

## Supply Chain Management of the Iron and Steel Industry

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**Abstract:** This paper is to research on the development and achievement of inter-related production system between the enterprises that exist in a vertical industrial link from the material type industry to the processing / assembly type industry and in addition, on "Integrated business support system" that aims at efficiency improvement, the speed-up of development and production by the simultaneous and parallel promotion cooperation between the enterprises about a new product development. The research on the development of the production scheduling algorithm in the steel production developed as part of the integrated business support system is contained. It is emphasized that in the iron and steel industry, which is the model of the material type manufacturing, the construction of an agile system that can respond to a rapid market change may acquire high customer satisfaction measurement, which can be found in a fierce competition of the manufacturing enterprise intended for a general consumer. The concept that exists in the basis of the proposal is the revolution of the steel maker that sells the steel products to the enterprise that sells services.

**Keywords:** Supply chain management, Agile manufacturing, Integrated business support system, Scheduling algorithm, Variety and variable quantities production

### 1. Introduction

The iron & steel industry in Japan has played a major role as the basic industry to support industrial revitalization and consecutive rapid growth for Japanese economy after the world war II. The industry had acquired production equipment and technology to manage and to operate from the U.S. and Europe through the mid 1950's. Since then, advanced technology and production enhancement has been in progress by themselves, and such efforts supported

the rapid growth of Japanese economy, with construction of many iron & steel works with their own technology. The computer of IBM of the third generation was exactly announced at this time, and we succeeded in the original practical use of the online system on the process control side in the later half of 1960's for the first time in the world. The productivity improvement and the cost reduction are advanced to the utmost limit by enlarging and making continuously the construction of the speed-up equipment, and the adoption of the online computer system. As a result a large amount of high-quality articles of iron and steel have been produced at a low price. And, the revolution from past mass production of a limited variety of goods to the variety and variable quantities production becomes a pressing need with the continuous change of a social, economic structure and values there-in. As the iron and steel industry is a model industry in material type manufacturing, the construction of an agile system that can respond to customer need for the iron and steel to a great satisfaction and to a rapid market change is an important goal just as in the manufacturing enterprise intended for the end consumer that is competing fiercely everyday.

The concept in the basis of the proposal is the revolution of the steel maker from the enterprise which sells the steel products to the enterprise that sells service.

The steel maker should get rid of the idea enough if the cold-rolled steel, which is a material for the automaker, is matched to the delivery date described in the sales order. The steel maker itself hour by hour must understand the production change of the automaker who is the customer, and necessary amount of steel sheet production and the production start time must be decided by an own judgment and must be executed. It is an approach in the revolution proposed above, "The steel maker sells the automaker the service called a raw material supply", and an approach on "Connected production between the enterprises that exist in a vertical industrial link from the material type industry to the processing / assembly type industry".

## 2. Background and purpose

The annual production of crude steel in Japan had reached 22.18 million tons in 1960, and 41.16 million tons in 1965, exceeding the expected volume beyond the national plan for doubled income of the Ikeda Cabinet, and finally had reached the peak of 119.32 million tons in 1973, the year of oil crisis under the rapid economic growth. Since then, severe competition in the market had been tensioned with energy saving, and natural resource conservation.

The effect on the equipment side was to introduce continuous manufacturing, direct connection in addition to the enlargement up to this time.

Primarily, it is a rapid conversion from the Ingot – Slab mill method to the continuous casting method of the steel making process. The concept of the charge becomes thin by the change of material management of the steel from the ingot base material management to the continuous-continuous casting material management that casts continuously two or more charges. Moreover, time and the space buffer like the casting and cooling, heating, and the slab mill rolling etc. of the steel ingot disappeared.

