Refining the Product-process Matrix from Mass Customisation -
A study of Packaging Carton Industry in China

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Abstract: The objective of the paper is to explore, discuss, refine the Product-process matrix from the evolution of the packaging carton industry in China. China Packaging carton industry developed very quickly in past 30 years, in different period, there are different decisions on product designs and process choices to get their suitable profits, but their match of product and process challenge the Hays and Wheelwright Product-process matrix.
1. Mass customisation

**Mass** production was the twentieth century's leading operations strategy, high-volume tools, simple work tasks, the separation of thinking and doing, and standardization of products and services permitted a dramatic reduction in real costs and prices. Mass customization is a word firstly invented to predict the new trends of goods manufacturing in the future (Alvin Toffler, 1970), but it is just a new word, no details, and then it was coined to describe a trend towards the production and distribution of individually customized goods and services for a mass market (Davis, 1987).

The concept of mass customization was first fully expounded by Pine (1993), based on a survey of US firms, and elaborated by him and by others in a series of articles in the *Harvard Business Review* (Gilmour and Pine, 1997; Pine, 1993; 1995). These papers all imply a view of mass customization as in some sense a historically inevitable successor to mass production, the principal way in which to compete in the future.

At the same time, there is an alternative view, which saw mass customization and mass production as co-existing in the same firm and the benefits derived from the synergy between them in the Japanese cases (Kotha, 1995).

From other hand, mass customization is introduced in recent editions of famous textbooks (e.g. Slack *et al.*, 2000, Chase 1998) or operations management journals and public newspapers.

1.1 Definition of Mass customisation

The broadest definition of Mass customization is as the ability to provide individually designed products and services to every customer through high process agility, and integration (Davis, 1989), MC production systems may thus reach customers as in the mass-market economy but treat them individually as in the pre-industrial economies.

The popular definition of Mass customization was given in Pine’s book, He defines mass customization as a process by which firms, in different industries, apply technology and management methods to provide product variety and customization through flexibility and quick responsiveness (Pine, 1993).

Pine provided examples of industrial practice and discussed diverse and related themes such as manufacturing flexibility, time-based competition, lean production, reengineering, and continuous improvement, but he fails to synthesize them into a coherent framework. Other authors propose similar and more practical concepts. They define MC as system that uses information technology, processes, and organizational structures to deliver a wide range of products and services that meet specific needs of individual customers (often by a series of options), at a cost near that of mass-produced items (Hart, 1995, Jiao, 1998).

1.2 Industrial background of mass customization

Pine thought the main reason lead to mass customization is fluctuant business environment, the breakdown of the stable mass market of yesterday, the mass market that gave birth to the concept and system of mass production in the first place. The fragmentation of the mass market is an ongoing, inexorable phenomenon, breaking down with it the previously smoothly running production system that was based on
efficiency, stability, and control.

So the most suitable industrial environment for mass customisation belongs to the industries full of fluctuant factors such as technology innovation, capital movement, and so on. In this kind of industry, product life cycles have become shorter and shorter, while keeping up with technological change has become increasingly difficult for both manufacturers and customers (Hart, 1994). Dell is the famous example in this kind of industry.

Mass customization—the selling of highly individual products but on a mass scale—is a logical next step in the progress of BTO ("build-to-order"), the manufacturing of goods only as and when there is an order from a customer. Studying on some special industries as cars (Renault, 3daycar), computer (Dell), so with washing-machines (Maytag), refrigerators, window-frames, packaging equipment and even collectable dolls, in order to put the mass customization into effect, manufacturers try to make their factories lean and flexible, freeing idle capital that has been tied up in stocks of parts and finished products. The Internet has provided a handy means of linking up supply chains. (Solihull & Newton, 2001).

Another research explores challenges to the implementation of mass customization in a services context. It uses a case study approach to examine the factors, which drive a firm to adopt mass customization, the difficult challenges of requiring a fully integrated information technology infrastructure and needing to transform business processes to handle unpredictability. (Peters, Linda; Saidin, Hasannudin, 2000).

1.3 Keys to success of Mass customisation

At the beginning, we know that the key to success of Mass customisation is a linkage system with four key attributes: Instantaneous, Costless, and Seamless. Frictionless (Pine & Victor, 1993). In order to guide companies in the development of mass-customization strategy, an analytical framework analogous in power to the Malcolm Baldrige National Quality Award was developed, it paid emphasis on four pillars—Customer sensitivity, Process amenability, Competitive environment, Organizational readiness (Hart, 1994).


More and more companies understand the concept of mass customization, but implementing it can be painful.

There are six factors most commonly emphasized in the literature:

- **Customer demand for variety and customization must exist.**
- **Market conditions must be appropriate.**
- **Value chain should be ready.**
- **Technology must be available.**
- **Products should be customizable.**
- **Knowledge must be shared.**

The advantages of Mass customisation have been known broadly now. But many people remain doubtful about the benefits of Mass customization, Mass customization has its
limits, several elements have to work well - both individually and together, it requires unique operational capabilities: elicitation (a mechanism for interacting with the customer and obtaining specific information); process flexibility (production technology that fabricates the product according to the information); and logistics (subsequent processing stages and distribution that are able to maintain the identity of each item and to deliver the right one to the right customer). Those elements are connected by powerful communications links and thereby integrated into a seamless whole. (Zipkin, 2001).

