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The rediscovery of postponement a literature review and directions for research

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Abstract

The concept of postponement is increasingly drawing the attention of researchers and practitioners. Postponement means delaying activities in the supply chain until customer orders are received with the intention of customizing products, as opposed to performing those activities in anticipation of future orders. This paper reviews the literature on postponement dating back to 1965, and puts it in a systematic framework. In light of the classification of the literature developed, opportunities are identified for integration and cross-fertilization between research papers in disciplines such as logistics and operations management and between the variety of research methods used. Some directions for research (in terms of content and methodology) are then formulated. For instance, the development of a more integrated supply chain perspective on postponement, and the application of triangulation rather than single methods. Specific research activities to meet these challenges are suggested in the paper.

Keywords: Logistics/distribution; Flexible manufacturing systems; Operations strategy

1. Introduction

1.1. The postponement concept

Postponement is an organizational concept whereby some of the activities in the supply chain are not performed until customer orders are received. Companies can then finalize the output in accordance with customer preferences and even customize their products. Meanwhile, they can avoid building up inventories of finished goods in anticipation of future orders. Moreover, transportation between warehouses and factories can be avoided by shipping products directly to the customer rather than keeping them in stock. Even though it should be noted that this may lead to smaller sized shipments over longer distances. As a result postponement is often more relevant when products are more sensitive to inventory than transport costs (e.g. higher value added products with large product variety). Additionally, lead time constraints may limited the possibility to perform postponed activities while still assuring delivery windows that meet customer's willingness to wait. Later sections will further introduce operational constraints and conditions for postponement.

Postponement can occur along the entire supply chain, from sourcing to final distribution. The concept can be applied to a minor or a major share of the operations in the supply chain. Consider Fig. 1. Mars (a Masterfoods company) postpones the packaging and distribution of special products for the Christmas season. Thus, postponement goes (only) as far as packaging on the horizontal bar. It remains in the lower area

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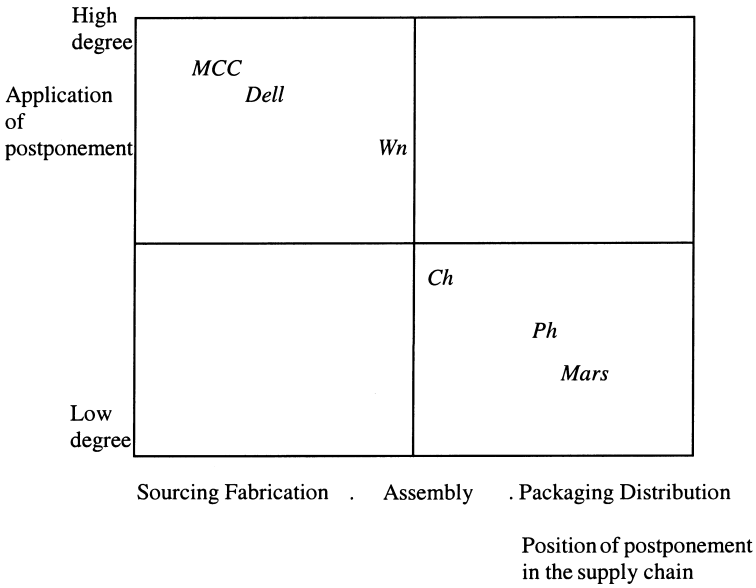

Fig. 1. The application of postponement.

of the vertical bar, as this application pertains to a minor share of the packaging and distribution operations. On the other hand, MCC (a DaimlerChrysler car company) and Dell postpone virtually every operation in their supply chains and apply this approach to every order. Hence, they are positioned in the top left quadrant of Fig. 1. Hewlett Packard, like Dell, is often cited as an example of a company that applies postponement in the final assembly, packaging, and shipment of many of its computer and printer products. The company has decided to standardize some of its modules and then combine those generic modules to customize its products. It is not suggested here that postponement in manufacturing is limited to the electronics and automotive industries. Consider the example of Wn representing the position of a wine company in Fig. 1. The company stores table wines in tanks close to the market until orders come in. At that point additives may be mixed in and the wines can be bottled, labeled, and shipped. In the same figure Ch is a chemical firm and Ph is a pharmaceutical company, both of which that postpone their compounding and packaging activities.

In applying postponement, firms can customize and localize products according to customer demand and local market circumstances from a vantagepoint close to the market (which is especially relevant when a company operates in varied international markets). This enhances the efficiency of various operations, as they avoid uncertainty about the specification of orders and order mixes. In other words, the company can cope with complexity without having to lower product variety; in fact, they may decide to expand it. Besides customizing (job shop) postponed operations, those activities that are not postponed (for example, up-stream activities) can be run (like a flow shop) in a mass production environment, thereby maintaining efficiency. Hewlett Packard has reported double-digit savings in supply chain costs by applying postponement in manufacturing and distribution. Similarly, Dell Computers-based a significant share of its competitive approach on its strategy of close-to-the-market customization and on the direct-delivery capabilities of postponement.

In summary, Table 1 compares traditional approaches with the postponement approach. Volkswagen and MCC might be used to illustrate the operations covered by the table. Volkswagen faces major uncertainty about order volume and mix; product variety only adds to the obsolescence risks. As a result, the strategy of limiting variety (through platform sharing for example) is actively pursued in the supply chain. Large volumes are considered favorable for efficiency.

Table 1
Postponement opportunities in operations

	Traditional operations	Postponement opportunities
Uncertainties	Limit operations; uncertainty about order mix and volume	Reduce risk of volume and variety mix by delaying finalization of products
Volume	Produce volumes (flow shop) with large economies of scale	Make batches of one (job shop for customization, flow shop elsewhere)
Variety	Create obsolescence risks	Prosume, customize, requiring flexibility
Lead times	Involve long response times	Offer accurate response, yet perform activities within order cycle time
Supply chain approach	Limit variety to gain efficiency advantages	Reduce complexity in operations, yet possibly add flexibility and transport costs

However, they exacerbate the long cycle times and poor service (the delivery lead time of a Volkswagen Passat to a consumer is now about 12 months). MCC assembles cars to order and allows customers to specify the car specs in discussion with the sales person. This is also referred to as prosuming. Prosuming means involving the consumer in production, in this case by having the consumer virtually specify the bill of materials. Whereas car modules can still be produced in a flow shop environment, cars are assembled as batches of one. The modular product design avoids complexity, while allowing for customization and a rapid and efficient final assembly. Storing only generic modules avoids the inventory risks arising from volume and variety risks. Furthermore, it prevents complexity in operations. As a final outcome of the postponement application, the customer can drive off a customized car with just a three-week lead time.

Postponement may be applicable in many industries. Yet the specific customization level and the extent to which postponement is applied can vary. In the electronics and automotive industry, modular product design allows for postponement in manufacturing. In process industries such as pharmaceuticals, some processing cycle times may last longer than the customer order lead time, while the process cannot be decoupled at an intermediate stage. These operating characteristics include product design; postponement may mean going back to the drawing board to design products for postponement using modularity and commonality as design principles. Thus operating characteristics influence the feasibility of various postponement forms. In addition to product and process design (continuous or decoupled process), the implementation of postponement also affects the supply chain structure, as postponement activities will most likely be placed close to the market (see Van Hoek, 1998a,b,c) and the examples of Dell Computers and Hewlett Packard). All in all the spatial and operational circumstances in the supply chain may require significant change management. In short the concept of postponement raises several issues: amount and level of postponement application; customization; supply chain structure; operating circumstances in technology (or product design); processes; product and markets (lead times!); and change management.

While postponement is an increasingly relevant method to realize (mass) customization in the supply chain, it is not the only method. Customization may also be embedded in the product (standard products such as computer software and lycra clothing allow for customer-specific use). Or customization may be achieved through services only, not impacting manufacturing or distribution of the physical product. Presenting examples of companies that respond to modern market circumstances can elucidate the increasing relevance of postponement, which dates back to 1965 theory. Those companies have been briefly introduced and will be examined in the following section.

1.2. Postponement in modern markets and operations

Markets may become turbulent, even volatile. Accordingly, product life cycles shorten, product variety increases, and customer demands escalate. Consequently windows of opportunity become narrower and more transitory. Then companies have to seriously consider manufacturing for and marketing to individual customers, as opposed to mass markets. As

a result, frame-breaking strategies become a necessity (Achrol, 1991). Mass customization is frequently presented as a strategy suited to this option to customize. Its popularity in the international business community is significant. This is not surprising, as it aims to combine an agile customization of products with lean production efficiency within one supply chain (Anderson and Narus, 1995; Kahn, 1998). It breaks with the dilemma that one has to choose between two options: low volume — high variety and high volume — low variety (Gilmore and Pine II, 1997; Kotha, 1995).

