order approvals on the web	Increase number of vendors communicated on the web
					Decrease average approval time

Figure III.61. Related Part of the Reengineering Master Plan.(III.5.2.5.a)

The goals of the solutions are given on the Master Plan page. They are;

- ◆ To increase number of vendors communicated on the web
- ◆ To decrease average sending time
- ◆ To decrease average approval time

The action plan to implement the solutions is as follows;

Action Plan to Redefine Sending / Approval Process of Purchase Orders:

6. IT Research & Surveys
7. Measurements on Sending/Approval Time of Purchase Orders
8. EDI Software Package Purchasing & Customization
9. Fax Automation Software Package Purchasing & Customization
10. Preparation of EDI Transformation Plan
11. Implementations

The expected sending/approval process after the study is shown in Figure III.62.

Sending/Approval Flow of Purchase Orders After Reengineering Study

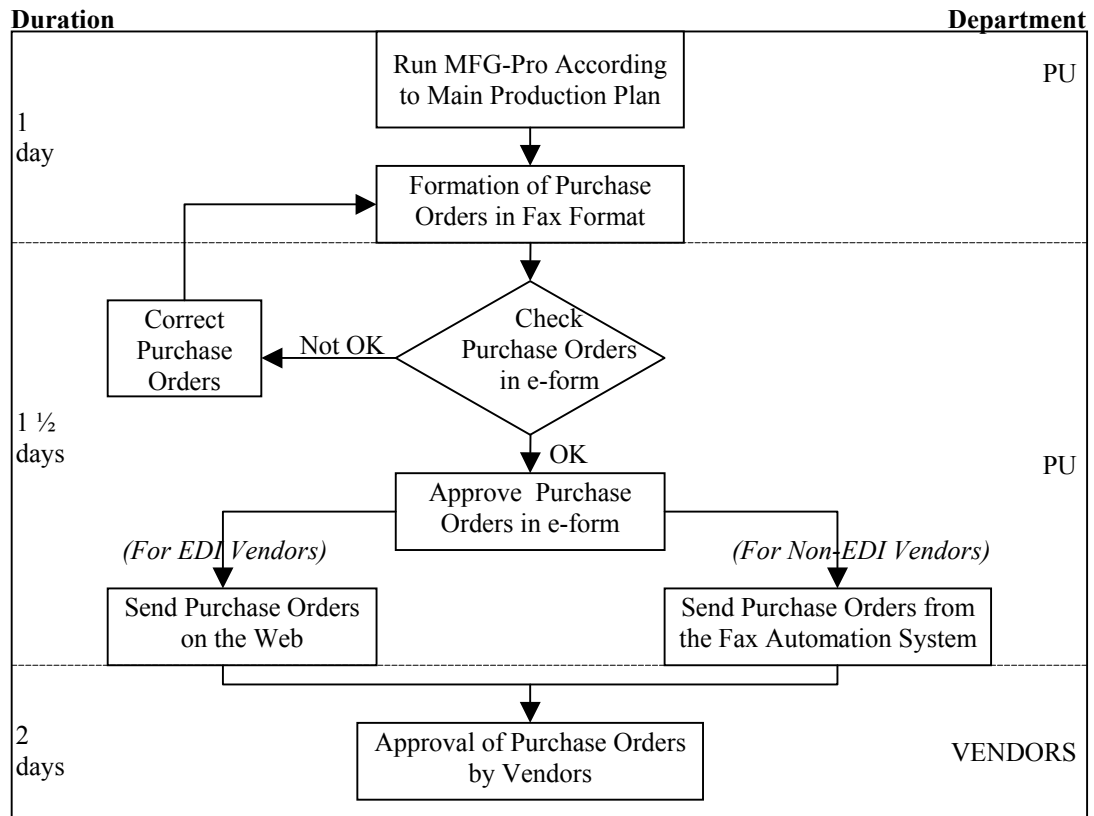


Figure III.62. Sending/Approval Flow of Purchase Orders After Reengineering Study

5.b. Long Lead Times:

The company was suffering from long lead times of some components from suppliers. This might be due to a couple of reasons. The suppliers were either physically far away from the facility, or they had low production efficiencies or they were not keeping any stocks. In addition to that, Purchasing Department was adding to the problem by ordering from a large portfolio of suppliers. The direct result was long transportation time and high transportation costs. Besides, the shortage of critical items due to their long lead times was causing line stops, and a high financial cost.

A team worked on these problems and related process flows, and generated some solutions. The related Master Plan Page is given below in Figure III.63.

One of the solutions was to decrease the total number of vendors worked with, in order to have a better coordination and power on vendors. To manage this, a study to group components and to purchase similar components from one or two vendors, should be conducted and redundant vendors should be eliminated. The performance of vendors was also a criterion, so the study should also include the elimination of

low performance vendors. Another solution was to bring critical vendors closer to the facility and that way decrease average transportation time and total cost.

Figure III.63. Related Part of the Reengineering Master Plan.(III.5.2.5.b)

To prevent shortage of critical items, the contracts with critical vendors were

5. Ordering Problems		TEAM: PU, QU, PL, PR			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
5.2.	Long lead times	3	PU	Nearer vendors	Decrease average transportation time
					Decrease total transportation cost
				Less vendors	Better coordination and power on vendors
					Elimination of low performance vendors
				Revised contracts with critical vendors	Change inventory policy of critical vendors

reviewed and revised forcing them to change their inventory policy and keep buffer stocks. This way it would be possible to eliminate the subcomponent supply duration of vendors and shorten the total lead times of critical items. Before this study, the flow of critical items was as shown below in Figure III.64.

Vendor to Facility Flow of Critical Items Before Reengineering Study

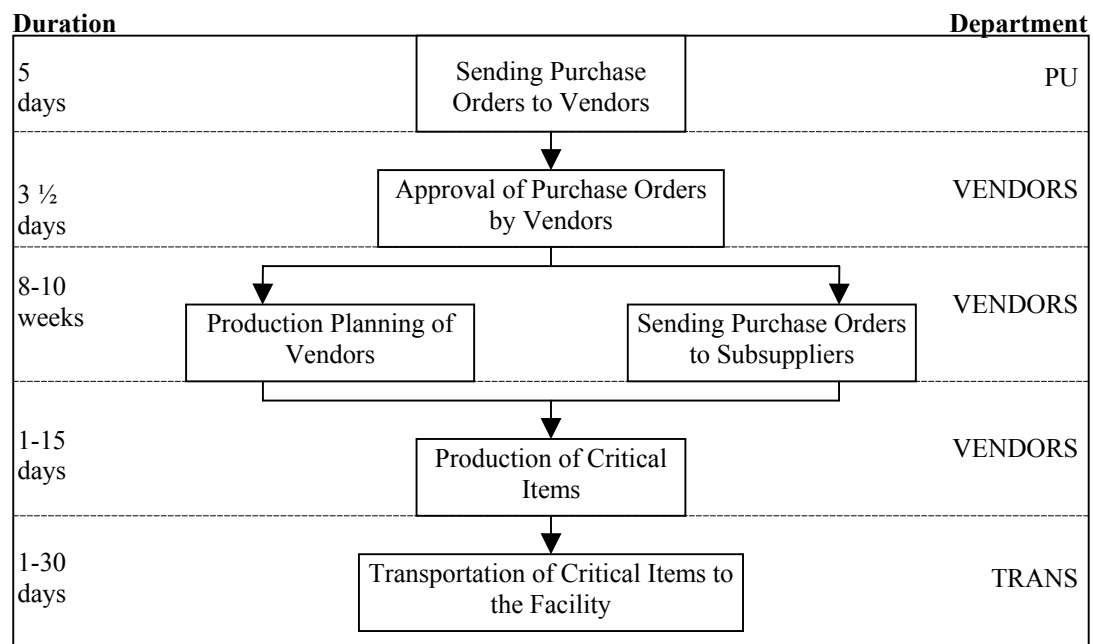


Figure III.64. Vendor to Facility Flow of Critical Items Before Reengineering Study

Action Plan to Decrease Long Lead Times

1. Grouping Similar Parts

2. Evaluating Vendor Performances
3. Determination of High Volume Vendors
4. Determination of Critical Items
5. Selection of High Volume and Long Lead Time Items
6. Determination of Required Buffer Stock Levels for Vendors
7. Review of Purchasing Contracts
8. Implementations

After this study, the expected flow of critical items would be as given below in Figure III.65.

Vendor to Facility Flow of Critical Items After Reengineering Study

Duration		Department
1,5 days	Sending Purchase Orders to Vendors	PU
2 days	Approval of Purchase Orders by Vendors	VENDORS
1-3 days	Packaging of Critical Items from Buffer Stocks	VENDORS
1-15 days	Production of Critical Items	VENDORS
1-30 days	Transportation of Critical Items to the Facility	TRANSPORTERS

Figure III.65. Vendor to Facility Flow of Critical Items After Reengineering Study

III.5.2.6. Incoming Material Entry Problems

6.a. Incoming Material Entry (Registry out of Factory / Acceptance Criteria)

Before the specialised team worked on the subject, the incoming materials coming to the factory were either counted and recorded at the entrance of the Main Stock Area or at the entrance of the Trailer Stock Area as shown below in Figure III.66. The unloading trucks were making long queues that did not allow smooth and comfortable materials handling and transfer. The counting, recording and paper check of the incoming materials and parts at the same time was not an efficient

implementation. Sometimes, recording of the incoming materials and parts were delayed and could result stock deviations.

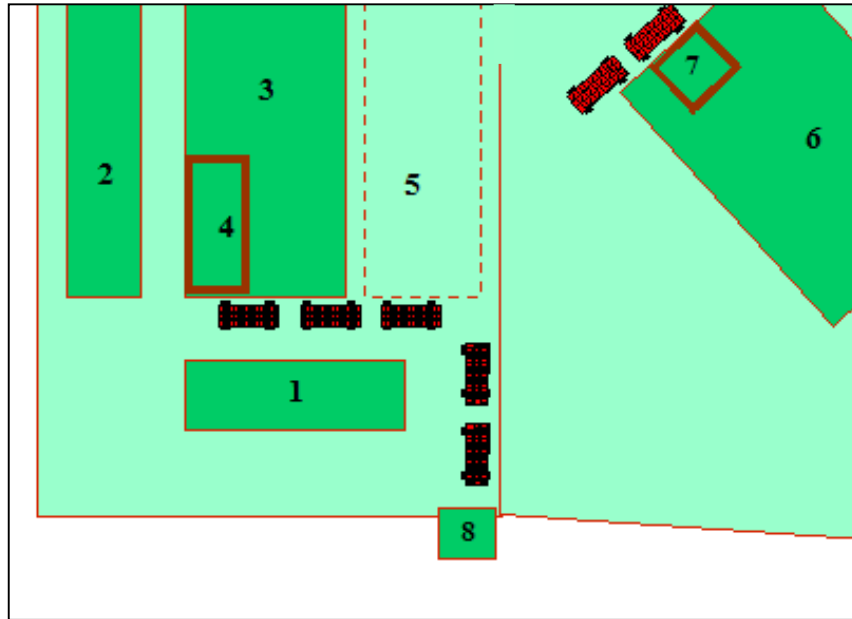


Figure III.66. 1) Administrative building, 2)Armoured production unit, 3) Commercial vehicles and light tactical vehicles production, 4) Main stock area, 5) Finished product storage field, 6) Trailer and commercial vehicles body production unit, 7) Trailer stock area, 8) Main entrance.

Besides, already unloaded materials and parts could not be rejected even if they were not ordered, early or excessive. This was another cause of excess stocks in Main Stock Area and on assembly lines.

The team worked on the process and decided to change the flow so that the trucks would not be a factor of disorder in the facility and all the recording, counting and paper checking could be done properly. The solution was to keep trucks waiting at a new truck park next to Main Entrance before entering the facility, record the incoming materials and parts at the Main Entrance and take the trucks in one by one and count and approve the materials and parts while unloading them.

Additionally an IT Solution would be applied to check whether the materials and parts were matching with purchase orders, if they were not, than it would be possible to reject them and send back to the suppliers without unloading them. A team in Purchasing department determined the criteria to accept or reject early or excessive lots, in accordance with the rules given in Table III.8. A considerable additional stock was calculated to be kept because of not rejecting the excess or early lots entering the factory.

Table III.8. Acceptance Criteria.

Material Group	Acceptable Additional Order (%)	Acceptable Additional Cost (USD)	Acceptable Early Days
A	10	0	3
B	10	0	10
C	15	0	15
D	20	40	15
E	20	40	15

The motion of the trucks at the entrance and in the facility would be as shown in Figure III.67 below.

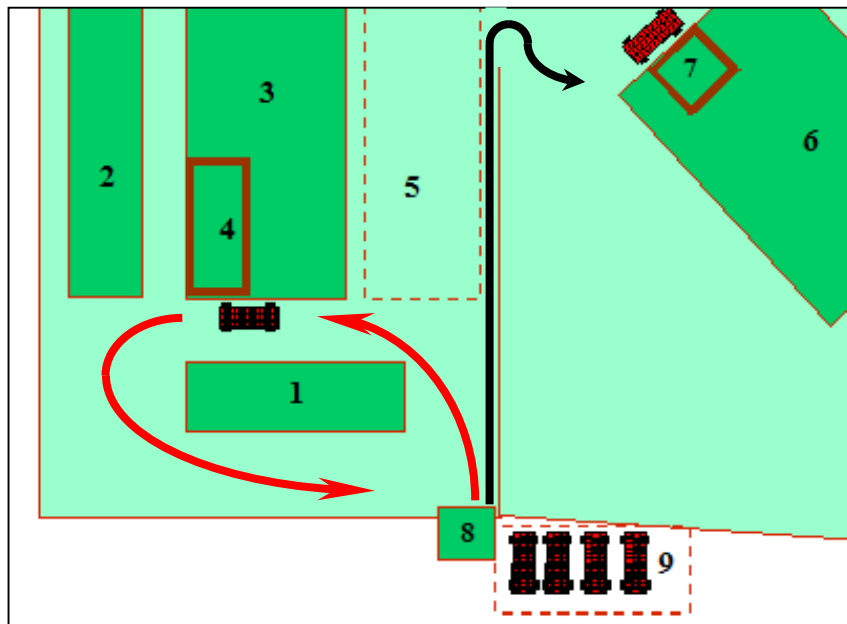


Figure III.67. 1) Administrative building, 2)Armoured production unit, 3) Commercial vehicles and light tactical vehicles production, 4) Main stock area, 5) Finished product storage field, 6) Trailer and commercial vehicles body production unit, 7) Trailer stock area, 8) Main entrance, 9) Truck parking area.

The flow before the study was as shown in Figure III.68.

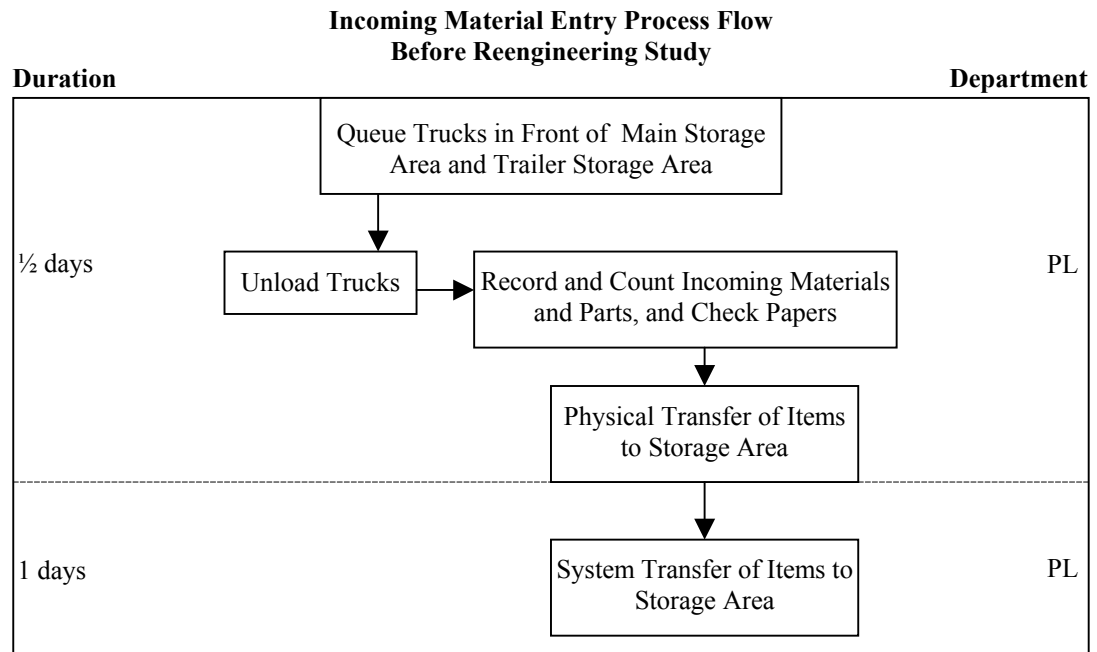


Figure III.68. Incoming Material Entry Process Flow Before Reengineering Study

The related Reengineering Master Plan page is given below in Figure III.69.

6.	Incoming Material Entry Problems	TEAM: PU, QU, MH, PL, IT			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
6.1.	Incoming material entry (registry out of factory / acceptance criteria)	4	PU, PL, MH	IT solution for acceptance criteria	Reject not ordered, excessive or early lots of materials and parts
				Early registry of trucks out of factory	Organize truck entries to the factory and decrease total unloading time

Figure III.69. Related Part of the Reengineering Master Plan.(III.5.2.6.a)

The goals of the reengineering study are stated as follows;

- ◆ To reject not ordered, excessive or early lots of materials and parts
- ◆ To organize truck entries to the factory and decrease total unloading time

The action plan to implement the solutions is as follows;

Action Plan for New Incoming Material Entry Process Flow:

1. Planning of New Truck Parking Area
2. Rearrangement of Parking Area and Vehicle Flow
3. Determination of Acceptance Criteria by Purchasing Team
4. Preparation of Software for New Criteria and MFG-Pro Software Customization

5. Informing Vendors & Transporters About New System
6. Definition of Recording Personnel and Hardware for Main Entrance
7. Documentation Changes for the New Flow
8. Implementation

The expected flow after the implementation of the above action plan is given in Figure III.70.

