A Quality Management Model for an Extended Enterprise Oriented Manufacturing Supply Chain and Its Empirical Study Based on Chinese Suppliers

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Abstract

The globalization of manufacturing and competition promote the manufacturing supply chain (MSC) integration to a wider scope. The extended enterprise supply chain concept, which was initially adopted by leading international giants, like IBM, HP and Chrysler, etc., has become a new competence to collaborate among the entire supply chain from the supplier's supplier to the customer's customer. A common understandable quality management platform is an essential basis for the OEM and all other partners in the chain to integrate together. Quality management has demonstrated its power, and the international quality standards are more and more involved in the supply chain's quality. However, quality management is still limited to the inside of a single company and its direct suppliers. Based on the available literatures, until now the quality management of the extended enterprise oriented MSC has not been well explored.

It is helpful for an OEM and its suppliers to have a quality management model that provides a common basis for building such a cross-company MSC and for maintaining its operating efficiently. There are several challenging questions: (1) Which processes are involved in quality management for an extended enterprise oriented MSC? (2) How can the quality of those processes be ensured through collaborative quality activities in an MSC? (3) Which kind of organization structure and improvement mechanism should be put into effect? (4) Which factors influence the quality performance of an MSC? (5) How can we evaluate the quality performance of the chain in order to implement improvement measures?

In this research based on leading industrial practices and existing theory, an ideal quality management model with three levels and eight processes is created with the function modeling method. This is intended to give a general view of the quality management of the cross-company MSC and related approaches. The quality organization structure, cross-company quality planning, continuous improvement, quality management for cross-company processes (which include product development, outsourcing, production and delivery) as well as the enable platform in the entire chain are discussed. Answers are provided for the first three questions above.

Based on systematic evaluation methods, first a performance-based evaluation of an MSC is discussed with the Six Sigma approach. Then a process-based evaluation system is required to check how an MSC is doing to reach the long-term goal in the ideal model. To do this a quality stage model, criteria and evaluation approach are established. Thus, the last two questions above are also answered.

In order to demonstrate the application of the quality model and evaluation approaches, a survey of top tier Chinese suppliers is carried out and a general view of the quality management capability of Chinese suppliers towards the extended enterprise MSC is depicted. Furthermore, a Chinese motorcycle manufacturing supply chain as a concrete case is analyzed by comparing it to the ideal model and an improvement roadmap is drawn up.

Key words: quality management, manufacturing, supply chain, extended enterprise

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List of abbreviations

APQP	Advanced Product Quality Planning
B2B	Business to Business
B2P	Business to Plant
BOM	Bill of Materials
CEO	Chief Executive Officer
CI	Continuous Improvement
Cp, Cpk	Process Capability Index
CPFR	Collaborative Planning, Forecasting and Replenishment
CQM	Collaborative Quality Management
CSCW	Computer Supported Collaborative Working
DOE	Design of Experiments
Dpmo	Defects per million opportunities
E. E.	Extended Enterprises
EAI	Enterprise Application Integration
ECR	Efficient Consumer Response
EDI	Electronic Data Interchange
EMP	E Marketplace
ERP	Enterprise Resource Planning
FMEA	Failure Mode and Effects Analysis
GNE	Global Net Exchange
IAQG	International Aerospace Quality Group
IM	Inventory Management
ISO	International Organization for Standardization
IT	Information Technology
KPIs	Key Performance Indicators
LIMS	Laboratory Information Management System
MCO	Manufacturing Connection Online
MES	Manufacturing Executive System
MRP	Manufacturing Resource Planning
MSC	Manufacturing Supply Chain

NISCI	National Initiative for Supply Chain Integration
OEM	Original Equipment Manufacturer
OPC	OLE for Process Control
PDM	Product Data Management
PDSA	Plan-Do-Study-Act
PIMS	Process Information Management System
POS	Point Of Sales
PPAP	Production Part Approval Process
PQM	Process Quality Model
PRODNET	Production Planning and Management in an Extended Enterprise
PWB	Printed Wiring Board
QA	Quality Assurance
QC	Quality Control
QD	Quality Data
QDM	Quality, Delivery and Management
QFD	Quality Function Deployment
QM	Quality Management
R&M	Reliability and Maintainability
RFQ	Request For Quote
S/C	System/Component
SCOR	Supply Chain Operation Reference Model
SCORE	Supplier Cost Reduce Effort
SCQM	Supply Chain Quality Management
SPC	Statistical Process Control
SQC	Statistical Quality Control
TQM	Total Quality Management
VIVACE	Value Improvement through a Virtual Aeronautical Collaborative Enterprise
VPN	Virtual Private Network
VSM	Value Stream Mapping
WIP	Work In Process

Chapter 1 Introduction

1.1 Research background

In the global economy multiple entities collaborate to deliver a product to the final customer. As stated by the vice president of the Boston Consulting Group, "As the economy changes, as competition becomes more global, it is no longer company vs. company but supply chain vs. supply chain" [Henko1994]. Supply chain operation, especially in the phase of manufacturing, strongly decides the time to the market, quality and cost of a product.

For a complex product the supply chain consists of multi-tier suppliers, from material suppliers, component suppliers, system suppliers, system integrators to OEMs. The whole manufacturing supply chain (MSC) is working as an extended enterprise; every party has its contribution to the whole chain. The efficiency of a manufacturing supply chain depends on the intra-organization of every partner as well as on the links between. Today's information technology provides the possibility to make all the members able to work together, no matter which geographic position they are in. However, there are several barriers that do not allow the efficient operation of a manufacturing supply chain.

- Every participant in a manufacturing supply chain is an individual company. What it considers is always from its interest and for its benefit. In the manufacturing supply chain the buyer and seller relationship makes cost reduction and quality product or service into a dilemma. When the conflict goes to an extreme, it causes short-term business behavior. This places a manufacturing supply chain, especially the OEM, under tremendous pressure from market competition.
- Traditionally, separated commercial working style makes the whole chain inefficient. For many years the company improves its own lead-time, inventory and process, but rarely looks at the possibilities of improving cross-company borders. Optimization of cross-company activity is not considered as advantageous for the own company, but in fact a higher inventory at the supplier also causes a higher purchasing price [Stocker 2000].
- In the Council Insight of the 18th Meeting of the International Aerospace Quality Group (IAQG) on Oct. 5-6, 2005 it was expressed that "the areas of potential source of risk that are linked to the nonconforming product are new material, poor control of sub-suppliers, understood methods, lack of visibility, no common vocabulary and few industry standards" [Dell 2005]. A new survey released on Nov. 16, 2005 announced that "the prevalence of outsourcing in electronics has resulted in companies losing control and visibility across their extended supply chain, creating increased risks" [McGra 2005]. Today, the companies could have visibility to their direct suppliers; some of their tier 2 suppliers, but the ones further down in the supply network,

there is no possibility to recognize the risk. “It has been found that 80% of quality problems are to be blamed on sub-tier suppliers” [Power 2001].

To improve the situation, many companies are re-designing their supply chains. Most companies today focus on the challenge of coordinating activity with their first-tier suppliers and distribution channels. But few have developed the skills needed to reach beyond this tier and coordinate the sourcing of raw materials to their final delivery [Hagel 2005]. After much exploring, leading companies like Cisco Systems, Dell, etc. found out that without improving the integration with its sub-tier suppliers and expanding the quality initiative to sub-tier suppliers, the manufacturing supply chain still cannot meet its market goal.

From analysis of industrial practices in the manufacturing supply chain it is shown that a quality management mechanism with a view of extended enterprise, which integrates all partners, can provide an overview of the whole manufacturing supply chain: either OEM or its suppliers in the chain. This gives them a common understanding of how they can improve quality in a collaborative way in cross-company manufacturing activities and what are the efficient approaches to assure cooperation in every important process that partners are involved in. It should provide the focal company with executable procedures to reach the most optimized result with the win-win principle for all members in the chain. It is not the same as re-engineering, which is designed to bring a transacting change immediately, but it helps to set a foundation for all members to improve the quality of the entire chain incrementally. This is the way to improve competitive advantage with an extended enterprise concept.

All kinds of international and industrial branch standards, e.g. ISO 9000 series, ISO/ TS 16949, AS 9100, etc. give clear requirements for manufacturing companies or suppliers. They are the foundational bricks for supply chain operation. But from the organizational and operational standpoint of an extended enterprise oriented supply chain, there is still insufficient research on a concrete guideline for cross-company quality management. Those standards answered the question about how every company should be in an MSC, but they are not expected to define how everyone could work better together with others for the whole chain.

Some leading companies like Cisco, Dell, Toyota and Daimler-Chrysler have implemented all kinds of programs to improve the collaborative quality of the manufacturing supply chain for their goals. The Supply Chain Quality Task Group also emphasizes the work on “Getting and promulgating common understanding and usage of key QA supply chain terms (dedication, graded approach, etc.)” [SCQTG 2003]. This research is intended to present such a collaborative quality management model and corresponding approaches based on best industrial practices up to now and theoretical research in the field of the manufacturing supply chain.

1.2 Research goal and methodology

Goal of the research

In a supply chain the organizations are only as strong as their weakest link, so the challenge is to integrate all functions efficiently. All parties must understand and be able to implement similar quality standards [Moham 2001]. This research is aimed at forming a concrete collaborative quality management model with executable approaches for cross-company manufacturing activities. It also concentrates on setting up an evaluation system to check a single company's quality management capability in an MSC as well as judging quality management performance of an entire manufacturing supply chain.

The purpose is to provide the focal firm with a complete quality management view of an extended enterprise oriented manufacturing supply chain, to help suppliers integrate into an MSC collaboratively and to help both to combine with each other under a general quality principle.

Methodology

In the theoretical part, based on the review of previous research on quality management of supply chains and the industrial practice in the leading companies, a comprehensive framework for collaborative cross-company quality management is presented. A hypothetical evaluation system is given for a single company's quality management capability in an MSC as well as for the entire MSC. The main research methods, which are used in this part, include literature analysis, case study, process analysis, function modeling and evaluation and selection methods.

In the empirical study, survey by mail and on-site interviews have been applied. In order to learn about the general situation of Chinese manufacturing suppliers, the mail survey is adopted. A questionnaire for the top tier supplier is designed with 40 questions in every function field of quality management related to the collaborative activities with its suppliers and customers. The on-site interviews and discussions were carried out with the focal firm, its key suppliers and their sub-tier suppliers in a Chinese motorcycle MSC.

1.3 General overview of the work

Supply chain management applies to all manufacturing industries: apparel, furniture, food and beverage, automotive, paper products, pharmaceuticals. Supply chain management includes internal production, planning and logistics capabilities, as well as relationships with suppliers and even with channel partners. In this dissertation the emphasis lies on discovering collaborative quality management measures for improving the cross-company processes and common interface among partners with a view to the whole manufacturing supply chain in order to ensure product quality, cut total cost, and reduce cycle time in an extended enterprise.

The second chapter will deal with the state of art of the extended enterprise oriented manufacturing supply chain. The quality management development from international and industrial branch standards to theoretical research will be reviewed. Based on that research, the concrete problem that should be targeted in this work will be defined.

In the third chapter the requirements for quality of an MSC are defined. By referencing the quality management concept of ISO 9000 and the Supply Chain Operation Reference Model (SCOR) as well as analyzing the main functions of the manufacturing supply chain, the main processes that affect cross-company quality management of an MSC will be defined and a collaborative quality management model will be established.

In the fourth chapter the quality foundation of management processes, key processes and enable technologies and the platform will be discussed. Based on best industrial practices, the quality organization, the quality planning as well as the continuous improvement mechanism for an extended enterprise oriented manufacturing supply chain are extracted and depicted.

In the fifth chapter a quality performance measurement system of an MSC is built based on the Six Sigma approach. In order to view the coordinated quality management capability in an MSC as well as the quality management level of an entire MSC, a hypothetical classification system with evaluation criteria is discussed.

In the sixth chapter the survey objects, methods and procedures are described.

The seventh chapter gives firstly a basic analysis of the quality management capability of a Chinese focal firm and system/component suppliers in an MSC according to the survey data. Secondly, the quality management practice in a Chinese motorcycle MSC is analyzed, the problems and week points are examined and an improvement strategy and roadmap are drawn up.

The last chapter concludes the findings of the work and points out future research that is needed in this field.

The structure of the work and the research methods are summarized in Figure 1-1.

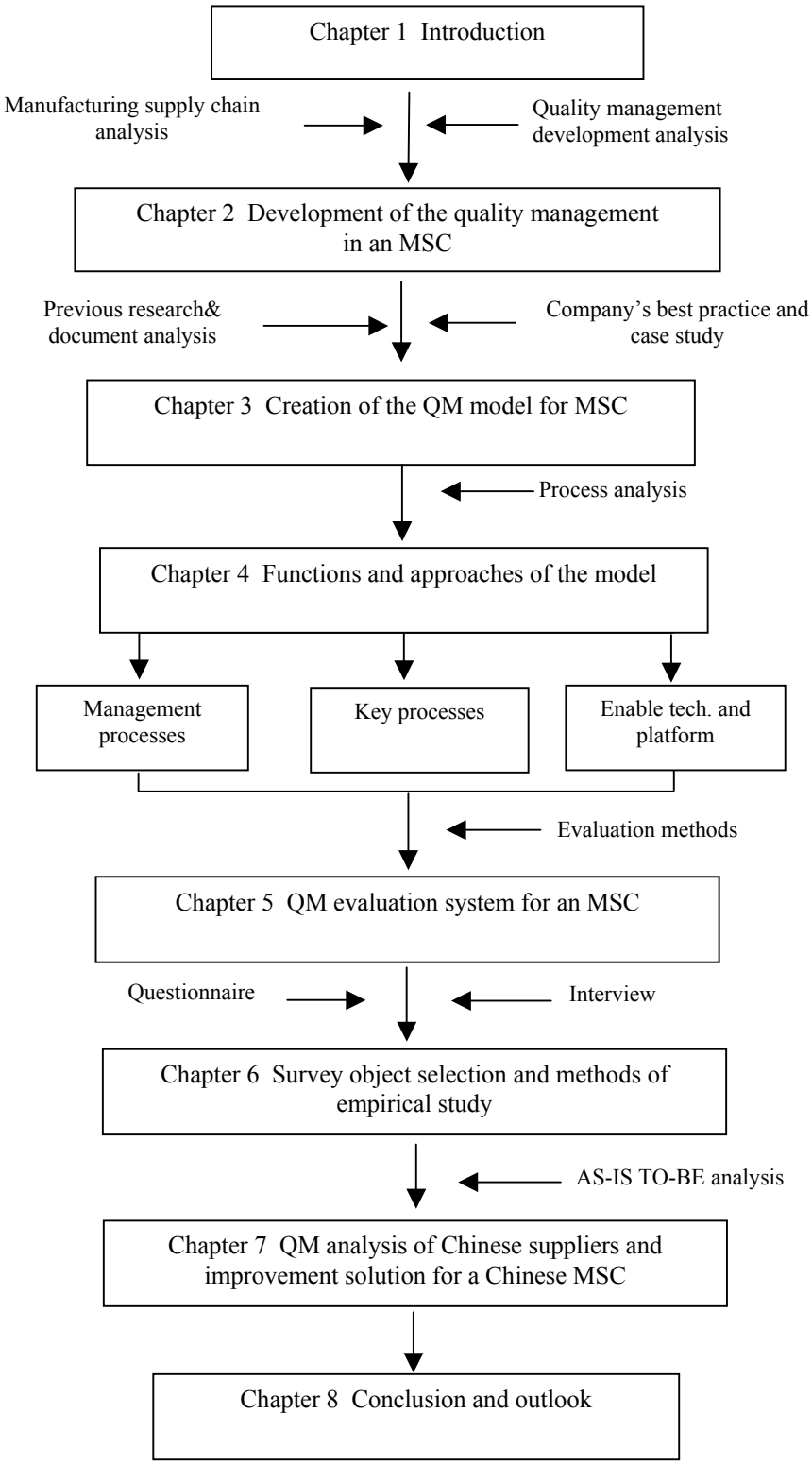


Figure 1-1 Working process and structure

Chapter 2 The Development Of Quality Management in the Manufacturing Supply Chain

2.1 The Manufacturing supply chain and its features

2.1.1 Definition of the manufacturing supply chain

The supply chain encompasses all activities associated with the flow and transformation of goods from the raw material stage to the end user as well as the associated information flows. Supply chain management is the integration of these activities through continuously improved supply chain relationships, to achieve a competitive advantage [Hanfiel 1998].

According to the definition by ISO Technical Committee 184 for Industrial Automation Systems and Integration, the manufacturing supply chain is a term for the layers of processes involved in the design or manufacture of a product. These processes may be carried out within a single company or may be carried out by different companies. A company designing (or making) a product or a portion of a product may subcontract parts of the design (or manufacture) to companies within the supply chain [Vaugh 2000].

A demonstration of the structure is shown in Figure 2-1[1].

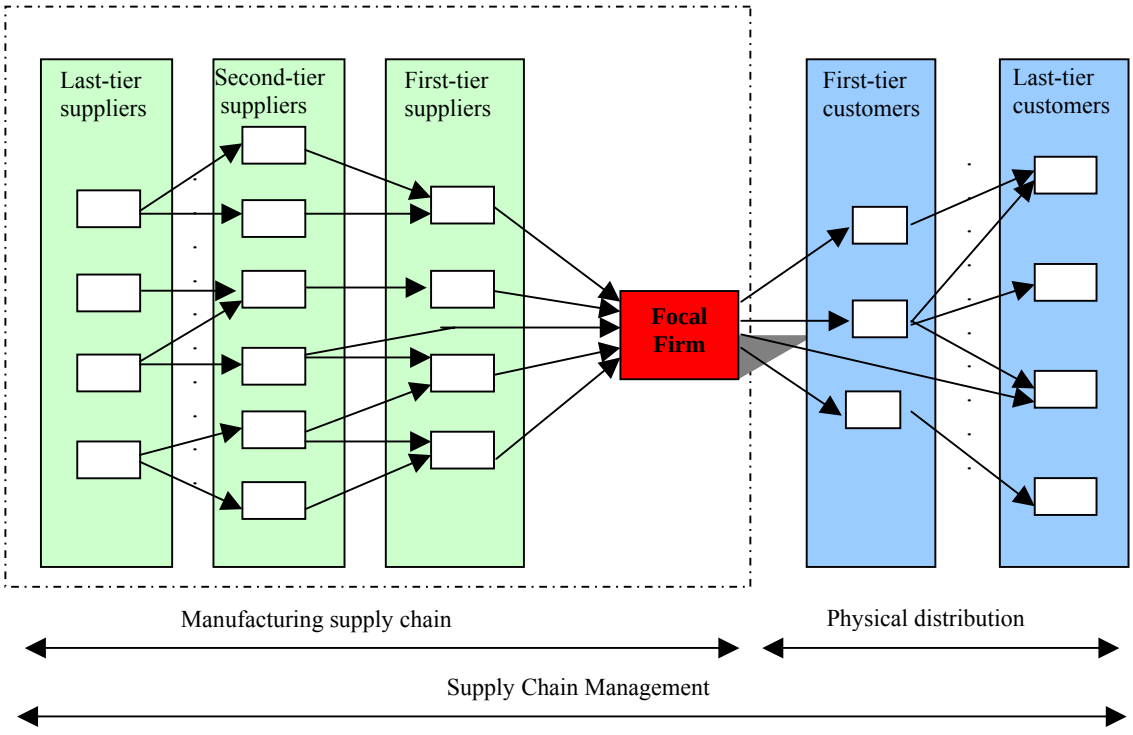


Figure 2-1 Supply chain structure

The whole chain can be viewed as two phases, i.e. the upstream network supply side and the downstream network demand side. In the early stage, people consider a supply chain more as physical distribution and logistics rather than manufacturing. Along with the globalization

[1] In the thesis the first-tier, second-tier and so on is equal to the tier 1, tier 2 and so on.

and IT development, the manufacturing supply chain plays an important role in the whole process. This research is more concentrated on the upstream network, i.e. the manufacturing supply chain, considering the product manufacturing process from raw materials to the final product, as well as information integration with customers.

In a manufacturing supply chain the partners play different roles:

- Focal firm

This is the dominant company in a supply network. From the entire manufacturing supply chain standpoint, it is the ultimate manufacturer or the final producer who carries out the last assembly or production process, e.g. the OEM manufacturer in an MSC. It plays the most important role in the management of the supply chain and works as a leading force in an extended enterprise.

- Intermediate suppliers

They are the producers or partners in every tier of the manufacturing supply chain. For their production they purchase material or middle products and modules from their up-stream suppliers. They deliver their products to their down-stream customers. Therefore, every member is a supplier to its customer and a customer to its supplier, as well as a sub-supplier to its customer's customer. Intermediate suppliers are members of an MSC; therefore their quality performances influence the quality of the final products and the operation of the chain. The quality management abilities of the key suppliers have a strong influence on the focal firm and the whole chain.

In the MSC the intermediate suppliers are normally classified as tier 1 supplier, tier 2 supplier, tier 3 supplier and so on. In the discrete manufacturing industry, they are classified as system supplier, sub-system supplier, component supplier and part supplier as well as material supplier.

In general, every member in the MSC is a manufacturer [2] or a service provider.

2.1.2 Features of the manufacturing supply chain

From a traditional point of view, the manufacturing supply chain just involves buying and supplying activities. The Global Supply Chain Forum, a group of international companies and a team of academic researchers, stated that "successful supply chain management requires a change from managing individual functions to integrating activities into a key supply chain process" [Roman 2001].

US AMR spent two years for benchmarking the supply chain performance across a number of industries and found out that the supply chain is changing from "a supply/internal orienta-

[2] In order to avoid confusion with the chain quality organization (that will be discussed in chapter 3 and chapter 4), "manufacturer" is here equal to "organization" as defined in ISO 9001.

tion to one focused on the demand signal and the integration of the multiplier value chain (from your supplier's supplier to your customer's customer)" and the supply chain mangers' role is shifting from "product movement to overall responsibility of the integrated supply chain" [Friscia 2004].

As globalization, outsourcing and product complexity increasing, the manufacturing supply chain is involved in different companies that work together by means of optimized manufacturing processes and activities.

The concept of the extended enterprise

The European ESPRIT program- PRODNET (Production Planning and Management in an Extended Enterprise) states:

"The concept of extended enterprise is better applied to an organization in which a dominant enterprise "extends" its boundaries to all or some of its suppliers" [Cama 1997].

E. W. .Davis defines in his book "Extended Enterprises - Gaining Competitive Advantage Through Collaborative Supply Chains":

"The extended enterprise is the entire set of collaborating companies, both upstream and downstream, from raw material to end-user consumption that work together to bring value to the marketplace" [Davis 2004].

T. T. Burton and others describe in their book:

"The lean extended enterprises view all the entities in the total value stream (e.g. suppliers, subcontractors, the company and customers) as if they were a single enterprise. The speed and effectiveness of each partner in the total value stream determine how successful the overall value stream will be among the competing value stream. This is a gold mine of opportunity, because 70 to 95% of many organizations' product costs, lead time, design, supply chain planning, and manufacturing are outside of their four walls" [Burton 2003].

From the view of the focal firm the extended enterprise oriented MSC is a community that integrates all strategic partners together in order to gain competence. It functions as an extended enterprise, structuring all the tiers of manufacturing enterprises and other partners. It is normally led by the focal firm, but collaboration between partners in planning, design, production and delivery takes place in the chain to gain a competitive advantage as a network capability rather than in a single company. Its main features are as follows:

- Competitive unit

The future lies in competing supply chains rather than in competing companies [Dutta 2004]. No single company can decide about its market position and success alone, and it is dependent on other participants in the chain [Stocker 2000]. In many industries competition is quickly changing from firm against firm to extended enterprise against extended enterprise [Dynes 2005].

- Collaboration

Many companys' experiences showed that the success of a manufacturing supply chain does not only come from advanced technologies and infrastructures, but also from seamless cooperation between the participants in the chain. "Collaboration has made it possible to reduce product development time by 50%, and 80% of product cost can be reduced if suppliers and customers place into effect "Collaboration" early in the design process" [Allerton 2004]. Collaboration is the lubrication for a chain to function smoothly and flexibly.

- IT as the enabler

Achievements in the field of IT make the integration of the manufacturing supply chain possible. Web-based technology provides the platform and tools for realizing global sourcing, design, manufacturing and delivery.

- Management inside as well as its interface

The focal firm and its partners in a manufacturing supply chain develop the management from the inside of a single company to manage the interface between companies in the chain. It is a management activity across companies and supply chains, but also closely related to the internal management capability of every participant.

The manufacturing supply chain is normally viewed from a different standpoint.

From a single company's standpoint, the manufacturing supply chain consists of its suppliers, its distributors and its customers. It often appears as "a company's supply chain".

The completed product, however, is really the result of the entire supply chain. This supply chain starts with raw materials and finishes with the final products, encompassing all the steps of the supplier's suppliers and ranging to the end manufacturer. Thus, the entire manufacturing supply chain consists of every single company's supply chain.

A comparison between the two definitions of supply chain is given in Figure 2-2.

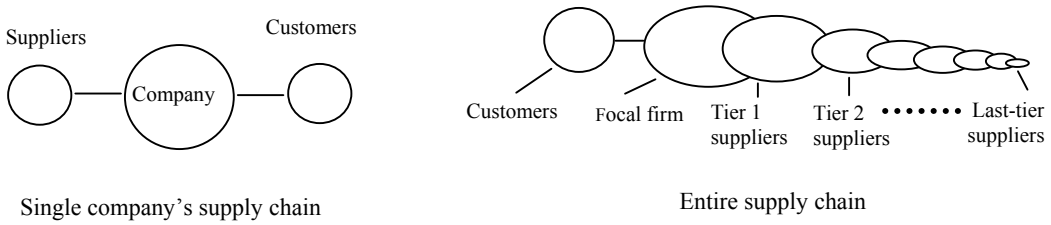


Figure 2-2 Two scopes of supply chains

The National Initiative for Supply Chain Integration (NISCI) insisted that "managing a supply chain means not just one's direct suppliers, but their suppliers, right on down sometimes

to the most basic raw materials" [White 2004]. Quality depends heavily on the implementation and coordination of quality management activities upstream in the supplier's operation" [Mendz 1997]. "The companies that fail to manage their supply chains will face not just individual competitive companies, but entire supply chains with synchronized goals and energized and involved management" [Trimmer 2001].

It is a very complicated issue to manage and optimize the entire supply chain. In this research, it is based on the strategic view of an extended enterprise oriented manufacturing supply chain going beyond the boundaries of only single supply chain quality management activities. The central idea is to set up a quality basis in the whole MSC. However, on the tactics level, the MSC is implemented by every participant through a closely planned quality management practice to its own supply chain.

2.1.3 State of the art of the manufacturing supply chain practice

The concept of the supply chain was established 30 years ago. Along with technical development, supply chain theory and practice have made tremendous progress. Many software companies offer manufacturing supply chain solutions in order to optimize the daily process and to enable more intelligent and economical decisions with efficient planning processes. The purpose is to enhance visibility across the whole supply chain; then to improve the supply chain reaction agility. Manufacturing supply chain management is moving from single company to cross-company first-tier supplier integration and then to multi-supplier integration.

In the 90s Cisco Systems Inc. created a Manufacturing Connection Online (MCO), a business to business (B2B) supply chain portal for its contract manufacturers, suppliers, distributors and logistics partners. It provides a central access point for manufacturing applications, reports, planning tools, forecast and data, inventory information and purchase orders. This system allowed its first-tier manufacturers to interact with Cisco as though they were part of the company. The system worked adequately until mid 2000, when a world-wide high-tech component shortage occurred. A missing link in Cisco's supply chain management system caused second and third-tier suppliers to over-order parts and components, for which Cisco was required to pay. The incident highlighted the need for increased visibility across the entire chain for all manufacturing supply chain partners. This accelerated its 'e-Hub' initiative. Its goal was to deliver end-to-end visibility, optimization, event alerting, and performance, as well as other information beyond tier 1 manufacturing supply chain partners to tiers 2 and 3 [Davis 2004].

Some time later, HP presented the next generation of a supply chain solution. It is a network of all the touch-points in the extended supply chain with cross-enterprises collaboration in product development, product lifecycle management, sourcing and procurement, supply and demand matching, logistics and distribution, sales force automation and customer support.

By linking the factory floor with the supply chain management environment, it provides real-time information on manufacturing progress and levels of quality that are achieved. It also enables the scheduling of the manufacturing environment in nearly real-time. By simplifying and standardizing supplier-based activities across the enterprises, it reduces costs, complexity and risk [Hpso 2004]. The system structure is shown in Figure 2-3.

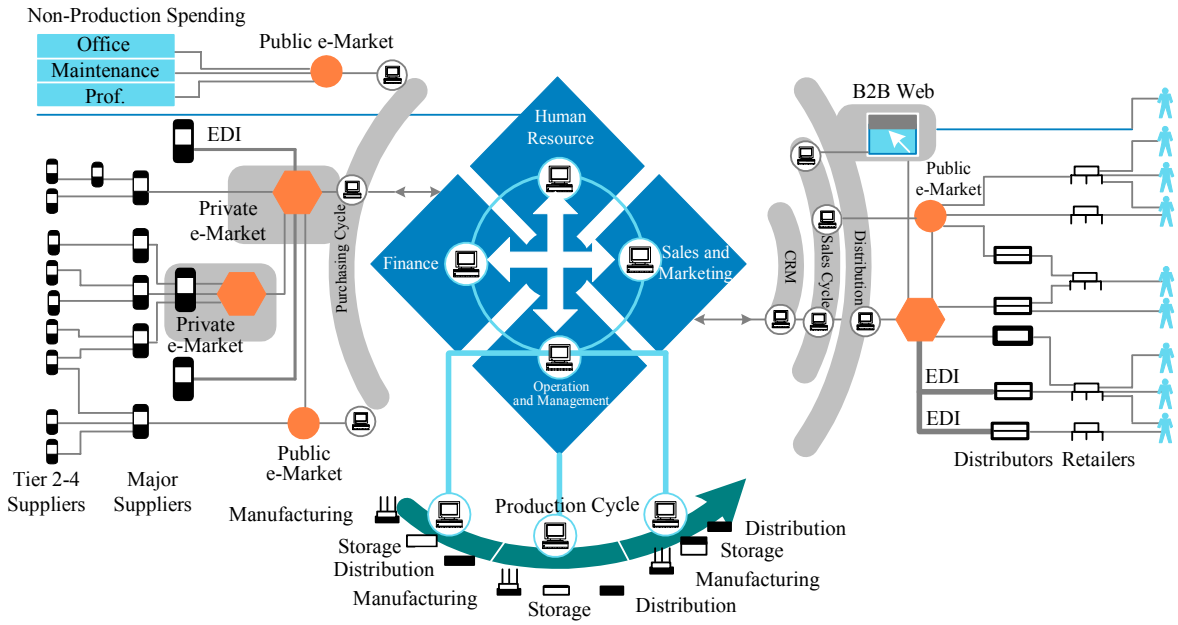


Figure 2-3 HP's next generation of supply chain solution [Hpso 2004]

However, according to the report of Capgemini in 2003, just 56% of the investigated German companies have a clear strategy for the internal and external connection of value-added processes [Capgem 2003]. Many companies, especially small and middle size manufacturers, still have a lack of knowledge for operating their supply chains efficiently. As Schweizer Co. CEO Rainier Hartel, one of Europe's largest PWB fabricators, said: "the supply chain was very often nothing more than a slogan. The understanding of the complex procedures over the complete supply chain is not as easy, and the systems to control them are not fully ready" [Pietz 2002]. In order to improve avoidance of weak links and to group the suppliers into homogeneous classes (especially small supply companies) VIVACE - Value Improvement through a Virtual Aeronautical Collaborative Enterprise, which is a manifestation of the European Commission's desire to fund cutting-edge research in the aeronautical sector - was set up to take account of the all overall supply chain needs and views. Its so-called "Capture of 3rd Tier Suppliers Requirement" project relates to new work environments for aeronautics, and ensures that those requirements are adequately taken into consideration in the research and innovation initiatives of large enterprises [Lisanti 2005] [Jean 2003].

2.2 Quality management and its role in the MSC

2.2.1 Quality management theories and the trends

Quality management has been tied together with supplier/supply chain in the literature.

The fourth item of Deming's 14 points suggests:

"Move towards a single supplier for any one item on a long-term relationship of loyalty and trust" [Deming 1986].

In Crosby's book: "Quality without tears", he writes about this operation:

"Suppliers are educated and supported in order to ensure that they will deliver services and products that are dependable and on time" [Crosby 1995].

In Masing's "Quality Management Handbook", it is stated:

"The suppliers must have the same quality demands with the manufacturer in order to reach the quality of the final product" [Masing 1999].

Above, the supplier's effect on quality and performance is emphasized. However, the quality management concept is always focused on only one organization, which is bordered inside a single company, taking into account the direct suppliers but not the supply chain as a whole.

How to carry out this quality management to suppliers is stated for the purchasing process in ISO 9001:2000 Quality Management Systems – Requirements:

*"The organization shall **evaluate and select suppliers** based on their ability to supply the product in accordance with the organization's requirements. Criteria for selection, evaluation and re-evaluation shall be established. Records of the results of evaluation and necessary actions arising from the evaluation shall be maintained"* [ISO 9001].

Along with rapid development of global production, the supplier's performance plays a more and more important role for the success or failure of other companies. The new version ISO/TS 16949: 2002, in conjunction with ISO 9001: 2000, provides a common quality system approach in the supply chain for suppliers/subcontractors. Here many more elements for supplier management have been added, and these can be applied throughout the automotive supply chain [Quali 2004].

ISO/TS 16949: 2002 specifies:

*"Where an organization chooses to outsource any process that affects product conformity with requirements, the organization shall **ensure control over such processes.** Control of such outsourced processes shall be identified within the quality management system"* [ISO 16949].

This development of the ISO standards reveals that quality management has expanded from the evaluation and selection of suppliers to the control of related processes, from signal com-

pany-oriented to throughout supply chain-oriented. Figure 2-4 illustrates the developing trend of quality standards -- from single-company to across many companies.

Therefore, many leading companies have singled out quality management practices of their suppliers throughout the supply chain as a key strategic edge. Final assemblers like GM and system integrators like Northrop Grumman not only manage their top-tier suppliers but go as far as to the sub-tier suppliers, especially for the key components [Choi 1999] [North 2004]. At the same time, in order to make the whole chain more efficient in their quality audits, three big auto makers have simplified the supplier auditing process to eliminate duplicate audits in their second-tier suppliers [Plumb 1992].

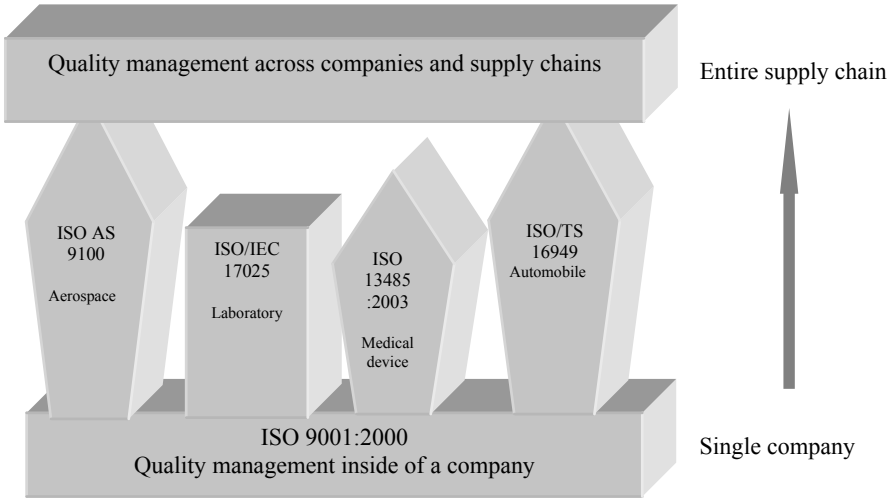


Figure 2-4 Development trend of quality standards

The requirements for quality express the needs or translate the needs into a set of quantitatively or qualitatively stated requirements for the characteristics of an entity to enable its realization and examination [Herrmann 1998]. The entity has been defined as the product, process and system, and the quality requirements are represented as the specification, process capability and system standard, e.g. ISO 9000 Series. But quality requirements, quality assurances and the controls of cross-company activity related to a supply chain still call for a great deal of research. Figure 2-5 shows the quality management objects in development.

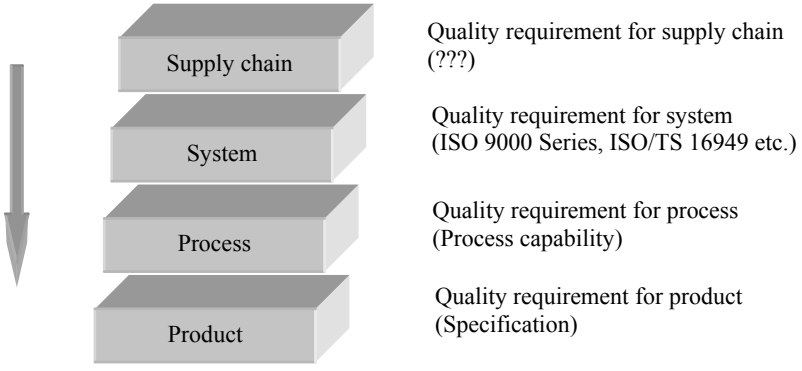


Figure 2-5 Quality management objects in development

2.2.2 The role of quality management in the MSC

J. L. Cawley defined:

"The evolution of the quality role in supply chain management (SCM) will be shaped by the goals of reducing procurement risk and overhead. This involves reducing the effects of sub-standard materials on process efficiency, product quality, and exposure to product liability. The long term goal of SCM quality programs is to reduce risk and variation, increase functionality and profitability" [Cawley 2002].

C. J. Robinson and M. K. Malhotra stated:

"The quality practices must advance from traditional firm centric and product-based mind-sets to an inter-organizational supply chain orientation involving customers, suppliers, and other partners" [Robin 2005].

In earlier time, "quality challenges were predominantly specification or process led and linked to equipment being unable to produce components and products of quality desired by customers to a desired specification in a reliable fashion. This was largely an enterprise challenge" [Puri 2002]. Today's challenge is changed. The quality of a product depends not only on the activities carried out within the enterprises, but also on every stage in the value chain.

Quality issues can cause a tremendous disaster for complete supply chain by breaking ongoing production. Once a supply chain is interrupted, it is extremely difficult to back in order. A study at Georgia Tech School of Management found out that "from 1989 to 1998 supply chain incidents caused company stock value to drop 20 percent over a 180-day period, more than any other external or internal cause" [Hoske 2004].

Just the opposite, quality management can bring a supply chain tremendous benefit. Quality projects are not like re-engineering: they focus on incremental improvement but not on monumental breakthrough. The companys' savings from their largest quality project for the supply chain ranged from $10,000 to a height of $50 M. The average savings are $ 5 M according to research by Best Practices LLC [Best 2005].

However, "in most cases, companies are not tackling the supply chain quality issue with as much vigor as they should", pointed by the president of Northwest Analytical. Wall Street analysts list supply chain quality problems as the number one threat to the value of the stocks of most global companies [Merritt 2001].

Actually supply chains cannot be controlled alone by a single company. In the frequently changing unpredictable global environment, synchronizing suppliers in a connected response to customer demands/changes should be the company's number one goal [Hoske 2004]. In a traditional MSC operation, the end assemblers transfer their quality and cost requirements to their suppliers; their suppliers forward these to their sub-suppliers. Apparently, in an MSC every participant manages the quality to its suppliers, so the final product should meet the requirements of the end customer. However, just passing on compliance demands and proce-

dures of requirements cannot reach the best efficiency for a manufacturing supply chain. The automobile industry is the leading branch in the quality management of supply chains. The main OEMs have made an effort to set up a concept with extended enterprise, which integrates all the suppliers in the supply chain in order to align the process among members, so that materials and information can flow smoothly and with minimal cost and time expenditure.

Only when every supplier in a supply chain is aware and puts effort into it, the chain is able to work more effectively and thus provides a competitive advantage. “This requires similar definitions of quality and training leading towards the methods of incorporating quality and improving it” [Mangi 2001]. Final customers and their needs/requirements should be transformed into requirements for all the participants in a manufacturing supply chain network. Each individual actor contributes in an integrated manner to satisfying the final customer. “Highly coordinated quality management practices/procedures and continuous monitoring of quality parameters are the ‘glue’ that has allowed the supply network to operate as a ‘whole chain’ ”[Roman 2001].

Therefore, it will be a meaningful topic to review the quality from the standpoint of the whole manufacturing supply chain - extended enterprise, not just from a single manufacturer’s view, but for all the partners based on a integrated framework to promote the common understanding of quality management processes in an entire MSC.

2.2.3 Research and application situation

In the wide field of quality management for supply chains, some researchers have done work which can be viewed as the following types.

- Work based on the principles of TQM

B. M Beamon and T.M. Ware presented a Process Quality Model (PQM). It attempted to provide a procedural approach to assess, improve and control the quality of the supply chain process. It consists of seven integrated modules, from identifying the process, technology and tasks being performed, identifying customers and their requirements, expectations, and perceptions, defining quality, identifying current quality performance measures, evaluating the current process and setting quality standards, improvement process, to the controlling and monitoring process [Beamon 1998]. It is a theoretical framework, however, and it did not define any quality elements in a supply chain, so it is too abstract to apply.

D. F. Ross developed Supply Chain Quality Management (SCQM) as the participation of all members of a supply channel network in the continuous and synchronized improvement of all processes, products, services, and work cultures with emphasis on generating sources of productivity and competitive differentiation through the active promotion of market-winning products and services; thereby providing total customer value and satisfaction [Ross 1997].

B. Villarre and others came up with a diagnostic analysis tool for supply chain improvement, which consists of a strategy alienation phase, the assessment of the current situation, the identification and evaluation of further improved areas as well as a phase of implementation and control [Villarre 2004]. It focuses on a single company's supply chains.

The above-mentioned research is based on the principles of TQM established by Deming, Juran, Crosby and Feigenbaum. The improvement efforts derived from this foundation are based upon a change in culture. The changes are small and everyone participates [Villarre 2004].

- Work based on quantitative models and simulation

The quality of a supply chain can be improved through further improvement for inventory management, demand forecasting, product production and distribution and redefinition of the structure of the supply chain. All kinds of tools based on quantitative models and with simulation functions are offered. Many leading international companies have implemented such programs. However, it requires participating teams with special knowledge and capabilities. Without a general understanding about supply chain operations and quality management processes, it is impossible to reach the expected goals in a whole chain.

- Other related reference models and research

G. Stegemann and others carried out a project in the *Technische Fachhochschule Wildau*, the so called "Integrated Quality Management in External Value Added Chain" in 2001. It analyzed supply chain quality management in the phase of distribution, repair and customer service of automobile products. The project was implemented by researchers together with the companies in the chain. It gave a theoretical model of quality management for a value added chain as well as a practical application reference in a down-stream supply chain [Stegem 2001].

R.G. Batson and K.D. McGough of the University of Alabama set up a quality planning model for the manufacturing supply chain by conducting in parallel strategic planning processes for production and the supply chain. It integrates two six-step strategic planning processes into the model, showing how closely supply chain planning is linked to production planning [Batson 2006]. However, it only considered the first-tier suppliers and did not involve much in quality activities themselves.

Based on the above, it can be concluded that the quality management model for a manufacturing supply chain with the goal of improving the whole chain's performance has still not well been researched.

2.2.4 Overview of Chinese suppliers and the MSC

The global supply chain has extended rapidly from the advanced industrial countries into developing countries. China as the fastest developing country with good industry infrastructure and low labor costs is becoming one of the most important outsourcing regions. More than 50% of North American manufacturers are planning to begin or expand outsourcing or sales/marketing operations in China [Moad 2005]. However, many western companies have had negative experience with Chinese suppliers. James Carbone said in his article "Expect Opportunity, Risk in China's Supply Chain": "Product quality from indigenous suppliers is often an issue... The indigenous suppliers may have the cheapest price for parts but may not have the quality systems that western suppliers do ... The issues involved in outsourcing in China can be daunting for any size OEM or EMS provider" [Carbon 2004].

In China the suppliers can be classified in three categories.

- The first category: Purely owned by western manufacturers, like Motorola or Intel, who opened up their own plants in China.
- The second category: Joint ventures. Western manufacturers have merged with Chinese companies.
- The third category: Local indigenous suppliers.

China has been changed from a totally government-controlled economy to a somewhat free market economy, especially after entering the WTO. However, Chinese manufacturers used to focus on improving the competition advantage by expanding the production capability, but without making much effort in connection with supply and market. Supply chain management was introduced in China in the 1990s. However, due to cultural differences, language difficulty, lack of experience and a common understanding for supply chain quality, it is more difficult for Chinese suppliers to join and collaborate in a global manufacturing supply chain.

However, more then 100 thousand manufacturing enterprises in the third category still make up the main part of potential cooperation partners. The enhancement of their quality consciousness in the supply chain will be a tremendous improvement for constructing more efficient global manufacturing supply chains.

