CONSIDERATIONS ON A CONTEMPORARY FLEXIBILITY APPROACH

Herwig Winkler* and Gottfried Seebacher*

* Production Management and Business Logistics, University of Klagenfurt,
Klagenfurt, Carinthia, 9020, Austria,
Email: herwig.winkler@aau.at

Abstract Because of rapidly changing customer requirements, current company-focused measures to enhance flexibility at the supply chain level are not sufficient. Therefore, flexible supply chain performance is essential for firms aiming to fulfill service level agreements despite increasing complexity, shorter delivery times, and dynamic market demands. Therefore, we suggest implementing flexibility-enhancing measures within and between supply chain entities that address the particular supply chain type and its flexibility requirements. Towards this end, flexibility management must be considered as a holistic management approach. This paper presents conceptual framework that helps to identify company-internal flexibility drivers to support flexible supply chain performance.

Paper type: Theoretical paper

Published online: 10 April 2012
Vol. 2, No. 2, pp. 147-161

ISSN 2083-4942 (Print)
ISSN 2083-4950 (Online)

Keywords: *Flexibility approach, management model, performance enhancement*

1. INTRODUCTION

The reduction in the vertical range of manufacturers, the increase in the complexity of product structures, and the increasing need for customized products are creating greater complexity within supplier-buyer relationships. These trends are also exacerbated by rapidly changing customer requirements, turbulent environmental conditions, and growing uncertainties within business management. To deal with these increasingly challenging issues, it is essential to improve firm and supply chain performance in terms of flexibility. Therefore, flexibility-enhancing measures must be implemented within and between all of the supply chain entities to achieve greater flexibility at the supply chain level. Thus, we understand flexibility management as an integrated and comprehensive concept within the managerial context of supply chain management. In this sense, successful supply chain management is, to a large extent, also based on highly flexible performance capabilities.

The characteristics as well as the flexibility degree of the performance capabilities are determined by the need for flexibility which is derived from the supply chain type, which depends on whether the supply chain is mainly forecast or customer driven. It is therefore essential to specify the particular need for flexibility as well as the required flexibility degree of both the companies and the entire supply chain in question (Pujawan, 2004, p. 80).

Furthermore, to achieve highly flexible performance, it is necessary to identify the crucial flexibility drivers within the supply chain and the associated companies. Assuming that the design of the flexibility drivers results from the particular supply chain type, i.e. make-to-order, make-to-stock and engineer-to-order, flexibility-enhancing measures, such as shortening the time of technical scalability or increasing the equipment versa-tility, must be planned, executed, and evaluated in a target-oriented and compre-hensive way. Therefore, we present a conceptual management framework that helps to identify the crucial flexibility drivers and to plan, execute, and monitor the development and exploitation of the flexibility potential. This procedure will facilitate greater supply chain performance and lower the costs of the performance adjustment because the firms will be able to produce a wider range of products at low changeover costs and improve the volume adjustment to address the volatile demand (Salvador, Rungtusanatham, Forza & Trentin, 2007, p. 1181), (Das & Ab-del-Malek, 2003, p. 1181). Moreover, this paper presents flexibility-enhancing variables and constraints as well as flexibility-enhancing measures and possible key performance indicators of greater flexibility.

2. CHANGING FLEXIBILITY REQUIREMENTS

2.1. Shift in flexibility management

The scientific literature reflects a broad understanding of flexibility and includes numerous different definitions of flexibility (Gerwin, 1987, p. 39), (Upton, 1994, p. 73), (Vokurka & O'Leary-Kelly, 2000, p. 486), (Garavelli, 2003, p. 141). These definitions also differ in their representation of flexibility as a reactive or proactive approach (Gerwin, 1993, p. 396). Therefore, to grasp the significance of flexibility and its major effects, it is important to reduce flexibility to a limited set of determinants. Generally, the flexibility of a system represents its ability to cope with changes and uncertainties by configuring system elements in a target-oriented way to maintain stable performance under changing conditions (Winkler, 2009, p. 16), (Barad & Sapir, 2003, p. 155). In accordance with the level of system complexity, the enhancement of flexibility will require the multidimensional adjustment of system elements (Kumar, Shankar & Surendra, 2008, p. 285). Therefore, in manufacturing supply chains, different types, dimensions, and parameters of flexibility have been defined and identified (Duclos, Vokurka & Lummus, 2003, p. 448), (Vickery, Calantone & Droge, 1999, p. 17). Overall, however, flexibility is characterized by two major factors. First, greater flexibility means having a greater number of available options to cope with challenging situations. Second, greater flexibility makes it easier to handle changing conditions in terms of time and cost (Ba-rad & Sapir, 2003, p. 155). In considering the different views of flexibility as reactive or proactive approaches, it is important to note that flexibility represents the ability to respond to internal and external changes. In that respect, flexibility must be proactively developed to meet changing requirements. Thus, being flexible may require proactive behaviour to achieve a certain degree of flexibility but also entails reactive responses to uncertainties and changing conditions (Gerwin, 1993, p. 396).

