Chapter 1
Background and Motivation

Abstract In today's global market, more and more manufacturing companies have realised that the ability to quickly develop a customised product in an economic and efficient way is critical for them to survive in today's competitive international market. This is particularly true for one-of-a-kind production (OKP) companies. A new generation of OKP systems needs to be developed to help these companies maintain competitiveness in the global marketplace and improve the ability to rapidly combine the strengths of manufacturing partners to meet market needs. This chapter gives a definition of OKP and introduces the main issues and objectives of rapid OKP development in the global manufacturing environment.

1.1 Rapid One-of-a-kind Product Development

Nowadays more and more manufacturing companies have realised that the ability to quickly develop a customised product in an economic and efficient way is critical for them to survive in the keen competitive international market. This is particularly true for those OKP companies. Wortmann (1991) defined various types of OKP companies using a 2D typology. One dimension is determined by a company's production system position strategies, *i.e.*, product-oriented or capacity-oriented. The other dimension is determined by a company's market strategies, *i.e.*, make to stock, assemble to order, make to order, and engineer to order. The research as reported in this book focuses on the rapid product development (RPD) problems in an OKP company which has a product-oriented production system and adopts an engineer-to-order market strategy.

OKP, as predicated by scholars such as Rolstadas (1991), Wortmann (1991) and Hirsch (1992), could be a promising manufacturing model for the factory of the future. At the same time OKP poses challenges to the factory of the future. Tu (1996) characterised the OKP philosophy as:

1. high customisation;
2. successful product development (PD) and production in one go;

3. optimal or rational utilisation of technologies and resources;
4. adaptive production planning and control;
5. continuous customer influence throughout the production;
6. incremental process planning;
7. distributed control and inter-organisational autonomy; and
8. virtual company structure and global manufacturing.

From a practical viewpoint, an OKP company can be loosely understood as an advanced manufacturing company, which provides customised products in a certain manufacturing area (*i.e.*, ‘kind’ in OKP). It is often a product-focused small or medium sized enterprise (SME). According to its market needs, it produces a very wide range of product variations according to the customer requirements. It has a much wider product domain and more flexible batch size (maybe one) than a product-focused batch production company has. A typical OKP company can be a sheet metal company, injection mould/tool manufacturer, a steel construction company, *etc.* An OKP company has a greater flexibility to adopt market changes than a mass/batch production company, and higher production efficiency than a job shop. However, OKP companies, owing to high customisation, face a large amount of uncertainties and consequently may deal with a lot of rework. PD cost is also normally higher and development lead time longer than product-focused manufacturing companies.

To rapidly develop products with low costs, a new paradigm called rapid product development (RPD) has been proposed for the rapid development of products with low cost, high value addition and acceptable quality. Bullinger *et al.* (2000) defined RPD as an interdisciplinary methodology to combine all influences of an engineering process to an iterative PD. Its research topics focus not only on product, but also on their development process. The rapid development of OKP product is a holistic organisational concept that describes the rapid OKP PD process achieved by combining and integrating various innovative technologies and tools, *e.g.*, rapid manufacturing (http://www.albright1.com/manufacture.shtml), simultaneous engineering, computer supported cooperative work tools (Bullinger *et al.* 1996), and a supportive environment (Tu *et al.* 2001).

In this book, the scope of RPD will focus on the development of customised, individual or engineer-to-order OKP products. The P in OKP means OKP products, *e.g.*, a crystal oscillator, a customised sheet metal product or injection moulding. As shown in Figure 1.1, the RPD processes include all the OKP PD processes starting from the customer’s requirements until the products are delivered.

