

Abstract Number: 025-1208

Abstract Title: Postponement Strategies in Pharmaceutical Supply Chains. Evaluation of Costs and Benefits

Authors Information: 1st author: Stephan Verhasselt

ETH Zurich, BWI Center for Industrial Management, Zurich 8032,  
Switzerland

Email: [sverhasselt@ethz.ch](mailto:sverhasselt@ethz.ch)

Phone: +41 44 63 20 527

2nd author: Felix Friemann

ETH Zurich, BWI Center for Industrial Management, Zurich 8032,  
Switzerland

Email: [ffriemann@ethz.ch](mailto:ffriemann@ethz.ch)

Phone: +41 44 63 20 534

Conference: POMS 23<sup>rd</sup> Annual Conference

Chicago, Illinois, U.S.A.

April 20 to April 23, 2012

Due to increasing cost pressure and rising demand fluctuations, the application of postponement strategies becomes more and more attractive for pharmaceutical companies. This paper presents different concepts for postponement strategies in pharmaceutical supply chains and evaluates postponement critically with regard to resulting costs and benefits.

Key Words: Pharmaceutical Industry, Postponement, Costs and Benefits

## 1 INTRODUCTION

Recently, the pharmaceutical industry is facing significant changes in business conditions. A growing market competition by generic manufacturers raises the cost pressure within the industry. Public health authorities force pharmaceutical companies more and more to operate performance and price oriented (Ewers *et al.* 2010). Emerging markets like China, Brazil or India gain in importance for the sector and the trend for personalized healthcare leads to a growth of pharmaceutical product portfolios (IMS-Health 2011). These and even more current developments within the industry require for comprehensive modifications throughout the pharmaceutical value chain. Especially structures and processes of the pharmaceutical supply chain are thereby affected.

For a long time the design of pharmaceutical supply chains was determined primary by the achievement of high delivery reliability as well as high delivery readiness. Pharmaceutical companies have obtained and in many cases still obtain these objectives by high inventory levels of finished goods located close to the customer as well as extremely reliable production and logistic processes. With the above mentioned developments within the industry, this situation changes. Besides delivery reliability and delivery readiness, cost efficiency, agility and responsiveness gain more and more importance as supply chain objectives for pharmaceutical companies (Verhasselt *et al.* 2012).

Regarding this, an ongoing discussion exist in practice dealing with the chances and limitations related to an application of postponement strategies in pharmaceutical supply chains (Savage *et al.* 2006). A postponement strategy is a product design strategy that shifts product differentiation closer to the consumer by postponing identity changes, such as assembly or packaging to the latest possible supply chain location (APICS 2008). During the last twenty years the application of postponement in industry was limited to a few sectors covering the textile, the electronic and the automotive industry (Dapiran 1992, Lee *et al.* 1993, Brown *et al.* 2000). Research related to postponement in these sectors is comprehensive and profound. In comparison, only a few cases of an application of postponement strategies in pharmaceutical industries are documented in literature (Van Hoek 1998, Savage *et al.* 2006). This leaves a considerable gap in research.

In order to close this gap, the BWI Center for Industrial Engineering of ETH Zurich investigated in close cooperation with pharmaceutical companies on the applicability and profitability of postponement strategies in pharmaceutical industries. The overall methodological framework, which was used during this project, was embedded into the action research process, consisting of the elements “research” from academia and “participation” of practitioners (Greenwood *et al.* 1998). Case study research was employed as the main form of data collection as well as for the verification of results (Yin 2009).

The findings, which were collected during the project, are presented in this paper. First, the results of a literature research on postponement strategies in pharmaceutical supply chains are summarized. This section gives the reader basic information about pharmaceutical supply chains and postponement strategies. Then, the paper describes a systematic structure defining different postponement concepts in pharmaceutical supply chains. Afterwards the economical evaluation of postponement in pharmaceutical supply chains is discussed incorporating an analysis of the main costs and benefits. The paper closes with a conclusion and an outlook for future research.

