DECOUPLING POINT IN SUPPLY NETWORK OF STEEL PRODUCTS - DYNAMICS OF CHANGES

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Summary
For the last dozen years Polish metallurgic products supply networks have undergone strong changes in their logistic systems. The article analyses the formation of metallurgic products supplies as regards suppliers and recipients. The author indicated a shift of the material distribution point for the determined assortment groups. Simultaneously, the author underlined the role of service centres and steel yards in the reorganization of a distribution network. It was also indicated that distribution networking is an opportunity to increase adaptivity of both individual distribution enterprises and all supply chains. The study presented in the article was carried out as part of the author's own research project entitled: An IT system to assist the management of material flows in a network as exemplified by metallurgic products.

Keywords: decoupling point, supply network, metallurgic products

1. INTRODUCTION

The notion of a supply network in the logistic literature is referred to the terminology concerning supply chains. Numerous authors specializing in research into supply chains [including especially: Chopra S., Meindl P. 2007, Mangan J., Lalwani Ch., Butcher T. 2008, Janssen M., Feenstra R. 2010, Christopher M. 2011 ] indicate that this notion is intuitionally referred to simple hierarchical relationships between organizations cooperating in order to add value to the product at the stage of manufacturing it and delivering it to the customer. Supply chains understood in this way provide the basis for research into shared planning, predicting or designing the product. In reality, however, relationships between enterprises are very complex and often bidirectional, which means that the same organization can be both a supplier and a recipient for an enterprise, and in connection with the large variability of micro and macro factors of the environment, they are often built horizontally. Such a look at contemporary networks of cooperating enterprises provides new research possibilities as regards logistic systems and processes.

A special role in such complex systems is taken by organizations which combine the part of the chain oriented on supply in the chain with the part oriented on demand. Such organizations are called decoupling points. The purposes of the study presented in the article was to indicate challenges faced by decoupling points in supply networks of metallurgic products and tendencies of locating them in supply networks of metallurgic products depending on the type of the product.

In connection with the above Chapter 2 analysed approaches to determining decoupling points and indicated the criterion for selecting objects fulfilling the assumptions of the decoupling point in a supply network. The production and logistic network 1 of metallurgic products was described according to attributes of complex adaptive systems, indicated on the basis of the carried out literature research. The secondary data analysis 2 enabled characterization of metallurgic products supply chains according to sectors of industrial production.

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1 The term: production and logistic network, used in this article as identical with the notion of the supply network
2 Data of the Polish Central Statistical Office in 2003-2010
assortment categories as well as for every category according to supplies formed at suppliers’ and at recipients’. The statistical analysis, carried out on the basis on those data, allowed, on one hand, selecting assortment groups in which there occurred shifting supplied from suppliers to recipients, and, on the other hand, describing the relationship between such variables as supplies (quantitatively and qualitatively), the stock turnover, the consumption of products in sections and industrial production sectors. The statistical analysis carried out on the basis of these data allowed, on one hand, selecting assortment groups in which there were the biggest fluctuations of the stock turnover indicator at suppliers’ and at recipients’, and on the other hand describing the relationship between such variables as supplies, the stock turnover, the consumption of products in sections and departments of industrial production. On this basis the authors indicated the manner of changes in the structure of tasks completed by decoupling points in this business line.

2. SUPPLY NETWORK OF METALLURGIC PRODUCTS

Enterprises cooperating in supply chains must react efficiently to variable conditions of the external environment as well as adapt skillfully to changes inside the structure of the chain. Turbulent and stormy environment is the main factor to influence reconfiguration and changes in the structures of supply chains, including increasing the width of individual steps of the chain³. Increasing the number of formed relationships on the supply stage, production or distribution is especially characteristic in periods of the growth of demand on products flowing in a supply string. Relationships between enterprises, created in this way, are defined in the literature as network supply chains [Cooper M., Lambert D., Pagh J. 1997, Lambert D. 2004] or supply networks [Vurro C., Russo And., Perrini F. 2010, Christopher M 2004]. The level of formation of complex networks (supply, production, distribution) depends on the product type (degree of its complexity, multivariantness, the differentiation level) and the characteristics of the recipients’ market (the differentiation of segments, the acceptable lead time, other service standards).