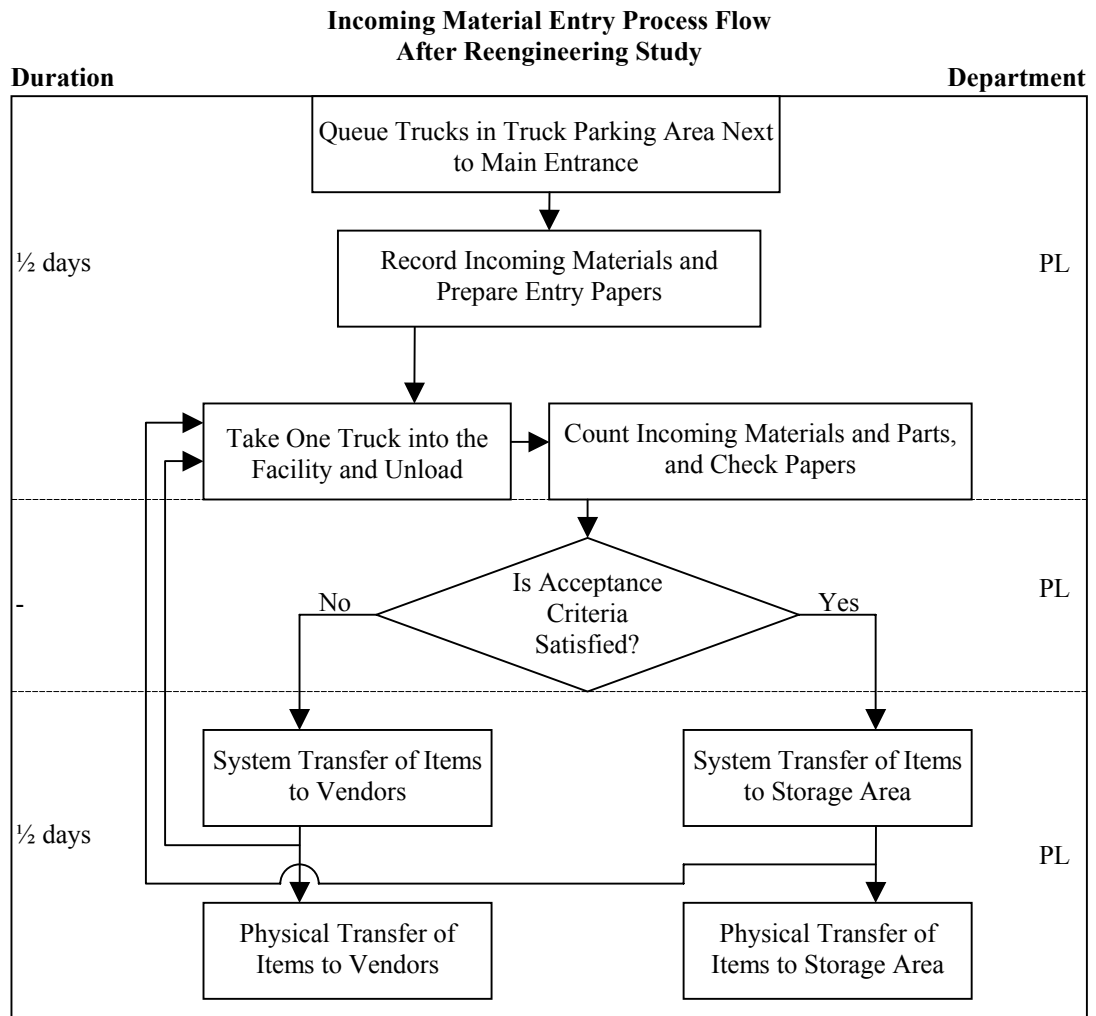


Figure III.70. Incoming Material Entry Process Flow After Reengineering Study

6.b. Lack of Tracking of Materials Going Out of Factory for Machining and Coating

For both in-house manufactured and purchased parts, machining and coating in a vendor out of factory might be necessary. Many in-house manufactured brackets, welded pipes, and purchased hardware and metal sheets were in this group. The systematic problem was, these items had part codes as they appeared on Advanced Product Lists and these part codes did not change after they were machined or coated

out of factory, and they reentered the factory with the same part codes. This was troubling both tracking of stocks and financial costs.

At the time these parts were machined or coated out of factory, on the MFG-Pro system they were assumed to be in factory stocks. This was deviating the ready to use stocks and could cause unexpected stockouts. Their reentry with the same part codes could also mislead the current stocks with redundant entries. Besides, it was not possible to follow the amount of stocks sent for machining and coating since they were seen as a part of the factory stocks all the time. In addition to that, different types of materials could easily get mixed since they were going out and coming back in bulk form. Financially, the only reentry should be for labour on these items when they reenter and these labor costs should be included in the total vehicle costs.

The work team studied the process and decided that the flow should completely be reengineered by defining a new coding system for these items, an additional character for work out of factory. That is,

AABCC-DDDDD-EE Standard part code of a part before work out of factory,

AABCC-DDDDD-EEI Part code for the same part reentering after work out of factory.

The items should be sent to vendors by planning department and to provide tracking of stocks they should be transferred to an imaginary location when they are sent and transferred to the next location when the I coded part re-enters. These changes necessitated a considerable amount of change on MFG-Pro system and a study on the software by IT department.

The flow was not formally defined and in the study it is totally redefined. For that reason, the flow before the reengineering study need not be presented here.

The related Reengineering Master Plan page is given below in Figure III.71.

6. Incoming Material Entry Problems		TEAM: PU, QU, MH, PL, IT			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
6.2.	Lack of tracking of materials going out of factory for machining and coating	3	MH, PL, PU	IT solution for part coding and reentry system	Eliminate mixing of parts send/not send to vendors for machining & coating
					Decrease stock deviations
					Correct reflection of labor costs to the total vehicle costs

Figure III.71. Related Part of the Reengineering Master Plan.(III.5.2.6.b)

The goals of the reengineering study are stated as follows;

- ◆ To eliminate mixing of parts send/not send to vendors for machining & coating
- ◆ To decrease stock deviations
- ◆ Correct reflection of labor costs to the total vehicle costs

The action plan to implement the solutions is as follows;

Action Plan for Tracking of Materials Going Out of Factory for Machining and Coating:

1. Listing of Out Worked Parts and Materials
2. Definition of New Coding system & Restructuring of Advanced Product Lists
3. Definition of a New Location for Parts and Materials Out of Factory
4. Review of Financial Aspects
5. MFG-Pro Software Customization
6. Responsibility Definitions for Sending and Reentry Recording
7. Implementation

The expected flow after the implementation is given in Figure III.72.

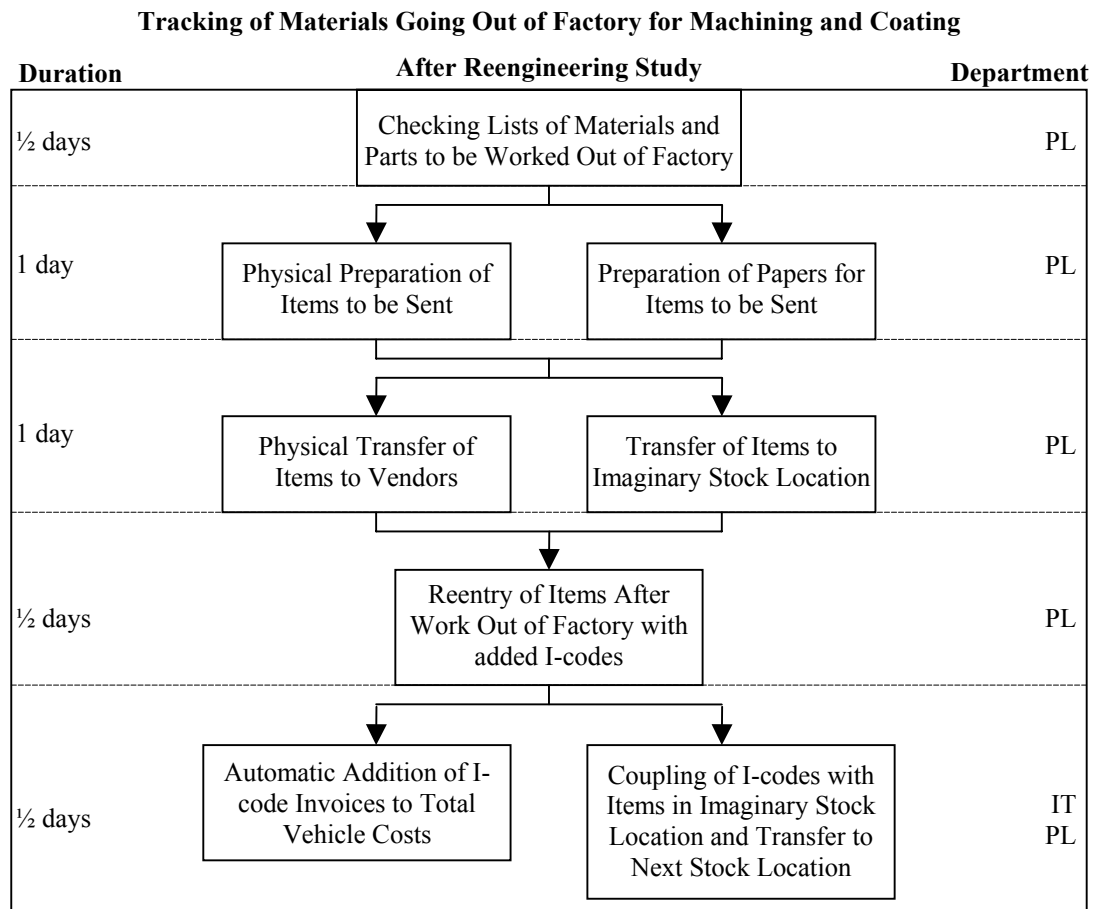


Figure III.72. Tracking of Old & Excessive Stocks After Reengineering Study

6.c. Material Quality Inspection Problems

Table III.9 presents the average values for number of daily incoming materials. It was a fact that both the number of production materials per inspector and first samples per inspector were very high and the task was only managed by working at weekends and overtime.

Table III.9. Average Values For Number Of Daily Incoming Materials.

2002	Jan	Feb	Mar	May	Apr	Jun	Jul	Agu	Sep	Oct	Nov	Dec
Number of Daily Incoming Materials	364	357	376	344	352	305	166	410	377	395	388	402

In short, the high number of daily incoming materials, long inspection time of some parts, lack of skilled personnel and long time of recording inspection results were causing a bottle neck at the incoming material inspection. The process flow before the reengineering study was as shown below in Figure III.73.

Incoming Material Inspection Process Flow Before Reengineering Study

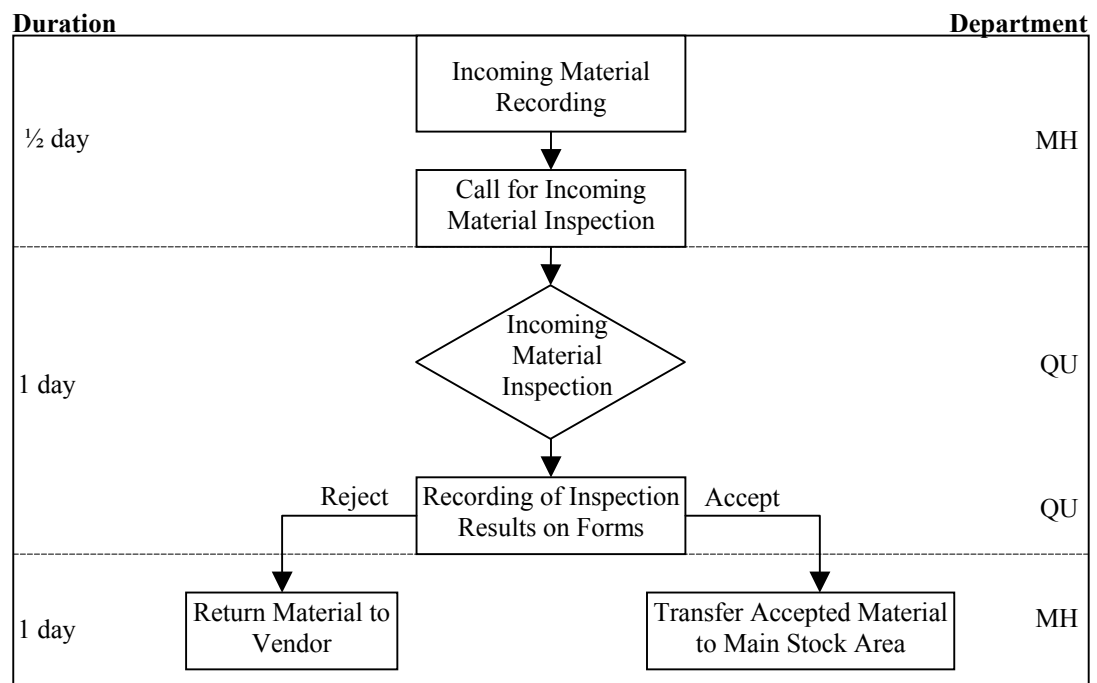


Figure III.73. Incoming Material Inspection Process Flow Before Reengineering Study

The work team studied the process in detail and decided that, for appropriate vendors and parts, it was possible to change the inspection frequencies and quantities if their quality was approved. Moreover, for appropriate vendors and parts, it was possible to pass incoming material inspection process and supply the parts directly to the assembly lines. The team also benchmarked similar implementations in automotive sector before defining a new process flow.

A “Periodic Control Authorisation List” would be prepared as a “living document” and vendors and parts that were appropriate to be under inspection less frequently would be monitored. The evaluation would mainly be based on Vendor Quality Performance Tracking and a proper procedure to define the criteria would be prepared. A sample Vendor Quality Performance Tracking Page is given in Table III.10.

Table III.10. Vendor Performance Evaluation Form.

Company										
VENDOR PERFORMANCE EVALUATION FORM								Date:		
Vendor Code	Vendor Name	Time Compl.	Price Compl.	Technical Support	Material Acceptance Rate	Logistical Planning Ability	Compliance To Packaging Standards	Last Audit Grade	Quality Certificate	Total

In addition to that, A “Pass Authorised Vendor List” would be prepared again as a “living document” and vendors authorised to provide parts directly to assembly lines would be monitored. The evaluation would mainly be based on vendor quality approval, vendor quality/process audits and a proper procedure to define the criteria would be prepared.

Another solution was to shift some of the time consuming inspections to appropriate vendors to decrease average inspection time per item.

The inspections and measurements were made according to hardcopy control plans and results were recorded on forms. This was also a time consuming process and could be eliminated by an IT solution. The team decided that IT department could prepare a software to automate inspection recording and save a great deal of the average inspection time per item. The related Master Plan page showing the applied solutions is given below in Figure III.74.

6.	Incoming Material Entry Problems	TEAM: PU, QU, MH, PL, IT			
		DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS
6.3.	Material quality inspection problems	4	QU, MH, PU, IT	Pass & Periodic Control Systems	Increase total number of daily approved parts
				IT solution for recording inspection results	Decrease average inspection time per item

Figure III.74. Related Part of the Reengineering Master Plan.(III.5.2.6.c)

The goals of the implemented solutions are stated as follows;

- ◆ To increase total number of daily approved parts
- ◆ To decrease average inspection time per item

The action plan to implement the solutions is as follows;

Action Plan for Restructuring the Incoming Material Inspection Process:

1. Revision of Vendor Quality Performance Tracking System
2. Determination of Pass Authorised Vendors
3. Preparation of Vendor Quality/Process Audits and Visits Program
4. Determination of Periodic Control Authorised Vendors/Parts
5. Review of Vendor Contracts for Pass and Periodic Control Authorisation
6. Preparation of Software Package for Online Recording
7. Determination of Inspections to be Shifted to Vendors
8. Implementations

The expected flow after the implementation of the above action plan is given in Figure III.75.

Incoming Material Inspection Process Flow After Reengineering Study

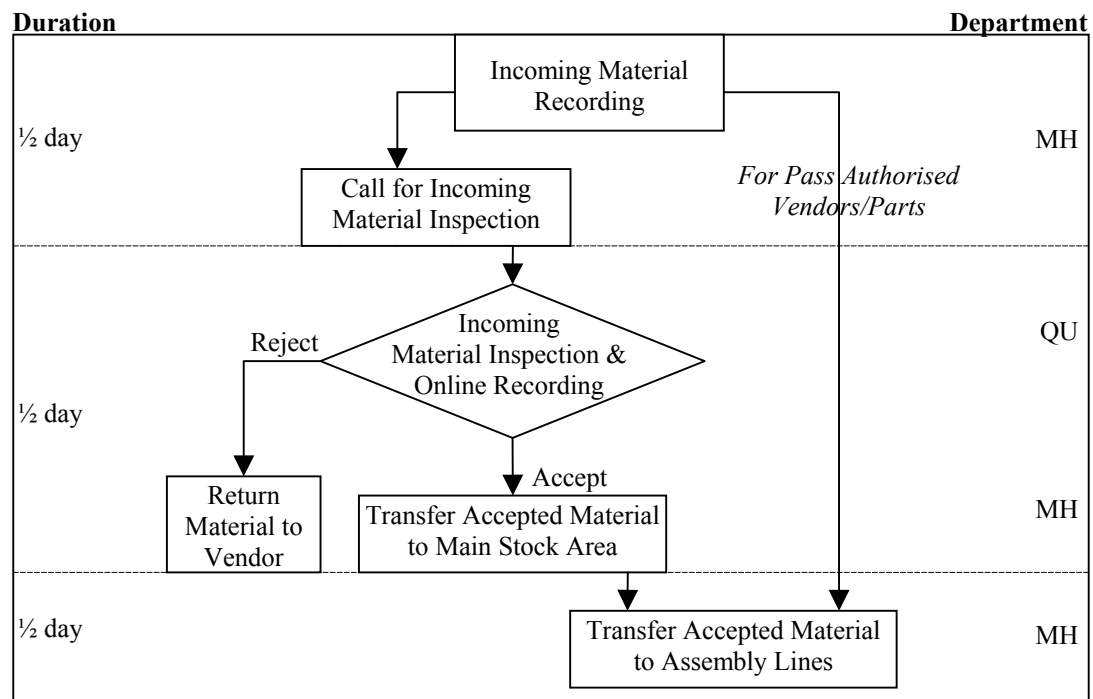


Figure III.75. Incoming Material Inspection Process Flow After Reengineering Study

PART IV

RESULTS AND DISCUSSIONS

IV.1. ADVANCED PRODUCT LIST MANAGEMENT OF DERIVATIVE PRODUCTS

IV.1.1. Formation of Advanced Product Lists for Derivative Military Vehicles

The solution identified by the reengineering team was to define 4 Base Products + Options System. The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.1. (All details for calculations are given in Appendix B.)

