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Lean Design and Management for Manufactoring Enterprise Lifecycle

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LEAN DESIGN AND MANAGEMENT FOR MANUFACTORING ENTERPRISE LIFECYCLE

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ABSTRACT

Most enterprises inducting lean production were confined by the innate limitations of existing production systems, which make it difficult to fulfill lean production comprehensively. To solve this problem, the theory of lean design and management for the manufacturing enterprise lifecycle was proposed. First, the necessities of lean design were analyzed and its theoretical system was established; second, the principles, process, methods and tools for lean design was introduced. Techniques and theories such as lean production, facility layout, system simulation and simultaneous engineering were integrated to support the implementation of lean design and management; finally, a case study of a cold-rolling enterprise was analyzed.

Keywords: lean design, lean production, lifecycle, simulation, manufacturing enterprise, production system

I. INTRODUCTION

Nowadays, the study and practice of “lean” have already extended from the production domains to other stages such as product development and sales. Theories such as Lean Supply Chain, Lean Six Sigma and Lean Product Development were proposed. For example, James Morgan and Jeffery liker [1] summarized the product development way in Toyota Corporation, and proposed a system model of Lean Product Development which integrated people, process and tools. Scholars in China also suggest that it is necessary to extend the application scope of lean. For instance, Yongsheng Gu [2] proposed lean factory and technique design for the automobile engine enterprise; Haicheng Yang [3] suggested lean concept should be extended from manufacturing to every steps and processes of design stage in order to form a superior plan; Tianbing Zhang [4] introduced the route of applying lean product design and how to choose proposal to avoid wasting.

However, few research focus on establishing a complete theoretical system of lean design and management for manufacturing firms which integrates product development, factory design and production; in the term of depth, further research is still necessary for concrete principle, process and available tools for lean design; in the term of time, previous research could be more systematical if they take manufacturing enterprise

entire lifecycle into account. Therefore, this paper will focus on the theoretical system, principles, process and available tools of lean design and management for manufacturing enterprise lifecycle. Then, a case study of a cold-rolling enterprise will be introduced.

II. THE NECESSARIES OF LEAN DESIGN

A. First-class Potency of Lean production

In the 1980s, Toyota Production System (TPS) was recognized in the world, and it was summarized as "Lean Production". And now the practice of lean indicates that the potency of lean production was first-class in the world:

1) During 2007, Toyota, which produced 9.37 millions automobiles in the global and sold its products in more than 170 countries, has surpassed GM and became the largest automobile manufacturer in the world.

2) In 2007, profits of Toyota were approximately equal to 15 billion US dollars while GM and Ford' profits were negative;

3) By February 3, 2007, the market value of Toyota reached 172.3 billion US dollars, which was 10 times more than GM's.

B. From Lean Production to Lean Design

Lean Production has proven to be the most effective production system for manufacturing firms. The way that how manufacturing enterprises induct lean production is to improve continually the existing production system. However, many problems inherit in the design stage, which may lead to the high cost, unsatisfactory effect and difficulties to fulfill "lean" comprehensively in the production and operation stage.

Many manufacturing enterprises plan to conduct new project or Business Process Reengineering (BPR). If Lean concept can be introduced in the early stage of enterprise lifecycle such as project construction period or product development stage, wastes will be eliminated radically from the headstream, rather than be solved when problems really occur. As a result, the efficiency of investment will be increased and the occupation of land and other nonrenewable resource will be deduced. In addition, the goals of improving productivity, saving energy and protecting environment will be easier to be fulfilled. To conclude, the eight types of waste in the enterprise and solutions by Lean Design are listed in Table 1.

Table 1 –Wastes and lean design solutions

8 Deadly Waste	Solutions
Excess production	Capacity design, Pull system design, Leveled production
Delays	Continuous flow, One-piece flow, Standardized work
Unnecessary transport	Production system and logistic system design
Excess or inappropriate process	Standardized work, Process design
Inventory	Pull system/Kanban system design, Continuous flow
Unnecessary movement	Standardized work
Making defective items	Jidoka，Lean 6sigma
Unexplored creativity of employee	Organization system design, Enterprise Culture

Techniques of Lean Design stem from lean production to a large extend, such as pull system, continuous flow and leveled production, and it also introduce some new elements like organization system design, information flow design and etc.

