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# Factors affecting the development of information systems in Japan: pioneering experience in the steel industry

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**Abstract:** This paper reviews the development of information systems in the Japanese steel industry, from the end of the Second World War to the early 1990s. Five distinct periods of development are identified and characterized.

**Keywords:** information systems; Japanese steel industry; steel manufacture; management information systems; order entry system; on-line control systems.

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**Abbreviations:** The following abbreviations of company names are used in this paper:

| | |
|---|---|
| Nittetsu | Nippon Iron and Steel Co. |
| Yawata | Yawata Iron and Steel Co. |
| Fuji | Fuji Iron and Steel Co. |
| NKK | Nippon Kokan K.K. |
| Kawatetsu | Kawasaki Steel Corp. |
| Sumikin | Sumitomo Metal Industry Co. |
| Kobe | Kobe Steel Co. |
| NSC, Shin Nittetsu | Nippon Steel Corporation (Shin Nohon Seitetsu) |

(Yawata and Fuji merged to form NSC in 1970.)

## 1 Introduction

The Japanese steel industry played an important role in the economy throughout Japan's period of rehabilitation and growth following the Second World War. In the 1950s and the 1960s, it transferred licensed technologies from the USA and Europe. After 1965, industry rushed to construct new steel works, adopting the newest management methods and technologies in steelmaking as well as in related computer applications. The world's first on-line production control system in the steel industry was implemented at the Kimitsu Works of the Yawata Iron and Steel Co. Ltd in 1968 [1], and other Japanese

Thus, by the end of the 1970s, the Japanese steel industry's information systems were widely regarded as surpassing those of other domestic industries as well as of foreign steel industries [2; 3]. This led, in turn, to increasing technical cooperation with European and later with US industries.

During the 1980s, progress centred on the enhancement of various management support systems and of information network systems, including those of trading companies. In time, steel companies established their information system divisions as subsidiary companies to serve as leading system integrators for other industries.

This paper seeks to analyse the processes whereby information systems were developed in the Japanese steel industry on the basis of the author's participation in developing Kimitsu's on-line system as well as his technical cooperation experience with European and with US steel companies.

The analysis focuses on four important factors whose combination at the right time promoted the development of information systems in the Japanese steel industry. These were:

1. the economic environment in which the steel industry was placed;
2. the prevailing technologies and management organizations;
3. the availability of needed human resources; and
4. the construction of new steel works for which information systems were to be developed.

The analysis divides the development into five periods, with especially detailed analysis of developments from 1965 to 1972, because certain unique features of these applications originated during that period. (For a more detailed review of related developments in other periods, see reference [4]).

## 2 Post-war rehabilitation period (1948–50)

Because of heavy damage during the Second World War, steel production in 1946 was only 677,000 tons. The so-called 'Inclined Production Plan for Coal and Steel' was initiated in 1947, and a policy of reducing government subsidies to the steel industry further encouraged rationalization efforts [5, p.41].

In 1949, besides NKK (Nippon Kokan), three companies – Kawatetsu, Kobe and Fuso (renamed Sumikin) – were permitted to restart as integrated steel companies [6, pp.33-34]. In 1950, the semi-nationalized Nippon Iron and Steel Co. was forcibly separated into two private companies, Yawata and Fuji, thereby forming the 'Big 6' integrated steel companies. (A full list of abbreviations of company names is given at the start of this paper.)

In 1955, the Steel Productivity Mission was sent to the USA. The effects of the visit were reflected in the various sectors of operations. Even though information systems activities had not yet started, fundamental techniques such as industrial engineering, instrumental and automatic control were being introduced [5, p.79], thus providing the foundations for later computerization.

## 3 First and second rationalization programs (1951 to 1960)

### *3.1 The First Rationalization Program (1951 to 1955)*

Influenced by the worldwide expansion of steel demand caused by the Korean War, the First Rationalization Plan was prepared. Its main objective was to replace rolling mills which had been devastated during the war, but realization of the plan was delayed until 1955. In the meantime, various new technologies were being absorbed from the USA and Europe, along with a substantial modernization of equipment, mainly in rolling mills. As a result, steel production doubled between 1950 and 1955 [5, p.60, p.70], although employment had increased only from 164,000 in 1950 to 184,000 [6, p.1005] as shown in Figure 1.

### *3.2 The Second Rationalization Program (1956 to 1960)*

Reflecting the so-called 'Jimmu Boom', the Second Rationalization Plan sought to expand steel production capacity through the construction of the newly located Tobata, Mizue and Nadahama Works, as well as through the expansion of existing Works. The total amount of investment reached ¥644 billion and resulted in 10 new blast furnaces, 15 LD converters, and various associated rolling facilities [5, p.91].

