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Innovative IT-Based Logistics

A Case Study Of KHD's 'Vision 2000' Engine Factory

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Abstract

This case discusses information technology (IT) issues at a new plant of KHD, the German diesel engine manufacturer, considered as one of the most modern engine factories in the world. It first describes how KHD's innovative manufacturing and logistics concept integrates suppliers, logistics service providers, and customers into the company's business and IT strategy. The case then presents the challenges that KHD faces in its effort to make its state-of-the-art production facility an economic success.

Introduction

This case raises some IT issues at a new plant of KHD, the German diesel engine manufacturer, considered as one of the most modern engine factories in the world. The related discussion is made from both a technical/functional perspective as well as an organizational/business viewpoint.

1 The author would like to thank Professor Tawfik Jelassi for his valuable contribution in revising this case for the Ninth International Conference on EDI-IOS (Bled'96).

The case is structured as follows: it first introduces KHD, its organizational structure and financial situation. It then presents the company's 'vision 2000', its rationale and underlying concepts. A description of KHD's product range with an emphasis on the new diesel engines is then provided along with the company's goal to make the new Cologne-based plant one of the most modern of its kind world-wide. The next section of the case describes the factory characteristics in terms of floor layout, production organization and material flow as well as the role played by information technology.

The subsequent part of the case focuses on the innovative engine manufacturing process highlighting its key components: the Progressive Assembly, the Stand Assembly, and the Test Floor. The IT-based logistics approach is then discussed along with its information requirements. The case concludes by raising some critical questions mainly related to logistics outsourcing and to the economic viability of KHD's state-of-the-art manufacturing facility.

The Company

Overview

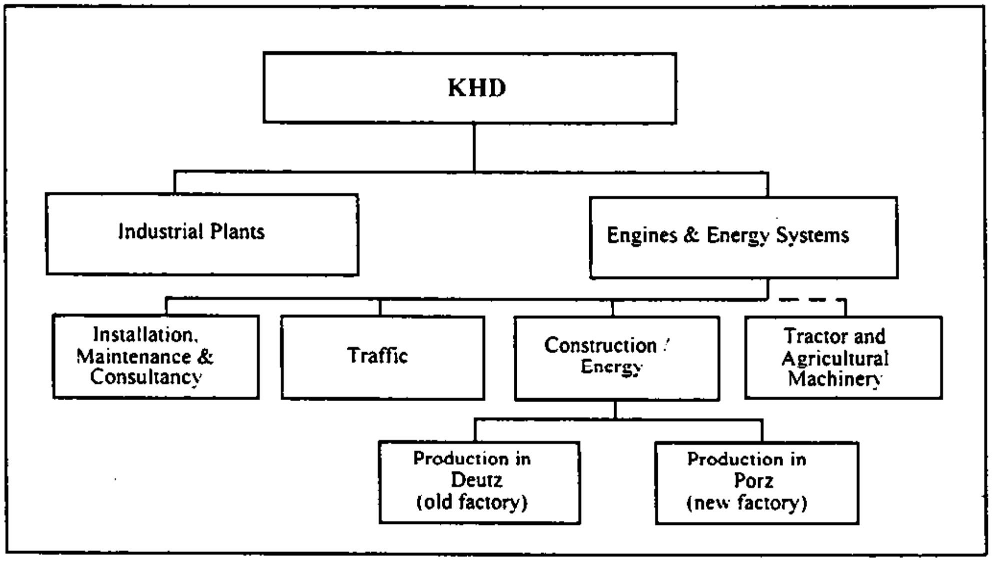
KHD is one of the leading engine manufacturers in the world. After a period of financial disturbance and in order to secure a lasting competitive edge, KHD has been since 1987 implementing a 're-orientation program' aimed at developing new products, adding value to the customer, and introducing new production technologies to slash throughput times. The company's overall goal is to be, for all its activities, closer to customers and markets than its competitors.

KHD's core operations are in engines and energy systems (i.e.: traffic, construction/energy, services) as well as the design and construction of industrial plants (such as those for basic materials, foodstuff, and environment). The Tractor and Agricultural Machinery division, which constitutes the setting for this case, was sold in 1995 to Same/Italy (see Exhibit 1).

The development in 1876 of the four-stroke engine by Nikolaus August Otto (who was also the founder of KHD) was the starting point for world-wide motorization. Since then, Cologne has been the oldest site of the manufacture of diesel engines in the world and KHD very influential in this industry. The company has made major contributions to mechanized farming and industrial plant construction. Its strength is mainly based on technological innovation and technical expertise. KHD's sales volume puts the company in the third place in the world as an independent (non-captive) engine manufacturer, behind two American competitors. KHD holds a market share in Europe of 28% in the industry engines segment and 80% in the compressor segment. World-wide, it has a market share of 19%.

In 1994, the engine manufacture contributed approximately 48% to KHD's total turnover. The company engine manufacturing facilities are located in Germany (in Cologne-Deutz, Cologne-Porz, Ulm, and Mannheim) as well as in Spain. KHD aims at increasing its annual production volume from 135.000 in 1992 to 170.000 engines in 1998 (with 130.000 produced in the Porz factory).