## **2 LITERATURE REVIEW**

In order to fully comprehend the chances and limitations of postponement strategies in pharmaceutical industries, a good understanding of pharmaceutical supply chains as well as postponement theory is necessary. For this purpose, the following section summarizes the current state of research in both fields and explains the most important facts.

### **2.1 The pharmaceutical supply chain**

Generally, the pharmaceutical supply chain can be divided into three different manufacturing steps (Shah 2004). The value creation process in pharmaceutical supply chains starts with the Active Pharmaceutical Ingredient (API) production. Within this step pharmaceutical companies produce the main substance for a drug. Subsequent to API production, the formulation step of pharmaceutical manufacturing follows. During formulation the API is mixed with several other materials ensuring the correct and efficient intake of drugs (Shah 2004). After formulation, the packaging process starts. In pharmaceutical packaging, two different types of packaging activities are distinguished (Savage *et al.* 2006). With primary packaging the pharmaceutical manufacturer ensures that the drug is protected against direct influences of the environment. For this purpose, solid drugs are packed into blisters or bottles, whereas liquid drugs are filled into bottles, vials or syringes. In contrast, secondary packaging guarantees the fulfilment of transport, storage and identification requirements. For this purpose, primary packed drugs are further packed into cardboard folding boxes enclosing information materials like leaflets. In order to benefit from scale effects, API production, formulation and packaging activities are in general executed in sites, which have a global responsibility. Therefore, these sites serve internal or external customers worldwide (Verhasselt *et al.* 2012). For transport activities between these sites pharmaceutical manufacturers rely on various types of transport modes encompassing sea, truck or air freight.

After packaging, the distribution of drugs starts. The distribution chain in pharmaceutical supply chains normally covers multiple logistic activities between various supply chain partners like pharmaceutical manufacturers, wholesalers, hospitals, pharmacies and patients. The present paper especially highlights the activities related to pharmaceutical manufacturers. For detailed information to the logistics related to the other supply chain partners please refer to (Pedroso *et al.* 2009). The distribution chain for pharmaceutical manufacturers starts at the above described packaging sites. From there, internally or externally managed warehouses are replenished with country specifically packed products. These warehouses represent the major stock of finished products in pharmaceutical supply chains and are normally located close to the customer in various countries all over the world. Due to the proximity to customers, the warehouses guarantee a fast and reliable product delivery in case of a customer demand. Normally, pharmaceutical warehouses only serve customers from a certain country. Regional or even global responsible warehouses are only operated in exceptional cases (Verhasselt *et al.* 2012).

## **2.2 Postponement**

Especially during the last twenty years, the scientific community has discussed various questions related to the theory of postponement and its implementation in practice. Today, three principle types of postponement are distinguished in theory named 1) logistic postponement, 2) form postponement and 3) full postponement. Logistic postponement relies on the idea to implement ship to order processes according to arriving customer orders for common finished goods at centralized warehouse locations (Alderson 2006). Delayed transport activities thereby cover intercontinental or comparable distances. In comparison to this, form postponement approaches contain late stage customization steps in labeling, packaging, assembling or manufacturing (Zinn *et al.* 1988). Like transport activities in logistic postponement, the execution of these activities starts with the arrival of a customer order. Normally, customization within form postponement approaches is executed at decentralized

manufacturing and distribution sites avoiding global transport activities (Van Hoek 2001). In contrary, a full postponement approach relies on the idea to customize products with the execution of late stage customization activities at centralized manufacturing sites. In this case, postponed activities encompass various form postponement related manufacturing steps like for example packaging activities as well as long distance transport activities (Pagh *et al.* 1998). Apart from the characterization between logistics, form and full postponement, types of postponement can further be characterized by the type of customer triggering the execution of postponed activities. Whereas a few authors argue for postponement concepts only triggered by orders of external customers, other authors encompass within the postponement definition moreover concepts where the execution of postponed activities depend on internal customer orders like orders from internally managed warehouses (Su *et al.* 2005).