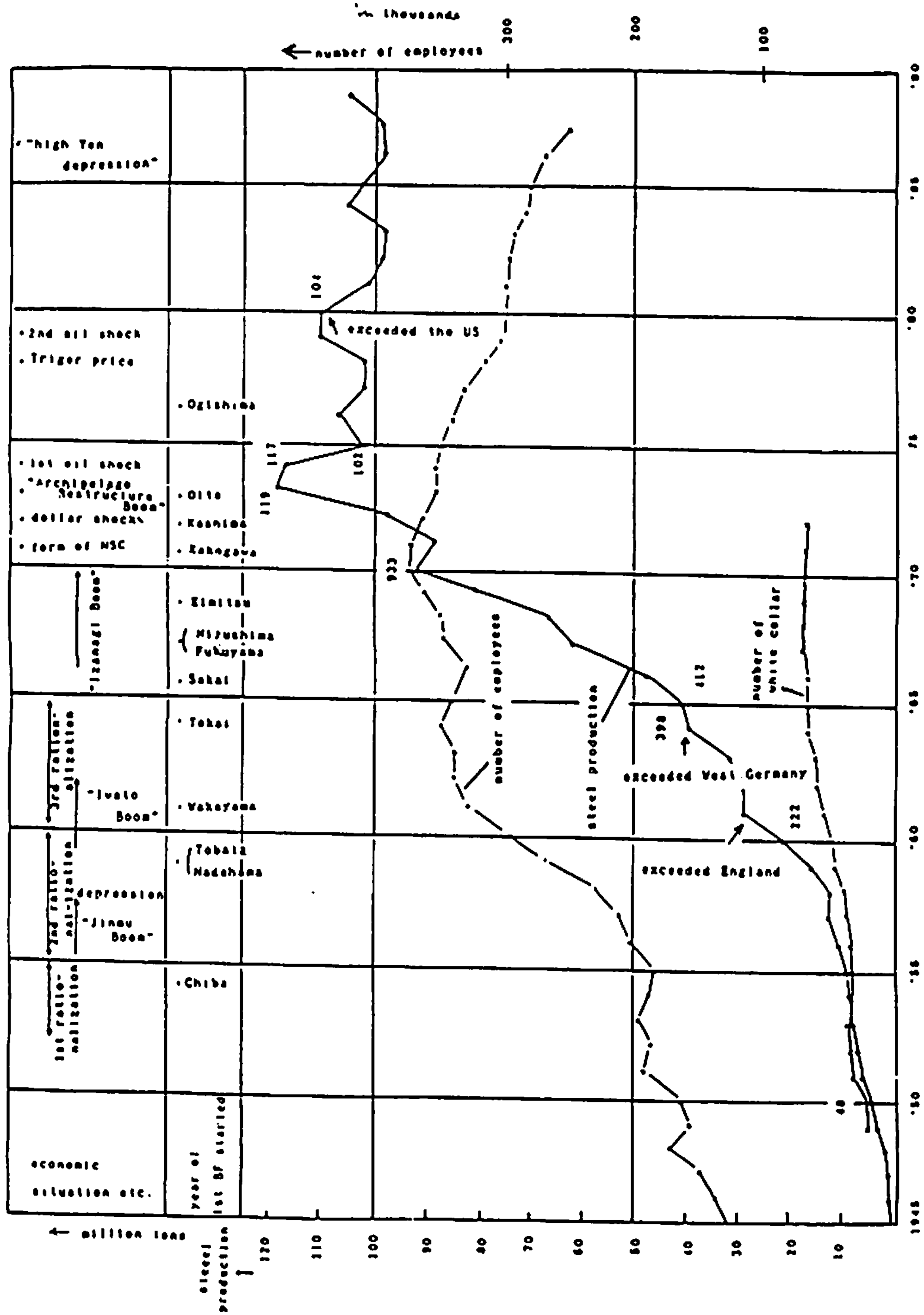
Technologically, various types of advanced equipment such as LD converters, continuous casters and strip mills were introduced from the USA and Europe. Also, modern American management concepts, such as the 'foreman' system and related operational know-how, were also widely studied and applied in modified forms thus helping to provide the foundations for later information activities. With the completion of this Second Program, steel production had increased from 11.1 million tons in 1956 to 22.1 million tons in 1960 [9, p.7].

During this period, the total number of employees rose from around 200,000 (of whom 31,000 were white-collar) in 1956 to 300,000 (of whom 48,000 were white-collar) in 1960 [6, p.1005]. To illustrate the nature of the associated changes in direct labour employment, the Yawata Works (from which many employees were later transferred to newer plants) hired about 3,000 high-school graduates under 25 years old from 1955 to 1957, and nearly 12,000 more young highly-educated workers from 1958 to 1962 [15, p.454]. Similar phenomena were observed in the other steel companies. Such workers obviously played an important role later in running the automated mills of the newly-built steel works.

### *3.3 Development of information systems in the steel industry*

The first punched card system (PCS) was installed in the Japanese steel industry in 1952. Its main purpose was to increase the productivity of white-collar employees so as to cope both with the rapid increase of production and also with other new higher-level management activities. Each steel company gradually extended the use of PCS to various daily transaction processing tasks in the early 1960s, gaining application know-how in the process and also introducing various needed standards and code systems [15, p.362; 20, p.141; 18, p.488].

Figure 1 Trends in Japanese steel production since 1945, and some related events




It is worth noting that each of the Japanese companies put more emphasis on early applications in production than the American steel companies. For example, at the Yawata Works, daily, 10-day, and monthly slab yard and ingot yard material reports began to be prepared by PCS as early as 1959 [15, p.368].