The major distinction between lean design and traditional lean improvement lies in that the latter emphasizes on improving an existing system, yet the former stresses on inducting lean concept from an early stage and eliminate waste from headstream. The distinctions between lean design and lean improvement are listed in Table 2.

Table 2 –Distinctions between lean design and lean improvement

Distinction	Lean Improvement	Lean Design
Concept	Improving on an existing production system	Inducting from the design stage
Content	Production and operation	Product development, factory design and etc.
Method	Continuously improving on production system	Systematical design for production, information, organization system and etc.
Focus	Middle stream in the supply chain: production stage	Upstream of production: design stage
Tools	JIT, Jidoka and other tools	Value Engineering, Simultaneous Engineering simulation and etc.
Potency	Limited by original system	Limited by data and design
Time	Inducting from a middle stage	Inducting from an early stage of enterprise lifecycle

The real savings of lean design come from allowing designers to integrate design and production, work out design errors on the early stage rather than on the actual system. The concept of reducing costs through working out problems in the design phase rather than after a system has been implemented is best illustrated by the rule of tens. This principle states that the cost to correct a problem increases by a factor of 10 for every design stage through which it passes without being detected (See Fig. 1).

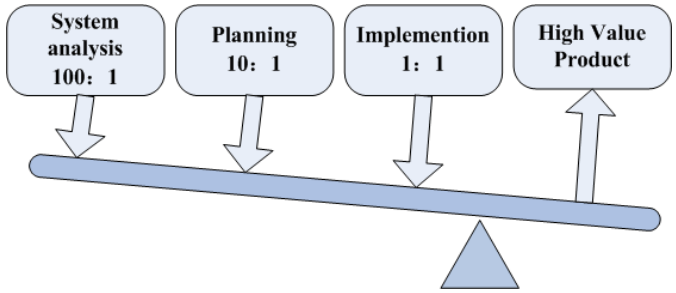

Figure 1 –Benefit of cost reduction effects in production system lifecycle.

III. SYSTEM, PRINCIPLES AND TOOLS OF LEAN DESIGN

A. Lean Design and Management for Enterprise Lifecycle

Lean Design refers to design for the entire process from the product design to delivering finished product to customer, including lean product development and lean plant design. Lean Design primarily contains design for “seven flows”: material flow, information flow, process flow, value stream, people flow, fund flow and time flow. Lean Design can also be integrated into a complete system, as shown in Fig. 2.

1) Lean product development. There are several typical wastes in the product development process: direction conflicts, errors of tool/prototype, premature criterion, useless information, test and validation, knowledge abandon, Separation of responsibility, action and knowledge and barriers of communication. Lean methods, such as Front-loading, set-based concurrent engineering can be utilized to create a continuous and smooth product development process.

2) Production system design. Apply lean methods and principles, such as U-shaped line, one-piece flow, and standardized work into the process flow design and production system design.

3) Logistic system design. Material flow design; select and dispatch transportations; define the batch size according to one-piece flow principle.

4) Information system design. Select information management system, for example the ERP systems, in order to realize the cooperation between lean and IT technology effectively; information flow design, enhances information transmission efficiency and reduces information redundancy in production and management

5) Organization system design. Establish motivation mechanism, and create the lean culture to respect and explore the employee's creativity; People flow design, multiskilled operator training and combined operation design and etc.

6) Production plan and control. Realizes leveled production and Just-in-time production; time flow design, including Takt time, lead time, cycle time and etc.

7) Production and operation management. Conduct value steam analysis and design, fund flow management and so on.