2.3 Summary: Required research work in the field

From the discussion above, it is clear that the performance of an extended enterprise (cross-company and chain) manufacturing supply chain is dependent not only on a single company's quality management but also on their partners and the collaboration between them. In order to ensure quality, to cut total cost and improve efficiency in a cross-company manufacturing supply chain, it is necessary to have a general model, which can be viewed as a refer-

ence for OEMs and suppliers in every tier. It will help the partners in an MSC to understand, communicate and work together in order to reach the goal above.

In this dissertation the central question is how one can assure the MSC's operation without error and more effective. A prime goal of this study will be to discuss all the aspects that relate to the quality of the manufacturing supply chain, and it will try to build a foundational structure for it. The work includes three parts. The first part answers the question about:

- *What should the quality management for cross-company MSC be?*

Which cross-company processes influence the performance of a manufacturing supply chain?

Which processes are involved in the quality management for a cross-company manufacturing supply chain?

How can the quality of those processes be ensured through collaborative work in an MSC?

Which kind of organization structure and quality activities can promote the collaborative improvement in an MSC?

What enable technology and platform are available for supporting quality activities?

If a system cannot be measured, it also cannot be improved. How can the quality performance be measured? Therefore, the next step should be:

- *How to evaluate a single company's MSC quality management capability and the total quality performance of an entire MSC?*

How can the quality performance of an MSC be classified?

What are the criteria for evaluating the quality management level of an MSC?

How can the quality management capability of an MSC be evaluated?

The last part is:

- *How could the model be applied to a concrete manufacturing supply chain?*

By concentrating on the previous research work and the analysis of quality management practices and measures for suppliers as well as supply chain quality management in many leading international manufacturing companies, answers for the first two parts will be given.

Based on the theoretical work and a survey, a general review of the quality management condition of Chinese focal firms and system suppliers will be analyzed. Further, a Chinese manufacturing supply chain will be chosen, and an investigation will be carried out by interviewing the key members in the three levels. By taking the ideal model as the development goal, the problems and week links will be detected and an improvement strategy will be presented.

Chapter 3 The Creation of a Cross-company Quality Management Model

3.1 Definition of quality requirements and quality management

- The **quality** definition according to ISO 9000:2005 [ISO 9000]:

"*Degree to which a set of inherent **characteristics** fulfils **requirements**".*

The requirements for quality consist of three elements: quality requirements for products, quality requirements for processes and quality requirements for systems.

The goal of supply chain management focuses on Cost, Quality and Time. From the expanded concept, the quality requirement for the manufacturing supply chain can be viewed as following:

To produce the right products at a lower cost and a shorter cycle time to meet final customers' requirements under the efforts of all the participants in an MSC.

Here, this entity is defined as the manufacturing supply chain. All quality management for the product, process and system, which has already been very well defined at a single company level, has a direct connection with the manufacturing supply chain. However, as Prof. Averboukh stated, "new business chains must be very flexible and should be organized and maintained in a stable way and be capable of providing solutions which meet the end-customer requirements and expectations in quality, quantity and time" [Averbou 2005]. From the standpoint of a cross-company organization, the key quality features of a whole manufacturing supply chain could be viewed as having five characteristics:

Time to market

The time needed from the customer's requirement analysis to product development, to series production and to the final product is a key characteristic. Today, the tempo of a product's upgrade is so rapid, that for a time-based competitive product, like a digital camera, coming merely two weeks later to the market will make a big difference in price and consumer preference. An MSC who can deliver in a shorter time to the market will be much more competitive than another one, who takes a longer time through the chain.

Quality in and between tiers

Some research has asked the question: "Is quality only related to the product itself or to the way the product is produced as well?" [Neergaard 2002]. The quality within every tier of the producers and their cooperation in the whole chain all influence the final product. The final product's quality depends on whether the quality requirement can be passed on to lower tier suppliers and then the physical material flow reaches the right producer at the right time within the chain. It happens very often in many car manufacturing operations that cars must be called back from the final customers at high expense because of a defect in some component or part from the suppliers or sub-suppliers.

Cost of the whole chain

The cost of a final product is the basis for the survival of a manufacturing supply chain. For many focal firms, up to 80 percent of the final product's costs comes from suppliers. Therefore, if non-valued-added work can be eliminated, e.g. redundant inspections at the supplier's factory and then at the customer's along with unnecessary transport between the supplier and customer[3], etc. in the chain, the final product's cost will be reduced. The cost does not only occur for every single company, but increases the total cost in the entire manufacturing supply chain.

Service between partners

Service consists of the willingness and activity to provide conveniences for the customer. It includes accessible and responsible contacts, accommodating change orders, availability and communication for potential problems, quick response to the requirements of the customer, and clear, timely documentation. Better service makes the chain more efficient.

Agility of the chain

The ability to adjust literally in real-time to changes in MSC is critical [Burton 2004]. A manufacturing supply chain must be able to adapt and react to market changes rapidly. It can be realized by technical advances in every member organization, as well as by efficient coordination between the members of the manufacturing supply chain. This ability allows the entire manufacturing supply chain to respond faster to dynamic demands.

In general, it can be said that shorter cycle time, lower cost but higher quality, better service and stronger agility are worthwhile characteristics for an MSC to pursue.

- **Quality management** according to ISO 9000:2005 [ISO 9000]:

"Coordinated activities to direct and control an organization with regard to quality".

Here the organization is not a single company any more, it is the extended enterprise that consists of all the partners (companies) in a cross-company manufacturing supply chain. With regard to the quality requirements of an MSC, the coordinated activities to direct and control the MSC should be built into a quality management model, which integrates quality planning, quality control, quality assurance and quality improvement with the quality goal of an MSC.

[3] Here the customer is also the member of a manufacturing supply chain. In the chain everyone is a customer of its supplier and the supplier of its customer.

3.2 Related research in depth

In the filed of quality management of manufacturing supply chains, some research results have been found in this direction.

In 2002, Rajiv Puri's and Sandeep's paper outlined the existing business problems of quality assurance and control in manufacturing and presented the emerging solution space. It analyzed that in the new global economy, multiple entities collaborate to deliver a product to the end-customer, and the quality of a product is a determinant factor of the work done across the supply chain by myriad entities. This study provided a wide view of the aspects that should be changed and improved in this field. It gave an IT enabled Collaborative Quality Management (CQM) model, which is focused on quality assurance and control activities that can be done on-line with a central quality database [Puri 2002]. However, the problems it mentioned: the lack of the clearly defined processes for managing quality throughout the sourcing, product development, manufacturing, delivery and service, have not been essentially discussed.

In 2000, Stocker and others gave a seven-components quality model for supply chains. The components model defined seven parts that essentially influence supply chain process management and supply chain quality: Product Development Management, Procurement Management, Inventory Management, Production Management, Distribution Management, Marketing Management and Supply Chain Controlling [Stocker 2000]. It has enhanced the integrated supply chain, i.e. cooperation between suppliers and customers. But it is still focused on one single company and more concentrated on the supply chain inside the company.

P. Neergaard built a tentative model of quality management for a global supply chain, shown in Figure 3-1. His research is based on a contingency approach to quality management. The synthesis of his research is that a number of contextual factors influence the way in which a specific company organizes itself. The contextual factors likely to influence the choice of controls in the supply chain are costs, size, strategy, and culture [Neergaard 2002]. It defined quality in a broader sense than usually done in the quality literature.

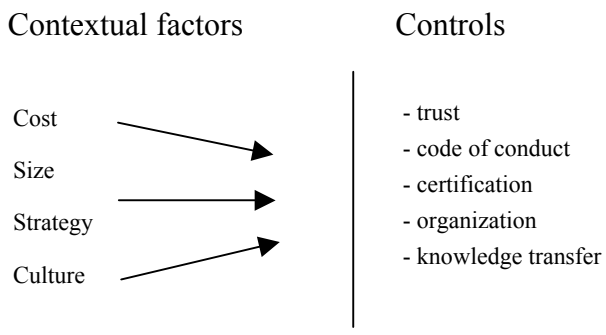


Figure 3-1 Quality management for a global supply chain [Neergaard 2002]

Generally speaking, there is relatively little research on the quality management of a supply chain's environment, even though many technologies and approaches have been used in many areas of supply chains.

3.3 Basic description of the general model

3.3.1 Modes of supply chain quality management

From industrial practice, the traditional and popular way to manage quality is supplier quality control as discussed in §2.2.1. The mechanism is that the focal firm (ultimate manufacturer) transfers the requirements for quality, cost, and delivery requirements to its suppliers, and the supplier passes its requirements to its sub-suppliers. The control mechanism is depicted in Figure 3-2. It is a point-to-point control mechanism and is still the basic process for an MSC. However, due to a lack of bilateral cooperation and optimization based on the entire manufacturing supply chain, the cost cutting and efficiency improvements in the entire MSC cannot be reached.

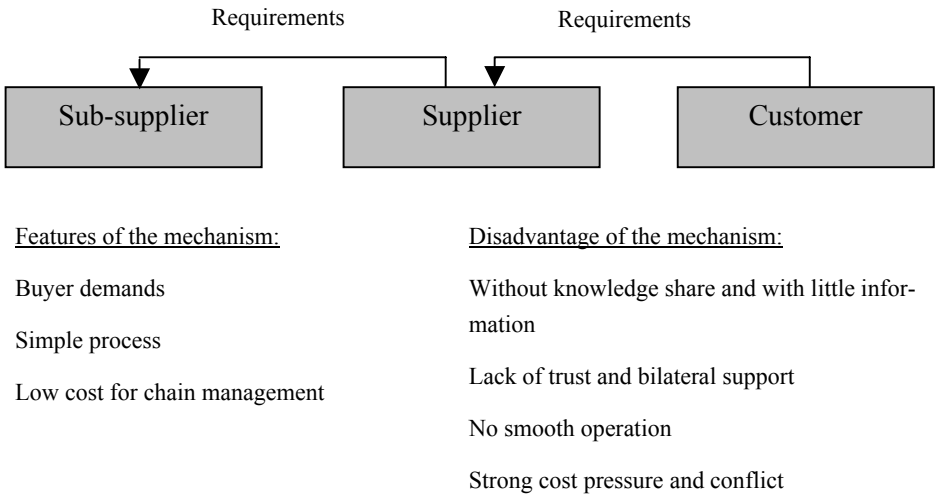


Figure 3-2 Traditional supplier quality control

As the maturity of information technology and quality content develops, an integrating quality management for cross-company supply chains is required. The goal is to reduce waste, to cut total cost and to guarantee product quality and short cycle times for the entire MSC, not just for one single company, through collaborative quality management, see Figure 3-3.

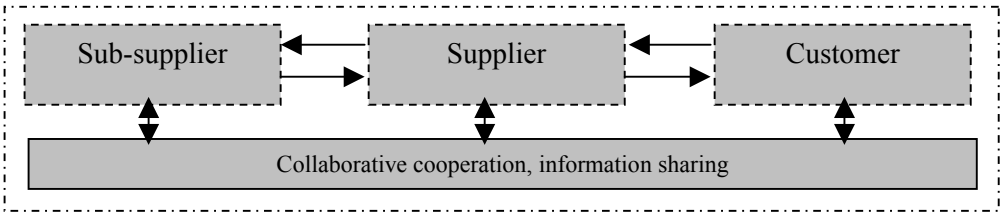


Figure 3-3 Collaborative supply quality management

Just as C. G. Cobb described the quality concept in his book "From Quality to Business Excellence": "...along with the integrating technology development – standards-based system, the next step will be to integrate the business process across the entire supply chain" [Cobb 2003]. Based on this concept, the development phase can be seen in Figure 3-4.

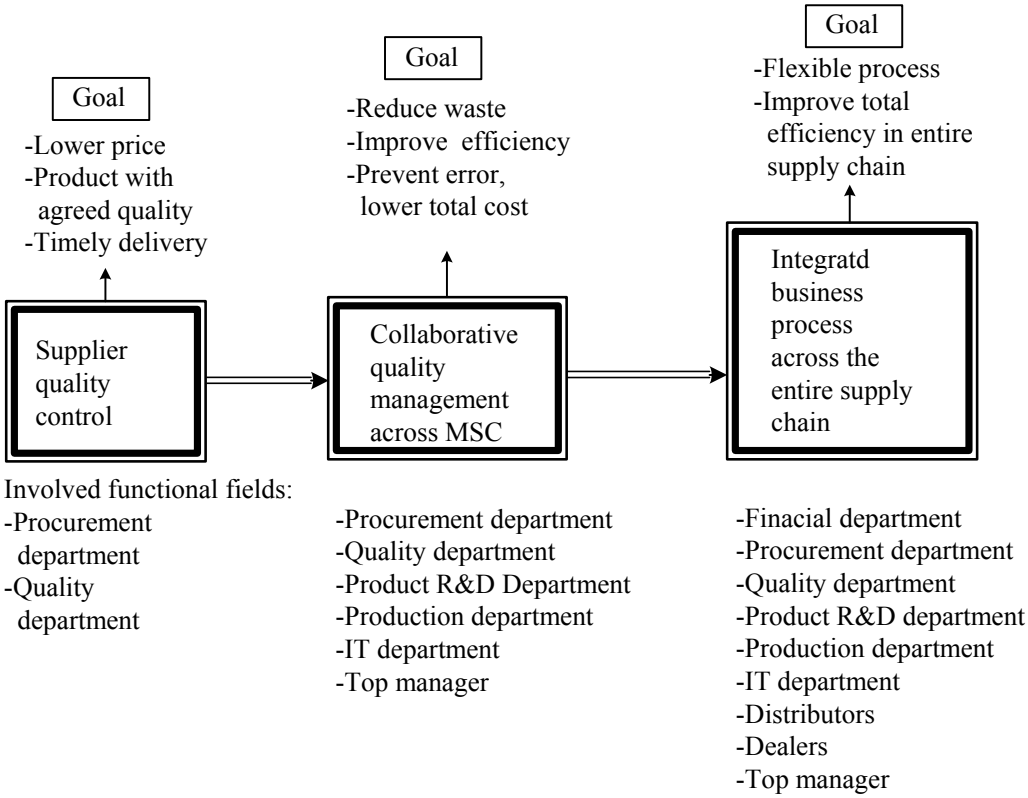


Figure 3-4 Quality management development in a supply chain

Here, collaborative quality management is an incremental way to improve the performance of an MSC. Even though some new techniques in this field are still in development, there is presently industrial experience and enable technologies to make it work. The integrated business process is a critical way; it focuses on the entire process integration together with re-

engineering, i.e. a completed, extended enterprise. But by implementing collaborative extended enterprise oriented quality management in an MSC, it develops a basic way to reach the new phase of the total integration of a supply chain.

3.3.2 Choice of modeling methods

A proper modeling method must be chosen for a certain research object. There are many kinds of modeling methods for describing a system. Table 3-1 lists their characteristics and application scopes.

Table 3-1 Modeling methods and comparison[Ning 2000]

Method	Future
Language based description	Expression that describes the processes. Concentrate on single tool and environment description. Complicated, difficult to maintain.
Diagram based description	Applies activities flow diagram. Easy to view. Stated structure, depends on the experience of the designer.
Rule based description	Rule based expert system. Flexible for modeling, good for process execution. Difficult to obtain knowledge. Does not support version management and configuration management.
Petri-net based description	Good at describing the processes of condition and change. Difficult to guarantee the efficiency of process operation as well as to describe improvement in the processes and the organization.
IDEF modeling family	An efficient method for complicated system analysis and modeling.
IDEF0	Describes system function activities and interaction. Focus on function modeling.
IDEF1x	Describes system information and interaction. Focus on information modeling.
IDEF3	Describes processes and interaction.
IDEF4	Software development method.

In this study the goal is to define the functionality of quality management to the cross-company and multi-tier manufacturing supply chain and the required support bases. Considering the complicated processes and activities, IDEF0 is an optimal tool to express its functionality. It is chosen as the main method for building a quality management model in this work. Another method, e.g. diagram based description, is also used for the expression of different implementation processes.

IDEF0 is a method of modeling activities or processes. The diagrams contain processes, shown by a rectangle, and information flows, shown by arrows, see Figure 3-5.

IDEF0 defines a *process* together with its *inputs*, *outputs*, *means* and *controls*.

A *process* is defined as an activity that adds value to its *input* and creates an *output*.

To perform the activity the *process* requires a set of *means* that allow it to function, and the *process* is controlled in how and when the activity is done by the *controls* [Vaugh2000].

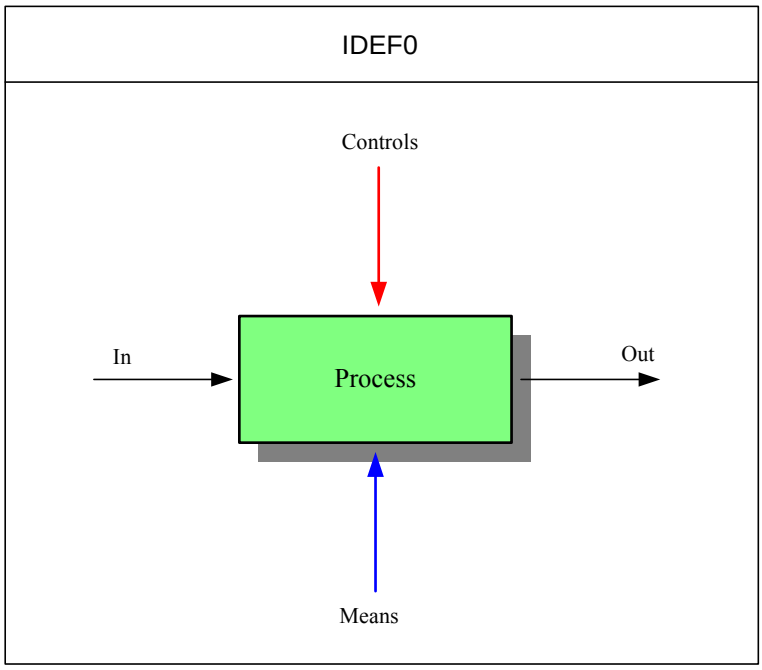


Figure 3-5 IDEF0 notation [Vaugh2000]

3.3.3 Creation of the general model

a. ISO quality management architecture

The ISO 9000:2005 standard defines the **quality management** including [ISO 9000]:

***Quality policy**: Overall intentions and direction of an organization related to quality as formally expressed by top management.*

***Quality objective**: Something sought, or aimed for, related to quality.*

***Quality planning**: Focuses on setting quality objectives and specifying necessary operational processes and resources to fulfill the quality objectives.*

***Quality control**: Focuses on fulfilling quality requirements.*

***Quality assurance:** Focuses on providing confidence that quality requirements will be fulfilled.*

***Quality improvement:** Focuses on increasing the ability to fulfill quality requirements.*

For product realization, C. S. Ma has divided the quality management aspects into three processes: the management process, the product realization process and the support process according to ISO 9000:2000 [Ma 2003]. This basic framework has been maintained in the ISO 9000:2005 standard as shown in Figure 3-6.

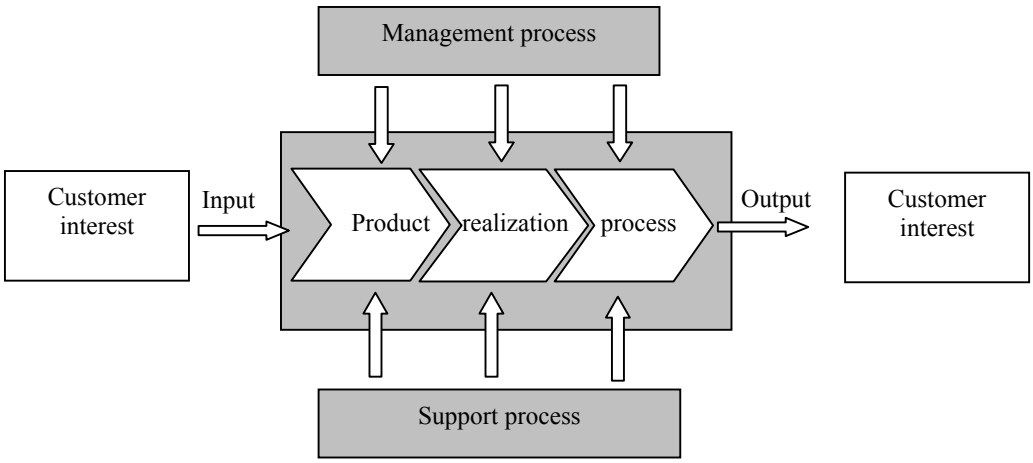


Figure 3-6 Quality management processes [Ma 2003]

b. Function configuration analysis

The Supply Chain Operation Reference (SCOR) model developed by the Supply Chain Council provides process reference models that integrate important business processes together, i.e. plan, source, make, deliver and return. It is a standard language that helps managers to focus on management issues across inter-company supply chains, see Figure 3-7 [SCOR 7.0].

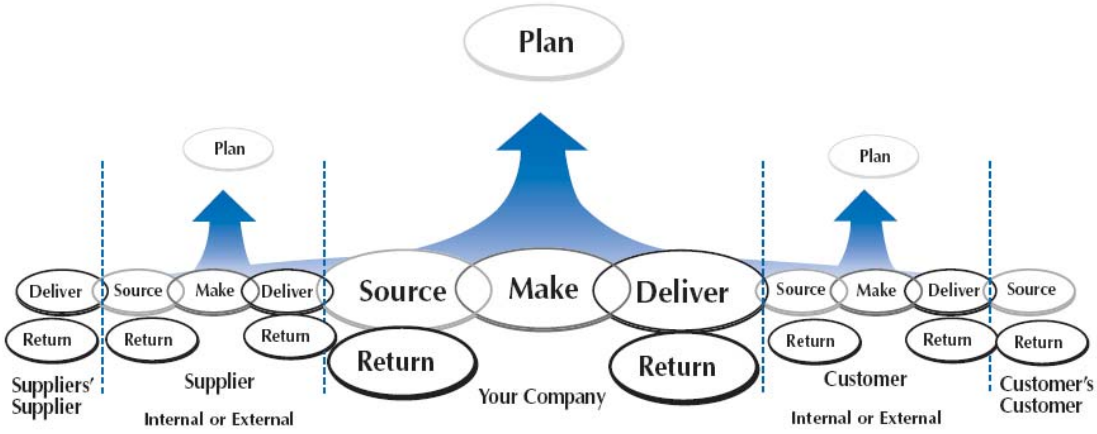


Figure 3-7 SCOR five distinct management processes [SCOR 7.0]

SCOR clearly states that it does not address quality issues, and also it is not involved in product development. However, as D. Dutta analyzed, "SCORs gap shows that product development, especially in short life cycle industries such as fashion, has always been collaborative and across companies. ……As Level 0 evolves, the SCOR model should start to address supply chain effectiveness with product development as an integral part" [Dutta 2004].

From a quality management standpoint, return has been clearly defined in manufacturing and delivery specification to suppliers.

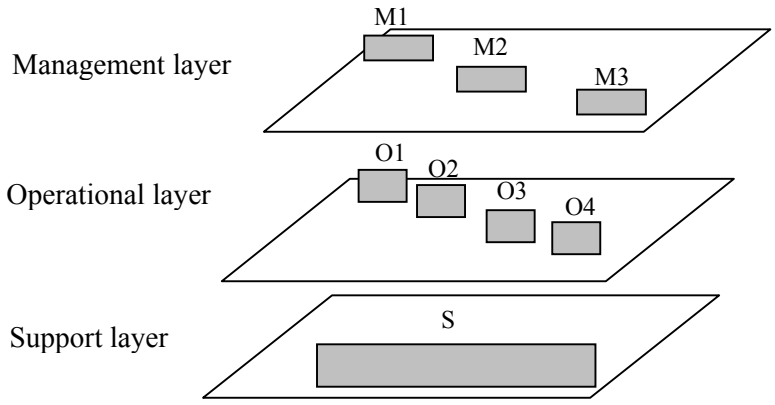
Based on ISO 9000:2005 quality management content, a manufacturing supply chain can be considered as a series of processes that are implemented by all the members in the chain as an extended enterprise. The activities of MSC quality management can be viewed in three levels: management layer (control), operational layer (process) and support layer (means) in accordance with the IDEF0 modeling method.

Management layer [M]: In this layer the processes set up the quality organization, planning and improvement mechanism for an MSC in order to guide it to follow the quality goal through regulation and critical characters, which influence the value chain directly.

Operational layer [P]: In this layer the processes affect the final product's realization and contribute directly to the performance of the manufacturing supply chain.

Support layer [S]: In this layer the processes do not directly work on the chain, but they provide the possibility for the above layers to carry out the quality policy and reach quality objectives.

According to this function definition, the quality composition of a manufacturing supply chain is configured as below in Figure 3-8.



M1	Chain quality organization	O1	Quality management for product R&D	S	Information & Communication platform
M2	Cross-company quality planning	O2	Quality management for outsourcing		
M3	Continuous improvement	O3	Quality management for production		
		O4	Quality management for delivery		

Figure 3-8 Composition of quality related processes in an MSC

Based on the analysis of the activities in a manufacturing supply chain and previous research as well as many leading companines' practices in the quality management of their supply chains, three levels including eight function areas are defined as the main aspects of the quality management in an MSC. There are quality management for key processes - product development, outsourcing, production and delivery - , the general management processes - chain quality organization, cross-company quality planning, continuous improvement, which control and coordinate the common key process for every partner in the chain - , and the enable technologies and platform that function as the means to supports all the processes.

In the management layer:

The ***chain quality organization*** forms a quality steering structure to manage quality in the cross-company MSC in order to promote information share between partners, reduce redundant activities, prevent possible risks among the cooperation and make the MSC operation more efficient.

The ***cross-company quality planning*** provides the integrated quality and production planning as well as the coordinating mechanism for product design, outsourcing, production and delivery function in the MSC by collaboration between the focal firm, customers and tier suppliers. The quality policy, quality objectives and planning process are defined in this process.

The ***continuous improvement*** creates a promoting mechanism in a cross-company MSC to improve the quality in every link.

In the key process layer:

The ***quality management for product design and development (R&D)*** decides on the competitive ability for a chain. If a manufacturer can integrate his suppliers at an early phase in its R&D and they can apply development quality control concurrently, it can greatly reduce the cost for later change and risk.

The ***quality management for outsourcing*** ensures the correct quality requirement transferal from the focal firm to sub-tier suppliers and builds an integrated quality control and quality development for suppliers to prevent the incoming material quality problems in the entire MSC.

The ***quality management for production*** tears down the boundaries between factories at different levels of suppliers and through quality data sharing to adjust production in order to fit the final quality specification or prevent mistakes in advance.

The ***quality management for delivery*** guarantees the delivery of the right material to the right place at the right time in the MSC.

The ***enable technologies and platform*** provide the possibility to realize the quality management concept in a real-time and global way.

All the members in an MSC should participate and collaborate in these function areas. This provides for quality objectives of the MSC to be realized in an efficient way.

Table 3-2 shows the contributions of all function areas to the quality of a manufacturing supply chain.

Table 3-2 The contributions of quality activities to the MSC

Quality activities / MSC	Chain quality organization	Cross-company quality planning	CI	QM for R&D	QM for outsourcing	QM for production	QM for delivery	Enable IT
Time	E	E	E	S	C	S	S	S
Quality	E	S	E	S	S	S	C	B
Cost	E	S	E	S	C	S	C	B
Service	E	B	E	B	C	B	S	E
Agility	S	E	S	E	E	E	E	S

The contribution to an MSC:

S: Strongly contribute
E: Effectively contribute
C: Contribute
B: Basic control/support but not direct effect
Here: QM: Quality management, CI: Continuous improvement

c. Interaction model and its decomposition

A description of the QM general scheme has been discussed above. In order to describe the control mechanisms and interaction between all the processes and the functions inside of them, by means of IDEF0 we can now describe the quality management for a manufacturing supply chains in detail.

According to the IDEF0 method, the model can be defined as input, output, control and means for MSC quality management as follows:

Process: Key processes of product design and development, outsourcing, production and delivery.

Control: Chain quality organization, cross-company quality planning, continuous improvement.

Means: IT platform and databases.

Input: Concept from the final customer's requirement

Output: Delivered product

The quality management model of an MSC is illustrated in Figure 3-9.

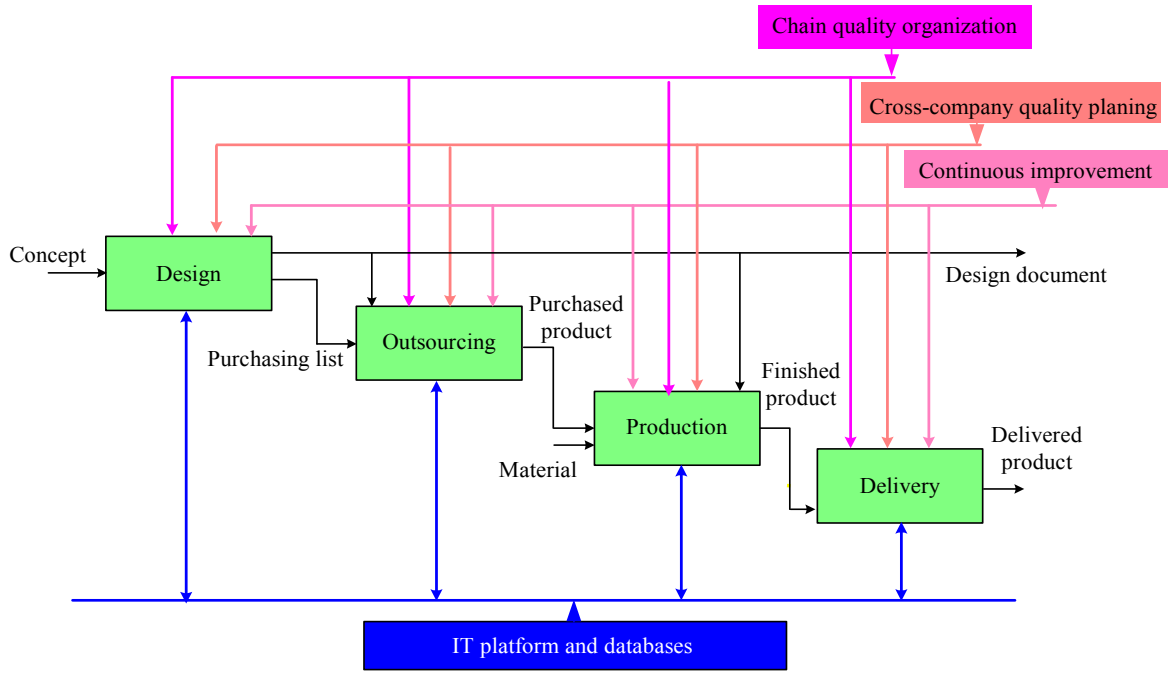


Figure 3-9 Quality management model

Through the design process, the final customer requirement has been transferred into design documents, which include the purchasing list. The purchasing list is the input for outsourcing. The outsourcing output is the purchased products[4] (systems, components or parts), which get into the production process, and then the output as finished products will be delivered to the customers. This is the general process running in an MSC and is carried out by every partner.

During the process above, the chain quality organization controls and coordinates all the processes and activities between different participants in the chain by means of the work of a supply chain quality team (will be discussed in Chapter 4). Cross-company quality planning sets up the common quality goal for the entire chain and communicates the requirements of the focal company to sub-suppliers. By uniting with cross-company forecasting, the partners in the chain can replenish their inventory together at the lowest cost. Continuous improvement forms a mechanism that promotes the participants in the chain to improve in all processes and links.

The IT platform provides the communication ability among all the controls and processes. The databases provide the design, outsourcing, production and delivery experience and knowledge to offer support to all the processes and controls.

[4] The purchased product or material includes systems, sub-systems, components and parts from suppliers.

Every process can be subdivided into sub-processes that demonstrate collaborative activities among all the participants, which will be discussed in detail later in Chapter 4.

3.4 Summary

In this chapter, by analyzing the ISO 9000 quality management function and Supply Chain Operation Reference (SCOR) model as well as the quality requirements for an entire manufacturing supply chain, a quality management model of an MSC is drawn up. It consists of the processes of the quality organization, cross-company quality planning and continuous improvement in the management layer, quality management for R&D, outsourcing, production and delivery in the key process layer as well as the IT enable platform as the support layer.

The chain quality organization, cross-company quality planning and continuous improvement direct and control the manufacturing supply chain with regard to the general quality standard. The IT platform and related databases give the support for quality management activities in the whole chain. The quality management in product design and development, outsourcing, production and delivery are the four main functional processes that relate with all partners in the chain and influence the quality of an MSC. If a collaborative working mechanism has been built in and the quality management has efficiently been implemented in those fields, the quality foundation of a manufacturing supply chain is in place. It can give the MSC a stable base to improve and develop incrementally.

Chapter 4 Model Decomposition and Analysis of Functions/Approaches

In this chapter the foundational processes for a collaborative quality management in a manufacturing supply chain, i.e. management processes - quality organization, cross-company quality planning, continuous improvement -, key processes - quality management for new product development, outsourcing, production, delivery - as well as enable technology and platform will be discussed in detail.

4.1 MSC quality organization

In the extended enterprise every participant concentrates on his core competencies and outsources his non-core business, forming a cooperative network of business alliances. The structure is open, dynamic and flexible, but calls for robustness. In 2000, a survey in Industry Week reported that "although there is much talk about value chain management and collaborating with partners across the entire supply chain, less than 2 percent of executives report that their firms function as full extended enterprises". This deficiency has been traced to cultural and corporate barriers. Lack of senior management commitment and inability to tie supply chain-wide efforts to strategy are considered as the main reasons.[Tanine 2000].

4.1.1 Organization principle

Flynn and others think that supply chain management is transacting from a traditional vertical perspective (usually to minimize costs) to a horizontal perspective. The new horizontal perspective recognizes that organizations have a symbiotic relationship, where each contributes to the other's success [Flynn 2005]. An effective organization of a manufacturing supply chain coordinates all the different individual companies in a chain as quickly as possible without losing any of the quality or customer satisfaction. To reach this goal, the companies in the chain that seem to work independently should function together as an extended enterprise.

Parker and others defined a new role as the supply chain integrator, who differs radically from those found in traditional supply-management, who have focused primarily on issues of cost, delivery and inventory control. Instead, it "can maintain product coherence from concept to customer often across numerous firm boundaries" [Parker 2002].

The focal company should act as the integrator. It leads the activities "to build process networks that encompass hundreds or thousands of participants across multiple tiers of extended operating processes" [Hagel 2005]. It defines standardized interfaces for the quality activities by bringing participants together for specific projects; establishes the incentive structures required to reward participants and ensures that each participant meets appropriate quality standards for its outputs.

To make sure that the chain maintains its core competence as well as improves its total quality level, two quality organization principles should be considered.

- Understand the entire manufacturing supply chain

The focal firm should have the entire view of its MSC. As Chrysler expressed that a Chrysler coordinated, goal-driven process unifies and extends the business relationships of suppliers and supplier tiers in order to reduce cycle time, minimize systems cost and achieve perfect quality. To reach this goal, Chrysler carried out supply chain mapping from raw materials to end-users. The suppliers are required to map their own supply chains, so that Chrysler can have a full picture and is used to find improvements in processes and material flow to cut costs [Allpar 2003].

- Establish a core chain with the key suppliers in different tiers

The multi-tier MSC is a huge network. It includes different types of suppliers. D. M. Lamber and others have given a model in which the focal firm should manage its first-tier suppliers and the suppliers on other tiers who belong to the focal firm key members. See Figure 4-1 [Lamber 1998].

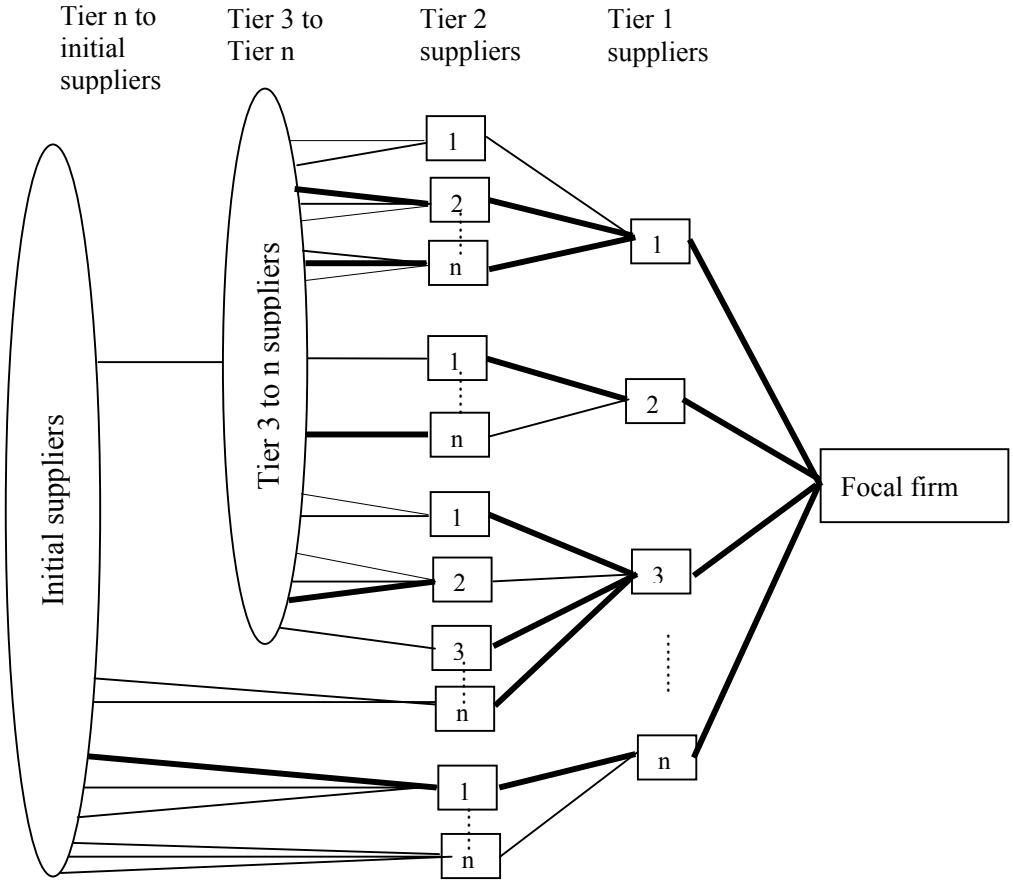


Figure 4-1 The core chain with key suppliers[5] [Lamber 1998]

[5] The thick lines represent the key supplier network.

It is essential to form a key supplier network in order to build a long-term and trust backbone for the MSC. This is the basis for chain stability and agility. The key suppliers should be chosen by the focal firm together with its direct suppliers according to the mapping of the MSC.

Based on the key supplier network and the entire view of an MSC, the quality requirements of the MSC will be transferred and "broadcasted" in the entire chain.

4.1.2 Organization structure and responsibility

The focal firm is the main organizer and coordinator. It views the manufacturing supply chain as one extended enterprise, which inherently brings competitive advantages for itself as well as for its partners. In order to integrate all the partners together to fulfill the quality requirements in the extended enterprise, a three level organization structure should be built in to the MSC, see Figure 4-2.

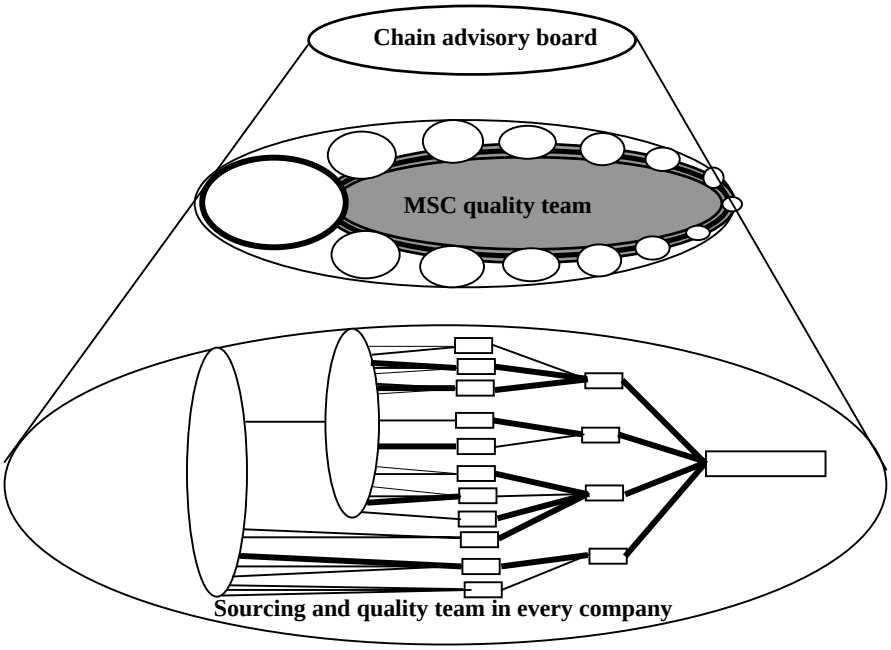


Figure 4-2 The organizational structure of the MSC

- ***Chain advisory board***

Feigenbaum emphasized that "managers and organizational involvement in improving quality are the quality facilitators" [Feigen 1983]. Philip Crosby insisted on the need to establish quality councils for communicating on a regular basis [Crosby 1997].

In the MSC as the steering committee, - i.e. the chain advisory board, in which all the key suppliers and other partners participate - it is essential to form a solidarity chain. This consists of the executive personnel of the partners, e.g. CEO, presidents. It represents the inter-

ests of the network and the single members. It clears quality policy and sets down the strategic quality objectives, it supervises the activities of the MSC quality team and assumes responsibility for the continuous improvement of the supply chain. It makes important decisions on the development of the chain and provides support to the executive team – MSC quality team.

- ***MSC quality team***

This team consists of the personnel of the focal company (OEM), key suppliers in the first and second-tier as well as other suppliers and partners. These are the professional people from the supplier quality team in the focal firm as well as the representatives of key suppliers and other partners, e.g. from their purchasing departments or quality departments. The quality team structure is shown in Figure 4-3. In the quality team all functions can be divided into three kinds of roles:

- Chain managers

The chain managers who come from the focal company (OEM) lead the quality collaborative activities in the extended enterprise. They generate the links among the extended enterprise and coordinate all the partners in the network. Their functions include:

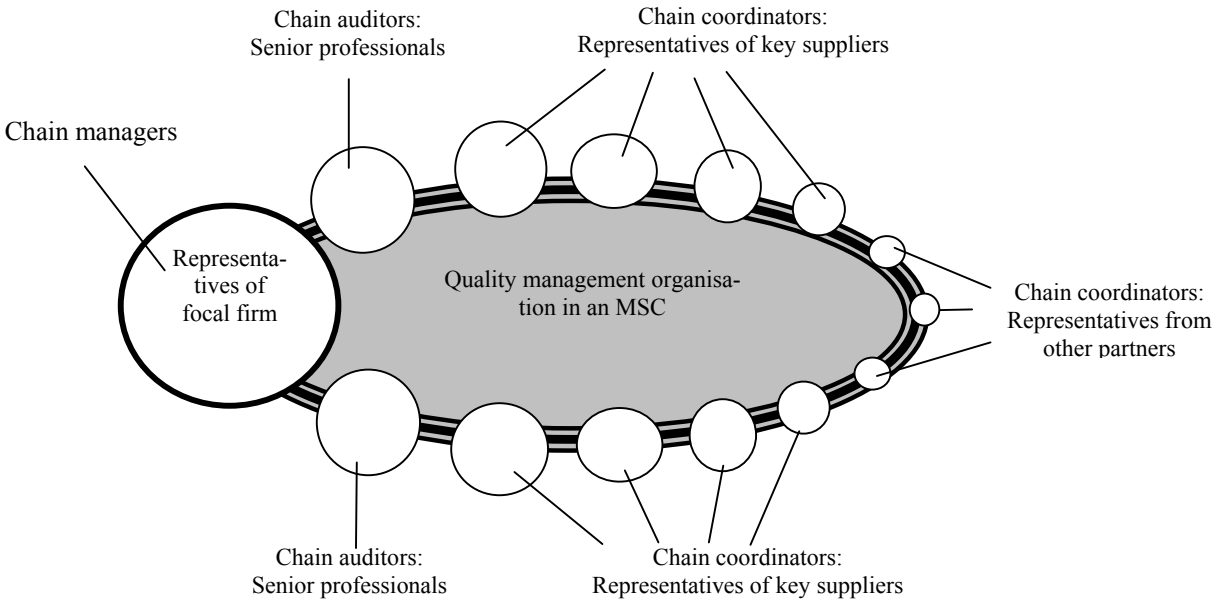


Figure 4-3 The structure of the MSC quality team

- Responsibility for the management. They uphold the connection in the chain, coordinate different competences and cultural differences, evaluate results and introduce new measures.

- Responsibility for control. They make and act on joint plans, observe the quality improvement goal, coordinate the activities of chain auditors, monitor and measure the actual performance, compare the actual performance with set targets, lead actions to correct and improve.
- Responsibility for information and reporting. They carry out information exchange and analysis and transfer it to the MSC quality team members, report to the chain advisory board.

- Chain coordinators

They originate from members in the manufacturing supply chain and play the role of linking the network and their own companies. They communicate with the chain managers and coordinate the tasks of the chain with their own companies [Stegemann 2001].