New management concepts and systems such as production control, industrial engineering, quality control, cost control and office work rationalization were introduced from US steel companies, beginning in 1951. For example, a rationalized management organization and related systems were designed and installed in the newly-built Tobata area of the Yawata Works. Here, a line and staff organization as well as a foreman system were introduced for the first time in the Japanese steel industry.

Also, a newly-designed centralized production control system began operation, utilizing actual production data recorded by three shifts of high-school graduates and sen by pneumatic tubes to the centralized control office. There, the data were processed by PCS as the basis for controlling production activities [14, p.464]. This new organizatio and data-handling system provided strong motivation and a valuable model fo constructing on-line-controlled steel operations at the Kimitsu Works.

## 4 Expansion of the steel industry

### 4.1 *The Third Rationalization Program (1961 to 1965): Further developments in the steel industry and management related needs*

Based upon the so-called 'Double-Income Plan' announced in 1960, the Thi Rationalization Plan targeted steel production at 38 million tons in 1965 and 48 millic tons in 1970. In accordance with the Second Rationalization Plan, construction of tl Wakayama, Tokai (renamed Nagoya), and Sakai Works was already progressing.

In addition, the Third Rationalization Plan provided for the construction of five ste works at coastal locations: Kimitsu, Oita, Mizushima, Kashima and Kakogawa Worl Encouraged by the so-called 'Iwato Boom' in 1959 and 1960, such plans called f maximum additions to capacity. However, from 1962 to 1965, the steel industry faced most difficult period since the end of the war, necessitating reductions in production well as in costs [6, pp.30–40; 9, pp.6–7].

The total number of employees in the steel industry was around 335,000 (of wh 54,000 were white-collar) in 1961, and rose only to 343,000 in 1965 (of whom 63,0 were white-collar), compared with the concurrent doubling of steel production [7, p.54 It is also worth noting the changes in employment of white-collar workers as illustra by the Yawata Works, where about 3,200 salaried employees and engineers ne graduated from high schools or universities were hired between 1955 and 1 [15, p.454]. Having gained sufficient training and experience at the mother steel work Yawata, a fair number of them later participated in the design, construction and operat of the Kimitsu Works. And other steel companies adopted similar human resou training and transfer policies to support their expanding and technically more advan operations.

*industry*

Just after the announcement of the IBM 7070 computer, NKK and Yawata each installed one in 1961. The rental fee for the machine at Yawata was about ¥13 million per month, which corresponded to the pay of more than 300 employees [15, p.371; 7, p.539]. This was a significant decision by top management, from the standpoint not only of raising office work productivity but also of providing opportunities for the more advanced training of the young staff members. Other steel companies, too, had installed a variety of second-generation computers by 1962 [11, p.586; 18, p.490; 19, p.626].

Each company was eager to develop batch-type data-processing applications in its steel works, especially production-related office work [24], in order to comply with management efforts to increase production to maximum capacity while minimizing increases in office workers and also decreasing production costs.

## 5 Arrival of the age of 100 million tons of steel production (1966 to 1973)

### *5.1 Start up of the gigantic new steel works*

In accordance with the Third Rationalization Plan, the construction of gigantic new steel works and the start-up of their huge blast furnaces began with Tokai (renamed Nagoya) in 1964, and progressed through the successive construction of Sakai, Fukuyama, Mizushima, Kimitsu, Kakogawa, Kashima, and finally Oita in 1972. As a result, steel production increased rapidly from 41.1 million tons in 1965 to 119 million tons in 1973 [8, p.22].

The Japanese economy enjoyed the so-called 'Izanagi Boom' from 1966 to 1970. Also, in 1970, Yawata and Fuji merged to form the Nippon Steel Corporation (NSC), which became the largest steel company in the world. The so-called 'dollar shock' in 1971 forced intensive rationalization efforts in Japanese steel companies, involving increased use of LD converters and continuous casters. Also, anti-pollution problems had become serious issues in the latter part of the 1960s. Although economic circumstances turned more favourable during 1972, the 'oil shock' in the Fall of that year forced the economy into another period of decline [8, p.24].

Starting in 1963, increasing demand for labour from the consumer goods industries caused a shortage of labour in Japan. And increasing economic growth from 1968 to 1973 caused the shortage of young labour to become serious. As a result the total number of employees in the steel industry rose from about 343,000 in 1965 to a peak of 379,000 in 1970, and then decreased to 356,000 in 1973 [7, p.548], despite the fact that during the same period seven gigantic new steel works had started operations and steel production had nearly tripled.

This amazing achievement resulted from well-prepared plans by each steel company to rationalize management, modernize facilities, adopt computer systems as well as automated operations, and transfer substantial numbers of young but experienced employees from the older steel works to the newly constructed ones.

Of course, the increased supply of steel resulting from the opening of numerous gigantic new works resulted in keen sales competition.

### *5.2 Need for more advanced information systems in the steel industry and their development*

All of the gigantic new steel works had been constructed within ten years after 196[illegible] [8, p.701]. All had developed similar hierarchically structured on-line productio[n] management and control systems as shown in Figure 2 and Table 1 (taken from referenc[e] [23, pp.136,138]), which were regarded as high-level achievements.