As noted earlier, postponement is consistently mentioned as one of the central features of mass customization. Oleson (1998) brings up the need to shift from "make to inventory" to "make to order" in an effort to enable an agile responsiveness to customers. Lampel and Mintzberg (1996) observe a general trend towards a combination of standardized design, standardized fabrication, and customized assembly and distribution. Pine II (1993) sees the customized final assembly of products from generic modules as the best option for achieving mass customization. These points are based on the system of combining speculative supply and fabrication with postponed assembly and delivery. This reflects the 1980 (!) perspective of Bowersox et al. (1980) on innovative ways to improve productivity in (marketing) channel structures:

1. the postponement of customer-specific product assembly, combined with,
2. rapid delivery directly to the customer instead of through multiple echelons of speculative inventory, and
3. non-stock-holding dealers that order from distribution centers (Bowersox et al., 1980).

Womack and Jones (1997) ask why a company should make anything when it is not sure whether or not there will ever be a customer willing to buy the product. Thus, they see postponement as a relevant operations initiative. Feitzinger and Lee (1997) emphasize the role of postponed manufacturing in making mass customization happen ("mass customization at HP, the power of postponement"). Furthermore, Dittman, as VP of Whirlpool, highlights the managerial interest in using postponement in adopting mass customization:

> The strategic intent to strive for mass customization is one thing, the process and systems to accomplish it are another. The journey towards this vision [. . .] will no doubt be evolutionary, far from linear. [. . .] A relation with strategy is a prerequisite for global leverage.

It may be well known to the academic audience that postponement theory dates back to the founding article of Bucklin in 1965. In a personal conversation with the author, Prof. Bucklin made the following statement:

> Postponement was introduced in the 1960s but look at the entire speculative inventory that is still stored in the channel.

There is a growing stream of publications on postponement in various disciplines (see, for example, Feitzinger and Lee, 1997 in strategy; Garg and Tang, 1997 in operations research; Pagh and Cooper, 1998 in logistics). Taken together with the stated interest of managers, does the increased production of knowledge on postponement mean that, after 30 years of incubation, the principle has finally been integrated in managerial practice and academic research? Maybe not. The consistent reference to the value of postponement for logistics strategy and capability development (by Bowersox et al., 1980, 1992) and the work on postponement (continued and published in the 1980s by Zinn and Bowersox (1988); Zinn (1990) suggest that the concept has not found a place in academic research. Bowersox et al. (1995) states that postponement has increased in application over the last few years. Morehouse and Bowersox (1995) predict that it will increase in application, to the extent that by the year 2010 half of all inventory throughout the food and other supply chains will be retained in a semi-finished state waiting for finalization-based upon customer orders. Still, postponement is not new to the research agenda. The number of important journal articles published over the last two decades, including publications in the fields of logistics, marketing, and operations demonstrates this. There are well-known case studies of companies that have grown (Dell; see Magretta, 1998) and flourished (HP; see Feitzinger and Lee, 1997) through postponement. Those studies suggest that in terms of managerial practice, postponement is not new, either in conceptualization or in application, to innovative companies. Perhaps we should interpret the growing interest in, and application of postponement as a rediscovery of the concept. In that case, we want to find out what is new and what has changed.

For one thing the market has changed. And the need for mass customization and agility is driven by market

circumstances. As part of the answer to the demands of the market and business environment, postponement may now a requirement in today's business world, not just another concept to consider. Furthermore, there may be a new organizational context of supply chain management, enabling the application of postponement. Traditionally, mass production might not have favored postponement, whereas the new format of supply chain management might do so. Indeed, mass production focuses on large batches and economies of standardization, not customization of single products. Supply chain management, in contrast, puts the customer at the center of its efforts, thus increasing the relevance of postponement.

If the academic community is rediscovering postponement, we need to ask ourselves another question, What do we already know and what do we still need to learn about postponement in the new business environment and organizational context? Unless we move on from the point where knowledge creation had already brought us and contribute to a better understanding of the rules of the new game, the fascination with postponement could turn out to be a fad.

It is especially important to build on existing knowledge because, notwithstanding all recent attention, insights in postponement appear to be underutilized. Most authors cite the seminal work by Bucklin, but more recent publications are referenced less often. Apparently, recent work has had less impact on the development of theory. Furthermore, postponement research is not well integrated across disciplines. Yet a thorough review that organizes and summarizes the research literature is lacking. As a result, it is unclear what exactly has been learned from research and which questions remain unresolved. The objective of this paper is to address this concern by providing such a review. The following section describes the method used.

1.3. Approach and method of study

This paper reviews the literature on postponement that has been available to date in academic journals or books. The aim is to compare and classify existing knowledge. It should be noted that textbooks such as Bowersox and Closs (1996) and Stern et al. (1995) which mention postponement, are not included in the review. These books explain the basics of postponement within the scope of a textbook, but do not present new research and findings. The academic papers included in the review are not limited to any one discipline, since postponement has been studied from various perspectives. The term postponement was used as a search key in the ABI-inform system. Apart from including those papers listed in the system, references in papers found were checked for further reference. Finally, authors in the field of postponement were consulted directly for further references to published work. Ultimately, this generated a list of 19 publications covering more than 30 years of research, as listed and briefly introduced in Table 2. Publications on postponement come from a wide field of operations management, ranging from operations research to logistics, marketing and since recently even strategic management. A classification is developed to identify gaps in research and knowledge. Those findings are used as an input to further research on the rediscovery of postponement. Some key elements of the postponement concept (as listed in Section 1.1) are used to characterize and classify existing work. These elements are:

- type of postponement and level of application in the supply chain,
- amount of customization,
- spatial configuration of the chain,
- the role of operating circumstances,
- the role of change management.

Finally, the research methods applied in the papers are classified. Not only the disciplines and elements of research (see above list) vary widely; the method applied varies as well. It is understandable that diverse research methods have been applied, given the variety of research questions (The reciprocal relation is obvious, certain research questions favor certain research methods). One question remains, To what extent do the various contributions add to consistent and greater insight into the postponement concept?

2. Elements of the classification

Both content and method of study can be taken as criteria in a systematic overview of the available literature. This section introduces the publications, but also summarizes relevant elements of their contributions.

Table 2
Literature reviewed

Publication	Description of study
Bucklin (1965)	Theoretical paper establishing the concept, focused on the role of postponement in positioning inventory in the marketing channel
Shapiro (1984)	Theoretical contribution from a logistics perspective positioning postponement in relation to inventory positioning broad in the supply chain
Zinn and Bowersox (1988)	Modeling study to assess the relevance (in terms of costs and service benefits) of specific postponement applications in distribution and manufacturing in the context of various operating circumstances
Zinn and Levy (1988)	Theoretical work building on the Bucklin (1965) paper on marketing channels, including economic and marketing theory such as transaction costs and the role of power in positioning inventories
Zinn (1990)	Modeling study expanding on the Zinn and Bowersox (1988) paper
Christopher (1992, 1998)	Specific section within book showing that postponement is a key concept for the (spatial) configuration of the (global) supply chain in the future
Bowersox et al. (1992)	Survey study to assess characteristics of organizations and (change) management in relation to postponement applications
Cooper (1993)	Theoretical work giving examples of specific postponement applications in (spatially) configuring the supply chain, using operating characteristics in trading off applications
Lee et al. (1993)	Modeling study with Hewlett Packard assessing the benefits of one specific postponement application in manufacturing compared to a situation without postponement
Bowersox (1995)	Follow-up survey of the Bowersox et al. (1992) study suggesting that postponement has increased in application over the last 5 years
Dröge et al. (1995)	Rigorous survey study relating the application of postponement in manufacturing to characteristics of organizations, such as centralization and decentralization
Morehouse and Bowersox (1995)	Expert study on the future of supply chains, including postponement as one of the key areas for future development
Van Hoek (1997)	Case study of postponement within a wine company, comparing the application with various alternatives with and without postponement
Feitzinger and Lee (1997)	Case study of Hewlett Packard showing managerial implications of postponement and describing its implementation
Garg and Tang (1997)	Modeling study comparing the application of postponement up- and down-stream in the supply chain for two types of products/operating environment
Van Hoek et al. (1998)	Four case studies on operating circumstances that impact the validity of postponement applications and a study of the implementation drivers and process
Van Hoek (1998a)	Eight case studies on the implementation of postponement and its impact on the (spatial) structure of the supply chain
Pagh and Cooper (1998)	Theoretical overview of the postponement concept-based mostly on earlier work by Zinn and Bowersox
Van Hoek (1998b)[a]	One case study and a survey covering postponement applications throughout the supply chain and drawing conclusions about the impact of operating and market circumstances

[a] Van Hoek (1998c) is not listed here; it is a combination of other publications already covered here and combines several studies.

The classification developed in this paper is method- and content-driven.