Secondarily, it is an on-going straight direct connection with the continuous casting equipment and the hot rolling equipment

It comes to Hot Charge Rolling, by aiming at the heat use of the slab after continuous casting as much as possible for promotion of energy conservation, transporting it quickly to the heating furnace though it heats again with the heating furnace of the cooled slab in front of the rolling equipment so far. It advanced to Direct Hot Charge Rolling charged directly on to the heating furnace. In addition, it came to adopt a part of Direct Rolling that connected the hot rolling equipment and the continuous casting equipment directly by the transportation equipment, did not pass the heating furnace furthermore, and turned it on directly to the rolling machine. The middle buffer became an exceptional treatment, and the connected production control that lumped from the steel making, the continuous casting and hot rolling together became important because the continuous cast steel slab was kept in a high temperature and it rolled out at once.

Thirdly, it is a conversion from the batch annealing method to the continuous annealing method in the steel sheet making process. Electrolytic cleaning line, Batch annealing, Temper rolling, Finishing line; those four processes connected directly, and it is consolidated in one Continuous Annealing Process Line.

Enlarging, making continuously, and connecting directly are effective measures in mass production of a limited variety of products at the same time as effective to both energy conservations, factory worker reductions, and costs down. In the inside where a quantitative expansion cannot be expected, however, fine customer response by the quality, the delivery date, and the product development, etc. is indispensable for the marketing competition. In

large-scale, continuous, direct connected equipment is suitable for mass production. The development of small amount making technology and the development of the production management technology became an extremely important problem. Moreover, quick customer correspondence to the staff who plan and execute the project is indispensable to acquire high customer satisfaction measurement to the change in the market corresponding to promptness. The development of the integrated business support system as arms to make it increase staff's ability by a factor of how many and demonstrate became an important problem.

## 3. Research Process

The aim of this research is to establish the production system that efficiently produce multi- variety and variable quantity production, getting rid of mass production of a limited variety of products in the past.

The first objective is to manage every booked product individually for each customer. Not only the booked price, but also non-pricing value is quite important for customer satisfaction. By confirming the booked product to have the expected value of specification and quality for customer, a possible offering of proposal is expected to enhance customer satisfaction beyond their expectation. Such offering can be supported through comprehensive data base to manage the entire production flow as well as customer status. The data base should include status of every product at customer, customer statistics of quality and satisfaction on every product, historic data of production process of every product, progress report on production and delivery, cost and profit data at the plant, and so on. Such data base is the sophisticated combination of in-house data, customer data as well as sales distribution data. Such data base can be consolidated through communication network for active utilization. Prompt access to the data base on demand is also required to manage effectively. Conventional data base with the main frame computer has difficulty with prompt response on demand. The integrated management system to enhance efficiency of business activity, will solve the conventional inadequate business process, so as to provide prompt response on any requirement on business front end.

The second objective is to supply the demand of the product with quantity at the required timing to the customer. Most of issues on production management tend to be recognized as optimization of multi-variable combination with multi-constraints, which may be difficult to find the mathematically strict solution in most cases.

And so we aimed to obtain an excellent solution by a heuristic algorithm, in addition, the solution can be corrected by the man-machine interactive mode, and the solution with high satisfaction rating of the target function with the highest needs can be obtained. The construction of the business system which had been treated by old-timer's staff's experience and intuition is advanced on

the integrated business support system base so far, about the optimization of various problems like the production scheduling in the multi-step multiple process, the material assortments, and the manufacturing method multiple choice problems, etc

Let's review the feature of the steel production here. In the most of assembly production such as machinery, vehicle, electric house hold goods and so on, adequate delivery of parts with quantity at any required timing is a key for production management. Based on itemized production schedule, various parts are delivered for the assembly operation. Efficient production pushes adequate parts to supply at adequate timing with quantity. The Kanban method is one of the unique solutions for such an issue.