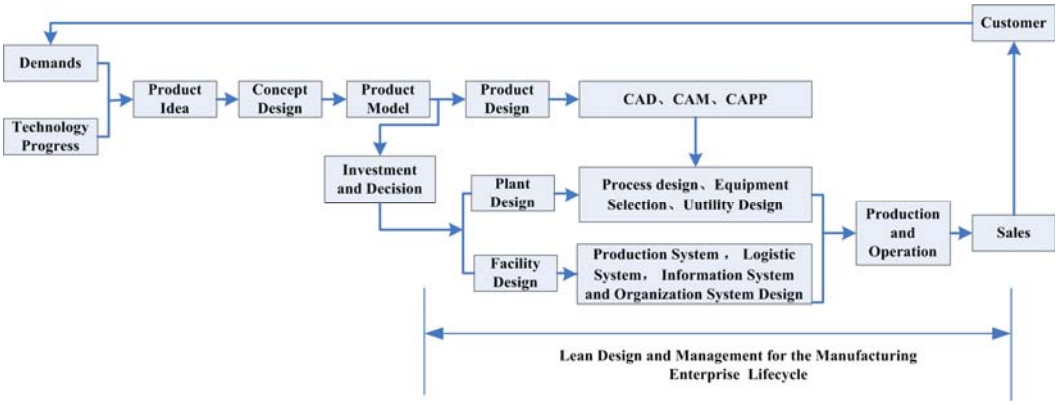

Figure 2 – Lean design and management for manufacturing enterprise lifecycle

B. Principles

Three main technical support systems for Lean Design are lean production, facility layout and system simulation technology. Lean thinking refined from lean production is the resource of concept of lean design. Concrete methods in lean production and facility layout serve as the technique support for Lean Design. Simulation is a significant tool to test and optimize the proposals of lean design.

Lean design originates from lean production; the lean thinking becomes the philosophy foundation for lean design. Jeffrey Liker summarized 14 principles for lean production in "The Toyota Way" [5]. On the basis of these principles and rules of product development and factory design in Toyota Company, 13 basic principles for lean design can be summarized from perspectives of concept, content and process, shown in Table 3.

Table 3 –PRINCIPLES FOR LEAN DESIGN

CATEGORY	PRINCIPLES
Process: SE and Front-loading	1) Technicians in different departments work together to put forward different proposals 2) Standardize and integrate process of design and production, equipment and tools and IT technique 3) Carry out SE activities in the design stage to synchronize different processes.
Content : eliminate waste from the headstream	4) Make processes flow continuously 5) Let the demand of customer pull the systems 6) Level out workload of processes 7) Use visual controls 8) Select Information system appropriately; make technology serve for process 9) Respect, develop and encourage staff; appoint and train staff appropriately
Concept: form a long term philosophy and improve continuously	10) Eliminate the waste from headstream 11)Base management decisions on a long term philosophy 12) Identify the value defined by customers 13) Integrate with lean production seamlessly to gain a continuous improvement

C. Process

Concrete methods for lean design stem from facility layout, production and logistic system design, management science and so on. Based on these theories and 13 basic principles, a series of methods and tools for Lean Design can be developed. These methods or tools should be implemented into a standardized process, including collecting initial information, creating proposal, optimizing proposal and implementing, as shown in Fig. 3. Note front-loading, whose three basic factors are Sharing "field", realizing synchronization through IT technology and implementing SE activities, is required to be widely used in the process of Lean design.

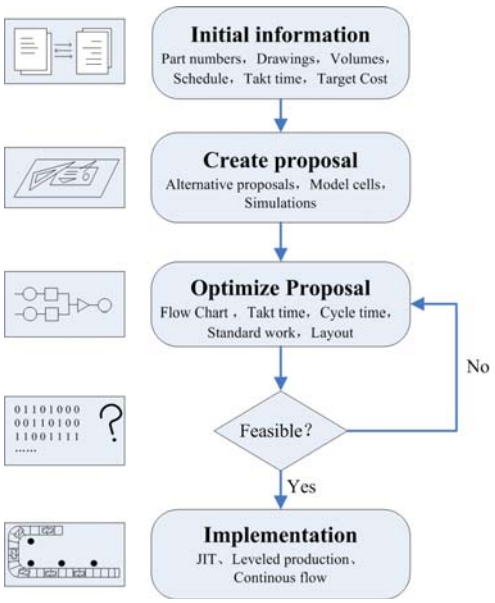

Figure 3 –Standardized process for lean design.