2.1. Elements of postponement studied

Initially, postponement was only applied in the distribution sphere. In that context, it entails delay of the forward movement of inventories (of finished goods) in the channel. Bucklin (1965) was concerned with where in the channel inventory should be positioned (up-stream waiting for customer orders, or down-stream in anticipation of future customer orders) and which player (supplier or customer) should carry the inventory. The time and place utility of a product, the traditional utilities provided by the logistics function, are impacted by this type of postponement. Subsequent studies have added a third utility to the postponement concept: a product's form/function

utility. Apart from the postponed forward shipment of goods (time postponement) and maintaining goods at central locations in the channel (place postponement) certain manufacturing activities can also be postponed. Zinn and Bowersox (1988) summed these up, labeling, packaging, and assembly/manufacturing. Postponing these tasks implies that products are finalized in response to customer orders and then shipped to that same customer. Thus, the notion of postponed manufacturing goes beyond time and place postponement; it also includes customizing the form and function utility of a product.[1] Postponed manufacturing is a cross-functional operating system in which final manufacturing activities are positioned in the distribution channel and performed in response to market signals. This cross-functional nature of the concept explains the relevance of postponement to a wide range of research streams, as mentioned above.

Christopher (1992) expanded the prevailing approach by pointing at the role of geographical scale in postponement applications. He also demonstrated how postponed manufacturing works at a European scale. The relevance of operating at a particular geographical scale, broader than one market region — including the European, Asian, or North American market — is also shown in the case of Hewlett Packard, which is described by Lee et al. (1993). Cooper (1993) elaborated the level at which activities may be postponed to include the position in the chain occupied by postponement applications (similar to those mentioned by Zinn and Bowersox, 1988). In particular, Cooper (1993) sums up the options, time postponement operated in the factory; packaging postponement separated from the factory in a down-stream regional warehouse; or postponed manufacturing separated from the factory in mid-stream central warehouses.

[1] Bowersox and Closs (1996) define time postponement as delaying the forward movement of goods until customer orders are received (delaying the determination of time utility), place postponement as the storage of goods at central locations in the channel until customer orders are received (delaying the determination of place utility), and form postponement as delaying product finalization until customer orders are received (delaying the determination of form/function utility). Van Hoek et al. (1998) explain that postponed manufacturing combines these three basic forms within one operating system; product finalization and shipment of goods are delayed until customer orders are received and operated from a central location in the channel.

2.2. Methods of study and theoretical contributions

Table 2 also mentions the method of study used in the work studied here. Four methods are used as appropriate to the purpose of study. As explained above Bucklin (1965) established the theoretical principle in the distribution channel. That theory centers on inventory positioning, which means determining the amount of time and place postponement based upon total storage costs. Shapiro (1984) listed a further set of possible degrees of postponement applications, ranging from no postponement (decentral stock of finished goods maintained) to time and place postponement (central stocks of finished goods stored) to form postponement throughout the channel (work in progress stored). This is the foundation for the approach used by Lampel and Mintzberg (1996) to classify supply chains, even though the authors did not reference the Shapiro (1984) article. Their categories range from no customization through customized distribution, assembly, fabrication to full customization in the chain. Also this is the first clue of the relevance of a supply-chain-wide approach to postponement.

Zinn and Levy (1988) elaborated the theoretical perspective on postponement by formulating theoretical notions and propositions for empirical research, on top of those proposed by Bucklin (1965). To date, these propositions have not been tested in published papers; just a few of the Bucklin propositions have been tested, and then only implicitly. Considering the application of postponement in marketing channels, Zinn and Levy (1988) remark that the assumption of integral cost minimization in the chain (an assumption adopted by Bucklin, 1965) implies that the theory holds less value in channels where an individual player can use powerplay to force inventory load onto another player's shoulders and minimize their own costs. The authors conclude that an integral supply chain perspective among players in the supply chain is a pre-requisite for the viability of postponement.

In addition to the assumption of integral cost minimization, the Bucklin (1965) model focuses on the role of time and place postponement in positioning inventories and designing direct or intermediate channels. There is a difference between the impact of time and place postponement, as included in Bucklin (1965), and form postponement, as included in later publications. Time and place postponement

pushes/maintains inventories up-stream, from national and regional stocking points to international warehouses, until customer orders have been received. Form postponement, on the other hand, often pushes manufacturing activities down-stream, from global manufacturing locations into international distribution channels, so that they can be performed closer to the customer. The implementation of postponed manufacturing may involve both a down-stream positioning of manufacturing activities and the up-stream centralization of inventories. Christopher (1992, 1998) offers a geographical classification of activities in the supply chain, from globally coordinated to localized activities. Product finalization is positioned at an intermediate level in the chain. This activity is centralized on a continental level, where centralized inventories are also positioned.

Furthermore, he includes postponement in the list of future directions for supply chain management, which highlights the (practical) relevance of further postponement research.

Pagh and Cooper (1998) published the most recent theoretical work on postponement. They provided a classification of postponement applications in the mid- to down-stream stages of the supply chain. Their classification is a reworked version of the applications mentioned in Zinn and Bowersox (1988) and Cooper (1993). Cooper (1993), in turn, cites Zinn and Bowersox (1988) regarding the postponement applications he developed, stating that his terminology was different but that the applications are essentially the same. Pagh and Cooper (1998) also reflect upon the role of factors in the operating environment of companies that influence the feasibility and selection of a particular postponement application. This approach in general and some of the factors in particular are the same as in Zinn and Bowersox (1988), Cooper (1993), and Van Hoek et al. (1998). Pagh and Cooper (1998) essentially present an overview of known applications and factors in the implementation of postponement. This overview really brings us to the point where we can develop new insights in new applications and operating approaches. We return to this challenge after a review of the other methods and specific issues studied.

2.2.1. Case studies

Case studies published as examples (Cooper, 1993), as in-depth case studies (Feitzinger and Lee, 1997 (HP); Van Hoek, 1997 (wine producer)) or four to eight cases (Van Hoek et al., 1998; Van Hoek, 1998a) center around the practical experience of companies in trading off and in implementing postponement. These papers are based on in-depth studies of cost and benefits. Cooper (1993) distinguishes four types of mid- to down-stream postponement applications, based upon different combinations of operating characteristics that favor certain types of postponement applications. He gives examples of companies that fit into that classification. Taking a single case, Van Hoek (1997) expands the classification into a framework of four categories. These are based upon technological, process, product, and market operating characteristics that do or do not favor specific postponement applications. The applications included are similar to those in Cooper (1993). Feitzinger and Lee (1997) use HP as a case study as in the other publications by Lee on postponement. These other works by Lee use a different method to assess the feasibility of postponement. Van Hoek et al. (1998) provide a cross-case comparison of postponement practices to allow for generalization. Statistical and mathematical generalizations are made on the basis of the final two methods used, modeling and surveys.

2.2.2. Modeling

Zinn followed the train of thought in one of the six propositions concerning how the value of goods favors postponement. In two publications (1988 and 1990), he developed this line of reasoning using a simulation model and developing heuristics on postponement. Findings indicate the role of operation conditions such as volume and value in achieving lowest logistics costs with postponement. The lowest-cost approach also follows the original Bucklin model, but the modeling significantly leverages the original model to a higher level of understanding. Time and place postponement from the original model are supplemented with form postponement applications. Lee et al. (1993, in an operations research journal) simulate a postponed manufacturing supply chain. In the simulation, postponed manufacturing is compared to a supply chain with manufacturing integrated in the factory. The simulation pertains almost exclusively to inventory levels. They state that further study is needed for transportation issues (less bulky transport of generic modules), the need to develop a

local supply base (location factors, local sourcing), and other non-quantifiable factors, e.g. the increased marketability of locally assembled products, which is relevant for marketing. The fragmentation of available material is evident in the publication by Lee et al. (1993). Their article has the same focus as the study by Zinn (1990), which appeared in a logistics journal. The latter study estimates the inventory savings resulting from postponed manufacturing as well as the operating characteristics that influence these savings. Zinn comes up with quite comparable results, including the role of commonality and product variety. But the study by Lee et al. (1993) makes no reference to Zinn (1990) yet there is some overlap.

Garg and Tang (1997) study two products, personal computers and hairdryers. Their findings are relevant to the decision whether to adopt postponement early (i.e. mid- or up-stream in the chain) or late (i.e. down-stream). Their point from departure is that a company has actually selected postponement as a supply chain concept to be implemented. Several case studies, as mentioned in the previous section, indicate that companies trade off specific postponement options against supply chain options without postponement. Thus, the trade-off studied in Garg and Tang (1997) tends to be integrated with the fundamental trade-off of postponement in configuring the supply chain.

2.2.3. Surveys

One of the rare instances of an empirically tested model of postponement is the research model developed by Dröge et al. (1995). It concerns the impact of form postponement on organizational structure. Organizational structure is studied in terms of formal control, horizontal and vertical differentiation, and size. The approach taken by Dröge et al. (1995) is comparable to that used by Bowersox et al. (1992). In the latter survey, organizational characteristics are linked to organizational capabilities in the field of logistics. Although postponement is not explicitly mentioned, several related strategies are: one such strategy entails product modification while the product is in the logistics system; another calls for flexibility in responding to specific customer requests. These strategies are linked to the availability of formalized logistics and a strategic plan. The findings shed light on a number of questions relevant to the implementation path (for example, criteria applied in the selection of a framework for case studies, as outlined in the Appendix A).