Currently, the lower vertical range of manufacturing is increasing the level of the division of labour and creating the need for a higher degree of coordination and greater complexity within the supply chain (Winkler, 2009, p. 16). As a result, it is now insufficient for a single entity within the supply chain to be flexible. In addition, it is absolutely essential to design and implement flexible processes within and between all of the supply chain entities (Lummus, Vokurka & Duclos, 2005, p. 2), (Hallgreen & Olhager, 2009, p. 747), (Stevenson & Spring, 2007, p. 689). To address the greater need for flexibility that is driven by greater coordination efforts, flexible material and information flows must be well established and coordinated within the supply chain network (Duclos, Vokurka & Lummus, 2003, p. 451). As a result, the improved coordination of flexible material and information flows within the supply chain makes it easier to adjust the production volume and allows for greater product variety while keeping inventory low and lead times short. Essentially, for the supply chain to become more flexible in terms of volume and variety, all of the operational aspects of the supply chain and all of the strategies to enhance flexibility must be taken into consideration. Consequently, flexible performance within the entire supply chain requires the target-oriented implementation of flexibility-enhancing measures within the supply chain management. Moreover, flexibility-enhancing measures should be the focus of an integrated management approach that supports the planning and monitoring of the flexible supply chain's performance.

2.2. Current requirements of flexibility

Many companies and whole supply chains are facing new challenges that require more flexible performance internally and as a part of cross-company processes, because they are shaped by customer-driven markets, shorter innovation cycles and increasingly rapid technological leaps. (Duclos, Vokurka & Lummus, 2003, p. 447), (Lummus, Duclos & Vokurka, 2003, p. 1). Generally, each industry has different requirements with regard to flexibility that are based on the products and the processes of the supply chain (Wadhwa, Saxena & Chan, 2008, p. 1374). In the case of customer-oriented supply chains that are fuelled by customer orders, it is important to ensure the rapid adjustment of production output and the rapid changes in variety. Although supply chains that provide less variety must be flexible in terms of volume because of fluctuations in demand levels, the provision of highly-customized products requires greater mix flexibility if customer demand is to be met (Pujawan, 2004, p. 86), (Lummus, Duclos & Vokurka, 2003, p. 5). A supply chain must also be able to vary its production volume to handle changes in order quantity in a cost-effective manner; changing the production volume should not lead to additional fixed costs (Salvador, Rungtusanatham, Forza & Trentin, 2007, p. 1182), (Jack & Raturi, 2002, p. 535). Otherwise, lower output levels will lead to division of the fixed costs over a lower number of products and will result in higher unit costs. Consequently, when making flexible adjustments in production output, it is essential to achieve greater flexibility in terms of resources and processes (Salvador, Rungtusanatham, Forza & Trentin, 2007, p. 1181), (Stevenson & Spring, 2007, p. 693), (Persentili & Alptekin, 2000, p. 2012). Furthermore, offering a wide variety of products in response to the increasing need for customized offerings makes many companies unable to profit from the economies of scale because of the lower product quantities and production processes that are more differentiated. Although flexibility depends on the products and goods that are provided by the supply chain, changing conditions and volatile market demands do not necessarily require a different level of flexibility in response to the uncertainty of the changing requirements (Pujawan, 2004, p. 86). In fact, stable supply chain performance under changing conditions depends on the ability of the supply chain to handle fluctuations in demand by being volume-flexible while inventory levels remain low. A high level of product flexibility is required to provide customized products to the market without penalties to the company in terms of costs or time (Das & Abdel-Malek, 2003, p. 177). Volume and mix flexibility are based on the flexible deployment of the resources and the design, execution, and coordination of the processes within the supply chain and its companies. Volume and mix flexibility allow a firm to better fulfil their service level agreements and enable supply chains to meet requirements that go beyond the service level.

