The evolution of production systems and conceptual frameworks

Afonso Fleury
Production Engineering Department, University of Sao Paulo, Brazil, and
Maria Tereza Fleury
School of Economics and Business Administration, University of Sao Paulo, Brazil

Received September 2006
Revised May 2007
Accepted June 2007

Abstract

Purpose – The development of a conceptual framework for the study of production systems in general derived from the analysis of the telecommunications industry; since this industry is considered as one of the pillars of the coming information society and knowledge economy, the application of that framework to other industries and production systems brings insights as to their recent changes and future trends. This paper looks at the stream of frameworks proposed for production and operations management, with the intent of contributing to the debate by addressing the following question: would an analytical framework derived from the telecommunications industry have distinct features relative to the analytic frameworks currently in use?

Design/methodology/approach – Following a literature review of the evolution of the telecommunications industry, the framework (TbF for telecommunications-based framework) was built from scratch, using grounded theory, case studies and Delphi methods. The field for research was the Brazilian Telecommunications industry, considered as a microcosm of the whole industry. The TbF was then applied to the automobile and textile/apparel industries for illustration purposes.

Findings – The TbF is composed by six types of companies, characterised by distinct profiles of organisational competences, interacting according to some specific patterns of relationships. Compared to the most commonly used conceptual frameworks, the TbF allows for critical assessments in regards to their basic assumptions and reveals ways to evolve in direction of more dynamic approaches to the study of production systems.

Research limitations/implications – As all other conceptual frameworks, the TbF is a simplification of reality and so its use requires a clear view of its assumptions. In regards to generalisation, the main assumption of the TbF is that other industries and production systems are accelerating their "clockspeeds" over time. As to the TbF's limitations, the main drawback relates to its development being derived from the most "traditional" segment of the telecommunications industry. This led to the exclusion of the internet-enabled industries which promise a great impact in the near future.

Practical implications – The main contribution is for practical work in the academic and consultancy spheres, because what is under investigation is the way in which knowledge about production systems is being produced. The use of the TbF might disclose the limitations of the most commonly used conceptual frameworks and reveal ways to produce knowledge which is more aligned to the dynamism and complexity of production systems now and in the future.

Originality/value – The TbF is original in its structure. Its value in the creation of knowledge which is relevant and applicable still depends on further development.

Keywords Manufacturing systems, Telecommunications, Brazil

Paper type Conceptual paper

Journal of Manufacturing Technology Management
Vol. 18 No. 8, 2007
pp. 949-965

1741-038X
DOI 10.1108/17410380710828271

Introduction

Once upon a time, there was a self-sufficient and self-contained successful manufacturer. In the 1910s and 1920s, the Ford Motor Company dominated the automobile industry's entire spectrum of activities, from rubber plantations in the Amazon region for tyre production to sales, after-sales and maintenance services. However, that is now history. In the last 30 years, as a result of profound changes in the structure of industry in general, production systems have become increasingly complex and firms have begun to play specialised and complementary roles in organisational networks. The book *How We Compete: What Companies around the World are Doing to Make It in Today's Global Economy* (Berger, 2005), based on the MIT Industrial Performance Centre's five-year study of 500 international companies, offers a detailed analysis of why manufacturing became fragmented, internationalised and complex. Nonetheless, questions such as "is there still an American model?" or "will a new American Model emerge?" are combined with propositions such as "Made All Over". The perplexity that underlies these questions is echoed in many other recent works, as expressed in the Harvard group's latest book, *Pursuing the Competitive Edge* (Hayes *et al.*, 2005, especially Chapter 1). It appears that in "the era of temporary advantage" (Fine, 1998), the evolution of production systems seems like a never-ending metamorphosis (Zysman, 2003).

In today's dynamic and, much of the time, turbulent environments, manufacturing companies are becoming different from each other; they then reassemble into distinct configurations, resulting in a variety of production systems. Configuration, in this case, is understood as comprising the typology of the enterprises that compose the system and the nature and dynamics of the relationship between them.

Given that the rate of change of production system configurations has been so great, it is not surprising that distinct frameworks are proposed to describe them. A supply chain is one example of an analytical framework and is possibly the one that is most studied and most important. The discussion and assessment of frameworks is relevant because both academic debate and managerial practices are based on frameworks, whether explicitly or implicitly. Moreover, since every analytical framework is derived from a theoretical approach, implicitly there is a choice of theory and the paradigm that "lies behind it".

Therefore, this paper looks at the stream of frameworks proposed for production and operations management (POM), with the intent of contributing to the debate by addressing the following question: would an analytical framework derived from the telecommunications industry have distinct features relative to the analytical frameworks currently in use? Would it bring special contributions for the understanding of the actual and future POM challenges?

Telecommunications is part of the telecommunications, information, media and entertainment (TIME) industry, which is considered the carrier of a new paradigm for the organisation of society as a whole. Because of its inherent complexity, telecom has rarely been seen as a role model for operations management, other than, notably, in Charles Fine's book, *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*, which was a source of inspiration for many innovative approaches to POM issues.

However, telecom industry studies, thus far, employ the only analytical framework proposed, Fransman's six-layer model (2001). In this model, the first and second layers are those that comprise conventional manufacturing industry; the third, fourth and fifth layers are reserved for internet-based operations; and the sixth is the consumer layer.

A field research, which will be described further on, was conducted in order to understand the configuration of firms primarily related to production and operations in the telecom industry. The outcome revealed a particular configuration composed of six types of mutually interrelated firms: network operators, integrators, developers, manufacturers, technology specialists and logistics operators.

