Triadic perspective on customization and supplier interaction in customer-driven manufacturing

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ABSTRACT
Customization and customer-driven manufacturing are both explicitly based on the focal actor's interaction with the customer actor. The impact of these aspects on the internal operations of the focal actor is relatively well known compared to the limited number of studies performed on the impact on the focal actor's supplier. The purpose here is therefore to investigate how the concept of customization complements the concept of customer-driven and how customer requirements affect interaction between a supplier and the supplier's supplier in a triad. Frameworks for different perspectives are developed where match and mismatch between the actors on the perception of flow driver and flow differentiation is highlighted. The frameworks are then applied on a case company to illustrate application.

1. Introduction
The customers' impact on supply conditions has received considerable attention in terms of to what extent the customer actually drives the supply process (see e.g. Giesberts & van der Tang, 1992; Hoekstra & Romme, 1992; Sharman, 1984). The customer order decoupling point (CODP) is used in this context to identify the boundary of the customer-driven activities. The literature on decoupling analysis has mainly emphasized internal operations in relation to the customer order based on e.g. customer-driven manufacturing (Wortmann, Muntslag, & Timmermans, 1997). The impact of the positioning of the CODP on supplier interactions has also been investigated and the findings suggest that the design of a supplier interface should be adapted according to whether the interface is upstream or downstream of the CODP (Wikner, Bäckstrand, & Johansson, 2017). The positioning of the CODP, in relation to the supplier interface, complements the purchasing strategy first developed by Kraljic (1983) since the end customer is explicitly considered in relation to the CODP. This extended Kraljic approach (Wikner et al., 2017) regards the driver of performed activities in the sense that forecast-driven activities are separated from customer-order-driven activities.

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This approach does, however, provide a too limited picture in some cases since differentiation related to customization of the product is not included in the analysis.

Customization concerns several different aspects of business operations as outlined by Fogliatto, da Silveira, and Borenstein (2012). In general, customization can be described from two perspectives: a process perspective and a content perspective. The process perspective concerns how customized products are developed (see e.g. Fettermann & Echeveste, 2014). The content perspective instead covers different aspects of the actual customization such as if it is related to whether the properties of the product are unique to a particular customer order or whether the product only has standard properties that are the same irrespective of the customer (see e.g. Lampel & Mintzberg, 1996). From a supply chain perspective, the issue of customization traditionally only refers to a dyad where a customer actor has unique requirements that the focal actor strives to fulfil (Lampel & Mintzberg, 1996). Extending the issue of customization to a triad context, where also a supplier actor of the focal actor is considered, results in a higher level of complexity due to that different perspectives of customization are introduced: that of the supplier actor and that of the focal actor.

During a research project, focusing on customer-order-driven manufacturing in combination with supplier interactions, the differentiation, i.e. the level of uniqueness, described above turned out to be a key property. The level of uniqueness is related to risk analysis with implications on where in the supply chain it is best to keep inventory and this turned out to be a significant issue in the project. Such positioning of inventory in the supply chain is related to deciding on different levels of postponement, in terms of positioning of the CODP (van Hoek, 1997), which as a consequence impacts the supplier interface in terms of flow drivers (customer-order-driven or forecast-driven supply). The literature did, however, provide limited support on how flow drivers in combination with flow differentiation (standardized or customized) affects supplier interactions. The purpose of this research is therefore to investigate how the concept of flow differentiation complements the concept of flow driver and how customer requirements affect the interaction between a focal actor and the focal actor’s supplier in a triad.

Next, the research approach is outlined to give a brief description of how the frameworks introduced here were developed. The three fundamental frameworks are then described in detail. First, the driver and differentiation are combined. Second, the two perspectives of differentiation are defined in terms of a triad context, hence involving an interface between the focal actor and its supplier actor, see, e.g. Wikner et al. (2017). Third, the two previous frameworks are combined. Once the three frameworks have been defined, an industrial case from the research project is used as an illustration of how the frameworks can be applied and an analysis is provided. Finally some conclusions are outlined.

2. Research approach

The point of departure for this research is a research project where the literature did not provide sufficient support in terms of conceptual frameworks (models) to support a discussion related to customization. This led to the pursuit of analytical conceptual research in order to develop such conceptual frameworks complemented with empirical case study research as suggested by Wacker (1998). From a theory-building perspective, the purpose of analytical conceptual research is to add new insights into traditional problems through logical relationship building. Wacker (1998) further states that analytical conceptual research
usually employs case study examples to illustrate the conceptualizations. In line with this, an empirical illustration of the applicability of the research results is provided.

The empirical case study research was performed in a research project involving six multi-national companies from different industries, and with sites in Sweden (companies C, E, F, H, HyPuMo and S in Table 1). The research has been carried out as a collaborative research project during 3.5 years in line with Larsson (2006). The empirical data for this study were mainly collected through company meetings (interviews), project workshops, and e-mails involving a number of people with different roles, see Table 1. The case companies in the project were represented by several different roles, covering the areas ‘Purchasing and Engineering’ and ‘Manufacturing and Logistics’, as reflected in Figure 11. The illustration used later in this paper, based on the company HyPuMo, emanates from this research and was selected due to its illustrative nature and complete coverage in these areas. However, in Bäckstrand (2012) illustrations based on the other five companies can be found.