3. HIERARCHICAL MODEL OF FLEXIBILITY MANAGEMENT

3.1. Basic structure and contents

In the following section, we present conceptual suggestions on the management of flexibility. To improve supply chain performance via greater flexibility within and across all of the actors in the supply chain, we understand flexibility management as a holistic management approach that is executed using our hierarchical model of flexibility management (Fig. 1). This management model helps to identify and to exploit a supply chain's flexibility potential to improve and accelerate cross-company processes. Thus, this model considers the supplier-buyer relationships within a supply chain and the role of each entity within the entire supply chain network. On this basis, flexibility-enhancing measures must be applied within each firm and on the level of the overall supply chain. Therefore, the following model supports improvements in flexibility on the supply chain, company, and shop floor level. According to this, the current model can be used to identify the relevant flexibility drivers and constraints within the company and to derive suitable measures to enhance the company's flexibility as well as to provide greater flexibility to the supply chain. Furthermore, it is useful to consider a target-oriented planning, monitoring and execution of measures that contribute to greater flexibility.

3.2. Supply chain level

Environmental changes may influence the need for flexibility of the supply chain to a certain degree, but the required flexibility mainly depends on whether the supply chain is driven by a make-to-stock, make-to-order or engineer-to-order environment. While the need of flexibility in a make-to-stock environment focuses on the demand driven adjustment of production volume, make-to-order supply chains have to provide flexible processes as well. However, the greatest need for flexibility arises among engineer-to-order supply chains, because an engineer-to-order environment calls for a flexible handling of production volume as well as a high flexibility in terms of products and production processes. From the supply chain perspective, supplier-buyer relationships are based on the service level agreements that determine the specific quantity of the goods, their level of quality, and their delivery time. Based on the assumption that proper supply chain performance is intended to help firms meet existing service level agreements, flexible performance is only mandatory for orders with parameters that exceed those stipulated in a service level agreement in terms of quantity, quality, delivery time, and/or product variety. As a result, efforts to improve flexibility should be focused on these types of situations. The supply chain level of the model, therefore, represents all of the existing companies in the supply chain and the interfaces between them, as described in the supplier-buyer service level agreements. A need for flexible performance arises either because of changing customer requirements or because of different supplier conditions. As a result, the overall flexibility of the supply chain depends on the ability of all of the actors in the supply chain to rapidly address the changing requirements that surpass the service level agreements while remaining cost-effective. Therefore, the entire supply chain must be able to handle fluctuations in the production volume and/or in the demand in terms of product variety according to the particular supply chain type. Thus, flexible supply chain performance involves being volume-flexible and mix-flexible. However, for the supply chain to become more flexible in these ways, it is essential to establish flexible processes, and applying rapid changes in processes may be necessary to adapt to the changing conditions. In other words, all of the actors in the supply chain must be able to rapidly set up, stabilize, and standardize new production processes that enhance performance while lowering unit costs via continuing efforts to increase efficiency. In addition, greater product variety requires product flexibility, and product flexibility includes all of the aspects of a new product design and product introduction (Vickery, Calantone & Droge, 1999, p. 17). Furthermore, mix flexibility is driven by product development, product postponement, and the ability to implement flexible ramp-up strategies (Duclos, Vokurka & Lummus, 2003, p. 452). Consequently, product flexibility represents the ability to adapt the supply chain product mix to changes in the customer demand at a low cost and within a short period of time, using the existing manufacturing system (Gupta & Somers, 1992, p. 168). In this sense, greater product flexibility is based on the ability to use the same resources for different tasks to achieve greater variety. There is a consequent need to enhance resource flexibility to attain greater product flexibility (Salvador, Rungtusanatham, Forza & Trentin, 2007, p. 1182). Overall, if supply chain entities are to become more flexible, it is essential that they provide volume, product, and process flexibility. If they succeed in this goal, the supplier companies will exhibit source flexibility and will also deliver that flexibility to the customers. The end result will be flexible supply chain-wide performance in terms of volume, quality, delivery times, and/or product variety. Of course, every company in the supply chain must exhibit flexibility along its entire company-internal value chain. This requires a comprehensive management of the flexibility-enhancing measures based on target-oriented support for flexibility drivers. Possible key performance indicators for the provision of greater flexibility are the delivery performance and the logistics capability of the company.