On the other hand, iron and steel production is, so to speak the branch type production, the process to split the original material into multi products booked. It is processed in the multi-step process consisting of the equipment of the batch processing type with a large-scale raw material, and it is divided piece-by-piece. The change of thickness, width, length, and making the quality are executed one by one by processing this multi-step process. Moreover, the same material is branched for different process line respectively on the way, become a different kind such as cold rolling products and the plated products. The orders are collected at the plan stage and the charge (for example about 350 Ton volume of the converter in the steel making plant) is assembled, and in an actual manufacturing process, the processing and the division branch are executed to the material one by one, and a suitable product will be completed each order at the end. Therefore, it is an important point to bring which order and which order together to fill the quality and the delivery date of the order, in which turn to process it in the converter and each process line to improve the utilization rates of each equipment and to minimize stocks between the processes.

The iron and steel product has been distributed in the market with on demand production. Booking triggers production through organizing raw material to fit into a single batch. Project material for construction of bridge etc. tends to have specific delivery date for the product. But, most thin steel plate for vehicle, electric house hold goods, food can and so on has no specific delivery date with quantity itemized at the time of booking due to their sales fluctuation in the market. However, the demand of the just in time delivery is strong, and we have stocked completed products at the factory warehouse and at the coil center to some degree, and we must correspond to the just in time delivery.

Product variation has been increased to respond various stringent high quality customer demands. Lead-time from booking to delivery is also significantly important. Frequent change of manufacturing condition of line is required to face such customer demands at each single line for different conditions of production. Lean change of manufacturing condition, with larger size of

production brings the best efficiency on production, on the other hand, increase intermediate inventory. On-time delivery of the thin steel plate should be maintained, while the actual demand is fluctuated. The flexible management of such antinomy to satisfy customer requirement and internal condition at the same time is the key issue for the steel production. We have been absorbed these conflicts with buffer stock. Our objective is to determine the best solution to ease these conflicts, production efficiency, cost reduction and inventory reduction.

The point is as follows. The manufacturer decides the production start timing necessary by his judgment for each customer, understanding a usage condition of each commodity and the customer's front stock accurately, and fulfills his responsibility of the material supply. So to speak, this is the production management system, one step closer to customer side. Analysis and synthesis of all the backlogs with plant condition from steel charge through final product will bring the optimal production schedule to solve the issue, subject to the re-schedule for adjustment of fluctuated at customer demands..

Originally, the production management of steel sheet should be "Order production management that makes the delivery date a key".

"Production management that depended on the stock" was a center so far, and "Total mass management" that took the balance adjustment of production in each process was finally executed, to accomplish the delivery responsibility to the customer, with above-mentioned not-clear delivery date at the time of the order. The gap with the realities of the mass management and each article has been covered by the stock increased. Moreover, each detail of the order have been managed as a management by exception only for the orders of delivery condition is strict like the just in time delivery etc.

It is necessary to answer the great constitution reinforced request that comes from the standpoint where the manufacturing industries of Japan that assumes making of the market request (This has appeared as the quality demand, and high-level product to many varieties and the delivery date request severely) and severely large competing age to be a background was put in the emergency. From the constitution reinforced request, the reduction in the cost that originates in the stock, the reduction in the exception distribution cost to a temporary place and the urgent transportation cost are pressing needs, in addition to product yield improvement, amount of reduction of use various materials, and improvement of labor productivity.

#### **4. Construction of the supply chain management system of the steel sheet**

We describe what event occurs in the operation of the steel sheet manufacturing site for the sake of the upgrade of the market request and the reinforcement request of strength of enterprise, and also what kind of improvement point is necessary.

(1) Subdivision and complication of operation condition by complicating, strict making quality about line operation condition (restriction at chance and scheduling restriction), high-level making kind, and making too many varieties.

Because the number of operation conditions has increased, the lot size becomes small. And, the stock for the chance waiting is needed between the back and forth processes. The point is smooth material flow is achieved by a consistent schedule of 55 process lines, from the upper process to the process in the under.

(2) Correspondence to the strict delivery response request The number of customers who demands the just in time delivery increases rapidly. And the short delivery date requests and the requests for the demand amount change and the delivery date change, too, increase in number. The point of the improvement is to decide the start of the production of necessary amounts by the judgment of the steel maker side, by the cooperation of the trading company, customer's usage condition, the amount of stock of circulation, and an amount of stock front of the customer are grasped by the steel maker side. Therefore, it is necessary to do the order progress management of each individual detail of all orders which has been done by exception.