Exhibit 1: Organizational Structure of KHD



Source: KHD

Financial Situation

In 1993, KHD achieved a turnover of DM 3.25 billion with a total workforce of 11.320. However, the company has faced over the last five years a major financial crisis (see Exhibit 2). Its overall earnings were about DM 180 million below the target set for operations and further losses of approximately DM 600 million are expected for 1995 and 1996[2].KHD did not have sufficient resources to overcome this crisis on its own. External help, especially from the Deutsche Bank which waived claims of DM 150 million, contributed to restoring KHD's financial health. The main reasons for the current problems are due to the deterioration of the sales mix which is a consequence of a higher share of foreign sales, a trend towards engines in the lower performance range, changes in currency parities and a stronger competition.

"The path thus far has sapped much strength. We only survived the recessions of 1992 and 1993 by tapping the last reserves available. With its new financing plan, KHD has now laid the foundations to successfully travel the remainder of the

2 See Annual Report 1994, p. 4.

path to rejuvenation. Engine sales are rising again ... Given this stronger basis, an improvement in earnings power should be possible in the medium term, and additional opportunities will potentially arise from co-operative ventures."

Werner Kirchgaesser, former CEO
Annual Report 1994

Exhibit 2: KHD Group Financial Data (in million DM)

	1990	1991	1992	1993[3]	1994[4]
Sales	4.060	4.122	3.665	2.721	2.695
Order receipt	4.183	3.745	3.665	3.578	3.647
Order backlog (as at Dec. 31)	1.820	1.443	1.464	2.243	3.171
Personnel expenses	1.158	1.149	1.149	919	885
Capital expenditures	89	140	319	244	139
of which on the new engine plant		56	247	162	36
Depreciation	102	96	101	102	130
R&D	177	183	158	125	104
Total assets	2.971	2.905	2.998	3.328	3.011
Stakeholders' equity	310	320	320	559	252
Group profit/loss	30	10	0	0	-308

Source: KHD, Annual Report 1994

The 'KHD 2000' Vision

"In order to secure an enduring competitive edge, KHD's reorientation program has, from its inception in 1987, been geared toward augmenting customer utility, developing new products and introducing new production technologies to slash throughput times. The net result will enable KHD to offer the speed, flexibility and high quality performance to satisfy today's customers. For all our activities none of our competitors will operate more closely to customers and markets than ourselves."

Werner Kirchgaesser, former CEO
Annual Report 1993

3 Excluding Tractors & Agricultural Machinery Division.
4 Excluding Tractors & Agricultural Machinery Division.

KHD has embarked on a corporate renewal effort by developing a vision called 'KHD 2000'. This vision was devised by the board and 1.300 staff members during more than 60 workshops which were held in 1991. Its was implemented with the reorganization of KHD's engines division. especially concerning the new factory.

The overall objective is to open up new markets and to strengthen the existing business. KHD wants to standardize its production program. ensure a maximum percentage of common parts. and gain from synergy effects in world-wide procurement. Therefore. the company aims at intensifying collaboration between development and manufacturing. materials management. as well as control and logistics. All sectors should be involved throughout the process from the initial product idea to the finished good/service including in the determination of target costs.

The New Diesel Engines

> "Our products definitely offer advantages regarding exhaust fumes and noise emission."
>
> Dr. Guenther Wagner. Chairman of the Board

With the water-cooled diesel engines (types 1012 and 1013) produced in its new factory. KHD launched a completely new production line. This line is aimed at strengthening the company's position in the combustion engines market. The new engines have a lower noise and exhaust fume emission in compliance with the European standards to be introduced in 1996.

While 2-. 3-. 4- and 6-cylinder engines are commonly used in the performance range of 30-190 kW. the new KHD production lines are tailored for the 4- and 6-cylinder engines. The company refrained from the production of the more complicated 3-cylinder engines. Beside the new models (1012/1013). the older 1011-line of air-cooled engines is also manufactured in the new plant. Exhibit 3 provides a brief comparison of the three types.

Exhibit 3: KHD's Diesel Engine Types

	Type 1011	**Type 1012**	**Type 1013**
Cylinder	2 / 3 / 4	4 / 6	4 / 6
Performance (kW)	10 - 53	27 - 123	80 - 190
Number of Revolutions (rev/min)	1.500 - 3.000	1.500 - 2.500	1.500 - 2.300
Cooling System	Oil-Air	Water	Water

Source: KHD

The new types 1012/1013 consist of 19 basic models (see Progressive Assembly) with approximately 3.500 - 4.000 possible customized versions (see Stand Assembly). Each engine is made up of approximately 900 parts. Due to the high degree of customization, a total of about 4.000 part numbers are to be managed. The new engines are specially designed for construction machinery and compressors, a sector in which KHD has a market share of 78% in Germany and 43% in Europe (see Exhibit 4). Furthermore the group intends to get into the new market for smaller trucks.