3.3. Company level

Comprehensive flexibility-oriented management requires continuous planning and monitoring and must include all of the functional aspects of a company's value chain. Flexible manufacturing is only one contributing element of a more flexible performance. It is also necessary to design, plan and execute pre- and post-production processes that enhance flexibility. In terms of product flexibility, increasing the modularization of the product design enables a higher degree of standardization and leads to easier process engineering and optimized product assembly. Product flexibility is primarily driven by the speed of product development, the level of product standardization and the product mix capability. Thus, possible key performance indicators can be the development speed, the degree of modularization or the vertical range of manufacture. Hence, it is necessary to speed up product development to achieve shorter time-to-market. Furthermore, it is essential to postpone product differentiation to reduce the costs that are associated with cultivating a higher degree of standardization in tandem with greater variety. Additionally, product development should focus on increasing the uniformity of the product components to create greater product flexibility (Lummus, Duclos & Vokurka, 2003, p. 7), (Holweg & Pil, 2001, p. 76). Greater uniformity of product components leads to a reduced number of components, lower inventory levels, and reduces complexity of product structure. Moreover, such efforts make it possible to produce a given number of product variants with fewer resources. Furthermore, decreases in set-up time and in the number of change-overs facilitate increases in output and allow for an enhanced level of volume flexibility. Given that the segmentation of production reduces operational complexity, operating partially autonomous production units will increase the level of flexibility. However, to enhance product flexibility, adequate process and product engineering is also required, as it facilitates the production of product variants on changing assembly lines. Moreover, designing products and processes for manufacturing and assembly leads to shorter assembly times and to greater volume flexibility (Salvador, Rungtusanatham, Forza & Trentin, 2007, p. 1182). Essentially, products and processes must be designed using standardized components and processes to increase product, process, and volume flexibility. Consequently, all of the company's efforts should aim to create a flexible system that allows for the flexible ramp-up of serial production and capacity adjustment, according to changing requirements.

Flexible supply chain performance is also driven by flexible sourcing and shipment. Sourcing flexibility includes three different factors: the number of available suppliers, the ease with which the supply chain can be reconfigured on the supply side, and the supplier's degree of flexibility in terms of product variety, product volume, and processes. First, the number of suppliers has a direct impact on the buyer's flexibility because it affects the buyer's ability to reconfigure the sourcing structures to increase flexibility (Tachizawa & Thomsen, 2007, p. 1126). An adequate sourcing strategy facilitates greater sourcing flexibility because increases in flexibility are not associated with higher coordination expenditure. Moreover, sourcing flexibility is defined by how easy it is to reconfigure the supply chain given limited time and a limited budget (Stevenson & Spring, 2007, p. 691), (Gosling, Purvis & Naim, 2010, p. 12). Thus, possible key performance indicators for sourcing flexibility are, among others, the reconfiguration speed of the supplier network or the sourcing complexity. Additionally, to achieve and maintain product flexibility, it is essential that the necessary materials are appropriately available (Duclos, Vokurka & Lummus, 2003, p. 452). Therefore, all of the supply chain entities that deliver materials and/or products for further processing must be mix-flexible for the supply chain to attain overall flexibility. Furthermore, supplier companies must develop adjustable processes and support process standardization to ensure volume-flexible supply chain performance (Salvador, Rungtusanatham, Forza & Trentin, 2007, p. 1183). Thus, close collaboration is required within the supply chain network. However, close cooperation is based on long-term agreements that have a negative impact on flexibility because reconfiguring the supply chain is much more difficult when these specifications are binding.

Clearly, a flexible manufacturing system is a key component of greater overall flexibility. Build flexibility is the ability of a production system to rapidly address fluctuations in the production volume and to ensure product variety while remaining cost-effective (Das, 2001, p. 4155). Flexible manufacturing depends on various factors that affect the adjustable handling of the production volume and product variety. Hence, enhancing the flexibility of manufacturing in terms of quality and quantity requires appropriate operational processes and flexible equipment. To cope with greater variety, the production processes have to be designed to cover a wide range of variations. Therefore, process design has to target on the avoidance of process set-ups resulting from the various requirements of different product variants. This leads to greater product and volume flexibility (Salvador, Rungtusanatham, Forza & Trentin, 2007, pp. 1181). Furthermore, the segmentation of the production processes that cover a wide range of product variants leads to more flexible routing due to the higher number of paths that can be followed to finish a product. Another major aspect of process design is the degree of automation. Although a high degree of automation results in cost and time savings due to economies of scale, automated manufacturing technologies generally lead to less flexible operational processing. Therefore, to become more flexible, the equipment must be able to produce various products at different volume levels. This requires flexibility-enhancing operations in terms of sequencing and dispatching decisions. Moreover, advanced manufacturing technologies are required to improve flexibility. Among other things, these technologies lead to shorter set-up times, improved workflows, and greater capacity utilization (Das, 2001, pp. 4155), (Chan, Bhagwat & Wadhwa, 2008, p. 22).