Table IV.1. Indicator Change of Reengineered Process (1.1)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Inactive stock generated / # of derivatives produced	458 USD/unit produced	375 USD/unit produced	330 USD/unit produced	66,400 USD	102,144 USD
Change in Stock <1 year / # of derivatives produced	79 USD/unit produced	62,5 USD/unit produced	55 USD/unit produced	13,200 USD	19,152 USD
Average # of work days from marketing request to purchasing order	31 days	11 days	11 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
production material transportation cost / # of derivatives produced	134 USD/unit produced	120 USD/unit produced	128 USD/unit produced	11,200 USD	4,788 USD

The reengineering study continued during the year 2002. The reengineered process was very successful from the inactive point of view because the new model efficiently limited wrong parts ordering. The generation of inactive stock was 28 % and 30 % less than the values before the study for base and optional systems, respectively.

This change also effected the production material transportation cost but not as much as expected. The positive change was only 4,5 %. The process was also successful for elimination of non-value added time and repetitive work of different departments. Time period between marketing request and purchasing order was almost decreased to 1/3 of the starting value at the end of the study.

The financial benefits due to process time change are given below in Table IV.2.

Table IV.2. Financial Benefits of Reengineered Process (1.1)

		FINANCIAL BENEFITS DUE TO PROCESS TIME CHANGE									
	Reengineered Process	Definition	Time Before Study	Time After Study	Saving (days)	Daily Work Hours	Allocation (%)	No of Occupied Personnel	Average Hourly Wage (USD)	No of Cycles/ Year *	Achieved Financial Benefits After Study (USD)
1.1.	APL Information Flow and Production Process of Derivative Military Vehicles	Tender Preparation	10	5	5	9	% 30	1	30	25	10.125
		Study on Technical Specs and Definition of Product	10	5	5	9	% 40	2	30	25	27.000
		Formation of Part Lists by Studying Previous Excel Sheets	10	0	10	9	% 20	4	30	25	54.000
		Transfer of Required Items to the Production Line	3	0	3	9	% 10	1	18	83	4.050

IV.1.2. Formation of Advanced Product Lists for Derivative Trailers

The first solution identified by the reengineering team was to define 6 standard products and get rid of part varieties and engineering changes. The second solution was to redefine product definition, purchasing and production process flows and start design freeze phase. The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.3.

Table IV.3. Indicator Change of Reengineered Process (1.2)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Inactive stock generated / # of derivatives produced	549 USD/unit produced	500 USD/unit produced	513 USD/unit produced	53.900 USD	41.940 USD
Average # of work days from marketing request to purchasing order	71 days	48 days	48 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
Production material transportation cost / # of derivatives produced	92 USD/unit produced	73 USD/unit produced	81 USD/unit produced	20.900 USD	12.815 USD
Average # of work days from marketing request to design freeze	21 days	6 days	6 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change

The reengineering study started in 2002 and continued until second half of 2004. The reengineered process was successful from the inactive point of view decreasing the generation of inactive stock by 6,6 %. This improvement was less than expected because the target was to define 6 standard products, but the project resulted only 3 standard types and still lots of derivative products exist.

The change effected the production material transportation cost quite well resulting a positive change of 12 %. The process was very successful for elimination of non-value added time. Time period between marketing request and production was decreased by 32,4 % and average number of work days from marketing request to design freeze was only 30 % of the starting value at the end of the study.

The financial benefits due to process time change are given below in Table IV.4.

Table IV.4. Financial Benefits of Reengineered Process (1.2)

FINANCIAL BENEFITS DUE TO PROCESS TIME CHANGE											
	Reengineered Process	Definition	Time Before Study	Time After Study	Saving (days)	Daily Work Hours	Allocation (%)	No of Occupied Personnel	Average Hourly Wage (USD)	No of Cycles/ Year *	Achieved Financial Benefits After Study (USD)
1.2.	APL Information Flow and Product Definition Process of Derivative Trailers	Engineering Releases	20	5	15	9	% 20	2	30	13	20.250
		Ordering and Procurement + Transfer of Required Items	50	42	8	9	% 10	8	22	5	6.336

IV.2. MISSING PLANNING FUNCTIONS

IV.2.1. Classification Of Urgency Of Demands Of Inventory From Different Functions (Production vs Spare Parts)

The solve the problems resulting from urgency cases, the first solution was to change and barcode labels of incoming materials and identify spare parts orders. Then a responsible personnel from Materials Handling department was defined to check Purchasing Approvals for the spare parts. This way, wrong routing of these materials would be prevented.

The other solution to improve the spare parts handling process was to built a new Spare Parts Stock Area and manage spare parts stocks separately.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.5.

Table IV.5. Indicator Change of Reengineered Process (2.1)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Annual number of stockout items due to priority mistakes / total annual inventory used	3.142 PPM	1.143 PPM	320 PPM	153.000 USD	306.500 USD
Turnover rate	3,14	3,21	3,51		
Annual number of back order items / total annual spare parts orders	%6,60	%4,80	%2,80		

The reengineering study started in 2002 and continued until mid 2004. The reengineered process was very successful from the stand point of stockouts due to priority mistakes which was decreased to almost 1/10 of the original value. The construction of new Spare Parts Stock Area was also a success speeding up the spare parts selling process both increasing the turnover rate more than twice and the total sales figure generating a new profit center.

Additionally, the financial benefits due to process time change are given below in Table IV.6.

Table IV.6. Financial Benefits of Reengineered Process (2.1)

FINANCIAL BENEFITS DUE TO PROCESS TIME CHANGE											
	Reengineered Process	Definition	Time Before Study	Time After Study	Saving (days)	Daily Work Hours	Allocation (%)	No of Occupied Personnel	Average Hourly Wage (USD)	No of Cycles/Year *	Achieved Financial Benefits After Study (USD)
2.1.	Spare Parts and Production Material Handling Process	Delivery to Dealers and Services	10	7	3	9	% 80	2	18	25	19.440

IV.2.2. In-house Manufacturing Control

The first solution was to decrease the amount of shortages and excess stocks due to planning mistakes, this way inactive stock generation would be prevented. Another implementation was to decrease amount of in-house production without work orders and another point was to decrease raw material safety stocks for in-house production.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.7.

Table IV.7. Indicator Change of Reengineered Process (2.2)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Quantity of stockout and excess items/cases due to planning mistakes	29.310 PPM	20.000 PPM	11.300 PPM	21.000 USD	49.560 USD
Difference between actual and registered stocks (financial)					
Production (%) without work orders	%21	%12	%6,10		
Amount/percent of raw material safety stocks	%29,60	%25	%26,80	5.520 USD	3.712 USD

The reengineering study continued during the year 2003. The reengineered process was very successful decreasing stockout or excess cases due to planning mistakes to almost 1/3 of the original value. Production without work orders was also decreased as required to 6,1 %. This improvement was very effective in decreasing the quantity of stockout or excess cases due to planning mistakes.

Another point was to decrease raw material safety stocks (including armour steel). The per cent was decreased by 2,8 % after reengineering but in fact the total figure for safety stocks of raw materials increased. (The steel crisis because of demand from China resulted an increase of safety stocks everywhere.)

Additionally, the financial benefits due to process time change are given below in Table IV.8.

Table IV.8. Financial Benefits of Reengineered Process (2.2)

		FINANCIAL BENEFITS DUE TO PROCESS TIME CHANGE									
	Reengineered Process	Definition	Time Before Study	Time After Study	Saving (days)	Daily Work Hours	Allocation (%)	No of Occupied Personnel	Average Hourly Wage (USD)	No of Cycles/Year *	Achieved Financial Benefits After Study (USD)
2.2.	In-House Manufacturing Process	Determine Requirement of In-House Manufacturing Items	3	1	2	9	% 10	1	30	83	4.500
		Manufacture In-House Items	15	10	5	9	% 80	4	18	17	43.200
		Transfer Items to Assembly Lines	5	3	2	9	% 80	1	18	50	12.960

IV.2.3. Tracking of Engineering Changes

The first solution to apply was immediate sharing of correct information between functions effected by engineering changes. After that, determination of correct effectivity dates and chassis for implementations and prevention of inactive stock generation could be possible.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.9.

Table IV.9. Indicator Change of Reengineered Process (2.3)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Inactive stock due to uncontrolled engineering changes	313 USD / unit	278 USD / unit	201 USD / unit	33.000 USD	118.984 USD
Number or percent of correct/on time engineering changes	%84,50	%89	%87,30		

The reengineering study continued from year 2002 to the year 2004. At the end of the study the inactive stock due to uncontrolled engineering changes per unit production was successfully decreased by 36 %. In addition to that per cent of on time/correct engineering changes increased to 87,3 %. This positive change in process indicators was supported by a high financial benefit from the decrease of annaul inactive stocks.

In this study, the process was almost newly designed. Therefore, no financial benefit due to process time change was expected.

IV.2.4. Weak Control on Hardware

A new Hardware Stock Area was planned to speed up hardware material handling and prevent inactive stock generation. Also by changing hardware transfer method to production lines it would be possible to decrease safety stocks. As a result, control on hardware material groups would be strengthened. After the construction of the Stock Area and installation of the shelves, all the hardware material in the Stock Area were picked, counted and stored in defined shelves of new Hardware Stock Area, and all the system records were corrected. A view from the new Hardware Stock Area is given below in Figure IV.1.



Figure IV.1. New Hardware Stock Area.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.10.

Table IV.10. Indicator Change of Reengineered Process (2.4)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Delivery time to production lines from inventory	13,9 minutes/per vehicle	10 minutes/per vehicle	6,4 minutes/per vehicle	13.650 USD	5.328 USD
Financial value of inactive hardware in stocks	42.000 USD	30.000 USD	22.200 USD	12.000 USD	19.800 USD
Amount/percent of hardware safety stocks	%60	%51	%40	928 USD	2.184 USD

The reengineering study continued during the year 2002. The reengineered process was very successful delivery time to production lines from Main Stock area by 54 %. The financial value of inactive hardware stocks was decreased to 19.800 USD at the end of 2002. The safety stocks were also taken into control and decreased by 40 % of total hardware stocks.

Speeding up materials handling and changing hardware transfer method resulted saving of man hours and achieved financial benefits due to process time change are given below in Table IV.11.

Table IV.11. Financial Benefits of Reengineered Process (2.4)

		FINANCIAL BENEFITS DUE TO PROCESS TIME CHANGE									
	Reengineered Process	Definition	Time Before Study	Time After Study	Saving (days)	Daily Work Hours	Allocation (%)	No of Occupied Personnel	Average Hourly Wage (USD)	No of Cycles/Year *	Achieved Financial Benefits After Study (USD)
2.4.	Hardware Transfer Process	List Hardware Requirement + Prepare Daily Hardware Transfer Lists + Arrange Hardware Items to be Transferred	3	0,5	2,5	9	% 60	1	18	83	20.250
		Complete Unsatisfied Requirements from Assembly Lines	3	0	3	9	% 20	1	18	83	8.100

IV.2.5. Material Handling Coordination Problems

To increase efficiency of coordination between Material Handling - Planning teams, and active manufacturing departments, Planning Department was established. In addition to many other planning functions like in-house manufacturing planning (Section III.5.2.2.b.), engineering changes tracking system (Section III.5.2.2.c.), loading of production lines was focused and reengineered.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.12.

Table IV.12. Indicator Change of Reengineered Process (2.5)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Establishment of new department and definition of responsibilities	-	-	-	-	-
Start of in-house manufacturing planning	-	-	-	Given in 2.2.	Given in 2.2.
Launch of engineering changes tracking system	-	-	-	Given in 2.3.	Given in 2.3.
Start of line loading via system data	-	-	-	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
Process time	19,6 minutes/per vehicle	13,6 minutes/per vehicle	8,9 minutes/per vehicle		
Number of stockout cases from production line	5,2 items/vehicle	3,8 items/vehicle	1,7 items/vehicle	19.040 USD	52.015 USD

The reengineering study continued during the year 2003. The line loading process was successfully decreased to an average value of 8,9 minutes per vehicle produced meaning a reduction by half. Another important indicator of the success of the process was the average number of stock out cases for vehicles produced during the year. The indicator value decreased from 5,2 to 3,8 items per vehicle which meant that the use of system data to load the production lines was very effective. The financial savings from ordering of stockouts is calculated to be about 50.000 USD.

Additional financial benefits due to process time change are given below in Table IV.13.

Table IV.13. Financial Benefits of Reengineered Process (2.5)

		FINANCIAL BENEFITS DUE TO PROCESS TIME CHANGE									
	Reengineered Process	Definition	Time Before Study	Time After Study	Saving (days)	Daily Work Hours	Allocation (%)	No of Occupied Personnel	Average Hourly Wage (USD)	No of Cycles/Year *	Achieved Financial Benefits After Study (USD)
2.5.	Line Loading Process	Arrange Required Items to be Transferred to Assembly Lines In Main Stock Area.	3	1	2	9	% 40	2	18	83	21.600
		Complete Unsatisfied Requirements from Assembly Lines	3	0	3	9	% 20	1	18	83	8.100

IV.2.6. Simultaneous Transfer of Materials (Recorded vs. Physical)

The aim of the process changes was to decrease number of late material transfer entries and decrease production line stock deviations. There should be no difference between the physical motion and registry of motion of materials in the

facility. To comply with this requirement a personnel from the stock area was assigned to assure that all physical material transfers were also realised on the system.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.14.

Table IV.14. Indicator Change of Reengineered Process (2.6)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Late material transfer entries	%6,80	%5,40	%2,10	20.400 USD	34.181 USD
Amount/percent of line stock deviations	%3,80	%2,80	%1,50		

The reengineering study continued during the year 2003. Late material entries were successfully decreased to an average value of 2,1 % of total entries from 6,8 % at the beginning of the year. Another indicator was the line stock deviations which was decreased to 1,5 % from 3,8 %. The financial savings came from less additional ordering costs for stockout items from late entries.

Additional financial benefits due to process time change are given below in Table IV.15.

Table IV.15. Financial Benefits of Reengineered Process (2.6)

FINANCIAL BENEFITS DUE TO PROCESS TIME CHANGE											
	Reengineered Process	Definition	Time Before Study	Time After Study	Saving (days)	Daily Work Hours	Allocation (%)	No of Occupied Personnel	Average Hourly Wage (USD)	No of Cycles/ Year *	Achieved Financial Benefits After Study (USD)
2.6.	Process of Physical and Registered Motion of Items	Record All Day Long Transfer of Items to the Assembly Lines (in the evening)	0,5	0	0,5	9	% 15	1	18	250	3.038

IV.2.7. Poor Coordination and Evaluation of Feedback from Production Line

The goal of the study was to find and eliminate incorrect inventory data, part routings and APL errors. To manage this, a Work Order Analysis Team and continuous inventory auditing was started.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.16.

Table IV.16. Indicator Change of Reengineered Process (2.7)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Number of Items Corrected / Number of Items Found	%65	%88	%82	27.200 USD	31.208 USD
Number of Items Corrected / Number of Items Found	%61	%71	%81		
Number of Items Corrected / Number of Items Found	%23	%33	%87		
Number of annual count cycles for each material group	A - 1,5 / B - 0,6 / C - 0,2	A - 4 / B - 2 / C - 1	A - 3 / B - 2,5 / C - 0,5		

The reengineering study continued during the year 2003. The Work Order Analysis Team identified existing errors on the system data. As a result 17 %, 20 % and 64 % higher errors of inventory data, part routings and Advanced Product Lists were corrected respectfully. Continuous inventory auditing was conducted for A, B, C material groups as defined in General Background Section II.2.1.1.

IV.3. INVENTORY AUDIT PROBLEMS

IV.3.1. Work-In-Process Inventory Audit Problems

The goal of the reengineering effort was to eliminate WIP listing, decrease WIP counting time and eliminate WIP manual counting errors. Total time for listing and counting and error percent due to manual counting were the indicators of the process performance.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.17.

Table IV.17. Indicator Change of Reengineered Process (3.1)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Total time for listing and counting	4 days	2 days	2 days		
Error per cent	%7,10	%4,90	%2,40	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change

The reengineering solution was applied in the inventory audit at the end of year 2003. As a result of the study total time for listing and counting of WIP was decreased to 1/2 and the other indicator, error percent was very successfully decreased to 2,4 % from 7,1 % the year earlier. Savings from this process change are calculated to be a part of financial benefits due to process time change given below in Table IV.18.

Table IV.18. Financial Benefits of Reengineered Process (3.1)

FINANCIAL BENEFITS DUE TO PROCESS TIME CHANGE											
	Reengineered Process	Definition	Time Before Study	Time After Study	Saving (days)	Daily Work Hours	Allocation (%)	No of Occupied Personnel	Average Hourly Wage (USD)	No of Cycles/Year *	Achieved Financial Benefits After Study (USD)
3.1.	Process of Inventory Audit Preparation of Work-In-Process	Preparation of Work-In-Process Vehicles Assembly Line Counting Lists	1	0,5	0,5	9	% 40	2	30	1	108
		WIP Counting	3	1,5	1,5	9	% 100	8	30	1	3.240
		Collection and Recording of Assembly Line Counting Lists	1	0	1	9	% 100	2	30	1	540

IV.3.2. Subassembly Audit Problems

The goal of the reengineering effort was to eliminate subassembly listing, decrease subassembly counting time and eliminate subassembly manual counting errors. Total time for listing and counting and error percent due to manual counting were the indicators of the process performance.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.19.

Table IV.19. Indicator Change of Reengineered Process (3.2)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Total time for listing and counting	4 days	2,5 days	2,5 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
Error per cent	%8,90	%6,10	%2,10		

The reengineering solution was applied in the inventory audit at the end of year 2003. As a result of the study total time for listing and counting of subassemblies was decreased to 2,5 days from 4 days and the other indicator, error percent was very successfully decreased to 2,1 % from 8,9 % the year earlier. Savings from this process change are calculated to be a part of financial benefits due to process time change given below in Table IV.20.

Table IV.20. Financial Benefits of Reengineered Process (3.2)

FINANCIAL BENEFITS DUE TO PROCESS TIME CHANGE											
	Reengineered Process	Definition	Time Before Study	Time After Study	Saving (days)	Daily Work Hours	Allocation (%)	No of Occupied Personnel	Average Hourly Wage (USD)	No of Cycles/Year *	Achieved Financial Benefits After Study (USD)
3.2.	Process of Inventory Audit Preparation of Subassemblies	Preparation of Subassemblies Parts Counting Lists	1	0,5	0,5	9	% 30	4	30	1	162
		Subassembly Parts Counting	3	2	1	9	% 100	6	30	1	1.620
		Collection and Recording of Subassembly Parts Counting Lists	1	0	1	9	% 100	2	30	1	540

IV.3.3. Counting the Inventory In Wrong Codes and Unit Conflicts (Causing Inventory Deviations)

The goal of the reengineering study was to eliminate double codes, eliminate R&D defined and purchased unit differences, decrease counting in wrong codes and unit conflicts in the short run and totally eliminate counting in wrong codes and unit conflicts by 2006.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.21.