Exhibit 4: KHD Engines - Market Share and Engines Sold (1992)

	Germany	Europe
	Market share / Engines	**Market share / Engines**
Construction machinery and compressors	78% / 23.500	43% / 52.600
Hydraulic excavating equip- ment	84% / 7,150	81% / 7.550

Source: KHD

Based on Simultaneous Engineering[5], the new engine types were developed in four years, instead of the previously needed five to six years. However, almost two years after starting the production, KHD is not satisfied with the new engines sales and aims at a significant increase of customer orders.

Towards one of the "Most Modern Diesel Engine Factories in the World"

> "The new plant will work with an outstanding efficiency, even in comparison with Far-Eastern standards. It stands for the realization of tomorrow's world of employment."
>
> Kajo Neukirchen, CEO 1987-08/1991

The new factory represents the highest investment (DM 600 million) in KHD's history. It represents several innovations: a new product, a new production technology, as well as a new logistics and employment concept which has even interested automobile manufacturers such as Daimler-Benz, BMW, Volkswagen and Audi.

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5 Simultaneous Engineering means that people of all divisions (purchasing, R&D, marketing, etc.) work simultaneously on the development of the new product in project-teams, instead of working sequentially. The concept was developed by Japanese automobile manufacturers and at first shocked their Western competitors because of its efficiency.

Strategic Goals

> "Our logistic concepts enable to satisfy every customer within a minimum of time."
>
> Werner Kirchgaesser. former CEO

In addition to the advantages of large-scale serial production (low cost and short delivery times). combining Stand Assembly and Progressive Assembly increases speed and flexibility. Limiting the production to only four key components. manufactured in-house. enables KHD to cope with the complexity of the production process (lean production). It also requires purchasing the other components world-wide. hence allowing a high degree of customization. A zero-defect strategy aims at improving quality and efficiency.

Factory Characteristics

> "The factory was designed at the same time as the new engines which are to be built there. Today these tasks cannot be separated."
>
> Franz X. Moser. Head of Engines Development

A small project-team developed the whole factory within 24 months. Despite modern IT-based tools. the most critical task was to combine different factory modules and related functions.

The design of the new factory aims at (1) moving from separating functions to interrelating all production activities. (2) flattening the organizational structure. and (3) supporting team-work. All functions which are directly related to production (e.g.. development. assembly. painting. testing, distribution and controlling) are now interrelated. A multifunctional service zone works rather independently' as an internal service center. Moreover. transparency between the production floor and the office floor strengthens the team-spirit. A flexible. multifunctional building structure enables adjustments to changes in the production environment.

The structure of the new factory is based on the principle of modular segmentation. Four small factories with 4.500 m^2 each were built for (1) the Progressive Assembly, (2) the Stand Assembly. (3) the Test Floor, and (4) the Paint Shop (see Exhibit 5 for the different production segments).

Tools and functions are located in the service-zone (development. logistics. purchase. computer center. a technical center. conference and meeting rooms. workshops, social and educational facilities. and the engine museum). A flexible wall and media systems allow for an easy modification of the current structure.[6] For the year 2000. KHD plans to produce 70.000 engines of the 1012 and 1013 lines. In 1994. only 14.000 instead of the planned 20.000 engines were built. hence keeping the new factory far below break-even. A total of 130.000 engines (new and old models) are to be built at the new plant. Initially. KHD expected to break-even in 1996 with an annual output of 100.000 engines: it now hopes to become profitable in 1997. As the new factory marks KHD's step into a new era of water-cooled diesel engines. it will take further time to run the factory at its full capacity. Customers using the new engines need first to be convinced that water-cooled engines are lighter. more economic and more ecological: they will then change their own construction machinery or commercial vehicles to prepare them for the new engine types.

Information Technology Backbone

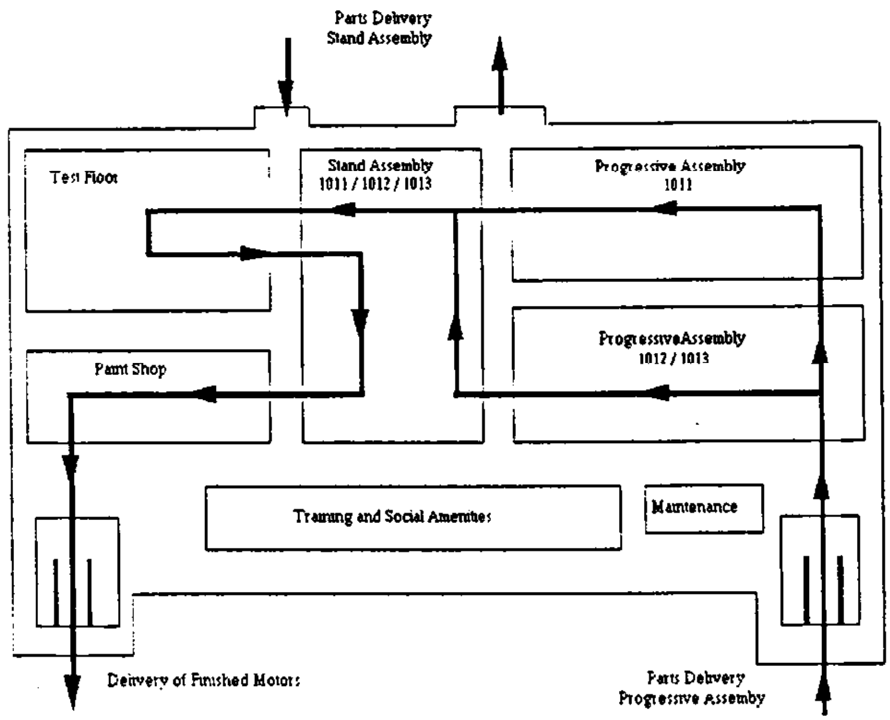
In the new factory. data throughput is almost fully automated. The role of information technology (IT) becomes critical with the synchronisation of material and information flows. Says system planner Martin Feller: "This synchronisation required IT functions not only to be allocated during construction. but also to integrate IT specialists in the project right from the very beginning." Accordingly. since the planning phase. Electronic Data Systems (EDS) Inc. was involved in the 'new factory' project. Klaus Schmittbetz. in charge of production in the new factory explains: "Information technology has to function smoothly and quietly at any time. For that reason. we needed the expert knowledge of a service provider that had already gained experience in similar projects."[7] Complex systems and network architecture constitute the backbone of the information transmission which is synchronized with the material flow.

