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On decoupling points and decoupling zones

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In a market with demand surplus, it is possible to compete with standard products available in finished goods inventory. Sooner or later, the products will be sold and mass production can prevail. Competition is however increasing and to strike a competitive balance between cost efficiency and market responsiveness, it is becoming ever more important to establish a competitive level of customer-order-based management (COBM). This paper outlines a framework for this management approach based on content, represented by four key decision categories, and an overview of a process for applying the content. The content is based on a generic decision-based decoupling theory that is used for deriving the decision categories; flow driving, flow differentiation and flow delimitation. The derivation of these decision categories is based on analysis of strategic lead-times. Thereafter, the decision category flow transparency is included as the fourth content cornerstone of the framework. A process is then outlined for application of the framework. A basic bill-of-material is used as an illustration of applying the framework for COBM.

Keywords: decoupling points; postponement; decision-making; decision categories; operations strategy

1. Introduction

Decoupling points (see e.g. Blackstone, 2008) have played a crucial role in production and logistics management since the infancy of materials management. The objective of decoupling points, usually associated with stock points, has traditionally been to disconnect the material flow into sub-flows and thus enabling more focused and local flow-management. It is well known that if the flow is not decoupled, it becomes more sensitive to disturbances since the disturbances then easily propagate through large parts of the flow due to the dependencies (Goldratt & Cox, 1984). Managing this combination of uncertainties (referred to as fluctuations by Goldratt and Cox) and dependencies is the key challenge to flow management. In isolation, local uncertainties can be handled by probability theory and dependencies without uncertainties are suitable for tools from optimization theory. However, when uncertainties are combined with dependencies, these tools are challenging to apply.

Henry Ford showed the potential of tightly coupled flows under certainty when he developed the Ford production system (Ford & Crowther, 1988). A major drawback of this type of system is its inability to handle variations in volume or mix, which can be seen as disturbances that affect the continuous one-piece flow. GM and other companies

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introduced frequent changes to the product lines which forced the system developed by Ford beyond its limits (Jones, 2001). Ford realized that one way to handle this challenge was to introduce a functional organization and stock points to decouple and reduce the dependency between different steps of the flow. GM went down a similar path but to a larger extent using arguments from cost accounting for decoupling the flow and this approach was adopted by many western companies for decades (Waddell & Bodek, 2005). This approach was also intrinsically connected to materials management systems such as material requirements planning (MRP). MRP is basically a system that is designed to maintain a target stock level, i.e. safety stock level, at the decoupling points of the materials flow. In general, this approach to decoupling points was indiscriminate to prioritizing different decoupling points even if the introduction of master scheduling and VAX-profiles provided some support (see e.g. Plossl, 1985, p. 177). The letters V, A, and X represent different types of material profiles, where the 'waist' of the profile is associated with a suitable level for performing master scheduling. The waist does not only provide an indication of suitable level for master scheduling but is also associated with the decoupling of customer-order-driven flow from forecast-driven flow (see e.g. Smith, 1989, p. 193), and hence a strategic location for inventory.

The importance of positioning decoupling points was further highlighted by the theory of constraints (TOC) (Goldratt, 1990) that emphasizes the importance of constraints for positioning of decoupling points. This approach proposes a design that can handle disturbances and dependencies by carefully positioning and dimensioning a combination of capacity buffers and material buffers. TOC uses time buffers, which are not in themselves decoupling points but rather an abstraction of flow segments related to non-constraints where the detailed flow analysis is replaced by earliest start time and latest finishing time for the time buffer (Stein, 1996). As a consequence, the time buffer will result in a physical buffer and hence a decoupling point. The most critical decoupling point is related to the bottleneck of the system. This is a different perspective compared to the VAX approach, which is material based. Olhager and Wikner (1998) showed how these two perspectives can be combined in support of master scheduling but provided limited support in terms of how to operationally combine them.

At the same time as MRP was established, Ford's original approach was further developed by Toyota that created Toyota production system (TPS) (see e.g. Ōno, 1988). TPS is the backbone of lean, which is a system that from a flow management perspective uses small decoupling points, referred to as supermarkets and FIFO-lanes, to handle product-mix demand uncertainties, and continuous improvement to reduce supply uncertainties. In all these approaches described above, the focus is on managing operational and tactical decoupling points (Wikner, Johansson, & Persson, 2009) when planning and controlling the materials flow. The lean approach also carries many similarities to the system simplification approach developed by the Cardiff group (see e.g. Wikner, Naim, & Towill, 1992). Both the lean and the Cardiff system approach emphasize simplification through elimination of unnecessary activities, i.e. waste. Lean is mainly concerned about waste at an operational level whereas the system's approach is concerned with waste at a structural level by creating effective control structures. The concept control structures as used here focuses on decision-making for creating effective flows whereas the lean approach has mainly been successful as an approach for creating efficient flows. The control structures of the system's approach can be described in terms of three components related to feedback and feed forward of information, and key decoupling points. These decoupling points are here referred to as strategic decoupling points (Wikner et al., 2009) due to their critical impact on competitiveness. In addition,

there are tactical decoupling points related to items and item stock points, and operational decoupling points related to queues and buffers in the flow. Below the focus is exclusively on strategic decoupling points even if they are referred to simply as decoupling points.