- Chain auditors

The chain auditors are senior professional members of the MSC quality team. They also invite third party quality auditors as well as the people from the chain advisory board when necessary. Their tasks are as follows [Stegemann 2001]:

- Implementation of the cross-company quality audit
- Evaluation of general cross-company quality improvement processes and
- Confirmation and monitoring of corrective and improvement measures.

- ***Sourcing and quality team in every company***

It consists of the supplier quality team in the focal firm, the sourcing team of the sourcing department and the quality team from the quality management department in every individual company in the chain. This personnel is responsible for the quality management and coordinates actives inside the company and between their customers and suppliers. Their representatives work as the members of the MSC quality team for the quality management within the whole chain. Their tasks are as follows:

- Optimize the inner business processes within their companies
- Build the base for across department collaboration
- Integrate different business areas as well as customers and suppliers in the process
- Be responsible for cross-company material flow and order processes, identify bottleneck situations, optimize processes, information flow and costs and define service levels between the internal and external customers

These people are often the product supply chain managers in their companies. They take the responsibility for running a product group.

Through this three level quality organization the quality management in an MSC is integrated together from the single company to the entire manufacturing supply chain.

4.1.3 Qualification of the quality team

The collaborative manufacturing supply chain needs all personnel to involve themselves and understand the principle. The most important personnel is the people in the MSC quality team. It consists of chain managers, chain coordinators and chain auditors. They are also the supply chain managers for their own company's supply chain. As Steffen Elsaeser, consulting company Cap Gemini Ernst & Young said: "The Supply Chain Manager is a cross-company authority. He combines the traditional functional areas of purchasing, production and logistics". They are active in connection with the functional departments inside of their own companies and with other chain members as well as the collaboration in the four key processes.

The Supply Chain Managers must be highly-qualified people. But just a good education is not enough. The most valuable thing is operative experience, not only just operative know-how, but also communication and project management skills and capabilities. The qualification for a supply chain manager is as follows [Kranke 2002].

- Rich experience in the field of purchasing, marketing, production planning, manufacturing control, distribution, and logistics
- Basic knowledge of the branch
- Prominent project management experience
- Across-functional and process-orientated thinking
- Basic IT skills
- Cooperation and teamwork abilities
- Very strong personality to deal with conflicts and solve problems
- Excellent communication capability on workforce and management levels
- Motivation all the way through to the cross-company's goals
- Leadership competence

It is a basic requirement for a manufacturing supply chain to assign, train and improve qualified supply chain managers. The MSC quality team is the key to improving the cross-company quality standard. Some leading companies in supply chain management, like the plastics company Nypro Clinton, have already worked in a team (so called cross-company quality improvement teams) to remove wastes and reduce the cycle time of the entire supply chain and have set up partnerships with seamless operations throughout the supply chain: from the raw materials to the customer [Godfrey 1998].

4.2 MSC quality planning and forecasting

ISO 9000:2005(E) states that quality planning is the part of quality management focused on setting quality objectives and specifying necessary operational processes and resources to fulfill these quality objectives [ISO 9000]. Now the quality objectives and their decomposition will be discussed first.

4.2.1 Defining quality policy and quality objectives

- ***Quality policy***

In ISO 9000:2005 (E) the quality policy is defined as the overall intentions and direction of an organization related to quality as formally expressed by top management [ISO 9000]. In the MSC the quality policy is to build an MSC to fit its quality requirements - shorter time to market, operational quality and efficiency between different tiers, lower cost of whole chain, better service between partners and agility of the chain, which have all been discussed in §3.1. It is the ultimate goal for an MSC to become a stronger, competitive and more successful extended enterprise that is lead by the focal firm and its key partners.

- ***Quality objectives***

The quality objectives in an extended enterprise oriented MSC must be set up and the partners in the chain must be aware of them. The quality objectives should meet the requirements as follows [Cochran 2000]:

- Be measurable
- Be unique to each participant member
- Be consistent with and support the quality policy
- Include objectives needed to meet final product requirements
- Communicate to all participant members the meaning of the objectives and how each party helps to achieve them
- Be able to monitored for consistency and improvement
- During management reviews, be able to evaluate the need for changes to quality objectives

Quality policy will be realized through progress by continually reaching the quality objectives. The quality objectives are set down according to the dynamic market changes and competitive situation. The quality objectives of an extended enterprise oriented MSC can be listed as following aspects:

- Improve product quality to reach a required specification

- Prevent the later design change and repeat work between partners
- Reduce the quality cost and total cost in the MSC by percentage
- Increase on-time delivery rate in the MSC
- Improve the responsiveness to the customer's specific needs

In a wider scope, all the intentions that aim to improve the five characteristics of an MSC can be considered as the objectives.

For example, Rolls-Royce and its suppliers set up four key Quality Renaissance Targets as a never-ending journey to excellence [Jenkins 2005]:

1: To cut in half the rate of customer incidents every three years

2: To cut in half the cost of non-conformance from all business processes every three years

3: To achieve a ten times reduction in delivered defects every two years

4: To set benchmark lead times and achieve them, including appropriate intermediate milestones within three years.

Rolls-Royce's experience illustrated that the sheer complexity of modern aircraft necessitates the participation of hundreds of specialist suppliers and sub-suppliers in manufacturing components. Meeting quality objectives demands a system that incorporates the full suite of Rolls-Royce quality, cost, delivery, responsiveness, management and environmental requirements and harmonizes all this across the entire global supply chain [Jenkins 2005].

Chain members, especially key members, must have a clear understanding of their position in the chain and their responsibility to the chain. They should set targets for their own quality objectives considering the total objectives in the chain. Targets must be set with an understanding of the underlying process capability[Cochran 2000].

4.2.2 Quality planning process

In Gryna's book quality planning has been defined in two areas of joint quality planning: joint economic planning and joint technological planning [Gryna 2001]. This planning occurs between supply partners. But in an extended oriented MSC the activities are viewed as a virtual enterprise that needs joint quality planning in the whole system and at different levels. Therefore, here the quality planning process is defined in three levels according to the MSC organization structure in §4.1.2.

- ***Joint strategic planning***

Top management has the broad perspective and understanding of the competitive environment. The Chain Advisory Board as the top management union is the leader and carrier for the quality planning function in the entire chain. According to the practice of Respironics, a fast-growing manufacturer in the sleep and respiratory market, business meetings should be held quarterly lead by the OEM with the strategic suppliers. They exchange information about critical business drivers, proactively discuss risk factors and have an open and honest exchange of ideas, concerns, and commitments. These meetings are tools to ensure that the supply chain is aligned, as the conversation extends beyond Tier 1 concerns. For example, they dealed with issues ranging from supplier capacity constraints to the root cause investigation of quality problems. This partnership planning and communication commitment established the basis of success for the lean activities of the supply chain [Morgan 2005].

- ***Joint systematic planning***

The customers' expectations must be transferred exactly from the focal firm to the up-stream suppliers. This requires the extended manufacturing supply chain integrated seamlessly and operating as a whole system. It is essential for the focal firm to master the entire MSC structure, i.e. not just understand its direct suppliers, but also the entire supply chain.

After an across-function, company and chain quality team has been built, which has been discussed in §4.1.2, the focal firm shares its well-articulated roadmap for success with its suppliers in the quality team. The roadmap shows in a logical and consistent manner how all the partners create value for the customers [Davis 2004]. By means of analysis of the quality requirements for the roadmap, the quality improvement objectives should be set up.

Figure 4-4 depicts the quality planning and implementation process in an MSC. To reach a certain quality goal, a supply chain mapping process starting from the focal firm/OEM to up-stream suppliers should be in action. Suppliers are required to map their own supply chains, so the whole manufacturing supply chain structure can be lucid and be a full picture of the focal firm and its suppliers in every tier. The map helps to visualize the supply chain and identifies the further analysis fields or shows obvious inefficiencies that are not as easily visible when examining only a small segment of the supply chain. It provides a communication tool to reach across firms, functions and corporate units [Gardner 2003]. This makes everyone know where his position and possible contribution for the whole chain is. Supply chain mapping can be used to find possible improvements in processes and material flow to cut costs [Stallka 2005]. Under the instruction of process evaluation criteria, which will be discussed in chapter 5, by comparing the 'AS-IS' condition to the 'TO-BE' condition in the quality management model of an MSC (discussed later in chapter four), the members in the manufacturing supply chain will find out the gap for improvement in the eight functional areas.

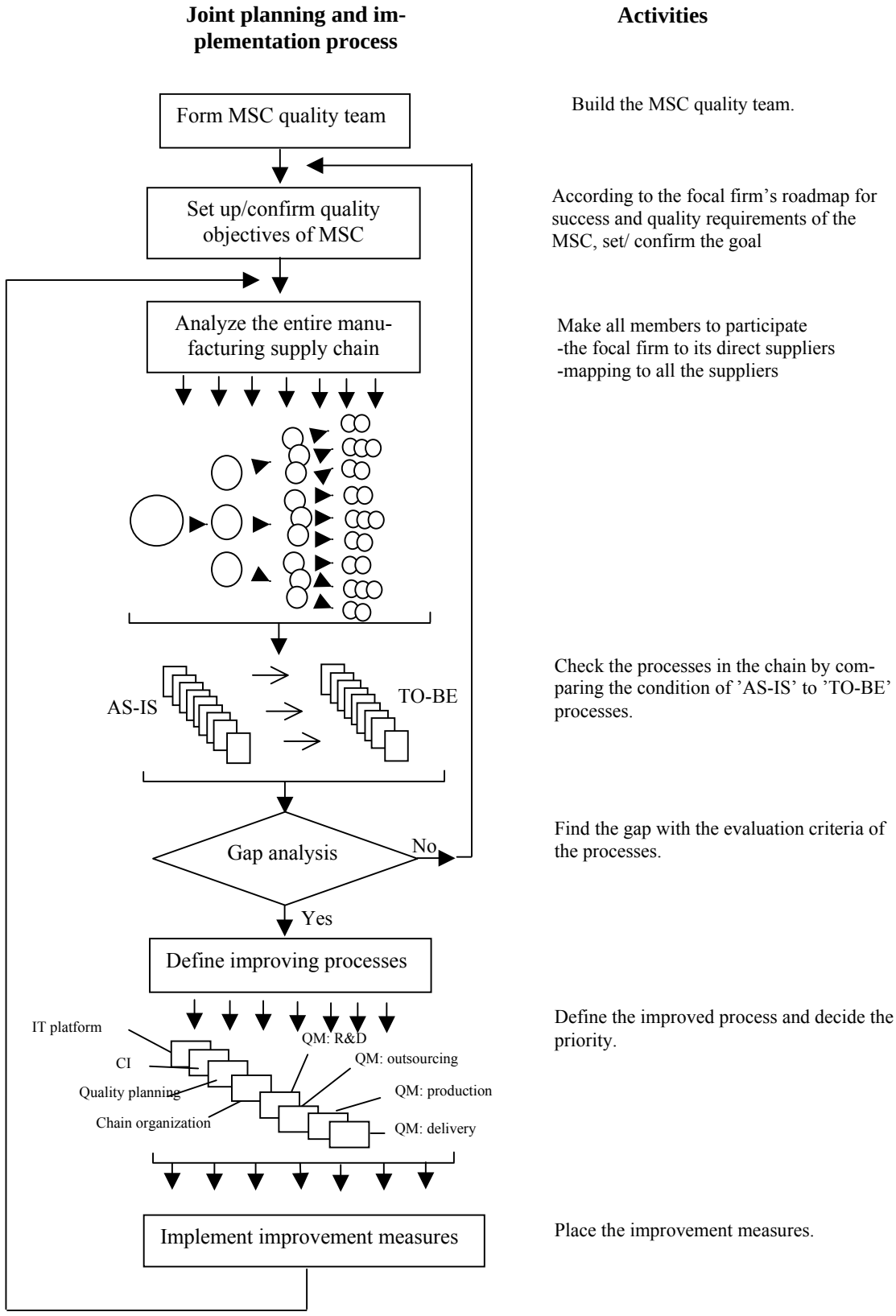


Figure 4-4 Joint systematic planning process

After the gaps are defined, the improvement priority should be decided on according to the possible contribution for the entire performance of the chain. The improvement measures can be chosen to improve the processes in the chain by referencing the collaborative quality management model in chapter 4.

Improvement activities always take place between chain members, so this co-coordinated effort is a prerequisite for the whole chain to collaboratively work together. Involvement of the participants in cross-company planning and implementation is depicted in Table 4-1. Quality organization and planning must be initiated and set up by the focal firm; then extended to the key suppliers in the chain. Continuous improvement and usage of enable platforms involve all the members. Quality management for outsourcing and delivery always directly interacts between the customer and the supplier. Quality management for R&D is especially important between the focal firm and its supplier/sub-suppliers. Collecting quality information of the production is a basic work for every participant and should be shared real-time in the MSC.

Table 4-1 People involved in the cross-company planning and implementation processes

Process	**Quality organization**	**Quality planning**	**CI**	**QM for Outsourcing**	**QM for R&D**	**QM for Production**	**QM for Delivery**	**Enable platform**
Involved parties	Focal firm, Key suppliers	Focal firm, Key suppliers	All	Every two connected members	Focal firm and its supplies/sub-suppliers	Every tier of suppliers	Every two connected members	All

- ***Joint operational planning***

It is carried out by the sourcing and quality team of every chain member. It aims to build an overall and similar quality management frame for all the members in the chain to deal with suppliers and customers. It will be fully discussed in the functional quality management process in product development, outsourcing, production and delivery in §4.4, 4.5, 4.6 and 4.7.

As the analysis by Batson in his thesis "Quality Planning for the Manufacturing Supply Chain" states, "Strategic supply chain planning, ..., must be carried out in parallel with strategic production planning. This parallel (or concurrent) planning provides the best opportunity for seamless integration, high-quality supplies, logistics and products and minimum cost" [Batson 2006]. Therefore, in an MSC joint forecast planning should be emphasized in parallel to ensure the operational quality of an entire MSC. In order to distinguish it from quality planning, it is discussed in the following §4.2.3.

4.2.3 Cross-company planning and forecasting

Most supply chains today contain unnecessary waste and cost in the form of redundant business processes and inefficient practices [Davis 2004]. The major problem is a lack of visibility across the supply chain. Traditional manufacturing models deal with functional silos that do not readily connect with integrated supply chain planning. This is changing. As companies use Internet-based e-commerce systems to share information and collaborate with vendors and customers, they are realizing the value of manufacturing data for supply chain decisions.

Some leading focal companies, like Hewlett Packard, Lucent Technologies, etc. have tried to visualize the planning and scheduling across their manufacturing supply chain to prevent the obstacle of business process integration in order to move away from repeated work, reduce inventory at their suppliers and shorten time to fulfill orders. For its monitoring products, HP set up a computer system to share information among all the participants. It posted its demand forecasts and revisions to its first-tier partners for using in their own forecasting. The partners could also post their plans and schedules and use the system to communicate with their own suppliers and customers. HP's procurement staff managed the entire process, monitoring upstream suppliers, resolving disputes and helping keep materials and products flowing. By using this collaborative process, "the number of managers for the supply chain was cut by 50 percent, time to fill an order dropped by 25 percent and sales increased for the products managed by this process" [Davis 2004].

- ***Collaborative planning, forecasting and replenishment***

Collaborative Planning, Forecasting and Replenishment (CPFR) is an advanced philosophy and tool for gaining higher quality of the manufacturing supply chain. It is operated by organizations to make their supply chains more responsive and keep all the supply chain members in tune with the end customer demands, both in terms of the product and its volumes [Decis 2001]. The CPFR committee developed a general model. It provides a set of guidelines on how companies can establish dense, collaborative partnerships within a supply network. CPFR defines all the participants in a supply chain to synchronize their different planning functions. The focal company and its trading partners can use common data to respond to the demand and supply variability, jointly addressing inventory needs. With these new levels of communication and visibility, partners throughout the supply chain can calculate shortages or excesses in real-time and adjust quickly. The practices from many companies, like HP, Karstadt-Quelle AG have shown that cross-company collaborative planning processes can drive a supply chain to be a world leader.

The CPFR process is divided into nine steps (see Figure 4-5) [Mart 2004] [Nokken 2004].

Step 1 Front-end agreement: Member companies identify executive sponsors, agree to confidentiality and dispute resolution processes, develop a scorecard to track key supply chain metrics relative to success criteria and establish financial incentives or penalties.

Step 2 Joint business plan: The project teams develop plans for promotions, inventory policy changes, store openings/closings and product changes for each product category.

Steps 3-5 Sales forecast collaboration: Customers and suppliers share consumer demand forecasts and identify exceptions that occur when partners' plans do not match or change dramatically. They resolve differences by determining causal factors, adjusting plans where necessary.

Steps 6-8 Order forecast collaboration: Customers and suppliers share replenishment plans, identifying and resolving exceptions.

Step 9 Order generation/delivery execution: Results data (POS, orders, shipments, on-hand inventory) are shared and forecast accuracy problems, overstock/under stock conditions, and execution issues are identified and resolved.

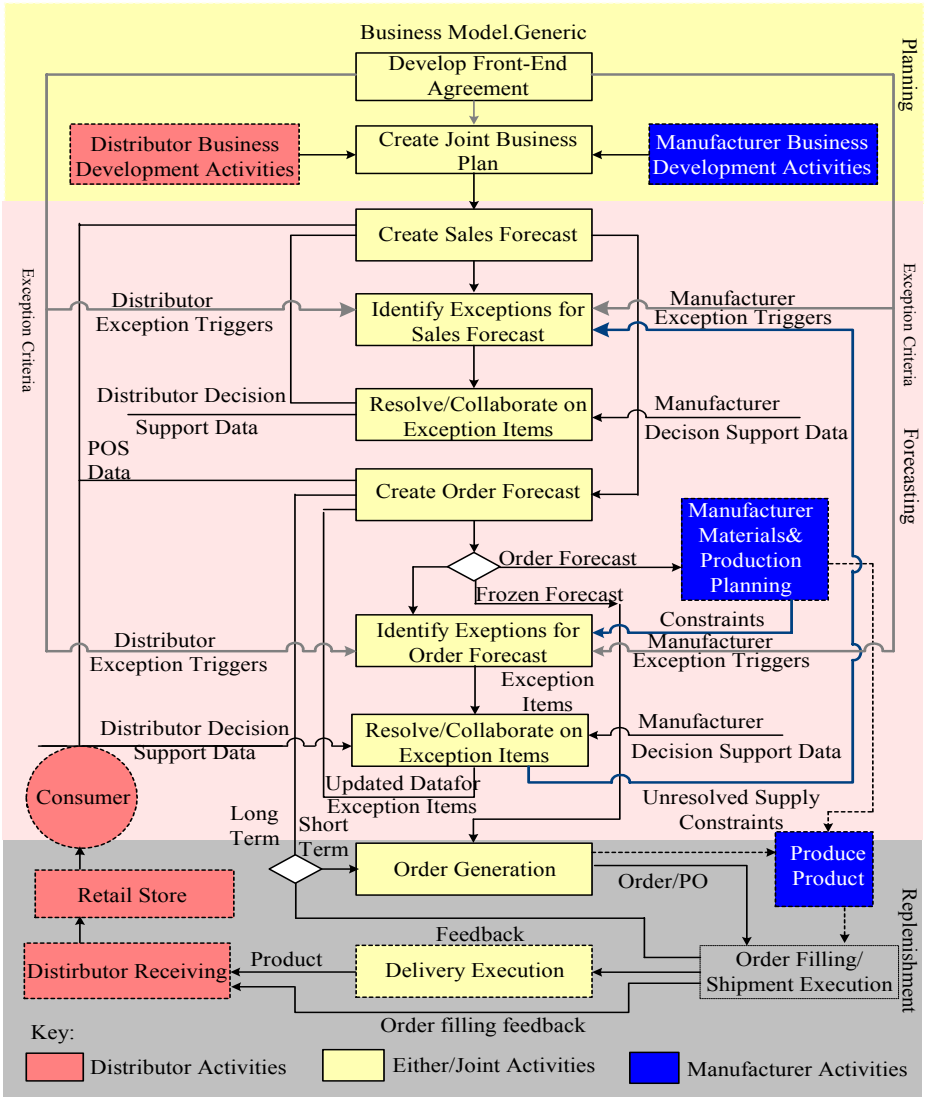


Figure 4-5 CPFR's nine process steps (Source:www.cpfr.org)

Step 1 ensures that each company has an adequate commitment to collaboration, and that all parties are aligned around common goals. This front-end agreement might be reviewed on an annual basis. Step 2 applies good category management principles - borrowed from the Efficient Consumer Response (ECR) initiative – to create a joint plan for going to market. This would typically be revised quarterly or semi-annually. In the steps 3-9, this joint business plan is used to control the day-to-day activities of manufacturing, delivery and selling products. This makes CPFR unique [Mart 2004].

- ***Tools and implementing structure***

Some leading companies have developed customer systems. But more and more professionals think that "the cost and risks of new technology can be dramatically reduced for most participants in the supply chain through common standards and open-system approaches". As a commercial platform the Syncra Xt collaboration platform collects, transforms, manages and analyzes supply and demand chain data, enabling companies to collaborate in order to improve planning and execution. It supports applications that address collaborative demand planning, forecasting and continuous inventory replenishment (CPFR) [Jusko 2003]. By integrating Syncra Xt with the existing system, it can unlock the value not available through company's ERP investment alone [Carrol 2002].

Karstadt-Quelle AG has been running CPRF projects through Global Net Exchange (GNE) [Kapell 2003] as shown in Figure 4-6.

In the GNE network the focal company provides suppliers every day with:

- Sale and inventory data per store
- Information about stock coming in and going out of the distribution centers
- Relevant forecasting and outstanding order data

The manufacturing suppliers provide:

- Data about the range of coverage and product inventory in their own warehouses
- Data about the flow of goods coming in
- Data about back orders and current orders

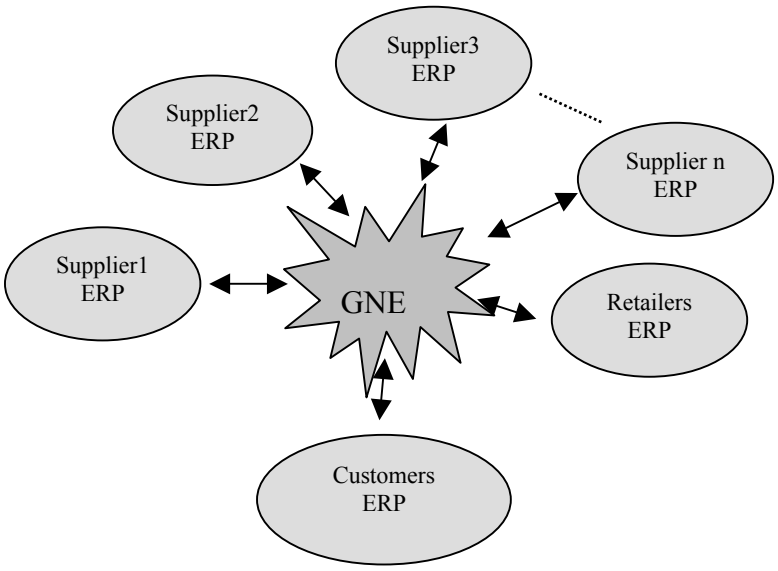


Figure 4-6 Karstadt-Quelle AG CPRF project through Global Net Exchange (GNE)

On the GNE task forces meet regularly (weekly) to discuss how things are going, which is more than just data exchange. This communication includes:

- Explain data to each other, analyze it and initiate counter measures, if needed.
- Match the inventory to the forecast demands (both sides try to do it). If or when critical situation arise, both sides are automatically alerted.
- Exchange all the information necessary to make forecasts.

In order to build up a hierarchy of collaboration to achieve optimization of the whole chain, according to some advanced focal firm's practices, a tiered system with CPRF can be set up through the focal firm and on to the lower tiers. For example, Metro's tiered system makes it possible to include all levels of suppliers in information sharing on promotions, creating an even larger critical mass of potential contributors. Beginning to view and share some information in lower tiers helps suppliers to build confidence with the focal firm as a reliable partner, and it is a good way for suppliers to get in the habit of planning further ahead [Demer 2005]. Table 4-2 lists the information sharing level in the tiered CPFR system.

Table 4-2 Information sharing level in the tiered CPFR system [Demer 2005]

Focal firm	Builds the Intranet with initial information of product planning and promotions.
First-tier suppliers	Exclusive access to the focal firm's category management; share initial information on planning assortments and times for product promotions.
Second-tier suppliers	Share in details on pricing and quantities of planned promotions and make suggestions for alternate products and pricing.
Third-tier suppliers	Access the focal firm's extranet, where they can share in some data on promotions but not participate in the planning processes by inserting suggested products or pricing.
Fourth and fifth tiers	Receive basic information on promotions through Electronic Data Interchange (EDI) or other means outside of the focal firm's extranet.

4.3 Continuous improvement

Along with globalization and competition, the cost issue is an especially hard stone for OEMs and suppliers. The traditional way, by which an OEM has power to control and command its suppliers to reach the planned quality and budget cost, has come to an end. The collaborative continuous improvement in a chain gives partners a new way to gain profit for every party.

Continuous improvement is not a new concept in quality science. As a part of TQM it has been used in an organization (single company) with many successful examples. Today, in supply chain improvement the concept of organization expands from company-wide to chain-wide, which consists of the companies from different tiers. Every supplier, no matter what size it is and which tier it belongs to, is an equal link in the chain [Stallka 2005]. On the other hand, the continuous improvement is different from collective action in a single company; it is an autonomous process to improve the quality of an MSC through every party of the system.

4.3.1 Pressure and weak links in the MSC

In the continuous improvement, the focal firm (OEM) is the principle establisher and organizer, however, as Stallkamp, ex-vice CEO of Chrysler, described in his book, "suppliers should take the lead in supplying total systems, not just in individual parts or components". The suppliers can play a bigger role in the performance improvement. The reasons are as follows.

- A big part of the final product's cost (up to 80%) depends on suppliers. Suppliers' costs and the way of business operation between the OEM and different tiers of suppliers strongly influence the competitive capability of a final product on the market.
- Suppliers understand their business and problems best. Without their active participation the OEM cannot move any further alone.

In the traditional operation the work mechanism is occupied with seller and buyer relations, i.e. contract relationships. Stallkamp criticized: "The suppliers run their companies from a perspective that they are isolated, and if they do know their place in the chain, they often assume that they have no real impact on it. ……The companies make a product and ship it to someone else. The communication is limited and seldom involves anything more than shipping and pricing information" [Stallka 2005]. The connection between the OEM and suppliers from different tiers is separated and difficult to combine together efficiently. The OEM is always under marketing competition and makes demands on its suppliers to lower the supply prices. Especially in the automobile industry, conflicts between the OEM and suppliers happened very often because of the control and command working style of the OEM [Lamp 2000]. Some manufacturers, e.g. Toyota and the old Chrysler, etc., had explored real continuous improvement mechanisms in their supply chains. Those leading companies then implemented their approaches with different named programs to reach their success in the business. Practical analysis shows that an efficient mechanism is required to motivate this effort in a cross-company MSC.

4.3.2 Mechanism of continuous improvement

According to Chrysler and other manufacturers' practices, a successful continuous improvement should be based on the mechanism in Figure 4-7 [Stallka 2005] [Xu 2006].

Figure 4-7 The mechanism of continuous improvement

- ***Voluntary base***

The manufacturing supply chain operates as an extended enterprise. However, every partner is independent as a legal party. Traditional control and command management can be successful for cost reduction initially, but never lasts for an extended period. All improvement activities must be put into effect on a voluntary basis. Otherwise, before the improvement proposal starts, the members in the chain are already against it [Stallka 2005].

- ***Encouraged strategy***

Without organization and promotion, the improvements will not happen automatically and spontaneously. The focal firm, as the biggest benefited party, must map its suppliers and transfer the mapping to sub-tier suppliers in order to link all the members in the chain. The focal firm as well as partners in different tiers should discuss problems with their suppliers and inspire the suppliers to contribute their ideas, giving suggestions for improving themselves and all possible links with their customers or the focal firm in order to reduce the cost and improve the quality in the entire chain.

The profit gained through continuous improvement activities should be shared by the focal firm (customers) and their suppliers. For example, suppliers are encouraged to keep some of the cost savings for themselves to improve their own profit margins and to make the focal firm (customers) business more profitable for themselves [Stallka 2005]. This is the principle of a win-win strategy.

- ***Top management involved***

It works closely with the quality team, which includes all the possible partners in the manufacturing supply chain. Improvement progress and results need to be summarized in a report card. By sending the report card to the CEOs of the suppliers, they are thus aware of how their company stands in overall improvement performance related to cost, quality and delivery objectives in the chain [Stallka 2005]. This involves the senior leadership of suppliers directly in the improvement effort.

- ***Enforced strategy***

The entire performance needs to be tracked. If a supplier does not have a good track record on approved cost reduction or other performance improvements, new business will be hard for them to obtain [Stallka 2005].

- ***Commitment***

Continuous improvement does not just take place in the core chain; it must be transferred to the lower tier suppliers. By means of commitment it should be streamlined from the focal firm to tier 1 supplier, then from tier 1 to their suppliers and further down the chain.

Based on the basic mechanisms above, continuous improvement in a manufacturing supply chain is possible and able to be realized.

4.3.3 Implementing tactics

For continuous improvement in a manufacturing supply chain, a recommended process as follows, which is generated according to the successful case of Chrysler's Supplier Cost Reduce Effort (SCORE). Figure 4-8 illustrates the implementation process.

To make the continuous improvement mechanism work, there are several prerequisites:

- Suppliers have a sense of belonging in the manufacturing supply chain.

Suppliers in the chain should understand that they are part of a team working for a final product goal, and their contribution is appreciated and valuable for the efficiency of the whole chain operation.

- Closer communication between partners in the chain

Old business tradition, e.g. take everything as the company's secrets, must be changed. A trust relationship must evolve in the chain in order to share a forward plan and exchange related information, making it into a competitive advantage for the chain as a whole.

From 1991 to 1998, Chrysler successfully implemented the SCORE program, a continuous improvement program, by motivating suppliers to reduce costs and improve quality through innovative shared-savings in its manufacturing supply chain. The total SCORE program saved Chrysler more than $5 billion in its material and operating costs, and suppliers got up to 5 percent of the total revenue returned from the Chrysler account each year in terms of approved cost-reduction items [Stallka 2005].

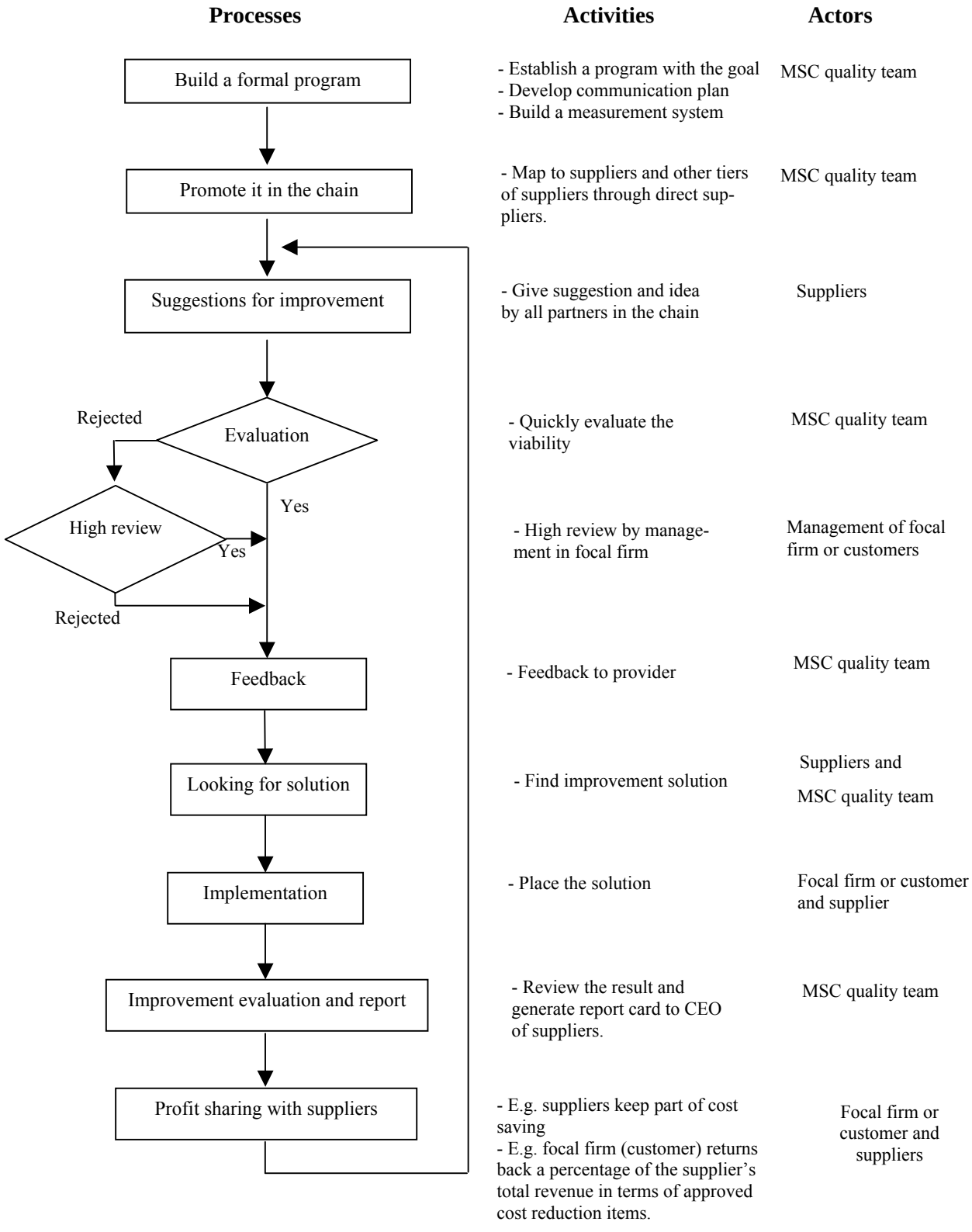


Figure 4-8 Continuous improvement processes, activities and executive parties

4.4 Quality management for product development

4.4.1 Quality model of product development

"Managing a global supply chain is the biggest single challenge in new product development", according to a recent survey by Infosys Technologies at the Electronics Supply Chain Association Spring 2005 Symposium. In principle, the new product development project should define the product "as early and as completely as possible, and then holds the design team to unchangeable specifications". By reusing previous designs and close partnerships with suppliers of critical components the process can be speeded up [Produ 2000].

However, in practice "the buyer decides on the design of components in details without the participation of suppliers. He starts to involve suppliers when the construction design is finished. Product quality and quality goal, e.g. the maximal number of failed parts, have already been decided by the buyer[6]" [Reinha 1997]. So a mistake that happens during the construction phase can often be found and corrected just a short time before or even after the series production. This brings much higher cost for the customer and its suppliers.

In a manufacturing supply chain, the product development activities subsist as a design supply chain. Collaboration and quality control must be built into this process. The quality model can be deduced from the general model in Figure 4-9[7].

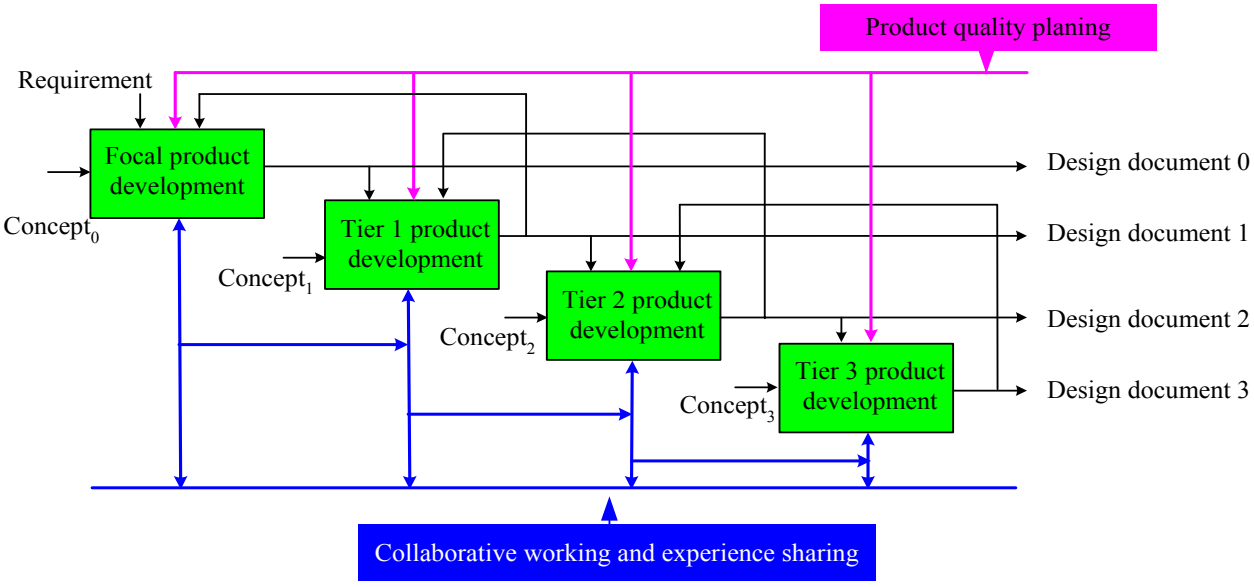


Figure 4-9 Quality model for R&D[8]

Here:

Input: Design concept

[6] The buyer is the customer or manufacturer in an MSC.
[7] In order to clearly express the inside relationship of the four key processes, the controls in the general model are not showed again in the sub-level model.
[8] The design chain can express more tier participants in the sub-model. Here just the first three tiers are shown.

Output: Product design

Process: Collaborative design process inside of every partner and between them

Controls: Quality management mechanism and approaches

Means: Collaborative working and experience sharing

The output of the higher tier provides control over product development of the lower tier. At the same time, the result of the lower tier also influences the design quality of the higher tier. Product quality planning is the main control for every product development process in every tier. Collaborative working and experience sharing provide the essential support for the design chain.

Below, the process, means and controls will be discussed in detail.

4.4.2 Collaborative working and experience sharing

Every design process, especially in the focal firm, should build up a collaborative mechanism with others in order to shorten the design times and prevent errors. Supply chain practice shows that in the planning phase of product development, the suppliers should be involved in order to utilize the manufacturing knowledge together and to achieve the required quality of the final product.

Figure 4-10 gives the Collaborative Design Architecture from HP as an example.

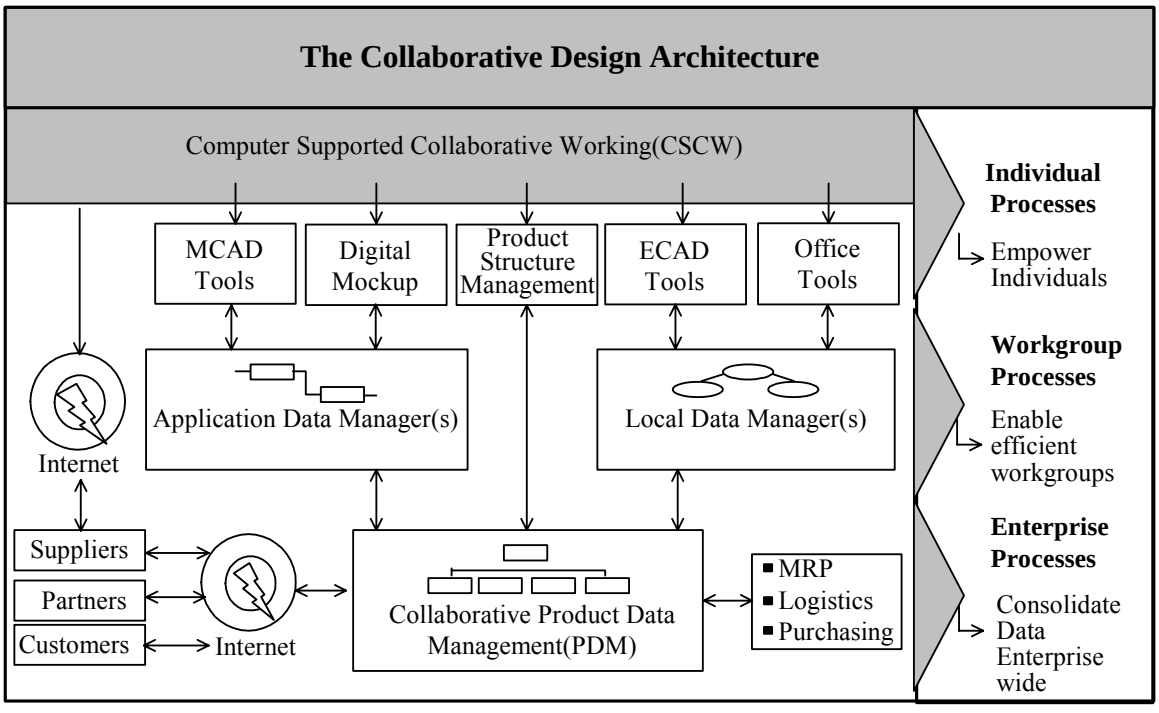


Figure 4-10 Collaborative design architecture (Source: Hewlett-Packard)

The team members are connected by a computer supported collaborative working (CSCW) environment as well as a product data management (PDM) system. The PDM, in turn, connects to other companys' systems such as manufacturing resource planning (MRP) and the bill of materials (BOM). Suppliers, partners and customers can connect to the PDM system with appropriate security measures in place through the Internet [Produ 2000].

Vesa Salminen and others at MIT USA and Tampere University of Technology demonstrated a distributed multi-tiered brokering structure seen in Figure 4-11 to show how knowledge is shared in a supply chain during product development. A supplier that acts as a knowledge provider, at a certain level of the product development brokering hierarchy, can also act as a knowledge broker at a lower level of the hierarchy. This process cascades down the product development supply chain until all product development participants (i.e. suppliers) are included. This multi-tiered brokering structure facilitates the product collaboration processes in a consistent and easy-to-manage process. Clusters of organizations collaborate with each other by using a common framework to deliver independent elements of value that grow with the number of participating organizations [9] [Salmi 2002].

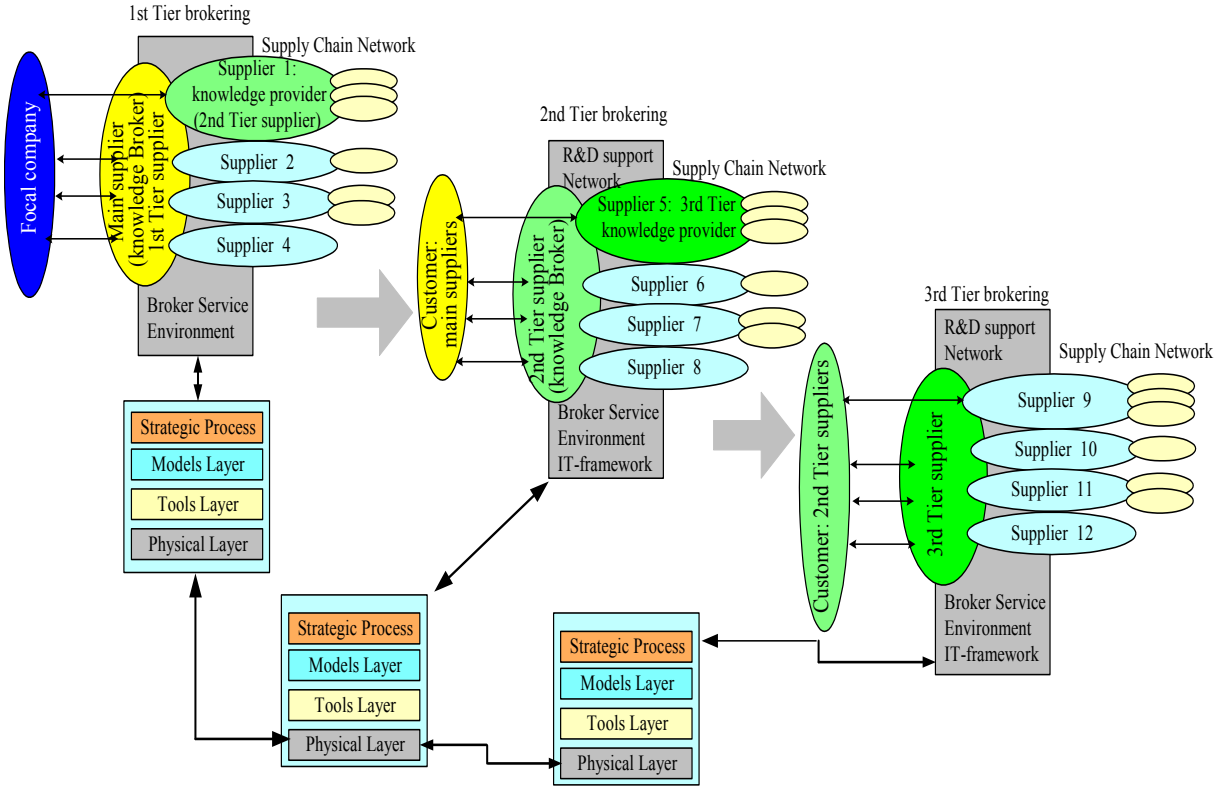


Figure 4-11 Knowledge share in product development [Salmi 2002]

A survey of PRTM and Infosys found that "despite clear indications of the growing importance of cross-company collaboration, companies are generally not satisfied with the per-

[9] Here the organizations are the participants in the product development chain, e.g. suppliers and partners.