Changes in Polish metallurgy observed for the last 15 years indicate the adequacy of choosing this business line in order to investigate the problems of distribution points in the supply networks. The Polish metallurgy gradually changes its own production offer towards deep-converted products. The specialization of metallurgic enterprises becomes a market necessity. Such tendencies concern both the production side of the supply chain and the distributional part. Offering value added services by distribution enterprises so as to differentiate their metallurgic products according to the specification of placed orders, is an answer to changes both in the environment of the supply chain and in its structure itself. Consequently the strongest distributors on the market combine their tasks resulting from the realization of the push strategy as well as tasks resulting from the completion of the pull strategy). These organizations are defined in the metallurgic terminology as service centres (flat products) and steel yards (long products). The completion of production and logistic tasks entails necessity to build numerous cooperation relations so as to gain substitution and complementary resources. Production and logistic systems designed in this way enable complex and punctual realization of complex orders.

Supply networks of metallurgic products consist of numerous cooperating nodes connected by different formal and informal relationships. Such a structure enables the network configuration to match current market needs. The adaptation of enterprises cooperating in a production and logistic network of metallurgic products to changes in the environment induces to characterize such structure as a complex adaptive system.

Complex systems consist of multiple parts which can adapt and transform into new forms with every step coming closer to solving a problem [Tanriverdi H., Rai A., Venkatraman N. 2010]. Finding an optimum solution of a complex problem is not real, parts of the problem enter into interactions with other elements of the system. Riddalls C.E. et al. (2000), characterizing supply networks as complex adaptive systems,

³ The width on individual steps of the supply chain refers to the terminology of distribution channels, where the channel width means the number of subjects on a given step of distribution (wholesale, retail).
indicated their feature: „every node can possess complex components allowing creating subsequent network connections with other supply chains”. Zhang L. et al. (2009) underline that every network supply chain is inherently complex because of its multi-level and multidimensional structure. Piramuthu S. (2005) proves that entre possibilities of various configurations for network supply chains result from the number of levels of the chain and the number of combinations between enterprises on each level. Sahin F. and Robinson E.P. Jr. (2002) notice, however, that the complexity is reinforced by the fact that enterprises in business networks can be included into the structure of different supply chains and play various roles in them.

The analysis of decoupling points in systems characterized in that manner is a new area of research into logistic tasks. An enterprise playing the role of the decoupling point in a supply network is responsible for synchronization of flows. Simultaneously, the need to establish network relations in order to gain specialist unique resources additionally imposes on this organization a duty to co-ordinate production and logistic tasks in the formed network. Due to the dynamic character of contemporary business networks, underlined in publications characterizing supply networks as complex adaptive systems, tasks realized by decoupling points are especially complex, hence it is essential to carry out research in this ran.

3. DETERMINING THE DECOUPLING POINT

Studies on production and logistic processes in network supply chains of metallurgic products are carried out by scientists both on the strategic level and the operating level. On the strategic level researchers analyse the configuration of metallurgical enterprises with regard to the strategy of central subjects in the network [Kramarz M. 2011] and factors determining the structure of production networks in metallurgy [Saniuk S, Saniuk A., Witkowski K 2010].

On the operating and tactical level though, attention is concentrated on scheduling tasks [Lenort R, Samolejowa A 2007] and managing material flows [Kramarz M, Kramarz W. 2011]. Lenort R and Samolejowa A (2007) indicate the importance of bottlenecks in production processes in the steel industry indicating problems of limited capacity of resources. Disturbances in completed tasks, resulting from limited capacity of resources, become more intense with large fluctuations of demand. Enterprises which are decoupling points in a supply chain are to a greater extent than other chain links, exposed to fluctuations of the utilization of production capacities, and consequently to disturbances resulting from insufficient production capacities during a sudden increase in demand.