The interest in decoupling points has developed in parallel streams of research related to, e.g. lead-time relation (see e.g. Mather, 1984; Shingō, 1989), decoupling point (see e.g. Hoekstra & Romme, 1992), customer order decoupling point (CODP) (see e.g. Bertrand, Wortmann, & Wijngaard, 1990), postponement (see e.g. Schmenner, 2001; van Hoek, 2001), order penetration point (Sharman, 1984), supply chain segmentation (see e.g. van der Veeken & Rutten, 1998), customization (see e.g. Graca, Hendry, & Kingsman, 1999), services (Fließ & Kleinaltenkamp, 2004; Wikner, 2012b) and leagility (Naim & Gosling, 2011; Naylor, Naim, & Berry, 1999). These different streams emphasize slightly different aspects of decoupling points but a fundamental property is the explicit focus on customers from a lead-time perspective. The main focus has been on the customer as the driver of the process but the literature on postponement (see e.g. García-Dastugue & Lambert, 2007), as well as the literature on CODP (see e.g. Hoekstra & Romme, 1992; Olhager & Östlund, 1990) have emphasized product differentiation as a separate aspect. Even if these streams have many similar properties, they have also to a large extent developed in parallel. They do however provide the decision-maker with a similar kind of decision support. In addition, a discussion on ‘multiple decoupling points’ has emerged in this context (see e.g. Banerjee, Sarkar, & Mukhopadhyay, 2011) where these issues are targeted to some extent but with a disperse foundation. An overall common structure is therefore needed that highlights key decisions related to decoupling points and thus enabling the development of a more cohesive theory related to decoupling points. The intention here is to identify a set of decision categories that outline the key decisions to be made when developing a competitive strategy for customer-order-based management (COBM), which here is defined as:

Customer-order based management (COBM) is a management approach that emphasizes the individual customer’s demand as a key input to flow-based decision making in the supply network.

COBM is a management approach and based on decision-making from a generic process perspective in contrast to, e.g. customer-order-based production (Borgström & Hertz, 2011), customer-driven strategy (Wallace, 1992), and customer-driven manufacturing (Berry, Hill, & Klompmaker, 1995; Wortmann, Muntslag, & Timmermans, 1997) that are explicitly targeting manufacturing. In complex decision-making, the sheer number of options makes the situation difficult to embrace for the decision-maker and the decision problem must be organized in a structured manner. One approach is to identify so-called decision categories by disintegrating the decision problem in relatively independent categories. One of the earliest, and probably the most referenced set of decision categories, was defined by Hayes and Wheelwright (1984). They divided decisions into structural and infrastructural decision categories based on a rather resource-oriented approach in that it focuses on the preconditions in terms of invested capital for the value-adding flow rather than the core properties of the value-adding flow per se. With a more process-oriented and lead-time-based approach, the focus shifts from different functional areas of the business to how and where customer value is created by processes in the flow. From a supply perspective, this approach puts the customer in focus and the extent of customer influence on supply management is here referred to as

decisions concerning the level of COBM that should be implemented. High level of COBM means that the customer can be offered a product that to a large extent is unique and may consist of services, but at the same time it also means that the customer must wait for delivery, i.e. for demand to be fulfilled. In contrast to this, a low level of COBM implies little customer influence, and that products are standardized goods with the possibility to be delivered with short lead-time.

In some cases, the decision on level of COBM is simplified to a decision about positioning of the CODP. This may be a sufficient description of the decision problem in some cases, but in many others it provides a too simplistic picture of the decision for segmentation of the supply chain from a customer perspective. Competition from low-cost countries has also put increasing pressure on companies in other countries to be more customer oriented. COBM is appropriate in this context as it involves more explicit customer focus both in terms of understanding specific customer requirements and cooperation with customers in different contexts. In this way, COBM rewards closeness to customers from a geographical perspective (due to costs and lead-times) as well as cultural/social perspective (due to the higher level of interaction between the parties) wherefore local suppliers, with high level of COBM, have advantages in this context compared to traditional goods focused providers.

Presently, there is very limited support available in terms of comprehensive frameworks concerning decision support for COBM. One reason is probably that COBM exists in a borderland between different challenges related to traditional manufacturing as well as service, distribution, and engineering activities. Due to these circumstances, it is interesting and important to investigate the challenges facing decision-makers in COBM to identify similarities and differences between these different types of businesses, and how synergies can be exploited to improve our ability to understand and manage these kinds of enterprises. It is also important to avoid adopting assumptions from specific industries. By keeping the approach focused on fundamental and generic concepts, the result can be employed in different kinds of industries. A consequence is however that industry-specific properties of importance may have to be added to the resulting framework.