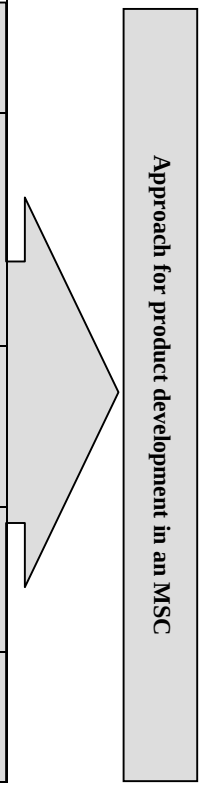
formance of collaboration to date". Even though they realize the importance of the extended value chain, but in order to be successful, new strategies, practices and IT systems are still required [PRTM 2003].

4.4.3 Quality control of product development

Efficient quality management and supplier involvement in the early phase of product development is the key to reaching a better performance for a design supply chain. A joint effort in the initial phase can offer a lot towards ensuring initial high quality ratings. Based on A. Chatterjee's analysis [Chatter 2003], the joint work and quality assurance measures in every phase of product development are summarized in Table 4-3.

Table 4-3 Joint quality assurance workings in the design phase

Phase	Work content	Goal	Approach
Product concept	Customer specification; Performance priorities	Sharing information; Decision	Cooperation, QFD, Evaluation
Product design	Quality problem prevention	Specifications for subassemblies, superior product quality, manufacturing compatibility, process quality	Mirrored quality management system; Product/Process FMEA
Verification of planning and testing	Test criteria	Superior quality, durability, performance	FMEA, test methods, Fault tree analysis; DOE
Pre-launch	Early problem resolution, defect identification and eradication	Smooth set up, production process stabilization.	Cooperation, SPC, FMEA quality management
Post-launch	Ratings, necessary design/manufacturing changes	Long-term product and service quality.	Close cooperation



Shown above, the most popular design quality approaches, e.g. QFD, FMEA, DOE etc, are used in the development process.

In an MSC new product development is carried out by the focal firm, its partners and subtier partners individually and at the same time they collaboratively work together. Therefore,

quality control should be a systematic approach that integrates all the quality management tools and gives a guide for the collaboration between the customers and the suppliers.

- ***Systematic approach- APQP***

Advanced Product Quality Planning (APQP) is a valuable and general tool that can help to proof a product and design processes by utilizing experience gained or lessons learned from previous projects in developing a new model process/product. It includes all the quality tools that are needed during collaborative product development and provides systematic guide steps. It was originally developed in the automotive industry. Because of the outstanding success of this application, it can be and has been used in many other branches.

One key element of the APQP development effort is to get across-functional teams involved, thus, suppliers are invited to join the development teams [Munro 2003]. Advanced product quality planning embodies the concepts of error prevention and continual improvement including error detection, and it is based on a multidisciplinary approach [ISO 16949]. The use of an across-functional team is intended to ensure a proper and smooth start-up phase of various process and tooling operations. It makes that customers and suppliers work together to achieve 'production readiness'. APQP makes possible the collaborative activities among the focal firm, system/component suppliers and part suppliers in an MSC as shown in Figure 4-12 [Ma 2003].

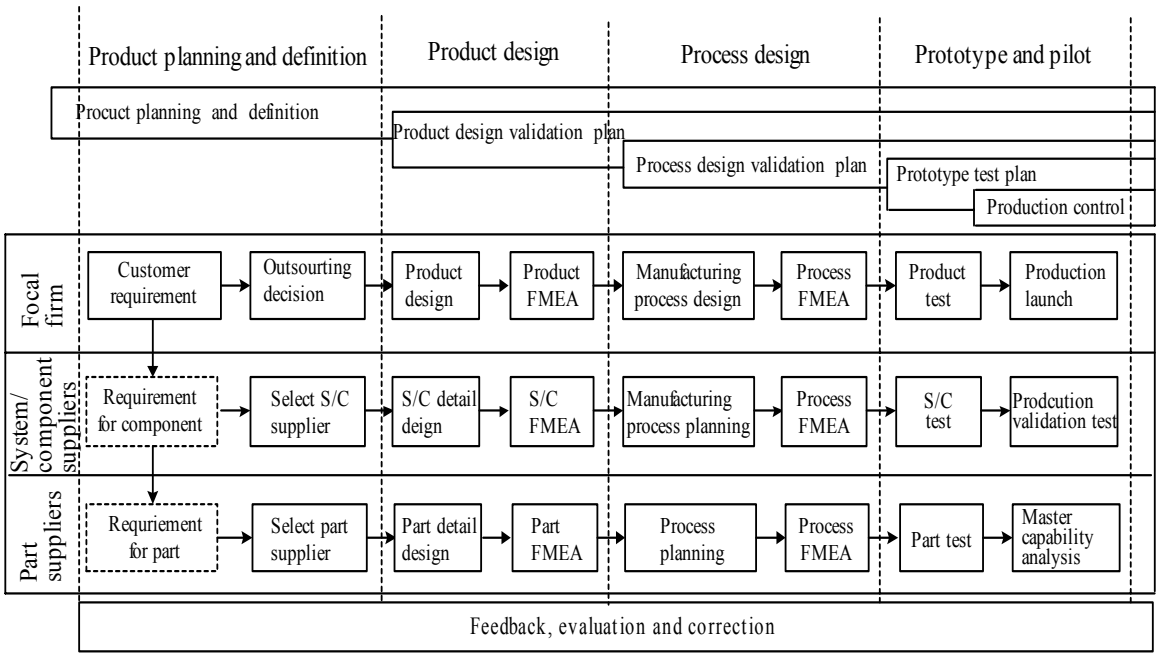


Figure 4-12 Supplier participation in product development quality assurance[10] [Ma 2003]

[10] In this figure, S/C means System/Component.

According to AIAG's APQP and FMEA Reference Manuals, APQP was designed to help deliver benefits to the entire supply chain through:

- Promoting early identification of required changes
- Avoiding later changes
- Providing quality products on time at the lowest cost
- Designing to be a 'before-the-event' action, not an 'after-the-fact' exercise.

➢ The principle of APQP

It combines the Product Life-cycle Management (PLM) approaches and requirements of the OEMs and participating suppliers and uses the Plan-Do-Study-Act (PDSA) improvement cycle. Engineers are using these to manage their products and processes before failures arise, rather than creating products that meet minimum specifications and letting the service and warranty departments handle the quality issues [Grus 2005].

The principle of APQP is shown as follows in Figure 4-13.

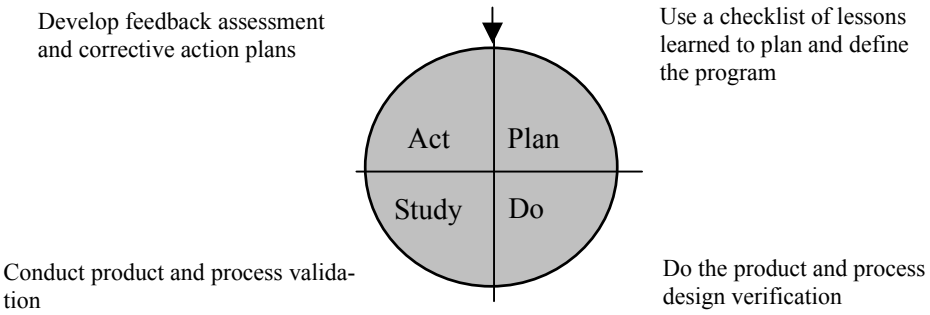


Figure 4-13 APQP principle

➢ The four phases of APQP

The process of APQP is broken into four phases and leads from one phase to the next. Each phase acts as a checklist to ensure all documentation and process requirements are met before continuing to the next phase. The four phases and their five main activities are presented in Figure 4-14.

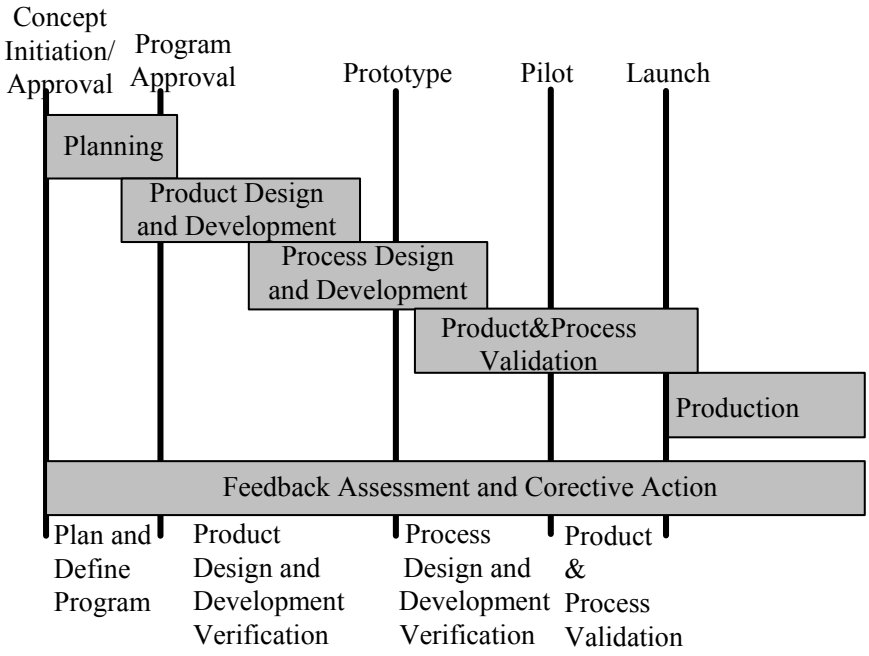


Figure 4-14 APQP four phases [Crow 2001]

The APQP process involves these major elements [Crow 2001]:

- Understand customer needs
- Proactive feedback & corrective action
- Design within process capabilities
- Analyze & mitigate failure modes
- Verification & validation
- Design reviews
- Control special/critical characteristics

➢ **Implementing step and suppliers' contributions**

Through the effort of the focal firm, quality management of product development should be included within the entire chain. Implementation is realized by integrating its preferred/key suppliers into a product development team and following the APQP process. The implementing steps, objects and approaches are demonstrated in Figure 4-15.

In the design team, the focal firm shares its product development plans with the suppliers. The suppliers are aware of the OEM's product road map, so that they can plan development efforts to meet the customer's future needs [Shih 2005]. Sun Microsystem's practice showed that the focal firm aims at a multi-tier approach, i.e. de-centralize its supplier structure by

working mostly directly with its prime suppliers and then leaving much other activity to these suppliers to manage the relationships with the vendors on the sub-tiers. It presupposes a key supplier to serve as an external manufacturer for a whole product system and to manage and coordinate the cross-task with the sub-tier suppliers. The focal firm is paying more attention to the value of developing an effective electronic network that will allow for across-the-board information sharing throughout the entire product development process. [OLough 1997].

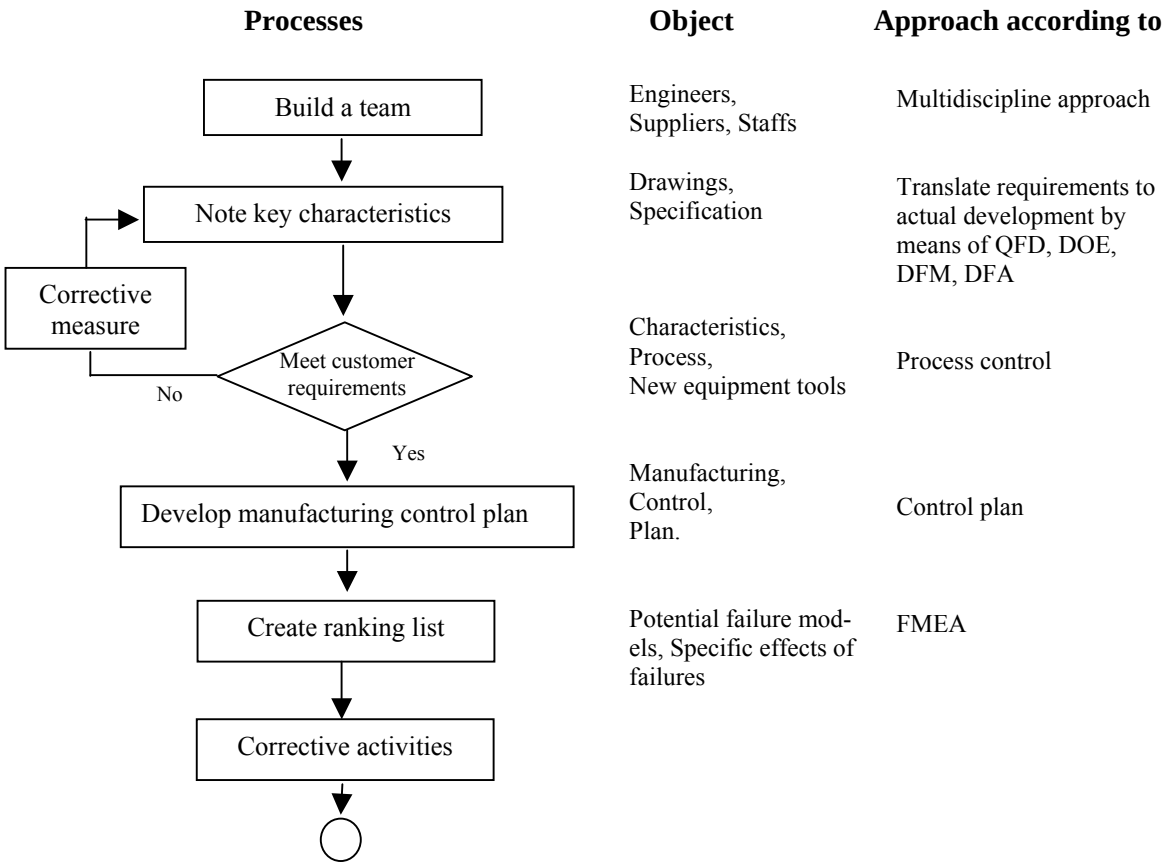


Figure 4-15 Implementing steps, objects and approaches

During this process, the supplier's engineers function as the product development team members. The supplier contributes during the product quality planning as follows [Stama 2001].

- Provides expertise and knowledge of the processes and products at its location for the product/process design and its reliability and maintainability (R&M) analysis
- Makes a commitment that a proposed product/process can be manufactured, assembled, packaged and shipped in a final form
- Defines the flow chart of the product/process for preparing its manufacturing

- Determines that the proposed control plan is capable of operating within the existing quality systems
- Develops a gauge measurement verification system to control processes and evaluate material conformance
- Provides documentation confirming its actions relative to producing a quality process/product that meets the customers' needs; the supplier is expected to submit to the APQP team the copies of the process flow chart(s), process FMEAs, design FMEA, process control plans, and statistical data pertinent to the product(s) being supplied, program timing charts, as well as the supplier's failure to meet promise dates for first piece approval programs
- Evaluates the product/process and reviews in supplier and sub-supplier sites for e.g. Initial Sample Review
- Suppliers who produce tooling and equipment must demonstrate accurately whether the machine acceptance or rejection is documented appropriately
- Inspects the movement of goods between companies

➢ **Web-based APQP**

APQP software can link information together so that a change in the attributes of a product or process is automatically provided to all associated documents. However, often APQP becomes more of an exercise in paperwork than quality due to the vast amount of data that must be exchanged. It places a heavy burden on the suppliers and the focal firm. By moving APQP to the Internet, the focal firm can cost-effectively connect everyone involved in the design and production process - engineers, suppliers and even customers. The connection is a virtual workspace where data and ideas can be shared across departments and the supply chain during the introduction process of a new product.

According to industrial analysis, the benefits are as follows [Mitchell 2003]:

- Save about half the time associated with the new product introduction cycle
- Be able to manage all function of the APQP process, including program management, change management and activity and task management from one interface
- Automate the entire APQP workflow
- Reduce the time to market for new products and tightly integrate quality into the design process

APQP has been originally applied by automotive manufacturers, but the basic tenants of the process are used across a wide variety of manufacturing activities. Industries as diverse as

medical device manufacturing, pharmaceutical manufacturing and aerospace are beginning to investigate Web-based APQP software to streamline their own new product introduction cycles [Mitchell 2003]. All manufacturers can benefit from using APQP functionality to manage supplier quality during the design process.

Many software companies like IQS, IBM, etc. have simplified and streamlined the APQP process to give the ability to electronically transfer APQP, etc. information across the entire supply chain and make it possible for an entire supply chain to implement the same quality process via the Web [IQS 2001]. However, the suppliers' involvement in new product development is a very complicated issue. Collaboration among design partners, suppliers and customers is "the key element of effective and integrated product management, and in the current new product development process, the collaboration environment is still sub-optimal" [Bure 2005].

4.5 Quality management for outsourcing

4.5.1 Quality model of outsourcing

Today outsourcing, which increases the territory of the manufacturing system, is causing tremendous changes. Most industries recognize that the raw materials and components account for more than 70% of a product's cost. In some cases, manufacturers have purchased goods at 60 – 80% of their value for the past ten years [Lee 2003]. The cross-company production activity brings challenges for quality control of the manufacturer. According to industrial expert analysis, "on average, 50 percent of a company's quality problems can be tracked back to the outsourcing quality of materials and services" [Thonem 2003].

The outsourcing process consists of all the sub-outsourcing processes that are carried out by all the participants in the chain. This process is decomposed in Figure 4-16.

In this model:

Input: Purchasing list

Output: Purchased product

Process: Outsourcing processes

Controls: Supplier quality requirements according to international standards, e.g. ISO 9000 series, ISO/TS 16949 or industrial branch standards e.g. QS9000, AS9100 etc; individual supplier quality requirements from the focal firm (customer) to its direct suppliers as well as sub-suppliers.

Means: Trust relationship between partners in the chain

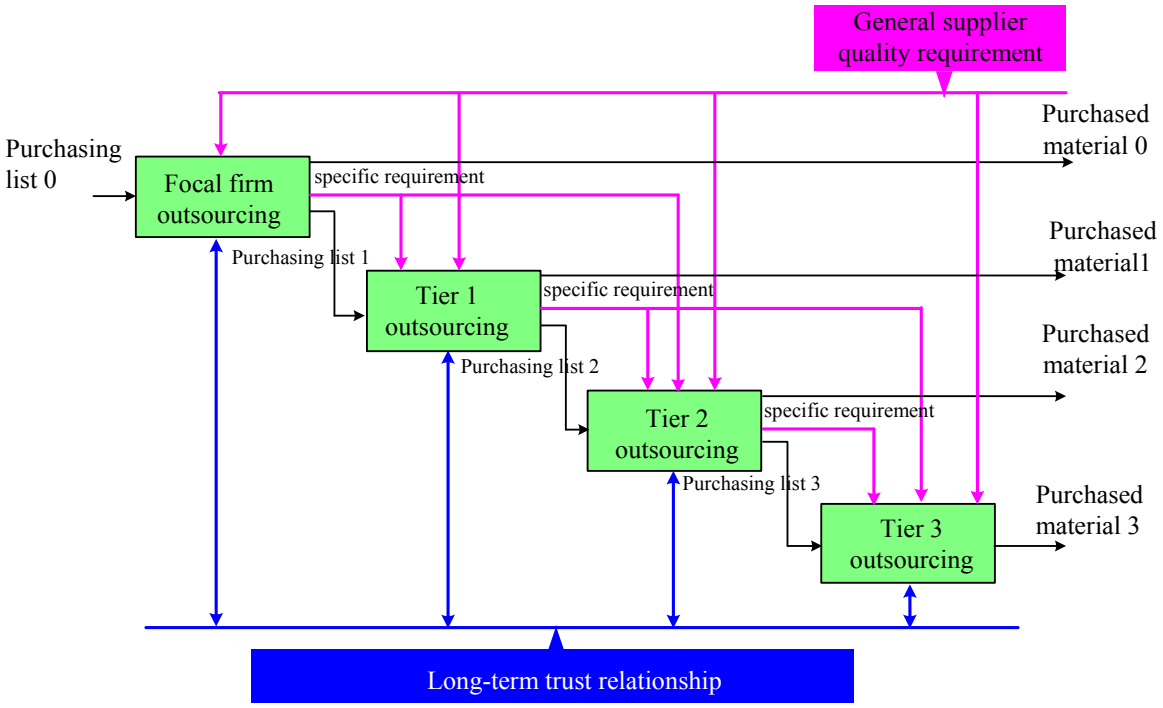


Figure 4-16 Quality model of outsourcing[11]

Only when the quality control mechanism and related support means have been built into the outsourcing chain, the quality of outsourced products can be assured. As illustrated below, the way to build the controls and means into an MSC will be discussed in detail.

4.5.2 Relationship between the supplier and customer

Outsourcing is a process with high risk. After much practice by many focal firms (OEMs), it was discovered that the solution is to form a collaborative supply chain with long-term trust relationships and proper control mechanisms to lower the risk, but it is also a long-term journey. It requires every partner to participate, especially the key suppliers in the manufacturing supply chain. The organization must go through a long process that places emphasis on the supplier's quality management. The level of trust among the supply chain actors drives the quality of information [Davis 2004]. Only when the trust relationship is established along the whole supply chain, the chain is able to achieve the best performance.

The relationship between customers and suppliers should be:

- Trust but monitoring of partner relationships; willingness to help the other side
- Optimization of the total cost for the other side
- From a pricing standpoint, support of the quality management activities

[11] The outsourcing chain can express more tier participants in the sub-model. Here just the first three tiers are shown.

- Based on the common goal to prevent mistakes, help to the supplier to apply systematic measures in order to improve quality

The customer-supplier relationship level is presented in Figure 4-17.

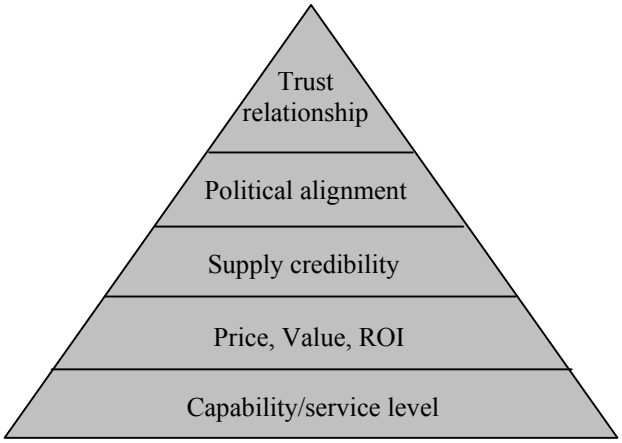


Figure 4-17 Supplier relationship level

When the trust relationship is prevalent in a manufacturing supply chain between partners, the chain is more competitive than others. An honest and open communication policy is the heart of building trust within the extended enterprise [Stallka 2005]. The trust relationship is dynamically developed through the effort of both sides of the partners, especially in the second phase of supplier development, as seen in Figure 4-18.

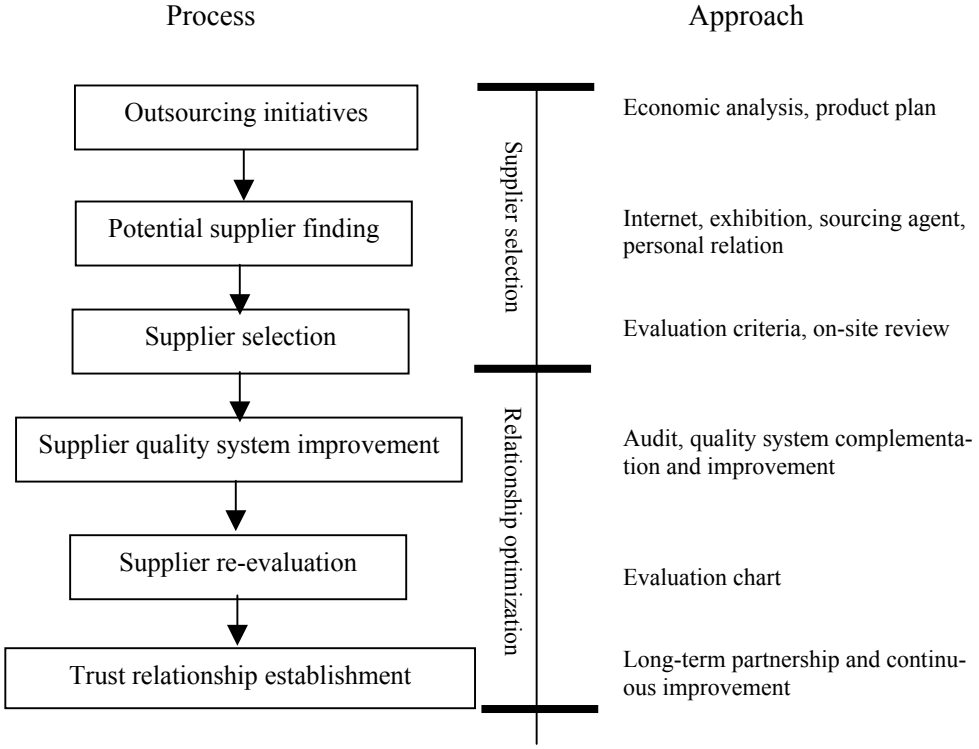


Figure 4-18 The process of supplier relationship establishment

To establish a long-term trust relationship, supplier quality management and development is an important initiative.

4.5.3 Supplier quality management and development

Outsourcing quality assurance is reached by the efficient quality management of suppliers in different tiers. Supplier quality management is under the guideline of general supplier quality requirements and individual/specific requirements of the outsourcing company. These controls are realized through two steps carried out by the outsourcing company together with its suppliers. Figure 4-18 already illustrated the two important parts for outsourcing quality assurance.

Supplier selection: How to identify new or potential supply partners. It is the basis to forming a competitive manufacturing supply chain.

Supplier quality development: It focuses on improving suppliers' quality management capability in order to integrate it into the manufacturing supply chain efficiently. This is one of the most important steps in building a long-term trust relationship between the customer and its key suppliers.

- ***Supplier selection***

Determining which suppliers are allowed to join the supply chain has become a key strategic consideration. Supplier selection goes according to the company's strategic planning and business requirement. The selection criteria include traditional supply chain thinking that is based on the premise of lower prices and added value as well as innovation and information capability as critical elements. It places importance on consistency (quality and delivery), reliability, relationships, flexibility, prices and service as follows [Choi 1996]:

- Quality: It depends on the product quality that has been tested as a sample by the customer/manufacturer, the process quality that has been shown by the Cpk and system quality that has been audited by the manufacturer or third party audit. It is the most important factor for international outsourcing.
- Cost: The price is quoted by the supplier, including the cost of production or often transportation for the supplied product.
- Delivery: The capability of the supplier to deliver products or material at the right time with the right quality; it is related to the capability of production management and to the transportation of the supplier.
- Technology and innovation: It includes capabilities in two aspects:

  Technical capability: ability to control field-related skills

  Technological capability (innovation): ability to work on research activities

Innovation ability requires that a partner must be a learning organization. When learning is valued and shared across supply chain members, purchasing efficiency is enhanced, and supply chain partners are better poised to gain a sustainable competitive advantage [Davis 2004].

- Responsiveness: The capability to respond to change with flexibility.
- Design capability: Ability to design new products and control related processes.
- Manufacturing capability: Ability to control manufacturing-related issues, e.g. production control, operational sequences, tooling, etc.
- Cooperation willingness: Willingness to share information and knowledge and adopt best practices.
- Financial stability: Track records of financial data to ensure a stable financial condition.

In addition to the above general criteria, manufacturers especially care about these aspects.

- Quality registration: Whether a potential supplier can demonstrate compliance with certain standards and customer's specific requirements
- E-business capabilities: Does it have email, Internet access and an Internet browser as a minimum for e-business capacity? This requires the participation in web based applications and communications.

Based on those aspects, the manufacturer (customer) can create an evaluation criteria system for supplier selection.

In practice, a "material need" is identified during the development phase of the customer. The sourcing team identifies a potential supplier for the "material need". A "Request for Quote" (RFQ) is issued to the potential supplier. Based upon the results of the RFQ, a Pre-assessment of the supplier will be carried out according to the customer's evaluation criteria. Based on the results of the Pre-assessment, the supplier becomes the possible partner for business [Bosch 2000].

- ***Supplier quality development***

The goal of sourcing quality management is zero defects, 100% on time delivery and continuous improvement. To reach this goal the customer must implement the supplier quality improvement process with the suppliers.

Goal of the process:

- Make suppliers understand customer's requirement for quality better
- Help suppliers to use state-of-art quality management approaches and methods

- Set up the quality foundation to form a collaborative manufacturing supply chain with a long-term trust relationship

Many focal firms and system/component suppliers have their supplier development programs. These programs present a PDCA (Plan-Do-Check-Act) cycle that is summarized in Figure 4-19 by analyzing some focal firms and system manufacturers [FSF 2002] [Bosch 2000] [ABB 2005].

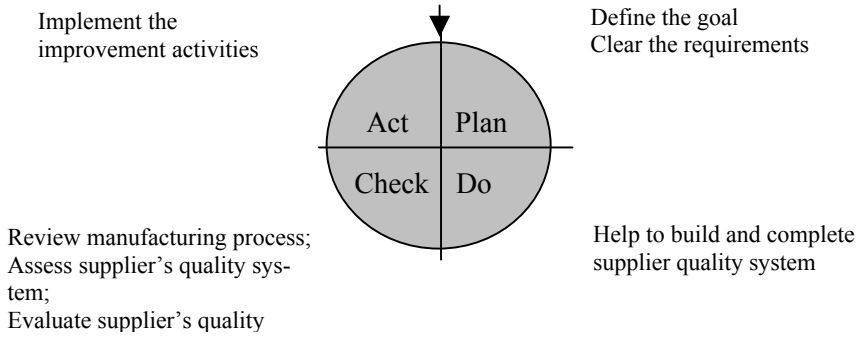


Figure 4-19 Supplier quality improvement model

Plan:

The focal firm (OEM) or purchasing companies (customers) assign a sourcing team to be responsible for the sourcing project. It presents concrete requirements to suppliers through its supplier quality manual. The supplier shall establish, document, implement and maintain a quality management system and continually improve its effectiveness. The general requirements that are presented in ISO 9001:2000, also adopted by ISO/TS16949, are essential for every industry as the control for supplier quality. They define that a supplier shall:

a) Identify the processes needed for the quality management system and their application throughout the organization

b) Determine the sequence and interaction of these processes

c) Determine criteria and methods needed to ensure that both the operation and control of theses processes are effective

d) Ensure the availability of resources and information necessary to support the operation and monitoring of these processes

e) Monitor, measure and analyze these processes, and

f) Implement actions necessary to achieve the planned results and a continual improvement of the processes

Based on these common requirements, the customers give their specific requirements according to their specific demands as another form of control to the supplier. They typically include the following contents [Bloom 2002]:

- General requirements for quality management methods (APQP), project management timeline, supplier production part approval process (PPAP), data submission, the requirements for nonconformance, corrective and preventive actions, etc.
- Part-specific requirements (dimensions, materials, performance characteristics, etc.)
- Process requirements (e.g. heat treatment)
- Delivery requirements

In the automobile industry ISO/TS 16949 has defined the fundamental quality management requirements for suppliers based on ISO9001: 2000. The automobile focal firms, e.g. Daimler Chrysler, GM and Ford automobile component and system manufacturers, e.g. Bosch, issue their own specific requirements for their additional needs.

The specific requirements must be agreed on between the supplier and the customer. Only when customer-specific quality requirements are coupled with common quality management requirements, the supplier's quality management becomes complete and meaningful in meeting the requirements of the customer.

In addition, normally a basic catalogue containing elements like terminology should be defined in order to have the same understanding on both sides.

When a supplier (subcontractor) to a customer is too small as not to have adequate resources to develop a system according to ISO/TS 16949:2002 or ISO 9001:2000, the customer has decision criteria for designating "small suppliers". A simpler quality management system approach could be used for the smaller suppliers. The decision criteria is in writing, approved by a higher-level customer or third party auditor, and applied consistently to determine the specially designated suppliers for which this provision may apply [Daimler 2005] [Ford 2003].

The focal firms and top-tier suppliers all have their own supplier management information system or supplier quality forum online. There, the requirements are clearly defined and suppliers and potential suppliers can find the quality documents, e.g. supplier quality manual, quality assurance guidelines for suppliers, 8D report form as well as supplier quality process management questionnaire, etc.

Do:

Only when a supplier has an equal quality level like its customer, the quality of the end product can be reached. Therefore, the customer is willing to help its suppliers to develop. The customer implements its supplier development manual/program with the goal of supplier conformity with the technical specification.

Conformity with ISO 9001:2000 is the first step in achieving this goal. In the automobile industry, the clause 7.4.1.2 - Supplier Quality Management System Development in ISO/TS 16949:2002 - has acted as the guideline.

In this phase, to assure that project 'timing and quality goals' are met, active and open communication between the supplier and the customer's sourcing quality team is required. The customer engages and demands that its suppliers apply the quality management methods to enhance their quality capability with a view to meeting its requirements. The most required methods are as follows:

- Statistical techniques:

First time yield, Statistical Process Control (SPC), etc.

- Analytical techniques:

Design of Experiment (DOE), Potential Failure Mode and Effects Analysis (FMEA), Theory of Constraints, Benchmarking, Hoshin Planning, Shainin Method , etc.

- Advance Product Quality Planning and Control Plan (APQP):

The supplier shall follow the planning procedures. All elements of the APQP are incorporated into the planning process. See §4.4.3.

- Production Part Approval Process (PPAP):

The supplier submits an initial sample report in accordance with the AIAG Production Part Approval Process Manual. Some specific instructions related to the PPAP include:

Material sample quantity: The number of standard sample for dimensional evaluation should be provided.

Statistical data: Supporting statistical data (i.e. SPC, process capability studies) for a PPAP submission should be assimilated from the view of the supply manufacturing process and the number of completed units.

Above the systematic approaches and processes are required first by the automotive industry and then expand to other industries with complicated processes.

During this process, the customer implements its supplier development program and provides a training program for its suppliers related to the requirements and technique application.

Check:

How is supplier development initiated? The check can be done in two ways.

- Second-party assessment: Customer on-site audit at its supplier's premises
- Third-party assessment: An accredited body that is independent of both supplier and customer organizations carries out the check

The audit aspects are as follows:

Review of supplier's manufacturing process

A review of the suppliers manufacturing process at a demonstrated line is essential. The purpose is to verify the supplier's production process readiness and assure complete understanding of the program requirements. The review consists of detailed observation and validation of the supplier's manufacturing process capabilities and corresponding documentation. 14 aspects as follows will be approved:

- Parts number, description and change level
- Material process flow diagram included in the manufacturing floor plan
- Design and process FMEA
- Process control plan
- Incoming and outgoing material qualifications/certifications
- Tooling, equipment and gauges identified
- Special characteristics identified
- Process monitoring and operating instructions
- Parts packing and shipping specifications
- Project management timeline
- Engineering standards identified
- Preventive and predictive maintenance plan
- Gage and test equipment evaluation
- Line speed demonstration and capability evaluation

Once the supplier manufacturing process has been approved, changes to the production process cannot be implemented without the customer's permission [Bosch 2000].

Process re-audits

The process re-audit performs the supplier's manufacturing process with special conditions, like

- Quality issues
- Engineering changes
- Process changes
- Plant location changes (e.g. tool transfer)

The audit criteria are based on the items of supplier manufacturing process above and other factors, which are defined by the customer's sourcing quality team.

Assessment of suppliers' quality systems

The assessment of a quality system is conducted at the supplier's or via supplier self-assessment.

In the case of quality system assessment, the accreditations of some industry standards and international standards are recognized.

E.g. in automobile industry:

- QS-9000 registered certification,
- VAD Volume 6 registered certification
- ISO/TS16949

Some accreditations may be recognized in conjunction with additional requirements:

- ISO9001/ISO9002
- Other certification i.e. AVSQ (Italian), EAQF (France), etc.

A re-assessment of the supplier's quality system will be conducted by a customer sourcing quality team if deemed necessary, i.e. quality issues, engineering changes, certification, etc.

Performance assessment and rating

The customers carry out a supplier performance rating process according to the supplier's working performance. The process consists of a data-driven approach to measuring regularly. The supplier performance rating process measures and monitors the Key Performance Indicators (KPIs), e.g. [ABB 2005] [Stocker 2000]:

- Quality: Defects per million opportunities (Dpmo)
- Delivery: Percentage of on-time deliveries
- Non-conformance issues (warranty, manufacturing, etc.)
- Quality of PPAP submissions
- Quality data submissions
- Quality system evaluation
- Process evaluation
- Quality concern response time
- Continuous improvement
- Cooperation: Multi-dimensional metrics consisting of commercial, technical, transactional and lead time criteria

The customer's sourcing quality team documents the results of quality performance assessments/ratings and communicates these with the suppliers. After that, performance assessments deemed unacceptable by the customer require the supplier to draw up corrective actions. The corrective actions have to be submitted to and approved by the customer's sourcing quality team.

Assessment of up-stream suppliers

The focal companies do not just concentrate on their direct suppliers, but they also place emphasis on the subcontractors, and many of them insist that all the suppliers in the chain must be assessed.

E.g. Ford Customer Specific Requirements stated that all subcontractors must be assessed. It authorizes tier 1 suppliers to audit subcontractors in support of QS-9000 Sanctioned C9 and ISO/TS 16949:2002 Clause 7.4.1.2. The efforts shall focus on their subcontractors' improvement with the highest impact on Supplier Improvement Metrics [Ford 2003].

Some companies provide their direct suppliers with guidance for managing of the sub-tier suppliers with their supply chains to ensure purchase order and technical requirements are maintained. Their direct suppliers are responsible for executing the inspection and audit to their suppliers according to the guide. For example, Northrop Grumman Integrated Systems Sector recommends that its suppliers manage their suppliers in the following aspects [North 2004]:

- Approval of sub-tier suppliers
- Special process approval
- Review of manufacturing plan: drawing requirements, special processor requirements, inspection
- First article inspection
- Periodic product/process audit
- Product acceptance: sampling plan, operator self-verification process, delegated acceptance program
- Root cause analyses and corrective/preventive action

Act:

The customer provides feedback for the suppliers. This feedback enables ongoing communication, continuous process improvement and supplier development. The improvement and corrective action must be installed after evaluation. The supplier is expected to develop the corrective action plan in those nonconforming areas and supply objective evidence of conformance within a mutually agreed-upon time frame.

The focal firm also looks for the possibility to improve the quality management efficiency for the entire chain. For example, in practical cases many companies work as second-tier suppliers but also supply products directly to the focal firm. Therefore, those suppliers have to face different audit programs and pass repeated audits. This paperwork and redundancies that have generated excess expenses ultimately add their costs to the final product. In 1992, the Big Three automakers made an agreement that the supplier who passes any one of the Big Three programs as a first-tier supplier is no longer subject to an audit as a second-tier supplier. This movement could save suppliers a combined half a billion dollars annually, according to related analysis [Plumb 1992].

4.6 Quality management for production

4.6.1 Quality model of production

Many companies have applied enterprise resource planning (ERP) for production planning and system controlling. ERP systems are used within a single company. However, as the magazine Automotive Design & Production stated, "as the collaboration requirements are increasing, the ERP will have to extend beyond the four walls of the user enterprise and be electronically accessible to all trading partners within the supply chain" [Gould 2000]. Without an integrated ERP throughout the MSC and information exchange with its suppliers and customers, the entire manufacturing supply chain cannot respond quickly enough or optimize performance.

ERP systems also provide the procedural corporate structure for product-related quality processes that tie in to broader business processes – like sourcing and procurement, supplier relationship management, customer order fulfillment and warranty claims processing. They have extended ERP-based quality functions within manufacturing, the common procedural touch points are shown in [Smith 2006]:

- Incoming inspection of raw materials upon arrival and determination of pass/fail for manufacture
- In-process inspection planning and routing design
- Finished goods inspection and final order shipment
- Electronic signature capture and signoff capabilities

Robert W. Atherton, worldwide manager for process control at Sun Microsystems Inc., stated that supply chains consist of factories and logistics, and that factories consist of organized systems of devices and machines. "Without adequate interconnection with the plant floor, the supply chain is just guessing about where orders are, what inventory is needed, and what the most profitable use of resources should be" [Hoske 2004]. In order to respond to the requirement of reducing large volumes of inventory and the accompanying increases in

the related customer demands, manufacturers need to synchronize their supply-chain operations with real-time shop-floor realities [Green 2004].

Based on the analysis above, to ensure the efficient operation and quality within the entire manufacturing supply chain, quality management for production in an MSC is related to real production control and quality data sharing between partners and with the support of the integrated plant-floor/ERP systems. This quality model of production is shown in Figure 4-20.

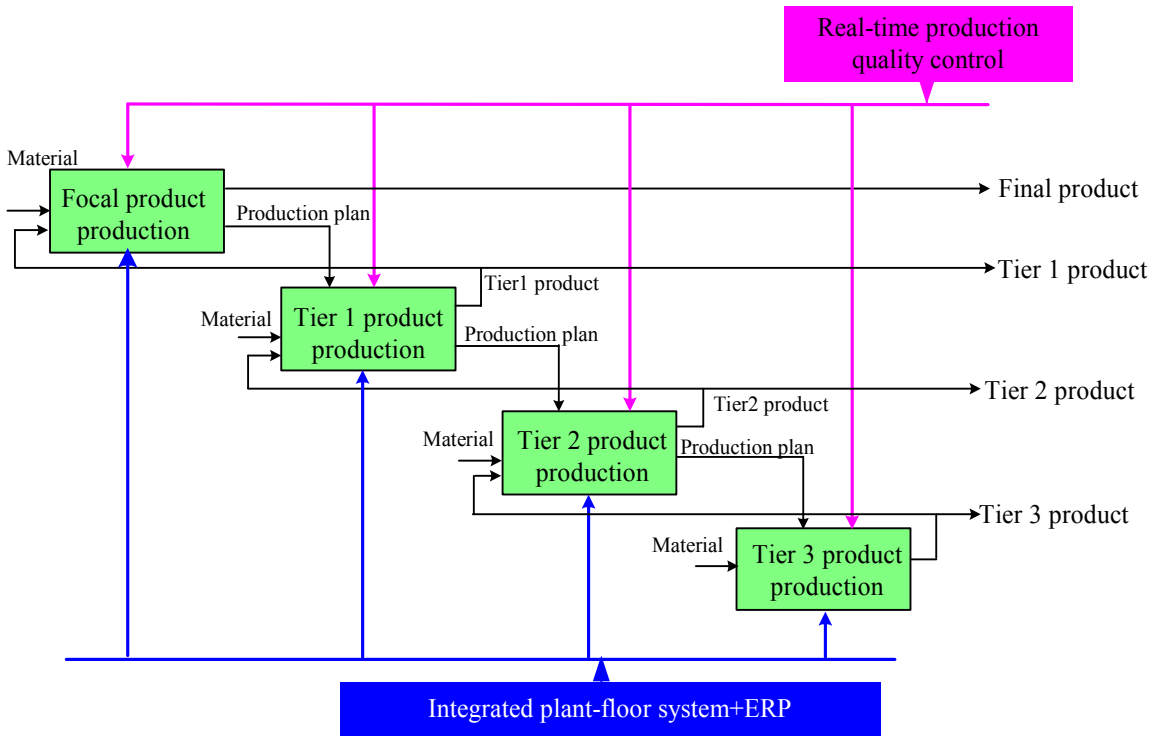


Figure 4-20 Quality model of production in an MSC[12]

In this model:

Input: Material of home-made and tier supplier

Output: Final product

Process: Production in every tier

Controls: Real-time production quality control for every supplier and the quality data share between partners.

Means: Integrated plant-floor system and ERP.

Below the controls and means will be discussed in detail.

[12] The production chain can express more tier participants in the sub-model. Here only the first three tiers are shown.

4.6.2 Integrated plant-floor system and ERP

The typical model for interfacing plant-floor systems with enterprises and supply chain systems is a direct database access to a production database. Figure 4-21 illustrates the typical relationship of plant-floor automation systems with the ERP and supply chain systems provided by Lockwood Greene [Hoske 2004].