Moreover, improved flexibility of the supply chain involves flexible outbound logistics processes, including logistics and value-adding processes, such as shipment, packing, storage and order picking along the entire logistics chain. Logistics flexibility is the ability of a company to design and execute flexible logistics and value-adding processes to deliver products rapidly and at a low cost, even under changing conditions (Duclos, Vokurka & Lummus, 2003, p. 452), (Lummus, Duclos & Vokurka, 2003, p. 11), (Kumar, Fantazy, Kumar & Boyle, 2006, p. 312). However, because an increasing number of logistics providers conduct a growing share of the logistics activities within a supply chain, it is much more difficult to achieve flexible performance because of the increasing complexity. Additionally, changing customer requirements, such as load and delivery times and/or means of transport, lead to higher carrier costs, changes in shipping volume and frequency, and/or the need to consider changing to other carriers. Consequently, to achieve flexibility, it is necessary to provide the products and/or goods in accordance with the given requirements. Therefore, if logistics providers are entrusted with the execution of the logistical processes and if the firms aim to increase flexibility, the firms must consider the context at hand and select the best-performing logistics provider. A capable logistics provider must be able to handle several products and fluctuating shipping volumes. Furthermore, a flexible logistics provider must be able to meet changing delivery times and to provide flexible value-adding services. Therefore, flexible supply chains must develop a logistics network that is fully adjustable to customer requirements using internal or external resources. Additionally, being flexible in terms of shipment and delivery requires the implementation of appropriate information systems and thorough operational expertise; otherwise, it will be impossible to develop the required logistics network rapidly and in a cost-effective manner.

Flexibility on a supply chain level is driven by the range of service levels that each company is able to provide. Flexibility requires a highly adjustable degree of performance according to product quality, delivery time and volume as well as reliability of the delivery method. Consequently, the ability to cover a wider range of service levels is synonymous with greater service flexibility. To achieve greater service flexibility in terms of time and quantity, it is necessary to either achieve on-time delivery that is based on shorter lead times or to keep products in stock to fulfill the service level agreements. Although higher inventory levels contribute to greater service flexibility, inventory levels also lead to limited product flexibility. As a result, flexible performance is better based on short lead times, which allow for the on-time delivery of customized products. In other words, flexibility-enhancing measures must keep inventory levels low. In addition, it is essential to consider the positioning of the inventory within the supply chain. Most supply chains are aiming to become more flexible to avoid costs and risks by moving inventory to the supply side of the chain. This relocation of the inventory lowers the amount of the invested capital because there is little progress in the value of the product. However, assuming that changing product generations require different input materials, moving inventory to the supply side has negative implications for sourcing flexibility. Accordingly, the planning and monitoring of the flexibility of the supply chain must take place throughout the supply chain to ensure flexibility. Not only are higher inventory levels associated with higher costs, but developing and configuring capable systems that ensure short delivery times and facilitate adjustments to product variety and volume can also be costly. Thus, to achieve greater service flexibility, it is necessary to design and operate the supply chain in such a way that the assets and operations can be successfully configured to meet customer requirements quickly and at a low cost. Furthermore, a comprehensive strategy for postponing product differentiation is required if firms are to provide highly customized products while also cutting costs due to product standardization (Kumar, Shankar & Surendra, 2008, p. 290). Postponing the order-penetration point via modular product design makes it possible to provide greater product variety quickly. Additionally, to enhance flexibility, it is necessary to be close to the customer and thereby to rapidly initiate the reconfiguration and deployment of the resources and processes. This ensures greater service flexibility in terms of product variety and quality, delivery times, and costs (Duclos, Vokurka & Lummus, 2003, p. 452).

To achieve flexible supply chain performance it is necessary to analyse the current flexibility potential of each supply chain member to identify the company-specific flexibility drivers and constraints. Subsequently, the emphasis should be placed on cultivating greater flexibility within the flexibility components at the company level. Therefore, flexibility-enhancing measures must be coordinated with the suppliers and customers to ensure that flexibility-improving efforts do not negatively influence one another. Such efforts require constant monitoring and comprehensive measurement. The results help firms to assess flexibility levels and to adjust their flexibility planning as necessary.