Whereas Bowersox et al. (1992) do not measure postponement, Dröge et al. (1995) do. They determine the extent of postponement by asking about the percentage of goods made to order. One drawback of this measure is that industry-specific operating circumstances have an impact on the degree of making to order. The surveys do not cover these particular circumstances. In fact, neither publication offers a comprehensive measurement method or scale of postponement that would cover the various applications found in practice throughout the supply chain. Other sources identify the following applications: assemble, configure, pack, label, and ship to order (recall Fig. 1). In fact, there is no scale for postponement along the chain other than the first attempt by Van Hoek (1998b) to classify the applications. That effort uses postponement throughout the supply chain (from engineering and purchasing all the way through manufacturing down to distribution) as a dependent variable explained by factors such as operating characteristics, IT applications (mentioned in Bowersox et al., 1992) and market characteristics. This model provides the first statistical generalization using factors from prior case studies and modeling studies. Also, it is the first study to include postponement applications along the entire supply chain, not just in final manufacturing and mid- and down-stream distribution. We return to this point in the gap analysis following the classification of the literature. But, first we identify specific focal points in the studies under review. Then we go on to develop a more comprehensive overview of the content of the studies and make a start on the design of an integrated overview.

3. Specific elements of study

3.1. Element I: customization

Lampel and Mintzberg (1996) refer to their continuum running from standardization (make to forecast) to customization (make to order) when discussing the trend towards the mass customization. They state that if there is one dominant move along their continuum of supply chains, it is towards intermediate positions of make to order and assemble-to-order situations.

In such situations, companies combine the efficiency of mass production in speculative up-stream manufacturing of semi-finished goods and modules with down-stream customization in order to achieve customization without cost penalty. The customer order decoupling point distinguishes between forecast- or push-driven operations that are run in anticipation of future customer orders and order- or pull-driven operations that are run-based upon customer orders. All activities in the supply chain performed after the CODP are customized and targeted at the specific customer order, while all activities in the supply chain performed before the CODP are standardized. The principle obviously holds a link with the postponement concept, yet there is more to postponement, such as the (geographical) positioning of operations close to the end-consumer, to which we will return latter.

While Lampel and Mintzberg (1996) relate the customer order decoupling point to mass customization, Morehouse and Bowersox (1995) relate postponement to mass customization. Following their lead, we include mass customization in the framework being developed here.

Postponement applications can be expected to contribute to the mass customization of goods and services. In postponed manufacturing applications, for example, the customization of products at an intermediate level in the supply chain (after customer orders have been received) allows a firm to combine rapid and reliable delivery with improved responsiveness to customer wishes. Local variations in taste and product formulation can be integrated in the process if driven by orders. In addition, improved customer responsiveness does not have to take place at the expense of efficiency levels. In postponed manufacturing, customization of products can be separated from the speculative manufacturing of basic materials. The separation frees primary manufacturing to focus on large economic runs of standard products or generic components and modules.

A list of ways to achieve mass customization of goods can be compiled on the basis of Pine II (1993) and Daugherty et al. (1992). That list gives seven suggestions:

1. Create products and services that are customizable by customers (involving the design function); for example, self-fitting clothing, bake-off products.
2. Modularize components to customize finished products and services (involving the manufacturing, distribution, marketing function, and the product design).
3. Provide quick response throughout the value chain (involving the design, manufacturing, distribution, and marketing function).
4. Customize services around standard products or services (involving the distribution and marketing function).
5. Provide point-of-delivery customization (involving the marketing function) such as adjusting clothes in the store.
6. Offer logistics support to sales and marketing incentive programs (involving the distribution function) such as assembly of promotion displays or shelf management to assure availability.
7. Offer customized logistics service levels (involving the distribution function) such as regionally targeted distribution.

The functional areas involved in the methods shown above in parentheses are based on Pine II (1993) and Daugherty et al. (1992). Like the customer order decoupling point (CODP) and postponement, mass customization can occur at various positions in the chain.

Pine II (1993, p. 196) states that customizing products from standardized modules (method 2) is the best way to achieve mass customization. This option reflects assemble-to-order situations and postponed manufacturing. Time and place postponement is reflected in method 7, which suggests offering customized logistics services. Postponed packaging in a regional warehouse is reflected in method 6, which calls for relatively easy finalization of products in warehouses. Method 5, providing point-of-sale customization, is related to CODP 7 positioned in the retail channel. Neither method 1, including customizability in the product design, nor method 3, providing quick response throughout the chain, is related to a specific CODP or postponement application. Quick response is said to be possible along the entire chain. Pine II (1993) does not deal explicitly with the product design being made to order or not. Offering customized services around standardized products (method 4) is the same as method 7, though it is not limited to logistics services. Its wider applicability makes it difficult to position method 4 anywhere along the chain.

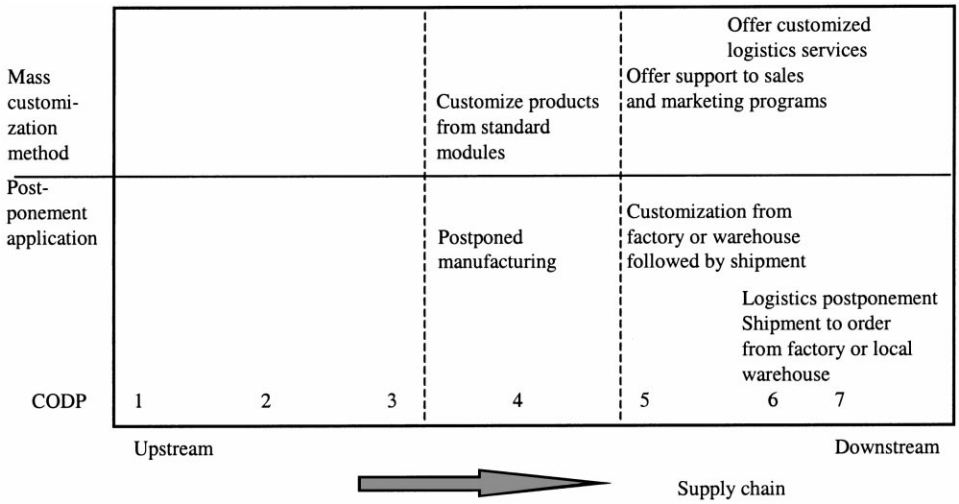

Fig. 2. Postponement in relation to mass customization approaches.

Fig. 2 specifies ways to achieve mass customization that can be directly related to a particular CODP and/or postponement application (applications from Zinn and Bowersox, 1988; Cooper, 1993). The postponed manufacturing segment is partitioned off. That segment unites a specific CODP position and a method for achieving mass customization. Several conclusions can be drawn from Fig. 2. First, the postponement applications presented here (and studied in the literature) appear mostly at mid-stream or down-stream positions in the supply chain, as opposed to up-stream speculation or forecast-driven activities. Furthermore, apart from a number of methods that can occur anywhere along the chain, the ways to achieve mass customization included in Fig. 1 are most likely to be applied at mid-stream or down-stream positions in the chain. These linked positions in the supply chain can be related to the basic principle underlying the effectiveness and efficiency of both mass customization and postponed manufacturing. That principle is the inclusion of up-stream speculative/mass manufacturing driven by forecasts and intermediate or down-stream postponed/customizing manufacturing and service activities within one supply chain structure.

In comparing mass customization with the CODP and postponement, based upon specification of customization, as found in the literature, methods for mass customization specify activities and functions involved in customization. The CODP specifies the position in the chain where the customization occurs. Furthermore, the CODP indicates the extent to which operations are pull/order-driven by customization versus push/forecast-driven by standardization. It also reveals which functions are involved in the customization, reasoning that all functional activities positioned down-stream of the CODP play a role in customization. Postponement combines these specifications, integrating both principles into one operating system.

To further illustrate the link between postponement and customization, Table 3 indicates the contribution that postponed manufacturing makes to the global marketing planning matrix, as developed by Quelch and Hoff (1986, p. 61). The table blocks out the area where postponed manufacturing can help to achieve partial adaptation or standardization when needed in areas such as packaging and distribution through its contribution to localization and customization in relation to customer orders. This matrix in itself aims to assess the amount of standardization possible across regional markets versus the amount of adaptation to regional markets needed for various elements of marketing. Promotion and product positioning is not included in the set of relevant segments. It has been excluded even though customization in the logistics system can be achieved by supporting special promotion campaigns and despite the fact that positioning can be affected by building customer displays. The direct impact of postponement is on customer service.

Table 3
Postponed manufacturing in the global marketing planning matrix[a]

		Full Adaptation	Partial Adaptation	Partial Standardization	Full Standardization
Business Function	Research & Development				
	Finance & Accounting				
	Manufacturing		▨	▨	
	Logistics				
	Marketing				
Marketing mix elements/ activities	Product design				
	Brand name				
	Product positioning				
	Packaging		▨	▨	
	Advertising				
	Pricing				
	Distribution		▨	▨	
	Sales promotion				
	Customer service		▨	▨	
Countries	Region 1 Country A		▨	▨	
	Region 2 Country B		▨	▨	
	Region 3 Country C		▨	▨	
	Region 4 Country D		▨	▨	

[a] Source: Quelch and Hoff, 1986. Key: full adaptation involves complete customization of items in the matrix, whereas full standardization is the complete opposite situation in which there is no customization at all. This being the extremes of the axis the other options hold intermediate positions between the two. The shaded area is the scope (consider items) of customization achievable (consider position along the horizontal axis) of postponed manufacturing applications as found in practice.