Besides findings to the different types of postponement, literature provides a few detailed descriptions about the application of postponement in practice. As introduced above, these papers are in general limited to the textile, electronic and automotive industry (Dapiran 1992, Lee *et al.* 1993, Brown *et al.* 2000). Only a few references in literature exist regarding an application of postponement strategies in pharmaceutical industries. Van Hoek for example describes a case study of the application of packaging postponement strategies in biopharmaceutical manufacturing (Van Hoek 1998). Besides, Savage summarizes a few enabling technologies related to a standardization of packaging materials promoting the application of postponement (Savage *et al.* 2006). However, both authors remain quite undetailed in their explanations. Especially, important questions related to costs and benefits of postponement approaches in pharmaceutical industries remain unanswered.

In turn, general economic evaluations of postponement do exist in literature. Zinn for example proposes a framework covering different cost factors starting from inventory costs to opportunity costs (Zinn *et al.* 1988). Lee supplemented this cost framework proposed by Zinn with cost factors related to the implementation of postponement strategies in practice e.g. financial burdens related to

design changes of products and processes (Lee *et al.* 1997). Recent papers in the field of the economical evaluation even suggest calculations within a bigger framework. Anand for example evaluates the profitability of postponement approaches in relationship with the market position of a company (Anand *et al.* 2007). Garcia-Dagustue in turn estimates the costs of postponement strategies not only from the view of the company implementing postponement, but with a supply chain view evaluating costs of all affected supply chain partners (Garcia-Dastugue *et al.* 2007).

### **3 POSTPONEMENT CONCEPTS FOR PHARMACEUTICAL SUPPLY CHAINS**

Before developing postponement concepts for pharmaceutical supply chains, it is first important to clarify applicable types of postponement in pharmaceutical industries. According to Cooper the similarity or diversity of brand, product and package characteristics needs to be taken into account for this decision (Cooper 1993). In pharmaceutical industries brand and product characteristics are in general identical for purely manufactured products. Characteristics of packaging materials however differ generally between various countries and lead to an increase of variants. With the current state of packaging technology thus labeling and packaging postponement (as two types of form postponement) represent the preferred types of postponement in pharmaceutical industries.

As mentioned above, a few technical enablers are documented in literature supporting labeling and packaging postponement approaches in pharmaceutical practice (Savage *et al.* 2006). Most of these enablers are related to a standardization of packaging material in pharmaceutical supply chains. The lowest level of standardization is thereby given by a redesign of primary packaging materials resulting e.g. in blisters, vials, syringes or bottles with generic packaging formats for different countries or customers. The next level of standardization represents a standardization of primary packaging materials not only with regard to formats, but also with regard to all printed data. This leads to primary packaging materials with standardized information like batch IDs or expiry dates which are applicable in multiple countries. After a standardization of primary packaging materials,

further standardization activities encompass a standardization of secondary packaging materials. Activities leading to a standardization of secondary packaging materials according to the vanilla box principle (Swaminathan *et al.* 2003) represent the lowest of level of secondary packaging standardization. Secondary packaging materials designed according to the vanilla box principle contain only generic information, which can easily be supplemented or adapted with late stage labeling activities during customization. Finally, the highest level of overall standardization is given by a complete standardization resulting in generic secondary and primary packaging materials. This level of standardization is related to serious challenges during an implementation. However, contrary to the above derived conclusions, in this extreme case of standardization even an application of logistic postponement due to similar brand, product and package characteristics becomes possible (Cooper 1993).

Apart from standardization, re-sequencing of packaging and logistic activities represents the second major approach for enabling postponement in pharmaceutical industries. In case of re-sequencing, logistic and packaging activities are shifted in their normal sequence resulting in different supply chain structures and processes with different performance characteristics.