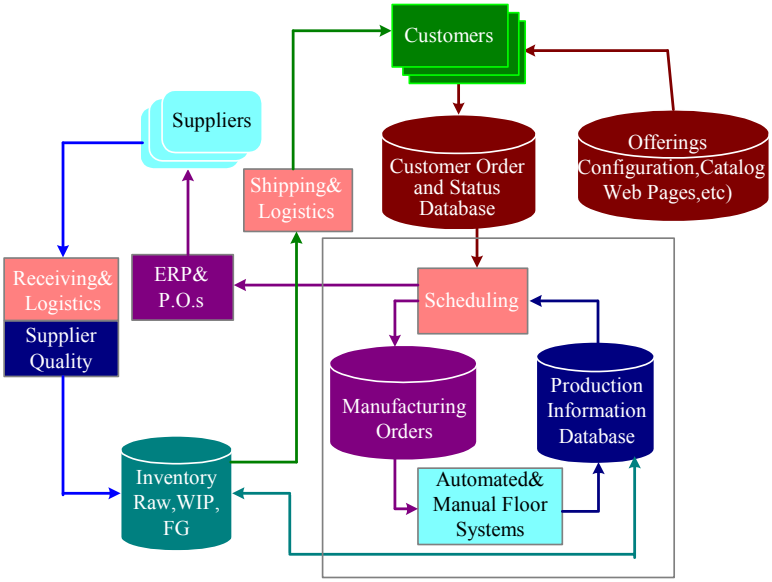


Figure 4-21 Typical relationship of plant-floor automation systems with ERP and the supply chain system [Hoske 2004]

In this system there are three primary interconnectivity schemes:

- Direct database access
- Inter-process messaging
- Flat files (using FTP, etc.)

This model enables the manufacturer to maintain the information available by relying on the relational database easily to modify with minimal impact on related processes. It provides current information to all processes, relieving many of the synchronization issues encountered with inter-process messaging and flat-file transfers.

The interactions of receiving, scheduling and shipping processes are the keys to integration. All must be tightly integrated with the plant floor systems via the production database.

The scheduling process is the primary interface to the shop floor. It converts customer orders into manufacturing orders (batch, assembly etc. based upon customer delivery dates, manufacturing capacity, available inventory etc.). This schedule is typically provided to area con-

trollers, which in turn drive the cell director selection of setup/recipe instructions for the cell controllers. The cell controllers report the status of the manufacturing process to the area controller (or directly to the production database).

At the same time, the scheduling input is provided to the ERP system so that supplier orders can be placed or materials released for shipment as appropriate.

Raw material receiving and finished goods shipping are important to plant-floor processes. Typically, they feed the scheduling algorithms, but the plant floor must have emergency responses to material shortages, storage/buffers for finished goods, etc.

In this way the plant floor is connected to the manufacturing supply chain. The chain operates with real-time production data that supports production efficiency in an MSC.

4.6.3 Quality control of the production chain

As already mentioned in §2.2.2., "quality issues can snarl a supply chain and bring the production to a grinding halt", according to Northwest Analytical. Once a supply chain gets interrupted, it becomes extremely difficult to get it back in order [Hoske 2004]. Quality control for production in the MSC is a key to preventing it.

In a manufacturing supply chain, the products or materials that one company has produced and supplied are the incoming material for the next manufacturer. The quality of the material directly affects further manufacturing processes. Therefore, it is very important for manufacturers to monitor the incoming quality and make the quality data available in real-time.

There are two reasons for monitoring the incoming quality, according to analysis of Paul LeMert , director of business programs for Wonderware's eManufacturing Systems Group:

- To ensure that the supplier is providing material that meets the specifications laid down in the purchase agreement;
- To correlate the incoming quality attributes against performance during the manufacturing process [Merritt 2001].

With advanced quality information from his supplier, the manufacturer can better meet his market requirements. The incoming product or material data help to meet regulatory requirements and allow a faster response to consumer requirements.

- ***Quality data transfer and effect on an MSC***

Statistical process control (SPC) and statistical quality control (SQC) play big roles in supply chain quality assurance.

In discrete production, especially automotive manufacturers have concrete solutions to require their suppliers to carry out all the quality control for the supplied products with little or no extra cost [Merritt 2001].

Concerning incoming quality control, there are different ways for discrete industry and process industry as following [Merritt 2001] [Hoske 2004]:

Discrete industry

Spot check:

This has been in use in discrete production for a long time; it is a simple pass/fail quality check. The manufacturer does spot checking and compares these results to the supplier's data. The result will be documented. If a supplier does not have a good record, the manufacturer will check it much frequently.

Quality data:

Many manufacturers demand of their suppliers to provide quality data on 100% of the incoming parts, so the supplier must develop a database of information on every aspect of the testing and manufacturing process for every component and then maintain the database for the lifetime of a product

With technological development and by using web-based SPC software throughout the supply chain, companies can mitigate or entirely avoid snarls in the supply chain. This helps manufacturers to prevent incoming quality issues dynamically and keep the chain running. Northwest Analytical provided a following picture for the solution: an engineer at a manufacturer can review web-based control charts for supplier A. If the control charts show that supplier A's process is drifting off target, it means that supplier A will be producing very low yields with its specs. The manufacturer's engineer checks the ERP inventory for stock on hand. If it is not enough to get through a shortage, he will look at supplier B. He calls up control charts for supplier B on the same web-based system. If supplier B's process is right on target as usual, then the engineer calls Purchasing and asks them to reduce supplier A's allocation and double supplier B's [Hoske 2004]. Northwest Analytical thinks that the web-based SPC software is an early warning system that provides the ability to avoid an impending crash in the supply chain.

Process industry

For the process industry, quality data is most meaningful. The pass/fail checks for discrete parts are not efficient for it. Normally, a manufacturer periodically samples and analyzes the material, e.g. fuel, to make sure it meets the manufacturer's specifications. Typically, it characterizes properties of the product, such as purity, viscosity, density, chemical composition, energy content, and so on.

A manufacturer is able to produce material to exact specifications by measuring incoming material statistically. With the measuring data, the manufacturer can compare and contrast materials from various suppliers and determine how they affect a given process. The process manufacturers make the following determinations based on the incoming feedstock quality [Merritt 2001]:

- How does the process respond to variations in each key material attribute?
- How do variations affect the cycle times/run rate?
- How do variations affect the downtime?

It is best that each of the suppliers provides quality control (QC) information with each batch of feedstock, when there are multiple suppliers and each supplier's material is acceptable. From here the manufacturer can automatically adjust its process to account for minor differences in the feedstock.

Many refineries use incoming quality data in their advanced process controlling. Advanced applications such as soft sensors and inferential calculations utilize it to improve their quality estimators. Feed quality information can also be used to automatically change production modes. "This is a trend, but still most companies do not do it", the actual situation is stated by industrial expert [Merritt 2001]. Experts supposed that the appropriate software has not been available until now.

The way of the feedstock QC data transfer and function in a supply chain is shown in Figure 4-22, which is a network-based QC system in an ideal plant.

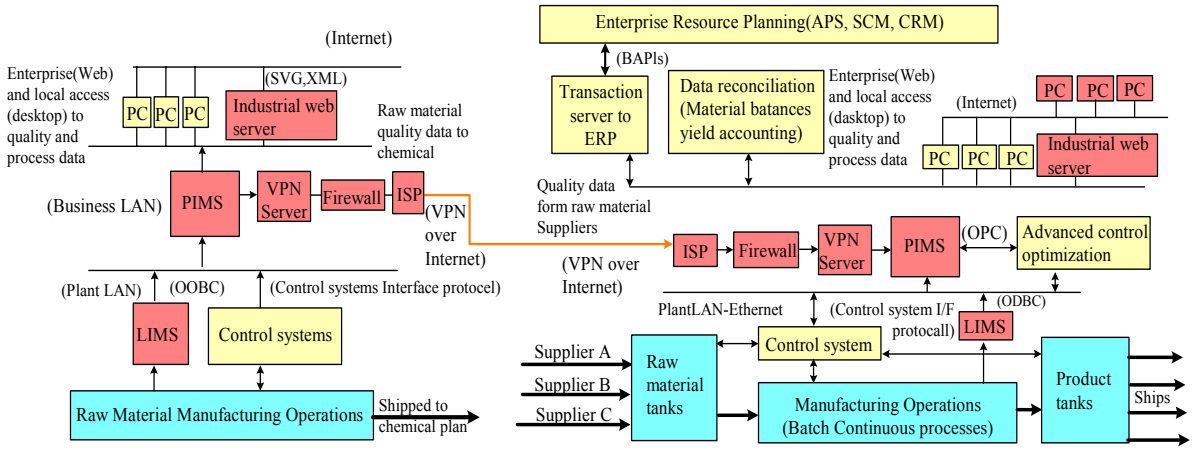


Figure 4-22 A network based QC system in an MSC [Merritt 2001]

QC information flows through a process from the supplier (left side) to the manufacturing plant of the customers (right side). Here the supplier gathers QC data during raw material manufacturing by a Laboratory Information Management System (LIMS) and stores it in a Process Information Management System (PIMS) database. QC data can be accessed by the manufacturer via the Internet through a web server, or alternatively by direct transmission via a Virtual Private Network (VPN) over the Internet. At the manufacturing plant the feedstock arrives and is stored in raw material tanks. QC data about the feedstock arrives via

VPN. Operators examine the QC information and use it to adjust the control system. QC data obtained during manufacturing is processed by the plant's LIMS; then put into the PIMS database and made available to downstream customers via the Internet and web browsers. Other systems in the manufacturing plant make use of all the QC data including ERP, material balance, control optimization programs and similar software [Merritt 2001].

The quality data has been generated and transferred between the supplier and customer in an MSC.

Generating the data

Generating the quality control data is a fairly easy process in the all. LIMS software packages are widely available for extracting data from plant laboratories and making it available in a database or on the Internet. Statistical Process Control (SPC) and Statistical Quality Control (SQC) software packages exist in many numbers. They examine the raw quality data from online analyzers and present the results as control charts, histograms, X-bar charts, moving averages and various other tools that make sense to quality control professional [Merritt 2001].

Making data available

Direct sending of QC to the customer

Every process control system has the ability to take quality data from another system in its own software family, plug it into its real-time control algorithms and control the process using QC data from a feedstock supplier. A prerequisite is that the supplier and manufacturer are running the same software. To obtain QC data the manufacturer needs a standard form, so it can take quality data form anybody, plug it into its control system and use it to run its plant. Similarly, the supplier needs a way to send QC to the manufacturer in the form its customers can use. According to related analysis, "at present, there is still no system available that will guarantee these plug-in functions. There exist some optimizing tools, though like OLE for Process Control (OPC), etc" [Merritt 2001].

Through the Internet

Making data available via the Internet or a private extranet. The data is in XML, HTML, text or some other universal format that can be manipulated easily and downloaded into a control system.

- ***Advantages for the manufacturer and supplier***

Production QC data transfer in a manufacturing supply chain should be applied in feedstock manufacturing industries, such as pharmaceutical, chemical, paper, food, steel, nuclear and wastewater. Today, software technology provides the available and easy solutions for all partners to pass feedstock data through the manufacturing supply chain.

The requirement and operation concept has existed in paper and food production for many years. The manufacturer requires both process and quality parameters for the proper setup and operation of the production line. Normally, it is required by manufacturers in order to control its process. But in most cases, “suppliers are still not tackling the supply chain quality issue with as much vigor as they should”, admonishes Cliff Yee, president of Northwest Analytical.

Sharing of quality data in the chain also brings advantages for suppliers. It allows suppliers to certify product quality by ensuring that their processes are well controlled, rather than by extensive laboratory quality testing. If the product stays within certain statistical quality control parameters during manufacturing, then by definition the product should meet the specification of the manufacturer. If the manufacturer has agreed that the QC data is sufficient, the supplier is able to greatly reduce his laboratory quality assurance testing [Merritt 2001].

4.7 Quality management for delivery

4.7.1 Quality model of delivery

Delivery is the process by which the supplier transfers the finished goods to its customer meeting planned or actual demands. That means, the products should be delivered with the right material, in the right amount and at the right time, i.e. Just In Time (JIT).

The internal JIT system can only be operated successfully if the material being fed into it has a sufficient quality and is delivered on time. To guarantee sufficient quality from the suppliers, a quality management system in-house coupled with collaborative forecasting as well as advanced logistics is essential for reaching this goal.

Figure 4-23 illustrates the quality model of delivery.

In this model:

Input: Finished product (after production)

Output: Delivered product

Process: Delivery

Controls: JIT mechanism and forecasting

Means: Efficient logistics, in-house quality management at every partner

Below the controls and means will be discussed in detail.

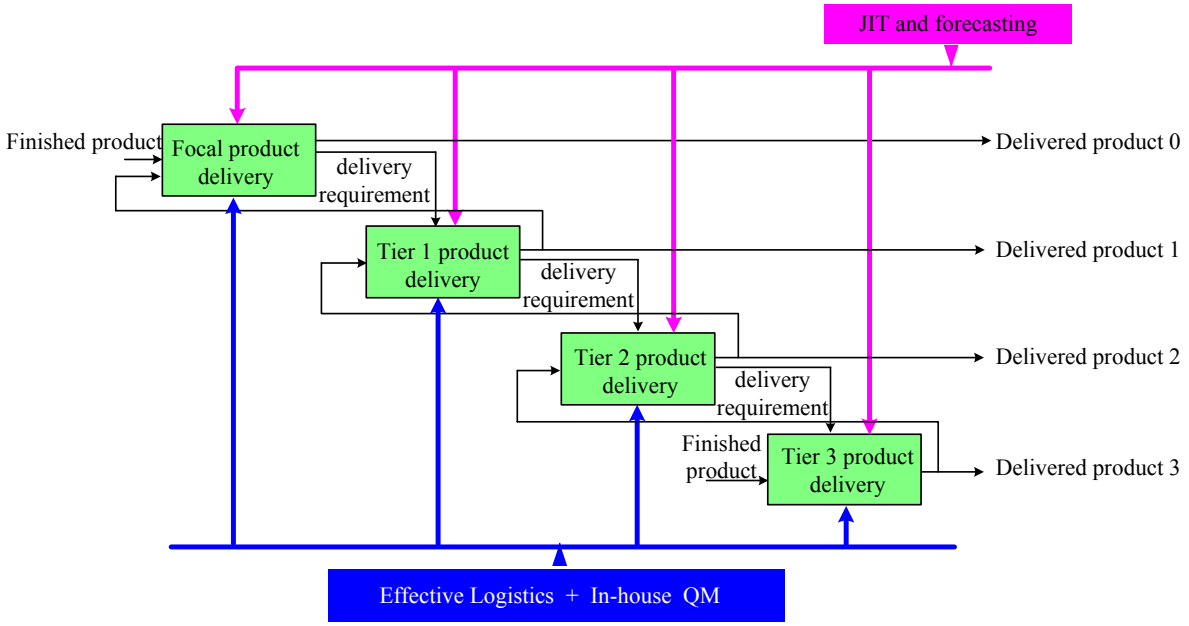


Figure 4-23 Quality model of delivery[13]

4.7.2 JIT and forecasting mechanism

The ideal condition is that the supplier delivers the products just when the customer needs them. However, to keep the production running, a safety stock is unavoidable. The suppliers must be able to respond quickly, flexibly and efficiently- delivering even small quantities directly and frequently to the point of use. JIT delivery as the pull control mechanism functions together with forecasting, which collaborates in the MSC with the push mechanism[14].

Normally, for suppliers there are two ways of doing the forecasting. The simple way is that manufacturers establish a contract with suppliers and provide rules for how much they want and when they want it shipped. Another way for the supplier is to address the forecasting issues by doing independent research. Besides using the information passed through the supply chain, the supplier adds its own judgment and pipes up when there are discrepancies.

In a trusting, collaborative relationship between the manufacturers and suppliers it extends to the sharing of planning data - operational, tactical and strategic. With CPFR, by operating inside of a supplier's company and exchanging information between partners, delivery on time will be more reliable (See §4.2.3). The manufacturer's and supplier's computer systems are needed to communicate through the supply chain integrated infrastructure (see §4.8).

Based on a long-term business plan and IT support, sequenced delivery is the ideal delivery mode of Just-In-Time application for assembly-oriented manufacturing between the focal firm (OEM) and its suppliers.

[13] The delivery chain can express more tier participants in the sub-model. Here only the first three tiers are shown.
[14] The across chain planning and forecasting is a control for delivery as well as for the entire MSC.

JIT/Sequenced delivery

A growing trend among automotive OEMs is the implementation of sequenced delivery on the production line. The suppliers are asked to package and ship their products in the sequence in which the automobiles are produced [Barcom 2006].

Sequenced delivery brings tremendous benefits with a view to zero level inventory, space utilization, high quality and increased productivity and flexibility. The advantages that have been demonstrated by Daimler Chrysler and other OEMs are as follows [Smith 2005]:

- Great reduction of stock in the work station of the assembly line
- Elimination of picking and selecting time
- Minimal handling with a resulting decrease in damage
- Partnership and cooperation between customer and supplier development to the highest levels

In the automobile branch, the big OEMs are planning to sequence more and smaller parts. The suppliers who do not deliver sequenced parts on time pay stiff financial penalties for stopping the line - anywhere from $3000 to $20,000 per minute [Navas 2005]. At the Belvedere plant of Daimler-Chrysler, sequenced delivery has brought a successful changeover and more than 80% of the parts for final assembly and trim were planned to be sequenced through a JIT/Sequenced Part Delivery building [Smith 2005].

The concept can be applied to various parts and suppliers; it is becoming an integral part of modern manufacturing operations [Bukey 1991].

4.7.3 In-house quality management system

If a supplier wants to guarantee that he can provide finished goods that meet the planned or actual demands, a quality management system in-house must be established according to the related requirements and the manufacture's (customer) demands, too.

- ***Supplier quality management system general requirements***

In accordance with the requirements of International Standards ISO 9001:2000 and ISO/TS 16949, the supplier shall establish, document, implement and maintain a quality management system and continually improve its effectiveness, which has been described in §4.5.3.

For different industries, there are various standards:

Automotive Industry: QS 9000, ISO/TS 16949, VDI 6.1, etc.

Aerospace Industry: ISO AS 9100

Medical Industry: ISO 13485:2003

Telecommunication Industry: TL 9000

- ***Related quality management techniques and approaches***

There are some quality assurance technologies that are recommended or even demanded by customers in the supplier's quality management process. The more stringent QS 9000 standard is helpful for the automotive industry, especially the concepts of APQP and PPAP. As industrial analysts stated, if performed correctly, they are extremely helpful for large production runs in any industry. Other methods, e.g. statistical techniques, analytical techniques Measurement System Analysis (MSA), error proofing, preventive/predictive maintenance and continuous improvement process should be applied.

In order to satisfy the customer and to assure the timing coordination with the customer, a project management timeline should be set up and maintained as a "controlled document".

- **Project management timeline**

The timeline shall be structured in the following phases:

Phase I: Design Program Approval

Phase II: Prototype

Phase III: Pre-launch

Phase IV: Launch

A controlled copy shall be submitted to the customer (buyer) sourcing team at the beginning of Phase I, the end of Phase IV or whenever the status of the timeline changes.

In order to deal with quality problems and returns, nonconformance, corrective and further preventive actions should be planned and taken.

- **Nonconformance, corrective and preventive actions**

For nonconformance issues with material, there are three measures that should be taken by suppliers [Bosch 2005]:

Initial containment

The containment action shall be implemented within a certain time, e.g. 24 hours. It includes all affected material in the supplier's control, in transit to the customer, in possession of the customer or products shipped to the customer's customers. The suppliers shall notify the supplier quality representative of their containment actions to discuss the coordination of the containment of the material at the customer and the customer's customers.

Certified shipments

All shipments of affected material shall be "certified" until corrective action issues are formally closed by the customer supplier quality representative. All material shall be shipped per approved methods and identified with the appropriate label.

Initial response

A written initial response shall be submitted to the customer within a certain time, e.g. 48 hours. The initial response contains:

- Customer concern number and date of nonconformance
- Name of the responsible person of customer
- Problem description
- Containment action description
- Containment action verification (quantitative results)
- Certified material shipment dates and identification
- Root cause analysis status

Each of the stated criteria shall contain an implementation date and assigned responsibility.

Formal corrective action report

A formal corrective action report shall be submitted to the customer's supplier quality department within a specified time, normally 10 days, of formal notification of the concern. It contains the items as found below:

- Description of the concern and customer concern number
- Containment action
- Root cause of the concern with verification
- Corrective action
- Verification of containment and corrective action; this is a measure of the action's effectiveness utilizing appropriate statistical or process performance analysis methods
- Preventive measures for "Lessons Learned" and applicability to similar products and processes
- Preventive action assessing the applicability of the action taken on similar processes; these are actions with a proactive and predictive intention with focus on avoiding occurrences
- Verification of process flow diagrams, update of product FMEAs and process control plans

Documentation

FMEAs, control plans and other appropriate documentation shall be revised to reflect changes resulting from the concern. The documents shall be maintained on file and provided to the customer's supplier quality representative for review as required.

Action/Timing plans

If additional time is required for resolution of corrective actions, the supplier should submit to the customer a written action/timing plan for approval.

Supplier containment level procedures

If supplier containment actions are not effective, progressive customer initiated procedures will be implemented for the supplier.

4.7.4 Effective logistics

In many industries the movement of products from one location to another is an important activity. There is a delivery process wherever a product needs to be moved, for instance delivery of the product from the producing (manufacturing) facility to the operator (customer) [Vaugh 2000].

In large-scale manufacturing, logistics is a critical element, because there are great amounts of materials and semi-products that must be transported and distributed to their customers to keep the production chain operable.

There are two options for logistics:

- Supplier-based JIT delivery system
- Third-party based JIT delivery system

The way that should be selected depends on the supplier's logistics capability, cost and efficiency. The logistics operation will not be a main point to discuss here.

4.8 Enable technology and platform for cross-company quality management

IT application is the prerequisite for supporting efficient communication between customers and suppliers and process-based quality management across the manufacturing supply chain. It enables documentation and identification of products, inventory information and real-time quality data exchange throughout the whole chain.

Effectively supported by innovative information technology, chain-wide quality management can assist in improving productivity, raising consumer confidence and ultimately result in higher profits.

A manufacturing supply chain can only work efficiently when there is collaboration between the partners. Modern information and communication technology makes collaboration between different partners possible.

4.8.1 Information & communication requirements

The selection and application of information and communication technology should take into account the following requirements:

- Information must flow in both directions, i.e. across the manufacturer and along the MSC to the end customer and include the feedback to different required suppliers and manufacturers.
- The information flow, which combines business data and manufacturing data, must move quickly and effectively.
- The information must be secure and available inside the chain to different levels of authorization; but it must be prevented from being accessed by the competitors.
- System development cost and time should be affordable for the participants.

4.8.2 IT platform and databases

- ***IT platform and enable technology***

There are two alternative solutions:

- Electronic Data Interchange (EDI)

Since the 1980's, along with computing technology development, EDI as a means of passing transactional information between trading partners became the most widely used solution. Many large companies have invested heavily in EDI technology as the only standards-based approach to gain efficiency with their supply chain partners and customers [Grosv 2001]. However, EDI has the following disadvantages:

- Time-consuming and expensive to set up

It takes sophisticated programming skills to establish and maintain end-to-end compatibility among the participants. The costs involved are insignificant to large OEMs and their tier1 suppliers but are out of reach for smaller suppliers. This limits the adoption of EDI.

- Batch-oriented

This application creates automatic time lags (order latency) between the time when an order is placed and when it is received. It causes a pipeline inventory.

- Web-based Internet solution

Today, a web-based Internet solution provides a flexible, cost-effective structure. It serves the customers at one end, and at the other end it interconnects with the plants.

- Collaborative E-commerce infrastructure – E-marketplace (EMP):

As an information and communication platform, E-commerce can provide a link between the focal firm and the suppliers to make sure the product is being made correctly. The manufac-

turers can pass requirements upstream to the contracting plants, and the plants can pass quality and safety data back downstream, so the manufacturers know the product will meet their standards.

EMP is differentiated into three types. Table 4-4 illustrates their characteristics. For the purpose of supporting planning capabilities, like CPRF and capabilities for collaboration around new product design and manufacturing quality information sharing, interaction services are required as a core service. It is intended to benefit participants by reducing the costs and increasing the quality of multi-party information exchange. In addition to the benefits of information sharing, participating in such collaborative efforts can benefit in terms of reduced IT costs [Christi 2002].

Table 4-4 The characteristics of E-marketplace [Christi 2002]

Type	**Characteristics**
Transaction EMP	Support buying and selling, search and selection.
Interaction EMP	Tighter links among existing partners and whole supply chain networks.
Support EMP	Support services like consulting services, software integration, application service provision, etc.

- Business to Plant (B2P):

B2P systems transform traditional hard-coded, spaghetti-like point–to–point systems into newer and simpler collaborative framework architectures. The extensible markup language (XML) based Enterprises Application Integration (EAI) software has finally begun to provide an answer [Gifford 2001]. It provides the possibility for OEMs and their suppliers and other partners not only to share blueprints, latest sales forecasts, but also to give each other real-time access to their own ERPs, product design, inventory and other systems.

A solution connecting ERP systems with virtual marketplaces is shown in Figure 4-24 [Koolwa 2000].

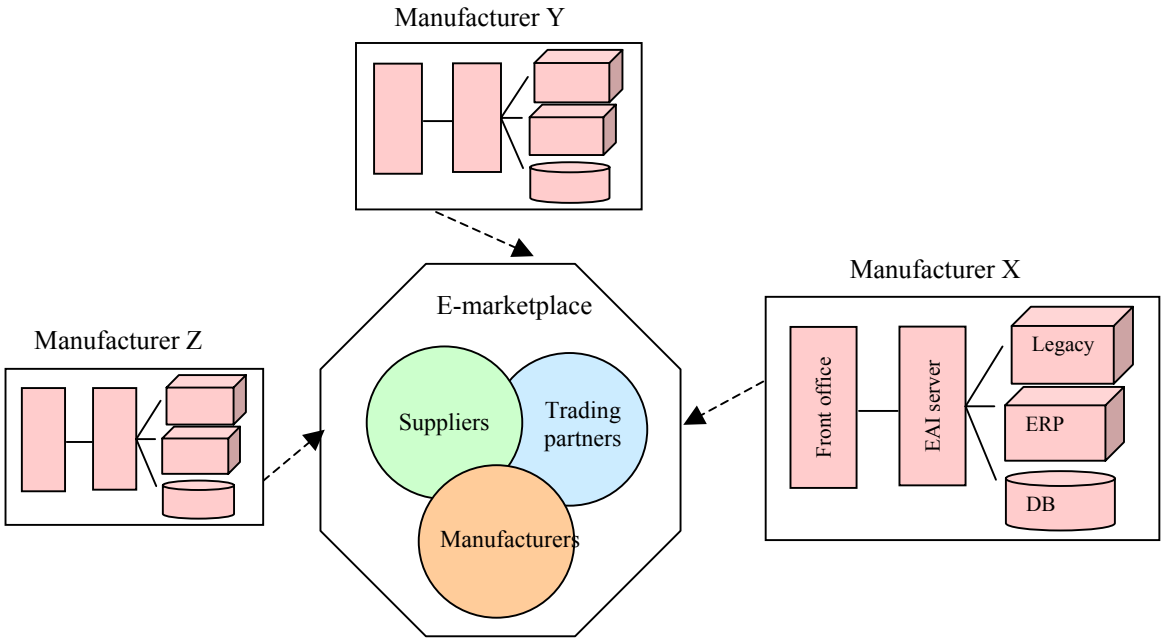


Figure 4-24 Connecting ERP systems with virtual marketplaces [Koolwa 2000]

- ***Communication tool - XML***

XML provides the common language for business-to-business communications. XML - an extension of the HTML technology that underlies all Web transactions - is text-based, easy to manipulate, and the basic skills required to work with XML are widespread. Therefore, it does not require large investments in new hardware, software or human capital. By using XML documents, the necessary level of automation and system-to-system integration can be achieved, avoiding the disadvantages that the web interface is only for lower volumes.

- ***Quality information databases***

To share quality information in the MSC, the quality information databases that support quality management activities in the chain may need to be created by the focal firm.

Quality organization and planning database

It should include the following information:

-Quality strategy and quality planning

-Product quality goal

-Quality cost control

-Quality documentation and standards

-Personnel/contact information for the chain quality organization

Quality continuous improvement database

-Quality improvement initiatives

-Improvement suggestions from partners

-Quality issue information collection

-Corrective action and results

-Improvement tracking info.

Product development quality information database

-Design quality goal disposition

-Quality tools application support: FMEA, QFD, APQP, etc.

-Design quality evaluation

-Design experience and reuse, etc.

Outsourcing quality information database

-Supplier quality management system certifying information

-Supplier and sub-supplier quality manual

-Supplier performance and dynamic evaluation

-Supplier quality development planning and programs, etc.

Production quality information database

-Inspection planning

-Production inspection information

-Product process control information from partners

-Defect product management information from partners, etc.

Delivery quality information database

-Dynamic delivery plan

-Delivery accuracy/ on-time delivery rate

-Product rejection rate

-Customer satisfaction rate, etc.

This provides the necessary enterprise-wide infrastructure to allow the tier suppliers to integrate with it. The focal firm itself or an entrusted third party builds, maintains and manages the central application system [Reddy 2001]. The partners and lower level suppliers can visit the customerized application service to carry out collaborative quality management in the MSC.

Regarding some advanced application cases, e.g. e-Hub from Cisco Systems, the Elemica, a consortium marketplace in the chemicals industry, etc., a general IT infrastructure of a cross-company manufacturing supply chain is pictured in Figure 4-25. It is a tentative model that starts from the focal company and integrates the suppliers in different tiers.

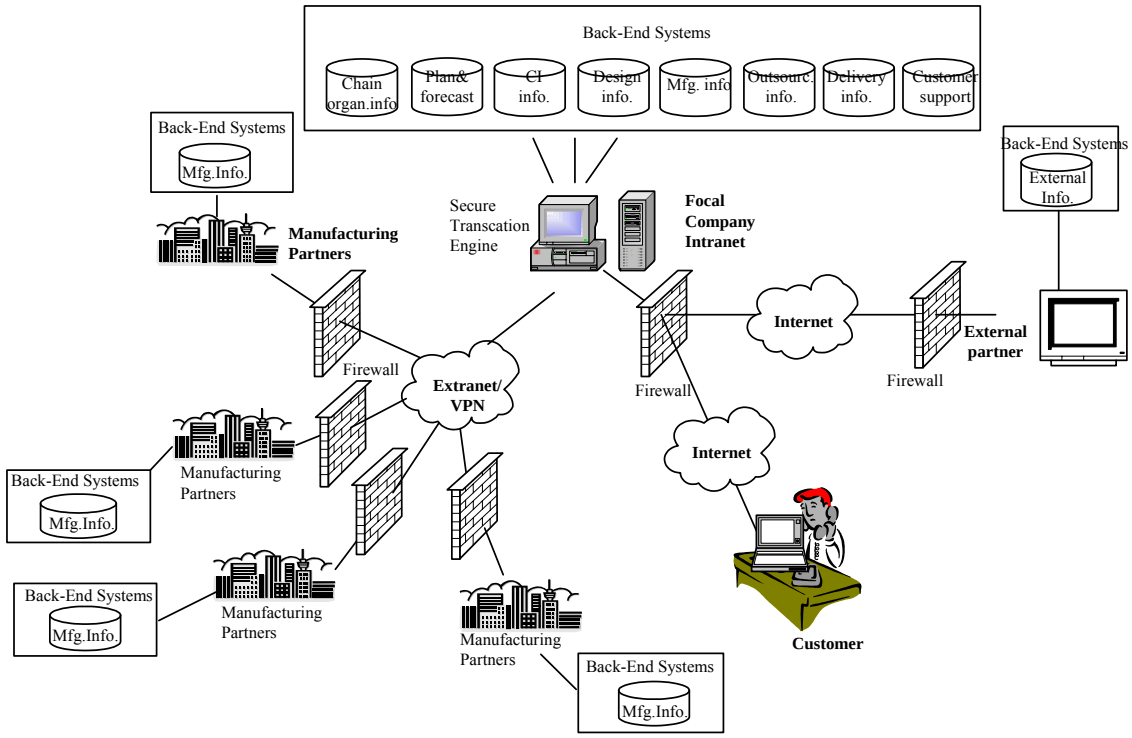


Figure 4-25 The network structure of a manufacturing supply chain

- ***Integrated software system***

To be successful, the E-commerce systems that communicate supply chain data must be easy to implement. And according to some industrial experts' suggestions, they must be quick to install with a minimum of staff time. For a manufacturing supply chain, the key E-commerce applications are systems that exchange manufacturing data/product requirements, safety and quality information within the MSC [Bradl 2000].

After much practice it was found that most practical overall solutions are probably assembled using core software that connects the existing plant system with downstream customers, both external and internal [Bradl 2000]. The costs and risks of the new technology can be dramatically reduced for most participants in the supply chain through common standards and an open-system approach. There are some commercial integrated software support systems, e.g. BizTalk translation system, with published standards and small amounts of "glue code" that can ensure that the organization XML-enabled specification system can talk to the partners's XML-enabled acceptance system, even if the systems have different bases. That

would greatly increase agility and flexibility in transferring manufacturing data. BizTalk is widely accepted, and has the power of vendors and users including Microsoft, SAP and Boeing behind it. Other available integration software systems with a similar function are iWork, Verano, Mercator, WebMethods, SeeBeyond. The vendors leading these efforts are the XML-based Enterprises Application Integration (EAI) tools that can improve chances for B2B success, because they integrate real-time plant data into the corporate and supply chain application [Gifford 2001].

EAI and supply-chain software vendors are now developing tools to extract data from plant optimization systems. These systems typically include MES, laboratory information management systems, finite capacity schedulers and process control systems [Gifford 2001].

4.9 Summary

In this chapter the eight processes that accomplish quality organization, planning, control, assurance and improvement in a cross-company/chain and extended enterprise oriented MSC have been discussed.

The quality organization forms the core competence with the key supplier network and keeps the entire chain functioning as a whole. In this part the organization principles, structures and the requirements for personnel qualifications are discussed in detail. Many practices demonstrate that an efficient quality organization with the leadership of the focal firm is essential for building an extended enterprise oriented MSC.

By defining the quality policy and the quality objectives of an MSC, joint strategic planning, systematic planning and operational planning are discussed within the quality planning. They form a completed quality planning for an entire MSC to achieve the quality objectives, as well as to realize the quality policy. Together with cross-company planning and forecasting process, the inventory in the whole chain can be kept at an optimized level. It makes possible cost savings and visibility of demand within the entire MSC. The CPFR model, tools and implementing cases have been introduced.

Under this leadership a mechanism should be established in order to implement continuous improvement for all the links and processes among an MSC. Based on some leading focal firms' practices, the mechanism with commitment, voluntary base, encouraged and enforced strategy and the implementing processes, activities and executive parties were discussed.

As the key process, the collaboration in new product design and development can make the time to market shorter as well as decrease the risk. In the sub-model, quality control and assurance in every R&D phase were analyzed and the systematic method - Advanced Product Quality Planning (APQP) approach - is recommended as a guideline for all participants to work together. Collaborative design process and knowledge sharing as the means to support collaborative product development in the MSC were introduced.

In the part dealing with quality model outsourcing, supplier quality management and relationship building with key suppliers were analyzed. If every partner in the chain follows the supplier quality management process, a basis to reaching the quality of the entire MSC will be established.

In the quality model of production, as the means of integrating with plant-floor and ERP, the MSC can operate with real-time manufacturing data. Through Internet-based SPC and real-time quality data sharing, inspection work can be reduced on both sides of the supplier and customer, and it is possible to prevent production quality problems for down-stream manufacturers in the chain.

In the delivery quality model, the factors that influence the delivery quality performance are analyzed and defined as JIT and forecasting control, in-house QM system as well as logistics. By combining the forecasting and JIT mechanism together, the sequenced JIT part delivery is discussed as the ideal delivery mode.

As the means for the entire MSC, the information and communication requirements for an MSC, the IT platform, required databases, network structure as well as integration software tools for an MSC are presented as a basic view.

Chapter 5 The Evaluation of MSC Quality and Management Performance

According to systematic evaluation methods, there are two ways to assess the quality of a manufacturing supply chain. One is performance-based evaluation, i.e. it focuses on how the quality performance of an MSC is. The other is process-based evaluation, checking how an MSC is doing to reach the long-standing goal described in the ideal model in chapter four, i.e. the collaborative quality management capability in an MSC.

5.1 Consolidation of quality performance

From the standpoint of final quality, the quality performance at the end of the supply chain is dependent on the procurement of defect-free components and parts [Mendz 1997]. This depends on the process capability of every partner in the chain or involved processes. For a supply chain performance, Six Sigma provides a performance measurement approach.

Defect per Million Opportunities (Dpmo) is defined as:

$$\text{Dpmo} = \frac{\sum \text{Number of Defect}}{\sum \text{Number of Opportunities}} * 1000\,000$$

It can be used to measure the discrete characteristic feature and the continuous characteristic feature. For discrete data it should have at least 300 measurements. For continuous data around 30 measurements should be enough. There are two ways to calculate the value of Dpmo, shown in Figure 5-1.

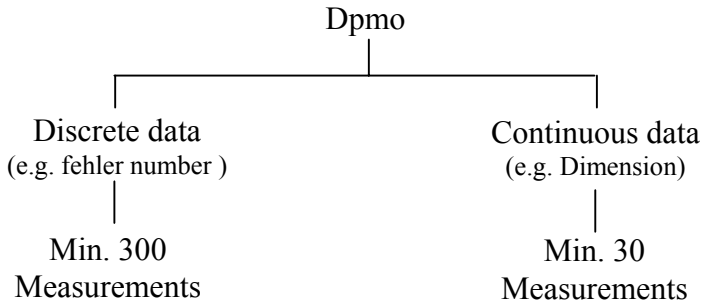


Figure 5-1 Dpmo in discrete and continuous process

According to Magnusson's and other's experience, everyone is very interested in forecasting the quality performance of a whole process, a product or even an entire enterprise [Magnu 2004]. To do so, process capability measurement has been consolidated. According to their research, if it fits to three perquisites, the consolidation of a process capability can derived.

1. It can come up with a fully functional process capability measurement structure that can summarize a huge amount of measurement values.
2. All processes use the same measurement unit, i.e. Dpmo (ppm or % can also be used).
3. There is a relatively large amount of measurements in order to provide a correct statistical consolidation value.

They have presented a simple consolidation method that takes the mean as the consolidation Dpmo value:

$$Dpmo_{consolidited} = \frac{Dpmo_{feature\ 1} + Dpmo_{feature\ 2} + \ldots + Dpmo_{feature\ n}}{n}$$

Here it is assumed that there are n features and all the features have the same importance. If considering that in an MSC, the processes or partners have different influence on the whole performance, then the quality performance of an MSC can be expressed:

$$Dpmo_{MSC} = \sum_{i=1}^{n} Wi * Dpmo_{feature\ i}$$ Wi: the weight of a individual partner

$$\sum_{i=1}^{n} Wi = 1$$ (n: the number of the key process or key members in the chain)

The consolidation of a manufacturing supply chain is depicted in Figure 5-2.

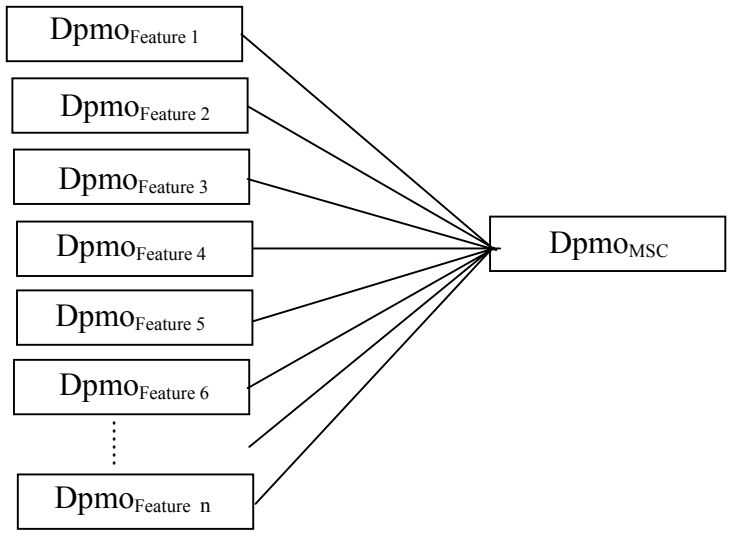


Figure 5-2 Performance measure system

As Magnusson and others stated in their book, top management must define the development goal of the overall organization critical quality indicator ($Dpmo_{total}$), so there can be a continuous measurement along the entire time [Magnu 2004]. In this way the focal firm can see how competitive the chain is in quality, and set an improvement goal for the entire MSC.

5.2 Metrics of quality management capability

A manufacturing supply chain consists of many partners. The focal firm, such as the final manufacturer or OEM, plays a most important role in the collaborative quality management of an MSC. However, the way that every partner manages quality between its suppliers and its customers in the chain influences the total quality of the chain. Therefore, there are two things that should be defined and can be viewed.

For a focal firm: How is the quality management performance in the entire chain? What and where are the weak aspects or points that affect the performance of the entire chain?

For every participant: How does he function as a link of the chain and how is his quality management capability in the manufacturing supply chain? Where are the weak points that should be improved?

The quality management of a manufacturing supply chain is involved in its controls, processes and means. From every participant's standpoint, it always stands on a certain management level. According to the ideal model in chapter four, the aspects of the quality management of a manufacturing supply chain are viewed in the fields as follows:

Controls: MSC quality organization

Cross-company quality planning and forecasting

Continuous improvement

Processes: Quality management for design

Quality management for outsourcing

Quality management for production

Quality management for delivery

Means: Enable technology and platform

Based on every aspect of the model, the evaluation aspects and factors of an entire MSC quality management performance are generated in Table 5-1.

The MSC consists of partners in different tiers. As discussed in §4.1.1, the key suppliers in the core chain play a big role in the quality management of the entire chain. When considering a discrete manufacturing chain, the focal firm takes the responsibility to build an extended enterprise. It initiates the quality organization in the entire chain. The system and

component suppliers transfer the quality goal to sub-suppliers and organize the quality activities in their own chain. The parts suppliers are engaged in a relatively smaller function. They participate in the quality activities in the chain, but focus more on inside quality assurance and coordination with their customers and material suppliers.

Therefore, the key suppliers in the core chain and the higher level partners in an MSC should be considered as the main participants to monitor the quality management capability of an MSC.

Based on the criteria in Table 5-1, an evaluation questionnaire for key suppliers and higher level partners in the chain is created in Appendix 2. A 5-point scale system is used in the questionnaires for evaluation, i.e. V= 1, 2, 3, 4, 5, meaning:

1: Totally does not fulfill the criteria.

2: Does not fulfill the criteria.

3: Is close to or is on the way to fulfilling the criteria.

4: Fulfills the criteria.

5: Perfectly fulfills the criteria.

The questionnaire can function as a checklist for every manufacturing company who is on a higher tier of an MSC.

Table 5-1 Evaluation aspects and main factors

	Processes	Aspect	Factor
Management layer	Quality organization	Strategic alliance and capability	Cross-company quality team Trained and qualified chain manager
	Quality planning	Integrated quality planning Cross-company planning and forecasting	Alliance quality planning and collaborative initiative Efficient information share between supplier and customers Demand planning and forecasting across chain
	Continuous improvement	Improve all processes	Continuous improvement mechanism Joint actions with all the partners to improve
Operational layer	QM for R&D	Supplier integration	Material suppliers[15] involved in R&D Facility suppliers involved in R&D
		Collaborative development process	Cooperation in new product development Network based collaborative design.
		Quality assurance methods	Design failure prevention measures application Advanced quality planning method in the chain
	QM for outsourcing	Supplier quality selection	Documented supplier quality management requirements Supplier evaluation/selection process Supplier audit periodically
		Supplier quality development	Customer guides supplier quality improvement process or program
		Relationship establishment	Willing to share investment in technology application Partner and trust relationship with key suppliers
	QM for production	Production process control	Process control in partners In time production quality information availability
		Joint reduction of waste	Reduction inventory in the MSC Reduction incoming inspection and repeated work
		Production flexibility	Integrated factory floor in the MSC Inventory and material tracking in the chain
	QM for delivery	Delivery control	Customer requirements transfer accurately in the chain JIT built in delivery
		Partner internal quality management	Quality certification of partners The in-house quality management system in partners
		Logistics management	On time delivery to request
Support layer	Enable IT	Platform and enable technologies	Information exchange platform Internal resource management capability Resource integration management through Internet

[15] Meaning system suppliers, sub-system system, and component/part suppliers here.

5.3 Classification of quality management for an MSC

Above, a criteria system for the ideal quality management in an MSC is presented. In industrial practice, it is a long way to achieving all the evaluation criteria. The quality management of a supply chain can be divided into four development stages as seen in Figure 5-3.