3.4. Shop floor level

At the shop floor level, flexible performance can be reduced to two main drivers: resources and processes. While resource flexibility represents the adjustable deployment of the available resources, flexible processes involve a wide range of process flows, steps, and timelines and allow for product variety without major set-up or changeover (Slack, 1987, p. 37). Thus, flexible job shop performance is driven by a firm's ability to apply the available resources to various processes in a cost-effective manner. Furthermore, it is essential to rapidly deploy the resources that are needed to achieve greater flexibility (Sánchez & Pérez, 2005, p. 684). The execution of highly flexible processes is also critical. Process flexibility is determined by the number of available starting materials, the process flow, and the adaptability of the process parameters, such as the process time and the number of steps (Sethi & Sethi, 1990, p. 302). If a production process is highly automated, the process flexibility is based on the equipment used. Therefore, greater resource flexibility also leads to greater process flexibility. Resource and process flexibility must be cultivated to increase product and volume flexibility. A possible key performance indicator for process flexibility can be the technical flexibility, which is primarily driven by the equipment versatility. Another indicator for the process flexibility may be the personnel flexibility which is mainly driven by the availability and the capability of the production staff. Whereas the flexible deployment of the resources and the process design are the main drivers of flexibility, the most influential constraints on flexibility are capacity, automation, scalability, routing, standardization, and instability. Whether the capacity of the manufacturing system is adjustable is primarily based on the equipment used and its ability to handle a wide range of operations and variations (Cheng, Simmons & Ritchie, 1997, p. 148). Consequently, optimal flexibility is achieved when the capacity utilization is independent of the product variation and its processing sequence. Therefore, modular product design and process standardization have a significant positive impact on volume flexibility.