So, the article assumes that one of the factors decisive about the structure of a supply chain, including also the level of networking of the chain, is the location of the decoupling point⁴. The decoupling point can be situated in a supply chain according to one of the four options: manufacture to stock and/or production and shipment to stock, assembly to order, production to order, design to order. The decoupling point separates two sides of the chain: the supplier-oriented (the supply side) and customer-oriented (the demand side). Its position depends on the adopted production strategy (ETO - manufacture of products designed to order, MTO - manufacture to order, ATO - assembly to order, MTS - manufacture to stock). In the ETO strategy the supply chain is not activated until there is no binding order placed by the customer. The order is completed in the pull system⁵. The push system⁶ is the most suitable when the demand is predictable (MTS method). The decision about the location of the decoupling point is connected with the leader’s competitive strategy and determines the logistic strategy of all cooperating subjects, first of all by choosing the key node gathering supplies thus enabling efficient material flows in the whole supply chain.

A logistic challenge which is faced by an enterprise playing the role of a decoupling point, is not only

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⁴ The interpretation of the decoupling point can be found in works by Bozarth C., Handfield R.B. (2007).
⁵ The pull system is a system in which processes realized by individual participants of the supply chain are activated by the customer's order.
⁶ The push system concerns those supply chains where products, beginning from the manufacturer, are transferred in batches to the subsequent steps of the distribution system, and are as it were "pushed" by the subsequent links of distribution channels.
handling a quantitatively variable demand but also delivering products in many variants, highly specialized for the customer's needs. Building into the chain of deliveries a buffer in the form of supplies for multi-variant products is very risky because it involves the risk of wrong prognoses and consequently costs of overstock or lost sales. This problem was considered in Chapter 3 indicating how tendencies for growth of product differentiation influences the formation of decoupling points for different product categories of metallurgic products.

Barriers connected with limited production and logistic capabilities, individual organizations analysed by Lenort R, Samolejova A (2007) and Kramarz M, Kramarz W (2011) consequently translate into the minimum time of the logistic and production cycle (P). The logistic and production cycle is determined by the total time essential to produce and deliver the product to the customer. Simultaneously, the demand side of the supply chain is determined by competitive parameters manifesting themselves in attributes both necessary and sufficient for taking over the customer's order. All of the factors which the customer's logistic service\(^7\) consists of, such as flexibility, the lead time of the order, the availability of products from stock, complexity, reliability, etc., ought to be considered in respect of the level making it possible to enter the market (necessary attributes) and in respect of the level which enables gaining a particular order (sufficient attributes). Sufficient attributes are the basis of competitive struggle. Hence, failure to provide their suitable level can result in the customer's leaving for a competitive enterprise. A. Harrison and R. van Hoek (2010) defines the acceptable lead time (D) as the maximum time which the customer is in a position to accept awaiting the completion of the order. The time of the production and logistics cycle and the acceptable lead time were presented on Fig. 1.

The difference between the production and logistic cycle time and the acceptable time of the order completion cycle determine the so-called production gap which indicates the level of the supply chain where materials a decoupling point should be situated. This point presented on Fig. 1 indicates the vertical line separating the time (D) from the time (P - D). In this point processes based on expectations (push) transform into processes subordinate to the reported demand (pull).

\[\text{Supply} \rightarrow \text{Production} \rightarrow \text{Distribution}\]

The length of the production and logistics cycle \(P\)  
\[P - D\]  
Acceptable Lead Time \(D\)

**Fig. 1** The decoupling point according to the time gap  

\(^7\) The logistic service of the customer is understood here as a capability of the logistic system to reacting to the customer's orders in respect of time, reliability, communication and comfort.
The presented ways of determining decoupling points persuaded the authors to attempt to indicate the main factors defining the organization playing such a role in the supply network. The key factor, indicated by many researchers into this issue, is the structure of supplies. From the perspective of the analysis of individual organizations, playing the role of the decoupling point, the condition concerning the structure of supplies is as follows: \((\text{input supplies} / \text{output supplies}) > 1\). This condition means that enterprises are supplied with large batches of the base product, which then, according to the reported demand, is transformed into the final product, adapted to specific needs of its recipients. Moreover, in a supply network, regardless of its complex character, in the group of additional factors characterizing the organization playing the role of the decoupling point, one can indicate: a large intensity of the material stream and a strong differentiation of the material stream. From the perspective of the whole supply chain, this point is characterized with a high level of supplies with relation both to its preceding links and the links which follow it. The article concentrated on the second from perspectives of the analysis as presented above.