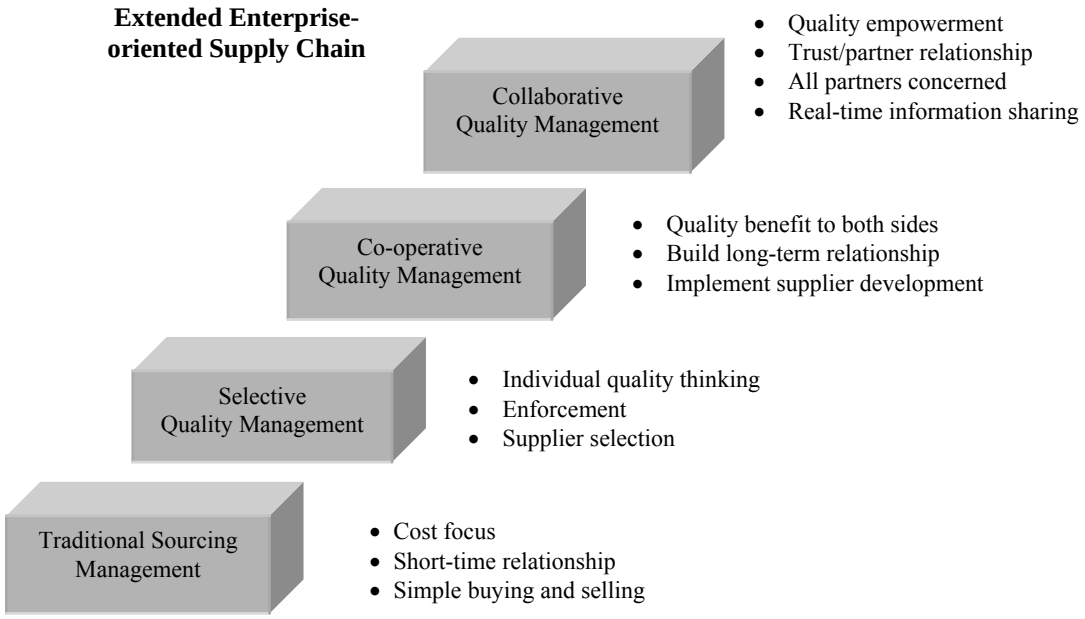


Figure 5-3 MSC quality management in four stages

In the first stage – traditional sourcing management:

The suppliers produce products according to their customers' specifications or blueprints. There is not much communication or coordination between the customer and supplier. The operation of a manufacturing supply chain is based on a simple purchasing and selling process; sourcing decisions are based almost exclusively on low price [Tompk 2003]. This is possible and sufficient just for simple and standard products.

The first stage is a natural and primitive phase based on selling and buying. The quality management activity is insulated inside the single company. Here it will not be considered as a main phase involved in quality management for a manufacturing supply chain.

In the second stage – selective quality management:

It requires everyone who participates in the MSC to function with proper quality ability according to ISO 9000, etc. The supplier is expected to run his in-house quality management system, but the customer places more requirements on his suppliers, because a trust relationship between partners still needs to develop, e.g. an enforcement philosophy with the driving

force of meeting product and process specifications. In order to achieve the qualified products, the customer applies all the selection, evaluation, inspection and audit activities to its suppliers. In this stage quality is gauged with product metrics such as the number of rejects, rework costs, etc. [Puri 2002].

In this stage there is relatively low visibility between partners. Much inspection work is repeated by suppliers and customers because of less coordination between partners in the chain. This leads to quality management losses of its true value. The MSC is often unstable, lacks flexibility and efficiency.

In the third stage – co-operative quality management:

The partners have built or make effort to build a relatively stable or long-term relationship. The customer company helps its suppliers to improve the quality management capability and tries to make its supply chain work more efficiently in order to benefit both sides. In this phase the manufacturer integrates the suppliers into new product development to shorten the time to market and prevent later changes. It coordinates with suppliers to reduce lead-time, shares knowledge and experience to make the total cost lower for the chain and carries out continuous improvement activities with suppliers to gain improvement in every weak link. The quality management is normally implemented between the customer and his direct suppliers with the driving force of process adherence, i.e. controlling and managing variability [Puri 2002].

In this stage the MSC runs relatively stable. However, it lacks real-time information support; improvement is only implemented in a single chain between direct partners.

In the fourth stage - collaborative quality management:

It improves the whole manufacturing supply chain through a multi-tier oriented strategy. Through network support all the suppliers understand their position and contribution to the chain. By means of integrated quality management of new product development at all levels, the risk of high costs and danger of failure can be prevented in advance. Real time quality data sharing between suppliers and customers can reduce repeated work and waste. The planning, predicting and replenishment of inventory and tracking through the manufacturing supply chain provide savings for every partner, and thus, ultimately lower the cost for the whole chain.

In this stage dynamic and continuous quality improvement is built into the entire manufacturing supply chain. The entire chain and every partner benefit from this quality improvement. There are a lot of challenges, e.g. cultural barriers, investment for infrastructure, intellectual rights. The focal firm plays a leading role, and collaboration between partners is the bridge to approaching the total quality goal.

Based on analysis of the classification of the quality levels of an MSC above, the chain quality level with critical features in the four phases is presented in Table 5-2, which is sorted according to the evaluation main factors in Table 5-1.

In order to evaluate the quality management of an extended enterprise-oriented MSC, an evaluation chart is formed from the chain quality level. Because the criteria of the first stage - traditional procurement management - is naturally fulfilled by every partner who is in an MSC, they are not considered here in the evaluation criteria. Every criterion can be judged with five value levels. The value is decided by evaluating the questionnaire that is filled out by survey mail or interview. The relationship between the evaluation mappings is shown in Figure 5-4.

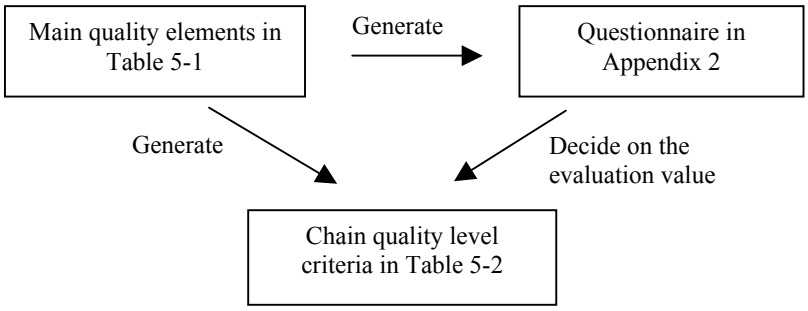


Figure 5-4 Relationships in the evaluation system

The numbers on the right side in Table 5-2 correspond to the questionnaire numbers in Appendix 2. There are 21 critical criteria for the last three stages; every stage is increased by seven criteria.

When a partner fulfills the requirements from criterion 1 to criterion 7 with a value ≥ 4, it is on the selective quality management level.

When it reaches all the criteria from 1 to 14 with a value ≥ 4, it can then be on the level of co-operative QM stage.

Only when a company fulfills all the key elements with the value ≥ 4, it enters the collaborative QM stage.

Table 5-2 Quality level with critical features in the four phases

Aspect			Criteria	No. correspond to Questionnaire
Traditional sourcing management			Cost dependent	
			Technical specification	
			Incoming check	
Collaborative QM	Co-operative QM	Selective QM	1 Clear company quality management system	5.1, 6.1, 6.2, 6.3
			2 Supplier selection and evaluation system	3.1, 3.2
			3 Information exchange with suppliers/customer through certain channel	1.8
			4 Responsible staff to deal with quality issues with suppliers/customers	1.3, 1.4, 1.5
			5 Periodical audit of supplier performance	3.3
			6 Quality requirements of customer can be transferred/received accurately	6.4
			7 Product delivery based on agreed date	6.5, 6.6
			8 Supplier help to improve their quality management performance	3.4
			9 Short lead-time by coordinating with suppliers and customers	6.7
			10 Continuous effort to improve quality with main suppliers/customers	1.9
			11 Has built long-term relationship with key suppliers	3.6
			12 Suppliers and customers involved in product development and quality management	4.1, 4.2, 4.4
			13 Sharing of quality data to reduce waste with suppliers and customers	5.6, 5.7
			14 Cross-company quality management activities with direct suppliers	1.6
			15 Leading/participating multi-tier quality organization and planning	1.10
			16 Deployment of quality management process through up-stream supply chain partners	1.2, 3.7
			17 New product development collaboration and quality assurance with suppliers through Internet	4.3, 4.5
			18 Full visibility of production quality data across supply chain	2.1, 5.3, 5.4, 5.5
			19 Dynamic inventory and WIP tracking in the chain	5.3, 5.8
			20 Collaborative planning, prediction and replenishment together with suppliers and customers through network	1.7, 5.2
			21 Partner willingness to invest in new technology	3.5

5.4 Evaluation of the quality management level of an MSC

According to every criterion in Table 5-1, the questionnaires can be created for checking each single partner in an MSC. The filled out questionnaire can then be combined and mapped to the criteria form for each one. This can be done by evaluating the manufacturing supply chain of the OEM, key partners in 1st tier suppliers to sub-tier suppliers. By doing so, we can get the evaluation chart for every tier in principle.

To the 21 criteria items, i=1.....21,

In an MSC there is one focal firm and assume:

The core chain with key suppliers is mapped to tier n,

The number of first-tier suppliers: e

The number of second-tier suppliers: m

……

The number of tier p suppliers: s

……

The number of tier n suppliers: k

For the suppliers in the same tier, assuming that their contributions to MSC quality are equal and of the same importance.

For every criteria in every tier, the mean value can be calculated as:

Focal firm: $\overline{V}0_i = V0_i$

Tier 1: $\overline{V}1_i = \sum_{t=1}^{e} V1_i/e$

Tier 2: $\overline{V}2_i = \sum_{t=1}^{m} V2_i/m$

.....

Tier p: $\overline{V}p_i = \sum_{t=1}^{s} Vp_i/s$

.....

Tier n: $\overline{V}n_i = \sum_{t=1}^{k} Vn_i/k$

For different tiers, it is considered that the different quality management levels have different influence on the entire chain.

If the weighting of different tier is set up as:

$$\sum_{p=0}^{n} W_p = 1$$

The total value for every criteria of the entire chain will be:

$$Vi = \sum_{p=0}^{n} \overline{V}p_i * W_p \quad (p=1….n,\ i=1…..21)$$

Table 5-3 Evaluation chart of the quality management level

Stages	Collaborative QM																				
	Co-operative QM																				
	Selective QM																				
Criteria	Clear company quality management system	Supplier selection and evaluation system	Information exchange with suppliers/customers through certain channel	Responsible staff to deal with quality issues with suppliers/customer	Periodical audit of supplier performance	Quality requirements of customer can be transferred/received accurately	Products delivery based on agreed date	Supplier help to improve their quality management performance	Short lead-time by coordinating with suppliers and customers	Continuous effort to improve quality with main suppliers/customers	Has built long-term relationship with key suppliers	Suppliers and customers involved in product development and quality management manamanage-	Sharing quality data to reduce waste with suppliers and customers	Cross-company quality management activities with direct suppliers	Leading/participating multi-tier quality organization and planning	Deployment of quality management process through up-stream supply chain partners	New product development collaboration and quality assurance with suppliers through Internet devel-	Full visibility of production quality data across supply chain	Dynamic inventory and WIP track in the chain	Collaborative planning, prediction and replenishment together with suppliers/customers via network	Partner willingness to invest in new technology
V	V_{1}	V_{2}	V_{3}	V_{4}	V_{5}	V_{6}	V_{7}	V_{8}	V_{9}	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}	V_{15}	V_{16}	V_{17}	V_{18}	V_{19}	V_{20}	V_{21}

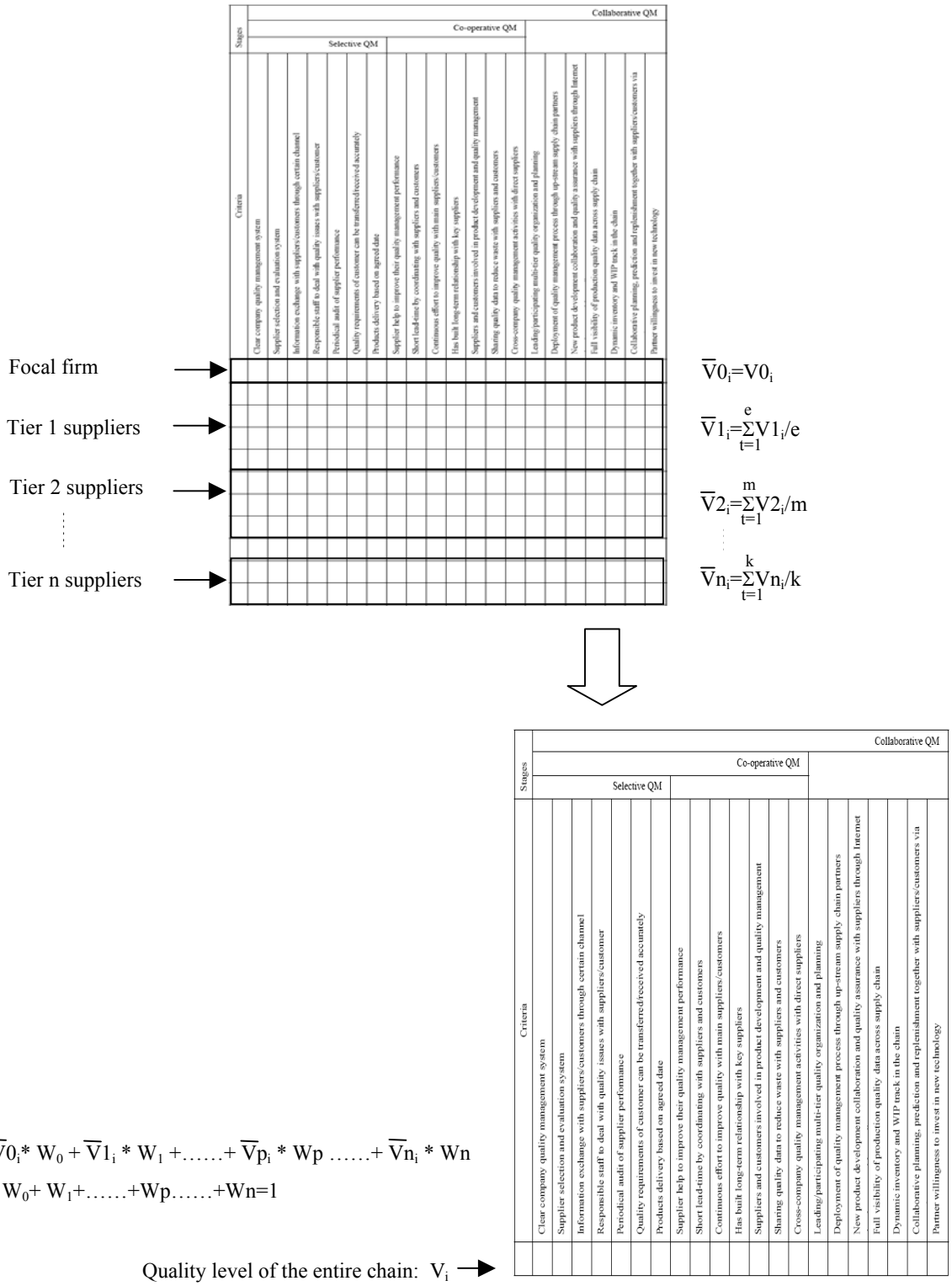


Figure 5-5 Definition of the quality management stages of the entire chain

Here the total quality management status of the entire chain is shown on the chart of Table 5-3. The process of value deciding is depicted in Figure 5-5.

5.5 Summary

In this chapter, MSC quality is evaluated in two ways. One is performance-based evaluation with a consolidated Dpmo for the entire MSC according to the Six Sigma theory by calculating the Dpmo of all key partners in the core chain. The prerequisite of this approach is an equal systematic standard for measuring the Dpmo of every partner.

In this chapter a process-based evaluation was also established. It checks how the MSC and the partners in the chain are on the way to reaching the highest quality level that is described in the ideal model in Chapter Four. The quality management aspects and criteria are created based on the ideal model. According to the criteria, a questionnaire for checking out the single partner' (key partner) chain quality management has been prepared. This questionnaire can function as an evaluation chart for a single company to check the quality management of its own supply chain.

To reach the collaborative quality management capability that is described in the ideal model, a four-stage model with 21 criteria for an MSC are classified. By merging the evaluation values of the focal firm and the key partners in every tier, a whole picture of the quality management level of an entire MSC is presented. We can find the weak points when the value of an item is below 4. This gives an entire picture of what the positions of every partner and tier are, and where there should be improvements in the whole chain in order to get into a higher level. It provides a basic view for the quality improvement and development in the entire manufacturing supply chain.

Chapter 6 Survey Object Selection and Methods of the Empirical Study

6.1 Goal of the investigation

Since the world economy has become increasingly integrated, China is playing a more and more important role as a world factory in the global value networks of many industries. As a link in the manufacturing supply chain, Chinese suppliers' performance impacts the total efficiency of the supply chain.

As introduced in §2.2.4, Chinese suppliers, especially the indigenous suppliers, have a relatively negative reputation for their performance. Therefore, it is essential to review the general quality management status of Chinese manufacturers for cross-company manufacturing supply chains. It will be meaningful to find out the general situation and its development trend. Based on fact-finding, a concrete manufacturing supply chain will be analyzed as a case study according to the established quality management model, and a way to improve it will be attempted.

6.2 Survey objects and methods

General supplier survey

The investigation focuses on the manufacturing industry. Through database searching and internal contact, 562 manufacturers (OEM and system/component suppliers) in the field of automobile and machinery were chosen. They are from three categories according to §2.2.4:

- Purely owned by western manufacturers
- Joint ventures
- Local indigenous suppliers

The investigation medium is a questionnaire. The questionnaire was sent per post as well as per email. Because the investigation could involve the staff from the outsourcing and quality department, the general manager was chosen as the first contact person. He/she was expected to arrange for the proper staff to fill out the questionnaire. The survey obtained the support of the General Industry Sub-council of the China Council for the Promotion of International Trade (CCPIT), the biggest foreign trade promotion organization in China.

Concrete MSC investigation

Originally, the motorcycle manufacturing supply chain and house appliance manufacturing supply chain, which are two of the biggest MSCs in their fields, were selected. After making contact, the motorcycle OEM showed great interest in being an interview object. The house appliance manufacturer refused to cooperate giving as his reason that he was presently doing strategic reengineering.

6.3 Questionnaire preparation

According to the evaluation aspects and main factors in Table 5-1 in §5.2, there are 17 first level criteria in a total of 8 function areas (including processes, controls, means). They are divided into 33 second level criteria in the questionnaire. With consideration of the work expenditure caused for the investigated staff, the questionnaire was limited to a total of 40 questions in order to obtain the basic information from the surveyed companies, see Appendix 2.

6.4 Survey procedures

General supplier investigation

Mail and email sending:

The questionnaire was prepared in English and then translated and printed out in Chinese. With the help of Jeelong Enterprises GmbH (Berlin) and Jeelong Enterprises Ltd. (Beijing), a joint consulting company for German and Chinese project cooperation, the first survey with 524 questionnaires was sent to related Chinese companies at the end of September 2005. In July 2006, the second survey emails were forwarded to 38 Chinese manufacturers through internal contacts.

Interview:

From October to November 2005, the author spent 5 weeks in China working on this research. The interviews were carried out with the outsourcing department and quality management department at Bosch-China and its suppliers, etc.

Concrete MSC investigation

The final investigation object was the motorcycle manufacturing supply chain. The procedure was as follows:

1 Interview OEM

The contact person is the head of the QM department. Between October and November 2005, the author came to the city of Chongqing in the Southwest of China to the headquarters of the OEM location, and had the first interview with him. Through his arrangement, all the departments related to supply chain management, i.e. design department, purchasing department, production department, were interviewed.

2 Create the core chain with key suppliers

In motorcycle manufacturing, there are more than 300 direct suppliers involved with the OEM. In order to understand the quality management status in the chain, the OEM had recommended seven key system/component suppliers in its first-tier. After the discussion with

the first-tier suppliers, their key suppliers were chosen. Therefore, the three levels of the MSC are investigated in the research.

3. Interview sub-tier suppliers

From January 8th to January 18th 2006, the author came to the city Chongqing again and participated in the annual supplier meeting that was held by the motorcycle focal firm, and then interviewed its key suppliers in the first-tier and second-tier at their sites. Their general managers and quality management managers introduced their situation and problems in the chain very actively.

6.5 Summary

Based on more than nine months of preparation and intensive interviews, a general view of the quality management of the manufacturing supply chain has been gained. Especially through the interview with the OEM and its sub-tier suppliers of the motorcycle manufacturing industry, a typical Chinese manufacturing supply chain is demonstrated.

Chapter 7 QM Analysis of Suppliers and the Quality Improvement for a Chinese MSC

7.1 General analysis of Chinese manufacturers

7.1.1 Data collection and its basic analysis

In this survey 562 questionnaires were sent out. In total 51 feedbacks were received including personal interviews with eight manufacturers. In the survey there are six OEM companies and forty-five companies working as system suppliers.

In the following, the quality management performance of their MSC will be analyzed in eight functional aspects according to the quality model for a cross-company manufacturing supply chain.

- MSC quality organization

71%[16] of the surveyed companies manage only their direct suppliers. 29% of them manage not only their direct suppliers but also their sub-suppliers; however, only 6% of the companies showed that they are considering the entire management of the MSC. See Figure 7-1.

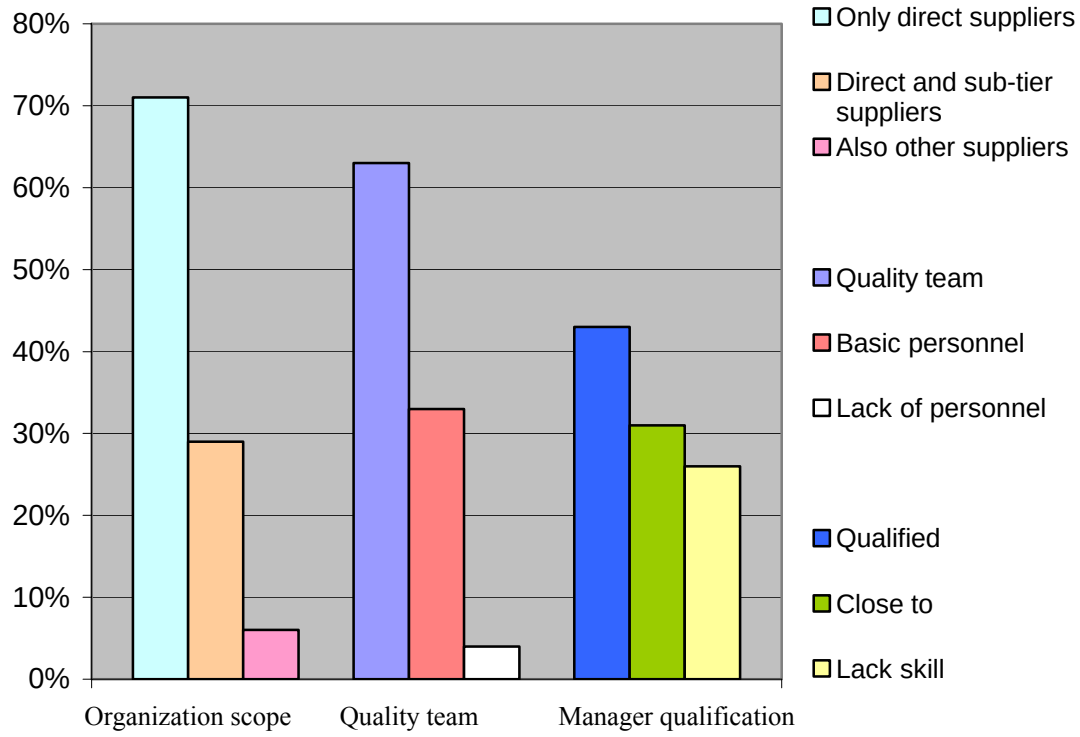


Figure 7-1 Quality organization status

63% of the participating companies have well-organized quality personnel for their supply chain quality control. 33% of the companies think that they basically have staffs that are responsible for supplier quality management, but they are still not satisfied with the personnel configuration.

[16] For a clear overview, here the statistical data is in rounded percentage.

More than 26% of the companies strongly expressed that the supply chain managers do not have enough knowledge and skill for the job. 31% of the companies stated that the qualification of their supply chain managers is close to fulfilling their expectations. Only 43% of the companies showed total satisfaction with their supply chain managers.

The OEMs and system suppliers in the automobile industry have played a leading role for quality management in their supply chains and have pushed this concept to their up-stream suppliers in China. The Chinese suppliers have started to pay greater attention to their supply chain quality management. However, many companies have not yet become involved in extended enterprise oriented manufacturing supply chain management. The qualification of many supply chain managers is a weak link.

- Cross-company quality planning and forecasting

Concerning the aspect of cross-company quality management planning and activities with customers and suppliers, nearly 20% of the companies gave scores of 4 or 5, i.e. they have concrete procedures and contents for quality activities with their suppliers and customers. Around 23% of the companies are close to or are thinking about doing so. However, another 57% of the companies have not yet considered taking action on this subject, so far. See Figure 7-2.

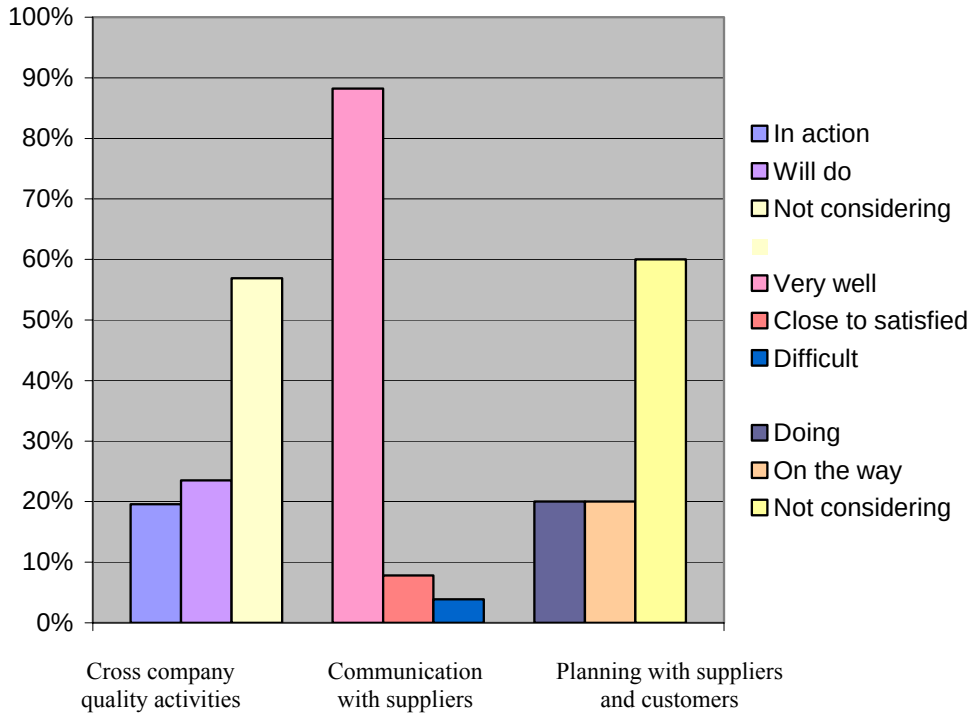


Figure 7-2 Cross-company quality planning status

Product and inventory forecasting, planning and replenishing are still an underdeveloped concept with suppliers and customers. 20% of the companies expressed that they are carry-

ing out planning and forecasting with their suppliers and customers, and around 20% are making an effort to do so, but more then 60% of the companies have not gotten involved with this at all. However, 88% of the companies stated that they could communicate efficiently with their suppliers. This could give a basis for cross-company planning, but effective methods and tools have not been put in place.

- Continuous improvement

The continuous improvement that is implemented together with suppliers and customers has brought advantages for the MSC operation. 53% of the companies stated that their suppliers accept the continuous improvement concept and improve the chain performance together with them. Around 33% of the companies expressed that they are developing towards this direction with their suppliers or are close to this situation. Around 14% of the companies admitted that their supply chains are still far away from reaching a joint improvement.

- Quality management of design

When considering supplier integration, 45% of the companies integrated their material suppliers in R&D, 31% of the companies are starting to work together with their suppliers during new product design and 24% of the companies have not done so, as yet. 60% of the companies integrated their facility suppliers; another around 20% have made very little effort. See Figure 7-3.

Regarding the aspect of collaborative product design, network-based collaborative development is a weak point. Less then 16% of the companies are doing design collaboration with their suppliers through an Internet-based platform. Around 22% of the companies are on the way, but 62% of the companies have not touched this topic, even though they are OEM manufacturers.

Considering the aspect of quality assurance processes and methods, 31% of the companies (all system suppliers) are participating in the new product design of their customers and are using quality assurance methods to ensure design quality. 33% of the companies are on the way, and another 36% of the companies are not involved in it. FMEA is still the most popular tool; 70% of the companies use it. 50% of the companies use APQP. About 30% of the companies use the 6 Sigma method. But some companies expressed that training has been carried out for the tools, like 6 Sigma, however, using it properly is still very difficult.

In the process of new product development, coordinating with suppliers has become an extended resource for OEM and system suppliers. However, only a few MSCs have taken up network-based collaborative design. Design quality management methods are used basically by automobile OEMs and system suppliers. But many companies still lack the ability to use them effectively.

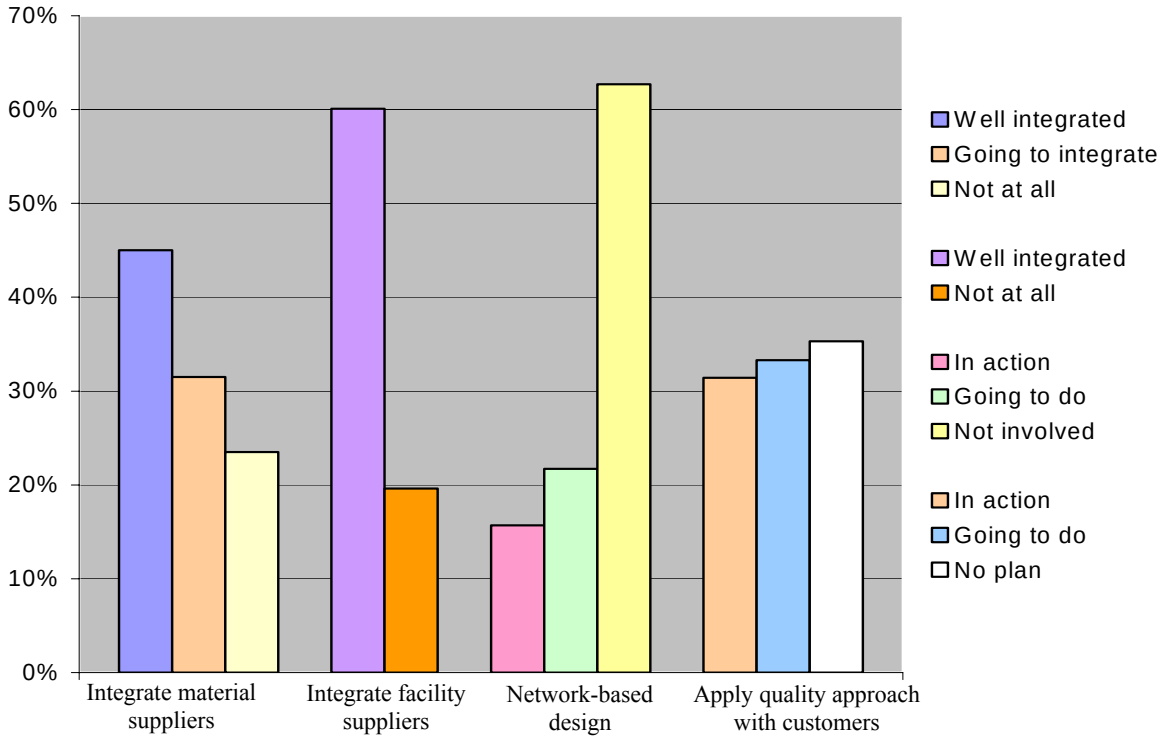


Figure 7-3 QM of design

- Quality management of outsourcing

Considering the aspect of supplier selection, around 69% of the companies have completed a supplier quality management manual. Around 20% of the companies have developed a supplier quality management manual, but they think it still needs to be improved. 11% of the companies still have not done one, so far. See Figure 7-4. 80% of the companies have an effective supplier selection and evaluation system, as they expressed. However, there are less companies (less than 63%) who review their suppliers periodically.

Considering the aspect of supplier quality development, 92% of the companies showed that they are helping or trying to help their suppliers to improve their quality management ability; 47% of the companies deemed that they made a tremendous effort on it and had good results. Only 8% of the companies are still below standard.

Considering the aspect of long-term relationship establishment, 82% of the companies believed that they have established long-term partnerships with their key suppliers. 18% are close to this kind of relationship. However, only 47% of the companies think that their suppliers can or could help them to improve the product quality and its process. And also only 49% of the companies think their suppliers are willing to invest in new technology application together with them to reach innovative competence. The other 51% of the companies have a negative attitude towards this.

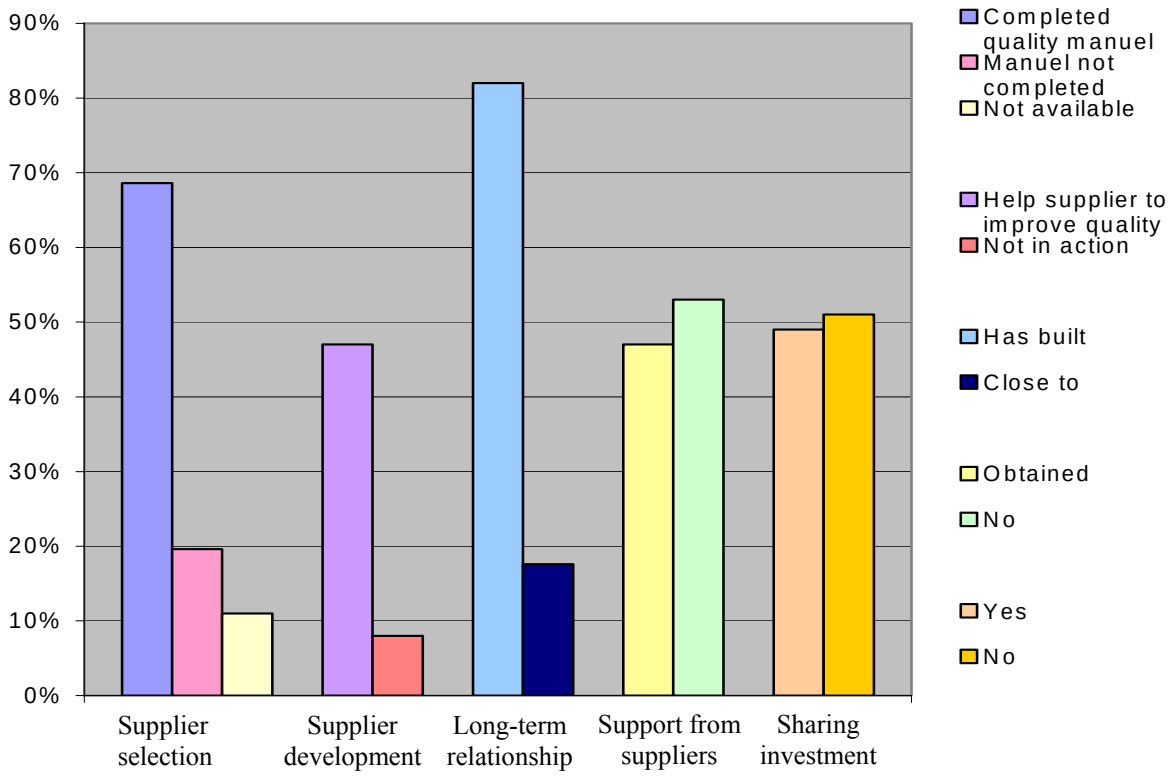


Figure 7-4 QM of outsourcing

Quality management of outsourcing is an advanced functional aspect. The supplier quality management process is relatively widespread. In order to make an effort to help their suppliers improve their quality management ability, most companies have established a long-term relationship with their suppliers. However, it is not easy for the companies to obtain help and support from their suppliers' side to improve quality and to share the investment for new technology.

- Quality management of production

By coordinating with suppliers and customers, companies can schedule their production more efficiently with lower inventory and better delivery capability. More than half of the investigated companies have been doing so, but this is only through an occasional information exchange; many companies have not increased their efforts in this field, as of yet. Just a few companies have integrated the shop floor with supply chain management. The statistical analysis is summarized in Figure 7-5 in the following aspects.

Considering the aspect of production process control, 82% of the companies have implemented a production process control in their production, but only 10% of the companies have integrated an information system of their shop floor with the supply chain management

system. Around 30% of the companies are doing so or considering integrating their ERP with the supply chain management; others have not acted on this. There are only 47% of the companies who can obtain real-time quality information from their suppliers, but 73% of the companies stated that they can provide real-time quality data to their customers.

Considering the aspect of the joint reduction of waste, around 40% of the companies stated that by coordinating with their suppliers, the inventories on both sides have been successfully reduced. 12% of the companies recognized the benefit, but 48% of the companies have not touched this topic. 54% of the companies have reduced incoming inspection and repeated testing by coordinating with their suppliers. 18% of the companies found that there is still a lot to be improved, but the rest of the companies have not paid much attention to it.

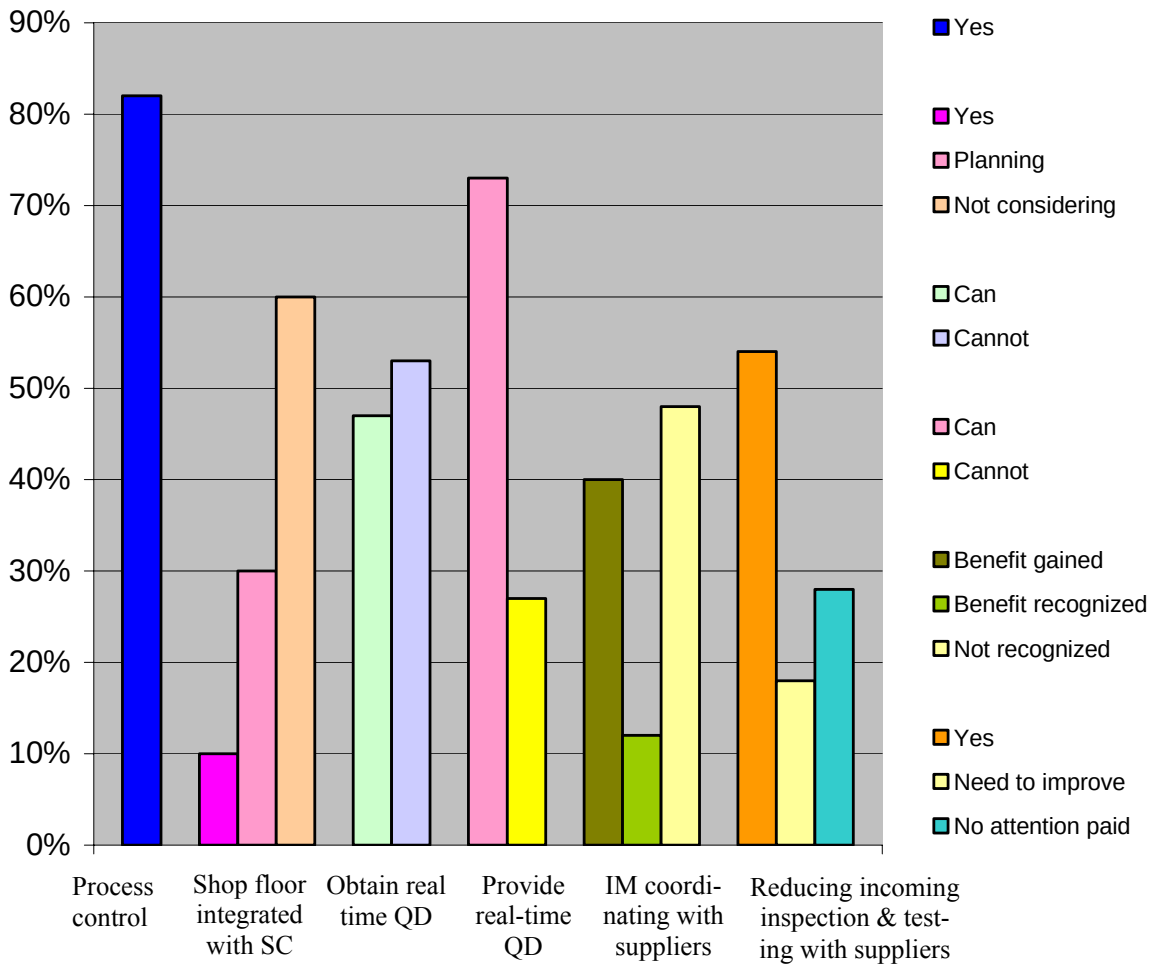


Figure 7-5 QM of production

Considering the aspect of a coordinated production schedule, around 55% of the companies coordinate well with their customers and suppliers to make up the schedule for their produc-

tion; about 25% of the companies are trying to do so. The other 20% of the companies found it very difficult and far away from practicality.

- Quality management of delivery

Most companies have a quality system to guarantee the delivery of a product in conformance. Most companies can realize delivery on time according to the customer's requirements.

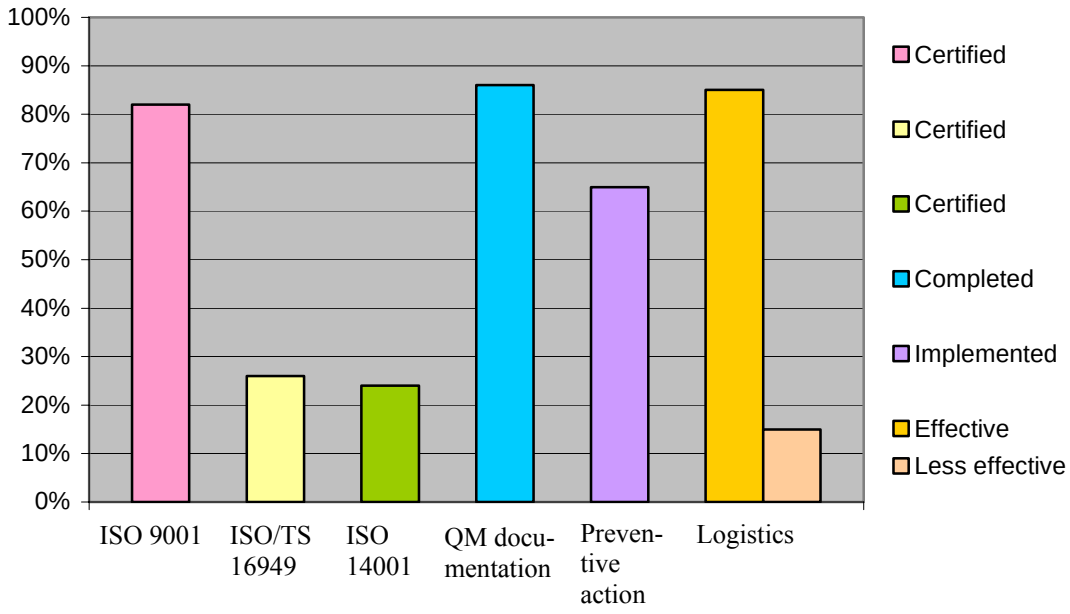


Figure 7-6 QM of delivery

Of the investigated companies, 82% of them have ISO 9001 certification, 26% of them have been certified with ISO/TS16949 and 24% are certified with ISO14001. 86% of the companies confirmed that they have a completely documented quality management system. 65% of the companies have implemented preventive and corrective action systems. One-third of the participants are sure that the quality requirements can be clearly transferred from the customer to their upstream suppliers, but the remaining participants expressed that it is still a difficult thing to do. 84% of the companies think they have effective logistics and can deliver their products on time according to their customer's requirements. Another 16% of the companies stated that they have nearly reached this goal. See Figure 7-6.

- Enable technology and platform

For information exchange between the supplier and customer, the channels used are still mostly the telephone, fax and couriers. Email (63%) is used more often by joint ventures or

in those companies which are purely owned by Western manufacturers. 18% of the companies use EDI, and also nearly 23% of the companies use an Internet-based information platform. 39% of the companies have implemented an MRPII or ERP system, but less then 5% of the companies have connected their ERP system with that of their suppliers and customers. 25% of the companies already started to implement ERP or thought about it. 71% of the companies do not plan to integrate themselves with their suppliers and customers through ERP.

7.1.2 General view of the survey

Through this survey an overview of Chinese manufacturers/suppliers demonstrated the following:

- The Chinese manufacturers in the automotive and machinery branches have paid more attention to quality management. They try to improve the operation quality of their MSCs by coordinating with their suppliers and customers. Quality management is going beyond one single company and extending to across the chain. An extended enterprise-oriented MSC management is becoming recognized by Chinese OEMs and system suppliers.
- Most companies have an in-house quality management system and have a relatively complete documentation of their quality management systems. Basic forms of quality management for the cross-company manufacturing supply chain are becoming a trend in the field of the automobile and machinery manufacturing industries in China.
- However, many companies have not yet established an operational mechanism. For example, the companies carrying out supplier auditing are not as many as the companies who have ISO 9001 certificates. Therefore, further effort is still needed in order to truly fulfill the quality requirement of ISO 9001.
- Chinese suppliers have excellent communication and coordination skills in dealing with their customers. But the quality tools and advanced IT application are still far away from the standards. Compared to the model, the controls and means of a systematic approach for application and support still have deficiencies in every aspect.

In §7.2 a concrete manufacturing supply chain will be analyzed and an improvement path will be drawn up.