The telecom industry's typical analytical framework was then applied to the automobile and the textile/apparel industries, which are symbols of past industrialisation waves. A literature review and data gathered in the preparation of two large surveys prepared for the Brazilian Government provided the basic inputs for the application. As studies on these two industries generally use, as their analytical framework, supply chains for the auto industry and global value chains for the textile/apparel industry, a comparative analysis revealed the potential advantages of the new framework in synthesising recent structural changes and in indicating trends for the different types of firms in the near future.

A note about frameworks

The term "model" has many meanings. In its most general sense, the word refers to a representative device through which some features of an object, person, process or structure can be characterised. Models, theories, conceptual frameworks and paradigms are all terms that help to organise thinking and action: they give differential priority as well as structure to ideas and practices.

Warr (1988) illustrates the issue by using the analogy of sieves and moulds. Scientific models and the other perspectives act as sieves in that they allow some items to pass through but disallow others; a sieve selects some things over others thereby rearranging these elements. The conceptual moulds give shape to thinking, establishing systems of meaning and creating familiar patterns that enable manipulation and work.

The author sees conceptual frameworks as the broadest among the four aforementioned terms:

> A conceptual framework provides a technical language system, a set of interpretative principles and important benchmarks for guiding thought. … A researcher's conceptual framework is likely to have been developed within a particular professional culture and internalised in such a way that the members of that culture can easily communicate with each other, share a common evaluative structure and routinely frame research questions and possible ways of finding answers.

In this study, the notion of conceptual framework will play a key role. The elements that constitute conceptual frameworks are the categories in which participant firms might be classified as well as the nature and type of relationships implicit in the dynamics between firms.

Most commonly used conceptual frameworks

During the twentieth century, the automobile sector was a role model for the organisation of industry as a whole (Womack *et al.*, 1990; Zysman, 2003). The emergence of the Japanese production model in the 1970s was considered a first break away from the Fordist paradigm and a trigger for the development of new forms of organisation. An immense number of methods and techniques were then proposed for specific applications and a set of new frameworks were developed aiming to capture the new industrial organisation requirements: supply chains (Slack, 2001), supply

networks (Harland *et al.*, 2001; Slack and Lewis, 2002) and global value chains (Gereffi *et al.*, 2002; Zysman, 2003), among others.

Supply Chain is defined as "a strand of linked operations through which goods and services flow into and out of the operation".(Slack *et al.*, 1999). In this model, relationships among the participant firms are assumed to be linear and unidirectional, a network containing leaders and followers. The supply network concept admits greater complexity:

> Supply networks encompass the mess and complexity of networks involving lateral links, reverse loops and two-way exchanges and include a broad, strategic view of resource acquisition, development, management and transformation (Harland *et al.*, 2001).

The global value chains framework (Gereffi, 1994; Gereffi *et al.*, 2005) considers three main dimensions:

(1) an input-output structure (i.e. a set of products and services linked together in a sequence of value-adding economic activities);

(2) territoriality (i.e. spatial dispersion or concentration of production and marketing networks, comprised of enterprises of different sizes and types); and

(3) a governance structure (i.e. authority and power relationships that determine how financial, material and human resources are allocated and flow within a chain).

Additionally, the global value chains approach takes into account two different structures, depending on the characteristics of the enterprise that heads the value chain. Producer-driven chains are governed by manufacturing/technology firms and buyer-driven chains by commercial and service sector firms.

Table I synthesises a comparative assessment of those frameworks.

Those are the frameworks currently in use in POM. The research question that is now addressed introduces the telecommunications industry into the picture. Since, this industry is considered as one of the pillars of the coming information society and knowledge economy, would the application of a framework based on its functioning to other industries and production systems bring insights as to their recent changes and future trends?

The telecommunications industry basic conceptual framework

The TIME industry is often mentioned as the driver of a new paradigm for industrial and societal organisation. However, very few models have been presented for the analytical study of that new reality. Particularly with regard to the Telecom industry,

	Motivation	Configuration	Coordination	Relationships
Supply chain	Focusing and subcontracting	Linear and unidirectional	Focal company	Hierarchical, asymmetric
Supply network	Focusing and networking	Messy and complex	Depends on type of network	Lateral, reverse loops
Producer driven value chain	Governance of value chain	Linear and unidirectional	Industrial entity	Market or modular or relational or captive or hierarchical
Buyer driven value chain	Governance of value chain	Complex but identifiable	Commercial entity	

Table I.
Comparative assessment of conceptual frameworks

the model developed by Fransman (2001) remains uncontested, though the author himself recognises its drawbacks. The framework is pictured in Table II.

For Fransman (2001), "the general purpose of the layer model is the development of a cognitive framework that will facilitate an understanding of 'the evolution of the structure of the Telecom industry'".

Layers I and II are those that refer to traditional Telecom industry enterprises; layer I corresponds roughly to manufacturing firms while layer II comprises service providers. The introduction of the upper layers (III-VI) is justified as follows:

> Traditionally (i.e. roughly until the advent of data communications and the Internet), the "Telecom Industry" was thought of as encompassing layers I and II. However, the evolution of the internet changed this decisively. Firstly, the TCP/IP interface provides an effective way of transferring data across disparate networks (in much the same way as containerisation allows goods to pass more easily and at lower cost across different transport networks). In addition, the TCP/IP interface provides a platform on which several higher layers can be built in order to offer end consumers a range of services, content and applications.

The distinctive characteristics of Fransman's model are the following:

- the consumer is an active player in the overall dynamics of the industry;
- individual enterprises can be players in different layers that are not necessarily adjoining and, eventually, on a temporary basis; and
- coevolution and coopetition coexist: technologies, products and markets change fast and unpredictably; thus, a set of firms might be cooperating in one market and competing in another.