**Table 1** Hierarchy of system control level

| *Control level* | *Span of control* | *Control cycle* | *Control objectives* | *Main job content* |
|---|---|---|---|---|
| A | Whole works | Daily for 10 days | Planning processing date | Order acceptance, order modification, material request, progress status, production and shipment records |
| B | Plant | By day, by shift | Scheduling by day, by shift, based on processing date and actual results | Data gathering (by day, by shift) prepare instructions for shift, decide quality |
| C | Main equipment | By shift, by few seconds | Delivery instructions and data gathering | Delivery instructions, display, inquiry, reportir |
| D | Each workstation in plants | Within few seconds | Give work instructions and control | Optimization, automatic control |

Mass transfers of workers took place within each company, supported by go[od] relationship between management and labour unions. For example, in the case of t[he] Kashima Works of Sumikin, 2,675 workers were transferred in from its Wakayama a[nd] other works, in addition to 3,100 newly hired workers [21, p.31].

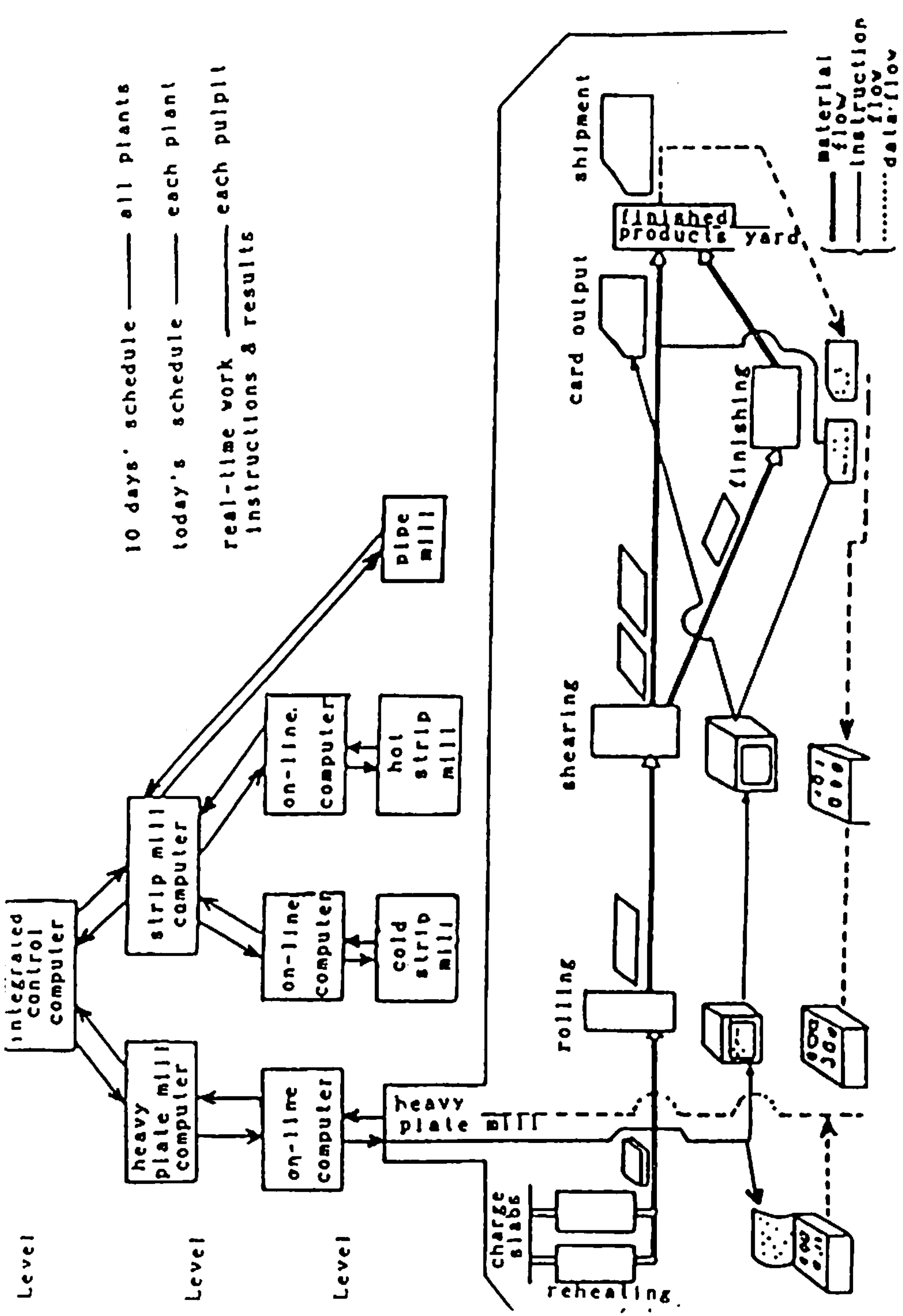
The discussion will now focus on the development of the on-line system at t[he] Kimitsu Works for two reasons: first, because it was the world's first implementation [of] an on-line steel works system running 24 hours a day; second, because the auth[or] participated in designing the system.

#### *5.2.1 Management's need for improved information systems*

Management needed improved information systems for three reasons:

- to contribute as soon as possible to increasing production;
- to reduce manpower requirements in order to adapt to labour shortages; and
- to improve competitiveness in respect of cost, quality and delivery terms, in spite o[f] the smaller lot sizes and frequent changes of orders caused by severe market pressures [10, p.569].