This backbone is based on an three-level. organizational concept: the Assembly Host System. the Production Control Level. and the Process Level (see Exhibit 6). The centralized assembly management enables automated management. control. and transparency of the entire production process. The Assembly Host organizes all assembled engines and the location of all assembly containers. Despite the high degree of production automation. people still play a crucial role in the factory. It is only them who know customer preferences. hence enabling the customization process.

6 A good lighting-system (indirect daylight. two-sided) leads to a pleasant environment. especially decreasing the reflection of sunlight on computer screens.

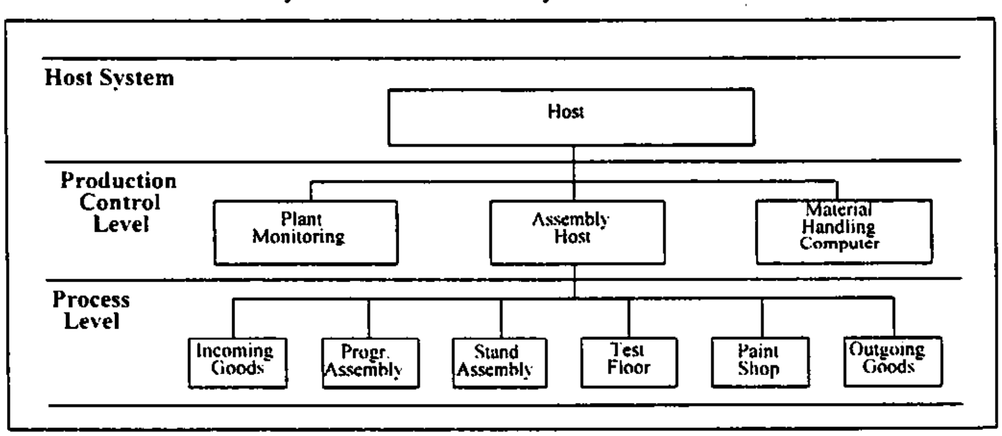
7 The services provided by EDS included consulting for logistics. material flow. and assembly control. EDS managed the material flow and assembly control of the logistics projects and was responsible for the overall implementation. Since June 1993. the IT service provider has been operating the assembly-control computer at KHD and maintaining the existing applications.

Exhibit 5: Floor Organization. Production and Material Flow



Source: KHD

Exhibit 6: New Factory - Production Control System



Source: KHD

Employees

There are 540 employees working in eleven shifts per week (5 times two shifts of nine hours from Monday through Friday with one -hour break between them, and one shift on Saturday). Weekly working hours range between 35 and 44 hours and is compensated using extended week-ends, weeks, or months. KHD doe not want to have a 24-hour production since it prefers to work without buffers and needs some time for maintenance.

All employees chosen for the 'New Factory' project had to pass an assessment test (which can last from one to three days and has a success rate of 75%). After determining an employee's strengths and weaknesses, special training sessions were organized focusing mainly on production technology and social competence. They also covered team-work and conflict management.

There are no timed assembly lines. Employees work in small teams which are in charge of a certain process and mostly organize their workflow themselves. Each team knows the common goals. All required data for certain tasks is displayed on monitors and the necessary material is ordered on-line via EDI[8]. Employees control the production quality as to only deliver 'perfect' material to customers - often the next group in the production process, just a few meters away. Maintenance staff is also integrated in the teams. Team-members' wages may differ, depending on the quality and quantity achieved by each one.

Although the division "Engines/Construction and Energy" wants to increase its annual production in Cologne-Porz and Cologne-Deutz from 185.000 to 200.000 engines by 1998, the staff will decrease from 1.800 to 1.100 people. The new factory is based on KHD's reorganization principles[9] of replace unskilled workers by machines (robots and computers) and purchasing more components externally. This has resulted in almost 1.500 redundancies.