That means achieving differentiated and customized customer service at a competitive price level. Table 3 also has an explicit geographical element, to which we return later on.

3.2. Element II: operating characteristics

Companies can choose not to implement postponement. That decision may be based on variations in the applicability of postponement. Not all products and processes may accommodate postponement. In the chemical and processing industry, for example, many processes are not amenable to separation in a primary and a secondary phase. Separation along those lines is required for postponing final manufacturing.

An overview of operating characteristics that are relevant to assess the viability of postponed manufacturing has been compiled by Van Hoek et al. (1998). That list (see Table 4) is partly based upon Zinn and Bowersox (1988) and Cooper (1993). The basic rationale is that operating characteristics favoring either postponement or speculation represent forces relevant to the structuring of supply chains. This reasoning ties in with the focus of one of the hypotheses formulated by Bucklin (1965). That particular hypothesis focuses on the role of operating characteristics. It posits that heavy, bulky, and inexpensive (low value density) products are likely to flow through channels with more intermediate, speculative inventories than products with the opposite characteristics.

Cooper (1993) classifies postponement applications in terms of three product characteristics: branding, formulation, and peripherals. At the same time he recognizes the importance of primary product characteristics. For example, he notes that products can have a global branding and homogeneous formulation, whereas peripherals (including documentation and packaging) vary between markets. In that situation, final manufacturing is most likely to be structured as a deferred/regional packaging system. Zinn and Bowersox (1988) also assess the viability of various levels of postponement by looking at the operating characteristics of brands (one or more), product variety, and unit value. But they also use fluctuations in sales and variation in package size/cube increase through final manufacturing. A cube increase through final manufacturing results in additional transportation volume and storage space needs. As a means to save

Table 4
Operating characteristics relevant to postponement[a]

Factor	Impact of postponement
Technological characteristics	
Limited complexity of final manufacturing operation	Limited loss of economies of scale through postponement and short processing times
Limited complexity of technological content in final manufacturing	Short set-up and changeover times, short processing times
Modularity	Rapid final manufacturing at low processing costs, increased possibility to adjust products to markets
Process characteristics	
Possible to decouple primary and secondary production system	(a technical pre-condition and needed for manufacturing within the lead time)
Limited complexity of final manufacturing process	Short set-up and changeover times, short processing times
Sourcing from multiple locations	Direct bulk shipments of modules
Product characteristics	
High commonality of modules	Lowered inventory levels and reduced risk of obsolete inventories
Product variety, specific formulation of products	Improved customization possible
Product variety; specific peripherals/packaging	Improved customization possible
High value density/unit value of products	Reduced pipeline expenses and inventory carrying costs
Product's cube and/or weight increases through customization/final manufacturing	Reduced transportation and inventory carrying costs
Market characteristics	
Short product life cycles/fashion cycles	Less risk of obsolete inventories
High sales fluctuations	Reduced inventory levels and less risk of obsolete inventories
Short and reliable lead times required	Improved delivery service
Price competition	Lowered cost levels
Varied and (physically) fragmented markets	Better targeting, segmentation, and positioning of products and sales

[a] Source: Van Hoek et al. (1998).

on those expenses, final manufacturing can be postponed.

Let us briefly explain why the other factors shown in Table 4 are relevant. The complexity of customization operations is a relevant factor in the sense that postponing final manufacturing would otherwise result in excessive loss of economies of scale and long processing times. That, in turn, would create the risk of not meeting lead-time restrictions. In view of the complexity of automobile manufacturing, Kotha (1995) assumes that mass customization in the automotive industry will be limited to mixing some modules. He does not expect it to go as far as customization at the component level. Neither cost nor service considerations would allow for postponed manufacturing. Another factor, listed in Table 4, technological content, refers to changeover times and processing times. Limited flexibility and a high technological content will result in lengthy process cycles and long changeover times. That will make postponement unfavorable under the constraints posed by lead time and processing costs (the competitive bar).

The possibility to decouple primary and secondary manufacturing is a pre-condition for implementing postponed manufacturing. Olhager (1994) assumes that if a production system cannot be decoupled, its operation will have to be either fully order-driven or fully forecast-driven. This is different from the combination of an order- and a forecast-driven activity in postponement. Also, the underlying production system has to allow for final manufacturing within acceptable lead times. Postponement allows the modules used in final manufacturing to be sourced directly from multiple regions, which is better than indirect sourcing through many echelons. The factor of commonality is also related to the principle of design for logistics. Zinn (1990) draws attention to the principle of risk pooling. He states that the number of modules

may be smaller than the number of finished products due to commonality. Storing modules instead of finished products pools the inventory risks across a smaller number of SKUs. In this situation, Zinn (1990) attributes inventory savings through postponement to two factors. The first is the size of the assortment and the variation in demand for finished products, which can be supplied from a limited number of modules. The second is the demand for modules, which is negatively related, allowing for effective risk pooling of generic modules. When modules used in the final manufacturing are interchangeable with a product's inventory, the levels and risks of obsolete inventories are lower. Kotha (1995) explains how competitors of National Pen-companies that did not implement postponed manufacturing — had to raise inventory levels to accommodate customization demands from customers. In the meantime, National Pen could provide almost unlimited customization from a relatively small base of modules and components. Product variety through differences in formulation, peripherals, or packaging, if included in products, can be created in the postponed manufacturing operation. Thereby, postponement would allow for improved customization.

Short life cycles and fashion cycles of finished products generate inventory risks. Postponing final manufacturing lowers that risk, especially if components have a high commonality and can be used in other products. Sales fluctuations and variations in sales volume and frequency create inventory complexities. Speculative inventories will have to be prepared to accommodate all volumes, frequencies, and combinations of products. When the final manufacturing can be performed within a limited time frame, the postponed manufacturing operation can continue to assure competitive lead times. In fact, the improved responsiveness may save on back orders, increasing the overall delivery reliability. In general, the ability to respond to individual customer wishes with specific product features or other adaptations is enhanced by following a "sense and respond" approach.

Having listed the factors mentioned in literature, this review also indicates how factors have been added to the list throughout the years of study and how some factors have received continued attention (such as value) in multiple studies, whereas others have not. Two other points can be made here. First, the aim of the studies listed in this section is to assess the feasibility and viability of postponement applications mid- and down-stream in the supply chain. This is approached as a cost minimization effort. We have shown, however, that postponement fits within mass customization and agility efforts and that the customer-focused approach brings new relevance and interest to postponement. As a result, cost minimization and feasibility studies have not lost their relevance. Nonetheless, they now come in second place after the first order issue, namely raising customer responsiveness. Our second point is that these studies, like the literature in general, tend to concentrate on mid- to down-stream applications in the supply chain.

3.3. Element III: geographical reconfiguration involved in the implementation of postponement

European researchers, starting with Cooper (1993), have drawn attention to the differences in geographical level of operating postponement applications. The variance ranges from the national level for deferred packaging to the European/continental level for postponed manufacturing (in Cooper, 1993). Christopher (1992 and the second printing in 1998) point at the continental level of operating for postponed manufacturing whereas other activities may be localized or globalized. Van Hoek (1998a) explicitly looks at the process of geographical repositioning and reconfiguring involved in the evolution towards, and implementation of, postponement. A link with international strategy is established in studying cases. The case studies suggest that the nature, timetable, and focus of the reconfiguration process differ depending on the organizational heritage. Thus, the resulting geographical structure and scale levels of operating may be comparable, as projected by Cooper and Christopher. The change process may differ, however, and the reconfiguration may be wider than when only the mid- to down-stream stages are involved.