Figure 2 Concepts of production control at Kimitsu Works (as of 1968)




### 5.2.2 *Developing the organization of the information system*

The construction of the new Kimitsu Works was pursued as a company-wide project [15, p.455]. The Yawata Works, which is located nearly 1,200 kilometres west of Kimitsu, played the role of the 'Mother Works'. In January 1967, the Kimitsu Project Bureau was organized at the head office of Yawata. It was responsible for establishing management policies in the design and construction phases of the new works, while the Construction Bureau, which had already existed for many years, was responsible for the actual design and project management of plant facilities and the relevant computer software.

The management policy requirements were clarified by the Project Bureau as follows:

1 development of an organizational structure and systems which would realize the maximum benefits of the consumer-oriented works location;

2 unprecedented pursuit of manpower efficiency; and

3 maximum employment of computers.

These policies, combined with the accumulated experience in management and technology, resulted in the following innovative design philosophy for the works:

> "In the new steel works, plants as well as their lay-out and operational methods should be designed on the basis of the state of the art in automation, on-line management and control technology of the time" [16, p.525].

In accordance with this policy and the associated design philosophy, such groups as the batch-type system, the on-line control system, and the process computer control system - all of which were organized in the Construction Bureau – worked together to carry ou: the integrated production management and control system in parallel with the design anc the construction of the plants, which were carried out by specified plant design groups withir the same Bureau [10, p.575]. These systems groups were a mixture of engineers an specialists from various functional fields, and *they taught their specialized functiona capacities to each other so as to integrate related functions.*

From the Yawata Works alone, 580 system-related engineers and specialists wer transferred to the Kimitsu Works in the latter half of the 1960s. From 1964 to 1969 another 2,600 workers were transferred to Kimitsu, some of whom became operators c the mills through computer terminals [15, p.455]. One of the most important elements i the project's success in the author's opinion, was that this large number of employees ha enough experience to understand the actual jobs but not so much as to become reluctan to change from conventional to innovative methods.

## 5.3 *Challenges to advancing beyond the accumulated technology in conventional works*

In addition to the transfer of personnel, a variety of other technologies and systems Yawata and other works were transferred to the Kimitsu Works, where they we integrated with one another and restructured into innovative management, equipmen operations and control systems as summarized below.

### 5.3.1 *Computer utilization technology*

At the Yawata Works, batch-type computerization of quarterly and monthly productic planning, as well as of actual production data gathering, had been realized in parallel wi the development and application of planned costs, profit forecasts, and actual cost determinations [24; 15, p.372].

### 5.3.2 *Process computer and automation technology*

In the Tobata area of the Yawata Works, mathematical models for computer control of LD converters and hot strip mills had been studied on the basis of technology transfers from the USA, and then applied to operations in 1964. Experience with these process computer controls and related communication technologies contributed substantially to the widespread use of process computers as well as of on-line business-use computer applications at the Kimitsu Works [10, p.306; 15, pp.168; 22].

### 5.3.3 *Organizational structure, production management and control*

At Tobata, a batch-based monthly and daily shift production management and control system was functioning rather successfully [23, p.133]. This system was designed to incorporate: the line and staff system concept; use of a centralized production staff combined with three-shift data dispatchers, who transmitted work instructions as well as actual data through pneumatic tubes; and batch-based data-processing computers and operators. Studies seeking to change this batch-based system into an on-line system were started in 1965 and although they did not succeed at Tobata such efforts contributed significantly to the eventual realization of an on-line system in the Kimitsu Works.

However, the batch-based heavy plate production system at Yawata, which enabled each plate to be guided through selected successive processes through the use of an accompanying card sent through vacuum tubes, was already operating successfully to support production of 120,000 tons per month [10, p.571].

### 5.3.4 *Industrial engineering (IE) and related technology*

In the report of the Steel Productivity Mission sent to the USA in 1955, the importance of the IE function in supporting efficient management was stressed. Typical activities of IE in those days involved the promotion of standardization, plant studies to promote production efficiency, and the use of operations research (OR) techniques to design improved plant operations [15, pp.33–39].

### 5.3.5 *New information-system-related technology: a challenge to the on-line system*

Through experience with the conventional systems adopted at the Yawata Works, the following findings were confirmed:

1. improved management control could not be attained due to the several days' delay in preparing production reports;
2. a substantial amount of personnel seemed to be indispensable;
3. it would be very difficult to convert the conventional system into a new on-line system due to the reluctance of related personnel [23, pp.33–39].

Because of these findings, it was generally agreed that the new on-line production systems at Kimitsu should be designed simultaneously with the design of the plant's layout, operations and staffing.

The new on-line systems were also necessitated by the difficulty of hiring workers. With the new system, the mill operator himself could receive work instructions from displays in front of him. If the production were then carried out as instructed, the application of the work instructions could be reported automatically as actual results; only in cases when actual production differed from the work instruction would the actual data have to be keyed in by the mill operator. It would thus be possible to reduce the number both of three-shift data-gathering workers, and of input errors, while achieving high levels of mill operations as well as guaranteed attainment of a high percentage of work instructions (for detailed discussion see [1; 25]).