The "consumption module" is a module of a special kind because the firms involved in the other five layers (though not necessarily in all of them) need to have in-depth knowledge of what goes on inside the consumption module since it is here that

Layer	Activity	Example companies
VI	Customers/consumption	–
V	Applications layer, including contents packaging (e.g. Web design, on line information services, broadcasting services, e-commerce, etc.)	Bloomberg, Reuters, AOL – Time Warner, MSN, Newscorp, etc.
IV	Browsing and middleware layer (e.g. browsers, portals, search engines, directory assistance, security, electronic payments, etc.)	Yahoo, Nestcape, Vizzavi, Genie, etc.
III	Connectivity layer (e.g. internet access, web hosting)	IAPs and ISPs
TCP/IP interface		
II	Network layer (e.g. optical fibber network, mobile network, DSL local network, radio access network, ethernet, frame relay, ISDN, ATM, etc.	British Telecom, France Telecom, Vodafone, NTT, NTT DoCoMo, etc.
I	Equipment and software layer (e.g. switches, transmission equipment, base station, routers, servers, CPE, billing software, etc.)	Nortel, Lucent, Cisco, Ericsson, Nokia, etc.

Table II.
The Fransman's layers model for the telecommunications industry

questions such as what the consumer wants and how much the consumer is willing to pay are determined.

The research design

In order to understand the eventual specific features of the configuration of the telecom industry, a study was conducted focusing on layers I and II of Fransman's model. Those are the layers in which the traditional manufacturing firms operate: the so-called manufacturing firms (the specialised equipment suppliers, such as Ericsson, Motorola, NEC, Alcatel, etc.) and the telecom operators (Telefonica, France Telecom, British Telecom, etc).

In first instance, the use of two layers seems to be a somewhat simplified perspective. Might it be possible to develop a framework to describe the configuration of firms involved in those two layers at a more detailed level? An important consideration for this study was the implicit assumption that, since those firms are in a very high-clockspeed type of industry, the dynamics between them would be different.

Therefore, the first choice made was not to use any of the existing frameworks for the field research and to try to build a specific one from scratch. This choice raises different challenges for the researcher and calls for specific methodologies. A detailed explanation of the methodological choices and procedures will be presented in the next section.

The first task was an extensive literature review in order to find out the recent evolution patterns of the telecom industry worldwide. This led to the conclusion that a significant restructuring at firm and organisational network levels was under way (Fine, 1998; Fransman, 2002; Fleury and e Fleury, 2003).

The second choice concerned the research field. This was Brazil, where, during the privatisation process, the State withdrew from actual industry operations, becoming merely a regulatory entity, which left the field open to any firm. The final picture was a structure in which a large number of subsidiaries of large global multinationals became the main local-market players, thus creating a microcosm that up to a point simulated the dynamics of the industry as a whole.

Initially, three subsidiaries of specialised equipment suppliers (one European, one Japanese and one American) and three telecom network operators (two European subsidiaries and a Brazilian enterprise) were chosen as the object of case studies. Of the two foreign network operators, one is engaged in both wireline and mobile communication, while the other deals in the mobile segment only. The Brazilian firm operates in both segments. As for the specialised equipment suppliers, two of them have been established in Brazil for a long time, whereas the third entered the country recently.

The first step in the study of each firm was to research secondary information in the specialised media and in company reports. Then, for each company, two or three people from the executive board, among those in charge of enterprise strategy, planning and human resources, where interviewed. The interview guidelines focused on the following: competitive strategy, critical organisational functions, supply network relationships (both upstream and downstream), service and product development, operations management and human resources management.

These case studies made it apparent that the sample needed to be complemented with Level VI firms – Consumers, as well as with enterprises concerned with the development of technology for the industry as a whole. Following referrals, two large users of telecom services (a bank and a newspaper publisher, both Brazilian) and the Centre for Telecommunications Research and Technology (CPqD), which played a key role when the

telecom system was still government-run, were also studied. Finally, while the fieldwork was conducted, another type of firm, not previously identified, was referred to by the aforementioned "Consumers" as well as by the telecom operators, namely, Engineering and Consulting firms with responsibility for the delivery of the complex equipment operated by the former firms for the delivery of their services and products. Based on their suggestions, three complementary cases were prepared, covering one large international consulting firm, a large local engineering firm and a medium-sized Software House.

A total of 21 people were interviewed and in one of the telecom operators a workshop was prepared for the discussion of the research findings.

In the final step, a Delphi-type exercise was carried out with 25 executive officers of firms representing the six different types of enterprises identified. About 14 responses were received and analysed.

The methodological options

The research method combined the case study method and grounded theory because, initially, there was no theory to be tested, but rather, distinct and independent bodies of theory. Thus, the first cases almost had a participative research nature, in that the researchers were looking for a pattern in order to build their conceptual framework. Gradually, the rationale of the entire system emerged and the tools were refined, leading to a questionnaire that was part of the Delphi exercise.

Glaser and Strauss (1967) state that the grounded theory approach:

> ... has much in common with the case study [approach] ... its most distinctive characteristic being that, in order to find out what views are underlying the similarities and differences, the researcher is constantly comparing the various items he/she is observing in reality, both with each other and with theoretical starting points.

According to Verschuren and Doorewaard (1999) the grounded theory approach has three main characteristics. The first one is "an inquisitive attitude" from the researcher, meaning that a theory or theoretical concept materialises slowly but surely in the course of the research project. Although the researcher does not start with a detailed theory that is subsequently tested, he/she must fulfil the criteria of reliability, validity and imitability by following certain specific procedures and techniques. That is why, after the initial case study, the case choice and questionnaire structure evolved gradually, as the variables and relationships became increasingly obvious and understood. Even the decision to study additional cases of users of telecoms services and consulting firms was made with the aim of clarifying specific aspects of the phenomena.