Introducing the link between postponement and international strategies (in particular through the spatial positioning of postponement operations) is relevant if we recall the statement by Dittman cited in Section 1.2, referring to the required relation with global strategy when considering customization and postponement, in addition to the papers mentioned above. In the same vein we might include the spatial dimension

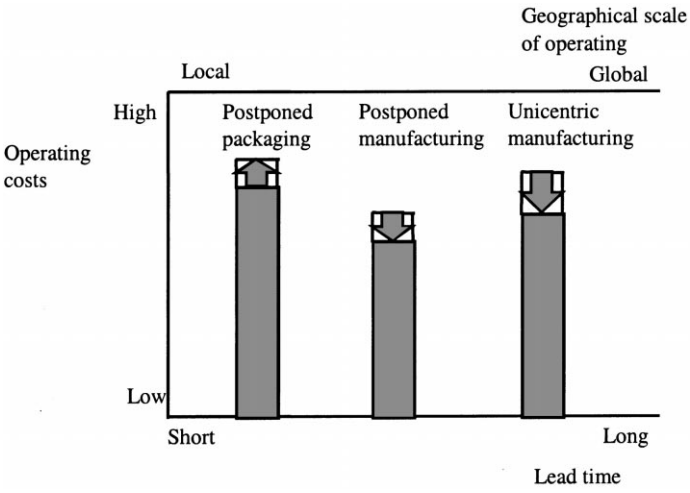

Fig. 3. Impact of higher value density on viability of postponed manufacturing.

in the postponement conceptualization and add another dimension to the temporal dimension used in the original Bucklin (1965) postponement model. Fig. 3 shows the original Bucklin model with a new horizontal dimension. The spatial dimension of postponement applications (i.e. is postponement practiced at a regional, national, continental, or global level) is used along with the time dimension (speed of delivery) as already introduced by Bucklin (1965). In this figure, postponement applications can be projected against each other along the temporal and spatial dimension. Examples of applications (including those mentioned by Cooper) that might be used are juxtaposed in Table 5 and specified using the dimensions of time and space for further clarification. The figure and the table refer to a challenge put forward by Heskett (1966), stating that time and space need to be integrated in logistic system design. According to Ballou (1995), research had not responded to that challenge yet.

Next, postponement applications can be projected for a case study and traded off in terms of costs (the vertical axis). Bucklin (1965) uses inventory costs to operationalize postponement and speculation costs. Taking a wider supply chain approach, postponement costs can be operationalized using the cost curves for materials, transport, inventory, and handling from

Table 5
Examples of postponement applications in relation to the spatial and temporal dimensions of the supply chain

Applications mentioned in literature	Sensitivity to postponement cost	Sensitivity to speculation cost	Time dimension	Spatial level of postponement application
Time postponement/unicentric or integrated manufacturing without delayed manufacturing	High, resulting in low levels of postponement	Low, resulting in high levels of speculation	Longer lead times (weeks) expected when more expensive transportation is used	Global scale
Time and form postponement in the factory/bundled manufacturing	Low, resulting in high levels of postponement	High, resulting in low levels of speculation	Longer lead times (4 days or more)	International or continental scale
Postponed manufacturing/ deferred assembly	Medium	Medium	Medium lead times (2–4 days)	International scale
Time and form postponement from the distribution channel/deferred packaging	High	Low	Short lead times (1–2 days)	National and regional scale

Christopher's (1992) cost model. Inventory and materials costs, for example, favor postponement of operations for capital in progress considerations. Transportation costs may favor speculative, large-volume shipments instead of flexible and frequent direct deliveries practiced under a postponement operating system. And handling costs favor standardized, large-scale operations for the sake of economies of scale instead of flexible postponed pull operating systems. These conditions lead to a total operating costs curve for cost minimization within a certain service window for a responsive operating system.

In using the total cost approach, it is also possible to compare calculated total costs of supply chain structures with and without postponement applications. This can be done at various positions along the temporal and the spatial dimension. For example, deferred packaging has a relatively short lead time, resulting from localized packaging and distribution operations. Thus, it can be positioned to the left of the horizontal axis. In postponed manufacturing applications, on the other hand, final manufacturing is operated at an international level, which may result in slightly longer lead times. The bars in Fig. 3 reflect total costs. Of course, operating costs derived from the Christopher (1992) model can be projected in a decomposed manner. It then becomes clear that the applications are particular "points" along the curves derived from the original Christopher and Bucklin models.

An operating structure can be selected to satisfy a required service window and a required level of responsiveness. For example, if required lead times are very short, it is not possible to perform final manufacturing activities in a postponed manufacturing structure. That is because of the lead-time penalties resulting from the final manufacturing that has to be performed after an order has been received. The deferred packaging structure may be favorable, due to the limited scope of form postponement, allowing for short cycle times. On the other hand, if acceptable lead times are very long, postponed manufacturing will lose some of its appeal. At this level, large-scale continuous manufacturing can be performed within the lead time. This model adds to the reasoning put forth by Bucklin (1965). He states that lead-time requirements are not the only important factors determining the amount of speculation needed. He also emphasizes the role of spatial considerations and the required level of customization that can be achieved with operating systems.

Apart from explaining the selection of a particular application, the framework can be helpful in the analysis of the impact of variations in operating characteristics on cost levels. A high value of a product, for example, favors postponement. The deferred packaging structure in the above example becomes more expensive (the break-even point shifts to the left, implying that the bundled manufacturing structure becomes more favorable). The higher expense is due to local inventories and earlier commitment of products. In contrast, the increase in costs of the bundled manufacturing structure is lower. The reason is that this structure favors inventory costs through inventory consolidation and the postponement of inventory commitment.

With respect to the point on the relevance of cost modeling, it should be noted here that the original Bucklin model, as well as this extension, should fit the customer responsiveness strategy. In other words, the structures evaluated should not be selected primarily for cost expectations but based upon their fit within the strategy.

3.4. Element IV: change management

The case studies on the implementation of postponement (Feitzinger and Lee, 1997; Van Hoek, 1997, 1998a) center largely on the managerial process — from feasibility study to the actual implementation of postponement. Central to the managerial process is the change management process (of course, best studied in conjunction and throughout the process using qualitative research). O'Laughlin et al. (1993) state that proper change management in logistic reconfiguration programs may be the single most critical success factor in such programs (Van Hoek et al. (1998) use the O'Laughlin change management action plan as a framework for studying the implementation of postponement).

Table 6 lists the factors that the literature deems relevant to the change management process, following the environment — strategy–structure–performance contingency framework. First of all, Dröge et al. (1995) point out the importance of IT as a driver of organizational change and its role in enabling postponement by speeding up customer information and making it

Table 6
Factors in the implementation of postponement and key references

Factor	Key references
Environment	
ICT as an enabler	Dröge et al. (1995); Bowersox et al. (1992)
Deregulation as an enabler	Van Hoek et al. (1998)
Market turbulence as a driver	Dröge et al. (1995); Feitzinger and Lee (1997); Van Hoek et al. (1998)
Strategy and structure	
Geographical restructuring required for the implementation	Christopher (1992); Van Hoek (1998a)
Operational characteristics should favor postponed manufacturing	Bucklin (1965); Cooper (1993); Zinn and Bowersox (1988); Van Hoek (1997); Garg and Tang (1997)
Organizational heritage influences the structure and timetable of change process	Bowersox et al. (1992); Van Hoek et al. (1998)
Performance	
Performance improvements realized through the implementation of postponement	Lee et al. (1993); Zinn and Bowersox (1988); Zinn (1990); Feitzinger and Lee (1997); Garg and Tang (1997)

transparent in the chain (contributing to customer responsiveness). Secondly, Van Hoek et al. (1998) identify deregulation as a second driver of supply chain reconfiguration. It can be expected that deregulation enables companies to establish postponement operations in major markets, while globalizing primary production instead of duplicating factories nationally. The notion that a trade relation is imperative to the supply chain structure (Dröge et al., 1995) explains that market turbulence is a relevant third driver of the growing attention for postponement. In international markets, a general move towards customization of products on a cost-effective basis is accompanied by residual differences in local markets. These differences require the localization of strategies, products, and operations, all favoring postponement. ICT and deregulation are thus expected to be enablers of postponement applications. Market turbulence is expected to be the new demanding context in which postponement can prove to be an effective solution. The reason why postponement is receiving more attention might be that the operating environment did not facilitate or require postponement in the past, whereas it now does.

Apart from the new technologies and the new market context, new organizational forms are also expected to influence the application of postponement. In particular the literature refers to geographical restructuring within the service window and the role of operating characteristics in favoring or disfavoring postponement. Finally the organizational heritage may exert a moderating influence on structure development through its impact on the time-line, the structure, and the nature of the change process.

Ultimately, the implementation of postponement, within the proper operational and strategic context, should affect performance levels. The literature is predominantly concerned with improvements in operational (cost) performance, with a slight concentration on logistics costs (see Lee et al., 1993 and Zinn, 1990).

4. Comprehensive classification of the literature

The literature is concisely characterized in Table 7. It specifies the available contributions to insights in postponement in terms of

- postponement types covered,
- amount of customization/activities postponed,
- spatial restructuring/spatial level of operating postponement application,
- coverage of operating characteristics,
- role of change management, and
- method of study.

Table 7 lists the publications reviewed in chronological order of their appearance in this study.

A first inspection of the table reveals some gaps in the systematic approach

- insufficient integration of studies and findings,
- inadequate support to (modern) operations management decision-making,
- and lack of studies in specific areas.