During the company meetings, researchers and representatives from one company at a time met to discuss the project’s conceptual results in light of the individual company. At the workshops, researchers and representatives from all the companies met and the company representatives presented empirical examples of the developed conceptualizations. The researchers and company representatives together discussed and analysed both conceptual and empirical results. E-mails were used to clarify and complement the content. As a result, the significance of the different perspectives was confirmed and the frameworks

### Table 1. Roles and participation of the research project members.

| Company | Role                          | Interview(s) | Workshop(s) | E-mail(s) |
|---------|-------------------------------|--------------|-------------|-----------|
| C       | Vice President design & logistics | X            | X           | X         |
|         | Business developer             | X            | X           |           |
|         | Business area manager (2 informants) | X            |             |           |
|         | Logistics and purchasing consultant (2 informants) | X            |             |           |
|         | Consultant manager             | X            |             |           |
|         | Logistics and Purchasing consultant | X            |             |           |
| E       | Manager supplier management (2 informants) | X            | X           | X         |
|         | Pre-CODP commodity manager      | X            |             |           |
|         | Manager planning & short-term dimensioning | X            | X           | X         |
|         | Post-CODP commodity manager     | X            |             |           |
|         | Manager process management logistics |             | X           |           |
| F       | Project manager SCM            | X            |             |           |
|         | Global purchasing director     | X            | X           | X         |
|         | Supply chain director          | X            |             |           |
|         | Plant manager Suzhou           | X            |             |           |
|         | Trading and outsourcing manager |             | X           |           |
|         | Production logistic manager    | X            |             |           |
|         | Business developer, supplier development | X            | X           |           |
|         | Supplier developer             | X            |             |           |
| H       | Supply chain manager           | X            | X           | X         |
|         | Project manager                | X            |             |           |
|         | Purchaser                      | X            |             |           |
| HyPuMo  | Manager production control     | X            | X           | X         |
|         | Senior buyer, strategic purchase | X            | X           |           |
|         | Product developer              | X            | X           |           |
|         | Trainee                        | X            |             |           |
|         | Division supply chain manager  | X            |             |           |
|         | Supplier development           | X            |             |           |
|         | Quality and supplier development | X            | X           |           |
| S       | Process and method developer   | X            | X           |           |
|         | Purchasing developer           | X            | X           |           |
|         | Manager demand and supply planning | X            | X           | X         |
|         | Supply chain developer (2 informants) | X            |             |           |
were developed in cooperation between the parties involved in line with the co-production approach to knowledge creation. The company representatives can thus be seen as informants rather than respondents in line with van Weele and van Raaij (2014).

### 3. Theoretical background

The challenge identified above basically concerns three different subjects that are covered here. The baseline subject is a supply chain approach where the triadic perspective is fundamental since differentiation, as investigated here, covers the requirements of a customer of a focal actor and how it affects the interaction between that focal actor and its suppliers. The other two subjects concern the impact of customer requirements in terms of flow driver and flow differentiation respectively.

#### 3.1. A triadic view of a supply chain

A general analysis of a complete supply network is complex and involves several actors and a multitude of interactions. To investigate the interaction between actors it is therefore common to focus on the subset of the network in terms of a dyad, i.e. two actors. This is however not sufficient if the intention is to investigate the impact of a customer on a supplier's supplier as in this case. Therefore, it is necessary to employ a model consisting of three actors, i.e. a triad, see Figure 1. In this setting, the consumption system consists of a customer actor (CA) and the supply system consists of two supply actors in sequence, meaning that the focal actor (FA) acts as a supplier to the CA and a supplier actor (SA) acts as a first-tier supplier to the FA. Note the notation used where the FA and SA both are supply actors, i.e. the supplier actor SA is a supply actor in relation to FA and the focal actor FA is a supply actor in relation to CA. It is worth mentioning that this triad setup differs from the ones defined by for example Dubois (2009), Dubois and Fredriksson (2008), Choi and Wu (2009a, 2009b), and Mattsson (1999) since they considered triads across two tiers of a supply chain i.e. one buyer interacting with two suppliers or one supplier interacting with two buyers. Our definition is more in line with Rossetti and Choi (2005, 2008) that investigated a phenomenon that occurs across three tiers of supply chain where the buyer/OEM (FA) sits between its customer and its supplier. In particular, we are interested in the interface between the FA and the SA, since this represents a buyer/supplier or purchasing relationship upstream in the triad. In this case, we assume that the SA and FA are not tightly integrated but acting as two separate legal entities, which is the standard scenario in most cases when a company procures materials from a supplier. This limited integration across the flow means that each actor acts with limited information about events outside its own context. The FA regards the CA as its customer and the information about this relation is not available to the SA. The SA instead regards the FA as its customer. This research...
concerns how the CA influences not only the FA but also the SA in terms of flow driver and flow differentiation. The concept of flow refers to the value adding activities performed and hence corresponds to a process view. By focusing on flow instead of product, i.e. an object view, we avoid unintentional exclusion of services, which is something inherently closely connected to flow.

3.2. Flow driver and the CODP

The triad in Figure 1 consists of three actors where the CA is the customer of the supply system. The CA impacts activities of the SA and the FA in terms of customer orders that the supply system is required to fulfil. In some cases, the CA can wait for the FA and the SA to perform activities, but in other cases it is not possible and the supply system must act on speculation about future requirements from the CA. To act on customer orders or forecast is related to the flow driver which is either actual customer orders or an expectation about future customer orders, i.e. a forecast. The CODP (Giesberts & van der Tang, 1992) is a concept related to this separation of the flow into forecast-driven (FD) and customer-order-driven (CD) and the CODP is a core component of customer-driven manufacturing (Wortmann et al., 1997). The CODP has been used frequently in the literature and its early application is most documented in relation to Philips (Hoekstra & Romme, 1992; Sharman, 1984). The flow driver is instrumental for deciding on flexibility and buffers to be employed (Angkiriwang, Pujawan, & Santosa, 2014). Consequently, the CODP is sometimes represented by a triangle to indicate that it is also a strategic stock point. It is, however, not absolutely necessary to keep inventory at this point, and a diamond is used here instead of the triangle (see e.g. Figure 2) to emphasize that this is mainly a separator between different decision domains rather than a stock point per se (Wikner, 2014).