The second feature of grounded theory is:

> ... a process of continuous comparison: the researcher is incessantly engaged in a process of comparing findings with previously found phenomena or interpretations, or with the ideas and notions others before him have published on the subject (Verschuren and Doorewaard (1999) p. 172).

The authors mention several types of appropriate comparisons. Secondary empirical comparisons, primary and secondary theoretical comparisons during the field work, and deductive comparison for the preparation of the conclusive framework were applied. In this regard, Fransman's book (2002) and the literature on competencies and capabilities (Prahalad and Hamel, 1990; Teece *et al.*, 1997, Fleury and e Fleury, 2005) were the main sources for comparisons.

The method's third characteristic is careful and consistent use of specific procedures and techniques. Through selective coding, the multitude of phenomena described and the formulation of concepts and key words into a concise description of the theory that is to be developed was reduced. This was done during and after the field work.

Finally, using Delphi-type research, the final outcome, the proposition of a new analytical framework for levels I and II of the telecom industry, was submitted to 25 executive officers from firms representing the six different types of identified enterprises. A total of 14 responses were received of which three disagreed with the proposition and eleven agreed. The disagreements were related to the failure to include internet operators, which was an aprioristic decision. Two respondents also questioned whether two of the types of firms identified (operators and integrators) would continue to be distinct from each other in the future or would merge. However, acceptance of the new conceptual framework was stronger than the criticisms.

Field research findings: the telecommunications-based framework

The field research led to the identification of six types of firms and their mutual relationships, which came to constitute the telecom-based framework (TbF).

Before proceeding with the presentation of the TbF and its elements, a word of warning is necessary in relation to the way in which firms are classified. In the large majority of cases, firms run different businesses and accomplish different production and operational activities. The categorisation of firms has taken into account each firm's main role in the functioning of the entire production network or system. For example, IBM is classified as an Integrator even if it performs activities related to Development and Manufacturing (Gerstner, 2003). The same holds true for the automakers, or for the firms considered in the aeronautics industry.

The Figure 1 shows a graphic representation of the TbF.

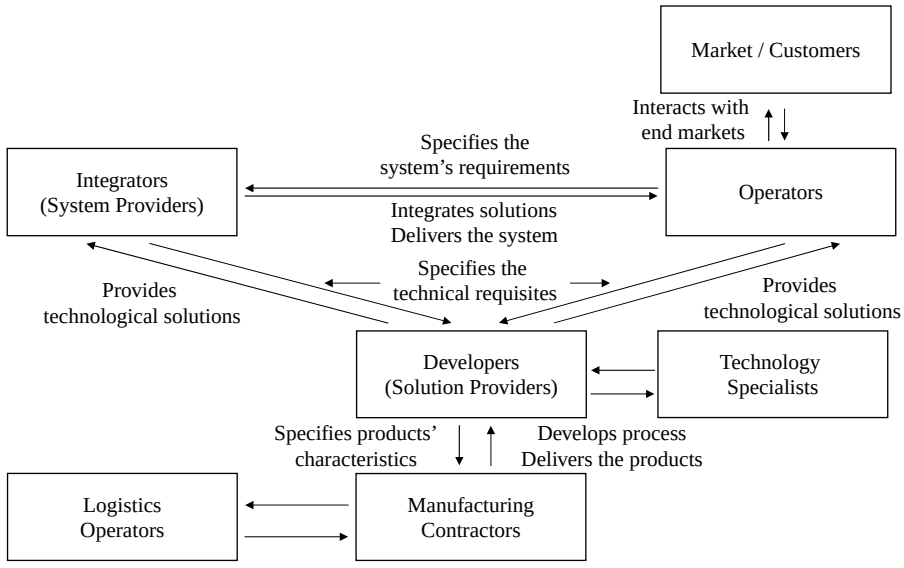

Figure 1.
The telecommunications-based framework (TbF)

Network operators

In the telecom industry, network operators are essentially concerned with delivering different types of telecom services to different types of markets. They can be distinguished from the other firms in the industry because their strongest competencies are marketing and customer relationships, i.e. competencies that support their product/market strategies.

Market segmentation creates three categories similar to those proposed by Silvestro (1999): mass services, service shop and corporate services. The first, mass services, concerns individual customers that only require voice transmission. In this market segment, the network operators act essentially as large-scale producers of standard services, operating according to the operational excellence strategy: the goals of the business are to increase scale and minimise costs, thereby optimizing the margin per client. The role of marketing is fundamental for the scale increase.

In the service-shop market, the network operators' goal is to identify, attract and retain new, differentiated clients. These are clients who like innovation, i.e. early adopters, for whom the network operators can offer new services and products or niche products at a premium price. The notion of co-evolutionary strategies underlies this market. Under these circumstances, marketing assumes a critical role related to the identification of clients' profiles and niche characteristics, thus guiding investment and operational decisions. This is the area in which the application of CRM – customer relationship management – is critical.

Finally, corporate services are considered the least developed and most promising market segment. For this type of client, the aim is to develop solutions and systems that will increase its competitive strengths through improved application of telecommunications in terms of voice and large volumes of data transmission. In the mobile telecommunications area, due to its newness and unresolved technological challenges, those services become large and complex projects, in which the network operators, specialised equipment suppliers and even consulting firms compete strongly for the position of prime contractor.