Bringing the above described enabling technologies of standardization and re-sequencing together with currently existing supply chain structures and processes in pharmaceutical industries (as described in section 2), the following postponement concepts with regard to internal and external customer orders in the area of logistic, labeling and packaging can be derived for pharmaceutical supply chains:

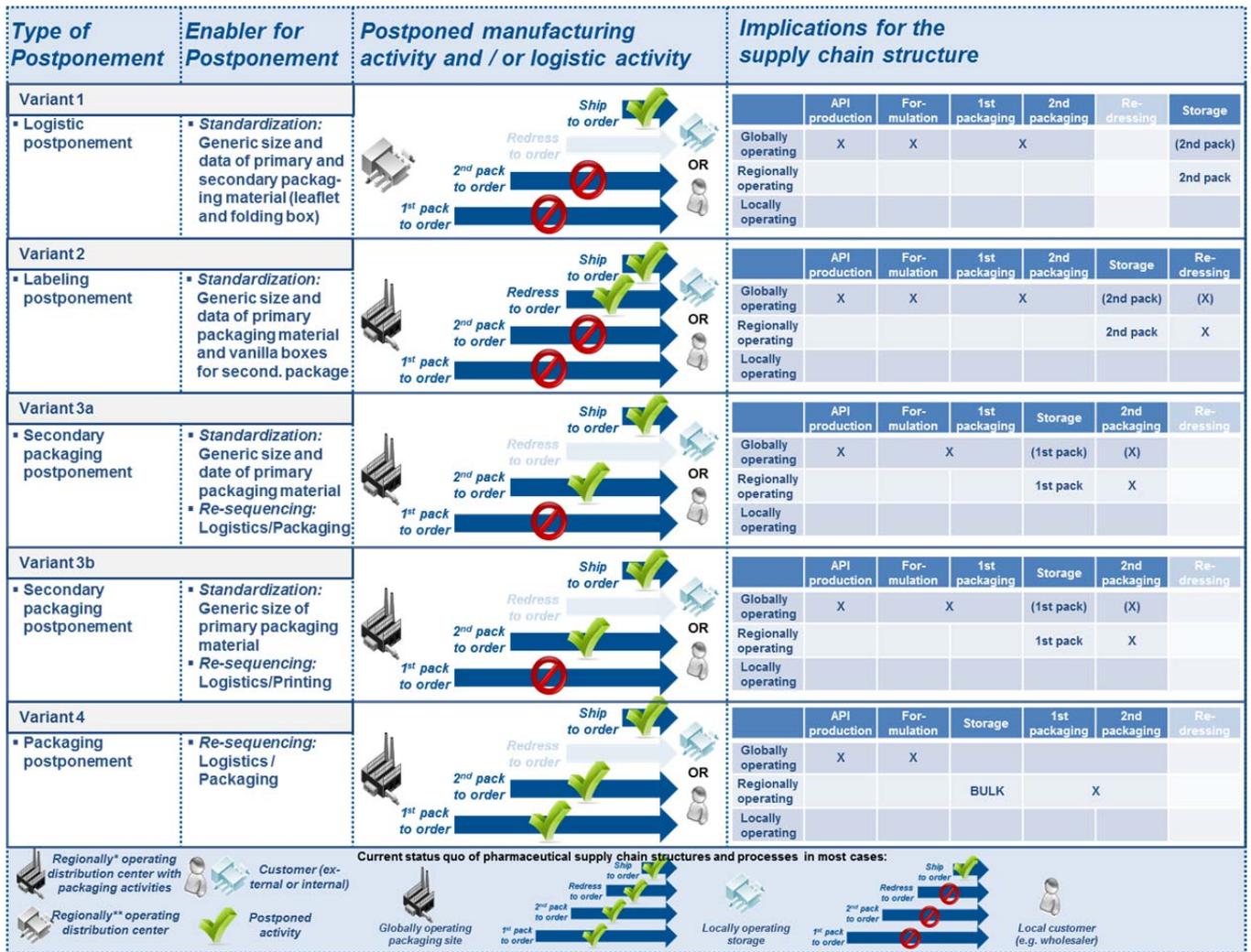


Figure 1: Overview of packaging, labelling and logistic postponement concepts for pharmaceutical supply chains