The purpose of this paper is therefore to outline a framework that captures key aspects of COBM and in particular the role of lead-times and decoupling points from a decision-maker's perspective. As outlined above, the real-world relevance of this purpose is based on that the different widely applied management approaches all would benefit from a more explicit recognition of COBM. The research objectives targeted in this paper are therefore focusing on the foundation of flow-based COBM:

- Define a generic framework for lead-time-based analysis of strategic decoupling points.
- Identify the lead-times of strategic importance for decoupling.
- Outline key decision categories of a flow-based framework for COBM.

To achieve these objectives, the paper initially identifies the so-called logical entities which are defined from a management perspective. Decision domains are then introduced and used to define decoupling points and resource-based and process-based decoupling zones which are positioned using strategic lead-times. Thereafter, more general compounded decision domains are established. Based on this flow-based theory, the three decision categories flow driving, flow differentiation, and flow delimitation are defined based on strategic lead-times. These decision categories are complemented with

flow transparency and altogether they constitute the four decision categories of the framework for COBM. Finally, the process for applying the content is outlined.

2. Research approach

The framework for COBM outlined below is the result of many lines of research related to both a deductive theoretical approach to theory development and an inductive empirical approach to both theory development and theory testing.

The theoretical baseline is a set of concepts developed in the literature related to decoupling points such as the CODP, postponement, customization, and leagility. The literature has mainly focused on the application of decoupling points in different areas and not so much on conceptual development. In particular, discussions on positioning of decoupling points (see e.g. Hoekstra & Romme, 1992) have gained much interest but less effort has been spent on investigating the more fundamental aspects of decoupling points and common properties of different kinds of decoupling. This is also the gap targeted here and the main contribution lies in the holistic perspective on decoupling points and the explicit flow-based approach.

The literature provided a set of theoretical concepts that were used in two research projects involving 5-6 companies. As the number of concepts used in the projects increased, a more general theoretical foundation of the decoupling-based concepts was established resulting in the generic framework presented below. The generic framework was then used as a platform for defining decoupling-oriented concepts providing a comprehensive and conceptual identification of COBM. The resulting framework for COBM therefore rests on a combined theoretical and empirical foundation. The actual cases from the research projects are rather complex and still not each covering all aspects of the framework. Hence, a fictitious example is used below that provides an opportunity to illustrate the application of the framework without introducing the complexity of the real cases.

3. Management perspectives

Cost efficiency has for many decades been the most important driver for enterprise development. This approach has turned out to result in focus on local efficiency where customers' needs are of lesser importance. The development of lean thinking (see e.g. Womack & Jones, 1996) as a framework for flow-based enterprise management has however put the customer in focus and as a consequence the enterprise's ability to create customer value becomes decisive. In this context, time is maybe the most important resource and the time that is available should be used to create customer value, otherwise the time is considered as wasted. This puts strain on the management system since time should be used for value creation at the same time as uncertainties must be considered. Before the importance of time in terms of lead-times is discussed, the context of lead-times is defined from a system's perspective.

3.1. Transformation-based system perspective

A lead-time analysis is performed in some kind of context in terms of a system's perspective. The context can, for example, be different aggregation levels or hierarchical control structures. The analysis performed here is however more management oriented and based on the transformation process.

Analysis of supply chains is often based on the interaction between different actors (see e.g. Harland, 1996). The actors may however be viewed from different perspectives (Wikner, 2012a). From an overall perspective, the actors are usually companies (legal entities) and the challenges are handled within *business management*. These *legal entities* interact through e.g. customer orders and purchase orders. In this way, the legal perspective handles issues associated with who is ultimately funding different types of transactions, i.e. who is acting as the *sponsor of transformation*, see Figure 1.

The financial and contractual dimension, represented by the legal perspective, is however only a reflection of processes being performed by resources at the physical entities in terms of geographical places or organizational units such as departments, production sites or distribution centres. To define actors from this perspective as *physical entities* is important when analysing localization issues or how different units collaborate from a production perspective. This also involves how different strategies for managing the supply chain are applied related to e.g. leagility and postponement. The management approach is therefore focused on logistics activities in a broad sense, including production, and can be referred to as *supply chain management*. A physical entity is hence a value-adding node in a physical network that performs transformation in terms of form, place or time and is associated with *type of transformation*.

The division into physical entities is not that obvious from an enterprise management perspective since the business information systems, such as ERP systems, now offer the possibility to manage multiple physical units as one integrated network, which may also be referred to as a virtual supply chain (Chandrashekar & Schary, 1999). The idea of virtual supply chains dates back to virtual inventory management and e.g. different types of base stock systems (see e.g. Clark & Scarf, 1960) which is interesting since inventory management in essence is concerned with the management of tactical decoupling points. The concept of virtual supply chains is emphasizing a transient property with short-term orientation as supply chains may change frequently based on market requirements. In contrast, the framework introduced here makes no assumption on short term vs. long term but rather emphasizes a structural management perspective. The key property here is that this type of network, from a planning and control perspective, is a system of multiple geographically or organizationally dispersed units that are managed as one entity and it is here referred to as a *logical entity*. Logical entities are not concerned with the type of transformation that is performed but defines the flow in terms of processes and objects and is thus associated with a generic *transformation* of input to output from a *process management* perspective. The concept logical entity is a fundamental construct of COBM and is hence explicitly defined here:

A logical entity is a network of one or more physical entities that from a management perspective can be considered as one integrated network, offering the same level of controllability in all its parts.