All of these services make use of network infrastructure and complex technical systems. For example, the infra-structure of one telecom operator might include sub-systems and components developed by Ericsson or NEC that are powered by components developed by Motorola or Cisco or Nortel. When procuring complex technical systems, network operators rely on specialised firms to organise and head the major projects that involve design, project specification, parts purchase, assembly, trials, delivery and implementation of their operational systems. In the TbF, those are the integrators.

Integrators

The telecom operators rely heavily on the work of integrators for infrastructure conception, design, procurement, assembly, installation and maintenance. The integrators are brought into the picture due to their knowledge of the intricacies of the local markets and institutions, as well as their competencies in systems engineering in the telecom field. They have the know-how for managing large complex inter-organisational projects and are considered to be producers of complex product systems, or CoPS (Davies *et al.*, 1999). Integrators' core competency consists basically of systems integration; however, this involves not only technology but also finance,

legal and jurisdictional issues and institutional analysis, structured in accordance with project management best practices. Integrators deliver and implement feasible and optimised complex systems that integrate hardware, software and operational procedures for network operators' operations. This has to be performed in such as way as to take into account the regulatory environment. Integrators must also evaluate both current and future possibilities, conduct the feasibility studies required to optimise the project, specify the products' characteristics and perform the procurement (sub-contracting included), assembly, trials, delivery, installation, and field testing. Finally, they must transfer the system to the network operators. In the Brazilian Telecom industry, engineering firms such as Promon and consulting firms such as Accenture play the role of integrators.

Developers

Those are the traditional specialised equipment suppliers of the telecom industry, firms whose role in the production network derives from their distinctive R&D competencies. According to the typology proposed by Hobday *et al.* (2005), they are essentially concerned with integrating technologies in the pursuit of solutions (products or product systems). The products or solutions will usually, but not exclusively, be based on their own-proprietary technologies. For example, the development of software (e.g. billing systems) and systems for network use optimisation are part of their portfolio. The organisational competencies that companies value the most include: market needs identification, both in terms of network operators and end-users; technology identification and assembly, developed at the headquarters or elsewhere, to create and deliver the best solution; and organisational networking, through strategic alliances and supply chain management.

For the technology identification and assembly (a Lego-like operation, according to Berger, 2005), developers rely on technology specialists. Brusoni and Prencipe (2001) justify the developers-technology specialists relationship as follows:

> As the number of disciplines for the design, development and manufacturing of products increases, [Developers] need to rely on specialised suppliers of equipment as well as knowledge, to complement their in-house R&D efforts.

In the telecom industry, developers might also maintain preferential relationships with an occasional Integrator, thus strengthening their presence *vis-à-vis* network operators. Moreover, regarding certain specific types of needs, developers may have direct access to network operators.

Technology specialists

Under this label there is a broad range of institutions that in the last decade or so have been described as constituents of "the National Innovation Systems" (Nelson and Rosenberg, 1993). Those systems include both public and private institutions, ranging from universities to specialised engineering firms and small labs supplying technical services (Kim, 1993). Their main role is to provide knowledge and information for the industry in general and particularly for R&D-intensive firms.

Manufacturing contractors

The telecom industry was the first one to witness the emergence of this type of firm (Sturgeon, 1997). Manufacturing contractors such as Celestica and Flextronics are

firms that can deliver to their clients products and services that comply with strict quantity, cost, quality and time requirements. Their core competence is process design and execution. This process-focused competence enables them to move into services delivery. Therefore, they are hired by developers not only to deliver standardised goods but also routine services.

Manufacturing contractors use specialised logistics operators services in their global procurement policies while developers are increasingly dependent on the supply of technology from specialised firms that focus on very specific types of R&D.

Logistical operators – this is a new type of organisation whose relevance is rising. Fedex and UPS might be considered, perhaps, the best known cases. However, there is a broad diversity of logistics operators that are key players in the dynamics of production systems. These firms are not only responsible for transportation but in certain specific fields they undertake further activities, such as purchasing and initial assembling for their clients.

Table III shows the main features of the different types of enterprises in the TbF.

The TbF applied to the automobile industry

The restructuring of the automobile industry dates back to when the Japanese automakers, newly installed in the USA, began to show signs of better

	Products/markets	Core competence	Key processes
Operators	Service providers (products and/or services), direct interaction with end markets, B2 C	Marketing, customer relations	Service identification, development, implementation and operation
Integrators	Complex system providers (integrating products, processes and operational systems, taking into account institutional requirements)	Customer-driven systems design, engineering and delivery Management of large multidisciplinary projects	Systems engineering, institutional and financial engineering, technology monitoring and assessment, systems specification, procurement, assembling and delivery
Developers	Providers of innovative products and solutions (product systems)	R&D Breakthrough innovations	Advanced R&D Complex products design and production
Manufacturers	Providers of parts, components (hardware and software), commodities, or routine services	Process and production engineering, efficiency	Manufacturing process conception, development and operation
Technology specialists	Providers of knowledge and information for the industry in general and developers in particular	Basic and applied research	Scientific research
Logistics operators	Providers of transportation services	Logistics	Technological services Transportation Warehousing Purchasing

Table III.
Key features of typical enterprises in the TbF

performance than the domestic manufacturers. It seems that normative propositions, such as those presented in "The machine that changed the world" (Womack *et al.*, 1990) have proven to be valid though only in part. Therefore, what one witnesses is a permanent search for improved configurations and better coordination of organisational functions and units. The changes that affect the automobile industry represent, to a certain extent, a radical departure from the previous systems of organisation. Lung (2003) describes this as "the automobile industry in a regime of permanent innovation".