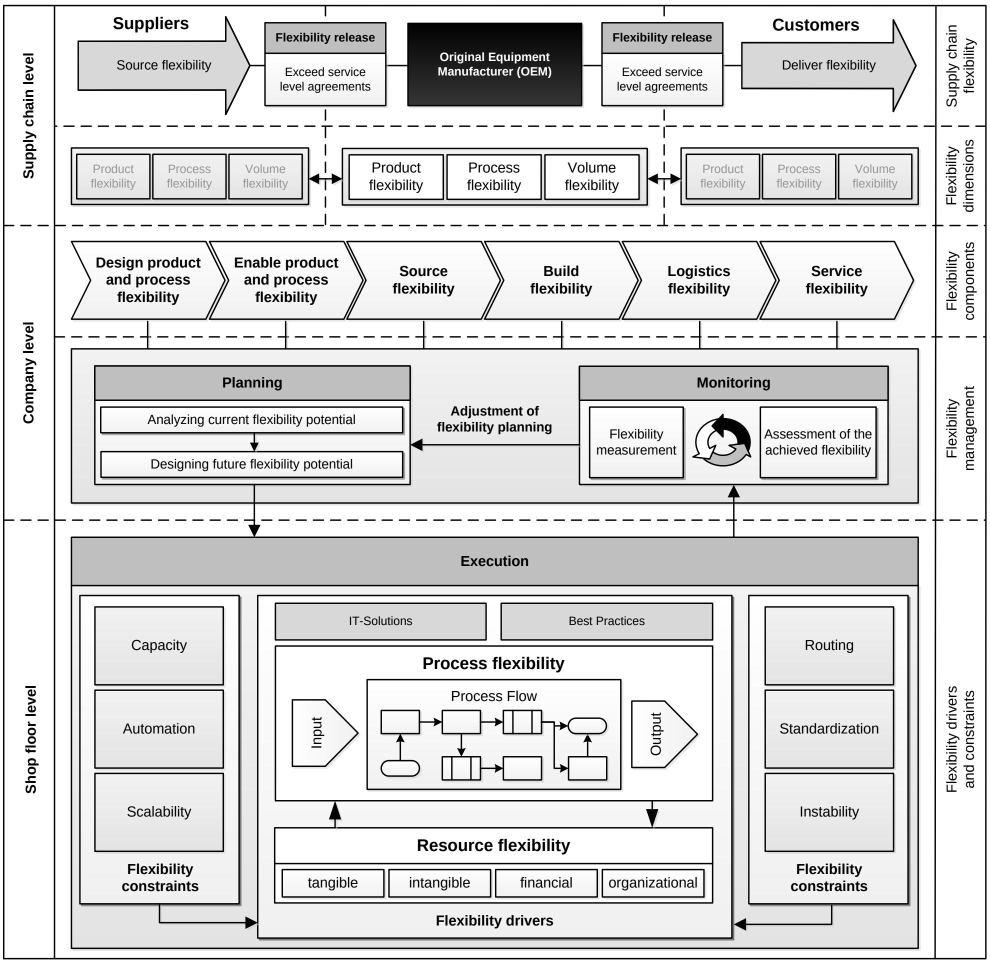

Fig. 1 Hierarchical model of flexibility management

Generally, increasing the standardization of the products and processes leads to a higher degree of automation, which is used to achieve a higher production volume. However, this leads to limited flexibility in terms of product differentiation. Thus, it is particularly important to adjust the product design in accordance with the process standardization and routing flexibility levels (Salvador, Rungtusanatham, Forza & Trentin, 2007, p. 1181). Additionally, the process design must allow for a wide range of adjustments that offer a high degree of scalability, as this improves volume flexibility. Moreover, to achieve greater product flexibility, the set-up times of the processes must be reduced to facilitate rapid changes between the product variants. The process improvements must lead to simplified processes that are as standardized as possible. It is therefore necessary to unify the processing methods and tools as much as possible (Oke, 2005, p. 975). Basically, process versatility can be improved by process standardization and a decrease of different production processes. This leads to an increase of the operational capability of the embedded production processes. Continuous improvement leads to greater process stability, and this process helps to increase volume flexibility because the breakdown periods are shorter. In other words, the standardized processes also lead to greater volume flexibility because they improve routing, making bottlenecks and unplanned or scheduled machine downtime less of a problem in terms of production volume (Kara & Kayis, 2004, p. 470). Enhanced process and resource flexibility is also based on the implementation of intelligent IT solutions and the continuous exchange and application of the best practices along the entire supply chain. Furthermore, enhanced labour flexibility is required for the shop floor. Overall, flexibility-oriented employee education and training is essential for the employees to acquire the skills that are necessary for them to become more flexible (Gerwin, 1989, p. 80).

4. CONCLUSION

Due to changing customer requirements and fluctuations in demand, there is an increasing need for supply chains to handle product variety and different levels of production volume without incurring significant costs. With this in mind, three major aspects of changing customer requirements should be considered: greater product variety, higher or lower production volume, and the processes that must be conducted to address the changing conditions. All supply chain entities must cultivate product, volume, and process flexibility to meet the related flexibility requirements. Thus, a comprehensive management approach within the framework of supply chain management is necessary to ensure improvements to the flexibility of the supply chain. Companies must create a well-coordinated supply chain and use target-oriented flexibility management procedures that complement one another. The flexibility-enhancing measures must be implemented based on job shop activities that are related to process design and resource deployment. This implementation will increase flexibility at the shop floor level and contribute to flexible performance on the company level. Hence, in the case of changing customer requirements in terms of product quality, order quantity, and/or delivery time, a flexible supply chain performance will be much easier to achieve.

REFERENCES

Barad M. & Sapir D. E., (2003), "Flexibility in logistic systems – modeling and performance evaluation", [in:] International Journal of Production Economics, Vol. 85, No. 2, pp. 155-170.

Chan, F., Bhagwat R. & Wadhwa S., (2008), "Comparative performance analysis of a flexible manufacturing system (FMS): a review-period-based control", [in:] International Journal of Production Research, Vol. 46, No. 1, pp. 1-24.

Cheng J., Simmons J. & Richie A., (1997), "Manufacturing system flexibility: the 'capability and capacity' approach", [in:] Integrated Manufacturing Systems, Vol. 8, No. 3, pp. 147-158.

Das A., (2001), "Towards theory building in manufacturing flexibility", [in:] International Journal of Production Research, Vol. 39, No. 18, pp. 4153-4177.

Das S. & Abdel-Malek L., (2003), "Modeling the flexibility of order quantities and lead times in supply chains", [in:] International Journal of Production Economics, Vol. 85, No. 2, pp. 171-181.

Duclos L. K., Vokurka R. J. & Lummus R. R., (2003), "A conceptual model of supply chain flexibility", [in:] Industrial Management and Data Systems, Vol. 103, No. 6, pp. 446-456.

Garavelli C., (2003), "Flexibility configurations for the supply chain management", [in:] International Journal of Production Economics, Vol. 85, No. 2, pp. 141-153.

Gerwin D., (1987), "An agenda for research on the flexibility of manufacturing processes", [in:] International Journal of Operations & Production Management, Vol. 29, No. 5, pp. 38-49.

Gerwin D., (1989), "Manufacturing flexibility in the CAM era – computer-aided manufacturing", [in:] Business Horizons, Vol. 32, No. 1, pp. 78-84.

Gerwin D., (1993), "Manufacturing flexibility: a strategic perspective", [in:] Management Science, Vol. 39, No. 4, pp. 395-410.

Gosling J., Purvis L. & Naim M., (2010), "Supply chain flexibility as a determinant of supplier selection", [in:] International Journal of Production Economics, Vol. 128, No. 1, pp. 11-21.

Gupta Y. P. & Somers T.-M., (1992), "The measurement of manufacturing flexibility", [in:] European Journal of Operational Research, Vol. 60, No. 2, pp. 166-182.

Hallgreen M. & Olhager J., (2009), "Flexibility configurations: Empirical analysis of volume and product mix flexibility", [in:] Omega, Vol. 37, No. 4, pp. 746-756.

Holweg M. & Pil F. K., (2001), "Successful build-to-order strategies start with the customer", [in:] Sloan Management Review, Vol. 43, No. 1, pp. 74-83.