Table IV.21. Indicator Change of Reengineered Process (3.3)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Number of double codes	4.898 items	2.250 items	1.330 items	2.520 USD	3.408 USD
Number of items with different units	216 items	100 items	62 items	34,150 USD	45,337 USD
Percent of total audit error	% 24	% 10	% 14		

The reengineering study continued during the year 2003 and 2004. At the end of the study the number of double codes and the number of items with different units decreased to almost 1/3 of the values before study. Additionally, percent of total audit error was decreased by 10 %. Financial savings were obtained from decrease of safety stocks of double codes and decrease of inactive stock items generated due to unit conflicts.

IV.4. STOCK AREA PROBLEMS

IV.4.1. Difficulties of Tracking of Hardware Materials

The goal of the reengineering study was to decrease total hardware stock and redundant shelves in Hardware Stock Area and stop generation of redundant codes. A new Hardware Stock Area was built to have a better control of hardware materials as explained in Section IV.2.4. Still it was necessary to eliminate redundant hardware codes from two separate companies before merger.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.22.

Table IV.22. Indicator Change of Reengineered Process (4.1)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Number of redundant codes	3.142 items	1.500 items	714 items	Given in 3.3.	Given in 3.3.
Total number of redundant shelves / Total shelves	%15,90	%8,10	%6,90	562 USD	647 USD
System launching	-	-	-		

The reengineering study continued during the year 2003. At the end of the study the number of redundant codes decreased to almost 1/4 of the values before study. Additionally, percent of number of redundant shelves decreased to 6,9 % from 15,9 %.

In this study, no financial benefit due to process time change was expected.

IV.4.2. Disorder in Main Stock Area

The aim of the process changes was to simplify material transfer to assembly lines and decrease material damage in stock area. Average transfer time to assembly lines and the damaged material percent in Main Stock Area were the two specified indicators of the study results. In addition tidiness of the material in Main Stock Area was achieved as views are given in Figure IV.2.



Figure IV.2. Views from Main Stock Area Shelves After Study.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.23.

Table IV.23. Indicator Change of Reengineered Process (4.2)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Average transfer time to assembly lines	19,6 minutes/per vehicle	13,6 minutes/per vehicle	8,9 minutes/per vehicle	Given in 2.5.	Given in 2.5.
Percent of material damaged in total stock	%0,0371	%0,0198	%0,0093	26.000 USD	42.000 USD

The reengineering study continued during the year 2003 and 2004. At the end of the study average transfer time to assembly lines was decreased by 55 % which

was an important change for the company. Besides damaged material percent in Main Stock Area was also successfully decreased to 1/4 of the value before the study.

IV.4.3. Difficulties of Tracking of Old & Excessive Stocks

The aim of the reengineering study was to decrease total old and excessive stock and increase turnover ratio. The indicator of the process was percent of old and excessive stocks eliminated by selling, rework or exchange in total old and excessive stocks, and turnover ratio.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.24.

Table IV.24. Indicator Change of Reengineered Process (4.3)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Old&excessive stocks eliminated by selling, rework or exchange / Total Old&excessive stocks	%1,03	%4,69	%15,90	117.000 USD	477.117 USD
Turnover ratio	12,6	14,6	16,4		

The reengineering study continued during the year 2003 and 2004. Percent of old and excessive stocks eliminated by selling, rework or exchange was increased to almost 16 % from the 1 % value before study. The turnover ratio increased to 16,4 from 12,6 during the same period.

The tracking process for old and excessive stocks was newly defined, therefore no financial benefits due to process time change was expected.

IV.5. ORDERING PROBLEMS

IV.5.1. Sending / Approval Time of Purchase Orders

The aim of the process changes was to increase number of vendors communicated on the web and decrease average sending / approval time of purchase orders. Sending time and approval were the indicators of the process

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.25.

Table IV.25. Indicator Change of Reengineered Process (5.1.)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Average sending time	5 days	1,5 days	1,5 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
Average approval time	3,5 days	2 days	2 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change

The reengineering study continued during the year 2002. At the end of the study average sending time of purchase orders decreased to 1,5 days from 5 days and average approval time of purchase orders decreased to 2 days from 3,5 days. The financial savings achieved due to process time change are given below in Table IV.26.

Table IV.26. Financial Benefits of Reengineered Process (5.1.)

FINANCIAL BENEFITS DUE TO PROCESS TIME CHANGE											
	Reengineered Process	Definition	Time Before Study	Time After Study	Saving (days)	Daily Work Hours	Allocation (%)	No of Occupied Personnel	Average Hourly Wage (USD)	No of Cycles/Year *	Achieved Financial Benefits After Study (USD)
5.1. and 5.2	Sending/Approval Process of Purchase Orders	Print-out /Approve/ Send Purchase Orders	5	1,5	3,5	9	% 60	2	30	24	27.216
		Approval of Purchase Orders by Vendors	3,5	2	1,5	9	% 0	0	0	71	0

IV.5.2. Long Lead Times

The aim of the process changes was to decrease average transportation time and cost, to provide better coordination and power on vendors, eliminate low performance vendors and change inventory policy of critical vendors. Average transportation mile and cost, total number of approved vendors, average vendor performance and number of vendors recontracted were the performance indicators of the processes.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.27.

Table IV.27. Indicator Change of Reengineered Process (5.2)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Average transportation mile	252 miles / item	225 miles / item	217 miles / item	114.000 USD	239.767 USD
Average transportation cost	188 USD / unit produced	150 USD / unit produced	117 USD / unit produced		
Total number of approved vendors	442 vendors	400 vendors	348 vendors	75.000 USD	138.880 USD
Average vendor performance	63 / 100	70 / 100	72 / 100	11.702 USD	23.603 USD
Number of vendors recontracted	7 vendors	10 vendors	26 vendors		

The reengineering study continued during the year 2002. After the study, average transportation mile decreased to 217 miles/item from 252 miles/item especially due to changing sheet metal and interior trim materials suppliers from İstanbul (145 km to the factory) with the ones from local city (5 km to the factory) and making plastic material suppliers move to local city from Bursa (160 km to the factory). Parallel to the above indicator, average transportation cost also decreased by 38 %. During the study number of vendors decreased to 348 and average vendor performance increased by 14 %. 26 vendors supplying critical items were recontracted to keep buffer stocks and altogether a financial benefit of 200.000 USD was provided.

IV.6. INCOMING MATERIAL ENTRY PROBLEMS

IV.6.1. Incoming Material Entry (Registry out of Factory / Acceptance Criteria)

The aim of the process changes was to organize truck entries to the factory and decrease total unloading time, and reject not ordered, excessive or early lots of materials and parts to get rid of not required stocks. The two indicators of the process

success were average unloading time and number of parts entering stocks although not ordered, excessive or early.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.28.

Table IV.28. Indicator Change of Reengineered Process (6.1)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Number of parts entering stocks although not ordered, excessive or early	4,418 parts	1,000 parts	1,603 parts	1,203 USD	1,025 USD
Average unloading time	17 min/parts	10 min/parts	11 min/parts	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change

The reengineering study continued from mid 2002 to mid 2003. At the end of the study, the total number of not ordered, excessive or early parts entering stocks decreased to 1,603 parts and average unloading time decreased by 35 % due to the rearrangements for truck entries.

Financial benefits due to process time change are given below in Table IV.29.

Table IV.29. Financial Benefits of Reengineered Process (6.1)

FINANCIAL BENEFITS DUE TO PROCESS TIME CHANGE											
	Reengineered Process	Definition	Time Before Study	Time After Study	Saving (days)	Daily Work Hours	Allocation (%)	No of Occupied Personnel	Average Hourly Wage (USD)	No of Cycles/Year *	Achieved Financial Benefits After Study (USD)
6.1	Incoming Material Entry Process	System Transfer of Items to Storage Area	1	0,5	0,5	9	% 100	1	30	250	33.750

IV.6.2. Lack of Tracking of Materials Going Out of Factory for Machining and Coating

The goals of the process changes was to eliminate mixing of parts send/not send to vendors for machining and coating, and decrease stock deviations, and correct reflection of labor costs to the total vehicle costs. These goals necessitated establishment and successful implementation of new coding system and stock control for out worked parts and integration of this system to MFG-Pro and accounting programs.

The expected process flow after the reengineering study was given in Section III.5.2.6.b. During the study the system was established and pilot implementation was conducted by sheet metals. The system still needs to be extended to other

material groups like in-house manufactured brackets, welded pipes, and purchased hardware materials.

IV.6.3. Material Quality Inspection Problems

The aim of the process changes was to increase total number of daily approved parts and decrease average inspection time per item. Pass and Periodic Control System and an IT solution for recording inspection results were started.

The expected process flow after the reengineering study was achieved and the specified indicators of the reengineering process performance and their values before and after the study are given in the below Table IV.30.

Table IV.30. Indicator Change of Reengineered Process (6.3)

INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
Number of approved parts / day	402 parts / day	450 parts / day	566 parts / day	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
Average inspection time per item	1,34 min / part	1,20 min / part	0,95 min / part		

The reengineering study continued during the year 2003. The number of approved parts per day increased by 40 % at the end of the study and by using the IT solution average inspection process time per item decreased by 29 %. The financial savings are included in financial benefits due to process time change as given below in Table IV.31.

Table IV.31. Financial Benefits of Reengineered Process (6.3)

		FINANCIAL BENEFITS DUE TO PROCESS TIME CHANGE									
	Reengineered Process	Definition	Time Before Study	Time After Study	Saving (days)	Daily Work Hours	Allocation (%)	No of Occupied Personnel	Average Hourly Wage (USD)	No of Cycles/ Year *	Achieved Financial Benefits After Study (USD)
6.3.	Incoming Material Quality Inspection Process	Incoming Material Inspection & Recording	1	0,5	0,5	9	% 90	5	18	250	91.125

PART V

EVALUATIONS AND CONCLUSIONS

1. All Reengineering Efforts on Materials Management System Aimed to Reverse the Accumulation of Error in MRP Cycle. The MRP system is a cycle which starts with the determination of material requirement for production, continues with calculation of delivery time of items, giving purchase orders, recording of incoming materials, system transfer of items in facility, reducing mounted materials from stocks, and restarts with the determination of material requirement for a new period. The cycle is illustrated below in Figure V.1.

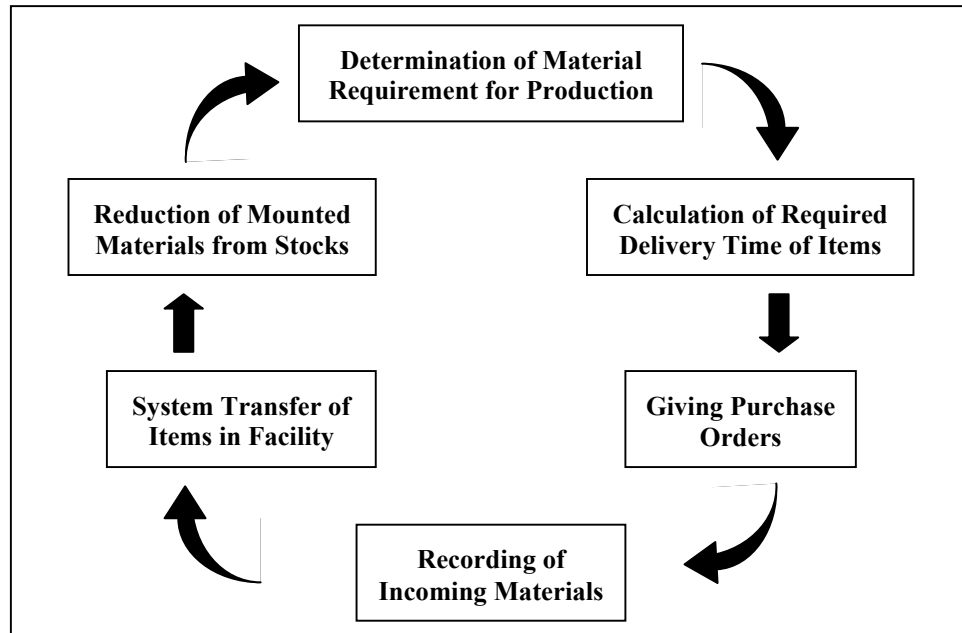


Figure V.1. The MRP cycle.

All requirement determinations and calculations depend on system data previously entered or generated and any deviation of the data results in wrong results. For instance, if all the materials mounted on vehicles are not reduced from stocks, the MFG-Pro system will make a wrong calculation for the material

requirement of the new period. This will result wrong purchase orders. Wrong purchase orders will result either excess stocks or stockouts. This will create problems of system transfer of items in facility and reduction of used material from stocks. If not stopped, this accumulation of error of system records will grow faster and faster. The only way to reverse this infinite cycle is to take all the precautions to prevent new errors on the system and at the same time, find out and correct the existing errors faster than the accumulation of errors. This was the principle of the study for all reengineering efforts.

Assume that there is a certain amount of error on system records, e_0 , at time zero and a constant percent of the existing error, α , accumulated on it in a time period t , then the accumulation of error on system at each time period can be expressed as,

$$a(t) = \alpha \cdot e(t-1) \quad (V.1)$$

where a is time dependent error accumulation function, and e is time dependent total system error function.

Also assume that constant percent of the existing error, β , is corrected or prevented, that is reduced in a time period t , then the reduction of error at each time period can be expressed as,

$$r(t) = \beta \cdot e(t-1) \quad (V.2)$$

where r is time dependent error reduction function, and e is time dependent total system error function.

Then total error on system records at any time can be expressed as,

$$e(0) = e_0, \quad (V.3)$$

$$e(t) = (1+\alpha-\beta) \cdot e(t-1) \quad (V.4)$$

The value of β/α is critical as shown in the graphical representation of the situation given below in Figure V.2. If no preventive or corrective actions are made the system error increases rapidly ($\beta/\alpha=0$). A slow implementation of preventive or corrective actions can only slow down the acceleration ($\beta/\alpha=0,5$) and an equal amount of error accumulation and correction can only keep the system error at e_0 ($\beta/\alpha=1$). To reverse this accumulation cycle the correction and prevention activities need to be faster than accumulation ($\beta/\alpha>1$) and that way it is possible to get rid of system record errors.

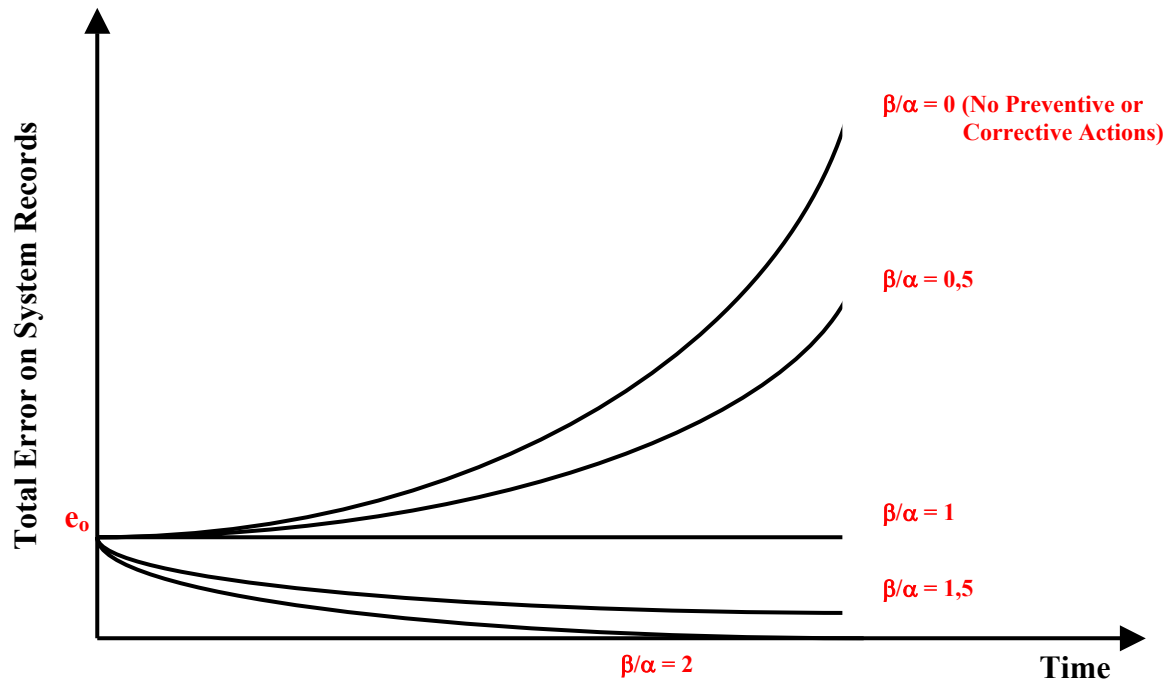


Figure V.2. Change of Total Error on System Records in Time for Different Values of β/α .

All the problems worked on are somehow to prevent stock deviations, creation of errors on system records or correction of existing errors and all the solutions applied served these purposes.

2. At the end of the study, the logic and structure of storage in the company was changed. Hardware, chemicals, spare parts and old and excessive stocks were taken out of the Main Stock Area and kept in separate stock areas resulting a higher level of control on total stocks and financial benefits as given in dissertation work.

3. Many IT solutions were introduced either to speed-up some processes or enable collection of valuable data. This also changed the ways of doing things and resulted remarkable gains.

4. To redefine some processes it was necessary to make some organizational changes and these changes started a better communication and coordination between functions and increased efficiency of processes.

5. The reengineering study on materials management system was successful as summarized in Table V.1 (the details are given in Appendix C).

Table V.1. Reengineering Success Level Summary Table.

AVERAGE INDICATOR REENGINEERING SUCCESS (%)	AVERAGE INDICATOR REENGINEERING SUCCESS (Corrected by Critical Level) (%)	AVERAGE PROCESS TIME REENGINEERING SUCCESS (%)	AVERAGE PROCESS TIME REENGINEERING SUCCESS (Corrected by Critical Level) (%)	ANNUAL FINANCIAL BENEFIT	
				INDICATOR CHANGE	PROCESS TIME CHANGE
88,17	79,32	55,96	56,43	1.777.765 USD	421.250 USD
WEIGHTED REENGINEERING SUCCESS LEVEL (40 % INDICATOR AND 60 % PROCESS TIME)			75,3		
WEIGHTED REENGINEERING SUCCESS LEVEL (Corrected by Critical Level)(%) (40 % INDICATOR AND 60 % PROCESS TIME)			70,2		

The Success Level Matrix shows the reengineering success from two different views. First one is the improvement of process performance indicators and the second one is the elimination of non-value added time. For both of them, corrections by critical levels of the processes are calculated. An overall weighted reengineering success level is also calculated by 60 % from process indicators average improvement and 40 % from elimination of non-value added time.