The three perspectives legal, physical, and logical are summarized in Figure 1.

3.2. Legal and logical entities

The three system's perspectives introduced above can be combined in different ways. A company (legal perspective) can be divided into manufacturing and distribution/transportation with different functional belongings (physical perspective) but due to integrated business information systems, they can be managed as one virtual integrated unit

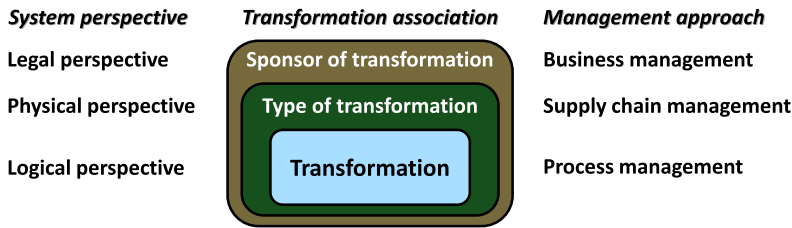


Figure 1. System perspective, transformation association and management approach.

(logical perspective). In particular, it is important to separate between the legal perspective and the logical perspective when performing flow analysis. Even if the economic consequences of the transformation in the flow is related to the legal entities, the mission for effective flow is created by considering the parts of the flow that can be managed as an integrated unit, i.e. as a logical entity. Figure 2 illustrates this with four fundamental configurations that can be identified by combining legal entities with logical entities. More general networks may of course contain multiple legal and logical entities but this would basically be a generalization of the simple configurations of Figure 2.

The configuration with one legal entity and one logical entity corresponds to two legal entities and two logical entities since in both cases there is one logical entity per legal entity, i.e. each company can be managed as one integrated system. This is probably the most common scenario since legal entities with one production unit usually can be managed as one integrated system and hence constitutes one logical entity. When there is one logical entity for two legal entities, it means that the two legal entities are integrated and managed as one unit. If, on the other hand, one legal entity has two logical entities, it corresponds to a situation where one legal entity has not been able to establish one integrated control approach but instead is divided in, e.g. different departments that are managed as separate, non-integrated units.

Below, the point of departure is different logical entities. How these logical entities relate to legal entities is of less importance for this framework since the focus here is on efficient and effective flows rather than who is responsible for different parts of the flow and economic evaluation of the flow. An implicit assumption below is therefore that one logical entity may correspond to a part of a legal entity, a complete legal entity or a multiple legal entities that are managed as one unit. Since the logical entity is defined from a flow and control perspective, it is also important for flow-based decision-making. By defining the specific preconditions that are valid for decision-making

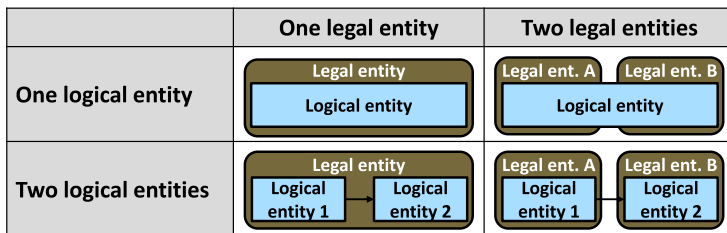


Figure 2. Four fundamental configurations of legal entities (actors) and logical entities.

in different parts of the logical entity, the key decision categories for COBM can be identified.

4. Framework for flow-based decision-making

Flow is a general concept that basically implies a ‘change’, or in other words a transformation, and a rate of transformation. The transformation can take place in the form, place, or time dimension (see e.g. Bucklin, 1965). Being a rate-based concept means that flow is closely associated to time and understanding implications of time in this context is critical. A detailed flow analysis does however require a more elaborate view in terms of the types of flow involved. Depending on the context of the analysis, different types of flow are significant but in most cases the five types identified by Forrester (1958) (information, materials, money, manpower, and capital equipment) suffice. At a higher level of abstraction, the concept of flow can be defined from a customer perspective as:

A flow represents the value-adding for customers through a set of transformation processes.

In this case, the concept of flow is used to represent that value adding is taking place, where value is added in a number of transformation processes (of course also non-value adding activities may be included but the emphasis is on value adding) which is in the spirit of, e.g. swift and even flow (Schmenner & Swink, 1998) and simplified material flow (Childerhouse & Towill, 2003). In every such process, a number of flow-based decisions are made that are decisive for how value adding is performed. The detailed design of the processes and the value-added flow may of course vary but here a common denominator is that for illustrative purposes, the flow direction is assumed to be from left to right and that the flow rate is directly or indirectly based on customer demand. The flow may hence be associated with materials flow but it is important to also recognize that the suggested framework does not exclude services since service can be defined as a process-based concept (Vargo & Lusch, 2004).