Distribution Center

KHD has opted for outsourcing components' purchase and distribution.[10] The forwarding agent 'Spedition Stute Verkehrs GmbH' ('Stute') in Bremen built a distribution-center in Porz-Lind (12 km away from the new factory), especially designed for KHD's diesel engines. Every 20 minutes a truck shuttles back and forth between the center and the factory, and each day approximately 2.000 boxes and numerous engines are moved.

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8 Electronic Data Interchange.

9 In line with its overall strategy of having a streamlined and lean structure, KHD also reduced membership in the Board of Management from six to three, halved the sized of the holding organization and trimmed management levels throughout the Group.

10 Guaranteed in-time delivery is an independent service within the industry, mostly offered by firms unknown to the public

The center consists of a high-shelf stock with a capacity of 10.000 palettes and an automated stock for smaller parts, on an area totalling 36.000 m^2. The assembly components are directly delivered via transportation lines from the high-shelf stock to automated loading ramps, from where they are shipped process-related to the factory by the shuttle truck. Finished engines and empty material containers are returned to the distribution center in the same manner .

Quality control (by KHD staff), receipt of in-bound logistics, packing of assembly containers, preparing outgoing goods, packaging, and storing empty material containers take place within an area of 10.000 m^2. The distribution center is managed by KHD's information system.

'Stute' is electronically connected to KHD and manages the stocking of purchased parts and self-made components as well as the shuttle to the factory (on average 'Stute' delivers 1.5 material-boxes per engine). It is also responsible for collecting finished engines, storing them, and then distributing them to customers. KHD and 'Stute' operate a closed, completely automated logistics system in which the only 'manual' job left is driving trucks back and forth between the distribution center and the factory.

Innovative Engine Manufacturing

In the new factory, only a select set of processes is automated; the remainder is handled by a combination of people and machines. In the Stand Assembly where engines are customized, automation is especially low due to the relatively small production volume (compared to the high output of, e.g., new automobile factories). The average process time for all production stages is 14.5 hours, which corresponds to a maximum of two shifts. For an order, the maximum process time is three weeks. Exhibit 7 provides an overview of the key logistics differences between the diesel engine and the automobile industry.

Exhibit 7: Diesel Engine versus Automobile Industry - Logistic Aspects

	Diesel Engine Industry	**Automobile Industry**
Customers	processing companies	end-customers
Product	customer-specific development	typical mass product
Number of units	relatively low	high
Variety	high	high
Procurement power	relatively low	high
Impact on customers	supplier of a components	dependent dealer

Source: KHD

Orders

Production begins with the customer order. Once received, data about components, functionalities or activities is first decomposed, then integrated into a unique bar-code. Needed parts are ordered via EDI from KHD's distribution center. (Most of the 190 vendors are connected via EDI with the company).

Inbound Logistics, Material Flow and Store Management

Assembly components are delivered just-in-time by 'Stute' with special roll-on/roll-off-shuttle trucks: The trucks dock directly to the loading-ramps of the distribution center or the factory. They are supplied with electricity through a socket placed at the loading-area. A transportation line on the truck moves the palettes on or off the loading ramps.

The whole loading and unloading process takes just five minutes. Data exists only in electronic form and is processed by the information system.

Delivered components are identified by bar-code scanners and automatically transported to the Progressive Assembly. The scanners also transmit components' information to the Assembly Host where it is first checked and then forwarded to the material handling system. A transportation-order is generated and transmitted via infra-red light to an automatically-guided vehicle (AGV). These AGVs move through the factory taking boxes to the assembly and buffer areas. The induction-controlled AGVs allow to fully automate just-in-time delivery. Furthermore, the material flow within the production processes is completely automated and the average material turnover in the factory is four hours.

Since there are no hidden material buffers, the material flow is constrained by the small store capacity. From entering to leaving the factory, the actual material processing time is approximately 50% while the average in German industry is approximately 20-25%.[11]

Progressive Assembly

The Progressive Assembly is not fully automated. There are 26 employees and 14 automated machines (including 8 robots) that work at an assembly line, producing a basic model every 3.3 minutes. Robots are used for difficult or monotonous processes that require a high precision level. The specially designed automated machines are mainly used for tightening screws, measuring, or controlling, and offer a high process-security. Using their experience and intuition, employees ensure speed, flexibility and quality.