On-line control of integrated steel works, however, requires unprecedentedly severe computer utilization conditions to ensure 24 hours of continuous operation every day throughout a year. Fortunately, the 'third generation' IBM 360 computer was announced in 1964, thus eliminating the hardware obstacles to continuous operations by the time the Kimitsu Project started. As for on-line applications, the Tokyo Olympic Games and th Mitsui Bank had already begun to operate their IBM 1440 systems in 1965, althoug these involved less severe operating conditions than in steel works. Thus, the staff wer able to study on-line systems inside and outside Japan before designing for Kimitsu' needs. In steel companies in Europe and in the USA, only small-scale experimental on line systems were observed. Domestically, studies were made of newly constructed stee works, such as the Fukuyama and the Mizushima Works. However, in these applications the primary focus of interest seemed to be more on process computers. Thus, it becam clear that the Kimitsu staff would have to solve their own difficult problems [10, p.572].

In particular, Kimitsu had to develop, with the support of mainframe and instrumen suppliers, technologies to:

1. transmit data between remote terminals and centralized computers;
2. use magnetic disks to store and process large amounts of production data; and
3. manage both hardware and software, such as a disk operating system.

Even though most of these technological problems had not yet been solved, Kimitsu's tc management, supported by the challenging spirit of the young staff, decided to develo an on-line system. After three years of intensive efforts, the world's first all-on-lin (AOL) system – which covers all processes from steelmaking to the shipment of produc – had successfully completed its initial stage in 1969.

The upper limit of the investment to be made in computer hardware was set by th amount of manpower cost saving to be gained through adopting the system, and wa actually kept well under that limit. Thus, the merits both of cost saving and of improve management control were achieved. The manpower required to develop the system w about 200 man–years [23, p.138], and the resulting savings were estimated as equivale to 2,200 to 2,300 plant workers [36, p.17]. (For the general concept and detail explanation of the system at the Kimitsu Works, refer to [1; 25]).

## 5.4 *Key elements in the success of the world's first on-line production management and control system*

Key elements in the success of AOL can be summarized as follows [10, p.573]:

- top management's clarification of the needs of information systems as the basis for positive decision-making;
- provision of adequate staff levels of well-trained employees with application experience accumulated at Yawata and other existing works;

- company-wide cooperation with the Kimitsu Project Bureau;
- integration of all the related plant facilities, hardware as well as software design and implementation functions within the Construction Bureau;
- participation in the system design phase of mill operators who were expected to use the on-line terminals; and
- the eagerness of employees to take responsibility for attaining progressively higher levels of production performance, thus supporting reliance on the concept of management by exception.

So far, only the case of Kimitsu has been described here. However, although their timing was somewhat delayed, the system development efforts of other Japanese steel companies were similar to those of Kimitsu. Thus, during the five years after 1966, computer application systems in the Japanese steel industry achieved remarkable progress compared with those in Europe and the USA.

### 5.5 *Expansion and integration of systems in new steel works and technical cooperation with other countries*

The initial stage of construction of the Kimitsu Works was completed in 1969 and was followed by a second stage involving the construction of No.3 and No.4 blast furnaces, as well as other related facilities. Besides the development of operating systems for each plant, the total production management and control systems were restructured. Quality control, budgeting, accounting and cost-control systems were also developed and gradually integrated into what was named the KIIS (Kimitsu Integrated Information System) [1; 16, pp.530–547].

With the KIIS model successfully developed and operating, technical cooperation projects in the field of systems for integrated steel works were started for the first time both in Brazil and in Italy in 1972. Since then, similar technical cooperation projects have been extended to several other steel companies in Europe and in the USA by Nippon Steel and by other Japanese steel companies [8, p.656].

### 5.6 *Implementation of order entry systems (OES)*

With the expectation of a rapid increase in steel production, each company had to plan to distribute its orders among several mills at different locations. Thus, each company started designing OES, and most of them were implemented in the latter half of the 1960s [10, p.582; 11, pp.307,603; 18, p.493; 19, pp.137–140].

In the case of Yawata, for example, the OES study team was sent to the USA and Europe to review recent advances. Taking into consideration both their findings and distinctive Japanese business practices, centralized systems were developed consisting of product-by-product sub-systems and also providing for the balancing of mill operations, but without including customer credit arrangements because these were mostly taken care of by trading companies. Owing to the merger of Yawata and Fuji to form the Nippon Steel corporation in 1970, the two systems were restructured into a new one which started operations in 1972 [10, p.582].

## 6 Countermeasures to deal with the oil crisis and qualitative changes in management since 1973

### 6.1 *The changing environment of the steel industry*

Japan's steel production reached a peak of 119 million tons in 1973. However, because the world 'oil crisis' in the Fall of 1973 and resulting damage to the world economy, ste production decreased in 1974 and remained close to 100 million tons until 19 [8, pp.24–25]. At that time an improvement in the steel market, despite widesprea efforts by industries to reduce consumption, accompanied by strong rationalization effor in each steel company, made 1979 the most prosperous year since 1973.

Thereafter, the worldwide depression from 1981 to 1982 decreased domestic ar foreign steel demand. In addition, the Japanese economy faced a depression because the progressively higher Yen/Dollar exchange rate after 1986. As a result, Japanese ste companies accelerated their efforts to diversify into such new areas as engineering, ne materials, electronics and information services [9, p.48].