The application of the TbF to the automobile industry requires some elaboration because the profile of the companies which constitutes that specific production system are different. There are companies in the interface product-markets which used to be independent dealers and maintenance services. These would be similar to the network operators of the telecommunications industry. Than there are the assemblers (like GM, Ford, Toyota, etc.), the first-tier suppliers (usually the mega-suppliers like Delphi, Visteon, etc.) and second-tier suppliers. The governance of the production system is in the hands of the assemblers.

Assemblers were originally manufacturing firms but they are changing their characteristics over time. They still do some manufacturing, but if the TbF is applied, Assemblers will be identified as market operators, integrators, developers and manufacturers.

Currently, assemblers are seeking to dominate as much as possible the functions that are performed by the operators, i.e. the commercial organisations: dealers and after-sales services, not to mention financial services. This downstream movement is strategic for several reasons. In relation to end markets, there is a need to create a direct interface with both consumers and institutional clients, thus avoiding the intermediation of dealers and representatives. Like Fransman's "consumption module" Assemblers need to have in-depth knowledge of what goes on since it is here that questions such as what the consumer wants and how much the consumer is willing to pay are determined.

The downstream expansion is also crucial to control the value-adding processes in the services and replacement markets. Lung (2003) in a study about the European automobile system observed that:

> Restructuring efforts at downstream level were just as intense [as upstream] whether this involved distribution, relational digitisation, automobile repair or recycling. This was the result of three driving forces: strategies pursued by the automobile firms and by new entrants (i.e. distributors and computers or telecom companies) trying to state their control and capture potential rents in these fields; technological change, with a greater role for electronics and the diffusion of ICT; and European policy, notably automobile distribution and environmental regulations.

In relation to strategic intents, it is the only way of making the implementation of new production strategies feasible, especially the "Building to Order" ideal. That goal, "up to this moment, have all stumbled over big problems relating to logistics and the organisation of production" (Lung, 2003).

While trying to control the downstream part of the production system, assemblers currently exert the function of integrators, organizing the work of Developers (first-tier suppliers) and manufacturers (second-tier suppliers):

> The products are complex, built up of many components and systems as well as many technologies. Production as well as product and process development for components and systems are often sourced, to a high degree, from a high number of suppliers, often in hierarchies (Karlsson, 2003).

The dynamics of the relationship between assemblers and first-tier suppliers is different from the one identified in the telecommunications industry because:

> Much of the electronics industry has this open, modular character. In carmaking this is not [or not yet] a full blown reality … For all these reasons, assemblers cannot just hand over a blue print to suppliers, but need to work with them throughout the design process of the car (Berger, 2005, p. 86).

Takeishi and Fujimoto (2003) concluded that:

> … modularisation in the car industry is still in the trial and error stage. [Nevertheless,] … research outcomes suggest that modularisation in product architecture sometimes changes the structure of the division of labour in the industry (from a vertical industry structure to a horizontal industry structure).

This observation can be illustrated by an interesting comparison between the automobile and the aeronautics industries:

> … the move into modularity in aeronautics essentially concerns adapting the organisational architecture to the pre-existing product architecture, while for automobiles, it is necessary to find the technical means of developing a modular architecture with an organisational architecture that is already globally structured in a modular way as the starting point (Frigant and Talbot, 2004).

Assemblers still invest a considerable amount in R&D, maintain manufacturing activities and command supply chains. However, the make-or-buy decision is established from the perspective of the integrative function.

Therefore, there is a trend for Assemblers to take more and more the function of integrator. In this sense, the concept of complex product systems integrators is well suited to the assemblers too. However, the existing structures of the industry and of the product make such transition difficult.

The first tier suppliers, or mega suppliers, have been taking the responsibility for a growing proportion of the design activities that manufacturers have been subcontracting out due to the rise in the number of models they offer. "… Some (like Matra automobiles) also took on a manufacturing activity … By so doing they almost achieved car manufacturer status " (Lung, 2003).

The mega-suppliers (or first-tier suppliers) also perform an integrating role. Lung (2003) mentions that:

> … whereas up to this point reorganisations had mainly affected firms' internal management organisation, this new rationalisation drive centred on inter-firm relationships and on coordinating firms within the automobile system. … This is why carmakers/OEMs delegated to the FTS the design, production, preparation and delivery of the main systems and modules, as well as the management of relationships with lower tier suppliers.

For Karlsson (2003) the division of labour between assemblers and their sub-contractors and suppliers is changing:

> ... the OEM manufacturer specialises in designing and constructing integrated concepts, being responsible for concept development and integration of technical functions. Specialist technical fields, however, become the domain of even bigger and more technically proficient suppliers.

Suppliers are specialist firms that might be characterised as developers and producers of low-value components and, eventually, small systems (Johansen and Riis, 2005). A point that calls for further investigation is why manufacturing contractors failed to become an integral part of that picture and whether, in the future, conditions for that will be created.

In summary, because the consumer is an active player in the overall dynamics of the industry, assemblers are moving downstream aiming to control the interface with end markets. Then, using product/service/functions approach they establish the basis of their integrative role in the production system. R&D, manufacturing and supply chain management are decided from that integrative perspective. The notion of co-evolution is clearly identified in the dynamics between assemblers and first-tier suppliers because technologies, products and markets change fast and unpredictably.

Evidently, the automobile production system is different from the telecommunications production system. However, the application of the TbF brings a new perspective for the understanding of the recent changes and future trends of the auto industry.