4.1. Decision categories and decision domains

Decision-making in COBM is comprehensive and covers a wide range of aspects to be effective. Providing a comprehensive framework for all types of decisions is both challenging to assemble due to the sheer number of different aspects to cover and would also be of limited value to the decision-maker due to the complexity provided by the comprehensiveness. To reduce the complexity due to a too high level of details, the decisions that should be covered can be classified according to their impact. Hayes and Wheelwright faced a similar challenge when outlining their framework for manufacturing strategy: ‘Because of the diversity of manufacturing decisions made in different businesses, an organizing framework that groups them into major categories is a useful tool in both identifying and planning the functional strategy for manufacturing’. (Hayes & Wheelwright, 1984, p. 84). The major categories for COBM are defined later but the decision categories, as a concept that were used by Hayes and Wheelwright, are also suitable for this purpose and is here defined as:

A decision category groups decisions into major categories that are fundamental to decision making for a particular purpose.

The scope of a decision category (DC) is based on some fundamental aspect of decision-making, which is here referred to as a decision criterion. Thus, decision categories are a way of classifying decisions and the decision criterion is what the classification is based on:

A decision criterion is a standard on which a decision may be based.

To manage an enterprise involves making numerous decisions of different character but all related to transformation processes. Some decisions are of more simple character and do not affect the flow to a large extent while others are of decisive importance to the performance of the process, such as initiating a process or not. Effective process management therefore requires that the critical decisions can be isolated and classified to enable the design and application of a management framework with decision categories. These categories should then be applicable on a wide spectrum of processes with similar preconditions. In support of this classification of processes, the concept of decision domain is introduced:

A decision domain is characterized by consistent preconditions for decision making related to a specific decision criterion.

A decision domain thus identifies what is common to a number of processes from a decision perspective and can hence be perceived as sub-categories within a DC (Wheelwright, 1984). A decision domain might, for example, define that the processes related to a decision domain are performed based on that a customer order has been received and hence that the process can be classified as customer-order-driven. This decision domain would then belong to the DC ‘flow driving’ and be based on the decision criterion ‘flow driver’ with the property ‘driven by customer order’ (see e.g. Figure 20 for an overview of decision categories). From this perspective, it would be reasonable to illustrate a decision domain as if the processes are within a decision domain. But for practical reasons, this relation is illustrated with a decision domain whose extension along the flow determines the processes associated with a particular decision domain, as shown in Figure 3. This means that the processes U1 and U2 in Figure 3 are classified as belonging to Upstream decision domain (from a flow perspective) and processes D1 and D2 as belonging to Downstream decision domain.

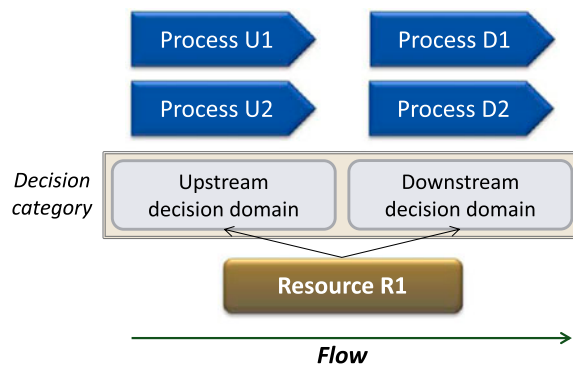


Figure 3. Relation between processes, resources and decision domains.

Resources that perform processes have a relation to decision domains that follow a different pattern compared to processes. Since a resource can perform more than one process, it can also be related to more than one decision domain. Resource R1 in Figure 3 is, for example, related to both process U1 and process D2. Process U1 may be forecast-driven and process D2 customer-order-driven wherefore they are classified differently in terms of the DC flow driving. But, since both these processes are performed by the same resource, the capacity of the resource is required by both forecast-driven and customer-order-driven processes. As Figure 3 shows, a decision domain is here illustrated by a rectangle with rounded corners and with black text on grey background. Processes are depicted with traditional arrows, resources with rectangles with rounded corners and white text on dark background.

4.2. Decision domains and decoupling points

The analysis above defines decision domains as a collecting concept for processes with a specific property in common. The decision domains can be relatively independent of each other in the sense that they can be based on different decision criteria that highlights different process perspectives, such as focusing on credit risk or representing disassembly decisions. From a flow perspective, it is of particular interest to focus on decision criteria that separates the flow into two separate parts. A specific example of this is processes that are customer-order-driven and processes that are forecast-driven. For the DC flow driving, these processes are completely different but still they are connected to the same decision criterion, i.e. what decides that a process is initiated. From a flow perspective these two decision domains can be seen as being in a sequence in the flow and characterized as one upstream decision domain and one downstream decision domain that from a decision perspective are disconnected from each other.

The decision criterion is decisive for the type of property that can be classified as either upstream or downstream. To emphasize this difference, a decoupling point is introduced that indicates that the decoupled decision domains are related to the same decision criterion:

A decoupling point separates decisions that are made under different consistent properties related to a specific decision criterion.

The decision domains are disjunctive in the sense that they represent completely different properties, such as forecast-driven or customer-order-driven, considering the same decision criterion. This relation is depicted in Figure 4 where a general decoupling point is illustrated with an ellipse which symbolically connects the two decision domains of the DC.