Many OKP companies in New Zealand and overseas are striving to develop new computer aided tools for supporting their PD activities including product design, validation, resource allocation and optimisation, scheduling and machining. The main objectives are:

1. to shorten OKP time to market (from product definition to market launch);
2. to develop OKP products by optimising key factors, *e.g.*, time to market, cost and quality;

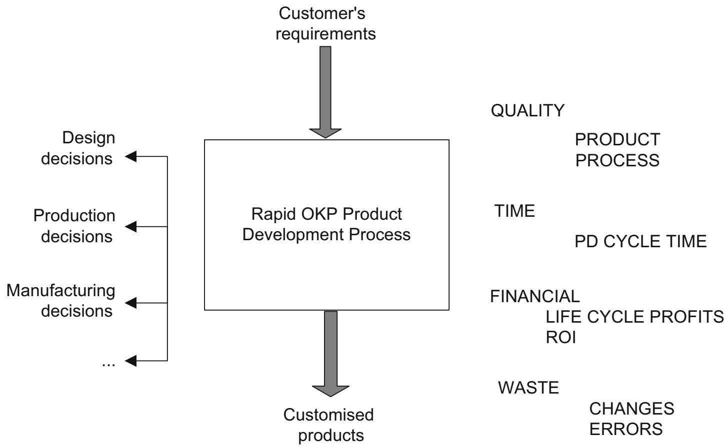

Figure 1.1 PD metrics and perceptions

3. to increase OKP products quality, achieve high profit and decrease waste (changes, reworks and errors);
4. to rapidly respond to the customer's requirements and market changes.

1.1.1 The Performance of RPD

The effectiveness of an OKP company's PD process must be evaluated against some objective criteria – a set of quantifiable parameters/metrics (as shown in Figure 1.1). Generally speaking, the metrics typically fall into the following four broad categories – quality, time, financial, and waste. Hence, the performance of PD can be weighed by following these factors (Floyd 1993).

1.1.1.1 Product Quality

The definition of quality is often used in today's manufacturing environment as "meeting the needs and expectations of customers". In today's market, it is no longer sufficient to define quality simply as "conformance to specifications". Sometimes, the specification may not fully meet the customers' needs which change with time. In the new definition, the operative words are needs, expectations and customers. The definitions of needs and expectations given by Floyd (1993) are briefly quoted in the following paragraph.

Needs are those functions, characteristics, and features that customers expressly want or must have in a product that they are acquiring. Customers are aware of their needs and, if asked, can usually state them with a reasonable degree of clarity.

Expectations are more difficult to determine and identify. Expectations are those things customers automatically assume to be inherent in the product. Often, they do not explicitly state their expectations, making it difficult to interpret using computer technology.

1.1.1.2 Lead Time

There are many ways to define the time to develop an OKP product. Some common terms are time to market, development lead time, PD time, and PD cycle time. These terms are generally used interchangeably – and all are intended to describe the total time it takes to implement the PD process from conception of a product idea to the point at which the product is both released for sale and in full production. In this book, the lead time is understood as the time from starting a product definition to finally delivering the product to the customer.

World-class OKP companies are constantly striving to improve their performance, and thereby to reduce the PD cycle time. Through a combination of innovative RPD process changes and continual improvement with new technology, many manufacturing companies have made dramatic reductions in the PD lead time. For example, during recent decades, companies striving for world-class status have cut cycle times by as much as 50%, as reviewed by Floyd (1993). These companies are continuing to improve.

1.1.1.3 Financial

For many OKP companies, the main reason to develop customised products is the possibility of bringing high profit returns. Product development not only requires a significant amount of investment, but also establishes the costs of producing OKP products. The return on investment (ROI) has always been the focus of PD. In recent years, cost control and containment have become even more important than before.

PD process costs are generally grouped into PD costs and product manufacturing costs. Others include costs associated with activities such as training and relocating resources. PD costs are the total costs incurred through a PD process. These costs are frequently referred to as NRE (non-recurring engineering/development) costs since they only happen once. The cost for an OKP product is mainly PD cost or NRE cost since an OKP product will be developed in one go and rarely repeated in future.