The structure of supplies in a supply chain defines tasks completed by the decoupling point. This structure (the ratio of supplies at suppliers' to supplies at recipients') depends on the degree of differentiation of the product according to the recipients' needs. Strongly differentiated products require larger supplies at suppliers' with relation to supplies at recipients'. Standard products, in accordance with the push strategy, are located closer to the recipients. This specificity of products determines the tasks completed by the decoupling point. It indicates, on one hand, on strategic investment areas and, on the other hand, on areas where enterprises playing the role of decoupling points should build network relationships. In connection to the above, Chapter 4 examined tendencies in the structure of supplies at suppliers' and the recipients' for selected classes of metallurgical products.

Supply chains of differentiated products for the recipients' needs can be designed according to the postponed production strategy in compliance with one of the variants: early differentiation and late differentiation. Early differentiation is fulfilled in a production enterprise, however, late differentiation means shifting the last stage of the production process (decisive about the product differentiation) to selected distribution enterprises [Anand K and Girota K 2007]. In supply networks of metallurgical products, one can observe a tendency for designing structures in compliance with the second variant. Hence the results of the carried out statistical analyses and conclusions concerning the tasks completed by decoupling points are related to distribution enterprises, defined in this business line as service centres and steelyards.

4. DECOUPLING POINT IN A SUPPLY NETWORK OF METALLURGIC PRODUCTS - SUPPLIES AND CONSUMPTION OF METALLURGIC PRODUCTS IN DEPARTMENTS OF INDUSTRIAL PRODUCTION

The tendency to specialize and concentrate on products with a high added value in the Polish steel industry, indicated by experts, is a factor which influences changes in the structures of supply chains. Deep-converted products, including especially flat products, are differentiated on different stages of delivery to the customer. In connection with the above it was hypothesized that the structure of supplies in a supply chain was indeed differentiated depending on assortment groups and segments of recipients. Simultaneously it was investigated whether the structure of supplies depending on segments of recipients is significantly correlated with consumption of products in these segments.

The study took into account data concerning the stock turnover at suppliers' and the recipients' as well as the consumption and the stock level for 5 assortment groups:

- W1 hot-rolled products, including: metal sheets, tapes, wire rod, rods, rails,
- W2 cold-rolled steel sheets,
- W3 metal sheets and tinned strips,
- W4 sheet metal and galvanized steel strips,
- W5 steel tubes
The average consumption of steelwork and the stock level at recipients' was investigated at the turn of 2006 - 2009. The segmentation of recipients was proposed according to the classification of the Polish Central Statistical Office (GUS), where among industrial production departments the following are mentioned: O1 - metal manufacturing, O2 - metal product manufacturing, O3 - computer, electronic and optical product manufacturing, O4 - electric device manufacturing, O5 – machine and device manufacturing, O6 – car vehicle, trailer and semitrailer manufacturing, O7 - other transport equipment manufacturing.

At the first stage of research the authors calculated relative values of consumption of metallurgic products in individual segments of recipients and relative levels of supplies in the investigated years establishing the year 2006 as the base period (Fig. 2). The consumption of products increased intensely in the segment O3 (computer, electronic and optical device manufacturing) in 2009 and 2010, which, however, did not entail any essential increase in supplies in this period of time. In 2008 one can observe an increase in consumption of products in segment O5 (machine and device manufacturing), supplies of products in this segment in each year show an increase with relation to the base period. However, in 2008 there was a strong increase in supplies of metallurgic products in segment O4 (electric device manufacturing) and O1 (metal manufacturing). Consumption in these segments was slightly higher than in the base period. The analysis of variance for the relative values of consumption indicates the strongest increase in consumption in the trade O3. This section indicates tendencies in the Polish metallurgy towards supplying deep-converted products. The analysis of variance indicated a significant effect of differentiation of consumption in this section between products, years and for the interaction year*section of industrial production (Tab. 1).