7.2 Case study of a motorcycle manufacturing supply chain

7.2.1 Case description

Background of the chosen case

China is becoming the biggest motorcycle manufacturing country in the world. Half of all motorcycles worldwide are produced in China. In export markets Chinese motorcycle manufacturers have been rapidly gaining a share, especially in the emerging markets in Southeast Asia and Africa, but also in Europe. This is happening largely because the average export price of a Chinese motorcycle has dropped from $700 in the late 1990s - when it was already several hundred dollars less costly than the equivalent Japanese model - to below $200 now. Chinese companies have also grabbed market share from the Japanese competitors. For example, the market share of Honda Japan in Vietnam declined from nearly 90% to only 30% in five years since Chinese manufacturers began selling to this country [Hagel 2005].

The city of Chongqing is the capital city of motorcycle manufacturing in China. After 20 years of development, there are 109 motorcycle OEM enterprises, 52 engine manufacturers and more than 1000 components and parts suppliers in this area. It formed an industry with a production capability of 7 million motorcycles yearly and a turnover of about 2.8 billion Euro. Half of the motorcycles in China are manufactured in Chongqing [China 2005], and one fourth of the motorcycles in the world market come from this area. It has become one of the biggest motorcycle and component-manufacturing sites in China and in the world [Sina 2003].

In 2004, five of the six biggest motorcycle manufacturers in China were located in Chongqing. Since the mid-1990s the city of Chongqing with its 32 million residents has become home to a vibrant business ecosystem built around incremental innovation in motorcycle design and manufacturing [Hagel 2005].

However, behind this brilliant picture Chinese motorcycle manufacturers are facing the following serious challenges:

- An image of low quality that makes the products finally lack competency in the world market and face strong competition from global players
- Crude and heavy price competition that exists between the focal companies and their supply chains
- High production volume with many variants bringing with it difficulty in supply chain management
- Dynamic product life cycle that calls for rapid new product development

- Unfair commercial behavior that puts OEMs and their suppliers in a conflict relationship[17]
- Enhanced national legal regulations for motorcycle producers, which means higher requirements for the motorcycle production
- Tremendous raw material price rises since 2005

Under those conditions, in 2005 the number of OEM companies has decreased from 155 to 103. Some experts forecasted that by the end of 2006 there will be just about 20 to 30 OEMs who will be able to survive [Chen 2005]. The motorcycle industry has set a goal, i.e. changing motorcycle manufacturing from the style of "volume expansion to quality efficiency" [Invest 2004]. To survive and develop, OEMs need to establish a quality-oriented supply chain to compete with others.

In this research, one of the top motorcycles OEMs in Chongqing has been chosen and its manufacturing supply chain is viewed as the object of my case study.

The focal company (OEM)

The focal company, XXX Motorcycle Group, has been producing motorcycles since 1980. In 1994 it reached a place on the list of the 500 strongest companies in China. In 1998 it obtained the ISO 9001 certificate and was also certified for QS9000.

The company has built a complete sales and service network in China that covers 2400 towns and cities with more than 6000 sales offices as well as more than 3300 maintenance stations. The company reached a sales volume of 248 thousand motorcycles in the fist half-year of 2003 and 501 thousand in the first half-year of 2004. It has the highest growth rate with 76.41% yearly [Invest 2004]. In 2004 its total sales volume reached 1.09 million motorcycles and had the third best performance in the branch.

It has developed its product series with engine volumes from 35cc to 250cc, in total 12 kinds with more then 300 types of motorcycles. All of the manufactured motorcycles meet European environment standard EC2002/24 and reach the Chinese national exhaust standard or have even higher performance. The company has become a leading manufacturer in the motorcycle manufacturing industry [South 2005].

The focal firm has started to apply process control. According to the estimation of their staff, the company can reach a Dpmo of about 30,000 [18].

[17] In the area of Chongqing, there is an informal but unfair habit that focal firms do not pay their supplier according to the supply volume, but a carry-over payment, i.e. just pay a percentage after every delivery.
[18] All the Dpmo data were collected according to the managers' estimations of survey objects during the investigation. They were not verified again by the specified method.

First-tier suppliers

In the MSC there are more than 300 direct suppliers to the focal company. Due to time limitation, seven key system and component suppliers are chosen. The configuration of the key components of motorcycles is illustrated in Table 7-1.

Table 7-1 The first-tier key suppliers

Supplier Name	Supplier Code	Component	Dpmo	Amount of Sub-suppliers (Tier 2)
Jianshe motor Ltd	$T1_1$	Engine	30000	50-60
Zhineng Co.	$T1_2$	Body frame	20000	20-30
Huayu Co.	$T1_3$	Starting motor	6000	50-60
Jinlun Co.	$T1_4$	Oil tank	1200	4-5
Zhenhua Co.	$T1_5$	Brake	5000	20-30
Taikai Co.	$T1_6$	Carburetor	10000	20-30
Guangneng Co.	$T1_7$	Covering parts	60	2-3

Second-tier suppliers

There are a great number of sub-suppliers to the first-tier suppliers. After discussing with the first-tier suppliers, their important sub-suppliers were defined in Figure 7-7.

The core chain of the motorcycle MSC is mapped in Figure 7-7.

MSC quality performance evaluation

Because some Dpmo data could not be obtained from the second-tier suppliers, here just the consolidated Dpmo's of the focal firm and the first-tier are considered. They are assumed to have the same weighting.

$Dpmo_{consolidated}=30000*0.5+10322*0.5=20161$

Here a question popped up. The focal firm announced that the average delivery qualification rate is around 85%. But the Dpmo value is much better than that. Almost all of the key suppliers stated that their reject rate is around 1 to 2 percent. After discussion with the focal firm, the reasons can be:

1) These suppliers have better performance than average

Some of the key suppliers are working for the automobile industry. They have much better performance than the average.

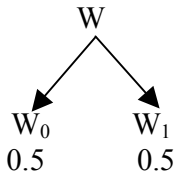
2) Different test standards

This occurred quite often, because some test requirements are different among the focal firm and its suppliers. Some components passed the testing in the supplier's factories, but could not pass the incoming test in the focal firm. On the another hand, the focal firm just rejects the components with serious problems; most substandard components or parts without functional problems are accepted by the focal firm at a lower price.

Quality management stage evaluation

Because the tier structure in the motorcycle industry is relatively simple, the entire quality management level depends on the focal firm and the first-tier suppliers and how they manage their manufacturing supply chains. Therefore, here the quality management level is reviewed based on the focal firm and its first-tier suppliers. Based on surveying and face-to-face interviews with the managing directors as well as the department leaders of Quality, Design, Outsourcing and Production in every partner, the evaluation value of the focal firm and the average value of tier 1 are shown in Table 7-2. The evaluation data of the tier 1 suppliers are shown in Appendix 3.

Assuming that the focal firm and tier 1 suppliers have the same influence on the whole chain's quality management system, weighting is set with:



The quality management level of the MSC is depicted in Table 7-2 with the total value of the chain.

Figure 7-7 The motorcycle MSC key supplier network

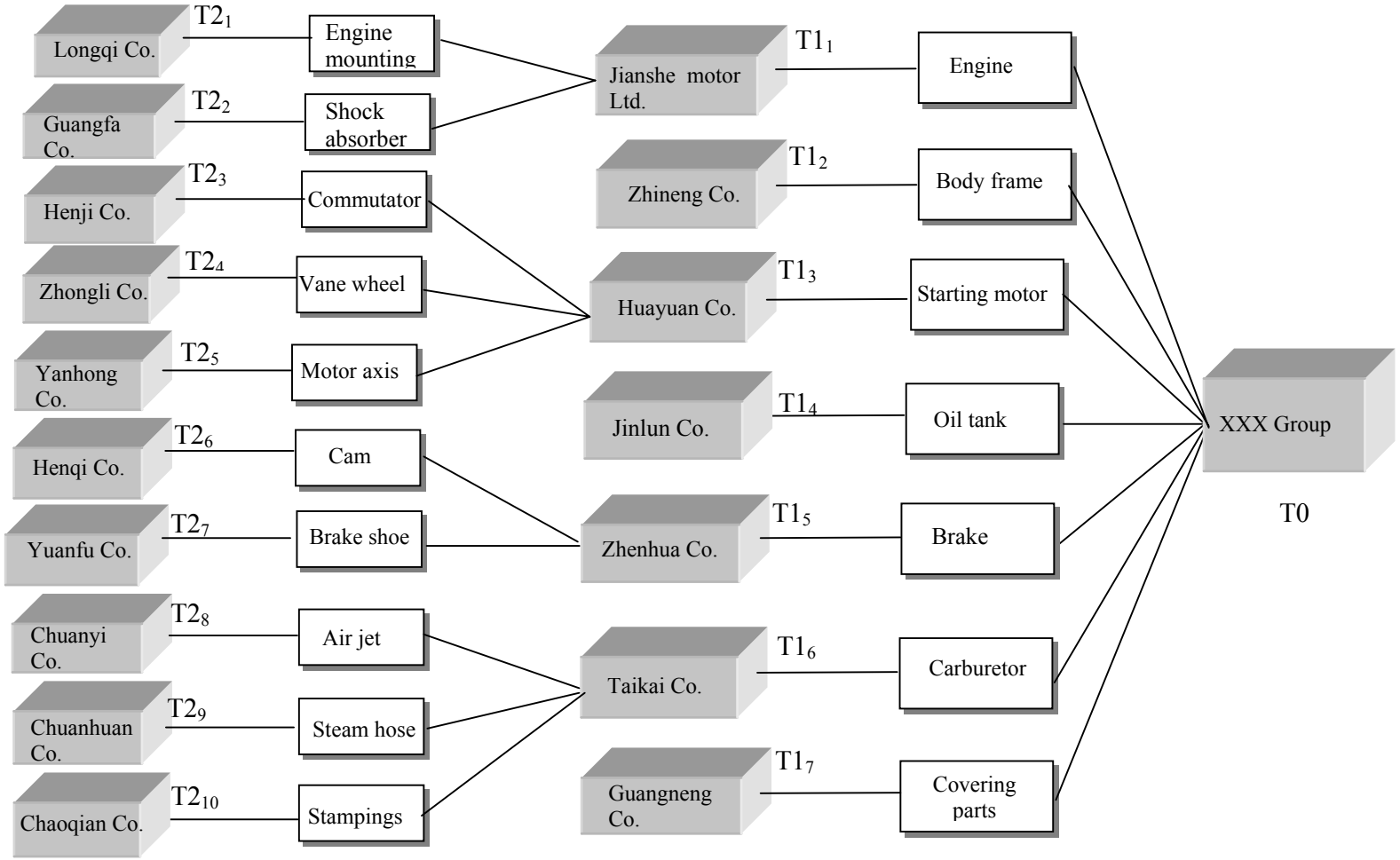


Table 7-2 The quality management capability in the core chain of the MSC

	Selective QM							Cooperative QM							Collaborative QM						
Criteria	Clear company quality management system	Supplier selection and evaluation system	Information exchange with suppliers/customers through certain channel	Responsible staff to deal with quality issues with suppliers/customers	Periodical audit of supplier performance	Quality requirements of customer can be transferred/received accurately	Products delivery based on agreed date	Supplier help to improve their quality management performance	Short lead-time by coordinating with suppliers and customers	Continuous effort to improve quality with main suppliers/customers	Has built long-term relationship with key suppliers	Suppliers and customers involved in product development and quality management	Sharing of quality data to reduce waste with suppliers and customers	Cross-company quality management activities with direct suppliers	Leading/participating multi-tier quality organization	Deployment of quality management process through up-stream supply chain part-	New product development collaboration & quality assurance with suppliers via	Full visibility of production quality data across supply chain	Dynamic inventory and WIP track in the chain	Collaborative planning, prediction and replenishment together with suppliers and c	Partners willingness to invest in new technology
V0	5	5	4	5	5	5	4	3	4	3	3	4	3	3	3	3	2	2	2	2	5
$\overline{V1}$	4.5	4.7	4.4	4.1	4.8	3.6	4.4	3.4	3.9	3.7	4.1	4	4	2.7	2.4	2.1	1.4	1.7	1.7	2	4.4
V	**4.8**	**4.9**	**4.2**	**4.6**	**4.8**	**4.3**	**4.2**	**3.2**	**4**	**3.4**	**3.6**	**4**	**3.5**	**2.8**	**2.7**	**2.6**	**1.7**	**1.8**	**1.8**	**2**	**4.7**

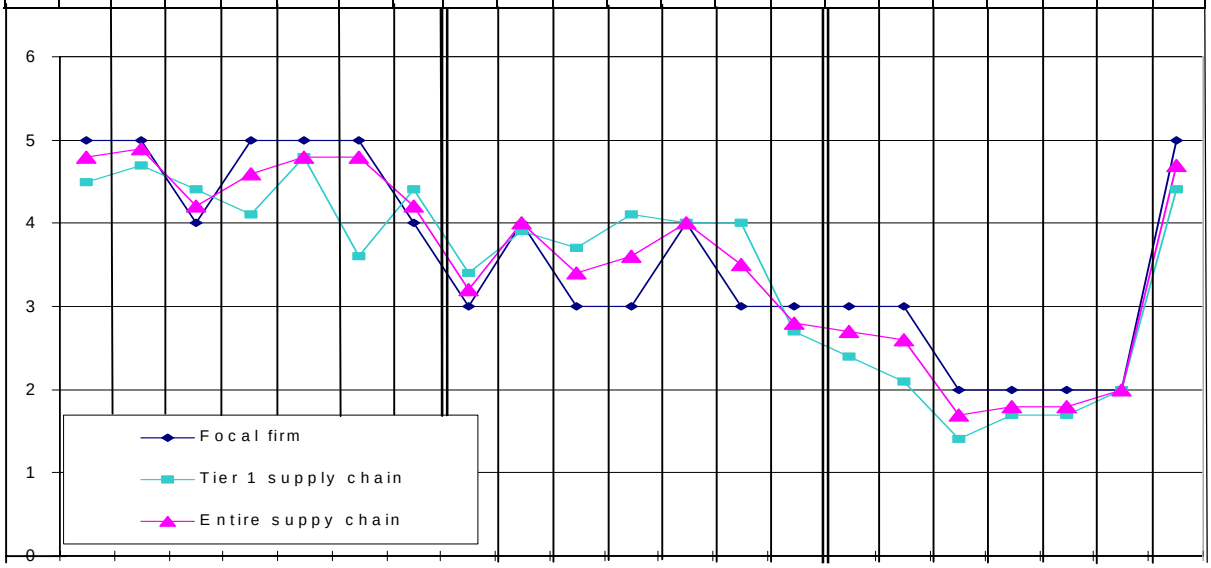


Table 7-2 shows that the MSC core chain has basically fulfilled the criteria of the selective quality management stage. From the OEM to its sub-suppliers most of them all hold a certified quality management system; at least ISO 9001. Most chain members have supplier evaluation systems and review their suppliers' performance periodically. Basically, they can deliver the system/components according to agreement with their customers on time. The MSC is still struggling in the stage of cooperative quality management. Under the aspects of helping suppliers to improve their quality management ability, long-term trust relationships and cross-company quality management actions are still at a lower level, even though product development cooperation and a continuous improvement concept have come into the chain. The partners in the chain have achieved very few of the criteria required by the concept of collaborative quality management. The most impressive point is that all the members in the chain are very confident that their partners are willing to invest in new technology with them.

Most of the partners in the chain have a quality basis and keep their chain moving. This evaluation chart showed that this particular motorcycle manufacturing supply chain with the key suppliers is on the way to the stage of co-operative quality management, even though some partners need to improve their abilities in the selective quality management phase, e.g. the customer's quality requirement transfer. To reach a collaborative quality management for the MSC there is still a long way to go.

7.2.2 Review of the MSC in comparison with the model

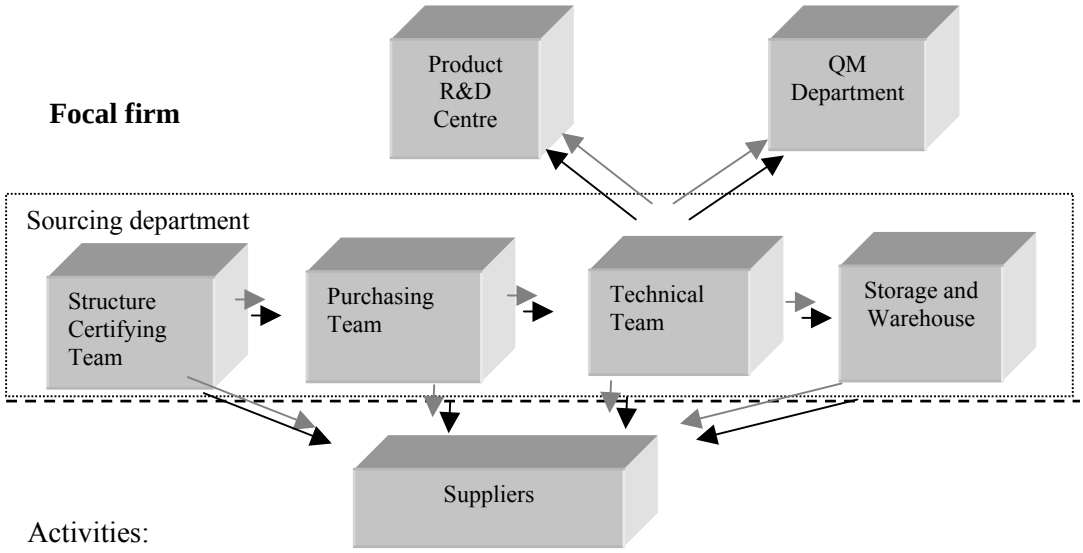
According to the quality model of the MSC, a review of the motorcycle manufacturing supply chain is carried out based on interviews with all of the key members in the chain as follows.

7.2.2.1 The MSC quality organization

Daily operation of the MSC is taken on by the sourcing department of the focal firm to implement quality control to its direct suppliers. Every direct supplier has his own team or personnel to manage his suppliers. The so-called "structure certifying team" is responsible for supplier selection and qualification. Figure 7-8 depicts the structure and its functions.

As the focal company emphasized, the organization goal is to decrease purchasing component cost in order to increase the product's competitive ability. Through much effort the focal firm reached big savings in outsourcing costs.

Almost every supplier sends 2 to 3 staff members to the focal firm in order to quickly communicate between the focal firm and their own company to solve problems occurring during assembly and thus provide better service. These staffs remain on site. This leads to better coordination and a more reliable relationship between the focal firm and its suppliers.



Activities:

Structure Certifying Team	Purchasing Team	Technical Team	Storage and Warehouse
Proof the qualification of suppliers; Optimize the supply system structure; Define the orders.	Purchasing: Body frame Engine Development Pursued the order	Communicate technical requirement; Transfer the improving requirement between suppliers and product development center and quality control division.	Purchased product monitoring and storage.

Figure 7-8 Organization structure and function

However, an organizational structure that is oriented on the entire manufacturing supply chain has not been established. The problems facing the MSC are as follows:

1) Lack of integrated core competence

As the manager in the focal firm stated, there is still a lack of the technical and quality management channels based on the suppliers' needs. Cooperation is just on a business level, even though the focal firm has a long-term relationships with many of its suppliers. But this relationship is still not on a strategic level.

2) Lack of the same understanding for quality

It was shown that there is a different quality awareness in some tier 2 suppliers. They complained that some quality requirements are not so necessary. But they admitted that when there are conflicts with their customers, they will change according to the customer's demands.

3) Unbalanced quality management capability in the chain

Even though there are key suppliers who also act as supplies for the automobile industry, many suppliers have a relatively low capability for quality. Sometimes the delivery qualification rate of tier 2 suppliers was just 50%-60%.

Because of the strong competition in the motorcycle industry, the focal firm already started arming "to build a world first class supply chain" [Yu 2005].

7.2.2.2 Cross-company quality planning and forecasting

The focal firm is making an effort to share information with its suppliers. It is implementing a computer network system to improve planning with its departments and suppliers more accurately and on time. Since 2005, the purchasing department has arranged for professional staff to be responsible for task decomposition, process control as well as planning adjustments in order to transfer the information more efficiently. The focal firm organizes a supplier conference for one day every year to announce its development strategy and also to award prizes to excellent suppliers. At its supplier conference in 2006, the focal firm strongly expressed that a world-class manufacturing supply chain is their most vital goal. However, joint strategic and systematic quality planning facing the entire chain have not come into action.

The focal firm signs a yearly contract with its suppliers, in which annual forecasting is given. In the manufacturing supply chain, the monthly forecast originates from the sales and export departments in the focal firm. It is a forecasting plan of the requirements for the next month. After confirmation by the development planning department and capability balance by the production department, the production plan with the variants and the production volume are decided. Then the focal firm provides suppliers with an order forecast for the next month as a reference to allow suppliers to plan and purchase material with lead-time. According to the order received by the sales department in the focal firm, a weekly order plan is generated. The suppliers receive the concrete delivery order weekly in several batches.

The order plan is generated according to the production plan with manual processing, and accurate inventory data is just available at the end of every month. The gap in this aspect is as follows:

1) An efficient forecasting system in the MSC is not in place

There is a big difference between the forecast and actual sales demands. The forecast hit rate[19] is about 50% to 60%. For example, in the first ten months in 2005 the gap between the forecasting plan and order production was more than 100 thousand motorcycles. This brings higher risk and an inventory/material shortage during production.

2) Repeated plan change cross-company

[19] The rate of order quantity vs. forecast quantity.

Normally, there are 30 to 40 types of motorcycles in production with 200 to 300 variants monthly. Because of lacks in the coordination plan for outsourcing products, the order plans to suppliers need to be changed quite often. This means much work for the focal firm and the suppliers, because they do not have an automated integrated system. All plan adjustments are done on paper and brought to the suppliers by staff[20] or per fax.

3) Supply capability is not ensured

Due to a lack of efficient forecasting, planning and replenishment with the sales network and suppliers, the outsourcing of material often becomes a bottleneck. The purchase order is issued seven days before production, but some required components are at a shortage when assembly starts up in the OEM plant. Very often, the material requirements for the focal firm assembly are just fulfilled by 80% to 90%.

7.2.2.3 Continuous improvement

Continuous improvement is a cultural approach to quality improvement. In the motorcycle MSC, the improvement activities are still limited inside every single company. The focal firm has paid high attention to continuously improving its product quality and customer satisfaction. The focal firm has implemented a program, the so called “Clever Star Sports Club”, to motivate all employees to contribute their suggestions with the goal of continuous cost reductions in the company. Since 2003, they have collected 30 thousand improvement suggestions from staff and workers, and more than 30% of them have been adopted. With this action, savings and new values have been generated by more than 5 million Euros.

Regarding the continuous improvement mechanism, an enforced strategy has been applied as the main force. The focal firm has implemented a QDM (quality, delivery and management) performance evaluation system together with on-site reviews to optimize suppliers. From Jan. to May 2005, by means of this approach 22 first-tier suppliers were deleted and 2 were added to the list. The focal firm also requires the suppliers to continue improvement. But the encourage strategy has not yet been adopted by the OEM in the chain. The joint effort to reduce waste in the chain by all the partners has not been placed into effect. The mechanism of continuous improvement, which was discussed in §4.3.2, has not been fully established in the manufacturing supply chain.

[20] In order to have quick response, almost all of the suppliers assign 2-3 staff members who stay in the focal firm all the time and are responsible for the information feedback between the focal firm and their own companies and deal with the noncomformance problem, material shortage etc.

7.2.2.4 Quality management for new product development

A wide range of variants and a small production batch is the trend in motorcycle manufacturing. 75 percent of the sales volume comes from new products in the focal firm. In 2004, it serviced the market with more than 40 new products or design-updated products. Therefore, new product development is crucial for the success of the focal firm as well as the whole manufacturing supply chain.

- New product development between the focal firm and tier 1 suppliers

Some key components were developed by the suppliers simultaneously with the focal firm. New product development cooperation between the focal firm and its suppliers follows the process in Figure 7-9 according to the supplier's explanation.

When the focal firm has decided about the key model of the product with specifying the general performance parameters, such as weight and size in rough design blueprints, it discusses with its supplier to make the design more detailed. The supplier will make an offer according to his experience. After that, the prototype data is defined, and the focal firm will sign a new product development and production agreement with its supplier, which includes price, technical requirements and the quality indicator. After the supplier has checked all the data, the prototype will be designed and made. The supplier is supposed to send the sample three times to the focal firm for proofing. Once it is confirmed by the R&D center of the focal firm, a confirmed document is signed and the supplier can get ready to prepare production.

This product development mode is very popular in the area of Chongqing. Design cooperation between focal firms and component suppliers is relatively early and close. Because in this case the focal firm is a leading company in the motorcycle industry, it takes more responsibility for component development in the design chain than other private final assemblers usually do. Two economists at Tokyo University studied the experience of Chongqing's motorcycle design-process networks in some depth. They documented a new approach to product development, which they describe as "localized modularization". They showed that with this architecture companies in a process network can deliver lower-cost components with satisfactory quality much more quickly than with conventional, top-down product design [Hagel 2005].

However, after the interview with some component suppliers, some background problems in the product design chain were found as follows:

1) Product life cycle research is backwards

Due to little product quality function research, some new products are far from the market requirements. In some cases just after one or two months of production, the life cycle of the new products comes to an end. This causes too much expense for production preparation and especially part making in the chain.

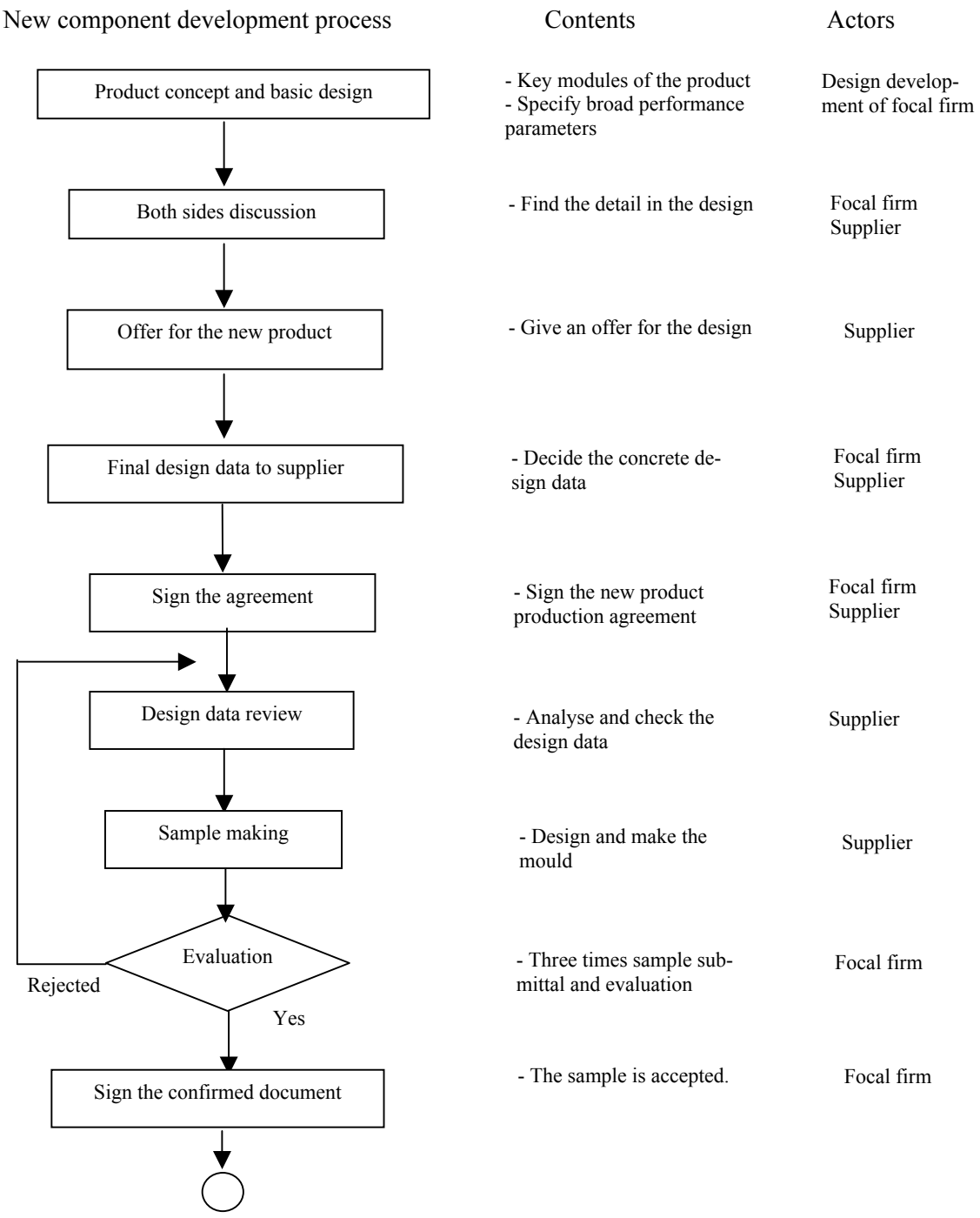


Figure 7-9 Development cooperation for a new component

2) Lack of design-process quality assurance

Design change is frequently in the chain. For example, the covering parts supplier complained that even after signing the design confirmation document, the focal firm's desire to change the design can last until the product is out of production, because the contract has

stated that the supplier must always make modifications according to the focal firm's requirements. This brings much higher costs and time expenditure. For example:

In Figure 7-10 there are three key components that all have an assembly relationship.

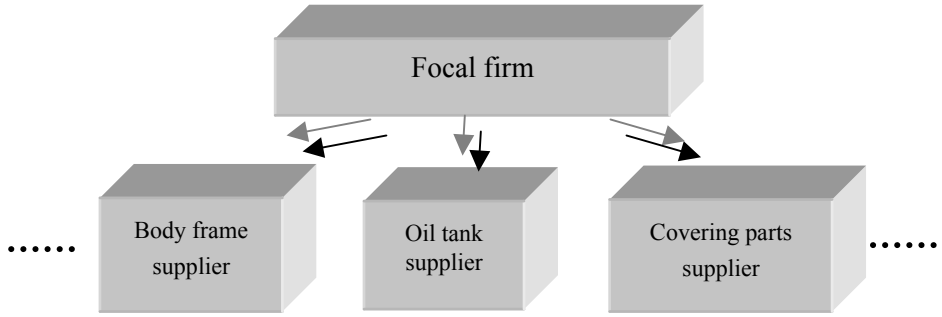


Figure 7-10 A part of the design chain

The focal firm works as an orchestrator in the chain. Sometimes, the final designed component, e.g. body frame or oil tank, does not fit to the completed design, or because of some mistake of the focal firm, the covering parts supplier is forced to change its design in order to make it possible for those components to fit together.

3) Incomplete design documentation

Product development cannot provide enough support for the production phase. During the design phase, production verification is a missing link. In the focal firm the production department criticized that the design change almost always accompanies the whole production life cycle. Change happens accidentally, just from one state to another, often without changing the record. This is even the case when a product has gotten into series production. However, due to a lack of related catalogue and drawing of the change, after a short period production is even unable to continue. And at the same time, the new part is not compatible with the old design. This causes tremendous problems for maintenance.

It also happened sometimes in the outsourcing process. The sample given to a supplier is different from its drawing. The supplier got confused and could not provide the right products.

- New product development between tier 1 and tier 2 suppliers

Most of the tier 2 suppliers have a quality certification. They provide components or parts to tier 1 companies with their own patent product or produce parts according to the customer's design documents, for example drawings.

When tier 2 suppliers provide products with their own patent, the product definition process between both sides is as follows:

Reach a technical agreement → sign the production contract → provide technical documents → make a sample → test sample and confirm → prepare batch production.

When a tier 2 supplier obtains an assignment, which is a finished design from its customer, the process between both sides is as follows:

Review the design → check design on computer → confirm change → make sample → confirm sample → prepare batch production.

Through those processes, the product design requirements are basically transferred between both sides. In the product design chain, even though the cooperation between partners takes place at a relatively early stage, from the focal firm to its suppliers, quality control for the product development process is still far away. The product R&D center in the focal firm is making efforts to set up a design process management (emphasis on task decomposition) and project management. But the advanced methods of quality control for the new product process have not been truly applied.

In the MSC, some key component suppliers also work as suppliers for the automobile industry. They have even more experience in applying the quality management approach in the product development process. Due to the lack of efficient collaboration, those advantages have not been taken on by this MSC. Because there is no clear demand from the focal firm to tier 1 suppliers about product development quality control, not much attention is paid to it. Some suppliers expressed that it is difficult to communicate without a common design quality platform.

Tier 2 suppliers work on a relatively clear task with less design initiative; some of them think that it is not so necessary to apply quality management tools for their jobs.

In this MSC the product development quality control for every level is not in place. In an MSC, the design chains are connected to each other with integration of the suppliers. Therefore, a collaborative design platform will be very helpful for design cooperation especially between the focal firm and tier 1 suppliers.

7.2.2.5 Quality management for outsourcing

Outsourcing quality management has gained much attention in the entire chain.

- Outsourcing quality management between the focal firm and tier 1 suppliers

The outsourcing department in the focal firm set up a complete supplier quality management system. The focal firm purchases 92 kinds of components from 200-300 suppliers and has nearly 30 key component suppliers. For every component and part there are three kinds of suppliers: main supplier, secondary supplier and candidate supplier. The supplier quality proofing process in the focal firm is illustrated in Figure 7-11 with four phases of supplier selection, supplier evaluation, batch testing and normal supplier management.

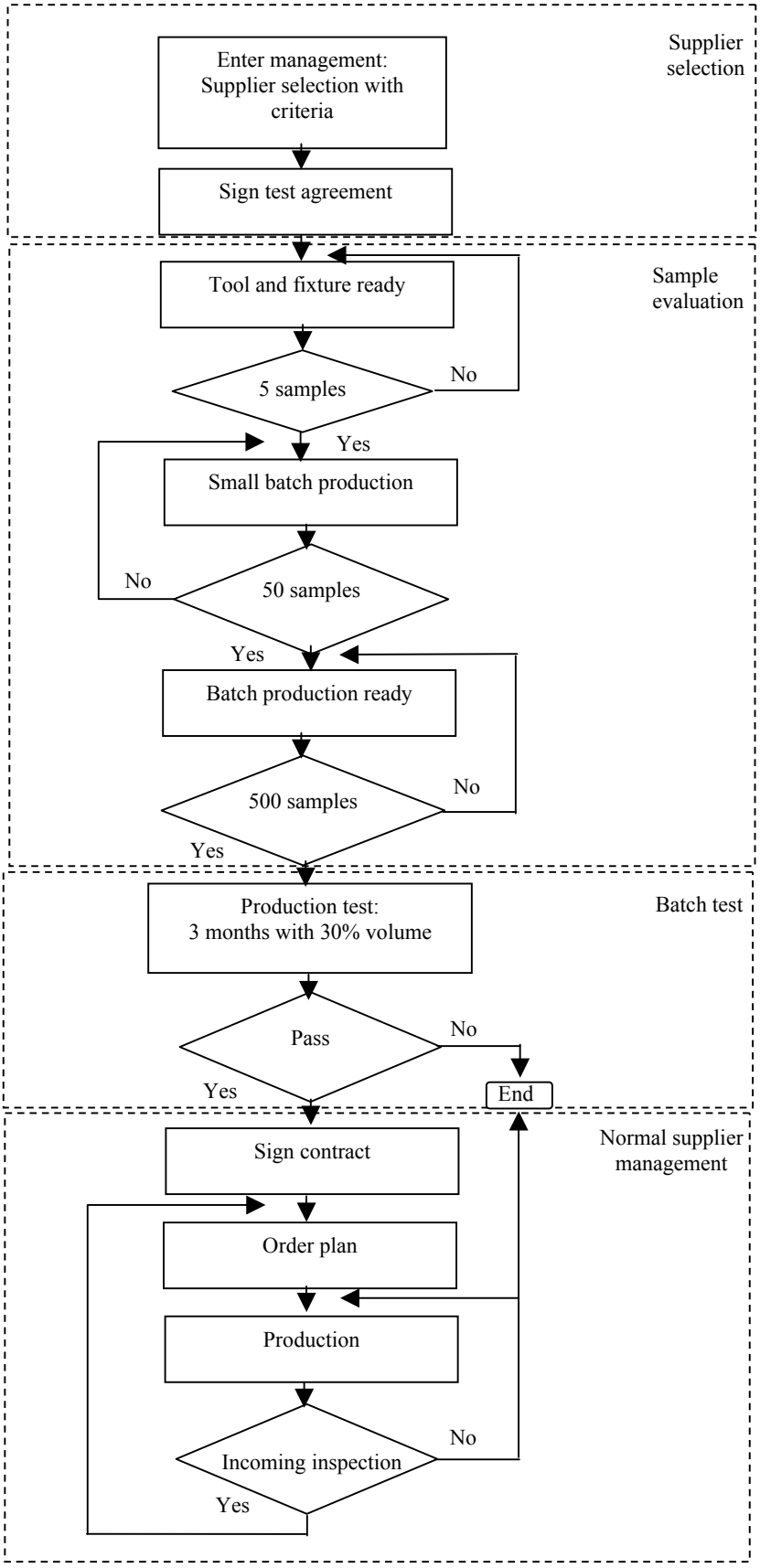


Figure 7-11 Supplier quality proofing process

Supplier selection

In this process the supplier selection criteria are defined with an evaluation system for technical ability, quality certification, financial status, cost, position in its branch, series production capability, delivery condition, business concentration degree, etc. By evaluating and on-site review, a gateway for suppliers with good potential to enter this manufacturing supply chain is opened. It implements a so-called "three 5-evaluation system for sample testing". When the tools and fixture tools are ready, the focal firm tests 5 sample products. When the supplier starts to produce in small batches, it requires 50 samples to test. When all the production is ready, 500 samples must be tested by the focal firm. When suppliers also pass the three-month batch production test (within 30% of total required volume), the supplier gets into the normal supplier management process.

Supplier audit

The focal firm reviews suppliers for aspects of quality, delivery, cost, service and product development, periodically. It has built a dynamic indicator system to evaluate the suppliers' performance, which includes a plan executing rate, e.g. order fulfillment, daily schedule fulfillment, assembly fit and after service, etc. By evaluation and analysis every quarter year, the last ten suppliers with bad performance will receive warnings and are expected to give details about corrective measures. The focal firm stated that the performance of suppliers has been improving every month since this action has been initiated. For a high-volume production type, it is planned that the acceptable process of key suppliers should reach $C_{Pk}>1$ or 1.33 starting in March 2006.

Supplier quality improvement

The focal firm has organized its financial staff and engineers to help suppliers with higher cost and unstable quality to improve their processes. They also hold quality improvement meetings with suppliers to analyze and discuss the issues, look for solutions and define the implementation process. The focal firm started the first training programs months ago for its suppliers for computer applications. However, there is no strategic supplier development program. The activities are occasional. Some suppliers still commented that the focal firm concentrates on checking but has not provided qualified professionals to help the supplier to improve.

The focal firm has basically established long-term relationships with its key suppliers. However, because of the payment arguments[21], the strategic trust relationship has not been widely established. Some tier 1 suppliers expressed that there are much higher quality demands for supplying in the automobile industry, but they prefer that, since the automobile industry has a very fair payment policy. Another point tier 1 suppliers complained about was that the fo-

[21] See the footnote 16.

cal firm has too much authority. Some ideas are possibly damaging to the product quality of the supplier, but they are forced to carry them out.

- The outsourcing quality management within sub-tier suppliers

The sub-tier suppliers are middle-size or small-size suppliers. Most of them do not own a well-documented supplier quality management manual. However, from the interview it was noticed that some of them have clear quality requirements to their suppliers, even for raw material suppliers. The relationship between supplier and customer is more dynamic and project-oriented. For some production orders, the customers do second party auditing and even send their engineers to suppliers in order to ensure the process and quality requirements. However, the quality management capability is not balanced. The rejection rate of some tier 2 suppliers sometime was 40-50%.

Above, outsourcing quality management has been established in the chain. It goes from a check-oriented system to preventive action-oriented management. It is the basis of a big-scale motorcycle production operation.

7.2.2.6 Quality management for production

- Production management

The production management of the focal firm is still based on a manual plan and is scheduled with the help of computer aided production planning. The information integration within the company has not been implemented. Some key suppliers that also serve the automobile industry are planning to build their Enterprises Resource Planning (ERP) systems, but are still in the feasibility phase. Therefore, a coordinative production planning between partners in the chain has not taken place. Factory floor integration with supply chain management is far from the reality.

- Production quality assurance

Inspection and checking is still the main measure in production quality control. The focal firm is starting to apply process control with experimentation in some type of product with the goal of Cpk: 1 to 1.3.

Some tier 1 key suppliers, who also work as automobile suppliers, have applied process control. For example, the covering part supplier has reached zero defects (ppm=0) since two months in Oct. 2005 for automobile component supply.

Tier 2 suppliers control their production quality by sample testing (e.g. 100 to 200 pieces per batch) for normal products and 100% testing for important parts. According to the customer's drawing tolerance, they set up a process tolerance, which is tighter, and try to control the production inside of it.

The production quality management is still on a very low level. The component non-conformance rate is up to 5-10%. Some key suppliers set the goal at about 1500-2000 PPM. Most suppliers still have a lack of knowledge to apply SPC. In-time production quality information in the chain is not available. Joint reductions of waste, e.g. inventory and incoming inspection, and production flexibility have not been paid attention to in this MSC.

7.2.2.7 Quality management for delivery

In the MSC more than 95% of tier 1 suppliers have been certified by ISO 9001. The focal firm and most of the key suppliers have QS 9000 and other quality certificates. The basic quality management systems in house have been established. However, advanced quality management approaches have not been widely applied by every partner.

The suppliers sign yearly supply contracts with the focal firm. They receive monthly delivery plans. Every week they get a week's delivery plan that can be adjusted by the focal firm. Most suppliers stated that they could deliver their products by the customer's required date with 2 to 3 days lead-time.

Because most of the suppliers are located in this area, logistics is quite well organized. The MSC is trying to reduce waste in the chain. After being certified by the focal firm, some parts of motorcycle engines can be delivered directly to the assembly line. This reduces intermediate storage, ensures short transportation route and improves just-in-time delivery.

7.2.2.8 Enable technology and platform

Since 2003, the focal firm has started to build an E-business platform together with several other focal firms in the area of Chongqing. The purpose is to connect the up-stream and down-stream supply chain, in order to enhance the motorcycle competence in this area. The platform is still under construction but will provide an efficient enable infrastrcture for resource sharing and collaborative development with suppliers.

An overview of the gap compared to the ideal model is summarized in Table 7-3.

Above, compared to the ideal model of quality management, it is shown that the entire manufacturing supply chain is relatively mature on the function side of quality management for outsourcing and delivery. Quality management for production has been paid much attention to, even though it is still on a very much lower level. An IT enable platform has been implemented, and it will bring basic support for the whole chain. Especially weak aspects are to be found in the quality management for design and basic management process, i.e. overall chain quality organization, cross-company quality planning and forecasting as well as continuous improvement, as depicted in Figure 7-12.

Table 7-3 The gap between ideal model and reality in the motorcycle MSC

	Processes	Fulfilled aspect	Gap
Management layer	Quality organization	Basic organization structure to direct suppliers	E. E. oriented quality organization Chain manager skill
	Cross-company planning and forecasting	Basic communication between partners	Cross-company quality planning Inaccurate forecasting Repeated planning changes
	Continuous improvement	Inside of the focal firm Requirements to suppliers	Without effective motivation mechanism Lack of participation of partners
Operational layer	QM for outsourcing	Well defined supplier selection/evaluation system	Without systematic supplier quality development Lack of info/knowledge transfer to suppliers
	QM for design	Suppliers involved in early stage	Without development quality process control Lack of knowledge sharing
	QM for production	Started to apply SPC in the chain partners Tie coordination between suppliers and customers	No production information integration Quality control at low level Much inspection and repeated work
	QM for delivery	Basically delivery on time	JIT delivery rate low
Support layer	Enable IT	Manuel info exchange Started to build E-business platform	Quality information system integration

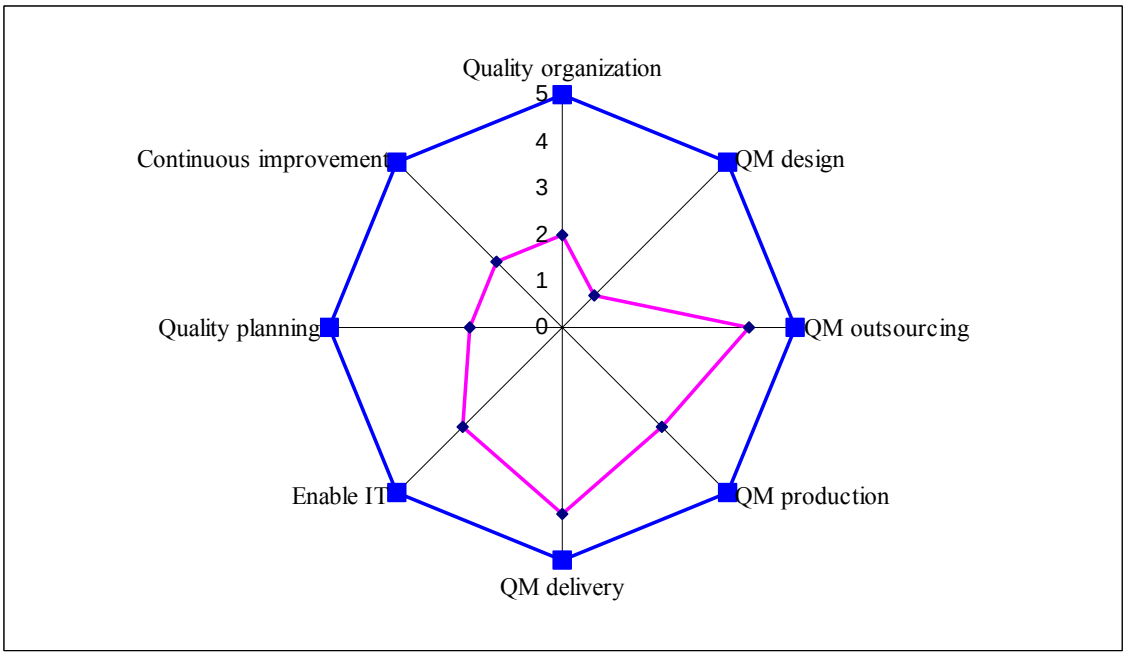


Figure 7-12 The gap between the chain and the ideal model

7.2.3 Road map for MSC quality improvement

In order to survive and develop in the highly competitive motorcycle market, the focal firm has recognized the importance of the supply chain. The focal firm has proposed a purchasing strategy that aims at building a world first class supply chain.