The manufacturing cost (sometimes called the recurring cost) represents the cost of producing one unit of the product. It includes material, labour and manufacturing overhead costs for the product. It is important to note that much of this cost is established during the PD process because of the design of the parts, the manufacturing methods, processes, tooling, *etc.* An OKP product also includes manufacturing cost as a part of its total development cost.

1.1.1.4 Product Development Waste

There are many contributors to waste in the RPD process, but the most costly factors are errors, reworks and changes. These result from a lack of proper preparation and planning, poor implementation, and poor PD processes that allow development to proceed between responsible departments without sufficient information interchange. Designers, for example, may develop the product without taking into account the needs of the manufacturing departments. A flood of design changes may overwhelm the organisation as it tries to modify the product to suit the manufacturing requirements. Although the cost of the changes may be huge, the biggest impact is the delay of market launch while the product is debugged. Another major source of waste results from inadequate product definition. The product designers may be required to rework many man-months of effort when the product definition is changed late in the development cycle.

1.1.2 Product Development Process Evaluation

The first step in improving a PD process is to measure the effectiveness of the one currently in use. This can be done by a comprehensive assessment that includes the use of both metrics and perceptions. The metrics are used as a quantitative assessment of the PD process and the perceptions are used as a qualitative assessment of the process. The combination of the two results in a detailed evaluation. Metrics are used to determine quantitatively how well the process is meeting its objective of yielding timely, competitive, and profitable OKP products. Metrics can provide a basis for comparing the PD performance of a company with its competitors, as well as measuring the ability of the PD organisation to develop products that meet their original plans and objectives.

The effectiveness of a PD process requires its use and support by the customers of the process. If the users of the PD process perceive that the employing process is not one of good quality – *i.e.* it is very bureaucratic and cumbersome – then they will resist using this process. The process will be ignored and the product developers will proceed in their own way.

Management's perception of the relative degree of success demonstrated may be critical to the funding of future OKP PD programmes. If their perception is that product developments are consistently marginal, the probability of obtaining adequate funding for future programmes becomes questionable. Management will have to be convinced, and rightfully so that the sins of the past have been addressed and are on the way of being corrected, before they can invest in development of the product.

Thus, many companies find themselves in a situation where new products are not giving adequate ROI to justify continuing long-term investment and without new products, there is no hope for long-term survival. The solution would be to develop an effective PD process that will yield competitive and timely products.

1.1.3 Benefits of RPD

In the market, successful products usually achieve high marks in each of the categories of performance metrics, *e.g.*, short lead time, low waste and low cost. Many of the metrics affect each other. Quality products, for example, can be sold well in the market, and hence lead to a higher life cycle profit.

Figure 1.2 demonstrates the benefits gained by two manufacturing companies through rapidly delivering quality products to the market. Obviously, company A entered its market early with a quality product, achieved a commanding market share, and generated much more life cycle revenue than its competitor, company B, who entered the market late with a product of equivalent quality.

Life cycle profits are negative during the PD cycle time and only turn positive when sufficient revenues are achieved. Figure 1.2c depicts the corresponding product life cycle profits for companies A and B.