The material is provided in 'full containers', i.e. parts are neither counted nor packed separately. A container has only one component type and is placed at the production

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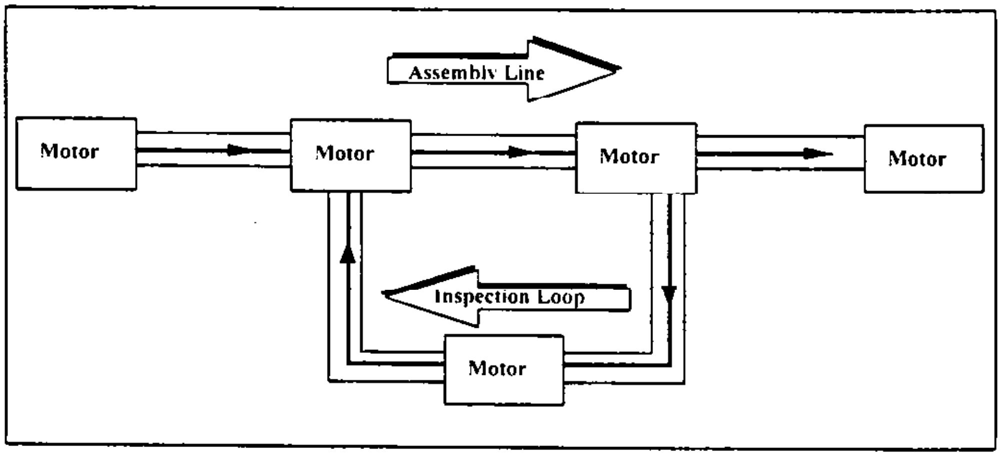
11 Source: KHD.

line (while another container remains in a buffer). Once removed from their container, components are scanned (through their bar-code) while another container gets automatically moved from the buffer to the assembly line.

If an error is detected, the engine is rerouted into an inspection loop where remedial action is taken without delaying the assembly line (see Exhibit 8). Once fixed, the engine is put back into the process. The sequencing of engines can be altered since all needed components are placed nearby. This repair strategy is considered better in terms of quality and production flexibility, and more efficient than the Japanese system since workers do not need to stop the whole production line to fix errors.

At the end of the assembly line, engines are checked through a 'cold test' designed to exclude all errors, except those related to performance and combustion. The engines are then transported by AGV to the Stand Assembly.

Exhibit 8: Assembly Line and Inspection Loop



Source: KHD

Stand Assembly

"Each customer gets his very specific engine."

Dr. Guenther Wagner, Chairman of the Board

In the Stand Assembly, engines are manually customized at 70 work stations (40 for engine types 1011/1012 and 30 for the 1013 type) with AGVs delivering all required parts. Each engine has its own container with all the parts needed to complete it. The container is filled by (mostly unskilled) workers in the Stute's distribution center.

These workers are led to the necessary components through LCD lights and are electronically instructed of the required number of parts.

The containers and the basic models are brought together at one of the 70 work-stations. There, to complete one engine, a worker needs 45 minutes on average (the range being 15 to 75 minutes). Once an engine is assembled, the container becomes empty and the engine ready to be moved to the test floor. KHD considers the high customization level offered by the Stand Assembly as giving the company a sustainable competitive edge since most competitors only offer "off-the-shelf" engines.

Test Floor and Painting

To compensate for the different assembly times of the approximately 4.000 engines (19 different basic models of the 1012 and 1013 types), a buffer zone for 170 engines (i.e., equivalent to 50% of the shift production volume) was added before the test floor. As test benches are costly, their number is kept as small as possible. KHD plans to work with only fifteen test benches for the 130.000 engines produced annually. The necessary set-up is made in advance so that the engines can be moved quickly to the test bench. The transport to and within the Test Floor is executed by the AGV.
On the test benches, the engines are adjusted to customer needs. A special program prepares the engines within an average of 20 minutes (19-26 minutes) for operation. However, it is a KHD employee who decides on the final release of the engine.[12]

Favoring environment-friendly solutions, the painting is carried out with water-soluble paints that provide colors and protection for the surface. Each engine is sprayed by two robots, leaving 10-20% of the contours for manual paint in order to minimize the program complexity. Six workers per shift finish painting an engine every other minute.

The IT-Based Innovative Logistic Approach

> "I don't know any other business which has automated its material flow so thoroughly and with so much impact."
>
> Robert Kurzweil, Project Manager, Indumat[13]

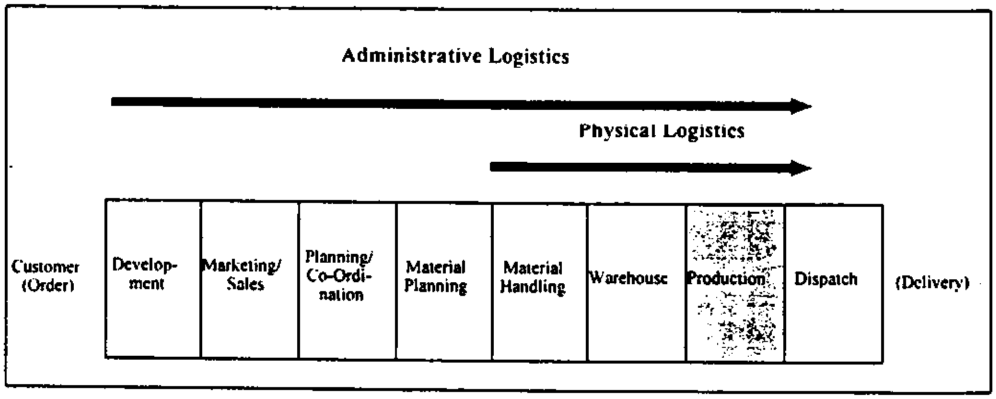
12 Sixteen workers are employed in the test floor, including those in charge of preparation and control.