### 6.2 *Restructuring of production management and control systems*

Since the first 'oil crisis' in 1973, measures to deal with the increasing intensity of sal competition and to save energy have been a major concern of management. In response variety of innovative improvements in steel manufacturing processes were introduce Typical examples included:

- changing from separate ingot-making and slabbing processes to the continuous casting process;
- charging hot slabs into hot rolling mills directly from the continuous caster (direct charged rolling); and
- changing from the batch annealing to the continuous annealing process in cold-rolling operations [9, pp.277–280].

But changing to a continuous casting process could not be realized without restructuri parts of the system, including the replanning of material flows, and the elimination time and space buffers in the continuity of operating processes. The direct charge rolli process facilitated further savings of energy in addition to shortening processing tir from steelmaking through rolling. However, such advances required a sophisticat restructuring of the systems not only to synchronize complete process controls from L converters through rolling mills, but also to integrate both production and qual controls. Each company has had to develop high-level production management a control systems integrated through process computers in order to achieve satisfacto results [26, p.11]. A general assessment of the effects of computer systems as of 1981 shown in Figure 3 (taken from [33, p.19]).

### 6.3 *Later restructuring of the order entry system (OES) and elaboration of the management information system (MIS)*

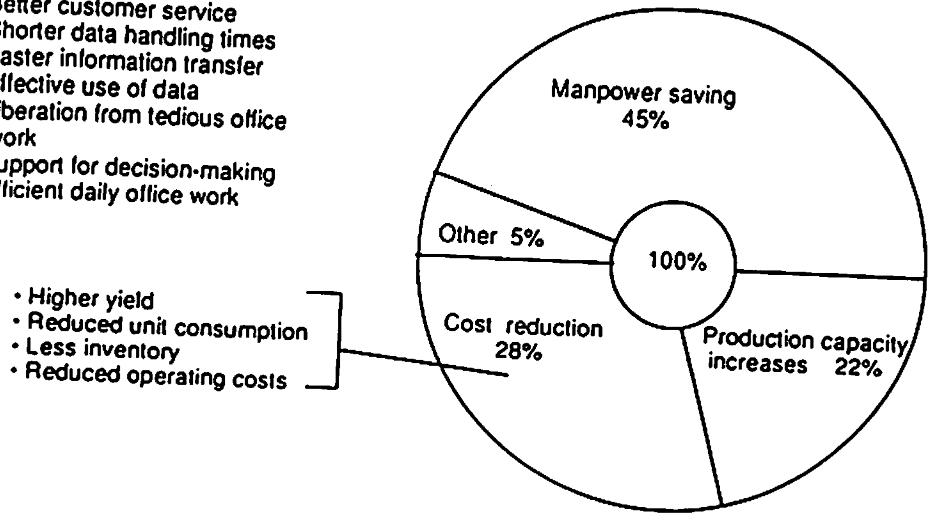
After the first 'oil crisis', the sales environment changed towards enhancement of produ quality and diversification of products. Consequently, each company started restructuri its OES around 1983. Common objectives of the new systems were [27; 30; 31]:

**Figure 3** Effects of the use of business computers in Nippon Steel Corporation (as of 1981)

(1) Qualitative effects:

- Better integrated control
- Better customer service
- Shorter data handling times
- Faster information transfer
- Effective use of data
- Liberation from tedious office work
- Support for decision-making
- Efficient daily office work

(2) Quantitative effects:




- to cope with the increasing production of multiple products in small lots;
- to receive orders from trading companies through on-line communication lines; and
- to facilitate the mutual use of information among such functions as the sales, production, and transportation of products.