In line with Shingō (1981), the relation between the supply lead time S (Shingo called this lead time ‘product lead time’ P) and the delivery lead time D is decisive for the positioning of the CODP and the CODP is thus a demand-based decoupling point (Wikner & Johansson, 2015). The lead time S covers both internal manufacturing lead time and external lead time of purchased materials. In addition, the driver can be a mix of customer orders and forecasts, which is referred to as the customer order decoupling zone (CODZ), and the flow is then mix-driven (MD) (Wikner, 2014). In summary, there are three different types of drivers that are included here: forecast-driven, mix-driven, and customer-order-driven.

Figure 2. The driver/differentiation framework.
3.3. Flow differentiation and the CADP

The CODP is related to the flow driver and usually not defined in relation to customization and the differentiation of the product in terms of the level of uniqueness, see for example Hofmann and Knébel (2013). A product that is CD, due to that the customer is willing to wait for delivery, may be either standardized or customized. The distinction in terms of the differentiation of the product is instead covered by the customer adaptation decoupling point (CADP), which separates flow that is unique for a particular customer order from the flow which is generic upstream of that point. The concept of CADP was introduced by Wikner and Bäckstrand (2012) but it is closely related to e.g. the point of product differentiation used by García-Dastugue and Lambert (2007). The ratio between the adapt lead time \( A \) and \( D \) is introduced and works as the baseline for positioning of the CADP, and the CADP itself is represented by a pentagon in figures (see e.g. Figure 2). The flow downstream from CADP is here referred to as delivery-unique (DU) flow, since the output provided is unique for the delivery based on a particular customer order. The uniqueness of the product is defined from a conceptual perspective and can refer to customization in terms of form, i.e. what is provided, as well as customization in terms of place, i.e. where it is provided. The actual timing of the provisioning is however related to the driver and the relation between \( D \) and \( S \).

At the other end of the uniqueness spectrum (Lampel & Mintzberg, 1996) is standardized flow providing standard products that may be offered to several different customers on the market and is therefore referred to as customer-generic (CG) flow. The concept of CG refers to the fact that the flow is not targeting a particular customer but is rather generic and suitable for many different customers in a market. Also in the case of the level of uniqueness, a hybrid may be identified, in this case a state between CG and DU. Recurring orders for the same customer-unique product is a common scenario in many cases, and to cater for this medium level of uniqueness, the customer-unique (CU) flow and the customer adaptation decoupling zone (CADZ) are introduced (Wikner and Bäckstrand, 2012). In summary, there are three different types of differentiation: customer-generic, customer-unique and delivery-unique (related to the colours green, yellow and red respectively in Figure 2 and subsequent figures).

Even if the concepts of CODP and CADP supports analysis of flow driver and flow differentiation they do not, as such, provide support for investigation of a triadic scenario and the different perspectives of a customer and a supplier. Therefore, they must be positioned in relation to a triad and this extension of application is developed next in terms of three frameworks.

4. Development of frameworks

Based on the subjects introduced above, i.e. the triadic supply chain, the flow driver and the flow differentiation, three frameworks are developed below.

4.1. Combining flow driver and flow differentiation for risk analysis

The three distinct types of differentiation introduced above (CG, CU, and DU) are independent of the type of driver (FD, MD, and CD) in the sense that the positioning of the
CODP is based on the delivery lead time D whereas the positioning of the CADP is based on the adapt lead time A. In some cases, A equals D (when all delivery-unique flow is also customer-order-driven flow) but this is of course not always necessary and in many cases, the lead times are not the same. For example, a standard product would have A equal to zero whereas the product could still be produced completely to customer order, i.e. D would be equal to S. The relation between A and D can be interpreted as related to constraints, from a risk perspective, on how flow driver and flow differentiation can be combined (Wikner, 2014). The lead times and the decoupling points can be illustrated in a time-phased product structure such as in Figure 7.

In Figure 2 the items can be categorized based on such a time-phased product structure. The framework is illustrated by combining the two perspectives of flow driver and flow differentiation, where the different flow drivers correspond to columns and the different flow differentiations correspond to rows in Figure 2. Downstream from the CODP (right column) a customer order is present and hence there is no need of forecasting, which means that the risk from a speculation point of view is low (note that the colours refers to the level of uniqueness, not the level of risk). Correspondingly, upstream from the CADZ (bottom row) the standard products (CG) are a relatively low-risk endeavour since they can be sold to different customers. Consequently, the cells in the third column and the third row all represent relatively low-risk combinations of driver and differentiation. However, if the flow is CU rather than standard (CG), the risk of speculating increases since the products are unique for a specific customer. However, if customer orders from that customer are frequent, the risk of speculating on future orders is relatively modest, but the less frequent the orders are, the higher the risk is. If there is only one order for a particular product (i.e. DU) it means that the risk of speculating on future, not yet received customer orders, is a high-risk scenario which should be avoided (intersection of row 1 and column 1). In summary, customization should only be carried out after a customer order is received, i.e. the CADP should be positioned downstream from the CODP since DU products should only be provided when there is a customer order that drives the flow. The positioning of the CADZ is upstream from the CADP but it is not as clear-cut in relation to the CODZ and in particular the frequency of the related customer orders is important.

The matrix in Figure 2 identifies nine risk scenarios related to a combination of flow driver and flow differentiation. The identified scenarios are absolute in the sense that they are defined independent of the actors involved but next, the perspectives of specific actors are introduced through a triadic context.

4.2. Triadic context for the flow interface

The buyer/supplier context in focus here is the interaction between the SA and the FA in the triad consisting of the three actors as in Figure 1. The different perspectives of these two actors on who the customer is are a natural consequence of the limited integration in the supply chain (Wikner et al., 2017). The level of uniqueness is defined from a customer perspective and since the SA and the FA have different customers, their perspectives on uniqueness might not be aligned. The FA uses the CA as a point of reference for differentiation at the interface with the SA, i.e. the Focal Actor’s Perspective of the interface (FAP). The SA on the other hand, has the FA as a point of reference for differentiation at the interface with the FA, i.e. the Supplier Actor’s Perspective of the interface (SAP).
The triad with the interface perspectives highlighted is illustrated in Figure 3, where the interface is supplemented by the arrows from the perceived customer to the related perspectives. In this figure, it is shown how the two different customer requirements meet at the interface between FA and SA where SAP and FAP have reference to different customers.