13 Manufacturer of the used FAT.

Overview

The new approach to logistics follows market/customer needs. The development of new engines requires production processes tailored to logistics and the management of variants becomes crucial. This new approach can be split into administrative and physical logistics (see Exhibit 9).

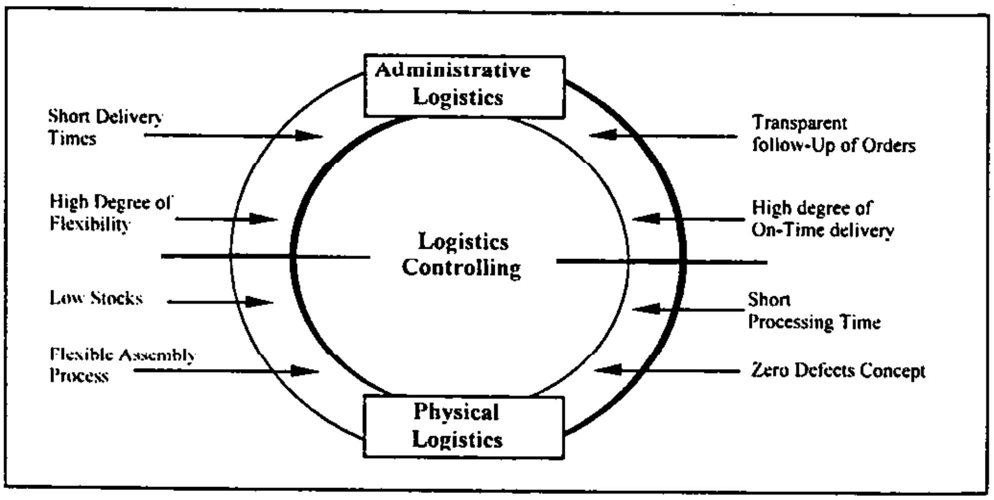
Exhibit 9: Administrative and Physical Logistics



Source: KHD

A compromise between conflicting objectives -mainly customer needs and competitive pricing- is needed at all stages. The main performance factors of both the administrative and physical logistics, as identified by KHD, are depicted in Exhibit 10.

Exhibit 10: Logistics Performance Factors



Source: KHD

The new internal logistics concept is based on five key points:

- All needed material for the engine is available before production.
- The maximum realization time between a material order (from an external stock at the distribution center) and the beginning of the assembly is 3 hours.
- The material stored in the containers next to the assembly lines is included in the material stock.
- The inventory is managed by stock- and assembly-quantities, and
- The material buffers next to the assembly lines cover a maximum of 4 hours.

The smooth functioning of the logistics substantially contributes to a price-sensitive, fast, and customer-oriented production. However, the tight interdependence between all processes increases the risk of interruptions, caused either by man or machine. In particular, the interfaces between logistics and the other production processes require a strong level of cooperation and coordination.

From a technical perspective, the automated incoming and outgoing of goods requires high security standards, machine-readable labels and an automated contour detection for containers. Due to the large volume of material flowing between the distribution center and the factory, each consignment's data (delivery bill) has to be transferred automatically. Furthermore, the use of AGVs demands high precision in handling the containers and palettes.

The completely automated material flow in the factory requires a detailed planning of containers (including their size, weight and label) during the process planning. The short production lead times demand a precise delivery of purchased goods (in terms of time and quantity). Hence, each component is marked using short codes so it can be easily handled in the factory.

All information is displayed on screens, hence making the factory paperless. Once an engine is released from the production stage, all of its related data is transferred to the assembly host where it is stored for up to 10 years. Such a documentation is a substantial prerequisite for KHD's zero-defect strategy. Moreover, the test protocol for all engines and the complete process data are stored on call for the customers.

Critical Questions

Outsourcing Logistics

The required investment level is the same for KHD or an external service provider. However, one advantage of outsourcing is the lower wages in the service industry due to different union agreements. Furthermore, the provider may profit from synergy effects by using the distribution center for various firms (see below).

On the other hand, the provider has hardly any competence in the manufacturing of diesel engines. Furthermore, he has to show a profit from operating the distribution center. For KHD, this means that the employment of unskilled workers may affect the production quality and the company's zero-defect strategy. In addition, the provider's high level of staff turnover conflicts with KHD's human resources management approach.

The general issue involved here is whether outsourcing the distribution center and external logistics does not lead to interruptions in the production process despite the automated and closed logistics system. More specifically, the underlying question is whether the business interests of both companies lead to compatible management choices/approaches, or in case of divergence, whether the overall production process can get affected in spite of the high degree of technical integration?

Geographical Distance between Distribution Center and Factory

Regarding purchasing, delivery, storage and distribution, KHD originally had planned to build its own distribution center on its premises next to the factory. However, due to the high cost involved, KHD decided to outsource the external logistics and 'Stute' was chosen as provider.