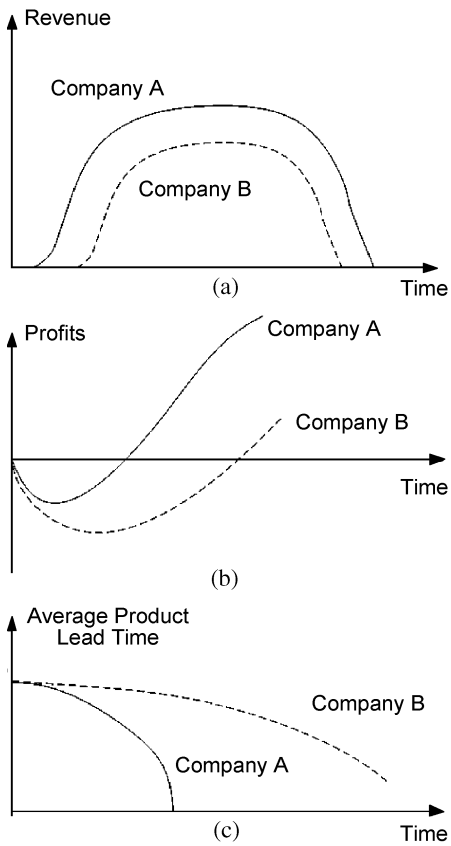

Figure 1.2 Financial and lead time results

1.1.4 Drivers for RPD

There are many factors driving the need for OKP companies to improve their PD process. Some of these factors are within the control of the company and some are not. Some factors within the control or influence of the company are:

1. ROI targets;
2. staff reductions resulting from downsizing activities;
3. excess production capacity.

These factors are specific to the company and its internal environment. They are all related to increasing profitability and hence long-term viability.

In addition to the company internal factors, there are several common external factors that are major drivers forcing the company to move towards RPD. These factors include:

1. aggressive global competition;
2. rapidly changing technologies; and
3. increasingly complex markets.

These factors are briefly discussed in the following subsections.

1.1.4.1 Aggressive Global Competition

Table 1.1 illustrates some key results during the global competition in the auto industry in the 1980s. Twenty auto manufacturers worldwide were evaluated and pertinent metrics determined. The metrics were normalised for a compact car. The chart clearly shows, as most of us are already aware – that the Japanese developed automobiles in far less time and for much fewer development dollars. The Japanese products were also better performers than those of the European high volume manufacturers.

Table 1.1 Global competition in car industry

Activity	Japanese volume producer	US volume producer	European volume producer	European high-end specialists
Engineering hours (millions)	1.7	3.2	3.0	3.0
Percentage to US	53	100	94	94
Lead time, concept to market (months)	45	60	57	63
Percentage to US	75	100	95	105

Source: Product Development Performance: Strategy, Organization, and Management in the World Auto Industry (Figures 4.2 and 4.4) by K.B. Clark and T. Fujimoto. Boston: Harvard Business School Press, 1991.

Although this analysis is for one industry, it is very representative of what is going on in the world. In this increasingly fierce competitive global economy, there are foreign as well as domestic competitors who can do it better, and when they do, they will seize market share. Virtually no industry or marketplace are immune to these competitive challenges.

1.1.4.2 Rapid Changing Technologies

Previously, technology usually remained the same for several generations of the product, but this is not the case today. Today, many technology changes take place within each generation. In some high-tech industries, such as the computer industry and the communication industry, it is not uncommon for technologies to change dramatically every two or three years.

As a result, product life cycles are rapidly declining. This, in turn, reduces life cycle revenues and profits. It is becoming more and more difficult to achieve satisfactory ROI, considering the expense of developing OKP products and the short periods available to obtain financial recovery on that investment. Hence, companies are being forced to develop OKP products at a faster and faster pace. OKP companies that are not making significant strides in reducing their RPD cycle times are struggling to remain competitive.

1.1.4.3 Increasingly Complex Market

Markets continue to become more diverse and complex. Customers, increasingly exposed to the advertising and marketing efforts of global competitors, are becoming more sophisticated and demanding. Competitors, seeking a marketing niche, are decreasing prices and adding product differentiation. This increasingly complex market has put a lot of pressure on OKP manufacturing enterprises to meet the diverse customer needs and demands.

1.1.5 Emerging Research Issues

To improve the performance of OKP manufacturing enterprises and to win the RPD competition, the major research problems for OKP companies to compete in today's global market have been identified (Tu *et al.* 2002).

1.1.5.1 High Customisation

It is obvious that engineer-to-order will result in high customisation. High customisation often leads to diversified customer's requirements and hence great uncertainties. These uncertainties result in numerous reworks, longer PD and production lead times, and high costs.