The concept of differentiation has been defined from a customer perspective in the sense that the product provided is in the range from being a standard product (CG) to a special product, unique to a particular customer order (DU). When only one actor is involved in supplying the product, analysing the challenges facing the supplier is quite straightforward. Involving more than one actor in supplying the product does, however, induce additional complexity. This supply system of two or more actors must be coordinated to enable competitive delivery reliability for the supply system. In particular, the interface between the two actors of the supply system is interesting to investigate further in terms of flow driver in combination with flow differentiation. Next, the concept of differentiation and level of uniqueness is positioned, first in terms of a single actor (intra-actor) and thereafter in terms of a triadic perspective (inter-actor). The intra-actor is defined as a building block of the inter-actor illustrations and not used explicitly in the subsequent case study.

4.3. Configurations of intra-actor flow differentiation

The dyad with one customer actor (CA) and one supply actor, here the focal actor (FA), represents the simplest structure from an external supply chain perspective (Harland, 1996). The FA is responsible for providing the appropriate differentiation in relation to what the CA requests. From a general perspective, the flow may transition through the levels of uniqueness CG, CU and DU through the FA. However, strict precedence relations are assumed along the flow of the FA, meaning that a standard CG flow may change into a more customized CU flow and then into a DU flow as illustrated in Figure 4. This is the only possible sequence, since the specificity of the flow should increase through the FA from left to right in the illustration. From a practical point of view, it is not logical to, for example, make the product CU, i.e. customized for a particular customer, at the beginning of the flow and then to change it later to some kind of CG product, i.e. standard product. There are a few special cases when the opposite would occur, such as when demand for something CU is cancelled and the product is reworked for other purposes, but these are exceptions and not covered here.
Considering these restrictions on how an actor may be configured in terms of increasing level of uniqueness, a set of possible intra-actor configurations can be identified. This analysis provides a baseline for the following discussion about the possible interfaces between supply actors involved in a triadic supply chain. There are three basic configurations where the flow has the same level of uniqueness throughout the actor, i.e. only CG, only CU or only DU. The second type of configuration would involve two different levels of uniqueness and considering that the level of uniqueness should increase along the flow it is possible to identify three configurations: CG-CU, CG-DU and CU-DU (notation here is upstream-downstream). The final configuration would involve all three levels of uniqueness: CG-CU-DU (such as in Figure 4). In total, this results in seven possible configurations given the precedence relationships based on flow differentiation. Considering these seven configurations in aggregate, it is obvious that all three levels of uniqueness are possible at both the customer interface (right side of a supply actor) and the supplier interface (left side of a supply actor). This analysis only involves one individual supply actor; the next step is to extend the scope to the supply system, i.e. the two supply actors in combination (SA and FA) and specifically the interface between the actors and the implication of the decoupling concepts. According to the logic introduced above, the differentiation should increase, or be the same, from left to right across one actor. In the case with two supply actors in sequence (SA and FA), this rule cannot be applied in the same way. If the two actors are not highly integrated, the baseline for defining level of uniqueness may differ between the two perspectives of the interface (SAP and FAP).

4.4. Configurations of inter-actor flow differentiation

The interface between the SA and the FA of Figure 3 is the point where levels of uniqueness, as perceived by the two supply actors SA and FA, intersect. For each of these two actors, there are three possible levels of uniqueness at the interface, as shown in Figure 5. In total, nine combinations of interface perspectives can hence be identified. In Figure 5, each perspective is represented by one dimension of the matrix. The columns represent the FA's perspective (FAP) and the rows represent the SA's perspective (SAP) where FAP and SAP are defined in relation to Figure 3.

For the configurations discussed below and denoted as \((y;x)\), \(y\) denotes row and \(x\) denotes column of Figure 5. The SAP is stated first and FAP second in order to follow the logical flow from left to right and an asterisk is used if a complete column or a complete row is referred to. For example, the configurations of the third row (CG;*) in Figure 5 are all based on the circumstance that the SA supplies standard flow (CG) irrespective of the level of uniqueness perceived by the FA. Hence, these configurations can be considered to be in line with normal procedures for purchasing standard items that FA uses to create products, i.e. a product consists of one or more item. The third column (*;DU) represents a set of configurations.
that may be handled by standard purchasing procedures where the FA provides to customer order at the highest level of uniqueness, i.e. DU. The FA hence procures items from SA per customer order since the items are DU. The SA, on the other hand, supplies items that it considers to be at the same or at a lower level of uniqueness compared to the FAP, which means that the risk level that SA perceives is not higher than the risk level of the FA based on the level of uniqueness.

The diagonal from lower left to upper right where the two actors perceive the same level of uniqueness, i.e. SAP = FAP in terms of differentiation, represents a balanced view of the level of uniqueness. The balanced view on the diagonal contain the configurations (CG;CG), (CU;CU) and (DU;DU).

The top left three encircled configurations (DU;CG), (DU;CU), and (CU;CG) do not follow the logic defined above and represent a decreasing level of uniqueness when moving from the SA to the FA, i.e. a counter-logic change in level of uniqueness across the supplier interface. The most characteristic configuration from this perspective is at the upper left of the table (DU;CG), where the FA receives items that the FA considers standard (CG) and hence are used for several different customers, but the SA considers each order from FA as unique (DU). In a similar manner, in the (CU;CG) configuration, from an SAP, the item is unique (CU) for one customer (the FA), even if the demand is recurring and hence not unique to each individual customer order from the FA. The configuration (DU;CU) has similar properties as the other two; the SA perceives the item to be DU from the SAP but the FA actually delivers this to one CA based on recurring customer orders and therefore the item is CU from the FAP.