The TbF applied to the textile-apparel industry

Generally considered "traditional" current transformations indicate that the textile-apparel industry is actually an extremely dynamic industry in which technological innovation and new forms of organisation create a very modern outlook. Its distinctive aspect is being a buyer driven global value chain, i.e. governance is exercised by commercial firms. Designers such as Louis Vuitton, Armani, Zegna, and others create fashionable items. Brand marketers such as Nike, Adidas and Levi's exploit specific markets and products. C&A, J.C. Penney and Zara, together with hypermarkets such as Carrefour and WalMart, establish standards for medium and large markets. All of them act as market operators defining fashion trends for the world markets and establishing world industry standards in terms of quality, diversity, scale, etc.

The developers are the synthetic fibre producers (Dupont, Basf, ...). Recently, the global fibre producers opted for a strategy of concentrating on development and marketing, leaving commodity products (bulk production) to new entrants, largely from China and Turkey. They influence market behaviour through their strong marketing effort to make their products and brands well known.

The redefinition of the roles and relations of the textile-apparel industry's traditional players led to the emergence of another type of firm that performs an integrating role: the "full package suppliers" (Gereffi, 1994). These are firms capable of globally coordinating supplier groups, including textile firms, assembling firms and logistics firms, among others, to deliver to retailers as ordered. According to the terminology adopted in this study, those firms play the role of integrators for the textile industry.

So, again, the use of the sieves and moulds associated to the TbF might bring new perspectives for the understanding of the textile/apparel industry.

Concluding remarks and research agenda

POM currently have to cope with the increasing complexity of production systems, coupled with profound changes in the structure of industry in general and the differentiation of roles to be played by different firms within organisational networks. This is caused by factors such as information technologies and globalisation and, eventually, it will require that a new paradigm be established for the evolution of POM as a research field.

In this paper, the possibilities of a renewed understanding of the path of POM by using an analytical framework derived from an industry that is seen as that new paradigm's carrier: telecommunications, was exploited. Its application to traditional industries proved to be interesting for describing the transition in roles and relationships among enterprises in general.

The advantages of the TbF can be summarised as follows:

- It allows for the analysis of properties that Fransman claims to be typical of the telecom industry: consumers are brought into the picture; individual enterprises might be seen as players in different layers that are not necessarily adjoining ones; and co-evolution and coopetition will be possibly an integral part of the dynamic relationship among firms in the organisational network.
- It proposes a typology that considers the evolutionary path of existing firms and introduces new types of firms, which are a by-product of the entire industry's reconfiguration.
- It allows one to discern more clearly how each individual firm is positioned in the production network and why.
- It provides a new framework for the study of the interrelationships among the network's firms.
- It provides a platform for an integrated view of operations management, by bringing manufacturing and services into a common framework.

If the TbF is compared to the current representations of organisation networks, it contributes to their improvement by creating a broader set of categories for the supply chain model, bringing new insights to the issues of configuration, coordination and complexity raised by the supply network model and unifying the producer-driven and buyer-driven models in a common framework.

From being derived from an industry that is a symbol of complexity and dynamism, perhaps, the TbF might be a reliable device for the analysis of future trends in many other industries. However, its value in the creation of knowledge which is relevant and applicable still depends on further development.

References

Berger, S. (2005), *How We Compete*, Currency-Doubleday, New York, NY.

Brusoni, S. and Prencipe, A. (2001), "Unpacking the black box of modularity: technologies, products, organisations", *Industrial and Corporate Change*, Vol. 10, pp. 179-205.

Davies, A., Tang, P., Brady, T., Hobday, M., Rush, H. and Gann, D. (1999), *Integrated Solutions: the New Economy between Manufacturing and Services*, CENTRIM, University of Brighton, Brighton, mimeo, p. 45.

Fine, C. (1998), *Clockspeed*, MIT Press, Cambridge, MA.

Fleury, A. and e Fleury, M.T. (2003), "The evolution of strategies and organizational competences in the telecommunications industry", *International Journal of Information Technology and Decision Making*, Vol. 2 No. 2.

Fleury, A. and e Fleury, M.T. (2005), "In search of competence: aligning strategy and competences in the telecommunications industry", *The International Journal of Human Resource Management*, Vol. 16, pp. 1640-55.

Fransman, M. (2001), "Evolution of telecommunications industry into the internet age", *The International Handbook on Telecommunications Economics*, Edward Elgar Publishing, Aldershot.

Fransman, M. (2002), *Telecoms in the Internet Age*, Oxford University Press, Oxford.

Frigant, V. and Talbot, D. (2004), "Convergence et diversité du passage à la production modulaire dans l'aéronautique et l'automobile en Europe", *Actes du GERPISA*,Vol. 37, GERPISA, Paris, pp. 107-18.

Gereffi, G. (1994), "Capitalism, development and global commodity chains", in Sclair, L. (Ed.), *Capitalism and Development*, Routledge, London.

Gereffi, G., Humphrey, J. and Sturgeon, T. (2002), "Developing a theory of global value chains: a framework document", paper presented at the Global Value Chains Conference, Rockport, MA, April 25-28, p. 24.

Gereffi, G., Humphrey, J. and Sturgeon, T. (2005), "The governance of global value chains", *Review of International Political Economy*, Vol. 12, pp. 78-104.

Gerstner, L. Jr (2003), *Who Says Elephants can't Dance?*, Harper Collins Publishers, New York, NY.

Glaser, G. and Strauss, A. (1967), *The Discovery of Grounded Theory: Strategies for Qualitative Research*, Aldine de Gruyter, Berlin.

Harland, C.M., Lamming, R.C., Zheng, J. and Johnsen, T.E. (2001), "A taxonomy of supply networks", *The Journal of Supply Chain Management*, Fall, pp. 21-7.

Hayes, R., Pisano, G., Upton, D. and Wheelwright, S. (2005), *Pursuing the Competitive Edge*, Wiley, New York, NY.