1.1.5.2 "Once" Successful Approach

The production in OKP companies is different from that in batch or mass production companies. In a batch or mass production company, a prototype of the product will be made first to approve the design and to study the manufacturing processes. In OKP companies, no prototype is made. The product must be made in OKP companies in one go, or a "once" successful approach. It is not economical for a mould/tool maker to make a prototype of the mould first prior to making the final mould. It would be ridiculous for a large oil cargo building company to make a prototype of the ship to approve the design and study the manufacturing processes first, before making another ship as the final product. They all must make their products according to customers' requirements in one go. This once successful approach to product production in OKP companies creates many challenges and problems for the companies:

1. uncertainties in product design, process planning and shop floor scheduling;
2. owing to the aforementioned uncertainties, product design and production must be carried out concurrently, or jointly planned and controlled through the whole PD life cycle;
3. hidden costs or reworks caused by inappropriate or wrong designs, process plan or production schedules;
4. it is difficult (if not impossible) to get a well planned production schedule and inventory plan, and OKP companies often run in a fire fighting situation.

1.1.5.3 Looser or Fatter Production Planning and Control

Owing to the uncertainties mentioned above, OKP companies normally plan their production and allocate production resources in a much looser or fatter way compared to batch and mass production companies. In a batch or mass manufacturing company, production is normally organised along a production line that synchronously moves according to a pre-defined cycle time. In a car manufacturing company, for instance, the cycle time may be 1–2 min. This means that production in this car manufacturing company can be synchronised by this cycle time. Operations in every section throughout the whole plant will be able to be completed in just one to two minutes. In every cycle time, a product (or a car) can be delivered from the company's final assembly line. This would be impossible for an OKP company. In OKP companies, production is asynchronous. The operations are loosely planned according to rough estimates of the processes. This loosely planned asynchronous production results in mixed material flows in an OKP company, and a higher work-in-process inventory and cost is incurred.

1.1.5.4 Continual Customer Influence

In OKP, customers may change their requirements throughout the production procedure, which is different from batch and mass production where the customer's requirements are confirmed or fixed before product design and manufacture. In OKP, owing to limited knowledge on how to produce the required product, the customer may change the requirements after the product has been partially made, *e.g.*, when the customer sees the design of the product, a plastic part made by a rapid prototyping machine, a part of the product, *etc.* In the worst case, a customer may wish to change some of his/her requirements or add some modifications in later stages of the production. It is obvious that the ability to cope with this type of continual customer influence will improve an OKP company's standing in the marketplace.

1.1.5.5 Complicated Product Data and Information Flows

An OKP company may produce a number of products at the same time. Due to the high customisation of these products, each of these products must be managed individually. It is not rare for a part of product A to be wrongly assembled into product B, a wrong order to be placed to the supplier, a wrong inventory to be kept in the company, *etc.* The information and data of product design, process planning, inventory planning and control, and production scheduling are determined for each of the products, and flow simultaneously in the company. On the other hand, no OKP company, particularly small or medium sized companies, would like to equip itself as a super company that can meet all kinds of customer requirements. They often use a lot of partners or subcontractors to compensate for their lack of manufacturing ability. This leads to complicated product data and information flows not only within the OKP company but also across companies.

1.1.5.6 Complicated Logistics Management

This is another problem resulting from the high customisation of OKP. The complexity of logistics management in an OKP company can be viewed internally and externally. Internally, an OKP company normally has complicated material handling and inventory control. Externally, it may have an extensive outsource network that consists of complicated supplier chains and partner/subcontractor chains, and a customer network that consists of complicated delivery chains and sale chains.

1.2 Motivation for the Book

To solve the problems mentioned above, OKP companies have been actively adopting new technologies, particularly computer technologies such as intra/internet communication technology, CAD/CAPP/CAM, rapid prototyping, MRPII/ERP (manufacturing resource planning/enterprise resource planning), PDM (product data management), and computer simulation technology. According to a survey (Whybrew *et al.* 2000), some of these technologies are also widely applied in New

Zealand manufacturing companies as well as overseas. Despite the large efforts that have been made to develop in these areas (a comprehensive review of literature will be given in Chapter 2), these technologies are often used separately rather than in a systematic and integrated way. The applications of these technologies are lacking in system integration and synergy. Our findings also show that most OKP companies find it difficult to adopt commercial software tools for their applications.