Table 1 The analysis of variance - the consumption of products according to departments of industrial production

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The consumption of metallurgic products was indeed differentiated in following research years, but did not show essential differences in hesitations of the consumption among segments of recipients.
The interaction factor "year*section PP" provides the answer to the question whether the variability among individual years is the same in individual sections. The significant level of interaction (p<0.05) shows that the differences in consumption of metallurgic products in individual sections in years 2006, 2007, 2008 and 2009 were essential. The results of the carried out analyses indicated an essential interaction in consumption of products in individual segments in the investigated years. This interaction means that the consumption of metallurgic products did not change in the same manner in all sections in years 2006 - 2009.

Moreover, the differences in variability of consumption of metallurgic products are statistically bigger between individual classes of products than between the investigated years.

Table 2 The analysis of variance - the stock level at recipients' according to departments of industrial production

| Source: The authors’ study |

<table>
<thead>
<tr>
<th>Absolute term</th>
<th>SS</th>
<th>Degrees of freedom</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section PP</td>
<td>2.86E+01</td>
<td>5</td>
<td>5.73E+00</td>
<td>0.49282</td>
<td>0.77821</td>
</tr>
<tr>
<td>Error</td>
<td>2.67E+02</td>
<td>23</td>
<td>1.16E+01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>YEAR</td>
<td>4.65E+01</td>
<td>4</td>
<td>1.16E+01</td>
<td>2.8565</td>
<td>0.02788</td>
</tr>
<tr>
<td>YEAR* Section PP</td>
<td>5.85E+01</td>
<td>20</td>
<td>2.93E+00</td>
<td>0.71886</td>
<td>0.79740</td>
</tr>
<tr>
<td>Error</td>
<td>3.75E+02</td>
<td>92</td>
<td>4.07E+00</td>
<td></td>
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The analysis carried out similarly for the stock level of supplies formed at recipients' according to segments (Tab. 2), showed the importance of the differentiation between the stock levels only between years. However, there are essential relationships between differences in the formation of supplies among departments of industrial production and also between stock levels in sections of industrial production in the investigated years (the interaction: year*section PP).

Striving to answer the question how the structure of supplies changes in a supply chain of metallurgic products, in the next step the authors examined correlations between supplies and consumption of products in particular years. The factor introducing changeability in the structure of supplies is classes of products and sections of recipients. For factors of changes determined in this way the authors observed strong correlations between changes in the area of consumption of individual categories of products in segments in 2006 - 2009 and differences in the stock level of individual classes of recipients according to segments in the investigated years. The obtained results indicate adaptation of the stock level in individual years to the real consumption of each of the groups of products in individual segments.

Expanding the analysis of supplies in supply chains of metallurgic products, in the next step the authors examined the stock turnover at the suppliers of metallurgic products and at recipients' (all segments in total) for all of the five product categories in years 2003 - 2010 (Fig. 3).
The stock turnover of products: W1, W2, W4, W5, in the investigated period was considerably higher at recipients’ of these products than at suppliers’ (producers’). Supplies of the W3 product are shown only at recipients’. The strongest tendency to the increase of supplies at suppliers’ can be observed at the W3 product, however, in case of the stock turnover at recipients’ one can notice large fluctuations of this quantity in the investigated period. What may seem definitely alarming is data from 2010, where with relation to the previous year the stock turnover decreased for products: W5, W3, slightly for W1 and W2 and only for the W4 product a slight increase was observed.