Managers should carefully analyze the technology and the demand, the costs and benefits, before committing their companies to a mass-customization strategy (Zipkin, 2001).

2. Product-process matrix

On base of the works of Skinner (1969), Abernathy and Townsend (1975), Hayes and Wheelwright (1979) developed the product-process matrix (PPMX) to link the process life cycle and the product life cycle. In the following 20 years, the product-process matrix is the most important analytical tool in the relationship between product structure and process selection for manufacturing managers.

2.1 Hays and Wheelwright's Model

Hays and Wheelwright suggested one way in which the interaction of the product and process life cycle stages can be represented. The columns represent the product structure ranges from a one-of-a-kind item (low volume) to a highly standardized item (high volume). The rows of the matrix represent the major stages through which a production process life tends to pass in going from the fluid form to the systematic form in the bottom row.

A company can find its product-process position in the matrix. It is better on the diagonal or very close to the diagonal, in order to balance the production efficiency and marketing variety. To achieve low production costs, according to this model, it is necessary to reduce product variety and process flexibility and to adopt a dedicated manufacturing process. On the other hand, high-variety customized production can be achieved only through low-tech, labor-intensive, relatively expensive methods.

So the Product-process matrix is an analytical tool of trade-offs between variety and volume, market responsiveness, quality and cost.
2.2 Empirical supports and challenges to Product-process matrix

Recently there are some empirical studies on the product-process matrix framework (McDermott et al., 1997; Safizadeh et al., 1996; De Meyer and Vereecke, 1996; Spencer and Cox, 1995, Ahmad 2002). Some findings of these studies support the product-process matrix (Safizadeh et al. 1996), but some findings challenge it. A study conducted by Safizadeh et al. (1996) took a sample of 400 companies from the Harris Industrial and Manufacturing Directory, 110 firms returned their questionnaires (22 percent job shops, 32 percent batch shops, 25 percent production lines, and 21 percent continuous shops). Their conclusion shows that manufacturing firms’ choice of production process by and largely agrees with the emphasis they place on product customization, and they uncovered that manufacturing performance suffers when there is a mismatch between product plans and process choices. Especially, customization in continuous flow shops is not supported by this program, manufacturing performance suffers. This study provides support for the product-process matrix.

Another important study conducted by McDermott et al. (1997) only partly supported the product-process matrix, these researchers chose the US power tool industry – a group of publicly and privately held companies which manufacture a broad array of hand-held
portable electric power tools— for study based on survey, interview, plant tour, this study raises serious questions about the validity of this framework. They argue that the old models (such as product-process matrix) on the basis of trade-offs have lost its relevance. At the same time, they found that the similarities between models such as mass customization and rigid flexibility are greater than are their differences, and these models did a good job of representing the sweeping changes in firms' ability to avoid manufacturing trade-offs in this industry.

Although these new models describe more closely what has been observed in this study than did the Hayes and Wheelwright model, on the whole they did not completely capture the dynamics of the competitive environment and do not explain completely the operations strategy choices of firms in the industry today. So they urged for more research into the development of a paradigm that reflects the complex manufacturing environment in the world today.

Ahmad and Schroeder (2002) undertook an empirical study of the Hays and Wheelwright model using data collected from 128 plants. They found that the relationship between product structure and process structure is significant, but not strong. Almost only 50% of the plants operated near the diagonal of the matrix. They found that the role of advanced technologies and methodologies are quite important for the off-diagonal plants to overcome the mismatch of product structure and process structure. At last, they proposed a third dimension added to the product-process matrix that measures how aggressively plants are implementing these innovative initiatives, thereby explaining their off-diagonal behavior.

\[ \text{Figure 2 The cluster plot (Ahmad and Schroeder (2002))} \]

Notes: 1 = mass standard-to-options providers; 2 = small batch caterers; 3 = large batch customizers; 4 = repetitive manufacturers
2.3 Car industry in product-process matrix

And from the researching findings of Clark and Fujimoto (1991), and Alford (2000), I put the match of product and process into the matrix (see figure 3), in this study, the process classification has been added a second Assembly line.

![Figure 3 Car industry in the Product-process matrix](image)

The first half of the curve is closely suitable to Hays and Wheelwright’s diagonal position; the later half of the curve represents the evolution trend to mass customisation. MC systems are positioned the main diagonal of Hayes and Wheelwright's product-process matrix, i.e. having medium to high volume process types such as manufacturing cells or assembly lines that are able to deliver the high product varieties usually associated to functional operations.

3. A study on Packaging Carton and Packaging Machine Industry in China

Euromonitor proclaimed that the global production value of packaging materials was around US$289 billion in 1999. 23.9% was produced in Far East.