As a result, it was observed that, the identified process indicators were improved 88 % as an average, and 56 % of the non-value added time of the reengineered processes was eliminated. Weighted reengineering success level was 75 %. When corrected by the importance of the solved problems the values were 79, 56 and 70 % respectively.

The proposed model has resulted the success level above for a specific type of company, namely having a strictly functional organization, centralized management and at after merger state. Implementing the same procedure on a process based organization for instance may not give similar results. Actually, well-known team based implementations may work better on such companies.

The values show that a remarkable positive change was achieved in almost all of the processes considered. The annual financial value of the process indicator changes was about 1,8 million USD and annual financial value of elimination of non-value added time was about 400.000 USD. This amount was of course considered to be an indirect benefit since the saved man hours would be effective if the related personnel are assigned to new operations or totally eliminated.

On the other hand, the reengineering studies had a cost while resulting the above gains. Mainly the spare parts stock area built, shelves bought for other stock

areas, IT investments made and meetings held were the costs, and an overall cost of 480.000 USD was calculated.

An NPV calculation referencing the beginning of year 2002 shows a total financial benefit of 1,9 million USD against an investment of 440.000 USD. The pay back period is calculated to be 17 months.

6. Table V.2 shows the relation between the reengineering success levels and related parameters.

Table V.2. Relation Between Reengineering Success Levels and Related Parameters.

	PROCESSES	INDICATOR REENGINEERING SUCCESS (%)	PROCESS TIME REENGINEERING SUCCESS (%)	RELATED PARAMETERS							
				Achieved Reengineering Time (months)	Planned Reengineering Time (months)	Achieved / Planned Time	Total Work Time (months)	Awareness/ Training	Company A/B/A+B	Cross-Functionality	Coordination of MMT
1.1.	APL Information Flow and Production Process of Derivative Military Vehicles	32	70	8	7	%114	8	4	A	4	1
1.2.	APL Information Flow and Product Definition Process of Derivative Trailers	31	33	31	27	%115	31	3	B	4	
2.1.	Spare Parts and Production Material Handling Process	53	30	26	27	%96	26	5	A	5	2
2.2.	In-House Manufacturing Process	47	39	10	10	%100	10	4	A	3	
2.3.	Engineering Changes Process	20	*	15	10	%150	15	2	A+B	6	
2.4.	Hardware Transfer Process	45	92	10	9	%111	10	3	A+B	2	
2.5.	Line Loading Process	61	83	15	12	%125	15	4	A	4	
2.6.	Process of Physical and Registered Motion of Items	65	-	6	6	%100	6	4	A	2	
2.7.	Process of Feedback From Production Line	151	-	14	10	%140	14	5	A	2	3
3.1.	Process of Inventory Audit Preparation of Work-In-Process	58	60	3	3	%100	3	3	A+B	3	
3.2.	Process of Inventory Audit Preparation of Subassemblies	57	50	3	3	%100	3	3	A+B	3	
3.3.	Inventory Counting Process	62	-	-	-	-	-	4	A+B	3	
4.1.	Hardware Materials Tracking Process	67	-	7	8	%88	7	4	A+B	3	4
4.2.	Main Stock Area Restructuring Process	65	-	16	13	%123	16	4	A	2	
4.3.	Old & Excessive Stocks Tracking Process	737	-	17	18	%94	17	5	A+B	4	
5.1.	Sending/Approval Process of Purchase Orders	56	59	7	6	%117	7	4	A+B	3	5
5.2.	Orders	72		10	8	%125	10	3	A+B	1	
6.1.	Incoming Material Entry Process	50	50	9	8	%113	9	3	A+B	3	6
6.2.	Tracking of Materials Going Out of Factory for Machining-Coating	-	-	-	-	-	-	2	A+B	3	
6.3.	Incoming Material Quality Inspection Process	35	50	12	12	%100	12	2	A+B	4	
						%112					

It is observed that, a 12 % average delay occurred during the reengineering studies. Other observed relations will be given in following items.

7. When the success levels and reengineering work time for each process is graphed, no significant relation is observed (See Figure V.3).

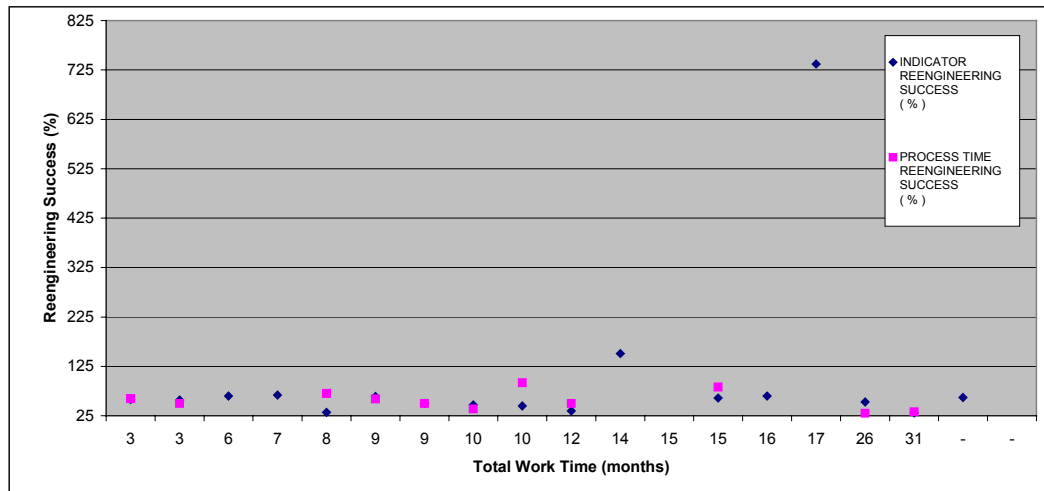


Figure V.3. Reengineering Success vs. Total Work Time. (The Reengineering Success Level of Elimination of Old / Excessive Stocks included in Total Work Time 17 months is considerably higher than the other indicators since it was only 1,03% before study and reached a value of 15,9% after the study)

8. When the indicator success level is graphed for level of awareness/training supplied to teams and related personnel (marked on 1-5 scale, 5 = full awareness/training), from this case study, it is acceptable to say that as awareness/training increases, the success level of engineering studies also increases. (See Figure V.4)

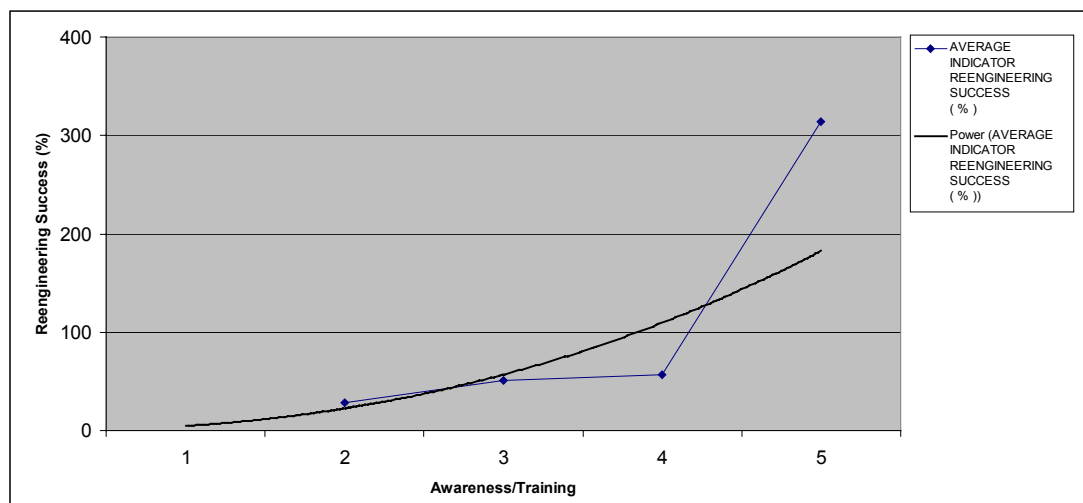


Figure V.4. Reengineering Success vs. Awareness/Training.

9. When the process time success is graphed against cross-functionality, the case study suggests that, as cross-functionality, that is the number of functions involved in a process increases, the success level of engineering efforts decreases (See Figure V.5).

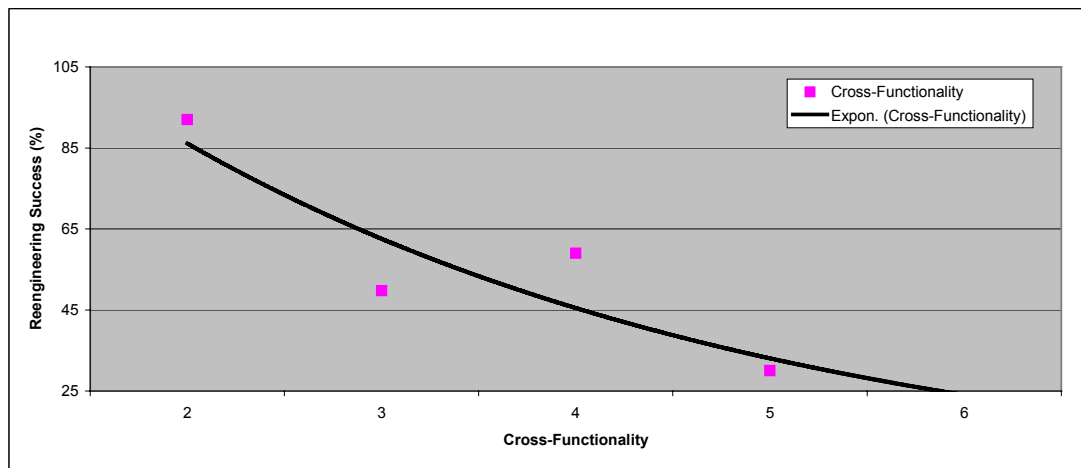


Figure V.5. Reengineering Success vs. Cross-Functionality.

10. The reengineering success levels are also graphed against materials management team members. This is not done to compare their performances with each other. The aim was to compare their performances on indicator and process time improvements (See Figure V.6). So, numbers are used instead of names.

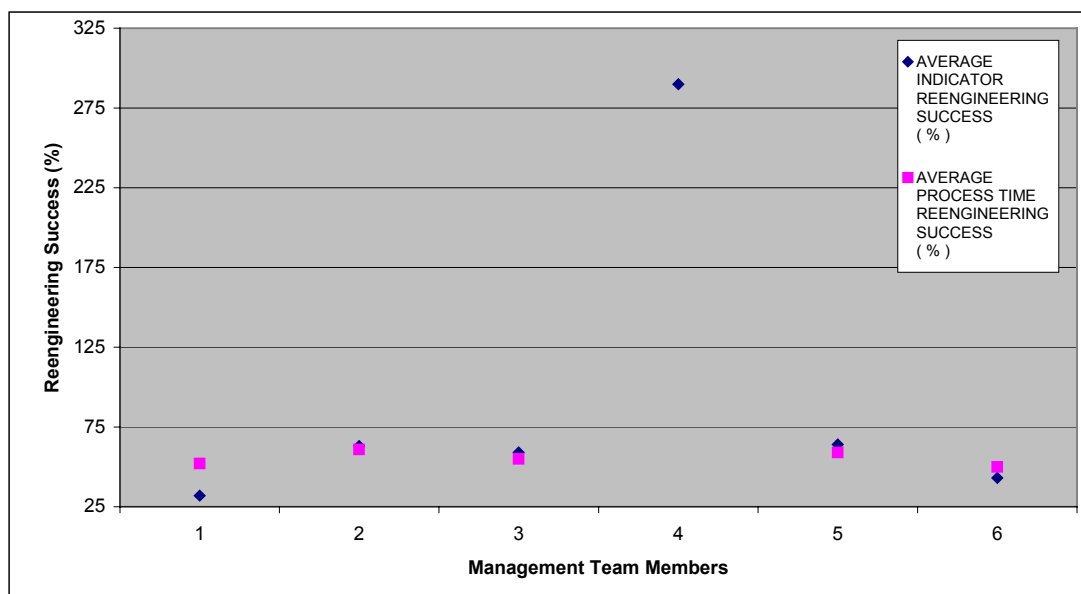


Figure V.6. Reengineering Success vs. Management Team Members. (The Reengineering Success Level of Elimination of Old and Excessive Stocks included in Management Team Members 4, is considerably higher than the other indicators since it was only 1,03% before study and reached a value of 15,9% after the study)

It was observed that the success level achieved by a manager on process indicators was very close to the success level achieved by him on process time.

11. The proposed Change Management Model resulted a successful reengineering study on materials management system of the company studied. This was mainly because the Change Management Team (Materials Management Team in this case) was an important coordinator and mediator between functions which otherwise would have strong barriers against communication and collaboration. BPR can succeed in a communicating and learning environment.

12. BPR can be successful if a complete plan for studies is prepared and implemented in line with the proposed scope and time. The case by case approach and coordination of the proposed model has helped to manage the change process smoothly.

13. The reengineering study is usually a long process from 3 months to 2 years depending on complexity of processes considered and functions involved.

14. Awareness/training, leadership and commitment are very important factors effecting the reengineering success.

REFERENCES

1. Davenport, T.H., "Process Innovation: Reengineering Work Through Information Technology", Ernst & Young, USA, 1993, pp.167-168.
2. Tersine, R.J., "Principles Of Inventory And Materials Management", N.J., Prentice Hall, 1994, pp.2-19,263,474.
3. Sandvig, J.C., "Vitalizing A Service Parts Inventory", Production and Inventory Management Journal , Vol. 39, No.1., 1998, p.65.
4. Dewar, R.D. and Dutton, J.E., "The Adoption of Radical and Incremental Innovations: An Emperical Analysis", Management Science 32:11, 1986, pp. 1422-1433.
5. Davenport, T.H., "Rank Xerox U.K. (A) and (B)",N9-192-071 and N9-192-072, Boston, Harvard Business School, 1992.
6. Davenport, T.H. and Short, J.E., "The New Industrial Engineering: Information Technology and Business Process Redesign", Sloan Management Review (Summer 90): 11-27.
7. Dean M.Scroeder and Alan G.Robinson, "America's Most Successful Export to Japan: Continuous Improvement Programs", Sloan Management Review (Spring 1991): 67-81.
8. Robert B.Kaplan and Laura Murdock, "Core Process Redesign", McKinsey Quarterly (Summer 1991): 27-43.
9. R.Hayes, "Strategic Planning: Forward in Reverse?", Harvard Business Review, (Nov-Dec 1985): 111-119.
10. D.L.Barton, "The Role of Process Innovation and Adaptation in Attaining Strategic Technological Capability", Boston, Harvard Business School, Division of Research, 1990.
11. Zuboff, S., "In the Age of The Smart Machine: The Future of Work and Power", New York: Basic Books, 1988.
12. Fritz J. Roethlisberger and William J. Dickson, *Management and the Worker* (Cambridge, Mass.: Harvard University Press, 1939).
13. Eric Trist and K. Bamforth, "Some Social and Psychological Consequences of the Longwall Method of Goal Getting," *Human Relations* 4 (February 1951): 3-38; also see Eric Trist et al., *Organizational Choice* (London: Tavistock Publications, 1963).
14. Thomas G. Cummings and Edmond S. Molloy, "*Improving Productivity and the*

- Quality of Work Life*" (New York: Praeger, 1977): 38-49.
15. Ikujiro Nonaka, "Redundant, Overlapping Organization: A Japanese Approach to Innovation," *California Management Review* 32:3 (Spring 1990): 27-38.
 16. Kaoru Ishikawa, "*What Is Total Quality Control? The Japanese Way*" (Englewood Cliffs, N.J.: Prentice-Hall, 1985): 89.
 17. Deborah Gladstein Ancona and David E. Caldwell, "Cross-Functional Teams: Blessing or Curse for New Product Development?" in Thomas A. Kochan and Michael Useem, eds., *Transforming Organizations* (New York: Oxford University Press, 1992): 154-166.
 18. Donna B. Stoddard, *Information Technology and Design/Manufacturing Integration*, Ph.D. Thesis., Harvard Business School, 1991.
 19. J. Richard Hackman, "The Design of Work Teams" in J. W. Lorsch, ed., *Handbook of Organizational Behavior* (Englewood Cliffs, N.J.:Prentice-Hall, 1987).
 20. For an overview of information technology support for meetings, see A. Dennis et al., "Information Technology to Support Electronic Meetings," *MIS Quarterly* (December 1988): 591-624.
 21. Susanna Oppen and Henry Fersko-Weiss, *Technology for Teams* (New York: Van Nostrand Reinhold, 1992).
 22. Robert Johansen, *Groupware: Computer Support for Business Teams* (New York: Free Press, 1988).
 23. Irene Greif, ed., *Computer-Supported Cooperative Work: A Book of Readings* (San Mateo, Calif.: Morgan Kaufmann Publishers, 1988).
 24. Richard E. Walton, *Up and Running: Integrating Information Technology and the Organization* (Boston: Harvard Business School Press, 1989).
 25. William Lazonick, "Value Creation on the Shop Floor: Skill, Effort, and Technology in U.S. and Japanese Manufacturing," working paper, Harvard Business School, February 1988.
 26. Robert Hayes and Steven Wheelwright, "Japanese Approaches to Manufacturing Management," in *Restoring Our Competitive Edge* (New York: John Wiley, 1984): 352-374.
 27. Craig Lambert, "The Electronic Tutor," *Harvard Magazine* (November-December 1990): 4251.
 28. J. Richard Hackman and Greg R. Oldham, "Motivation Through the Design of Work: Test of a Theory," *Organizational Behavior and Human Performance* 16 (1976): 250-279.
 29. R. Hill, "Working on the Scanlon Plan," *International Management* (1974): 39-43; also E. Smith and G. Gude, "Reevaluation of the Scanlon Plan as a Motivational Technique," *Personnel Journal* 50 (December 1971): 916-923.
 30. Gibson and Davenport, "Systems Change: Managing Organizational and Behavioral Impact", 1998, pp. 23-27.
 31. Gini Graham Scott, "Making Effective Decisions Through Brainstorming," *Manage*, 41:3 (November-December 1989): 34-36.