(3) Multi target of production management performance Mutually contradictory requests are often demanded, and so are requests for an improvement of the yield, decrease of a unit consumption, decrease of the frequency of the condition change, stock volumes, temporary transportation, and the correspondence to the change of demand amount and the change to the delivery date. Each evaluation item value can be forecast at the planning stage, consistent schedule is obtained satisfactory overall and being able to re-schedule again in addition corresponding to the situation change, and how the value of the evaluation changes by the taken action is quantitatively predictable are the points of the improvement.

(4) Large-scale production plans of 15000 numbers of schedule objects, of 55 processes and each process has many working conditions can be made in a short time every day, and, in addition, the solution of the re-schedule is obtained for the situation change in a short time..

## 5. Result

"The supply chain management system of the steel sheet" is constructed as a system that supports the planning system to enable correspondence to severe market demands and the constitution reinforced request upgrade, etc. in this highly competitive age with the speed on the basis of "Article management accuracy".

Two important items, "Introduction of the commodity code" and "Scheduling model's development" comprise the entire frame.

We have improved the production system as required to

shift from the past model of mass-production of a limited variety of goods to a new model that efficiently produces a wide variety of goods in variable quantities—capable of matching rapidly changing customer needs and producing only necessary amounts as needed.

The main points are summarized here.

(1) All articles which are received as an order are designated as "designed article", and all processes of each article from the order to the delivery are managed.

(2) A practical use machine scheduling algorithm is developed that takes into account full particulars, complete process cycle, and long-term articles which are received as an order. The solution is obtained in a short time. It is a multi-step process, job shop scheduling problem. The work start time of all candidate resources is given while meeting the restriction requirement for the schedule candidate resources that should treated in each process in the multi step process.

The desired properties of the schedule is that it should be able to answer many demands, balance well, the size of the lot of the material treatable continue by the same manufacturing condition is enlarged, minimize the amount of intermediate stock, the time required for manufacturing is shortened.

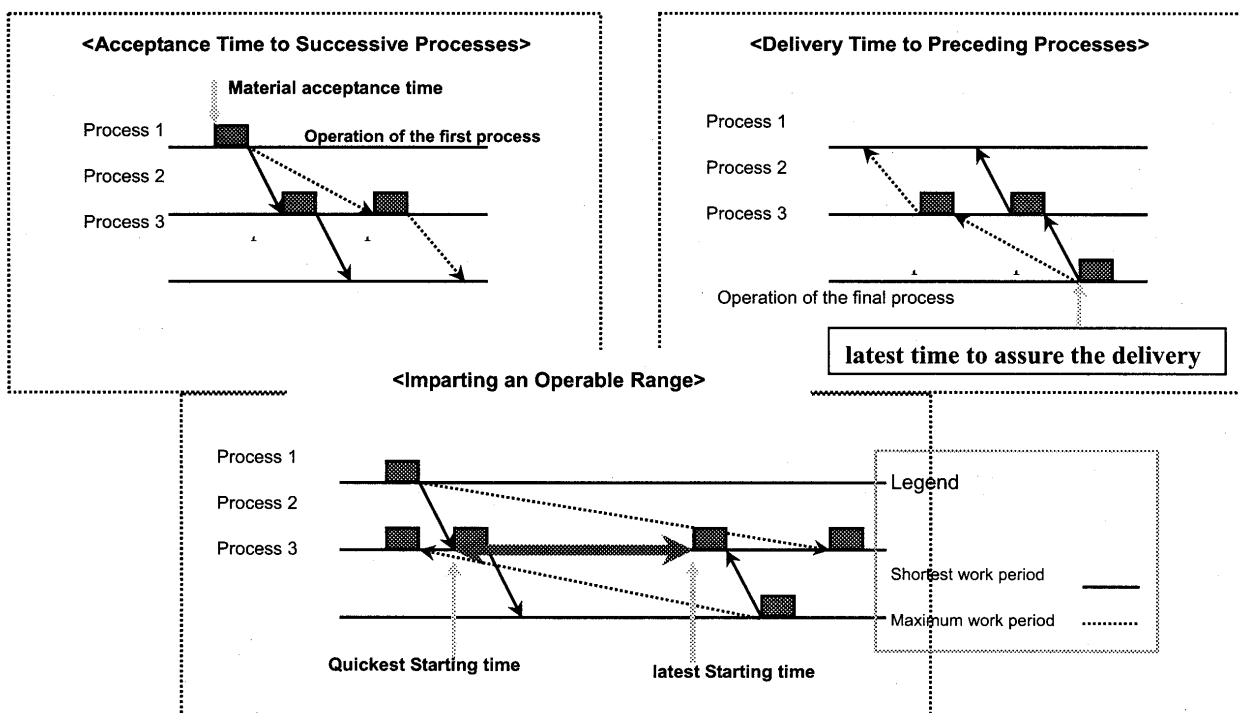
The outline of the algorithm①—⑥ is described.