Finally, the lower right three encircled configurations (CG;CU), (CG;DU), and (CU;DU) follow the logic defined above and represent an increasing level of uniqueness, but the flow across the supplier interface is not balanced, i.e. a logical but unbalanced flow. This means that the FA purchases a CG or CU item and uses it to create a product that the CA interprets as CU or DU.

In summary, as outlined in Figure 5, there are two perspectives at the interface, the SAP and the FAP. In total, it is possible to identify nine (3^2) configurations based on the level of uniqueness and the two perspectives. However, in practice the inter-actor flow does not only relate to flow differentiation but also to the flow driver of the activities.

Figure 5. The inter-actor differentiation perspective framework.
4.5. Configurations of inter-actor flow driver and flow differentiation in combination

The framework of Figure 5 only captures flow differentiation (level of uniqueness) as perceived by the different supply actors SA and FA. By also considering the flow driver, as of Figure 2, a more comprehensive picture unfolds as illustrated in Figure 6. These configurations are not summarized in one table but instead illustrated as two tables in combination where the left table represent SAP and the right table represent FAP. The interface between the two actors can now have $9^2 = 81$ different configurations. Each cell of the supplier actor’ SAP can be connected to any cell at the focal actor’s FAP. One such connection is illustrated in Figure 6 where item X at the FA is purchased from the SA, which is illustrated by a line representing that item X is CU from SAP but CG from FAP and for both actors, X is FD. Due to the complexity of many combinations, the inter-actor driver/differentiation perspective framework, as illustrated in Figure 6, does not explicitly highlight all 81 configurations, which hence differs from the framework of Figure 5 which illustrates all 9 possible configurations when only flow differentiation is considered.

The three frameworks outlined above covers different aspects of flow driver and flow differentiation. In support of applying these frameworks, a method was developed in the research project. It is referred to as the customer-driven purchasing method (CDP-method) (Bäckstrand, 2012). In this paper, only some parts of the method are employed. Hence, an adapted version of the method is used in the case study below, which is an illustration of applying the frameworks for supply chain perspectives on flow driver and flow differentiation.

5. A case study on the triadic perspective on customization and supplier interactions

The case study originates from the research project mentioned above and describes the empirical application of the conceptual frameworks in a company (in line with Wacker (1998)). This case description is based on Bäckstrand (2012) where it is presented in full, together with additional descriptions of the other companies involved in the research project and their application of the CDP-method. The case company is henceforth referred to as HyPuMo since it manufactures Hydraulic Pumps and Motors (HyPuMo). The case is presented based on six steps of the CDP-method and focuses on the interface between the focal actor HyPuMo and its suppliers.

HyPuMo manufactures motors with fixed and variable displacement in three product lines: the fixed product line, the variable product line, and the truck product line. The fixed
product line has delivery speed and product quality as order qualifiers, while the ability to customize the products with maintained delivery lead time is regarded as an order winner. A hydraulic motor in the fixed product line Fixed Motor (FM) and part of the product family F12, was selected for this case study. Product family F12 constitutes 30% of the total manufacturing volume in the fixed product line, and the fixed product line constitutes 50% of the sales volume of HyPuMo. Approximately 200 F12 motors are manufactured every day, and an average order is for just under five motors. Some of the items of F12 are standard in the family (CG), some items have various options (here referred to as ‘standard with options’ and henceforth considered as CG items) and some are customized (CU or DU). By just combining ‘standard with options’ items (without customizations), 850 variants of F12 can be created. However, HyPuMo has identified ten variations that satisfy 90% of all F12 orders. These combinations are referred to as the standard collection. This case is concerned with the remaining 10% that are customer order driven and customized.

5.1. Step 1: identify product structure and BOM

In Table 2, the indented bill of materials (BOM) for F12 is presented. The item IDs in Tables 2–4 do not correspond to the actual item numbers used by HyPuMo but are here merely used as identification numbers to refer to in this example. In addition, the table contains the items’ internal lead time (I) (HyPuMo’s, i.e. the FA’s, manufacturing lead time) and/or the external lead time (E) (the lead time of HyPuMo’s suppliers, i.e. the SAs), and the item supply lead time (S), which is the cumulative lead time related to the item (Bäckstrand, 2012). The items’ supply lead times are calculated by adding up the supply lead time for the parent item and the maximum item lead time for the item in question (as indicated in the rightmost column of Table 2). Items 1, 2, 3, 4, 5, 6, and 7 are subassemblies and are indicated in bold in Table 2. For HyPuMo, the most appropriate time unit to use is days but all actual numbers are normalized here and henceforth the unit used is referred to as ‘time unit’.

The items in consignment inventory (items 9, 11, 14, 16, 21, 26, 29, and 30) are excluded from further supplier-interaction analyses in this example since they are considered to always be available, i.e. their lead time is zero. The last 20 time units of assembly are performed by HyPuMo only.

5.2. Step 2: identify item supply lead times and supply lead time S

Categorization based on flow driver is supported by a lead time based perspective and a time-phased product structure (based on the BOM in Table 2) where the item supply lead times for the items in F12 are used and depicted in Figure 7 (in addition to S, Figure 7 also includes D, CODP, A, CADP and the colour coding corresponding to level of uniqueness which are related to Steps 3 and 4). The item supply lead times are shown in the second to last column of Table 2. The numbers on the lines in the figure correspond to the item IDs. For items 12 and 18 there are two alternative suppliers with different supply lead times and this is indicated in Figure 7 by 12a and 12b, and 18a and 18b. In Figure 7 it can also be observed that from an overall product structure perspective it is possible to identify different flow drivers for different items that are partly parallel in the structure. Since each item only can have one flow driver, i.e. the production of an item is initiated either as FD or as CD, it is the starting point (left point of an item in the figure) that defines the flow driver of an item.
The CODP of the product structure in Figure 7 is positioned at \( D = 75 \) meaning that all items with a starting point downstream of the CODP (to the right of the CODP in the figure) can be CD. For example, item 4 and 5 can be CD (starting downstream of the CODP) but not item 20 or 22 (starting upstream of the CODP). Item 22 will therefore be FD whereas the following item 5 can be CD. In this example, the connection between items 22 and 5 can therefore be interpreted as the position of one CODP and the connection between items 20 and 4 as the position of another CODP. The CODPs may hence be positioned at different places for different branches of the time-phased product structure, which is in line with the assumption of atomic items (see e.g. Wikner & Rudberg, 2005). Here we do however not explicitly recognize the concept of multiple CODPs but instead have a more elaborate view on the type of flow driver for an individual item and preserve the use of ‘CODP’ as related to a complete product structure, as shown in Figure 7.