As shown on Fig. 4, globally (for all classes of metallurgic products) the stock turnover at suppliers’ is considerably lower than at recipients’ in all the investigated years. The results of the analysis of variance, presented on fig. indicate that the major factor differentiating the stock turnover are the categories: supplies at supplier's ZD and supplies at recipient's ZO. However, the time does not differentiate significantly the stock turnover

Source: The authors' study

The structure of supplies in a supply chain of metallurgic products, where one can observe a slight stock turnover at suppliers’ with relation to supplies at recipients’ indicates a decoupling point located in the
distributional part of the supply chain. Depending on the width of assortment, including especially the kind of assortment groups which are in the distributor's offer, it plays a different role. Products with the greatest differentiation of rotation at recipients' require formation of a buffer in the supply chain. These are mainly cold-rolled products and steel pipes. Other flat products require the distributor to provide supplies of base products which then are differentiated depending on placed orders. The increasing stock turnover at the suppliers (manufacturers) of metallurgic products is connected with the growth of the role of distributors of metallurgic products in the Polish steel industry. Distributors fulfil their own role enabling a growth of the stock turnover in the production part of the supply chain. However, in the demand part of the supply chain the increase of orders strongly individualised according to the recipients' needs caused difficulties in adaptation of the distributors' potential. Large fluctuations of the demand on metallurgic products and their individual variants results in worsening indicators of the stock turnover in individual segments of recipients. Hence distributors face the necessity to improve their own processes so as to finally ensure the enlargement of the stock turnover for all assortment groups and to protect recipients against negative results of fluctuations of demand. Building a network relations in order to gain complementary resources of other distributors is an opportunity to increase the efficiency of distribution enterprises playing the role of the decoupling point.

5. CONCLUSIONS

Supply chains of metallurgic products dynamic undergo dynamic changes. Both the consumption of individual assortment groups and the formed supplies show substantial differences in departments of industrial production in the investigated years. The structure of the consumption of steelwork indicates a strong growth of demand in the segment: computer, electronic and optical product manufacturing. This segment reports demand for precise products, deep-converted with a high added value. The structure of supplies in individual segments generally corresponds to the level of consumption of products in these segments. The increase of supplies was observed especially at recipients' belonging to the segment "metal manufacturing" and also a slightly lower increase in segments: "electric device manufacturing" "machine and device manufacturing". The stock turnover at suppliers' and recipients' at the turn of the investigated years indicates the role of contemporary distributors of metallurgic products. The low stock turnover at recipients characterizes such products as: metal sheets and galvanized steel strips and steel pipes. In the investigated years there as a strong increase in the stock turnover of cold-rolled steel sheets. The stock turnover of hot-rolled metal sheets remained on a relatively high level. Globally, the stock turnover at suppliers' in the investigated period showed an upward trend. Definitely stronger fluctuations in the stock turnover for individual product categories were reported at recipients. Metal sheets and tinned strips have the highest indicator of the stock turnover at recipients, however, this indicator is clearly on the decrease. Steady but slight growth of the turnover is noticed as regards such assortment groups as: hot-rolled products and metal sheets and tinned strips.

As revealed by the carried out research, the decoupling point of steelwork is located in the distribution part of the supply chain. Such a configuration of the chain is connected both with characteristic features of steel products and with conditions imposed by recipients. The analysed structure of supplies in the whole supply chain and the consumption of products in individual segments confirms that the meaning of the organization manner of distribution processes is on the increase. The high levels of supplies in all the investigated assortment groups at suppliers and a slight stock turnover with relation to the stock levels and the stock turnovers at recipients confirm that service centres and steel yards are the points in a supply chain which transform the part of the supply chain controlled with supply into the part of the supply chain controlled with demand. Depending on the segment of recipients, distributors playing the role of the decoupling point fulfil tasks in compliance with the strategic option accepted by the leaders of the supply chain, which is: manufacture to stock or assembly to order. In the first case enterprises fulfilling tasks of the decoupling point concentrate on typical functions of the warehouse, while manufacturing processes are realized comprehensively by manufacturers. In the second case distributors additionally take over tasks connected
with postponed production. The second strategic option is the direction at which steelwork supply chains aim and it gradually eliminates the model of manufacture to stock. The realization of the postponed production strategy, connected with the tendency to differentiation of the product in chain links of the supply chain as close to the customer as possible requires enlargement of the supply base of distributors. The necessity to enlarge the access to specialized resources is an impulse to build network relationships. Complex production and logistic systems created in this way require a new approach to the problems of flow management. The management of material flows by the distributor playing the role of a decoupling point in such a network is a new area of analysis, a source of the of authors' further research.

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