To help manufacturing companies, particularly OKP companies, to rationally adopt these computer application technologies to effectively shorten their PD cycle time and reduce PD cost, a research programme has been funded by the Foundation of Science and Technology of New Zealand (NZ) since 1998. This research programme aims to provide these NZ OKP companies with a reference production management system framework, concepts and software tools to support the applications of these computer technologies. The research work reported in this book is a part of this research programme, and mainly focuses on the strategies, algorithms and technology for rapid development of OKP products.

The principal goal of this book is to develop new technology, algorithms, tools and systems to reduce PD lead time and cut down the cost for OKP PD. This goal is to be achieved by the proposal of an Internet-based PD system which integrates modern technologies such as information technology (IT), RPD paradigm, information modelling, distributed multi-objective optimisation, and Internet-based information management. The developed Internet-based RPD or IRPD system is for the strategic purpose of improving the New Zealand manufacturing level in the world, particularly for new PD. The methods, algorithms and tools however, will be useful to many OKP companies in the world. In the book, theories, concepts and methods from the areas of modern control engineering, rapid manufacturing, CAD/CAPP/CAM integration, engineering optimisation, information technology and knowledge-based technology are developed and applied to industry. The research has used two typical New Zealand OKP companies, *i.e.*, customised sheet metal manufacturers and tool/mould makers, as pilot companies or test beds to validate the proposed system and other major research findings. Following similar principles, it can be envisaged that a number of high-tech RPD tools can be developed to help other manufacturing enterprises in New Zealand to better compete in the global market.

1.3 Book Organisation

The presentation of the book strives for a balance between modularity and integrity of the chapters. The chapters are carefully structured in a self-contained fashion in order to address specific issues involved in the rapid development of OKP products. Each of these chapters starts with an overview of the technique and research background of the major objectives of the research, which form the main points of the new system structure, concept and method. The book will provide answers to most of the main research activities that are ongoing around the world in the OKP research field. The main contents of the book are summarised as follows.

1. Investigation of current hurdles that hamper RPD and proposal of a reference architecture for building an Internet-based integrated PD system. Nowadays, the operation of an OKP company tends to build on the basis of cooperation between the company and its partners in its manufacturing network. It is often driven by customer focus and volatile markets. In short, OKP companies operate in a global competitive and collaborative environment. To rapidly develop a new product in this global environment, OKP companies need to update their traditional manufacturing systems and traditional PD processes to meet the requirements of this global environment. The hurdles blocking the way to this upgrading process need to be identified and further studied. To meet the requirements of the global environment and to facilitate the complicated communications between an OKP company and its partners, and between the company and its customers, a reference structure of an Internet-based integrated PD system needs to be developed.

2. The development of a system architecture proposed for OKP PD. To test the feasibility of the proposed reference system architecture, the proposed system architecture is implemented to speed up sheet metal PD. Sheet metal manufacture is a major part of the New Zealand manufacturing sector.

3. An Internet-based information platform or framework for RPD. To rapidly develop a sheet metal part/product, an Internet-based information platform needs to be developed as a major part of the Internet-based rapid sheet metal part/product development system.

4. A new compound machining method to speed up sheet metal PD. A compound cutting and punching production method supported by an integrated CAD/CAPP/CAM system in sheet metal manufacturing needs to be developed to speed up sheet metal product design and manufacture. Many existing commercial CAD/CAM systems are not suitable for this manufacturing method, especially in concurrent and global design and manufacturing environments. Some problems have to be solved before these CAD/CAM systems can be employed and integrated for this compound manufacturing method.