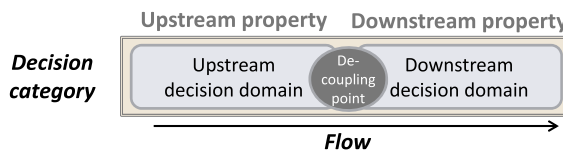


Figure 4. Decision domains with disjunctive properties.

However, in many cases, the decision support is not homogenous and based on only one property at each side of the decoupling point. In some cases, the transition is not instantaneous along the flow, i.e. an upstream property is not changed to a downstream property at one point, but rather can be seen as a gradual transition consisting of a mix of properties from each side of the decoupling point of Figure 4. A process driver may, for example, be a combination of forecast and customer order. This type of mixed properties is here associated with a hybrid decision domain, see Figure 5. It is then logical to model this as three decision domains and consequently two decoupling points for each DC.

Hybrid decision domains represent more complex decision-making where the criterion has mixed properties. In some cases, it can be an advantage to use both decoupling points but this approach also increases the complexity. An alternative is to emphasize only one decoupling point and this is a useful approach when the decision criterion is intrinsically linked to one of the decision domains. A typical example is the flow driver criterion of COBM, which is customer focused and hence the logical place to decouple is upstream of the customer-order-driven decision domain. This domain is customer focused, whereas the other decision domains also have other properties. Since the focus below is on COBM, only decoupling point 1 will be considered and below simply be denoted 'decoupling point'. The mixed properties that the hybrid decision domain relate to represent, from a flow perspective, a transition from the properties valid upstream to the properties valid downstream of the hybrid decision domain. This transition with a hybrid decision domain can be seen as a zone that decouples the two single-property decision domains.

Decoupling points by definition mean, as described above, that different preconditions exist upstream and downstream from the decoupling point. From a material flow perspective, this type of discontinuity corresponds to that the preconditions for the flow changes significantly which leads to disturbances of the flow. Different kinds of buffers are used to reduce the impact of these disturbances. Capacity buffers, related to resources, offer interesting possibilities since they increase the capability to be agile in processes performed to, e.g. customer order or backorders at stock points. A drawback with capacity buffers is however that they do not provide instant reaction but requires a lead-time before a result can be delivered (since the capacity is used to perform some kind of transformation which takes time). The material buffers do not have this drawback since they provide immediate availability of what is demanded even if this type of buffer provides less flexibility since decisions, about what to include in the material buffer, are made before the requirement is identified. In this way, the material buffer is a more lead-time responsive type of buffer that is suitable in relation to decoupling points. The capacity buffer does, however, provide important support downstream from the

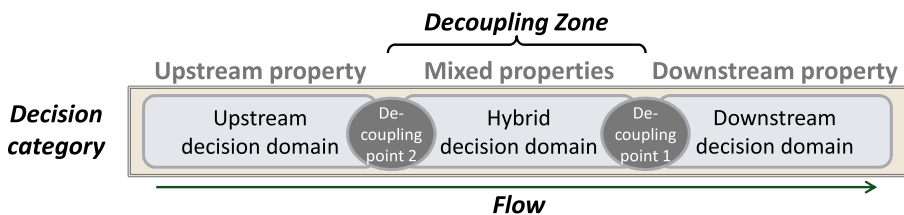


Figure 5. Decision domains and strategic decoupling points.

decoupling point as it enables the resources to be more flexible. The material buffer is here referred as a stock point and later illustrated in the figures by a black triangle pointing downwards representing physical inventory in the flow.

The significance of so-called discontinuities can be reduced, or even eliminated, by introducing decoupling zones that enable a softer transition from the conditions at the upstream decision domain to the conditions at the downstream decision domain. If discontinuities are completely eliminated, there is also no need for a corresponding buffer at a stock point.

4.3. Decision domains and decoupling zones

Decoupling points are positioned at an instantaneous transition along the flow from upstream property to downstream property. This represents a ‘black or white’ scenario which in some cases is too simplistic. The transition may be gradual and hence represents a zone with different ‘shades of grey’ related to the hybrid decision domain as described above.

A decoupling zone covers decisions that are made under mixed properties related to one or more decision criteria.

There are mainly two different perspectives that require these ‘shades of grey’. The first perspective is the gradual transition from upstream property to downstream property and it is here called *process-based decoupling zone* since it exists along one individual flow and corresponds to one single decision domain. The other perspective exists when multiple flows are considered in parallel, from an aggregate perspective, and is in particular related to when one resource is involved across multiple flows at the same time. This scenario has its roots in how resources are positioned in relation to decision domains in Figure 3 and is therefore here referred to as *resource-based decoupling zone* that corresponds to an aggregation of two or more different decision domains.

4.3.1. Process-based decoupling zones

The concept decoupling zone refers to a mix of different properties related to decision domains. In case there is a gradual transition along a flow, a number of attributes related to the property can be affected. The properties can, for example, be associated with uncertainty or certainty concerning customer orders. The certainty can however be based on different types of attributes related to the customer order such as requested delivery date or requested quantity. When deciding on the number of attributes to use, a balance between the complexity of using many attributes and not challenging the relevance of the attributes, by using too few, must be established. In this framework for COBM, two attributes are used for each DC related to a process-based decoupling zone, but from a more general perspective, one or more than two attributes can also be used.