### Variant 1: Logistic postponement using generic packaging material

In case a pharmaceutical manufacturer realizes a full standardization of primary and secondary packaging material for a certain region or even the whole world, it becomes possible to apply a logistic postponement concept for pharmaceutical supply chains. Within this concept, all manufacturing and packaging activities of pharmaceutical products are executed according to forecast calculations and therefore are not postponed. A customization of products only occurs, when an arriving customer order triggers a transport activity allocating the product to a certain customer. Due to in general small order sizes and short customer tolerance times in pharmaceutical industries, regional distribution centers are the preferred starting point for these shipments. In exceptional cases

also globally operating distribution centers are reasonable. Since merely transport activities are postponed, a logistic postponement concept using generic packaging material represents the least distinct postponement concept for pharmaceutical supply chains.

***Variant 2: Labeling postponement using generic primary packaging material and vanilla boxes***

Normally, public health authorities require for a certain amount of country specific information on pharmaceutical packages to ensure the secure use of drugs in domestic markets. If this information is limited to secondary packaging materials like folding boxes and leaflets, a labeling postponement concept becomes feasible for pharmaceutical supply chains. Within a labeling postponement concept, drugs are packed into primary packaging materials having identical formats and data sets for multiple countries. During secondary packaging, these primary packs are further packed into folding boxes which are designed according to a vanilla box principle (Swaminathan *et al.* 2003). As described above, these boxes contain only generic information, which can easily be supplemented or adapted with late stage labeling activities during customization. Customization again occurs preferable in regional distribution centers, whereas packaging of generic boxes may occur in global packaging sites exploiting economies of scale. During customization specifically designed labels are used to finalize the package layout according to an arriving customer order. Moreover, country specific leaflets are in general attached outside to the folding box using especially designed pockets. This prohibits the opening of folding boxes during customization and therefore increases the process quality especially with regard to counterfeiting. The redress and ship to order cycle closes with the transport activity. Again, in exceptional cases, covering certain customer types and certain markets, also the customization from globally operating distribution centers with corresponding global transport activities may be reasonable.

### ***Variant 3a: Secondary packaging postponement using generic primary packaging material***

This variant is quite similar to the above described variant 2 of pharmaceutical postponement. Comparable to variant 2, manufactured drugs are packed into primary packaging devices having identical formats and data sets applicable in multiple countries. In contrast to variant 2 however, these primary packs are not further packed into vanilla boxes, but directly shipped into regional distribution centers. In these centers customization takes place. If a customer order arrives, the already produced primary packaging devices are packed together with country specific leaflets into country specific folding boxes. Afterwards, the shipment to the customer happens, comparable to variant 2.

### ***Variant 3b: Secondary packaging postponement using white line technology***

If public health authorities also require for country specific information on primary packaging materials, white line technology (Plewa *et al.* 2011) offers further opportunities to implement postponement in pharmaceutical supply chains. Requirements for an application of white line technology are limited to a standardization of primary packaging devices with regard to their formats. These devices are used for primary packaging at centralized formulation manufacturing sites directly after the formulation of products is finished. This is comparable to variant 3a. In contrast to variant 3a however, the primary packaging devices are not preprinted with country specific information. In general, only a generic code is printed on the device in order to identify the pack in all later stages of the supply chain. Customization occurs again preferable in regional distribution centers. For this purpose, automated white line packaging machines, which are installed at regional distribution centers, execute all customization activities, in case a customer demand is confirmed. By applying online printing technologies inside the machine, primary packaging devices like blisters are supplemented with country specific information. Leaflets and folding boxes can either be fed into the machine as complete finished materials with all required country specific

information or supplemented with online printing technologies inside the machine requiring a certain standardization level of secondary packaging material. The secondary package and ship to order cycle closes with the transport activity to the customer. Again, in exceptional cases also in this scenario the customization from globally operating distribution centers may be reasonable.

***Variant 4: Packaging postponement using re-sequencing of logistical and packaging activities***

If standardization of packaging material is technically or economically not feasible, a simple re-sequencing of all packaging and logistic activities combined with an implementation of pack to order principles represents a further possible postponement concept in pharmaceutical supply chains. Within this concept all packaging activities are accomplished at regional packaging and distribution sites. For this purpose, manufactured drugs are transported as bulk material into the regions. In case a customer demand is detected, primary packaging activities, secondary packaging activities as well as all transport activities are executed from these sites. This of course requires long customer tolerance times and sufficient high order sizes.