To reach this goal, it is essential to form a high quality manufacturing supply chain from the viewpoint of an extended enterprise, i.e. not just considering purchasing and delivery, but also quality improvement in new product development and the production chain; not only thinking about quality management of the direct suppliers, but also of the entire chain.

It requires every partner's participation to improve the quality standard of the motorcycle manufacturing supply chain, however, the focal firm must take the leadership, establish a strategy and carry it out by promoting it to every tier supplier in the entire chain.

The strategic intent is presented in two aspects:

- To form a lean MSC with strategic partners (key suppliers in different tiers) in order to transfer the quality requirements and
- At the same time, to establish an extended enterprise culture in the entire chain to adopt all the synergy.

The goal of the MSC:

Zero defects, no fault (Quality), low inventory and 100% delivery on time (Delivery) and increase productivity and decrease total cost in all fields.

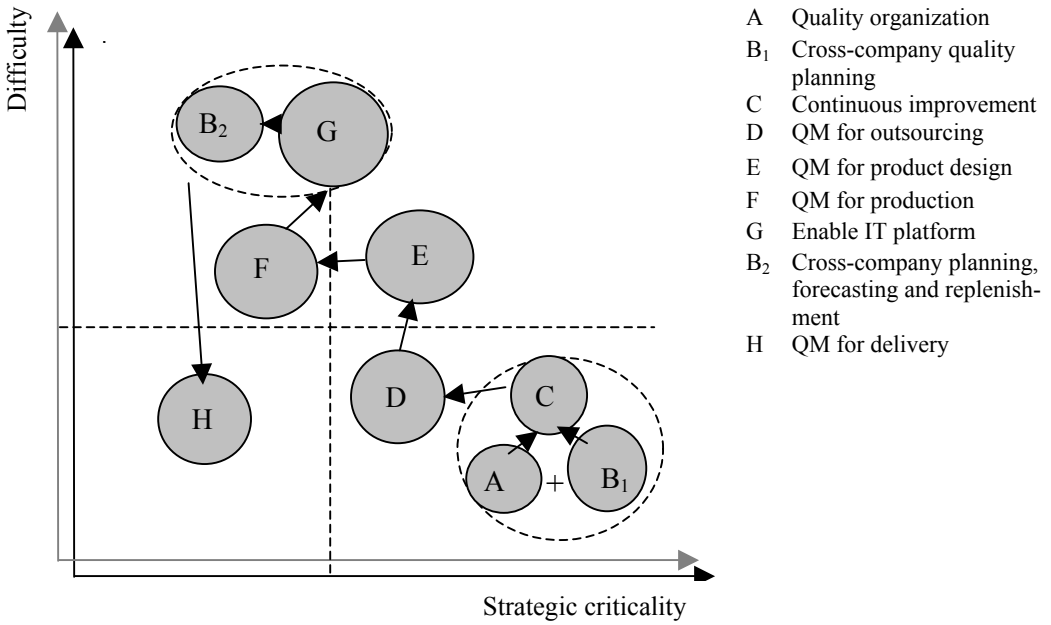


Figure 7-13 Improvement aspects and strategic relationship

It is necessary to draw up a road map for improvement and implementation. In Figure 7-13 the relationship between strategic urgency (contribution) and the difficulty degree of implementation (technology available, involved investment) for MSC quality management is analyzed. The diameter means the amount of the required effort or resource.

From the analysis above, the improvement process is recommended in Figure 7-13.

The first step: Establish a quality organization and quality planning structure as well as continuous improvement mechanism in the entire chain.

Quality consciousness must be enhanced in the MSC from top managers of the partners to the executive units. To form the core competence in the MSC, all the partners should participate. A three level quality organization and related quality planning structure should be established in the MSC.

Top level - Chain advisory board

The top managers of the partner company normally meet once a year at the supplier conference. There is not much communication among the top managers of the chain. The top managers are only involved when some serious problem occurred. To change the quality problem solving to prevention, a council like a chain advisory board will be helpful to lead the quality initiative in the MSC. The top managers of every partner in the chain should be invited as members of the chain advisory board in order to:

- Give a feeling of belonging for partners in the MSC
- Plan the further development of the MSC and set a quality improvement goal
- Promote the improvement initiatives in the chain
- Communicate the quality requirements and transfer to suppliers' own supply chain

Executive level - Chain quality team

A chain quality team should be formed on the basis of cooperation between the focal firm and its suppliers as well as sub-key suppliers. The basic form in Figure 4-3 and related personnel have already existed. However, the working style should be changed from audit-oriented to total quality improvement-oriented. The chain quality team should be active in the following aspects.

- Organize and map the entire MSC
- Make and act on joint plans, observe the quality improvement goal
- Coordinate the improvement activities and different competences in the chain
- Evaluate performance with targets and lead actions to correct and improve performance

- Transfer quality and other requirements from the focal firm to the participating companies

Button level - Quality team in chain member

The investigation found that all the partners in the MSC have their quality team or staff in quality control. However, there is a big difference in the quality management capability of the different partners. Training for quality management approaches, e.g. SPC, APQP, are necessary for most of the suppliers. This should be planned into the supplier development program, which will be discussed in the next step of the supplier development.

With these three level quality organizations and related quality planning for the entire chain, the quality management base in the MSC is formed. To make this quality organization function properly, the personnel, so-called supply chain managers, should be qualified.

Supply chain manager qualification

The supply chain managers should be trained and motivated in the following fields:

- Loyalty to the job
- Supply chain and quality management knowledge
- Communication skills

In the quality organization, the continuous improvement in the entire chain should be introduced.

Establishment of a continuous improvement mechanism in the entire chain

The continuous improvement mechanism should be built in and transferred to lower tier suppliers through the three levels of the quality organization. The focal firm should take into account:

1) Every partner in the chain is an equal link that can contribute to the performance of the chain. No matter how big or small, they should be treated with respect.

2) There must be a stimulation for continuous improvement regarding system cost, quality, and cycle times. These encouragement measures should be announced and adopted at every chain level. This can be done in the following way:

- The performance improvement result is distributed online or in the newsletter to form an atmosphere for continuous improvement.
- The profit that is made from this improvement should be shared between the focal firm (customer) and its suppliers. The focal firm or customers should transfer back a certain percentage of the profit to the suppliers and give them more orders as an encouragement policy.

The focal firm must take the initiative to build an extended enterprise oriented MSC integration foundation, which can then pass the quality requirements from the top tier to the upstream tier suppliers.

The second step: Add supplier development to outsourcing quality management

The focal firm has developed an efficient and complete supplier selection and evaluation strategy. But in order to strengthen the competence of the MSC, it is essential for the focal firm to set up a supplier development strategy and require its suppliers to transfer this procedure and method to the whole supply chain, making them become the best suppliers in their branches [Bosch 2005].

To implement supplier development, there are several basic processes that must be complemented first by the focal firm.

Define the key business processes and required elements

It is helpful to motivate the suppliers to develop towards a clearly defined goal with ideal conditions and principles. According to many leading focal firms' practices, a common understanding for the key business should be defined, so that the suppliers are aware of all the steps of the processes and know which organization unit is involved as well as when it should be done. This provides a basis for all the partners to work together as well as for the signal supplier to struggle for its success by improving its process quality within this frame. The key business processes were discussed in Chapter Four, including:

- Product development process
- Outsourcing process
- Production process
- Delivery process
- As well as the quality management inside of a company, controlling, sales processing and personnel management, etc.

Corresponding principles and methods should be provided, and a basic ideal picture should be drawn up for every process, which include the basic requirements and elements. Here all the aspects should be defined in a supplier development manual to be shared by all the partners.

Set up the supplier development program

In this motorcycle MSC, the quality management capability is different from the suppliers as discussed in §7.2.2. Some suppliers who also deliver components to car manufacturers have reached a higher standard, but most suppliers are still on a low level. Therefore, the suppliers should be differentiated with a supplier development program according to their perform-

ance. The suppliers can be classified in four levels as in Table 7-4, referring to some leading company's practice.

Table 7-4 Different levels of suppliers [Bosch 2005]

Supplier level	Criteria	Development strategy
1:	The supplier has no or just very few points matching the required elements.	Supplier development project
2:	The supplier has matched the required elements in one process successfully.	Training program
3:	The supplier has implemented the required elements in several processes successfully.	Working cycle
4:	The supplier has implemented the required elements in his company successfully and is able to transfer the required elements to sub-suppliers.	Independent development

For the first level suppliers: It involves a total process improvement. The supplier development team must review its AS-IS status by process analysis, and then set the improvement goal/TO-BE status and action plan for it. By working together closely with the suppliers or even taking over the leadership to carry out the improvement process, the suppliers will be trained practically and theoretically to reach level 2.

For the second level suppliers: They need to transfer the basic experience that was learned in the level 1 development to other fields. Therefore, they should be trained in the knowledge and methods intensively in order to help them to apply preferred products, production lines and processes.

For the third level suppliers: They have successful experience in several processes. An efficient way for them is to participate in a working group. In the working group, several suppliers on this level are invited to exchange ideas, search for further improvement paths and establish their own supply network in order to move to the fourth level.

For the fourth level suppliers: They have the capability to develop further and transfer the required elements to their suppliers. They are also valuable to function as tutors in the supplier development program for other suppliers.

The third step: Apply product development quality management in the focal firm and tier suppliers

Quality management in product development is a bottleneck in the entire chain. At the moment, the focal firm is working on building a process management for product development in order to define the product development phase and related work. To improve the situation that has been discussed in §7.2.2.4, a quality management system and mechanism of a supply chain based on concurrent product development processes must be established from the focal firm to the component suppliers. Based on the AS-IS status, the following measures should be applied.

Apply APQP to the entire chain suppliers

APQP is a systematic quality model, and it integrates all the necessary tools for the product development process. It transfers the customer requirements accurately through the whole process from product development to production, even as far as after sales service.

To apply APQP, there are some features that should be noticed.

- The focal firm is still lacking knowledge and experience.
- Some first-tier suppliers who work as component suppliers for the automobile industry have accumulated experience for applying APQP, etc. methods.
- Most suppliers have little consciousness for product development quality control.

Implementing APQP in the design chain, especially in the focal firm and first-tier suppliers, can follow the process as below.

- **General training for top managers**

Some top managers of the suppliers have very poor education. They are more concentrated on production and have little knowledge about the quality of the product development. By introducing the basic knowledge and quality planning frame, they will be provided with a new view and motivation to promote the approach in their companies and suppliers.

- **Training design quality methods to the staff**

Intensive training should be provided for them with four phases of product definition and planning, product design and development, process design and development as well as product and process verification.

For the sub-tier suppliers, the training of general design quality methods should be offered. For example:

- Quality Function Deployment (QFD)
- Failure Mode and Effects Analysis (FMEA)
- Fault-Tree Analysis

- Design of Experiment (DOE)
- Design for Manufacturing (DFM)
- Design for Assembly (DFA)
- Robust Design, etc.

- **Demonstration of application at leading suppliers'**

The leading suppliers who also work for the automobile industry have applied APQP in their companies. During the interview, they expressed that they are often confused by the product development process and are willing to help build a "good process". With the assistance of the leading suppliers, this demonstration will promote the application of this method in the chain.

Set up clear requirements for product development

Even though the focal firm and many suppliers have ISO 9001 or ISO/TS16949 certificates, without clear definitions the requirements of those standards have not been carried out in the design chain. A development quality control process is essential for the partners to have common communication and a working platform. The project phases and milestones should be defined such that every phase can be checked with technical, economic and time limitation. It also requires that the supplier sets up the same process and transfers the requirement to its sub-suppliers. This process control is depicted in Figure 7-14 [Bosch 2005].

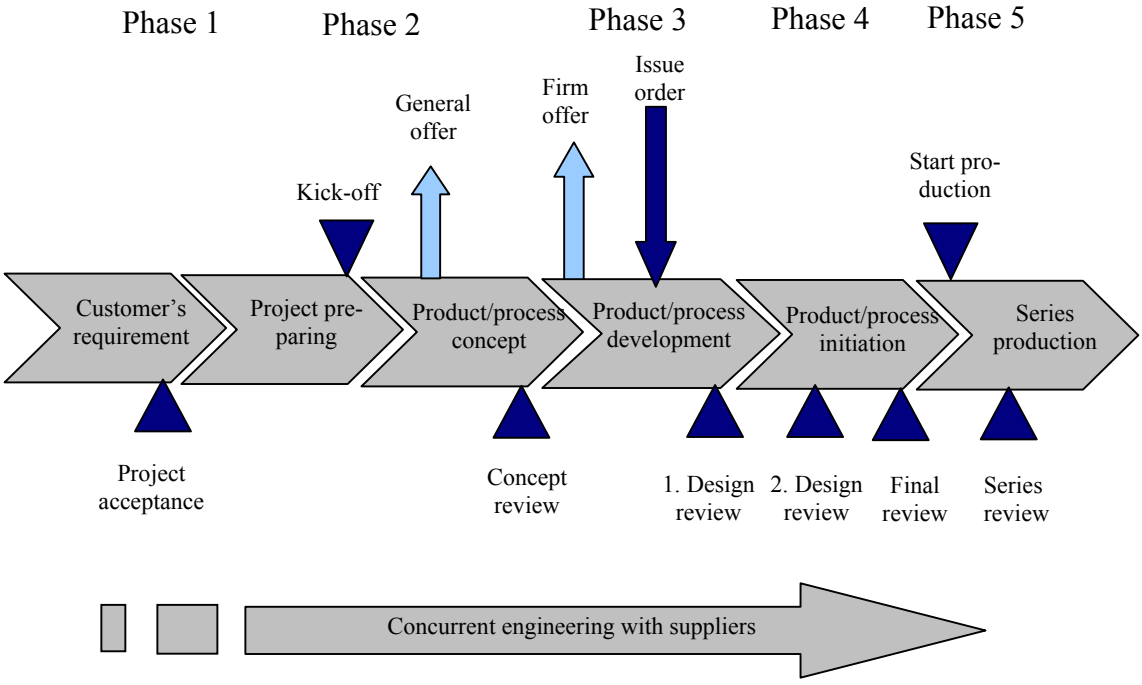


Figure 7-14 Development process control

Change the working culture - strictly follow the control process

APQP and QFD, etc. provide the methods to transfer the customer's voice to product design requirements. However, the motorcycle industry has developed rapidly in China and many products have been produced by copying existing products. It happened that the decision maker decided on the new product without much research of customer desires. The result is that the new product comes to the market quickly to only leave the market within a short period of life cycle time.

At present, the focal firm has set up a rough product development cooperation process with its suppliers (shown in Figure 7-8), and it is supposed to sign the confirmed document before the supplier starts production. However, sometimes the process was ignored until problems occurred. This working style must be changed, and the product development process should be carefully followed.

Move to collaborative design

The focal firm is building a design knowledge sharing system in order to provide design experience for design staff and suppliers. When the E-business platform is up and running (it is under construction), a Web quality forum should be set up to allow the designers on different levels to communicate. By installing the support software, e.g. Netmeeting and Outlook, etc., collaborative design will improve along with design cooperation and quality [Ma 2003].

The fourth step: Enhance process control capability and production quality management in the chain

Clear up the quality goal for the MSC

All suppliers should aim at achieving the "0-defect quality" standard in the foreseeable future. The concept of supply with 0 PPM and production with zero error should become the quality standard in the entire chain. 95% of the first-tier suppliers are certified with ISO 9001 or ISO/TS 16949; this is a basis for quality consciousness. It is essential for the focal firm and for the suppliers to recognize that inspection does not belong to the production process, but it is just the last firewall to protect the customer from quality damage. Process control should be brought into effect at every partner in the chain and should be transferred to every partner's staff through TQM.

Enhance process control capability

The focal firm has started to define process capability-Cpk since 2005, and the process has been improved in certain products. To expand the application experience and improve MSC production quality management, several measures should be taken:

- Define PPM figures for a time period

Set up an improvement milestone for the suppliers, e.g. reach the Cpk=1.33 in 12 months. This gives the suppliers a clear achievement goal to work on. The method used at the moment, i.e. ranking the suppliers every month and then getting rid of suppliers in the last positions, is not efficient for improving the quality capability of the MSC.

- Recommend techniques and tools

It should be required that SPC technical methods are used. For example, control charts and capability studies, quality analysis (causes of nonconformity, etc.) should be built into the supplier's routing quality management.

The application of statistical process control technology in China lags behind Western countries. The first SPC software was developed in 1995. Small suppliers are afraid of the complex mathematic calculations. It will be helpful if the focal firm recommends the proper system and organizes the application experience exchange in the chain.

- Emphasize the documentation requirements

Even though documentation is a basic requirement in ISO 9001, it is still not executed in the focal firm as well as at many suppliers. The causes of non-conformities should be determined, and the results must be documented during the whole production process and in the form of customer complaints analysis. With sufficiently large quantities of data having been analyzed, important conclusions can be drawn with regard to process improvement.

A training program is necessary to offer to the suppliers, and a knowledge and experience exchange between the leading suppliers and other partners in the chain should be included.

Reduction of non-value-added work

There is much inspection and repackaging work that can be reduced. For example, the brake supplier packs its products in cardboard boxes with his company insignia. In the focal firm all the products are unpacked and re-inspected. It would be more efficient to design a new container for the brakes. By supervising process control and with a long-term trust relationship, incoming inspections can be reduced. There are many similar cases that could be improved in the chain.

Implement MRPII/ERP system with alliance

The implementation of ERP systems during the 1990s has been very significant and has had a big impact on integrating the business processes across different areas, like engineering, finance, human resources as well as project management within a company. The focal firm and the partners in the MSC are considering the implementation of MRPII/ERP. A strategic planning and system selection with a view towards entire chain development will bring immense advantages for further integration of the ERP with the supply chain management among the partners. For example, selecting the same ERP system vendor will make integra-

tion among supply chain partners much easier. This in turn will provide cost saving for planning and implementing for every partner and greatly decrease the difficulty and expense for the supply chain. In the Chinese supply chain, the backward situation in implementing ERP system can become an advantage to reaching a high level of supply chain integration in a favorable and simple way.

The fifth step: Complete the B2B platform and implement collaborative planning, forecasting and replenishment

The E-business platform is under construction. Once it is ready and the up-stream suppliers and down-stream customers (including the more than 6000 retailers in 2400 cities and towns all over China) can be connected together, the CPFR should be considered being implemented in the chain. It will combine the intelligence of multiple trading partners in planning and fulfillment of the customer demands. It brings tremendous benefit for the entire chain regarding forecasting and planning, but also with inevitable challenges.

A pilot project should be initiated with preferred key suppliers based on the implementation of the steps mentioned above when these prerequisites are fulfilled [Lake 2000]:

Trust relationship: The partners have built long-term and multi-trust relationships with the focal firm and have aligned business objectives.

Collaborative organizational culture: The top-level executives should release company information from their direct control, and the members of all levels should be aware of the requirements that CPFR needs management's commitment.

Matched processes: The business processes of each partner must be changed in order to match and support CPFR implementation. The partners must define, understand, document and abide by agreed inter-company processes.

Training: Employees in the member companies should be trained in new technology and processes that accompany CPFR.

The pilot project can determine the feasibility of CPFR as a scalable practice. Through it, the changes that affect the people, processes and technology through CPFR, can be found out and adjustments can be made, accordingly. This will significantly reduce the amount of work necessary for the expanded rollout of CPFR according to the suggestion of the management consulting firm LakeWest Group.

A step-wise implementation of CPFR should be followed according to CPRF instructions that were discussed in §4.2.3.

The sixth step: Implement JIT/sequenced part delivery

As most of the suppliers and sub-suppliers are located in the area of the city of Chongqing, it seems that logistics have not become a bottleneck in the MSC.

To optimize material flow, the focal firm has started to arrange the delivery of certain engine parts directly to the assembly line. To improve the delivery quality and reduce costs, the JIT/sequenced part delivery should be further explored and applied.

Based on the steps above, the quality of the entire manufacturing supply chain will be fundamentally improved. Those steps do not necessarily occur sequentially; activities of each phase may overlap on a time line. It is impossible to wait until one process is perfect and then start the next one. Many actions should be in process, concurrently.

7.3 Summary

By analyzing the survey data and the case study in this chapter, an overview of a Chinese manufacturing supply chain and quality management status has been presented.

Quality has become an important topic for Chinese manufacturers. Many companies have obtained certain quality system certificates, especially ISO 9000 series. However, application of the quality management approach is still on a relatively low level. Some companies are not used to following the quality management requirements that are specified in ISO 9001, even though they are certified.

Many manufacturers have recognized the importance of the supply chain. Supplier integration and cooperation in new product development has been practiced. However, the quality management of an MSC is presently most concentrated with the sourcing of quality management or supplier management. Supplier management focuses more on the supplier selection and auditing. The focal firm has not paid enough attention to improving the total quality of the MSC. Due to the invisibility in an MSC, especially with the lower tier suppliers who are often the instable factors in quality, the risk of a Chinese MSC is higher than that of a Western MSC. Because of the low quality standard, waste of resources is still a serious problem in the Chinese manufacturing industry.

This investigation and evaluation was highly encouraged by the motorcycle OEM company. They stated that it is a good opportunity for their suppliers to check their quality performance in all aspects that are involved in the motorcycle manufacturing supply chain. At the moment, the effort of the OEM is more concentrated on meeting the short-term challenges of supplier management, e.g. purchasing price and product quality as well as delivery time, but the OEM already started to consider enhancing the total quality management capability to reach substantial competency.

Chapter 8 Conclusion and Outlook

Supply chain management has been discussed widely. Extended enterprise is becoming a convincing concept to gain a competitive advantage in the rapidly changing market. However, the traditional quality management is mostly concentrated inside a single company, and supply chain quality management has more focused on supplier quality management. Therefore, as the Journal of Operations Management recently announced, more scholarly work is needed to rethink models, constructs, and frameworks for quality management in order to fit the increasing emphasis on supply chain management.

8.1 Innovative points of the work

In this research an ideal model is developed to show the quality management in an extended enterprise oriented MSC by three levels of controls, processes and means. The control level states the quality organization policy, structure, quality planning and forecasting and improvement mechanism. The process level constructs the common connected processes between chain members with the typical quality control and assurance approaches. The means provide an entire supply chain and every process with the realization of the possibilities and support.

Based on the Six Sigma theory and the ideal model, the measurement approach for quality performance of the MSC were discussed. In order to review the quality management status of an MSC, a development stage model, corresponding criteria as well as a tentative evaluation system are established.

By a survey within the Chinese automobile and machinery industry, a general overview of quality management for a supply chain in Chinese top tier suppliers is shown. By detailed analysis of a Chinese motorcycle manufacturing supply chain, a development roadmap is suggested.

The innovative points of this research work are as follows:

1) The supplier quality management was extended to the entire supply chain, with a view of direct suppliers as well as sub-tier suppliers.

2) A whole picture of quality management and required support in an extended oriented manufacturing supply chain was shown. It illustrated how all members of the MSC function and how the quality goal of an MSC can be reached in the entire chain by means of the collaborative quality activities in the key processes.

3) New product development was added as a key process in the MSC quality management, which was not considered in the SCOR model but plays an important role for the success of the MSC.

4) An MSC quality management level model was developed that helps a focal firm and key suppliers to review the quality management capability of their own chains as well as the status of the entire MSC.

8.2 Findings and thoughts of this research

Through this theoretical and empirical study, there were the following findings:

1) The same quality standard and management capability is essential for an MSC

The case study clearly showed that an MSC should establish understandable and accepted quality standards and requirements, and then transfer them efficiently down to lower tier suppliers. Every partner having the same quality goal is the basis for the success of an MSC.

2) Quality organization and cross-company planning give a brain to an MSC

An extended enterprise oriented MSC targets the cost, quality and efficiency of the entire chain. The ISO 9000 series, etc. industrial standards set up a baseline for every participant. The total quality performance cannot be reached without collaboration in the chain. The focal firm should establish the leadership with key partners to promote the implementation and coordination of quality management activities in the entire MSC.

3) Continuous improvement mechanisms should bring a breakthrough

Every partner improves himself but should also contribute to improving the interface and process between his customers and suppliers. A system of promotion together with an enforcing mechanism must be built into the entire chain through commitment. It is put forth from the focal firm to its tier 1 suppliers down in the chain.

4) The application capability of quality management approaches affects the entire chain

In an MSC the quality control and assurance approaches become more important to the chain's success. The quality control approach to design provides a common platform and communication language for partners in the product development. Quality data sharing between partners can assure or improve downstream production quality and reductions of in-value-added work. The application of quality management approaches is not just the affair of a single company.

5) Quality management of outsourcing is the basis for forming a chain with quality

Regarding supplier selection, audit and development, there should be a constant standard in an MSC, at least in higher tiers. That is the reason for some leading OEMs providing a supplier quality management manual not only to their suppliers, but also to second or sub-tier suppliers.

6) Modern information technology enables across-border quality activities

Information technology has become one part of building an MSC with quality. Without this enabling platform, efficiency of the quality management cannot be reached.

7) Training and experience exchange are the keys

The investigation of the Chinese supply chain has shown that the quality management ability is very unbalanced in an MSC, especially the quality consciousness and application ability. Quality management ability at similar levels is a common requirement for the improvement in the key processes. The focal firm should provide training and experience exchange opportunities first to the top managers of key partners and the first-tier suppliers, then commit them to do it with their suppliers.

8) The quality management scope is expanding

Quality management has developed from the across functional border within an enterprise to across enterprise border in a supply chain. Quality management for an MSC is transferring from traditional thinking that concentrates on the company's success to extended enterprise-oriented thinking that depends on the success of others in the chain. The quality management pushes every single company in the MSC to put their efforts on increasing the total quality for the entire chain.

9) Quality management principles maintain their importance in MSC

Even though the quality movement has recognized the need to link the historical views of quality control and quality assurance with the broader aspects of customer satisfaction and business results [Cobb 2003] as well as the multi-company collaboration, quality management principles that were established by Deming, Feigenbaum and Crosby are still the most fundamental elements. The principle of institute leadership, continuous commitments, etc. play the most important roles in building a high quality MSC.

8.3 Discussion about the research

Extended enterprise oriented manufacturing supply chain quality management is a complex and special topic. There are several points that are necessary to discuss about and rethink, e.g.

1) For which type of MSC is the model suitable?

In many sectors there are supply chains with an almost fixed structure (little variation in terms of suppliers). Those sectors have a dominant company "surrounded" by a relatively fixed network of suppliers [Cama 1997]. It will be meaningful for the automobile industry, complex machinery manufacturing and many high-tech. manufacturing industries.

2) Who will be the user?

This model is from the standpoint of focal firms, most of whom are OEMs, but also can be a final product assembler or even a system manufacturer who has the upstream supply network. The model and evaluation approach helps managers in different tiers to understand the feature by focusing on MSC quality. It informs the MSC members about their contribution to the total quality of the MSC and demonstrates how each one fits into the puzzle. In this way, extended enterprise members are involved in ensuring all processes and links in order to provide a fundamental and substantial improvement frame that focuses on the end user and brings superior value to the marketplace.

3) How ripe is the technology for the model application?

Theoretically, today's technologies provide all possibilities. The organization principles and approaches are the extension of an existing quality management. There are not many obstacles in the communication and information exchange through the IT platform. However, some function and process integration as the support means, like collaborative design, different ERP system integration, are still not popular or affordable. However, as Crosby emphasized, the key to quality improvement is understanding the concepts, not implementing some complex systems.

4) What is the combination of quality management and supply chain management?

Supply chain management is concentrated on "doing things well", e.g. to reach the best performance. Its evaluation factors are the cycle time, operation cost of a supply chain, on-time delivery rate, etc. Quality management for an MSC is more focused on "doing right things and doing the right things right". It prefers to set up a basic frame to secure "doing things well".

8.4 Further research in the field

This research has made an effort to give an entire picture of the quality management of an extended enterprise oriented MSC. There are some aspects that have not been explored sufficiently before, e.g. for an extended enterprise supply chain, the design chain was chosen as a main topic discussed in the Supply Chain World North America 2006 Conference & Exposition. To improve and complete the model and provide more support for application, there is further and deeper research that should be engaged. For example:

1) Efficiently integrate other quality management approaches with it. For example, Six Sigma. This model is based on ISO 9000 quality management theory and absorbed all the quality management elements that Six Sigma includes. However, as an approach much applied in industrial practice, Six Sigma could have more combination with it.

2) In the model, the MSC structure mapping is carried out by every tier supplier. To identify the MSC inconsistencies and reveal the root causes in the chain, systematic tools are needed. Value Stream Mapping (VSM) is an efficient tool. But it has been used mostly to analyze the

stream chain in one company's supply chain. How it can expand across different tiers should be further researched.

3) To identify and construct the core chain with key partners, a systematic evaluation and selection tool is needed. As the key suppliers are located in different tiers with different competencies, a multi-criteria synthetic evaluation model should be developed.

4) In this research the case study has adopted an equal weighting for the first-tier and focal firm, assuming they are of the same importance to the MSC. But with a multi-tier supply network, the evaluation weighting system between different tiers is complex; weighting decision-making criterion needs further research.

5) Further research is needed on how to deploy the training system in an extended enterprise oriented MSC. Which courses should be offered by which tier of the organization, the cooperation relationship and cost sharing mechanism - all this needs to be explored further.

This work has made an effort to demonstrate the importance of a quality management model for the extended enterprise oriented manufacturing supply chain. Those supply chain participants that are able to vigorously implement the principles of these structures will surely enjoy a competitive edge.

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Appendix

Appendix 1: Survey Letter to Companies

Dear Ms./Mr. President,

I am a doctoral student at the Technical University of Berlin, Germany. Under the supervision of Prof. Dr. Herrmann in the Quality Science Department, I am doing my research work in the field of quality management modeling for cross-company manufacturing supply chains. At the same time, I am also responsible for the research project: The Quality Management Strategy for Chinese Manufacturing Enterprises in the Global Supply Chain, which is sponsored by a Chinese governmental department. About my detailed information, please see the attached resume.

In order to make the research more practically oriented, I am looking for several manufacturing supply chains with typical products, which can help me to learn more about the basic quality management condition and requirements of Chinese supply chains, with a view to checking out the adaptability of the developed model and as well as to improve it. If your company would kindly participate in this investigation, it will be of great help. Through this participation, your company will profit in the following ways:

- Obtain related documents about leading companys' supply chain quality management in your field or in a similar field
- Provide your company with information and options to improve your supply chain
- Enhance the contact of your company with the European market. You will be recommended to participate in the seminar: Outsourcing Management and Cooperation in Europe, which will be held by The General Industry Council of the CCPIT and Jeelong Enterprises GmbH next Spring. About the concrete particulars, please get more information on the website of : http://www.ccpit-gi.org.cn/goglobal/

I hereby guarantee that all information is confidential and will be used only for research purposes.

Please arrange for the professional personnel in your Quality Management Department to fill out the questionnaire. To cover all the questions, it may require the assistance of the staff in the Purchasing and Order Management Department. Kindly forward your feedback before 30. September 2005.

Thank you very much in advance for your help and support!

Sincerely yours,

Ms. Yongrong Li, Certified Engineer

Curriculum Vitae

Personal info.	Name: Yongrong Li Address: Dovestr. 13, 10587 Berlin, Germany Birthday: March 30, 1965 Nationality: P.R. China Tel: 0049 30 34709120, Mobile phone：0049 1711177452 Fax：0049 30 3240973 Email：yrli@hotmail.com
Education	Sep.1983. – July 1987 Mechanical Engineering Department, Nanjing Technical & Science University, Bachelor Degree obtained. Oct.1999 – June 2002 Global Production Engineering, Technical University of Berlin, Dipl.-Ing. Obtained. Oct.2002.10– present Doctoral student, Quality Management, Technical University of Berlin.
Professional Career	Aug. 1987 – July 1997: Research assistant, Beijing Advanced Manufacturing Technology Consulting Center (BAMTECC). Engaged in manufacturing information research. In 1995 became the certified consultant in Beijing Consultant Council. July 1997 – Oct.1999：Vice senior researcher and vice director, BAMTECC. As research team leader, participated in the Computer Integrated Manufacturing System (CIMS) Research in the National Hi-tech. Program. Responsible for the establishment of the 863/CIMS Information Network, and provided consulting service for Chinese manufacturing enterprises. July 2002 – Aug. 2006: Consultant for the cooperation between General Industry Sub-Council of CCPIT and Jeelong Enterprises GmbH. Assisted in the project cooperation between Germany and China. Sep.2006 – present: Project manager, international business development in Willy Vogel AG. Responsible for the coordination of marketing, production activities with SKF Group members in China.
Other capability	♦ Many years working experience in the field of manufacturing technology and marketing operation. ♦ Familiar with and good understanding of Chinese and European culture. ♦ Fluent speaking and writing in English, knowledge in German. ♦ Master quality management tools and simulation tools as well as computer/network skill.

Appendix 2: Survey Questionnaire

Survey of Cross-company Collaborative Supply Chain Quality Management

（Pls. to be filled out by the quality department under the assistance of the purchasing department)

Company Name：

Filled out by (Department)：

Contact Person：

Email：

Tel：

Fax：

Date：

This survey is supported by the General Industry Council of the CCPIT and Jeelong Enterprises GmbH. You can send the filled out questionnaire to one of the representatives of the organizations in Beijing.

1. General Industry Council of CCPIT

Tel/Fax: 010 68963307 Contact person:：Prof. Yuhua Tian

Mailbox 2413 Beijing ZIP：100089

2. Representative office Beijing, Jeelong Enterprises GmbH

Tel/Fax: 010 84615400 Contact person：Mrs Yuexia Wang

Yangming Int. Building B-1104, No. 10 Xiaoying Street, Chaoyang District, Beijing

ZIP：100101

You are sincerely welcome to send me the feedback directly. If you have any inquiries about the questionnaire, please do not hesitate to contact me or leave a message at one of the organizations. I will come back to you soon.

Ms. Yongrong Li Email：yrli@hotmail.com

Tel：0049 30 34709120 Mobile：0049 1711177452

Fax：0049 30 3240973

Thanks a lot for your cooperation and support !

The Survey of Cross-Company Collaborative Supply Chain Quality Management

Pls. select the proper answer or a level according to your company's situation and your judgment. As the number increases, the agreement level increases. It can be understood as:

1：Total disagree or does not fit to your company
2：Basically do not agree or does not fit
3：Nearly agree or on the way to fitting
4：Agree or fits
5：Total agreement and perfectly fits

1 **About the basic management processes ***Pls. consider one product in your company to answer about.

Pls. give your selection（can be multi-items）						
1	Pls. list a typical product of your company：　　。With this product, which level your company is on ☐final assembly ☐system supplier ☐sub-system supplier ☐component supplier					
2	Which tier of suppliers do you manage? ☐direct supplier ☐supplier's supplier ☐other related suppliers					
Pls. rate the level of your agreement according to the situation in your company. 1: strongly disagree, 5: strongly agree.		Disagree → Agree				
		1	2	3	4	5
3	We have a quality team for supply chain quality management.					
4	We have assigned staff who are responsible for supply chain quality.					
5	The supply chain managers have required knowledge and skills.					
6	The cross-company quality initiate has been implemented with our suppliers and customers.					
7	The product requirement and inventory is planned, forecasted and replenished with our customers and suppliers.					
8	We exchange information with our supplier efficiently.					
9	The suppliers accept the continuous improvement philosophy and work together with us to improve the quality in the chain.					
10	We implement quality strategy in the entire chain including key suppliers in different tiers.					

2 Enable technology and platform

Pls. give your selection（can be multi-items)	
1	In the supply chain, the info. exchange is through： ☐telephone ☐fax ☐carrier ☐Email ☐EDI ☐info. platform on the Internet
2	Whether your company uses ERP： ☐yes ☐no ☐consider to apply ☐in process

3	Whether your ERP is integrated with your suppliers or customers: □yes □no □consider to implement □in process

3 Outsourcing quality management in the chain

Pls. rate the level of your agreement according to the situation in your company. 1: strongly disagree, 5: strongly agree.		Disagree → Agree				
		1	2	3	4	5
1	We have complete supplier quality management manual.					
2	We have complete supplier selection and evaluation system.					
3	We review supplier performance periodically.					
4	We help suppliers to improve their quality management systems.					
5	Key suppliers are willing to invest in new technology application with us.					
6	We have built long-term relationship with our key suppliers.					
7	We also set up quality requirements to sub-tier suppliers.					

4 Design quality management in the chain

Pls. rate the level of your agreement according to the situation in your company. 1: strongly disagree, 5: strongly agree.		Disagree → Agree				
		1	2	3	4	5
1	In the early stage of product development, the material suppliers have joined.					
2	In the early stage of product development, the production equipment suppliers were involved.					
3	We participate/join the new product development of our customer with corresponding quality control methods.					
4	We cooperate in the design process through network/Internet.					
Pls. give your selection (can be multi-items）						
5	Which kind of tools does your company use to ensure the product development quality： □Quality function deployment(QFD) □Failure mode and effects analysis(FMEA) □Advanced product quality planning(APQP) □Six sigma □others：					

5 Production quality management in the chain

Pls. rate the level of your agreement according to the situation in your company. 1: strongly disagree, 5: strongly agree		Disagree → Agree				
		1	2	3	4	5
1	We implement process control in the production.					
2	We make the production schedule by coordinating with the suppliers and customers.					

3	We have integrated the plant-floor with the supply chain management.					
4	We can obtain real-time production quality information from our suppliers.					
5	We can provide our customers with real-time quality data.					
6	By coordinating with suppliers we have reduced the inventory on both sides.					
7	By sharing production quality data the repeat test and waste have been reduced in both sides.					
8	By coordinating with the suppliers, the production flexibility is improved.					

6 Delivery quality management in the chain

Pls. give your selection（can be multi-items）						
1	Which kind of quality certificate does your company have? ☐ISO9001 ☐ISO/TS16949 ☐QS9000 ☐AS9100 ☐ISO14001 ☐TL9000 ☐others：					
Pls. rate the level of your agreement according to the situation in your company. 1: strongly disagree, 5: strongly agree		Disagree → Agree				
		1	2	3	4	5
2	We have well-documented quality management system.					
3	We define all the non-conformance product and apply corrective and preventive measures.					
4	The customer's quality and delivery requirements can be transferred accurately in the supply chain.					
5	The logistics arrangement to the customers is ready and effective.					
6	We can supply our customers on-time according to the customer's needs.					
7	By coordinating with suppliers/customers we can shorten the lead-time.					

7 Others

Pls. give your selection（can be multi-items）	
1	Which kind of role does the quality certificate play for the quality management improvement in your company:： ☐very big ☐so so ☐benefit smaller than investment ☐not necessary
2	What do you need the most in your supply chain quality management： ☐related knowledge ☐experience ☐tools ☐investment ☐too busy with business, no time to implement ☐others：
3	You wish： ☐to receive the documents related supply chain quality management in leading companies. ☐to receive this research report. ☐to have my company recommended on the list of Outsourcing Management and Cooperation in Europe. ☐to visit our company and discuss further.

Appendix 3: Summary of Surveyed Feature Data of Chinese Suppliers[22]

MSC quality organization:

Item	Only direct suppliers	Direct and sub-tier suppliers	Also other suppliers
Quality organization scope	36	15	2

Item	Advanced (4-5)[23]	On the way (3)	Backwards (1-2)
Quality team/responsible staff for MSC quality	32	17	2
Qualified chain manager	22	16	13

Cross company quality planning:

Item	Advanced (4-5)	On the way (3)	Backwards (1-2)
Cross-company quality planning activities	10	12	29
Information sharing with suppliers	45	4	2
Demand planning and forecasting	10	10	31

Continuous improvement:

Item	Advanced (4-5)	On the way (3)	Backwards (1-2)
Supplier participation in CI	27	17	7

Quality management for design:

Item	Advanced (4-5)	On the way (3)	Backwards (1-2)
Integration with material suppliers	23	16	12
Integration with facility suppliers	31	10	10
Network-based design	8	11	32
Applying quality approach with suppliers/customers	16	17	18

Item	QFD	FMEA	APQP	Six Sigma
Quality tools for design	16	36	26	16

Quality management for outsourcing:

Item	Advanced (4-5)	On the way (3)	Backwards (1-2)
Supplier quality management manual	35	10	6

[22] This is the statistical data from the 51 survey feedbacks. Here the number of companies is listed.
[23] Here the 5-point scale system is summarized in three groups: advanced group (scale point 4-5), close to the criteria /on the way group (scale point 3) and backwards group (scale point 1-2).

Supplier selection and evaluation system	41	8	2
Audit suppliers periodically	32	11	8
Help supplier to improve QM system	24	23	4
Long-term relationship with suppliers	42	9	0
Suppliers help to improve process and quality	24	19	8
Suppliers willing to share technical investment	25	20	6

Quality management for production:

Item	Advanced (4-5)	On the way (3)	Backwards (1-2)
Process control	42	7	2
Coordinated production schedule with suppliers	28	13	10
Plant floor integrated with supply chain	5	15	31
Obtain real-time quality data from suppliers	24	12	15
Provide real-time quality data to customers	37	2	12
Coordinating with suppliers to reduce inventory	20	6	25
Joint reduction of waste	28	9	14

Quality management for delivery:

Item	ISO 9001	ISO 14000	ISO/TS 16969	QS 9000
Certified with international/industry standards	42	12	13	8

Item	Advanced (4-5)	On the way (3)	Backwards (1-2)
Documented quality management system	44	7	0
Applying corrective and preventive measures	33	10	8
Quality requirements transfer to sub-tiers	34	9	8
Logistics and on-time delivery	43	8	0

Enable technology and platform:

Item	Email	EDI	Internet-based platform
IT& management support	32	9	12

Item	Implemented	Under con-struction	Planning/ considering	No action
MPRII or ERP implementation	20	7	6	18
Integrate ERP with the suppliers	2	6	7	36

Appendix 4: The QM Capability of MSC in Tier 1 Suppliers

	Collaborative QM																			
	Cooperative QM																			
	Selective QM																			
Criteria	Clear company quality management system	Supplier selection and evaluation system	Information exchange with suppliers/customers through certain channel	Responsible staff to deal with quality problem with suppliers/customers	Periodical audit of supplier performance	Quality requirements of customer can be transferred/received accurately.	Products delivery based on agreed date	Supplier help to improve their quality management performance.	Short lead-time by coordinating with suppliers and customer	Continuous effort to improve quality with main suppliers/customers	Has built long-term relationship with key suppliers	Suppliers and customers involved in product development and quality management agemddmanage-	Sharing of quality data to reduce waste with suppliers and customers	Cross-company quality management activities with direct suppliers	Leading/participating multi-tier quality organization and planning	Deployment of quality management process through up-stream supply chain partners	New product development collaboration and quality assurance with suppliers via Internet	Full visibility of production quality data across supply chain	Dynamic inventory and WIP track in the chain	Collaborative planning, forecasting and replenishment together with suppliers /customers via network	Partners willingness to invest in new technology
$V1_1$	5	5	4	5	5	5	4	3	4	3	2	4	3	2	3	1	1	2	2	2	5
$V1_2$	4	4	4	3	5	3	4	3	5	3	4	3	3	3	2	2	1	1	2	2	5
$V1_3$	5	5	5	5	5	5	5	4	5	5	5	5	5	3	2	3	3	3	2	2	5
$V1_4$	4	5	4	3	5	2	5	4	4	4	4	4	4	2	2	1	1	1	2	2	5
$V1_5$	4	4	4	4	4	3	4	3	3	4	4	4	4	3	3	3	1	1	2	2	4
$V1_6$	5	5	5	5	5	4	4	3	4	3	4	3	4	3	3	3	2	3	1	2	3
$V1_7$	5	5	5	4	4	3	5	4	4	4	5	5	4	3	2	2	1	1	1	2	4
$\overline{V1}$	4.5	4.7	4.4	4.1	4.8	3.6	4.4	3.4	3.9	3.7	4.1	4	4	2.7	2.4	2.1	1.4	1.7	1.7	2	4.4