The longest branch in the time-phased product structure in Figure 7 represents the longest item supply lead time (item 23), which hence corresponds to the supply lead time \( S \) for F12, in this case 125 time units. The last 20 time units, indicated by FM in Figure 7, represent the time needed for assembly of subassemblies and items before shipping to the CA.
5.3. Step 3: categorize items based on flow driver

In order to categorize the items based on the flow driver, e.g., whether an item is FD or CD, the CODP and the delivery lead time D are used. HyPuMo’s delivery performance is measured against the requested D from the customer. The requested D for the product line FM, where F12 is included, varies to some extent, which means that there is a CODZ. In this particular case, the scenario was simplified and the CODZ is excluded and only the CODP is positioned in the analysis. Based on historic demand and market analysis, D was estimated at 75 time units and hence the CODP is positioned at 75 time units. More information about positioning of CODP and CODZ is available in Wikner (2014), and more information regarding the positioning of HyPuMo’s CODP can be found in Bäckstrand (2012).

The item supply lead times in relation to the CODP are compiled in Table 3. The CODP corresponds to the vertical line in the time-phased product structure of Figure 7 where FD flow is separated from CD flow. All items to the left (upstream) of the CODP in the product structure thus need to be provided based on forecast while all items to the right (downstream) of the CODP can be provided based on customer order.

5.4. Step 4: categorize items based on flow differentiation

Following the previous categorization based on flow driver, this step categorizes the items based on flow differentiation. For F12, all iron castings are available in a number of options. The iron casting options can then be manufactured into a number of options of the subassemblies (in this example, items 1, 2, 3, 4, 5, 6, and 7). The predetermined options are seen as alternatives and are hence ‘standard with options’, here categorized as CG. However, some of the subassemblies (items 1, 2, 3, and 4) can also be unique (CU or DU). In addition, item 4 is a key item and can be DU. The remaining items are CG. This is summarized in Table 4, where also the CADP is indicated.

This categorization is also illustrated in Figure 7 where the level of uniqueness is indicated by the respective colours in the branch that represent each individual item.

### Table 3. Items for F12 categorized based on flow driver.

| Item ID | 125 | 120 | 115 | 90 | 85 | 80 | 75 | 65 | 60 | 45 | 40 | 35 | 20 |
|---------|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|
| Driver  |     |     |     |    |    |    |    |    |    |    |    |    |    |
| FM      | 23  | 19  | 12b | 24 | 20 | 8  | 4  | 27 | 10 | 6  | 5  | 1  | 2  |
|         | 18b | 25  | 22  | 12a| 13 | 15 | 18a|    |    |    |    |    |    |
| Driver  | Forecast (FD) | CODP |          |
| CODP    | Customer order (CD) |

### Table 4. Items for F12 categorized based on flow differentiation.

| Item ID | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 | 1 2 3 4 | 22 23 24 25 26 27 28 29 30 |
|---------|--------------------------------------------------------|---------|-----------------|
|         | Customer-generic (CG)                                | Customer-unique (CU) | Delivery-unique (DU) |
| Item ID | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 | 1 2 3 4 | 22 23 24 25 26 27 28 29 30 |
|         | CADP                                                   |             |                 |
5.5. Step 5: categorize items based on make or buy

Since the focus here is on the interaction between the HyPuMo and the SAs the items are categorized in terms of make or buy. In F12, items 1, 5, 6, and 7 are made by HyPuMo. Items 2, 3, and 4 have a make-or-buy alternative. The remaining items (items 8–30) are purchased items. For item 3, the CU versions are being outsourced. For item 4, both CU and DU versions are outsourced. The items 1, 5, 6, and 7, which are make-items, are omitted in the following steps since the focus here is on buy-items and supplier interaction.

5.6. Step 6: categorize items based on the inter-actor differentiation perspective framework

As a prequel for step 7 the items are categorized based on the actor differentiation perspective. From HyPuMo’s perspective (FAP), the level of uniqueness is stated in Step 4 and summarized in Table 4. In this step, HyPuMo’s perspective (FAP), is combined with the respective SAs’ perception of level of uniqueness, i.e. ‘Supplier actors’ perspective’ (SAP), represents the perspective of 26 different SAs, one supplier per purchased item. A more detailed analysis of the SAs’ perspective reveals that in some cases there is a discrepancy between HyPuMo’s perspective (FAP) and the SAP (i.e. for items 4, 11, and 14), see Figure 8. Figure 8 is a compact version of Figure 5 in the sense that the triad at each configuration of Figure 5 is represented only by the colours at the interface in the order of SAP-FAP.
5.7. Step 7: categorize items based on the driver/differentiation framework

Finally, the items are categorized based on the combination of flow driver, flow differentiation and an inter-actor perspective. In Step 3, the CODP was positioned at 75 time units upstream from delivery. Items 1–7 and items 10, 17, 27, and 28 have item supply lead times that are equal to or shorter than 75 time units and are hence CD. However, items 1, 5, 6, and 7 are pure make items and do not involve any supplier interface. These items are thus excluded from this step.

According to Table 4, item 4 is DU, items 2, 3, and 4 are CU, and the remaining items are CG. When the type of driver is combined with the type of differentiation, the resulting matrix can be found in Figure 9, which is based on Figure 2.