Hobday, M., Davies, A. and Prencipe, A. (2005), "Systems integration: a core capability of the modern corporation", *Industrial and Corporate Change*, Vol. 14 No. 6.

Johansen, J. and Riis, J. (2005), "The interactive firm-towards a new paradigm", *International Journal of Operations & Production Management*, Vol. 25 No. 2, pp. 202-16.

Karlsson, C. (2003), "The development of international networks: challenges for operations management in the extraprise", *International Journal of Operations & Production Management*, Vol. 23, pp. 44-61.

Kim, L. (1993), "National system of industrial innovation: dynamics of capability building in Korea", in Nelson, R. (Ed.), *National Innovation Systems: A Comparative Analysis*, Oxford University Press, New York, NY, pp. 357-83.

Lung, Y. (2003), "The challenges of the European automotive industry at the beginning of the 21st century", paper presented at Auto Industry Symposium The RIETI – Hosei – MIT-IMVP Meeting, p. 18.

Nelson, R. and Rosenberg, N. (1993), "Technical innovation and national systems", in Nelson, R. (Ed.), *National Innovation Systems: A Comparative Analysis*, Oxford University Press, New York, NY, pp. 3-21.

Prahalad, C.K. and Hamel, G. (1990), "The core competence of the corporation", *Harvard Business Review*, Vol. 68 No. 3, pp. 79-91.

Silvestro, R. (1999), "Positioning services along the volume-variety diagonal: the contingencies of service design, control and improvement", *International Journal of Operations & Production Management*, Vol. 19, pp. 399-420.

Slack, N. (2001), "Exploring the trade-off concept", *International Journal of Operations & Production Management*, Vol. 21, pp. 949-64.

Slack, N. and Lewis, M. (2002), *Operations Strategy*, Wiley, New York, NY.

Slack, N., Chambers, S., Harland, C., Harrison, A. and Johnston, R. (1999), *Operations Management*, Pitman Publishing, London.

Sturgeon, T. (1997), "Turnkey production networks: a new American model of industrial organization?", *Berkeley Roundtable on the International Economy*, Working Paper 92 A.

Takeishi, A. and Fujimoto, T. (2003), "Modularization in the car industry: interlinked multiple hierarchies of product, production and supplier systems", in Prencipe, A., Davies, A. and Hobday, M. (Eds), *The Business of Systems Integration*, Oxford University Press, Oxford.

Teece, D., Pisano, G. and Shuen, A. (1997), "Dynamic capabilities and strategic management", *Strategic Management Journal*, Vol. 18 No. 7, pp. 509-33.

Verschuren, P. and Doorewaard, H. (1999), *Designing a Research Project*, LEMMA, Utrecht.

Warr, P.B. (1988), "An introduction to models in psychological research", in Chapman, A.J. and Jones, D.M. (Eds), *Models of Man*, BPS, Leicester, pp. 289-309.

Womack, J., Jones, D. and Roos, D. (1990), *The Machine that Changed the World*, Harper Perennial, New york, NY.

Zysman, J. (2003), "Strategic asset or vulnerable commodity: manufacturing in a digital era", Paper presented at the New Directions in Manufacturing, National Academies Press, Washington, DC.

Further reading

Ferdows, K. (1997), "Making the most of foreign factories", *Harvard Business Review*, March, pp. 73-88.

Corresponding author

Afonso Fleury can be contacted at: acfleury@usp.br

This article has been cited by:

1. A. Fleury, Y. Shi, S.F. Junior, J.H.D. Cordeiro, M.T.L. Fleury. 2015. Developing an analytical framework for study of emerging country multinationals' operations management. *International Journal of Production Research* **53**, 5418-5436. [CrossRef]
2. Afonso Fleury, Yongjiang Shi, Maria Tereza Leme Fleury, Silas Ferreira Jr., Jose Henrique Cordeiro, Xingkun LiangFraming International Operations Management: Contributions from Emerging Country Multinationals 351-377. [Abstract] [Full Text] [PDF] [PDF]
3. Bennett David. 2014. Future challenges for manufacturing. *Journal of Manufacturing Technology Management* **25**:1, 2-6. [Abstract] [Full Text] [PDF]
4. Ana Beatriz Lopes de Sousa Jabbour, Charbel José Chiappetta Jabbour. 2013. Contributions of operations management to the competitiveness of the Brazilian electronics sector. *Journal of Business Economics and Management* **14**, S358-S376. [CrossRef]
5. Stephen Fox. 2013. Paradigm shift: do-it-yourself (DIY) invention and production of physical goods for use or sale. *Journal of Manufacturing Technology Management* **24**:2, 218-234. [Abstract] [Full Text] [PDF]
6. Denise Jarratt, Ramzi Fayed. 2012. Services Segmentation and Emergent Customer Behavior: A Case Study. *Services Marketing Quarterly* **33**, 49-67. [CrossRef]
7. Mario Binder, John S. Edwards. 2010. Using grounded theory method for theory building in operations management research. *International Journal of Operations & Production Management* **30**:3, 232-259. [Abstract] [Full Text] [PDF]
8. Ari Jantunen, Jaana Sandström, Hanna Kuittinen. 2009. Boundary choices in the pulp and paper industry. *Journal of Manufacturing Technology Management* **20**:3, 314-329. [Abstract] [Full Text] [PDF]
9. Ángel Calvo. 2009. Estado, empresa, mercado. Standard Eléctrica y la industria de equipo de telecomunicación en España, 1926–1952. *Investigaciones de Historia Económica* **5**, 43-72. [CrossRef]