#### **4 ECONOMIC EVALUATION OF POSTPONEMENT**

Within an economical evaluation of the above described postponement concepts various cost factors need to be considered. Referring to existing cost models from literature (see section 2) as well as industry specific singularities especially the following cost factors are thereby of major importance:

*1) Costs related to design changes*

The implementation of postponement concepts in pharmaceutical supply chains leads to several expenditures minimizing the profitability of postponement. These expenditures depend highly on the postponement concept anticipated and might encompass costs related to the adaption of packaging

material, the adaption of packaging technology or the adaption of complete supply chain structures. Typical cost elements of these expenditures can cover spending for research and development activities, spending for investments in assets as well as spending for an accreditation of changes at public health authorities.

### *2) Savings related to inventory costs*

One of the major financial benefits related to the implementation of postponement represents the reduction of inventory levels due to risk pooling effects. With reduced inventory levels, savings related to the cost of capital as well as savings related to write offs are established. This directly affects the overall operational costs of pharmaceutical supply chains. The impact of the overall operational costs thereby depends especially on the value of products. Whereas for high value products which bind a lot of capital a reduction of inventories is important, the importance of inventory savings for low value products on the operational costs is less important. Also the contribution margins of products need to be taken into account when estimating the impact of postponement savings related to inventories. In case of products with a high contribution margin, inventory costs and related savings are of minor importance in a total cost consideration. However, if contribution margins are low, inventories have a considerable impact on the overall profitability of pharmaceutical supply chains.

### *3) Savings related to resource utilization*

Another major benefit of postponement comes with the exploitation of scale effects. The exploitation of scale effects increases the resource efficiency along the supply chain. Therefore, the overall operational costs are reduced, especially in case of disinvestment of resources. Again, the impact of savings related to an implementation of postponement especially depends on market and product characteristics. For products with a small contribution margin savings related to more efficiently

used supply chain resources like machines or transports have a considerable impact on the overall profitability of a pharmaceutical supply chain. Moreover, the amount and size of markets related to pharmaceutical products needs to be taken into account when evaluating the impact of resource related savings due to postponement. Regarding this, especially small, but multiple markets allow for a considerable exploitation of scale effects with postponement and therefore for significant savings.

#### *4) Savings related to higher responsiveness*

The last benefit directly related to an implementation of postponement represents the increased responsiveness of supply chain structures. Late stage customization activities guarantee a fast and customer order related finalization of products. Even with the existence of considerable demand fluctuations of markets the occurrence of lost sales and related opportunity costs can hereby be avoided. The effects of lost sales and corresponding savings with an implementation of postponement increase thereby with the contribution margin of pharmaceutical products and the degree of demand variability of markets.

#### *5) Impact of customs and taxes*

Taxes and customs in pharmaceutical industries are calculated due to product prices or values of intermediate products. Since product contribution margins in pharmaceutical industries are rather high, the related expenditures for taxes and customs have normally a considerable impact on the overall costs of pharmaceutical supply chains. Consequently changes in customs and taxes always need to be considered, when adapting supply chain channels in accordance with an implementation of postponement.

Summarizing the above explained relationships between market and product characteristics with financial benefits of postponement in pharmaceutical industries, figure 2 indicates situations, in which an implementation of postponement implementation is rather profitable or not:

	Product margin	Demand volatility	Market size	Product value	2) Importance of inventory	3) Importance of resource efficiency	4) Importance of responsiveness
<b>Reliable Supply Chain</b>	H	L	B	H			
	H	L	B	L			
	H	L	S	H			
	H	L	S	L			
<b>Agile Supply Chain</b>	H	S	B	H			●
	H	S	B	L			●
	H	S	S	H			●
	H	S	S	L			●
<b>Cost efficient Supply Chain</b>	S	S	B	H	●		
	S	S	B	L	●	●	
	S	S	S	H	●	●	
	S	S	S	L		●	
<b>Lean Supply Chain</b>	S	H	B	H	●		●
	S	H	B	L	●	●	●
	S	H	S	H	●	●	●
	S	H	S	L		●	●