It was planned that in the next phase 'Stute' would run the distribution center on KHD's site or would buy the land from KHD, but no agreement was reached. Finally, it was decided to build the center in Porz-Lind, about 12 km away from the factory. Outsiders doubt the overall profitability of the current combination which consists of having, on the one hand, an automated material flow into and out of the trucks and, on the other hand, human-driven trucks. While the geographic separation has been already implemented, its economic impact must be re-assessed since KHD's new engines sales are below expectations and the factory continues to operate below the break-even threshold.

A Distribution center just for KHD

As mentioned above, 'Stute' also planned to offer its logistics system designed for KHD to other firms. If this move materializes, KHD hopes that the outsourcing services would then become cheaper. Currently, such synergy effects are found in the distribution of consumer goods, e. g. in shared stocks of different retail chains. However, no examples are known in the context of storing and handling specified products like engines and engine components. Consequently, the distribution center, which was designed for more than one customer, will most probably end up being used only for KHD in the end.

Thus, the arguments for outsourcing the center and the external logistics can no longer be based on potential synergy effects. The question about the optimal degree of specialization versus integration of different production functions under the roof of the own company springs up again.

Future Issues

Limits of Teamwork?

Despite KHD's positive description, concerns are raised[14] that the team-work concept not only results in philanthropy but also in pressure to make profit. Many managers have recently realized that effectiveness cannot be reached by strict control. The former tasks of the department heads are now transferred to group pressure. Psychologists warn that the euphoria concerning team-work will decrease after three years. For example, the employees' new knowledge and the encouraged ambition cannot be fully applied in the flat hierarchical standards. Can the 'group-philosophy' sustain one of KHD's core success factor in the future?

In this context it is also interesting how the intended Zero-Defects-Strategy can be more than a common goal. Where humans work, errors are made and each additional quality control creates additional costs.

The Right Product for the Right Market?

Although water-cooled engines have significant advantages over the previous generation of air-cooled engines, the market has not yet fully accepted KHD's new engine types. The question is, when this will happen, especially taking into account KHD world-wide reputation for its air-cooled engines. Another question is if KHD's competitors will be able to produce similar engines 'just in time' when the customers will be ready to integrate them into their machines? Will it pay off to have been the innovator, or will followers make the big money with lower and later investments?

How reliable are announcements by the European Union that emission standards will become tougher Europe-wide? Will customers accept an advanced product as long as they are still able to use older ones? Concerning the limitations of the engines' size, is it safe to assume that - with regard to volume - engines will not significantly 'grow' with future technological developments? The new factory with its state-of-the-art technology, production and logistics concepts, and employees can only be profitable if KHD can sell enough engines. Capital investments are less flexible than investments in manpower. In case the break-even cannot be reached (at planned prices), the impressive building with all its innovations would only widen the hole in KHD's financial pocket.

Outlook

KHD has shown a remarkable creativity in the design of their 'Vision 2000' factory. It integrates a vast amount of logistical know-how in combination with state-of-the-art information technology. On the one hand, KHD was thus able to reduce its unskilled labor force, an important advantage in times of already high and ever rising labor

14 See Lamparter, D.H · Schoene neue Fabrik, in: Die ZEIT, 14.04.1995, p. 26.

costs. On the other hand. KHD can still offer customized products at reasonable prices. It is probably safe to say that the competitive advantage lies in the mix of these two. This advantage of KHD's 'Vision 2000' IT-based logistics concept is bound to lead it to success.

> "Many of our ideas can be seen in numerous engine factories around the globe. The consequent implementation of a comprehensive concept though. cannot be found in any other diesel engine factory in the world. Decisive for success is the efficient combination of modern manufacturing components. highly committed personnel. as well as the absolute will to succeed."
>
> Hartmut Meinecke KHD Project Manager 'New Factory'

Lessons Learned

The main lessons that go beyond the production of diesel engines can be summarized as follows:

- Within the production chain of machines with diesel engines EDI standards are not widely applied et. Nevertheless. the case of the KHD diesel engine factory shows that 'EDI' within a company or even within a production facility promises efficiency advantages. These advantages also occur if adjustments at the company's boundary are to be achieved 'manually' engine by engine.
- The case provides an example of how IT applications can contribute to produce 'customized products in 'quasi mass production' facilities. Once such a customization gains market acceptance. customers will most likely understand the potential benefits of inter-organizational EDI systems. The latter will not be crucial as long as diesel engines are produced 'on stock'.
- The close cooperation between KHD and the distribution center operated by Stute shows state-of-the-art application of IT-based logistics for customized 'mass products'. From an IT-perspective. it is irrelevant whether the involved systems are to be considered inter-organizational or intra-organizational. Outsourcing the distribution center is. however. at least questionable from a management point of view. Interesting enough. this is true although IT-based information sharing, EDI. and integrated process automation work beneficially for both parties.

This last point opens several questions which have traditionally been discussed in the outsourcing literature. and which recently were also brought up under the topic of 'virtual enterprises'. The KHD case, taken from an industry which is not at the forefront of virtualization. might enhance a more theoretical discussion by outlining some critical issues based on a real-world story.

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