1) Technicians in different department are required to share the "field", challenge problems positively and select the optimal solution from several proposals. Then, the optimal solution will be standardized and be shared by staff. In Toyota, design, appraisement and production technique departments, main plants and other departments which directly participate in the production of automobile are all located in the Aichi-ken and 10 kilometers around it in order to promote the communication of different departments.

2) Realize synchronization through IT technology. Highly concern about new technology, and let technology serve for the process rather than let process be adapt to the advanced IT tools. Before determining to induct IT tools, check the benefit it can bring about for process. In Toyota, for example, in the early 1980s, two dimensions (2-D) CAD is the mainstream tool for the design of Powertrain in order to test products earlier and check the quality of automobiles before mass production. In 1995, 3-D CAD was used to improve the efficiency of the editorial design through parameters design. In 2000, Toyota took advantage of IT technology to synchronize the process design and production lines design, using x-ray and CT to measure parts and inducting the results into 3-D CAD.

3) Simultaneous Engineering (SE) activities are required to be carried out in the process of Lean design as much as possible. SE is a systematic approach and technique to parallel and integrate products and related process, including the manufacturing process

and supporting process. It requires product developers to take into account factors such as function, manufacture, assembly, job scheduling, etc. in different stages of product life cycle from the very beginning. It also stressed that all departments working together to minimize the repeated design. By sharing "field" and Realizing synchronization through IT, Toyota brought the process of roughcast design and equipment/tools design forward and synchronized the process of product design, roughcast design, and equipment/tools design. As a result, the process of design and development cycle time can be reduced to 10-12 months, as shown in Fig. 4.