① The appropriate one is added as a material to make it follow one process at the processing end time of the early material bringing each same working condition together.

② The Quickest Starting Time, beginning time that could begin to be processed, and The Latest Starting Time, beginning time that should begin to be processed are decided and have been given one by one in this process in each material (schedule candidate resources). It is a range where this candidate resource can work between both time.

③ The relation to the process in the back and forth goes only by the delivery of The Quickest Starting Time and The Latest Starting Time, and scheduling is executed. The result of scheduling is reflected to the back and forth process as a new value of this both time. The image of the possible range is shown in the figure in the top of next page.

④ To request where the lot be able to be enlarged within the range where the delivery date to the customer of candidate resources of other working conditions in this process is not obstructed when the size of the lot in which candidate resources of the working condition with this process are added is decided, "Room time" is defined. "Room time" is the maximum value in the range where it doesn't influence the delivery date



achievement of candidate resources of all other working conditions in this process. The image from which the "Room time" for the working condition B is requested is shown in the figure below.

⑤ The priority rule to add the material of which working condition is selected from among each extraction candidate resources of each working condition, was made to an external table (expression of knowledge), and made to be a structure that is selected by the situation in which equipment and production are put.

⑥ Scheduling of all processes is advanced one by one, reflecting the result in the back and forth process by repeating each process scheduling. And so we have adopted an external table so that we can control the scheduled process order selection. For example, the bottleneck process of that time can be scheduled previously.

In the past, there is not a success case of scheduling that is actually in operation, intended for multi process, a large scale, and a long term, though there was an scheduling for a short term of a single process. All of the order 22-28 day ahead of the steel sheet process, including "designed article", have evolved to the scheduled state, in the past there is only a production schedule of a few days ahead.

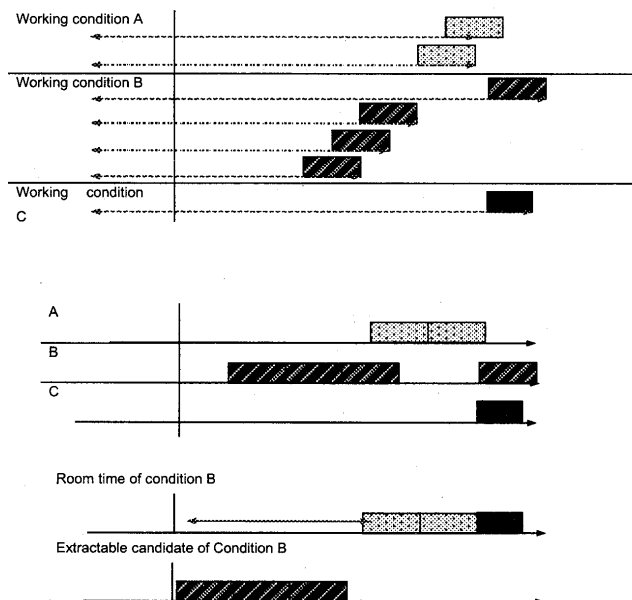
It became to be scheduled from the time of "design article", the object of the schedule came to be expanded more greatly than in the past. Executing the production not contradicted where compatibility without uselessness was able to be taken became possible, became to be able to correspond by the first move,

foreseeing enough ahead.