H: High L: Low B: Big S: Small ● : Considerable impact of postponement ■■■ : Most of pharmaceutical products/markets today

Figure 2: Influence of market / product characteristics on postponement

The biggest impact coming with an implementation of postponement in pharmaceutical supply chains is related to product and market characteristics requiring lean supply chain structures. In this case, all possible savings related to postponement have a considerable impact on the overall profitability of pharmaceutical supply chains. This makes the costs related to an implementation of postponement for all introduced postponement concepts in many cases financially feasible.

However, most of today offered pharmaceutical products require due to high product contribution margins and rather stable market demands reliable supply chain structures. This might explain the rare dissemination of postponement in today’s pharmaceutical supply chains, which is mentioned in

various references (Savage *et al.* 2006, Verhasselt *et al.* 2012). In case of reliable supply chain situations the implementation of postponement is simply too expensive. In this situation benefits coming with postponement on the overall profitability are rather negligible.

With rising demand fluctuations and stable contribution margins however, more and more pharmaceutical products require for more agile supply chain structures. In this case postponement might increase the achievable level of responsiveness and therefore decrease the occurrence of lost sales situations. In comparison to postponement however, other measures related to an increase of responsiveness like lead time reduction might be effective as well and probably less cost intensive.

With rising cost pressure and stable demand situation in comparison, the implementation of cost efficient supply chain structures becomes necessary. In this case postponement can efficiently decrease the operational costs related to inventories and resources. A profitable implementation therefore might be realistic.

However, as mentioned above the full exploitation of postponement in pharmaceutical supply chains will only arise with a simultaneous occurrence of demand fluctuations and an increased cost pressure. With the current developments and trends in the pharmaceutical industry this might happen within the next years. In this case the importance of postponement concepts for pharmaceutical supply chains will increase and will no longer be limited to certain products in certain markets, but have general implications.

## **5 CONCLUSION AND OUTLOOK**

The present paper comprehensively discussed the application of postponement strategies in pharmaceutical supply chains. Five different postponement concepts for current pharmaceutical supply chain structures were introduced and extensively described. Moreover, the paper summarized the most important costs factors needed for an economical evaluation of postponement concepts in pharmaceutical supply chains and discussed certain product and market characteristics supporting a

profitable application of postponement in pharmaceutical industries. Thereby, it was shown that current business conditions for most pharmaceutical products do not promote an application of postponement in pharmaceutical industries. Since current developments and trends in pharmaceutical industries however adapt more and more existing business conditions, a growing importance of postponement in pharmaceutical industries is very likely.

Consequently, comprehensive areas for future research exist in the field of postponement for pharmaceutical industries. One possibility for future research encompasses the investigation of best practices for an implementation of postponement in pharmaceutical supply chains. Related research questions for example would analyse the factors supporting and prohibiting a successful implementation of postponement in pharmaceutical industries. Besides, research related to the development of advanced calculation methods would further increase the profitability estimation of postponement in pharmaceutical industries. Regarding this, the results of this paper may form the basis for the development of simulation supported calculations allowing decision makers from practice solid and pragmatic recommendation for an implementation of postponement.