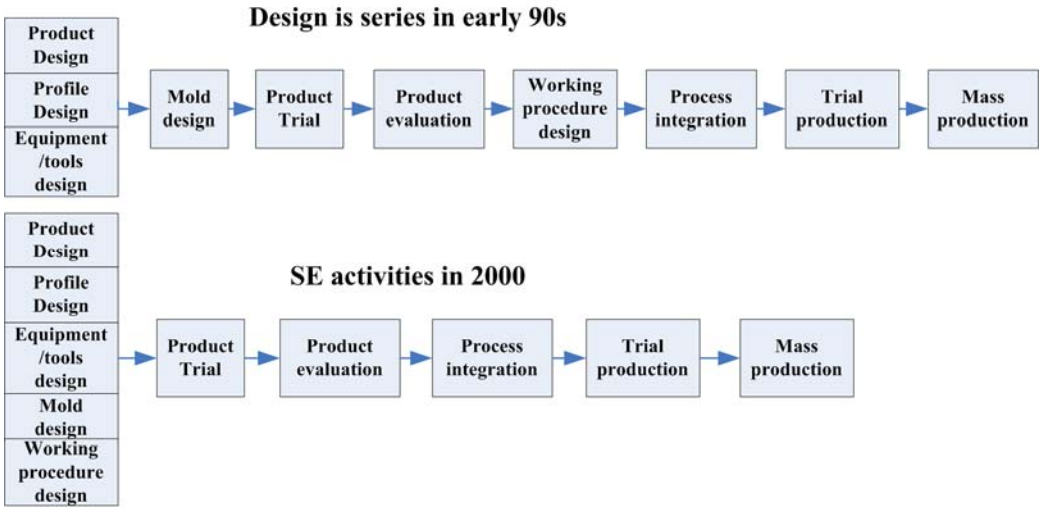

Figure 4 –Comparison between design in series and SE activities

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D. Tools

It is widely accepted that simulation has become an integral part of effective system design. System simulation technology can be utilized into the following domains: improve equipment utilization, reduce waiting time and queue sizes, establish optimum batch sizes and part sequencing, train operators in overall system behavior and job related performance and etc. These techniques can be used into lean design to conduct production and logistic system design, information flow and value stream analysis and etc. As shown in Fig. 5, in the three-dimension framework of simulation for manufacturing enterprise [6], in time dimension, simulation model can be introduced from the early stage of lifecycle to help designer revise and optimize their proposal; in width dimension, simulation can be used to design the production system and supply chain; in depth dimension, simulation can be integrated with other information system such as ERP systems to serve useful purpose for production plan and decision-making.

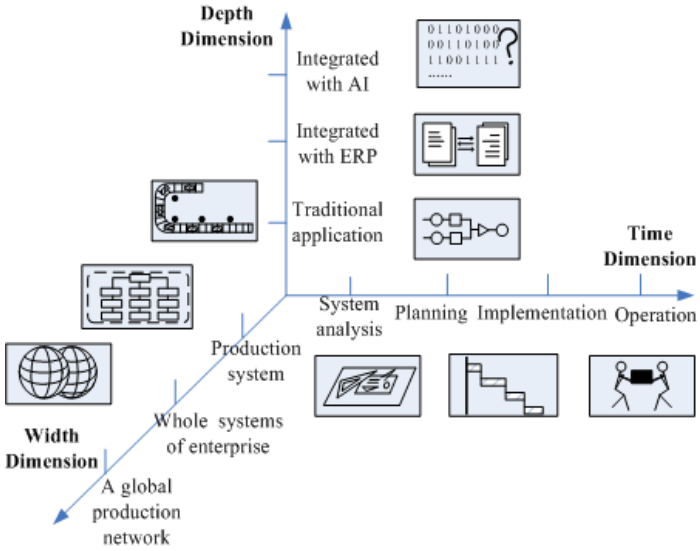

Figure 5 – three-dimension frame of simulation for manufacturing enterprise

IV. CASE STUDY

Lean Design for the project of 900 thousand-ton upscale cold-rolling product of an iron and steel cooperation will be chosen as a case study. Main products of this enterprise are Cold-rolled coil, Hot Galvanized Coil and Hot Pickling Coil, which have been widely used in the automobile, refrigerator, air-conditioning, microwave oven and other industries. Along with the increasing demands for these products, cold-rolling enterprise met unprecedented opportunities. This enterprise began to reengineer its business process or rebuild their plant, and adjust its product structure at the same time. This enterprise is still in the production system design phrase; production system, information system design and value stream analysis will be selected as illustrations.

A. Production System Design

1) Production line design. The technique process of its main products contain picking, cold-rolling, degreasing, annealing and etc, on the basis of which, the facility layout of the plant is shown in Fig. 6.