Table 7
Overview of publications on postponement

Publication	Content						Method:			
	Postponement type?	Amount of customization/ activities postponed?	Spatial scale level?	Position in the supply chain?	Role of operating characteristics?	Role of change management?	Theoretical/ conceptual	Cases	Simulation/ calculation model	Survey
Bucklin (1965)	Yes	–	–	Down-stream	Yes	Yes	Yes	–	–	–
Shapiro (1984)	Yes	–	–	Complete chain	–		Yes	–	–	–
Zinn and Bowersox (1988)	Yes	Yes	–	Mid- to down-stream	Yes		–	–	Yes	–
Zinn and Levy (1988)	Yes	–	–	Mid- to down-stream	–	Yes	Yes	–	–	–
Zinn (1990)	Yes	–	–	Mid- to down-stream	Yes		–	–	Yes	–
Christopher (1992, 1998)	–	Yes	Yes	Mid- to down-stream	–		Yes	–	–	–
Bowersox et al. (1992)	–	Yes	–	Mid- to down-stream	–	Yes	–	–	–	Yes
Cooper (1993)	–	Yes	Yes	Mid- to down-stream	Yes	–	–	Yes (examples)	–	–
Lee et al. (1993)	Yes	Yes	–	Mid- to down-stream	Yes	–	–	–	Yes	–
Bowersox (1995)	–	Yes	–	?	–	–	–	–	–	Yes
Dröge et al. (1995)	Yes	Yes	–	Mid-stream	–	Yes	–	–	–	Yes
Morehouse and Bowersox (1995)	Yes	Yes	Yes	Down-stream	–	–	Yes	–	–	–
Van Hoek (1997)	Yes	Yes	Yes	Down-stream	Yes	–	Yes	Yes (1)	–	–
Feitzinger and Lee (1997)	–	Yes	–	Mid- to down-stream	–	Yes	–	Yes (1)	–	–
Garg and Tang (1997)	–	–	–	Mid- to down-stream	Yes	–	–	–	Yes	–
Van Hoek et al. (1998)	Yes	Yes	–	Mid- to down-stream	Yes	Yes	–	Yes (4)	–	–
Van Hoek (1998a)	Yes	Yes	Yes	Mid- to down-stream	–	Yes	–	Yes (8)	–	–
Pagh and Cooper (1993)	Yes	Yes	–	Mid- to down-stream	Yes	–	Yes	–	–	–
Van Hoek (1998b)	Yes	Yes	–	Complete chain	Yes	–	–	Yes (1)	–	Yes

Let us start with the insufficient integration of studies and findings. First, the scope of the supply chain studied in most publications reflects only a segment of the supply chain (down-, mid- or up-stream), and few papers taken the entire supply chain into consideration. This narrower scope is partly due to the fact that postponement has been studied in various disciplines, including logistics and manufacturing. Actually, the supply chain should represent an integrated operating environment within which the separate disciplines can contribute to a deeper understanding of the issues and challenges of operation management. Also, the relation of postponement to mass customization and related operating concepts deserves a more thorough examination. Furthermore, the methods used in most papers do not reflect integrated efforts or a structured progress of knowledge creation. Such progress would start with theorizing, qualitative research and then move onward to mathematical and statistical generalizations. The development of the literature did start with the seminal Bucklin article, but then progressed into modeling, back to conceptualization, cases, and surveys. Of course, knowledge development can to some extent be iterative. New factors to consider are added in time or the concepts are altered in response to interim findings. Still the body of literature appears to be fragmented across various fields.

Let us now consider the contribution to decision-making. Even though elements such as operating characteristics and change management have been recognized as relevant in various fields, there is not much (explicit) cross-referencing and fertilization, as may be clear from the previous sections. Operating circumstances that do and do not favor postponement, for example, have been documented fairly extensively in various studies. In this paper a list of relevant factors has been developed (Table 4) on the basis of various studies. What is lacking is a framework for operations decision-making on matters such as the feasibility of various postponement applications in specific operating circumstances, as judged by the criteria in Table 4. Ideally, that framework would link those criteria, drawing upon factors from various fields, including logistics, marketing. The development of such a framework would bring existing knowledge beyond the point of merely listing and assessing individual relevant factors. Rather, it would be a heuristic device to understand the "big picture" and provide more robust support for decision-making.

On top of this, factors such as the spatial dimension of postponement applications have been studied only rarely. Several studies have pointed at the spatial reconfiguration of the supply chain needed in the implementation process and the positioning of postponement at a specific spatial level of operating but almost entirely based upon qualitative evidence (examples, single and multiple case studies) only. This lacks robustness of findings, if not generalization.

Within the context of these points, specific gaps in existing knowledge can be identified. These deserve attention, as specified in the following section.

5. Directions in the rediscovery of postponement

Based upon a review of Table 7 two elements appear crucial to a successful rediscovery of postponement. The first task is integrating the lessons learned in previous research to reconceptualize postponement. The challenge is to fill the gaps in Table 7, drawing upon knowledge from various areas, and to capture the new dynamics of the concept. Secondly, we need to improve the methodological robustness of the concept. Having noted the iterative knowledge development in this area, integration of methods within a more structured or comprehensive study plan seems important. We can generate suggestions in the form of challenges to research. The suggestions start with a new focus: looking at postponement in the supply chain instead of in the marketing or distribution channel only. General challenges are identified below, linked to suggestions for specific research topics.

5.1. Challenge 1: postponement as a supply chain concept

Fig. 4 presents the focus in the supply chain of the studies reviewed here, positioning them in terms of methods used. This vertical axis is merely aimed at structuring study areas. It is not intended to suggest a hierarchy in methods (as methods should predominantly fit a research question). In time, research questions may advance towards more structured, qualitative generalizing and testing methods (we return to this point in the section on methodological upgrading).

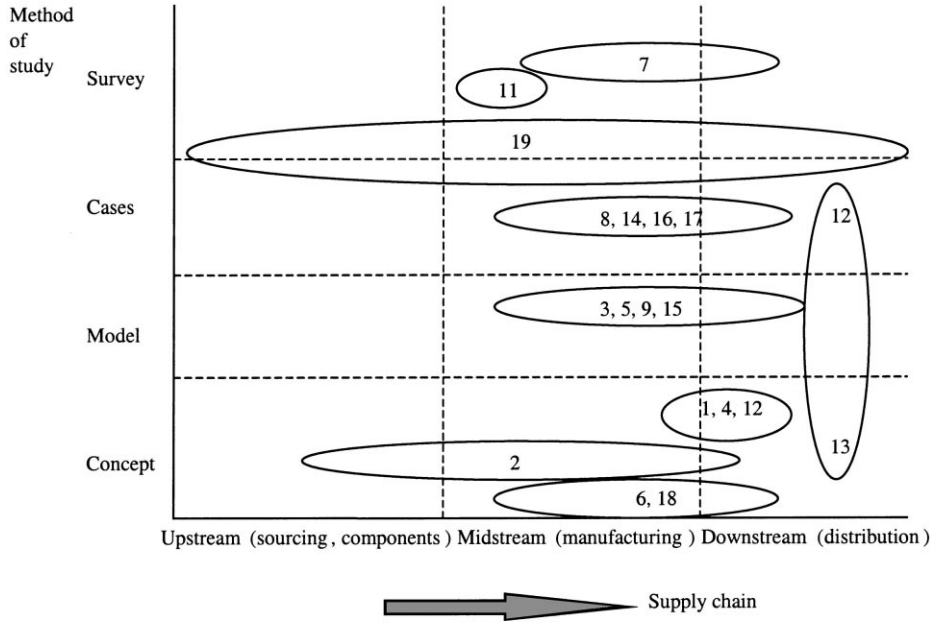

Fig. 4. Publication along the supply chain.

Whereas Bucklin (1965) focused his groundbreaking article on down-stream distribution, subsequent (time and place postponement) studies have included form postponement in the mid-stream final manufacturing stage of the chain. Most recent publications have claimed a supply chain approach to postponement (Feitzinger and Lee, 1997 for example). However, their content does not go beyond that of Zinn's work in the 1980s nor does recent work reflect an integrated study of postponement applications throughout the entire supply chain. Van Hoek (1998b) one of the first attempts to measure postponement applications along the Lampel and Mintzberg (1996) continuum throughout the supply chain. This study started out with statistical generalization of postponement as a supply chain construct. Eventually, in-depth empirical insights into the levels and points of application along the supply chain may deserve further conceptualization.

Specific study should be undertaken to assess to what extent postponement is applied at various positions in the supply chain. The Lampel and Mintzberg (1996) classification of supply chains needs some improvement along several lines. First of all, it does not include various activities relevant to postponement, such as packaging. Furthermore it did not include the cross-company dimension of the supply chain. Whereas it suggested a focus on one company only, companies such as MCC and Dell Computers involve suppliers heavily in their postponement applications. Finally, the classification suggested that companies can either customize and postpone activities in the supply chain or not, whereas Fig. 1 indicates that it is not a question of either/or. It is possible to postpone a certain amount of operations in one specific activity (e.g. 50% of packaging operations).