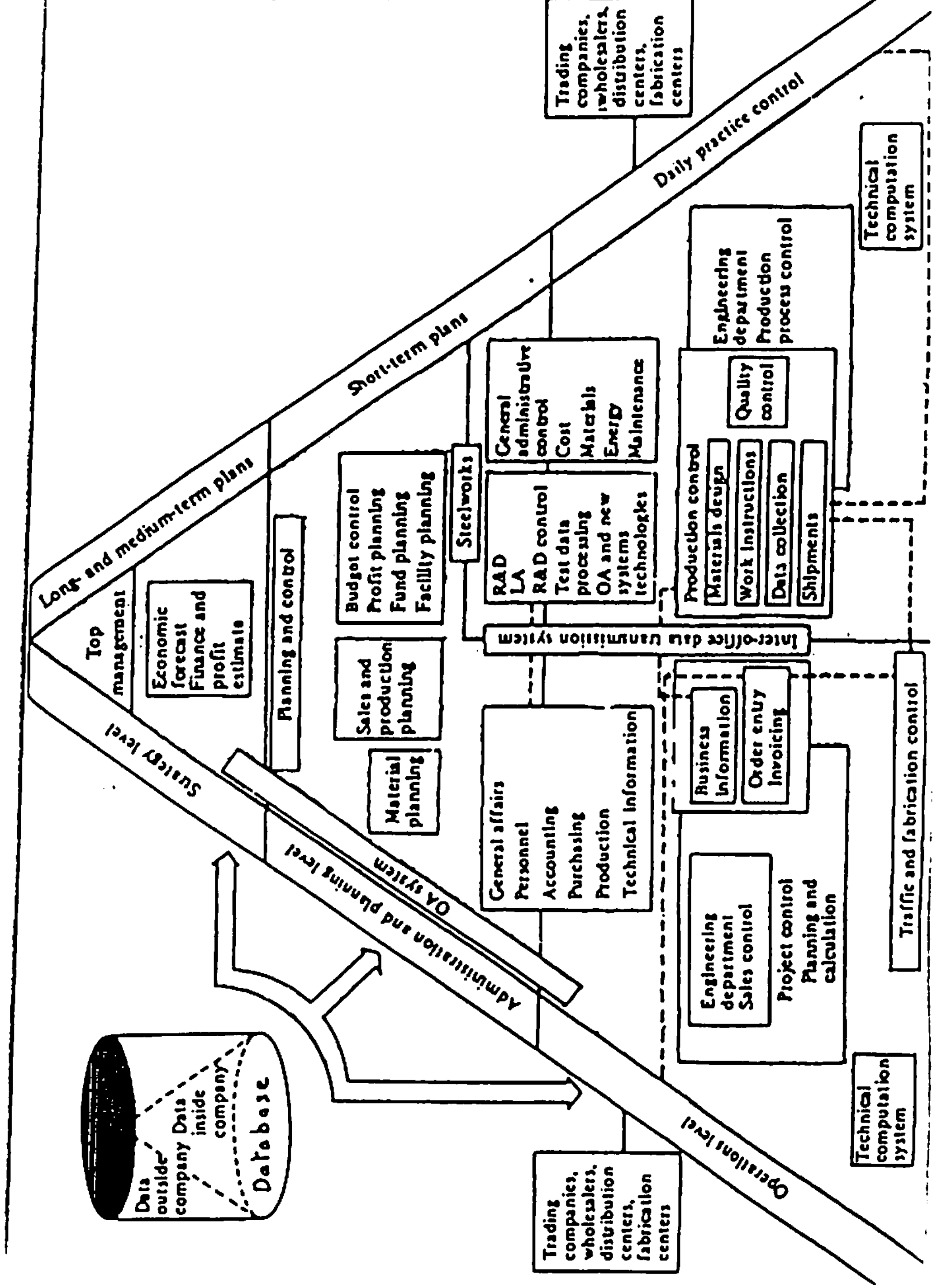
Parallel with the development of operational level systems, such as order entry and production control, each company was eager to elaborate its management information system (MIS), which covered almost every level of every function in management by the end of 1970s. The enhancement of MIS continued in each company at strategic as well as management levels and through increasingly effective integration of various functions [28; 29; 35]. A typical structure of MIS as of 1987 is shown in Figure 4 [34, p.16].

## 6.4 *Establishing the independence of system divisions as subsidiary companies*

By the late 1970s, the shortage of systems engineers and programmers was widely recognized, and each company was eager to increase its system development productivity as well as to rely more on outside software houses [32, p.33].

Several subsidiary software companies had been established by the steel companies around 1975, and towards the end of 1985 the dominant parts of their system divisions were organized as subsidiary companies. The main objectives of such separations were: first, to make profitable use of the system integration technologies which had been developed within the steel industry; and, second, to learn from target applications in other industries as a basis for further enhancing the capabilities of computer technologies, and thereby also contributing to the further development of information systems in the steel industry.

**Figure 4** Typical utilization pattern of management information systems in the Japanese steel industry (as of 1987)



## 7 Concluding comments: factors affecting development of information systems and their future role in the steel industry

In short, the key factors affecting the development of information systems in the Japanese steel industry were:

- clarification of the information needs of management at the time;
- pioneering the adoption of these new technologies;
- training and utilization of an increasing number of highly educated interdisciplinary personnel; and
- the construction of new steel works, utilizing the expanding capabilities of information systems.

These four factors were developed and combined under highly favourable conditions. The first round occurred between 1961 and 1965 with the introduction of batch-type systems in new steel works, which were introducing advanced facilities and technologies as well as management systems and which were also hiring and training large numbers of new and well educated personnel. The second round occurred between 1966 and 1973 with the development and application of on-line systems in these gigantic works, utilizing the accumulated technologies and expertise developed earlier. The third round, which occurred after the 'oil crisis', involved advancing production processes with the support both of sophisticated production control systems at the works and of enhanced management support systems at the head offices. During that decade, such developments in the steel industries of other countries lagged for a variety of reasons which have not yet been fully explored.

However, demand for the Japanese steel industry's products has not grown since 1973. Hence large investments in the construction of new steel works in Japan cannot be expected in the near future. This means that there will be less opportunity to develop design for new large-scale plants, except in restructuring existing facilities. In these circumstances, it may prove more difficult for the industry to develop major advances in technology, to keep recruiting highly-qualified personnel, and even to retain younger experienced system development engineers.

In order to overcome such restrictive horizons, it is important to increase explorations of potential applications in other industries where the steel industry's accumulated experience and technology are still urgently needed. And, of course, the acquisition of practical experience in such new environments would be highly likely to contribute to the enhancement of information systems in the steel industry. Within this perspective, the separation of system divisions into subsidiary companies may well contribute significantly to generating further advances in the competitive capabilities of the Japanese steel industry in future.

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