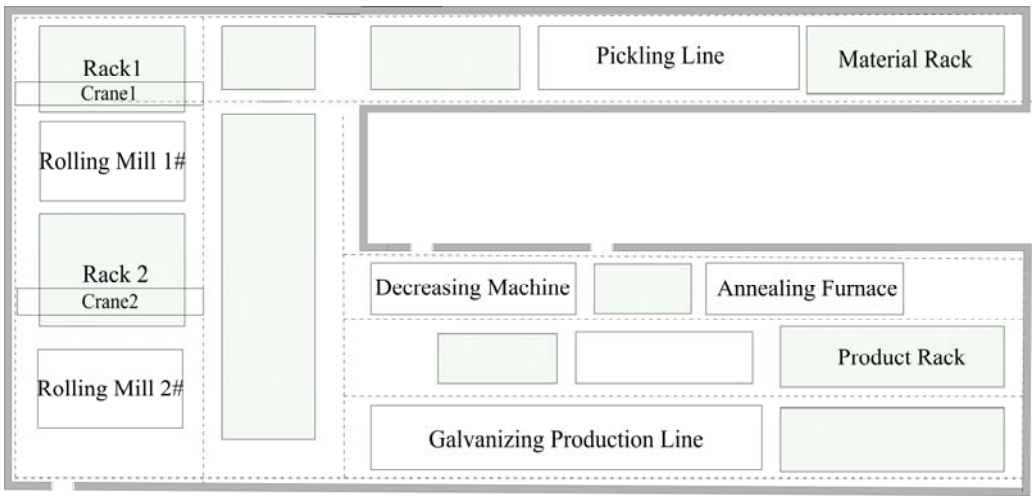

Figure 5 – Facility layout planning.

The production line of this plant is designed in accordance to the one-piece flow and continuous flow principle. Advantages of this U-shaped line are listed in the Table 4.

Table 4 –Advantage of U-shaped Line

ADVANTAGES	INSTRUCTIONS
Reduce transportation	Machine was arranged by processing, transportation between processes was reduced
Reduce space	Save the space for transportations and WIP
Reduce WIP	WIP was reduced because Buffer reduced
In and Out at one access-egress place	Simplify transportation route and avoid movement inside the plant
Multiskilled Operators	Distance between workstations is short. Operators can handle different processes
Easier to communicate	Operators can help each other more readily

2) Visualization of technique process. Simulation software was used to establish the model for production system in order to realize the visualization of process, whose main steps contains data collection, model translation, validation and etc. As shown in Fig. 7, established model for this plant contains 204 entities and hundreds of relationships between entities, which can be used to test capacity, improve equipment utilization, set production plan and etc.

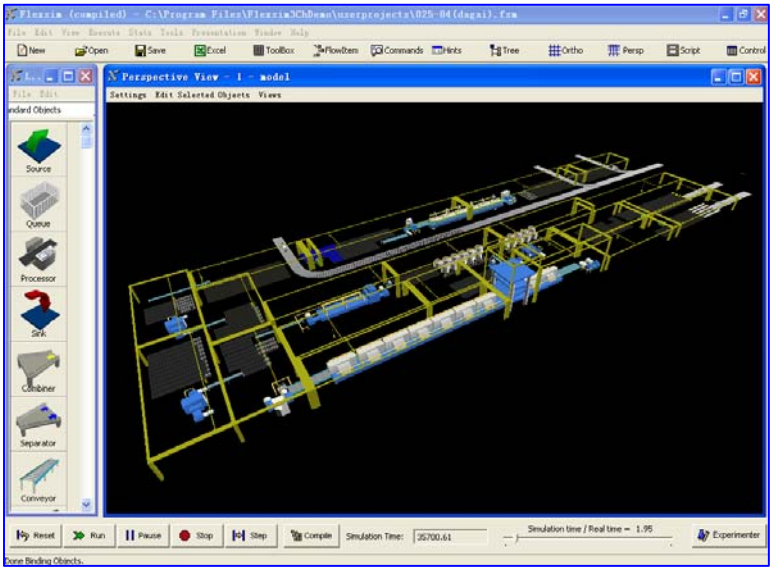

Figure 7. Perspective view of the simulation model.

B. Information system design

According to Michel Nilsson [7], current scheduling software, including some ERP systems, does not provide sufficient support for generating and verifying alternative solutions when changes such as rush-orders and machine breakdowns occur. Besides, as described below, production planning and scheduling of this plant is stricter than common manufacturing plants. For example, the Hot Galvanizing Line could not be halted at will, thus inventory is required to guarantee its continuous work; however, "safety cushion" could be translated into a huge volume of excess inventory which causes a great waste. Therefore, simulation analysis of sensitivity of safe production is required to define its optimum inventory. The Integrated system between simulation model and traditional system can be developed as the bridge for the communication between market demands and production system (See Fig. 8).