(3) A consistent scheduling in the entire process of the steel sheet, starting from the steel making and hot rolling process was achieved for the entire unit of the article ("design article" is included).

(4) Daily rescheduling was achieved.

Order results change like the production results change of



every day and order addition and cancellation etc. is processed on the same day, resulting in a schedule consistent with the latest information. This capability is largely owing to the rapidity with which a workstation

running the machine scheduling algorithm can be used to generate a new schedule when new order details are received, according to the same procedure every day by the same machine scheduling algorithm.

Despite repeated efforts, trials of weekly production planning have yielded only failure with an unbridgeable gulf between the schedule and reality observed on day 2 or 3 of the one week schedule. As a result, it is actually not used after all in the past. I think that the achievement of the rescheduling of every day is a big factor in this development for the entire system to succeed.

(5) Minor adjustments to the machine scheduling result can be easily done as necessary using the man-machine interactive mode. Whether the correction is added by what policy based on the machine scheduling result displayed on a screen is discussed, and the correction instruction is input to the workstation.

(6) We, the manufacturing side of the iron and steel depressed to the customer side by one step, have begun to decide the manufacturing start timing, to deliver the material to the customer with responsibility at necessary timing for the material supply. The management of the order by the "Introduction of the commodity code" is efficient. A consistent scheduling system contributes both to the improvement of delivery management accuracy and to accomplishment of the manufacturing responsibility.

## 6. Conclusion

Progress of all order of each commodity code is managed, and consistent management from the order to customer front yard delivery is executed, and we have achieved big reduction in costs. In addition, the quality data of each commodity code is accumulated, the quality change is always observed, and an exact, quick correspondence is executed. This quality database is possible to use effectively in the jointly work between enterprises on a new product development corresponding to the commodity new function request. And, the cost, earnings of each commodity code are managed, and the manufacturing section staff can use the database to do the content analysis easily as basic data that improves an exact manufacturing method.

The processing cost of grasping each article in each production process for middle semi-finished coil is maintained in every case as data, and a consistent manufacturing cost of each article can be understood though processing is received in each process through the multi-step process, and it arrives at the end-products coil by the type that totals the cost at the stage of the end-products coil.

Operation cost on each process is generated through the individual intermediate process with processing time, temperature, material variety, thickness

and width of steel coil, special treatment required, total weight and so on, and such cost is accumulated for the executed cost of the final product. Some intermediate process cost may only be taken as processing time without any further itemization. Some steel coil may be divided into several steel coils. Some steel coils may be integrated as a single coil. Such variety of intermediate processes is also considered for the cost analysis of the final product. The device that uses chained of the article data well is necessary for the middle semi-finished coil for the grasp of a consistent manufacturing cost. Reprocessing and modification cost in the process should be recognized as well for each coil. Such cost recognition on each process will allow us to recognize any variation of product cost and to have some cause of frilled cost for prompt action to improve the process.

We expect to use the proposed system as a means for analyzing cost reduction. For each section staff to access the consistent cost database directly, to process data for myself by various cuts, and to use it for the attribution analysis actively, the earnings management system is constructed on the end user computing environment. The raw data of the detail of every one article is used easily, and the cross section of a different cut can be caught visibly on the display instantly. Moreover, many staff can analyze the factor from all directions by a different view. Integrated business support system is growing as a system that supports all staff in brain-labor in analysis, investigation, and planning.

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