32. Dorothy Leonard-Barton, "The Case for Integrative Innovation: An Expert System at Digital," *Sloan Management Review* (Fall 1987): 7-19 and "Implementation as Mutual Adaptation of Technology and Organization," *Research Policy* (February 1988): 251-267.
33. Steven Dichter, "The Organization of the 90's," *McKinsey Quarterly* 1 (1991): 145-155.
34. David A. Nadler, "Organizational Frame Bending: Types of Change in the Complex Organization," in Ralph H. Kilmann and Teresa, J. Covin, eds., *Corporate Transformation: Revitalizing Organizations for a Competitive World* (San Francisco: Jossey-Bass, 1987)
35. David A. Nadler and Michael L. Tushman, "Beyond the Charismatic Leader: Leadership and Organizational Change," *California Management Review* 32:2 (Winter 1990): 77-97.
36. Michael Beer, Russell Eisenstat, and Bert Spector, *The Critical Path to Corporate Renewal* (Boston: Harvard Business School Press, 1990): 5,184.
37. Deborah G. Ancona and David A. Nadler, "Top Hats and Executive Tales: Designing the Senior Team," *Sloan Management Review* (Fall 1989): 20.
38. Andrew Campbell, Marion Devine, and David Young, *A Sense of Mission* (London: Economist Books and Hutchinson, 1990); see also Beer, Eisenstat, and Spector, *The Critical Path to Corporate Renewal*, 189.
39. Hammer, M., "Reengineering Work: Don't Automate, Obliterate", *Harvard Business Review*, 68, Jul-Aug 1990, pp. 104.
40. Harrison, D.B. and Pratt, M.D., "A Methodology for Reengineering Businesses", *Planning Review*, Mar-Apr 1993.
41. Wilcocks, L. and Smith, S. (1995) 'IT-enabled Business Process Reengineering: organizational and human resource dimensions', *Journal of Strategic Information Systems*, 4(2).
42. Hall, G. et al., "How to Make Reengineering Really Work", *Harvard Business Review*, November-December 1993, pp. 119-131.
43. McCabe, D. et al., "Making Sense of Quality: Towards a Review and Critique of Quality Initiatives in Financial Services", *Human Relations*, 51 (3), 1998, pp. 389-411.
44. Grey, C. and Mitev, N. "Reengineering Organisations: Towards a Critical Appraisal", Dept. of Management, University of Leeds, 1995.
45. Grint, K. and Wilcocks, L., "BPR in Theory and in Practice", *New Technology, Work and Employment*, 1995, pp. 99-109.
46. Willmott, H., "Reengineering Business Processes, Managing Human Relations", *New Technology, Work and Employment*, 1995, pp. 89-98.
47. Vankatraman, N., "Information Technology and the Network Firm", in M.S. Scott Martin (ed.), "The Corporation of 1990s: IT and Organisational Transformation", Oxford University Press, 1991.
48. Filipowski, D., "Is Reengineering More Than a Fad?", *Personnel Journal*, Special Report, December 1993, 48.

49. Hammer, M. and Champy, J., "Reengineering the Corporation: A Manifesto for Business Revolution", London, Nicholas Brealey, 1993.
50. Brown, T., "*de-engineering the Corporation*", Industry Week, April 1994, pp. 18-26.
51. Conti, R.F. and Warner, M., "Taylorism, Teams and Technology in Reengineering Work Organization", New Technology, Work and Employment, 1994, pp. 93-102.
52. Pascale, R., "Intentional Breakdown and Conflict by Design", Planning Review, 22(3), 1994, pp. 1-7.
53. Alter, A.E., "Japan Inc. Embraces Change", Computer World, March 7, 1994.
54. Schlender, B.R., "Japans White Collar Blues", Fortune, 21 March 1994, pp.32-37.
55. Hammer, M., "Hammer Defends Reengineering", The Economist, 5 November 1994, p.96.
56. Ballou, R.H., "Reengineering at American Express: The Travel Services Group's Work In Process", Interfaces, 1995, pp.22-29.
57. Dutta, S and Teboul, J., "Reengineering Customer Services", INSEAD Fontainebleau, Paris, 1994.
58. Masri, S. and Nagle, D., "Merrill Lynch: The Securities Process Automation Project (A)", Columbia Business School, New York, 1994.
59. Masri, S. and van Biema, M., "Solomon Brothers: The Tampa Operations", Columbia Business School, New York, 1994.
60. Topp, W., "Southern Life Association: Critical Evaluation Within Business Process Reengineering", In Solving Problem Solving, Ed. Flood, R.L., Wiley, Chichester, 1995.
61. Vankatraman, N., "IT Enabled Business Transformation: From Automation to Business Scope Redefinition", Sloan Management Review, Winter 1994, pp.73-87.
62. Peppard, J. and Preece, I., "The Content, Context and Process of BPR", Kogan Page, London, 1995, pp.157-185.
63. Peppard, J. and Rowland, P., "The Essence of Business Process Reengineering", Prentice Hall, Hemel Hempstead, 1995.
64. Peppard, J., "Broadening Visions of BPR", International Journal of Management Science, Vol 24, Elsevier, Oxford, England, 1996.
65. Davenport, T.H. and Stoddard, D.B., "Reengineering: Business Change Mythic Proportions", MIS Quarterly, June 1994, pp. 121-127.
66. Shingo, S., "The Toyota Production System", Productivity Press, Cambridge MA, 1989.
67. Edwards, C. and Peppard, J., "Business Process Redesign", Journal of Information Technology, 9, 1994, pp.251-266.
68. Meirs, D., "Process Product Watch", Vol. 1-4, Richmond Surrey, England, 1994-95.

69. MacArthur, P.J. et al., "A Strategy for Evaluating Alternative Information System Designs for BPR", *Int. Journal of Information Management*, 14, 1994, pp.237-251.
70. Martinez, E.V., "Successful Reengineering Demands IS Business Partnerships", *Sloan Management Review*, Summer 1995, pp. 51-60.
71. Morgan, G., "Images of Organisations", Sage, Newbury Park CA, 1986.
72. Cooper, R.S. and Markus, M.L., "Human Reengineering", *Sloan Management Review*, Summer 1995, pp.39-50.
73. Willcocks, L. and Smith, G., "IT-enabled Business Process Reengineering: Human and Organisational Dimensions", *Journal of Strategic Information Systems*, 1995, p.3.
74. Willmott, H., "The Reengineering of Human Resources", In *Exploring Business Process Reengineering: Reflections and Research Directions*, Kogan Page, London, 1995, pp.306-315.
75. Caron, J.R. et al., "Business Reengineering at CIGNA", *MIS Quarterly* 18, 1994, pp.233-250.
76. McHugh, P. et al., "Beyond Business Process Reengineering: Towards the Holonic Enterprise", Wiley, Chichester, 1995.
77. Quinn, J.B. and Hilmer, F.G., "Strategic Outsourcing", *Sloan Management Review*, Summer 1994, pp.43-55.
78. Normann, R. and Ramirez, R., "From Value Chain to Value Constellation: Designing Interactive Strategy", *Harvard Business Review*, July-August 1993, pp. 65-77.
79. Davidson, W.H., "Beyond Reengineering: The Three Phases of Business Transformation", *IBM Syst. J.* 32, 1993, pp.65-79.
80. Womack, J. and Jones, D.T., "From Lean Production to the Lean Enterprise", *Harvard Business Review*, March-April 1994, pp.93-103.
81. Johansson, H.J. et al., "BPR: Breakpoint Strategies for Market Dominance", Wiley, Chichester, 1993.
82. Prahalad, C.K. and Hamel, G., "Strategy as a Field of Study", *Strategic Management Journal* 15, 1994, pp.5-16.
83. Hammer, M. and Stanton, S., "The Reengineering Revolution: A Handbook", Harper Collins, New York, 1995.
84. Rohit, T., "Business Reengineering- A Strategy Driven Approach", Elsevier Science Ltd., Oxford, England, 1993.
85. Wild, T., "Best Practice in Inventory Management", Woodhead Publ.Ltd., Cambridge, England, 1997.
86. Van DeMark, R., "Inventory Control Techniques", Dallas, Van DeMark Inc., 1981, pp. 40-70.
87. Wagner, H.M. and Whitin, T.W., "Dynamic Version of the Economic Lot Size Model," *Management Science*, Vol. 5, October 1958, pp. 89-96.
88. Silver, E.A. and Meal, H.C., "A Simple Modification of the EOQ for the Case of

- Varying Demand Rate”, *Production and Inventory Management*, Vol. 10, No. 4, 4th Qtr., 1969, pp. 52-65.
89. Groff, G.K., “A Lot Sizing Rule for Time-Phased Component Demand”, *Production and Inventory Management*, Vol. 20, No. 1, 1979, pp. 47-53.
 90. Bowersox, D., “Logistical Management: The Integrated Supply Chain Process”, McGraw Hill, 1st Ed, 1996, pp. 24-45.
 91. Stock, J.R. "Managing Computer, Communication and Information Technology Strategically: Opportunities and Challenges for Warehousing," *The Logistics and Transportation Review*, 26:2, June 1990, pp. 132-148.
 92. Introna, L.D. "The Impact of Information Technology on Logistics," *International Journal of Physical Distribution. and Logistics Management*, 21:5, 1991, pp. 32-37.
 93. Emmelhainz, M., “EDI: A Total Management Guide”, New York: Van Nostrand Reinhold, 1990.
 94. Youngblood, C., “EDI Trial and Error”, *Transportation Distribution*, 34:4, April 1993, p. 46.
 95. Gordon, G., “System Simulation”, Englewood Cliffs, NJ., Prentice-Hall, 1969.
 96. Forrester, J.W., “Principles of Systems”, Cambridge, Wright-Allen Press, 1969.
 97. Maffei, R.B., "Simulation: Tool for Better Distribution", *Harvard Business Review*, 38:6, November-December 1960, pp. 65-75.
 98. Parker, D.D., "Improved Efficiency and Reduced Cost in Marketing," *Journal of Marketing*, 26, April 1962, pp. 15-21.
 99. Camp, R.C., “Benchmarking: The Search for Industry Best Practices That Lead to Superior Performance”, New York: Quality Resources, 1989.
 100. Mohanty, R.P., “Value Innovation Perspective in Indian organizations, Participation and Empowerment”, “*International Journal of Production Economics*”, 7 (4), 1999, pp. 88 - 103.
 101. S. Aggarwal, “Reengineering A Breakthrough or Little New”, *International Journal of Technology Management*, 13 (3), 1997, pp.326-344.
 102. Mohanty, R.P., “What We Need to Know About BPR”, *Industrial Engineering Journal*, 23 (12), 1997, pp. 1 - 8.
 103. Zairi, M., “Business Process Reengineering and Process Management”, *Work Study*, 44 (6), 1995, pp.3-16.
 104. Evans, G.N., Naim, M., “Business Process Reengineering the Supply Chain”, *Production Planning and Control* 6 (3), 1996, pp.227-237.
 105. Davis, T., “Effective Supply Chain Management”, *Sloan Management Review*, Vol. 34, 1993, pp.65-73.
 106. Farley, G., “Discovering Supply Chain Management”, *APICS*, 1997, pp.38-39.
 107. Mohanty, R.P., “Reengineering of materials management system: A case study”, “*International journal of Production Economics*”, Elsevier, 2001, pp. 267-278.
 108. Morris, D.C., “Reengineering Your Business”, McGraw-Hill, New York, 1993.

109. Olsen, S.A., "Group Planning and Problem Solving Methods in Engineering Management", John Wiley, New York, 1982.
110. Mohanty, R.P., "Reengineering of a Supply Chain Management: A Case Study", Production Planning and Control, 11 (1), 2000, pp. 90-104.
111. Mohanty, R.P., "Goal Programming Applications for Some Problems in Materials Management", Engineering Costs and Production Economics, 3 (8), 1984, pp.221-234.
112. Nonaka, I., "The Knowledge Creating Company", Harvard Business Review, 71 (1), 1991, pp.97-103.

APPENDICES

APPENDIX A

REENGINEERING MASTER PLAN

1. *APL Management Problems for Derivative Products*

TEAM: PE, PU, PL, PR

	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
1.1.	Formation of Advanced Product Lists for Derivative Military Vehicles	1	PE, PU, PL, PR	4 Base Product Definitions + Options System	Decrease the quantity of inactive items after production for base products
					Decrease the quantity of inactive items after production for optional systems
					Time period between marketing request and purchasing order
					Decrease production material transportation cost
1.2.	Formation of Advanced Product Lists for Derivative Trailers	1	PE, PU, PL, PR	6 Standard Product Definitions	Decrease the quantity of inactive items after production
					Decrease time period between marketing request and production
					Decrease production material transportation cost
				Description of product definition, purchasing and production process flows	Start declared standard time (design freeze) for product definition

REENGINEERING MASTER PLAN

2. *Missing Planning Functions*

TEAM : MH, PL, PR, IT

	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
2.1.	Classification of urgency of demands of inventory from different functions (production vs spare parts)	4	MH, PL, PR, SP, IT	Redesign of delivery labels	Control material transfers and take precautions before shortage due to priority mistakes
				Responsibility definition to track the cases	
					Separate spare parts stock and increase turnover rate
				New Spare Parts Stock Area	Separate spare parts stock and increase control over spare parts safety stocks
2.2.	In-house manufacturing control	3	MH, PR, PL	Planning of In-house Manufacturing on MRP system	Decrease the amount of shortages and excess stocks due to planning mistakes
					Decrease differences between actual and recorded stocks
					Decrease production without work orders
				Raw material tracking system	Decrease raw material safety stocks
2.3.	Tracking of engineering changes	2	PL, PE, PU, QU, PF, IT	IT Solution for New Product Release & Effectivity	Immediate sharing of correct information between functions
					Prevent inactive stock formation
				Engineering Change Meetings	Determination of correct effectivity dates and chassis numbers

REENGINEERING MASTER PLAN					
2.	Missing Planning Functions	TEAM : MH, PL, PR, IT			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
2.4.	Weak control on hardware	4	MH, PU	New hardware stock area	Speed up hardware materials handling
				New hardware transfer method to production lines	Decrease hardware material safety stocks
2.5.	Material Handling coordination problems	3	MH, PL, PE, IT	Organizational Change	Increase efficiency of coordination between Material Handling and Planning teams
					Increase efficiency of coordination between active manufacturing departments
				Line Loading via System Data	Introduction of lacking planning functions
2.6.	Simultaneous transfer of materials (Recorded vs. Physical)	3	MH, PR	Definition of responsible personnel in stock area	Speed up line loading
				Definition of coordination between Stock Area and Production line operators	Prevent production line stockout problems
					Decrease number of late material transfer entries to the system
2.7.	Poor coordination, evaluation of feed-back from production line	3	PL, PR	Formation of Work Order Analysis Teams	Decrease production line stock deviations
					Prevent product cost errors
					Find and eliminate incorrect inventory data
				Continuous inventory auditing using WOAT and material tracking team results	Find and eliminate incorrect part routings
					Find and eliminate APL errors
					Correction of existing errors on system records
REENGINEERING MASTER PLAN					
3.	Inventory Audit Problems	TEAM: PR, PU, MH, IT, PF			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
3.1.	Work - in - process inventory audit problems	4	PF, IT, PR	Bringing All Vehicles in One Location to the End of Location Montage Level	Eliminate WIP listing and decrease WIP counting time
3.2.	Subassembly audit problems	4	PU, MH, IT	Bringing All Subassemblies to Completed Form	Eliminate WIP manual counting errors
					Eliminate Subassembly listing and decrease Subassembly counting time
3.3.	Counting the inventory in wrong codes and unit conflicts (Causing inventory deviations)	3	PU, MH, IT	Review of part codes of trailer company	Eliminate Subassembly manual counting errors
				Review units of part groups (sheet metal, pipes, oils, chemicals etc.)	Eliminate double codes
				Inventory Audit preparations (Education, detailed line addressing, personnel planning, equipment planning, consultancy teams)	Eliminate R&D defined and purchased unit differences
				Fixed addressing and barcoding	Decrease counting in wrong codes and unit conflicts in the short run
					Eliminate counting in wrong codes and unit conflicts by 2006

REENGINEERING MASTER PLAN					
4.	Stock Area Problems	TEAM: PL, MH, PU, QU, PR			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
4.1.	Difficulties of tracking of hardware materials	4	PL, PU, PR	Eliminate redundant codes	Decrease total hardware stock
					Decrease redundant shelves in Hardware Stock Area
				Decrease variety of hardware material types	Decrease total hardware stock
				Use single coding system	Decrease redundant shelves in Hardware Stock Area & purchasing orders
4.2.	Disorder in Main Stock Area	2	MH, PL	Redesign of stock area on a product basis	Stop generation of redundant codes
				Increase total storage area	Ease of material transfer to assembly lines
4.3.	Difficulties of tracking of old & excessive stocks	2	PL, MH, PU, QU	Separate Old & Excessive Stock Area	Decrease material damage in stock area
					Decrease total old&excessive stock
					Increase turnover ratio
REENGINEERING MASTER PLAN					
5.	Ordering Problems	TEAM: PU, QU, PL, PR			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
5.1.	Sending / Approval time of purchase orders	2	PU, QU, PL, PR	Sending order plans on the web	Increase number of vendors communicated on the web
					Decrease average sending time
				Fax automation for vendors not using EDI	Decrease average sending time
				Receiving order approvals on the web	Increase number of vendors communicated on the web
5.2.	Long lead times	3	PU		Decrease average approval time
				Nearer vendors	Decrease average transport time
					Decrease total transportation cost
				Less vendors	Better coordination and power on vendors
					Elimination of low performance vendors
				Revised contracts with critical vendors	Change inventory policy of critical vendors
REENGINEERING MASTER PLAN					
6.	Incoming Material Entry Problems	TEAM: PU, QU, MH, PL, IT			
	DEFINED PROBLEMS	PRIORITY LEVEL	RELATED DEPTS	PROPOSED SOLUTIONS	GOALS
6.1.	Incoming material entry (registry out of factory / acceptance criteria)	4	PU, PL, MH	IT solution for acceptance criteria	Reject not ordered, excessive or early lots of materials and parts
				Early registry of trucks out of factory	Organize truck entries to the factory and decrease total unloading time
6.2.	Lack of tracking of materials going out of factory for machining and coating	3	MH, PL, PU	IT solution for part coding and reentry system	Eliminate mixing of parts send/not send to vendors for machining & coating
					Decrease stock deviations
					Correct reflection of labor costs to the total vehicle costs
6.3.	Material quality inspection problems	4	QU, MH, PU, IT	Pass & Periodic Control Systems	Increase total number of daily approved parts
				IT solution for recording inspection results	Decrease average inspection time per item

1. APL MANAGEMENT WORK SCHEDULES

1.1. Formation of Advanced Product Lists for Derivative Military Vehicles

	Action Plan for Launching 4 Base Products + Options System	2002												2003												2004																							
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D												
1	The definition of the 4 base products by Product Reengineering.																																																
2	The definition of the options by Product Reengineering.																																																
3	Updating of the documentation.																																																
4	Presentation of the new system.																																																
5	Implementation.																																																