Jack E. P. & Raturi A., (2002), "Sources of volume flexibility and their impact on performance", [in:] Journal of Operations Management, Vol. 20, No. 5, pp. 519-548.

Kara S. & Kayis B., (2004), "Manufacturing flexibility and variability: an overview", [in:] Journal of Manufacturing Technology Management, Vol. 15, No. 6, pp. 466-478.

Kumar P., Shankar R. & Surendra S. Y., (2008), "Flexibility in global supply chain: modeling the enablers", [in:] Journal of Modelling in Management, Vol. 3, No. 3, pp. 277-297.

Kumar V., Fantazy K. A., Kumar U. & Boyle T. A., (2006), "Implementation and management framework for supply chain flexibility", [in:] Journal of Enterprise Information Management, Vol. 19, No. 3, pp. 303-319.

Lummus R. R., Duclos L. K. & Vokurka R. J., (2003), "Supply chain flexibility: building a new model", [in:] Global Journal of Flexible Systems Management, Vol. 4, No. 4, pp. 1-13.

Lummus R. R., Vokurka R. J. & Duclos L. K., (2005), "Delphi study on supply chain flexibility", [in:] International Journal of Production Research, Vol. 43, No. 13, pp. 2687-2708.

Oke A., (2005), "A framework for analyzing manufacturing flexibility", [in:] International Journal of Operations and Production Management, Vol. 25, No. 10, pp. 973-996.

Persentili E. & Alptekin S. E., (2000), "Product flexibility in selecting manufacturing planning and control strategy", [in:] International Journal of Production Research, Vol. 38, No. 9, pp. 2011-2021.

Pujawan I. N., (2004), "Assessing supply chain flexibility: a conceptual framework and case study", [in:] International Journal of Integrated Supply Chain Management, Vol. 1, No. 1, pp. 79-97.

Salvador F., Rungtusanatham M., Forza C. & Trentin, A., (2007), "Mix flexibility and volume flexibility in a build-to-order environment", [in:] International Journal of Operations & Production Management, Vol. 27, No. 11, pp. 1173-1193.

Sánchez A. & Pérez M., (2005), "Supply chain flexibility and firm performance: A conceptual model and empirical study in the automotive industry", [in:] International Journal of Operations and Production Management, Vol. 25, No. 7, pp. 681-700.

Sethi A. K. & Sethi S. P., (1990), "Flexibility in manufacturing: a survey", [in:] Journal of Flexible Manufacturing, Vol. 2, No. 4, pp. 289-328.

Slack N., (1987), "The flexibility of manufacturing systems", [in:] International Journal of Operations and Production Management, Vol. 7, No. 4, pp. 35-45.

Stevenson M. & Spring M., (2007), "Flexibility from a supply chain perspective: definition and review", [in:] International Journal of Operations and Production Management, Vol. 27, No. 7, pp. 685-713.

Tachizawa E. M. & Thomsen C. G., (2007), "Drivers and sources of supply flexibility: an exploratory study", [in:] International Journal of Operations and Production Management, Vol. 27, No. 10, pp. 1115-1136.

Upton D. M., (1994), "The management of manufacturing flexibility", [in:] California Management Review, Vol. 36., No. 2, pp. 72-89.

Vickery S., Calantone R. & Droge C., (1999), "Supply chain flexibility: an empirical study", [in:] The Journal of Supply Chain Management, Vol. 35, No. 3, pp. 16-24.

Vokurka R. J. & O’Leary-Kelly S. W., (2000), "A review of empirical research on manufacturing flexibility", [in:] Journal of Operations Management, Vol. 35, No. 3, pp. 16-24.

Wadhwa S., Saxena D. & Chan F. T. S., (2008), "Framework for flexibility in dynamic supply chain management", [in:] International Journal of Production Research, Vol. 46, No. 6, pp. 1373-1404.

Winkler H., (2009), "How to improve supply chain flexibility using strategic supply chain networks", [in:] Logistics Research, Vol. 1, No. 1, pp. 15-25.

BIOGRAPHICAL NOTES

Herwig Winkler is an Associate Professor and Head of the Department of Production Management and Business Logistics at the Alpen-Adria University of Klagenfurt. He is the author and co-author of various articles addressing current topics in many areas of industrial management like flexibility, production planning and optimization, mass customization, supply chain management, green logistcs.

Gottfried Seebacher is a Research Assistant at the Department of Production Management and Business Logistics at the Alpen-Adria University of Klagenfurt. He is currently working on his PhD thesis dealing with the flexibility of industrial supply chains. His research interests are manufacturing and supply chain flexibility, value stream analysis and design as well as the flexible design of international supply chains.