5. Cost estimation and optimisation for rapid development of sheet metal part/product. In order to maintain a strong competitive ability, sheet metal manufacturing companies have to look for the cheapest way to develop their products. This is a cost estimation and optimisation process.

6. An integrated product data model for PD life cycle and application for rapid tool/mould making. As mentioned before, OKP companies tend to design, manufacture and maintain a product through global collaboration in a team. The team members may include engineering, manufacturing and service firms and they are often geographically dispersed. They work together to design, manufacture and support the product. For this reason, an integrated information model has to be developed to support the definition and exchange of product data unambiguously and consistently between team members during the entire course of the PD process. Developing and manufacturing a product through this type of global collaboration is termed virtual manufacturing, and a company that adopts the virtual manufacturing strategy is called a virtual manufacturing company. It is obvious that the virtual manufacturing concept is particularly suitable for rapid OKP PD since the virtual manufacturing strategy can improve the company's flexibility and capacity to handle much wider and diversified customer requirements. Tool/mould making is a typical one-of-a-kind production and is also another major part of the New Zealand manufacturing sector. To apply the research findings and to widely support New Zealand manufacturing companies, the proposed data model is tested through a mould development process instead of sheet metal part/product development.

7. Development of an Internet-based information management system. It is obvious that an Internet-based information management system needs to be developed as an important part of the Internet-based OKP PD system to manage the various databases which can be directly accessed via Internets.

8. An Internet-based DFX (IDFX) system for rapidly tool/mould manufacture. DFX, or design for X, is a broader concept to encapsulate various concurrent engineering approaches for RPD, such as design for manufacture (DFM), design for assembly (DFA), *etc.* To test the suitability and feasibility of adopting this concept into the Internet-based rapid OKP PD system, an Internet-based DFX system or IDFX system needs to be developed and tested in a typical company.

References

Bullinger H-J, Warschat J, Warner K (1996) Management of complex projects as cooperative task. In: Koubek RJ, Karwowski W (eds) Manufacturing agility and hybrid automation: I. Proceedings of the 50th International Conference on Human Aspects of Advanced manufacturing: Agility and Hybrid Automation: Maui, HI, USA, August, 1996, pp 383–386

Bullinger H-J, Warschat J, Fischer D (2000) Rapid product development – an overview. International Journal of Computer in Industry 42:99–108

Floyd DT (1993) Winning the new product development battle. The Institute of Electrical and Electronics Engineers, New York

Hirsch BE (1992) Future research in one-of-a-kind production. In: Hirsch BE, Thoben K-D (eds) One-of-a-kind production: new approaches. Elsevier Science Publishers B.V., North Holland, pp 87–94

Rolstadas A (1991) ESPRIT basic research action 3143–FOF production theory. International Journal of Computer in Industry 16:129–139

Tu YL (1996) A framework for production planning and control in a virtual OKP company. In: Technical Papers of North American Manufacturing Research Institution of SME 1996, pp 121–126

Tu YL, Xie SQ, Zhou ZD (2001) An information modeling framework to concurrent product design and manufacturing. In: Proceedings of IAM'2001, American University in Dubai, U.A.E., pp 564–571

Tu YL, Xie SQ (2002) Rapid one-of-a-kind product development in a global and virtual manufacturing environment. In: Proceedings of AMPS 2002, September 2002, The Netherlands

Wortmann IC (1991) Towards one-of-a-kind production: the future of European industry. In: Eloranta E (ed.) Advances in production management systems. Elsevier, Amsterdam, pp 41–49

Whybrew K, Raine JK, Shaw A, Aitchison DR (2000) Summary of results of the survey: Rapid product development for world class manufacturing. Technical Report 58. Dept of Mechanical Engineering, University of Canterbury

http://www.springer.com/978-1-84996-340-4

Rapid One-of-a-kind Product Development
Strategies, Algorithms and Tools
Xie, S.; Tu, Y.
2011, XVII, 449 p., Hardcover
ISBN: 978-1-84996-340-4