1.2. Formation of Advanced Product Lists for Derivative Trailers

	Action Plan for Start of Design Freeze	2002												2003												2004																							
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D												
1	First meeting – Studies on process flow																																																
2	Determination of empirical work durations																																																
3	Implementation and control																																																
4	Corrections																																																
	Action Plan for Standardisation	2002												2003												2004																							
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D												
1	Definition of Standard Types																																																
1.1.	Product 1 Advanced Product List																																																
1.2.	Product 2 Advanced Product List																																																
1.3.	Product 3 Advanced Product List																																																
1.4.	Product 4 Advanced Product List																																																
1.5.	Product 5 Advanced Product List																																																
1.6.	Product 6 Advanced Product List																																																
2	Updating of the documentation.																																																
3	Presentation of the new system.																																																
4	Implementation.																																																

2. MISSING PLANNING FUNCTIONS WORK SCHEDULES

2.1. Classification Of Urgency Of Demands Of Inventory From Different Functions

	Action Plan for Redesign of Labels	2002												2003												2004																							
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D												
1	Description of required information on new labels																																																
2	Preparation of digital labels by IT department																																																
3	Integration to the current system																																																
4	Pilot Implementation																																																
5	Deployment																																																
	Action Plan for New Spare Parts Stock Area	2002												2003												2004																							
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1	Investment Planning for New Spare Parts Stock Area																																																
2	Supply of Required Shelves and Equipment																																																
3	Construction & Installation																																																
4	Counting and Transferring the Spare Parts to New Spare Parts Stock Area																																																
5	Definition of Responsibilities for the New Process Flow																																																
6	Implementation																																																

2. MISSING PLANNING FUNCTIONS WORK SCHEDULES

2.2. In-house Manufacturing Control

	Action Plan to Control In-House Manufacturing	2002												2003												2004													
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D		
1	Collection of all machine capacities data																																						
2	Time studies for in-house manufactured items																																						
3	Definition of process sequences																																						
4	Determination of lot sizes with respect to Vehicle Production Plan																																						
5	Completion of operation pages																																						
6	Start of work orders for in-house manufacturing items on the system by Planning Department																																						
7	In-house manufacturing depending on MFG-Pro results																																						

2.3. Tracking of Engineering Changes

	Action Plan for New Module Definition and Implementation	2002												2003												2004													
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D		
1	Meetings to define the new work flow and required module to IT																																						
2	Design of New Module																																						
2.1	Design of Data Entry Form for Purchasing																																						
2.2	Design of Data Entry form for Production Facilities																																						
2.3	Design of Data Entry form for Planning																																						
2.4	Design of Data Entry form for Quality																																						
3	Preparation of engineering changes meetings procedure																																						
4	Presentation of new module and flow																																						
5	Implementation																																						

2.4. Weak Control on Hardware

	Action Plan for New Hardware Stock Area and Transfer Method	2002												2003												2004													
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D		
1	Requirement definitions for new hardware stock area																																						
2	Arrangement of shelves and review of part codes																																						
3	Construction and physical arrangement																																						
4	Counting and transfer of hardware materials to the new hardware stock area																																						
5	Definition of responsibilities for the new hardware transfer method to assembly lines																																						
6	Determination of new safety stock levels																																						
7	Implementation																																						

2. MISSING PLANNING FUNCTIONS WORK SCHEDULES

2.5. Material Handling Coordination Problems

	Action Plan for Establishment of Planning Department	2002												2003												2004													
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D		
1	Preparation of job definitions for Planning Department Personnel																																						
2	Arrangement of offices and equipment																																						
3	Posting required personnel																																						
4	Definition of new process flow on procedures																																						
5	Declaration																																						
	Action Plan for Automatic Line Loading	2002												2003												2004													
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D		
1	Pilot implementation of listing line requirements using system data																																						
2	Determination of deviations from actual requirements																																						
3	Elimination of Advanced Product Lists and routing errors																																						
4	System establishment to track Advanced Product Lists and routing errors																																						
5	Definition of new process flow on procedures																																						
6	Implementation																																						

2.6. Importance of Registered Transfer of Materials, at the Same Time with Physical

	Action Plan to Control Registered Material Flow	2002												2003												2004												
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
1	Preparation of job definition for Stock Area Operator																																					
2	Posting required personnel																																					
3	Definition of coordination between Stock Area Operator and Line Operators on procedures																																					
4	Declaration																																					
5	Implementation																																					

2.7. Poor Coordination and Evaluation of Feedback From Production Line

	Action Plan for Production Line Feedback Coordination and Evaluation	2002												2003												2004												
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
1	Examination of the Current Flow																																					
2	Preparation of Procedure for Work Order Analysis Team and Meetings																																					
3	Formation of Infrastructure for Corrective Action Tracking																																					
4	Implementation																																					
	Action Plan for Organizing Continuous Inventory Audits	2002												2003												2004												
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
1	Assignment of a Responsible Personnel for Continuous Auditing																																					
2	Determination of Material Groups and Audit Frequencies																																					
3	Defining the System of Auditing																																					
4	Preparation of Procedures and Declaration																																					
5	Implementation																																					

3. INVENTORY AUDIT WORK SCHEDULES

3.1. *Work-In-Process Inventory Audit Problems*

	Action Plan to Change Inventory Audit Preparation of WIP Vehicles	2002												2003												2004																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
1	Study of Necessary Completion Montage Time on Assembly Lines																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				</

3.2. *Subassembly Audit Problems*

	Action Plan to Change Inventory Audit Preparation of Subassemblies	2002												2003												2004																							
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1	Study of Necessary Completion Time of Subassemblies																																																
2	Study of Necessary Materials Handling Change																																																
3	Definition of New Work Flow and Responsibilities																																																
4	Declaration																																																
5	Implementation																																																

3.3. *Counting the Inventory In Wrong Codes and Unit Conflicts (Causing Inventory Deviations)*

	Action Plan for Establishment of Fixed Addressing and Barcoding	2003												2004												2005																							
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D												
1	Preparation of Material Flow Models for Product Groups																																																
2	Benchmarking Fixed Addressing from Companies with Similar Products and Flows																																																
3	Selecting Appropriate Barcoding System																																																
4	Investments for New Shelves and Reorganization of Assembly Lines and Stock Areas																																																
5	Installation of Barcoding Infrastructure																																																
6	Addressing and Labeling of Containers and Shelves																																																
7	Training (Barcode Usage)																																																
8	System Introduction Briefs																																																
9	Implementation (Inventory Audit at the End of 2005)																																																

4. STOCK AREA WORK SCHEDULES	
4.1.	<i>Difficulties of Tracking of Hardware Materials</i>

[illegible]

[illegible]

4.3.	<i>Difficulties of Tracking of Old & Excessive Stocks</i>
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[illegible]

5. ORDERING WORK SCHEDULES

5.1.	<i>Sending / Approval Time of Purchase Orders</i>
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[illegible]

5. ORDERING WORK SCHEDULES

5.2. Long Lead Times

	Action Plan to Decrease Long Lead Times	2002												2003												2004												
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
1	Grouping Similar Parts																																					
2	Evaluating Vendor Performances																																					
3	Determination of High Volume Vendors																																					
4	Determination of Critical Items																																					
5	Selection of High Volume and Long Lead Time Items																																					
6	Determination of Required Buffer Stock Levels for Vendors																																					
7	Review of Purchasing Contracts																																					
8	Implementations																																					

6. INCOMING MATERIAL ENTRY WORK SCHEDULES

6.1. Incoming Material Entry (Registry out of Factory / Acceptance Criteria)

	Action Plan for New Incoming Material Entry Process Flow	2002												2003												2004												
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
1	Planning of New Truck Parking Area																																					
2	Rearrangement of Parking Area and Vehicle Flow																																					
3	Determination of Acceptance Criteria by Purchasing Team																																					
4	Preparation of Software for New Criteria and MFG-Pro Software Customization																																					
5	Informing Vendors & Transporters About New System																																					
6	Definition of Recording Personnel and Hardware for Main Entrance																																					
7	Documentation Changes for the New Flow																																					
8	Implementation																																					

6.2. Lack of Tracking of Materials Going Out of Factory for Machining and Coating

	Action Plan for Tracking of Materials Going Out of Factory for Machining and Coating	2002												2003												2004													
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D		
1	Listing of Out Worked Parts and Materials																																						
2	Definition of New Coding system & Restructuring of Advanced Product Lists																																						
3	Definition of a New Location for Parts and Materials Out of Factory																																						
4	Review of Financial Aspects																																						
5	MFG-Pro Software Customization																																						
6	Responsibility Definitions for Sending and Reentry Recording																																						
7	Implementation																																						

6.3. Material Quality Inspection Problems

	Action Plan for Restructuring the Incoming Material Inspection Process	2002												2003												2004												
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
1	Revision of Vendor Quality Performance Tracking System																																					
2	Determination of Pass Authorised Vendors																																					
3	Preparation of Vendor Quality/Process Audits and Visits Program																																					
4	Determination of Periodic Control Authorised Vendors/Parts																																					
5	Review of Vendor Contracts for Pass and Periodic Control Authorisation																																					
6	Preparation of Software Package for Online Recording																																					
7	Determination of Inspections to be Shifted to Vendors																																					
8	Implementations																																					

APPENDIX B

	INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
	Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
1.1.	Inactive stock generated / # of derivatives produced	year 2002 307.000 USD/670 units = 458 USD/unit produced	year 2003 300.000 USD/800 units = 375 USD/unit produced	year 2003 264.000 USD/798 units = 330 USD/unit produced	(458-375) USD/unit x 800 units produced = 66.400 USD	(458-330) USD/unit x 798 units produced = 102.144 USD
	Change in Stock <1 year / # of derivatives produced	year 2002 53.000 USD/670 units = 79 USD/unit produced	year 2003 50.000 USD/800 units = 62,5 USD/unit produced	year 2003 44.000 USD/798 units = 55 USD/unit produced	(79-62,5) USD/unit x 800 units produced = 13.200 USD	(79-55) USD/unit x 798 units produced = 19.152 USD
	Average # of work days from marketing request to purchasing order	31 days	11 days	11 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
	production material transportation cost / # of derivatives produced	year 2002 89.800 USD/670 units = 134 USD/unit produced	year 2003 96.000 USD/800 units = 120 USD/unit produced	year 2003 102.000 USD/798 units = 128 USD/unit produced	(134-120) USD/unit x 800 units produced = 11.200 USD	(134-128) USD/unit x 798 units produced = 4.788 USD
1.2.	Inactive stock generated / # of derivatives produced	year 2002 528.000 USD/961 units = 549 USD/unit produced	year 2004 550.000 USD/1100 units = 500 USD/unit produced	year 2004 597.000 USD/1165 units = 513 USD/unit produced	(549-500) USD/unit x 1100 units produced = 53.900 USD	(549-513) USD/unit x 1165 units produced = 41.940 USD
	Average # of work days from marketing request to purchasing order	71 days	48 days	48 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
	Production material transportation cost / # of derivatives produced	year 2002 88.400 USD/961 units = 92 USD/unit produced	year 2004 80.000 USD/1100 units = 73 USD/unit produced	year 2004 94.500 USD/1165 units = 81 USD/unit produced	(92-73) USD/unit x 1100 units produced = 20.900 USD	(92-81) USD/unit x 1165 units produced = 12.815 USD
	Average # of work days from marketing request to design freeze	21 days	6 days	6 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
2.1.	Annual number of stockout items / due to priority mistakes / total annual inventory used	year 2002 275 items / 350 items (average number of items per day) x 250 days = 3.142 PPM	year 2004 100 items / 350 items (average number of items per day) x 250 days = 1.143 PPM	year 2004 32 items / 400 items (average number of items per day) x 250 days = 320 PPM	(Additional amount sold x profit margin) - Holding Cost = [(7,7 - 6,6) milyon USD x 15 %] - [(2,4 - 2,1) milyon USD x 4 %] = 165.000 - 12.000 = 153.000 USD	(Additional amount sold x profit margin) - Holding Cost = [(8,75 - 6,6) milyon USD x 15 %] - [(2,5 - 2,1) milyon USD x 4 %] = 322.500 - 16.000 = 306.500 USD
	Turnover rate	year 2002 Turnover rate = CGS / Average monthly stock = 6,6 milyon USD / 2,1 milyon USD = 3,14	year 2004 Turnover rate = CGS / Average monthly stock = 7,7 milyon USD / 2,4 milyon USD = 3,21	year 2004 Turnover rate = CGS / Average monthly stock = 8,75 milyon USD / 2,5 milyon USD = 3,51		
	Annual number of back order items / total annual spare parts orders	year 2002 3942 items / 238 items (average number of items per day) x 250 days = 6,6 %	year 2004 3000 items / 250 items (average number of items per day) x 250 days = 4,8 %	year 2004 2074 items / 298 items (average number of items per day) x 250 days = 2,8 %		
2.2.	Quantity of stockout and excess items/cases due to planning mistakes	year 2003 39.600 items / 400 (Average in-house items produced per vehicle) x 3.377 (total production in 2003) = 29.310 PPM	year 2004 32.000 items / 400 (Average in-house items produced per vehicle) x 4.000 (total production in 2004) = 20.000 PPM	year 2004 19.756 items / 400 (Average in-house items produced per vehicle) x 4.371 (total production in 2004) = 11.300 PPM	5.000 less inactive stock items x 4,2 USD (average value of inactive stock generated) = 21.000 USD	11.800 less inactive stock items x 4,2 USD (average value of inactive stock generated) = 49.560 USD
	Production (%) without work orders	year 2003 283.600 items produced without w/o / 400 (Average in-house items produced per vehicle) x 3.377 (total production in 2003) = 21 %	year 2004 192.000 items produced without w/o / 400 (Average in-house items produced per vehicle) x 4.000 (total production in 2004) = 12 %	year 2004 106.650 items produced without w/o / 400 (Average in-house items produced per vehicle) x 4.371 (total production in 2004) = 6,1 %		
	Amount/percent of raw material safety stocks	end of 2002 770.000 USD (safety stock armour steel included) / 2,6 million USD (total raw material) = 29,6 %	end of 2003 750.000 USD (safety stock armour steel included) / 3 million USD (total raw material) = 25 %	end of 2003 884.000 USD (safety stock armour steel included) / 3,3 million USD (total raw material) = 26,8 %		
2.3.	Inactive stock due to uncontrolled engineering changes	year 2002 283.000 USD (total amount in 2002) / 904 units = 313 USD / unit	year 2004 250.000 USD (total amount in 2004) / 900 units = 278 USD / unit	year 2004 164.016 USD (total amount in 2004) / 816 units = 201 USD / unit	(283.000 - 250.000) USD = 33.000 USD	(283.000 - 164.016) USD = 118.984 USD
	Number or percent of correct/on time engineering changes	year 2002 1.524 issues / 1.802 total issues = 84,5 %	year 2004 1.600 issues / 1.800 total issues = 89 %	year 2004 1.673 issues / 1.917 total issues = 87,3 %		
2.4.	Delivery time to production lines from inventory	Start of 2002 Average time = (153 minutes / (5 minibuses + 6 midibuses) = 13,9 minutes/per vehicle	Start of 2003 Average time = (110 minutes / (5 minibuses + 6 midibuses) = 10 minutes/per vehicle	Start of 2003 Average time = (45 minutes / (3 minibuses + 4 midibuses) = 6,4 minutes/per vehicle	(13,9 - 10) minutes x 1 USD x 3.500 vehicles = 13.650 USD	(13,9 - 6,4) minutes x 1 USD x 3.377 vehicles = 25.328 USD
	Financial value of inactive hardware in stocks	Start of 2002 older than one year = 42.000 USD	Start of 2003 older than one year = 30.000 USD	Start of 2003 older than one year = 22.200 USD	(42.000 - 30.000) USD = 12.000 USD	(42.000 - 22.200) USD = 19.800 USD
	Amount/percent of hardware safety stocks	start of 2002 148.000 USD (safety stock) / 247.000 USD (total hardware stock) = 60 %	start of 2003 125.000 USD (safety stock) / 247.000 USD (total hardware stock) = 51 %	start of 2003 108.000 USD (safety stock) / 271.000 USD (total hardware stock) = 40 %	at the start of 2003 60% x 247.000 USD = 148.200 USD safety stock would be kept Holding cost saved = (148.200 - 125.000 USD) x 4 % = 928 USD	at the start of 2003 60% x 271.000 USD = 162.600 USD safety stock would be kept Holding cost saved = (162.600 - 108.000 USD) x 4 % = 2.184 USD