The three items identified ‘off the diagonal’ in Figure 8, items 4, 11, and 14, are shown in Figure 10 with the perspectives for HyPuMo and the SAs of these items respectively, considering both type of driver and type of differentiation. The versions of item 4 that are CU and DU are ‘on the diagonal’ and hence not illustrated in Figure 10.

Figure 8. Differentiation perspectives for F12 items based on the inter-actor differentiation perspective framework.

Figure 9. Risk strategies for F12 items based on the driver/differentiation framework.
6. Analysis

The application of the frameworks in a case context was outlined above and organized in line with the CDP method for illustrative purpose. The application highlights how the frameworks can support decision-making based on a triadic perspective on customization and supplier interaction in customer-driven manufacturing. Some aspects of this application are outlined in this analysis.

6.1. Analysis 1 based on the driver/differentiation framework

The first four steps of the CDP method are related to categorization of items based on the lead times in combination with flow driver and flow differentiation. These steps basically constitute preparatory steps for the interaction perspectives analysed thereafter.

6.1.1. Item categorization based on flow driver

By plotting the item supply lead times in line with Table 3 it is possible to identify the position of the CODP and some critical lead times for the FA, in this case HyPuMo. In general, the lead time distance to the CODP for a FD item is critical as it indicates the potential of lead time reduction. On the other hand, the distance to the CODP for CD item indicate the potential for delivery lead time reductions without implications for that particular item. Shortening a FD item's lead time upstream, but close to the CODP, may change the item from FD to CD whereas the corresponding lead time reduction for an item further upstream has no implications on the type of flow driver for that item. For example, item 4 is ordered right at the CODP and is thus sensitive for any kind of lead time variation (extension). Items 8, 12a, 13, 15, and 18a are ordered five time units before the CODP and hence not as sensitive.

Figure 10. Perspectives for three F12 items based on the inter-actor driver/differentiation perspective framework.

Figure 11. Triadic perspective on customization and supplier interactions in customer-driven manufacturing.
to lead time changes as item 4 from this perspective (they are already FD). On the other hand, by actively working on reducing their lead times slightly, these items may become CD. On the contrary, for item 23, a radical change would be needed in order to make that item CD, due to the long lead time and the focus should hence rather be on forecasting and stock keeping. Table 3 hence provides an overview of the preconditions for each item as it is organized based on the time distance to the CODP.

### 6.1.2. Item categorization based on flow differentiation

Flow differentiation concerns the level of uniqueness and whether an item is CG, CU or DU. When the result in Table 4 is compared with the result in Table 3, it can be concluded that the item supply lead times for all the CU items (except for item 4, i.e. items 1, 2, and 3) are 35 time units while the item supply lead time for the DU item (item 4) is 75 time units. This is crucial information when communicating with the CA, since these two supply lead times for example limits the ‘available-to-promise’ logic if FD supply of CU items should be avoided.

### 6.2. Analysis 2 based on the inter-actor differentiation perspective framework

Step 5 of the CDP method identified the purchased items which are in focus here and constitute the third type of categorization. The intersection of these different types of categorization is in focus next. Flow differentiation is a general concept related to product uniqueness and hence customization. In a supply chain context, the actors may explicitly consider differentiation from both a customer perspective and a supplier perspective since each perspective provides different challenges at the interface. This analysis is related to step 6 of the CDP method. A product may be a CG (standard product) for the FA’s product line (FAP) but still the product may be unique for the FA from a SAP. Also, a product may be unique for a particular FA’s customer from a customer perspective but from a supplier perspective, i.e. the FA, it is still CG. The framework presented in Figure 5 captures these configurations, among others, and hence provides some important insights that provide support for designing supplier interactions.

During the research project where supplier interactions were investigated, two non-balanced configurations (CU;CG) and (CG;DU), turned out to be representative for several products at the participating companies (see Figure 8 for an example). However, these configurations have limited support in both the literature and standard purchasing procedures. In particular, these configurations imply additional challenges not faced in the other, more traditional, configurations concerning, for example, where to keep inventory, who should be responsible for buffering, and risk sharing in general. As highlighted in Figure 5 there are two set of ‘off-diagonal’ configurations that require further analysis.

### 6.2.1. Counter-logical interaction based on flow differentiation

Counter-logical here refers to the upper left encircled configurations in Figure 4 in that a precedence condition that we assumed for the level of uniqueness changes in the flow. For example, configuration (CU;CG) corresponds to a situation where the purchased item is used in many products of the FA and hence is regarded as a standard CG item internally at the FA. From the SAP, the situation is completely different since the item is only sold to one customer, the FA. The item can be assumed to be a key item for the FA since it is probably
used in many products (as in the HyPuMo case) and the FA will need continued supply for the foreseeable future. The SA is, however, exposed to the fact that the FA is the only customer and unless the FA continues to buy the item, all business related to that item is lost for the SA. The FA could, for instance, decide to change suppliers to reduce cost and suddenly the SA would lose this business. This example highlights the asymmetrical risk exposure in these configurations. Correspondingly, the upper left configurations in Figure 5 and consequently also in Figure 8 (DU;CG), (DU;CU), and (CU;CG) would argue for avoiding stock keeping at the SA beyond any firm delivery contracts, since the risk premium would have to be significant compared to when this kind of stock is held at the FA, which is the actor in a much better position to estimate the risk level.

This situation was identified in the case study. For all products in HyPuMo’s product family FM, the same type of O-ring gasket, item 11, is included, regardless of product variant or customization of the end product. It is therefore considered as a standard CG item by HyPuMo (FAP). However, this O-ring has been specifically engineered for HyPuMo by the supplier since HyPuMo has specific requirements regarding durability and dimension specifications. Hence, this O-ring is not intended to be sold to any other customer than HyPuMo by the SA and is therefore classified as CU at the SA (SAP). This corresponds to the counter-logical (in the sense that the level of uniqueness decreases along the flow) configuration (CU;CG) in Figure 5 and consequently also in Figure 8.