A process-based decoupling zone is based on the gradual transition between two properties of one decision criterion related to one flow.

The process-based decoupling zone (PB-DZ) is in Figure 6 illustrated by a rectangle placed above the hybrid decision domain. The zone is expanded to a two-dimensional surface that represents two attributes that each can take values on a scale from upstream

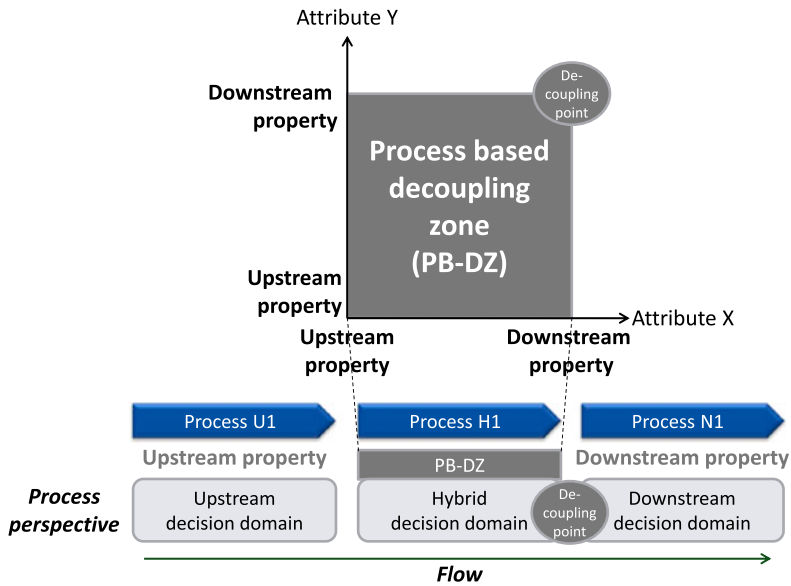


Figure 6. Process-based decoupling zone along one flow.

to downstream property. The end-points (the corners) where the attributes have the same ‘value’ represent the limit of upstream and downstream decision domain, respectively. Based on the definition of decision domain and how it is related to processes means that there are now, at least, three types of processes along the flow; in Figure 6, this is illustrated with the processes U1, H1 and N1. At the beginning of the flow (on the left in the figure), the upstream property is of relevance to decisions. When the flow reaches the PB-DZ, the decision preconditions correspond to the lower left corner of the two-dimensional surface. The flow through the PB-DZ corresponds to that the preconditions change as the value of the two different attributes changes along a trajectory from the lower left corner to the upper right corner of the surface, i.e. when the decoupling point is reached. Thereafter, the downstream property is relevant for decision-making until the end of the flow is reached.

4.3.2. Resource-based decoupling zones

From a resource perspective, it looks different compared to the process perspective since resources can be connected to multiple decision domains with different properties as shown in Figure 3. This multi-property load on a resource is related to resource-based decoupling zones.

A resource-based decoupling zone is based on the intersection between different properties of one decision criteria across one or more flows.

In Figure 7, this is illustrated with the two flows, Flow A and Flow B, where each consists of two processes related to one upstream and one downstream decision domain, respectively, and thus has one decoupling point each. One individual flow is therefore relatively simple from a process perspective with two basic decision domains both based

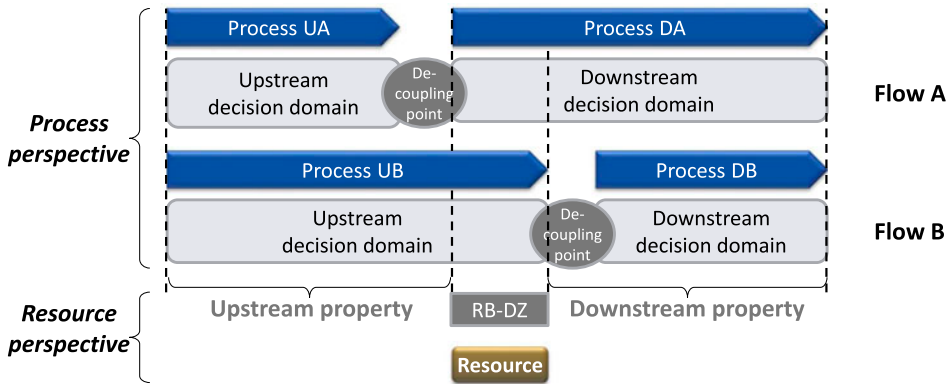


Figure 7. Resource-based decoupling zone across multiple flows.

on the decision criterion in question. In Figure 7, one resource is identified and from the resource's perspective, the situation is more complex since it is involved in process DA and process UB, i.e. two processes that are related to different decision domains with different properties. This type of scenario is here referred to as a resource-based decoupling zone (RB-DZ) and could, for example, mean that some of the load on the resource is forecast-driven (based on UB) and some is customer-order-driven (based on DA). This means that the load analysis becomes considerably more complex compared to when only UA and UB or only DA and DB are involved, where the preconditions would be more homogenous what concerns the actual DC. Note that the assumption is that the same decision criterion is in focus for all processes, i.e. they belong to the same DC. In addition, the individual flows may not contain a process-based decoupling zone but in aggregation a resource-based decoupling zone can be identified. In case the decoupling points of the individual flows are positioned at the same place also, the aggregate would not contain a decoupling zone and the decoupling point could be referred to as a 'resource-based decoupling point'.