3.1 Introduction to Packaging Carton industry in China

The Far East accounted for 34% of the world’s output of paper and board packaging in 1999, but only 26% in terms of value.
The major markets and producers in Asia is Japan, the second one is China (see graph1). The packaging industry has been developing rapidly in China, and now employs almost three million people. The industry's contribution to the country's gross domestic product (GDP) has risen steadily, but its development has been plagued by such factors as limited scale, backward technology, shortage of capital, and low productivity. But as a low-cost base producer, China is seeing the benefits of more open trade in the 1990s. It is having a twofold effect. Many global manufacturers have set up joint ventures, or have started to source product from this low-cost base. This has resulted in rapid economic growth and increased consumer expenditure as the densely populated cities such Shanghai, Beijing, Guangzhou, Shenzhen and so on.
Up to now, the country has had no modern packaging machines, materials or patented products but has had to rely on imports for advanced technology, machines and luxury packaging materials.

### 3.2 Introduction to the cardboard and carton designs
Cardboard and carton are not a complex product, but there are also a lot of kinds and types according to the different size, thickness, and graphs on the outsides.
3.3 The simple history of Packaging Carton Industry and Packaging Machine in China

There is more than 100 years of history to design and produce packaging machines in developed countries, but only about 30 years in China. In the past 30 years, the packaging carton industry developed very quickly, transforming its production paradigm from job shop to mass production, and then to mass customisation (see figure 5).
Handcraft Before 1970s
Before 1970, there was no modern machines used in packaging carton industry in China, almost all of the cartons were made by hand. Technical workers designed the size and shape of cardboard according to the customer’s demand, and then a group of workers began to corrugate the paper materials, and stick two other plain papers on both sides of the corrugated one with glue, and cut it into the desired shape by scissors. In this period, high product variety was gained, but efficiency was low and quality was poor.

Single-wall In 1970s
In 1970s, most of the carton companies bought single-wall machines, operated by hand in low efficiency. This kind of carton production still existed in some undeveloped district in western China. The corrugated paper is processed by machine instead of handwork, but each single-wall machine keeps a special width of operations. So the flexibility is going down, but efficiency and quality go up.

![Figure 6. DMWL-A Single-wall machine (source: JSQJ website)](image)

Single Corrugated Board Production Line in 1980s
From 1980s, several Chinese packing companies imported advanced packaging machines from Japan, Italian, and Taiwan and then Chinese packaging machine manufacturers began to design and produce carton production lines following foreign companies. Because of the price advantage based on low labour costs, local manufacturers developed very quickly.

![Figure 7. Single Corrugated Board Production line (source: JSQJ website)](image)
A single corrugated line consists of three single machines: mill roll stand, single facer, slitting & cutting machine, the single facer can be with finger or fingerless, the mill roll stand can be mechanic or hydraulic operation. It is a simple kind of production line operated by hand, the production efficiency increases apparently.

**NC Production Line in 1990s**
In 1990s, some advanced cardboard production lines were imported from USA, Germany, France and other developed countries, there are more than 10 famous local manufacturers in carton packing machine industry, such as Jingshan Light Machinery Group, Zhaoqing Jialong Packing Group, Shoudu (capital) Machine Factory, Liaolin Dandon Machine Factory and so on. They can make many styles of cardboard production lines, and they exported their products to southern Asia, Middle East and Russia, but still faced large challenge from foreign manufacturers in technology innovation and quality improvement.

![NC Cardboard Production Line](source: JSQJ website)

All of jobs cab be finished by the machines and the production line is controlled by computer system, engineers only input the detailed data about different contracts, the computer software can design the size and shape of the cardboard and arrange the schedule. This production model can obtain high efficiency and stable quality, and high flexibility, and keep a lower unit cost.

Che Xiangfu, deputy secretary-general of the China Packaging Technology Association, said China hopes to develop its own core packaging technologies and packaging brands in 20 to 30 years.

4. Conclusion
The objective of the paper is to explore, discuss, and refine the Product-process matrix from the evolution of the packaging carton industry in China. We conclude that in general, from the study on packaging carton industry, the product-process matrix model of Hays and Wheelwright is only partially supported,
before 1990, the evolution history of China packaging carton industry is quite similar to
the diagonal position of Hays and Wheelwright model. When this industry transferred
from mass production to flexible production, and then to mass customisation, the Hays
and Wheelwright model cannot explain the contradiction between variety and efficiency
and low unit cost.
We acknowledge that the production paradigm changing was based on the use of NC
production lines, which was controlled by modern computer system. All of jobs cab be
designed and finished by the machines and computer system, engineers only input the
detailed data about different contracts, the computer software can design the size and
shape of the cardboard and arrange the schedule. So this production model can obtain
high efficiency and stable quality, and high flexibility, and keep a lower unit cost.
The implementation of advanced production lines and information technology change
the mismatch of product variety and production efficiency in the carton industry in China.
And we need more empirical studies in this field; we need more empirical evidences from
different industries with detailed analysis on production machines and product structures.
We also need construct a more advanced analytical frame to explain the industrial
practices and fulfil the Hays and Wheelwright model.

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