In a similar manner, item 4 is included in all end-products of F12 at HyPuMo and is hence CG for HyPuMo but can also be adapted to be CU or even DU. At the SA, item 4 is CU for HyPuMo, which means that they cannot sell this item to any other customer. However, when a customer requests a DU customization of item 4 from HyPuMo, the SA will also perceive this item as DU but then with HyPuMo, not the CA, as their customer. Item 4 can hence be positioned in configurations (DU;DU), (CU;CU), and (CU;CG) in Figure 5 and consequently also in Figure 8.

6.2.2. Logical but unbalanced interaction based on flow differentiation
The lower right configurations in Figure 5, and consequently also in Figure 8, follows the precedence conditions of Figure 4 are here referred to as logical. The intersections (CG;CU), (CG;DU), and (CU;DU) would argue for keeping inventory at the SA, where the level of uniqueness is lowest and the items can be sold to several different customers, of which FA is one.

In the case company, another part of the product consists of a different O-ring. In the standard product range, item 11 is used again. However, one specific customer requires the product to be compatible with a different hydraulic fluid, hence resulting in a CU product. In this CU product, another type of O-ring, item 14, is needed and it is sourced from another supplier than the supplier of item 11. This item 14 type of O-ring is found in the standard product range at this specific supplier, corresponding to configuration (CG;CU) in Figure 5 and consequently also in Figure 8.

6.3. Analysis 3 based on the driver/differentiation perspective framework
This analysis is related to step 7 of the CDP method and provides further information on the alignment of the two actors of the supply system.
6.3.1. Misalignment between perspectives
As shown in Figure 10, the perspectives of the SA (SAP) and HyPuMo (FAP) on item 4 are aligned (both are CD), while there is misalignment for items 11 and 14. Item 11 is FD and regarded as CG at HyPuMo but as CU at the SA. Item 14, on the other hand, is also FD but CU at HyPuMo and CG at the SA. This misalignment between HyPuMo’s and the SA’s view of differentiation is important to identify as the speculation risk in the supply chain can be allocated more efficiently. In general, a lower risk is associated with manufacturing and stock keeping of items with lower levels of uniqueness (CG) compared to manufacturing and stock keeping of CU items. The inventory and safety stock for item 11 would hence benefit cost-wise from being kept at HyPuMo, rather than at the SA. Based on the same argument, HyPuMo should avoid keeping inventory of the CU item 14 since it is a CG item at the SA from their perspective. The general recommendation is thus that the actor with the lowest perceived level of uniqueness should stock that item when there is a discrepancy between perspectives on differentiation in terms of customization.

6.3.2. Alignment between perspectives
For item 4, the differentiation at HyPuMo seems to correspond to the perspective of the SA even if they have different customers as a point of reference, CA and HyPuMo respectively. However, in order to assure correspondence, HyPuMo should be transparent with information regarding the differentiation required from the CA when placing an order at the SA. HyPuMo should also closely monitor the supply lead time for item 4, since it corresponds to the position of the CODP, i.e. 75 time units according to Table 3. If the supply lead time for item 4 was extended by one single time unit, the risk would increase from low to medium/high risk according to Figures 2 and 9 as it would then shift cell in this framework.

7. Conclusions and further research
The three frameworks introduced above each capture some key issues for decision-making related to the content of customization, whereas the process of customization (see e.g. Fettermann & Echeveste, 2014) has not been elaborated upon.

The first framework (related to Figures 2, 7 and 9) for driver/differentiation is based on flow driver and flow differentiation where the strategic lead times S, D and A are instrumental in positioning the CODP and the CADP. This type of flow analysis is frequently used in Manufacturing and Logistics in e.g. the context of value stream analysis. The actual categorization of items is based on the structure in Figure 2 and in practice the analysis is usually based on a time phased illustration of the product structure as in Figure 7 (which is summarized in Figure 9). As a result, all items are categorized in terms of flow driver and flow differentiation. This framework thus extends and complements existing literature (see e.g. APICS, 2012; Hoekstra & Romme, 1992; Mather, 1999; Sharman, 1984; Wikner, 2011).

The second framework (related to Figures 5 and 8) is used for analysis of inter-actor differentiation perspectives to highlight aspects of supplier interactions in combination with customization. These aspects are key in the collaboration between Purchasing and Engineering in the context of supplier selection and supplier development. This framework thus extends and complements existing literature on customization such as Lampel and Mintzberg (1996) and Saccani and Perona (2007).
These two frameworks capture key aspects of two different areas each and the third framework (related to Figures 6 and 10) is developed by integrating the two previous frameworks as illustrated in Figure 11. This integration results in the inter-actor driver/differentiation framework supporting a more holistic view of the Enterprise and an integrated triadic perspective.

In summary, the three frameworks developed here are based on the concepts of flow differentiation and flow driver in combination with the interaction between a supplier and the supplier’s supplier in a triad, which is in line with the purpose.

The three frameworks of Figure 11 provide several avenues for further research. The frameworks support categorization of items but more work is required on how to use this information for managing the different item categories. By including flow driver and flow differentiation the items are categorized from a process perspective that supports process analysis rather than the traditional product based categorization. Such a foundation for categorization can be expected to support process management but more research is needed on this and also on how this affects product development. The extension to include supplier interaction can further improve a more elaborate approach to managing a purchase portfolio. Finally, the triadic perspective in combination with the information components flow driver and flow differentiation highlights the importance of communication both internally between functions and externally with suppliers to reduce the risk of information distortion in customer driven settings. Improving such communication supports effective and efficient processes both in terms of content and the process as such.

Acknowledgements

This research has been performed in collaboration with six companies in the project KOPeration. The project was funded by the Swedish Knowledge Foundation (KKS), Jönköping University, and the participating companies.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Swedish Knowledge Foundation (KKS), Jönköping University, and the participating companies, Stiftelsen för Kunskaps- och Kompetensutveckling [grant number 2008/0537].

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