## **6 REFERENCES**

- Alderson, W., 2006. Marketing efficiency and the principle of postponement: A twenty-first century guide to aldersonian marketing thought. *In: Wooliscroft, B., Tamilia, R.D. & Shapiro, S.J. eds.: Springer US, 109-113.*
- Anand, K.S. & Goirotra, K., 2007. The strategic perils of delayed differentiation. *Management Science, 53 (5), 467 - 712.*
- Apics, 2008. *APICS Dictionary*, 11th eds., Alexandria, VA: APICS.
- Brown, A.O., Lee, H.L. & Petrakian, R., 2000. Xilinx improves its semiconductor supply chain using product and process postponement. *Interfaces, 65-80.*

- Cooper, J.C., 1993. Logistics strategies for global businesses. *International Journal of Physical Distribution & Logistics Management*, 23 (4), 12-23.
- Dapiran, P., 1992. Benetton - Global logistics in action. *International Journal of Physical Distribution & Logistics Management*, 22 (6), 7-11.
- Ewers, C.L.J. & Mohr, J., 2010. *Exzellente Pharma Supply Chain*: Editio Cantor Verlag Aulendorf.
- Garcia-Dastugue, S.J. & Lambert, D.M., 2007. Interorganizational Time-based Postponement in a Supply Chain. *Journal of Business Logistics*, 28 (1), 57-81.
- Greenwood, D.J. & Levin, M., 1998. *Introduction to action research: Social research for social change*: Sage Publications, Inc.
- Ims-Health, 2011. The Global Use of Medicines: Outlook Through 2015. Available from: [http://www.imshealth.com/deployedfiles/ims/Global/Content/Insights/IMS%20Institute%20of%20Healthcare%20Informatics/Global\\_Use\\_of\\_Medicines\\_Report.pdf](http://www.imshealth.com/deployedfiles/ims/Global/Content/Insights/IMS%20Institute%20of%20Healthcare%20Informatics/Global_Use_of_Medicines_Report.pdf).
- Lee, H.L., Billington, C. & Carter, B., 1993. Hewlett-Packard gains control of inventory and service through design for localization. *Interfaces*, 1-11.
- Lee, H.L. & Tang, C.S., 1997. Modelling the costs and benefits of delayed product differentiation. *Management science*, 40-53.
- Pagh, J.D. & Cooper, M.C., 1998. Supply chain postponement and speculation strategies: How to choose the right strategy. *Journal of Business Logistics*, 19 (2), 13-33.
- Pedroso, M.C. & Nakano, D., 2009. Knowledge and information flows in supply chains: A study on pharmaceutical companies. *International Journal of Production Economics*, 122 (1), 376-384.
- Plewa, S. & Steiner, S., 2011. Practice/White-Line - A Concept for the Packaging of Least Batch Sizes. *Pharmazeutische Industrie*, 73 (3), 587-590 Available from: <Go to ISI>://000289502800005.

- Savage, C.J., Roberts, K.J. & Wang, X.Z., 2006. A holistic analysis of pharmaceutical manufacturing and distribution: Are conventional supply chain techniques appropriate? *2006*, 26 (4).
- Shah, N., 2004. Pharmaceutical supply chains: key issues and strategies for optimisation. *Computers & chemical engineering*, 28 (6-7), 929-941.
- Su, J.C.P., Chang, Y.L. & Ferguson, M., 2005. Evaluation of postponement structures to accommodate mass customization. *Journal of Operations Management*, 23 (3-4), 305-318.
- Swaminathan, J.M. & Lee, H.L., 2003. Design for postponement. *In: Graves, S.C. & Kok, A.G.D. eds. Handbooks in Operations Research and Management Science*. Elsevier, 199-226.
- Van Hoek, R.I., 1998. Reconfiguring the supply chain to implement postponed manufacturing. *International Journal of Logistics Management*, 9 (1), 95 - 110.
- Van Hoek, R.I., 2001. The rediscovery of postponement a literature review and directions for research. *Journal of Operations Management*, 19 (2), 161-184 Available from: <http://www.sciencedirect.com/science/article/pii/S0272696300000577>.
- Verhasselt, S., Festel, G. & Schönsleben, P., 2012. Supply Chain Structures and Processes in the Pharmaceutical Industry: Current models and trends in a changing environment. *Pharmazeutische Industrie*, Article in Press.
- Yin, R.K., 2009. *Case study research: Design and methods*, 5th ed.: Sage publications.
- Zinn, W. & Bowersox, D.J., 1988. Planning physical distribution with the principle of postponement. *PLANNING*, 9 (2), 111.