	INDICATOR CHANGE				FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
	Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
2.5.	Establishment of new department and definition of responsibilities	-	-	-	-	-
	Start of in-house manufacturing planning	-	-	-	Given in 2.2.	Given in 2.2.
	Launch of engineering changes tracking system	-	-	-	Given in 2.3.	Given in 2.3.
	Start of line loading via system data	-	-	-	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
	Process time	year 2003 Average time = (216 minutes / (5 minibuses + 6 midibuses)) = 19,6 minutes/per vehicle	Start of 2004 Average time = (150 minutes / (5 minibuses + 6 midibuses)) = 13,6 minutes/per vehicle	Start of 2004 Average time = (62 minutes / (3 minibuses + 4 midibuses)) = 8,9 minutes/per vehicle		
2.6.	Number of stockout cases from production line	year 2003 17.560 stockout items / 3.377 (total production in 2003) = 5,2 items/vehicle	year 2004 15.000 stockout items / 4.000 (total production in 2003) = 3,8 items/vehicle	year 2004 7.592 stockout items / 4.371 (total production in 2003) = 1,7 items/vehicle	(5,2 - 3,8) x 4.000 stockout items x 3,4 USD (average additional ordering cost) = 19.040 USD	(5,2 - 1,7) x 4.371 stockout items x 3,4 USD (average additional ordering cost) = 52.015 USD
	Late material transfer entries	start of 2003 38 late entries per day / 560 items loaded per day = 6,8 %	start of 2004 30 late entries per day / 560 items loaded per day = 5,4 %	start of 2004 14 late entries per day / 665 items loaded per day = 2,1 %	1,5 x 4.000 less stockout items from late entries x 3,4 USD (average additional ordering cost) = 20.400 USD	2,3 x 4.371 less stockout items from late entries x 3,4 USD (average additional ordering cost) = 34.181 USD
	Amount/percent of line stock deviations	start of 2003 130,000 USD / 3,4 million USD (total line stocks = 3,8 %	start of 2004 100,000 USD / 3,6 million USD (total line stocks = 2,8 %	start of 2004 54,000 USD / 3,6 million USD (total line stocks = 1,5 %		
2.7.	Number of Items Corrected / Number of Items Found	start of 2003 11,1 average items corrected per day / 17,2 average items found per day = 65 %	start of 2004 15 average items corrected per day / 17 average items found per day = 88 %	start of 2004 14,6 average items corrected per day / 17,8 average items found per day = 82 %	2 items/vehicle x 4.000 vehicles less stockout items due to incorrect system data x 3,4 USD (average ordering cost) = 27.200 USD	2,1 x 4.371 less stockout items from late entries x 3,4 USD (average additional ordering cost) = 31.208 USD
	Number of Items Corrected / Number of Items Found	start of 2003 4,4 average items corrected per day / 7,2 average items found per day = 61 %	start of 2004 5 average items corrected per day / 7 average items found per day = 71 %	start of 2004 14 average items corrected per day / 17 average items found per day = 81 %		
	Number of Items Corrected / Number of Items Found	start of 2003 1,4 average items corrected per day / 6,2 average items found per day = 23 %	start of 2004 2 average items corrected per day / 6 average items found per day = 33 %	start of 2004 14 average items corrected per day / 17 average items found per day = 87 %		
	Number of annual count cycles for each material group	year 2004 (second half) A - 1,5 / B - 0,6 / C - 0,2	year 2005 (first half) A - 4 / B - 2 / C - 1	year 2005 (first half) A - 3 / B - 2,5 / C - 0,5		
3.1.	Total time for listing and counting	start of 2003 4 days	start of 2004 2 days	start of 2004 2 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
	Error per cent	start of 2003 432 items (total manual error) / [30 WIP vehicles x 203 (average manually counted items)] = 7,1 %	start of 2004 300 items (total manual error) / [30 WIP vehicles x 203 (average manually counted items)] = 4,9 %	start of 2004 153 items (total manual error) / [30 WIP vehicles x 211 (average manually counted items)] = 2,4 %		
3.2.	Total time for listing and counting	start of 2003 4 days	start of 2004 2,5 days	start of 2004 2,5 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
	Error per cent	start of 2003 147 items (total manual error) / [226 subassemblies x 7,3 (average manually counted items per subassembly)] = 8,9 %	start of 2004 100 items (total manual error) / [226 subassemblies x 7,3 (average manually counted items per subassembly)] = 6,1 %	start of 2004 34 items (total manual error) / [211 subassemblies x 7,6 (average manually counted items per subassembly)] = 2,1 %		
3.3.	Number of double codes	mid 2003 double codes = 3.256 hardware items + 1.642 raw material items = 4.898 items	mid 2004 double codes = 1.500 hardware items + 750 raw material items = 2.250 items	mid 2004 double codes = 796 hardware items + 534 raw material items = 1.330 items	213.000 USD (total safety stock before study) - 150.000 USD (total safety stock after study) x 4 % = 2.520 USD	213.000 USD (total safety stock before study) - 127.800 USD (total safety stock after study) x 4 % = 3.408 USD
	Number of items with different units	mid 2003 216 items	mid 2004 100 items	mid 2004 62 items	(216 - 100) x 6,4 USD (average value of inactive stock item generated) x 46 units = 34.150 USD	(216 - 62) x 6,4 USD (average value of inactive stock item generated) x 46 units = 45.337 USD
	Percent of total audit error	start of 2003 24 %	start of 2004 10 %	start of 2004 14 %	-	-
	N/A	-	-	-	-	-

		INDICATOR CHANGE			FINANCIAL CHANGE DUE TO INDICATOR IMPROVEMENTS	
	Definition	Before Study	Expected After Study	Achieved After Study	Expected After Study	Achieved After Study
4.1.	Number of redundant codes	start of 2003 3,142 items	start of 2004 1,500 items	start of 2004 714 items	Given in 3.3.	Given in 3.3.
	Total number of redundant shelves / Total shelves	start of 2003 147/926 shelves = 15,9 %	start of 2004 75/926 shelves = 8,1 %	start of 2004 64/926 shelves = 6,9 %	72 shelves x (0,4x0,5x0,5) m ³ space saved = 7,2 m ³ x 78 USD/m ³ = 562 USD	83 shelves x (0,4x0,5x0,5) m ³ space saved = 8,3 m ³ x 78 USD/m ³ = 647 USD
	System launching	-	-	-		
4.2.	Average transfer time to assembly lines	year 2003 Average time = (216 minutes / (5 minibuses + 6 midibuses) = 19,6 minutes/per vehicle	Start of 2005 Average time = (150 minutes / (5 minibuses + 6 midibuses) = 13,6 minutes/per vehicle	Start of 2005 Average time = (62 minutes / (3 minibuses + 4 midibuses) = 8,9 minutes/per vehicle	Given in 2.5.	Given in 2.5.
	Percent of material damaged in total stock	start of 2003 Annual total damaged 56.000 USD / 151 million USD total material purchased = 0,0371 %	end of 2004 Annual total damaged 30.000 USD / 151 million USD total material purchased = 0,0198 %	end of 2004 Annual total damaged 14.000 USD / 151 million USD total material purchased = 0,0093 %	(56.000 - 30.000 USD) = 26.000 USD	(56.000 - 14.000 USD) = 42.000 USD
4.3.	Old&excessive stocks eliminated by selling, rework or exchange / Total Old&excessive stocks	start of 2003 Annual total eliminated 33.000 USD / 3,2 million USD total Old&excessive = 1,03 %	end of 2004 Annual total eliminated 150.000 USD / 3,2 million USD total Old&excessive = 4,69 %	end of 2004 Annual total eliminated 542.000 USD / 3,4 million USD total Old&excessive = 15,9 %	150.000 USD - 33.000 USD saved = 117.000 USD	[542.000 USD x (3,2 / 3,4)] - 33.000 USD saved = 477.117 USD
	Turnover ratio	start of 2003 CGS / Average monthly stock = 121 million USD / 9,6 million USD = 12,6	end of 2004 CGS / Average monthly stock = 140 million USD / 9,6 million USD = 14,6	end of 2004 CGS / Average monthly stock = 151 million USD / 9,2 million USD = 16,4		
5.1.	Average sending time	start of 2002 5 days	start of 2003 1,5 days	start of 2003 1,5 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
	Average approval time	start of 2002 3,5 days	start of 2003 2 days	start of 2003 2 days	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
5.2.	Average transportation mile	year 2002 252 miles / item	year 2003 225 miles / item	year 2003 217 miles / item		
	Average transportation cost	year 2002 342.500 USD (total transportation cost) / 1.823 (total production in 2002) = 188 USD / unit produced	year 2003 450.000 USD (total transportation cost) / 3.000 (total production in 2003) = 150 USD / unit produced	year 2003 396.000 USD (total transportation cost) / 3.377 (total production in 2003) = 117 USD / unit produced	(188 - 150) USD / unit x 3.000 = 114.000 USD	(188 - 117) USD / unit x 3.377 = 239.767 USD
	Total number of approved vendors	year 2002 442 vendors	year 2003 400 vendors	year 2003 348 vendors	0,5 % (average discount rate due to turnover increase) x 15 million USD (turnover of parts from eliminated vendors) = 75.000 USD	0,64 % (average discount rate due to turnover increase) x 21, 7 million USD (turnover of parts from eliminated vendors) = 138.880 USD
	Average vendor performance	year 2002 63 / 100	year 2003 70 / 100	year 2003 72 / 100	Annual value of scrap x Change in total annual number of scrap = 4,6 USD x (7.544 - 5.000) = 11.702 USD	Annual value of scrap x Change in total annual number of scrap = 4,6 USD x (7.544 - 2.413) = 23.603 USD
	Number of vendors recontracted	year 2002 7 vendors	year 2003 10 vendors	year 2003 26 vendors		
6.1.	Number of parts entering stocks although not ordered, excessive or early	mid 2002 4.418 parts	mid 2003 1.000 parts	mid 2003 1.603 parts	8,8 USD (average value of not ordered, excessive) x (4.418 - 1.000) parts x 4 % = 1.203 USD	9,1 USD (average value of not ordered, excessive) x (4.418 - 1.603) parts x 4 % = 1.025 USD
	Average unloading time	mid 2002 17 min/parts	mid 2003 10 min/parts	mid 2003 11 min/parts	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
6.2.	Establishment and successful implementation of new coding system	-	-	-		
	Establishment and successful implementation of stock control for out worked parts	-	-	-	Stock deviation due to parts going out of factory for machining & coating = 2,5 USD (average value of items) x 500 (quantity of items) = 1250 USD	Stock deviation due to parts going out of factory for machining & coating = 2,8 USD (average value of items) x 596 (quantity of items) = 1670 USD
	System Integration to MFG-Pro	-	-	-		
6.3.	Number of approved parts / day	start of 2003 402 parts / day	start of 2004 450 parts / day	start of 2004 566 parts / day	Included in Financial Benefit Due to Process Time Change	Included in Financial Benefit Due to Process Time Change
	Average inspection time per item	start of 2003 540 minutes / 402 parts daily = 1,34 min/part	start of 2004 540 minutes / 450 parts daily = 1,20 min/part	start of 2004 540 minutes / 566 parts daily = 0,95 min/part		

APPENDIX C

		WEIGHT	(60 % of Overall Reengineering Success)					INDICATOR REENGINEERING SUCCESS (%)	INDICATOR REENGINEERING SUCCESS (Corrected by Critical Level) (%)	(40 % of Overall Reengineering Success)		PROCESS TIME REENGINEERING SUCCESS (%)	PROCESS TIME REENGINEERING SUCCESS (Corrected by Critical Level) (%)	ANNUAL FINANCIAL BENEFIT	
PROCESSES		CRITICAL LEVEL	INDICATOR PERFORMANCE							ELIMINATION OF NON VALUE ADDED TIME					
			Definition	Units	Value Before Study	Value Expected After Study	Value Achieved After Study			Non-Value Added Time Before Study (days)	Non-Value Added Time After Study (days)			INDICATOR CHANGE	PROCESS TIME CHANGE
1.1.	APL Information Flow and Production Process of Derivative Military Vehicles	8,5	Inactive stock generated / # of derivatives produced	USD/unit produced	458	375	330	28	0,81	33	10	70	9,66	102.144 USD	95.175 USD
			Change in Stock <1 year / # of derivatives produced	USD/unit produced	79	63	55	30	0,88					19.152 USD	
			Average # of work days from marketing request to purchasing order	days	31	11	11	65	1,87					Included in Financial Benefit Due to Process Time Change	
			production material transportation cost / # of derivatives produced	USD/unit produced	134	120	128	4	0,13					4.788 USD	
1.2.	APL Information Flow and Product Definition Process of Derivative Trailers	8,4	Inactive stock generated / # of derivatives produced	USD/unit produced	549	500	513	7	0,19	70	47	33	4,50	41.940 USD	26.586 USD
			Average # of work days from marketing request to purchasing order	days	71	48	48	32	0,93					Included in Financial Benefit Due to Process Time Change	
			Production material transportation cost / # of derivatives produced	USD/unit produced	92	73	81	12	0,34					12.815 USD	
			Average # of work days from marketing request to design freeze	days	21	6	6	71	2,04					Included in Financial Benefit Due to Process Time Change	
2.1.	Spare Parts and Production Material Handling Process	3,45	Annual number of stockout items due to priority mistakes / total annual inventory used	PPM	3142	1143	320	90	1,06	10	7	30	1,69	306.500 USD	19.440 USD
			Turnover rate	Annual Circulation	3,1	3,2	3,5	12	0,14						
			Annual number of back order items / total annual spare parts orders	%	%6,60	%4,80	%2,80	58	0,68						
2.2.	In-House Manufacturing Process	5,3	Quantity of stockout and excess items/cases due to planning mistakes	PPM	29310	20000	11300	61	1,11	23	14	39	3,38	49.560 USD	60.660 USD
			Production (%) without work orders	%	%21	%12	%6,10	71	1,28						
			Amount/percent of raw material safety stocks	%	%29,60	%25	%26,80	9	0,17					3.712 USD	
2.3.	Engineering Changes Process	7,05	Inactive stock due to uncontrolled engineering changes	USD / unit	313	278	201	36	0,86	-	-	-	-	118.984 USD	-
			Number or percent of correct/on time engineering changes	%	%84,50	%89	%87,30	3	0,08						
2.4.	Hardware Transfer Process	4,1	Delivery time to production lines from inventory	minutes/per vehicle	13,9	10,0	6,4	54	0,75	6	0,5	92	6,13	5.328 USD	28.350 USD
			Financial value of inactive hardware in stocks	USD	42000	30000	22200	47	0,66					19.800 USD	
			Amount/percent of hardware safety stocks	%	%60	%51	%40	33	0,47					2.184 USD	
2.5.	Line Loading Process	5,6	Establishment of new department and definition of responsibilities	-	-	-	-	-	-	6	1	83	7,61	-	29.700 USD
			Start of in-house manufacturing planning	-	-	-	-	-	-						
			Launch of engineering changes tracking system	-	-	-	-	-	-						
			Start of line loading via system data	-	-	-	-	-	-						
			Process time	minutes/per vehicle	19,6	13,6	8,9	55	1,04						
			Number of stockout cases from production line	items/vehicle	5,2	3,8	1,7	67	1,28					Included in Financial Benefit Due to Process	
2.6.	Process of Physical and Registered Motion of Items	4,65	Late material transfer entries	%	%6,80	%5,40	%2,10	69	1,10	0,5	0	-	-	34.181 USD	3.038 USD
			Amount/percent of line stock deviations	%	%3,80	%2,80	%1,50	61	0,96						

		WEIGHT	(60 % of Overall Reengineering Success)					INDICATOR REENGINEERING SUCCESS (%)	INDICATOR REENGINEERING SUCCESS (Corrected by Critical Level) (%)	(40 % of Overall Reengineering Success)		PROCESS TIME REENGINEERING SUCCESS (%)	PROCESS TIME REENGINEERING SUCCESS (Corrected by Critical Level) (%)	ANNUAL FINANCIAL BENEFIT	
	PROCESSES	CRITICAL LEVEL	INDICATOR PERFORMANCE							ELIMINATION OF NON VALUE ADDED TIME				INDICATOR CHANGE	PROCESS TIME CHANGE
			Definition	Units	Value Before Study	Value Expected After Study	Value Achieved After Study			Non-Value Added Time Before Study (days)	Non-Value Added Time After Study (days)				
2.7.	Process of Feedback From Production Line	5,25	Number of Items Corrected / Number of Items Found	%	%65	%88	%82	26	0,47	-	-	-	-	31.208 USD	-
			Number of Items Corrected / Number of Items Found	%	%61	%71	%81	33	0,59						
			Number of Items Corrected / Number of Items Found	%	%23	%33	%87	278	4,98						
			Number of annual count cycles for each material group	number of cycles (A,B,C)	1,5	4,0	3,0	100	1,79						
					0,6	2,0	2,5	317	5,67						
					0,2	1,0	0,5	150	2,68						
3.1	Process of Inventory Audit Preparation of Work-In-Process	3,1	Total time for listing and counting	days	4	2	2	50	0,53	5	2	60	3,03	Included in Financial Benefit Due to Process Time Change	3.888 USD
			Error per cent	%	%7,10	%4,90	%2,40	66	0,70						
3.2	Process of Inventory Audit Preparation of Subassemblies	3,1	Total time for listing and counting	days	4,0	2,5	2,5	38	0,40	5	2,5	50	2,53	Included in Financial Benefit Due to Process Time Change	2.322 USD
			Error per cent	%	%8,90	%6,10	%2,10	76	0,81						
3.3.	Inventory Counting Process	5,35	Number of double codes	items	4898	2250	1330	73	1,33	-	-	-	-	3.408 USD	-
			Number of items with different units	items	216	100	62	71	1,30						
			Percent of total audit error	%	%24	%10	%14	42	0,76						
			Number of redundant codes	items	3142	1500	714	77	1,91						
4.1.	Hardware Materials Tracking Process	7,25	Total number of redundant shelves / Total shelves	%	%15,90	%8,10	%6,90	57	1,40	-	-	-	-	Given in 3.3.	-
			System launching	-	-	-	-	-	-						
4.2.	Main Stock Area Restructuring Process	6,5	Average transfer time to assembly lines	minutes/per vehicle	19,6	13,6	8,9	55	1,21	-	-	-	-	Given in 2.5.	-
			Percent of material damaged in total stock	%	%0,0371	%0,0198	%0,0093	75	1,66						
4.3.	Old & Excessive Stocks Tracking Process	4,1	Old&excessive stocks eliminated by selling, rework or exchange / Total Old&excessive stocks	%	%1,03	%4,69	%15,90	1444	20,17	-	-	-	-	477.117 USD	-
			Turnover ratio	Annual Circulation	12,6	14,6	16,4	30	0,42						
5.1.	Sending/Approval Process of Purchase Orders	6,55	Average sending time	days	5	2	2	70	1,56	8,5	3,5	59	6,28	Included in Financial Benefit Due to Process Time Change	27.216 USD
			Average approval time	days	4	2	2	43	0,96						
5.2.		5,8	Average transportation mile	miles / item	252	225	217	14	0,27	-	-	-	-	239.767 USD	-
			Average transportation cost	USD / unit produced	188	150	117	38	0,75						
			Total number of approved vendors	number of vendors	221	200	174	21	0,42						
			Average vendor performance	points over 100	63	70	72	14	0,28						
6.1.	Incoming Material Entry Process	3,5	Number of parts entering stocks although not ordered, excessive or early	parts	4418	1000	1603	64	0,76	1	0,5	50	2,85	1.025 USD	33.750 USD
			Average unloading time	min / part	17	10	11	35	0,42						
6.2.	Tracking of Materials Going Out of Factory for Machining/Coating	5,75	Establishment and successful implementation of new coding system	-	-	-	-	-	-	-	-	-	-	1.670 USD	-
			Establishment and successful implementation of stock control for out worked parts	-	-	-	-	-	-						
6.3.	Incoming Material Quality Inspection Process	3,95	System Integration to MFG-Pro	-	-	-	-	-	-	1	0,5	50	3,22	Included in Financial Benefit Due to Process Time Change	91.125 USD
			Number of approved parts / day	parts / day	402	450	566	41	0,55						
			Average inspection time per item	min / part	1,3	1,2	1,0	29	0,39						
AVERAGE INDICATOR REENGINEERING SUCCESS (%)								88,17	AVERAGE PROCESS TIME REENGINEERING SUCCESS (%)				55,96	1.777.765 USD	421.250 USD

BIOGRAPHY

Mehmet Karaaslan was born in İstanbul in 1971. He received his BS degree in Mechanical Engineering from Boğaziçi University, İstanbul in 1994. He started MSc in Mechanical Engineering in the same university and worked as a research assistant during the years 1994-1995. He worked on materials science and prepared his thesis on industrial applications of monotectic alloys. He received his MSc degree in Mechanical Engineering from Boğaziçi University in 1997.

During his professional life he focused on quality and conducted quality audits in various automotive suppliers. Later on concentrated on both strategic planning and production planning. He prepared his PhD dissertation on Change Management Models in Engineering Management, Marmara University, İstanbul.

He is a graduate of Executive Development Programme of Kellogg School of Management, Northwestern University, 2004 and he is a Six Sigma Black Belt and has implementations in automotive industry.