5.2. Challenge 2: integrating related supply chain concepts

Widening the scope of the postponement concept to cover the entire supply chain research will have to do more than identify relations among streams of research on postponement. It may also have to undergo cross-fertilization with related concepts such as just-in-time (JIT) manufacturing and sup-

ply, vendor-managed inventory, efficient consumer response (ECR) and the associated quick-response distribution techniques. These concepts may fit very well within a supply chain conceptualization of postponement. In fact, they may even prove to be related to the Bowersox et al. (1980) projection of future channel structures. Not only is quick response included as one of the methods for achieving mass customization, which ties it to postponement, but ECR also involves order-driven distribution from centralized warehouses directly to the customer in the retail channel. This fits in with time and place postponement. Vendor-managed inventory involves time postponement up-stream but not necessarily place postponement. The reason is that inventories of parts are stored at the customer facility, and ownership is transferred when components are needed in production. JIT goes beyond that by adding up-stream form postponement to time postponement. Supplies are manufactured and shipped to order in this approach. JIT may not involve place postponement, as doorstep plants are commonly used for JIT operations. This may prove to be an interesting extension of postponement studies in the mid- to down-stream stages of the supply chain. As Zinn and Bowersox (1988) argue, time postponement is always combined with place postponement in this segment of the supply chain. Apparently, this is not the case in the up-stream stages of the supply chain. Adding related concepts to the postponement research might bring conceptual richness to the concept through cross-fertilization of the research taking place within the expanded focus area in the supply chain.

Studies should look into third-party logistics service providers. Specifically the studies should target concepts such as ECR and postponement as a possible extension of their service offerings. That extension places postponement in relation to outsourcing and third-party logistics services throughout the supply chain. It would be interesting to assess the application of these concepts in this sector as well as the factors that explain this practice. Multiple third parties claim to be active in this field, but the empirical evidence to suggest that this is really happening in the area of postponement is actually weak. It would be relevant to assess the application of postponement by these companies in relation to other concepts that might be practiced more often. For instance, account management and virtual integration might support the application of postponement by these companies.

5.3. Challenge 3: postponement in the globalizing supply chain

Having mentioned place postponement as an area of enrichment we should also touch upon the spatial dimension of postponement. Bowersox (1995) include postponement as one of the elements in constructing a model for World Class Logistics. Thereby, they and asses the application rates across the board (not at specific point in the supply chains) in different continents, thus relating postponement to the globalization of supply chains. Based upon case studies, Van Hoek (1998a) examines reconfiguration practices in-depth. He identifies differences in globalization approaches and reconfiguration processes between companies from different continents. Even if the World Class Logistics model is more or less comparable across companies in different regions of the world (a universal answer, as argued by Bowersox, 1995), the process of getting there is not. The importance of change management/moderating variables and market/operating variables (Table 7) in the construction of postponement applications may cast some doubt on the universality of the World Class Logistics cross-country and cross-continent empirical assessment. It might be reasoned that postponement is most (or more relevant) to the European marketplace in comparison to other markets such as Asia, given the remaining (even after deregulation) differences in language, culture, and consumer behavior across the many countries in a relatively small geographical area. (Incidentally, that is also the experience of Hewlett Packard).

It would be very interesting to compare applications of postponement. For example, they could be assessed in a study like the one suggested with Challenge 1, across countries: between European countries and between continents, perhaps Europe and the US. It would then be possible to compare applications not only among companies and through supply chains but also between various levels of spatial aggregation. In fact this might yield benchmarking information on companies as well as on regions. In that respect, it would be interesting to assess the potential differences in drivers and inhibitors of postponement applications across countries and continents.

5.4. Challenge 4: postponement in the customized supply chain

Having mentioned differences in consumer behavior, we now return to the relevance of postponement in achieving customization. In light of the limitations in existing feasibility models and operating characteristics used, there is a clear need to re-conceptualize these models. Probably, this should go far beyond listing a set of relevant individual market characteristics, as done in Table 4. Cooper (1993), Pagh and Cooper (1998) and Table 4 describe some initial attempts to identify and group/relate factors that influence the feasibility and viability of postponement.

Research should lead to a typology of postponement applications using operating circumstances that impact feasibility and validity of postponement. The typology should go beyond a listing of factors, as done in Table 4and the publications mentioned above. Rather, an effort should be made to juxtapose these factors by using them as separate and related dimensions of the typology. It would help to integrate the insights even more if input from existing typologies in areas such as manufacturing and marketing could be used. Additionally, a broader typology of postponement opportunities should include service processes beyond distribution and logistics services. Even though literature on postponement focuses on manufacturing and logistics related postponement applications the concept also applies in services. Part of the fundaments of services is that consumption and production partially coincide indicating that prosuming and customized delivery and processing are central to service organizations. In short, postponement should not be considered within a manufacturing context only.

5.5. Challenge 5: methodological upgrading of postponement

A viable methodology to integrate findings from the literature into a coherent research plan is triangulation. Not only is it a good way to mix qualitative and quantitative methods, but it also leads to robust results and potentially to cross-method synergies (Jick, 1979). Mentzer and Flint (1997) state that triangulation is the single best method to study logistics, a pivotal area in postponement research.

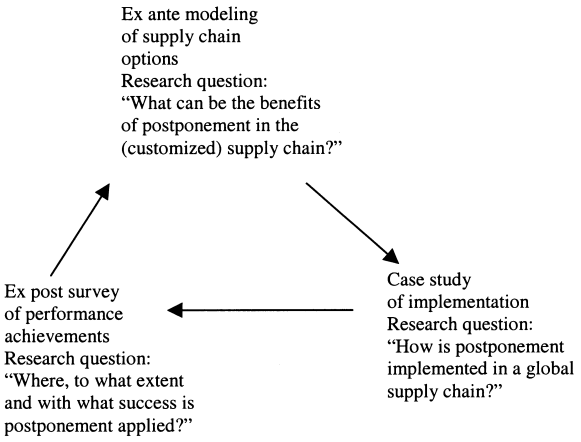

Fig. 5. Example of triangulation in postponement.

Triangulation requires a comprehensive, coherent, and carefully integrated research design. It is well worth the effort, though. One of the benefits is its capacity to bring research to a more advanced methodological level. Another is its potential to enhance the richness of the findings by filling in gaps in available knowledge.

An example of a research proposal that would benefit from triangulation is shown in Fig. 5. It starts with the ex ante assessment of postponement applications in the supply chain, using Fig. 3 for developing and evaluating supply chain structures within an integrated framework. Developing customer-based and customization-oriented measures, in addition to cost measures and modeling of supply chains, forms a challenge in this part of the proposed research. These measures should go beyond the lead times and delivery reliability previously used (Lee et al., 1993; Zinn and Bowersox, 1988). Any customer will want fast and reliable order fulfillment. Customization, however, might pertain to functionalities, product specifications, and the degree of customer-defined component selection.

The second step in this example could then be to study the implementation of selected supply chain structures. Change management, adjustment of organizational characteristics (e.g. those identified in Dröge et al., 1995), and the required geographical reconfiguration throughout the implementation process are relevant elements to consider in this part of the study. Given the comprehensiveness of these elements and

Table 8
Summary of categories and directions for research

Item in classification	Gap in knowledge and literature identified	Research directions
Postponement types covered	Poor integration across logistics, manufacturing and operations in the operations in the supply chain	Postponement as a supply chain concept
Amount of customization		Integration of related supply chain concepts
Spatial level of operating	Postponement studied without explicit reference to spatial dimension	Postponement in the globalizing supply chain
Role of operating characteristics	Various studies but lacking integration into decision framework	Postponement in the customized supply chain/typology of validity-based on operating circumstances
Change management		
Method of study	Limited cross-fertilization between methods and limited structured knowledge development	Triangulation

the potentially long time period covered by implementation processes (disfavoring a single measure moment), a case study method might be advisable here.

The third step in the triangulation framework in Fig. 5 is an ex post evaluation of performance improvements and achievements following the implementation process. A survey of multiple plants within the global supply chain or within industries might be instructive here. Generalizations on points and degree of application along the supply chain can be developed in relation to market operating circumstances and contingencies. In order to close the loop, these findings can be used as input to new postponement and supply chain initiatives.

6. Closing remarks

In this paper we have tried to classify the available literature on postponement systematically. In the process, we have found that the recent growth in publications reflects a rediscovery of postponement, driven by market turbulence within the organizational context of the supply chain and in relation to customization efforts. In order to contribute to the knowledge of the global, agile, or customized supply chain, we have formulated some challenges for upgrading and repositioning the content and the method of research, as summarized in Table 8. We hope our efforts will facilitate a migration of knowledge and practice so that industry can start benefiting from postponement applications. Hopefully, postponement will be recognized as a common business practice, not dismissed as an old theoretical notion or labeled as a practice of a limited number of frame-breaking companies.

We have intentionally not called this section "Conclusion". Now that the body of work on postponement is growing rapidly, we see continual progress in building knowledge and insight. The work initiated and in progress, as well as the challenges put forward here, indicates that we are not in the stage of reaching conclusions on the field or on the concept as a whole. To some extent we hope that the literature review presented here will soon be outdated by the publication of new findings contributing to the future of operations. Hopefully, the (re-) conceptualizations and research approaches suggested here will facilitate the rediscovery of postponement through leveraging the lessons learned. As the state of knowledge creation progresses surely new research questions will be put forward. We are anxious to get our hands on these pieces of the puzzle.

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