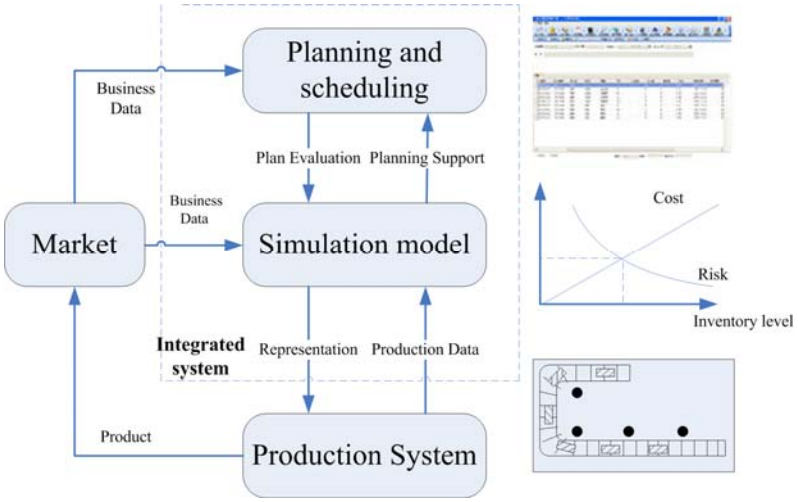

Figure 8. Simulation analysis of sensitivity and scheduling

C. Value Steam Analysis and Design

A value stream is all the actions, both value added and non-value added, which are required to bring a product through the main flows essential to nearly every product: the production flow from raw material into the arms of the customers, and the design flow from concept to launch. Value stream could be used to define value-creating time and none value-creating time, on the basis of which, waste could be identified and improvement could be fulfilled to increase productivity and reduce waste.

The price of cold-rolling products fluctuates frequently. When it is expected to rise, companies will increase inventory, which means price fluctuations will impact the production plan. Different with fully pull system, this enterprise could be converted into a half-pull system, in which a balance between low inventory and system safety could be struck. In terms of price stability, production plan could be set according to the Just-in-time production and leveled production principle; In terms of price fluctuate, production should be arranged into a pull system. The value stream map was shown in Fig. 9.

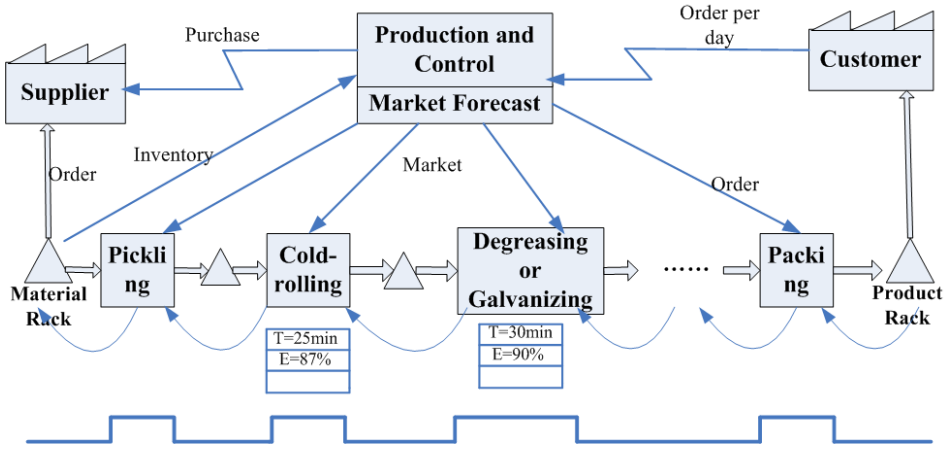

Fig. 9. Value stream map

CONCLUSION

This paper studied theoretical system, principles, process and tools of the theory of lean design and management for manufacturing enterprise and illustrates a case study of a cold-rolling enterprise finally.

Research results highlight that lean design and management, which extend lean concept from production stage to the whole manufacturing enterprise lifecycle, can eliminate problems and wastes which could emerge in implementation stage from its headstream rather than improve on an existing system. It also can swept away barriers for comprehensively lean production.

Further research could focus on the special methods and tools for lean design and its connection with lean production.

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