The aggregation discussed above is across multiple flows. The corresponding situation can occur in the case of aggregation in time where, for example, weeks are used as time periods rather than days. With a resolution of days, a more detailed analysis can be performed resulting in that resources are either loaded with forecast-driven or customer-order-driven activities. Using the aggregation level of weeks on the other hand might result in a mix of different types of load for a particular resource since the timing of load cannot be determined as exactly as in the case of time periods based on days. Also, resource aggregation may create a similar problem as individual resources are not loaded, but instead groups of resources are loaded. Hence aggregation in terms of flows (i.e. products), time, or resources can generate similar challenges from a capacity requirement perspective.

In summary, the capacity requirement for a resource may be created by seven different combinations of processes related to three different decision domains of one single decision criterion. Note that Figure 7 is based on that each flow consists of two decision domains whereas Table 1 is based on the existence of also a hybrid decision domain, i.e. PB-DZ. In Table 1, these combinations are illustrated and the first three cases (type 1–3) in the table are based on one decision domain each with capacity requirement from

Table 1. The seven different types of capacity requirement.

| | Upstream DD | Hybrid DD | Downstream DD |
|------------------------------|-------------|-----------|---------------|
| Capacity requirements type 1 | X | | |
| Capacity requirements type 2 | | X | |
| Capacity requirements type 3 | | | X |
| Capacity requirements type 4 | X | X | |
| Capacity requirements type 5 | X | | X |
| Capacity requirements type 6 | | X | X |
| Capacity requirements type 7 | X | X | X |

the respective decision domain. Three of the combinations originate in the combination of two types of decision domains. Capacity requirement type 7, finally, is based on three different types of decision domains, i.e. one resource would be used in processes of three different decision domains. The example of Figure 7 can, based on this, be classified as a resource with capacity requirement type 5 since the capacity requirements originate from a upstream DD and a downstream DD.

For both the PB-DZ and the RB-DZ, the ‘length’ of each decision domain is important since it determines the position of both decoupling point and decoupling zone. The decision domain is based on one decision criterion; for example, flow driver, which means that the length of the decision domain and the priority of the chosen decision criterion are different sides of the same coin. The definition of important decision categories for COBM can therefore be based on the identification of important lead-times.

4.4. Positioning of decoupling point and decoupling zone

The extension of decision domains have so far been based on a relative perspective. A decoupling point has been identified that separates the flow into two distinct parts related to one decision domain each. In addition, a hybrid decision domain may be positioned between these two decision domains resulting in a sequence of three decision domains along the flow. Identifying the decision domains is a first step but it is also important to determine the actual extension of each decision domain and as a consequence also the position of the decoupling point and the decoupling zone.

A useful measure for the extension would operationalize the concepts introduced so far. A number of candidates exist for acting as a point of reference such as the physical extension of the flow, organizational properties such as functions involved, or cost aspects related to e.g. resource ownership. It is however important to have a baseline that is absolute in the sense that it is not something that can easily be manipulated to suit different purposes. It should rather be something that can act as a point of reference that is important and transparent to all concerned interest parties. Considering the history of operations and supply chain management, a number of cases have shown that the key resource to manage is time as time lost can never be recovered. In addition, time has also been shown to be a key driver of competitiveness. Henry Ford was one of the first to explicitly highlight time as one of the pillars of his management philosophy (Ford & Crowther, 1988) and time has continued to play a key role in, e.g. Time-based management (Stalk & Hout, 1990), BPR (Hammer & Champy, 1993) and lean thinking (Womack & Jones, 1996). Presently, the main proponent of time as a key resource is probably lean in all its flavours such as lean thinking, lean production, lean services, lean administration, etc. At the core of all these, lean ‘flavours’ is the continuous

improvement to reduce waste, and waste is basically different incarnations of lost time. For example value stream mapping (Rother & Shook, 1998), the most highlighted part of the analysis is the timeline capturing the total lead-time as well as the value adding and non-value adding time. From a time perspective, the timeline positions the different parts of the value stream in relation to the customer, i.e. the end-point of the value stream.

The decision criterion and the related decision domains provide a conceptual division of the flow from a decision perspective. The decision in itself and what it involves are important to define the decision situation, but the timing of the decision is absolutely critical in defining the preconditions for the decision-maker. The timing is defined in relation to when the result of the sub-flow, corresponding to the decision domain, is required. With this as a point of departure, three lead-times can be defined as of Figure 8, related to one decision domain each: upstream (US), hybrid (H), and downstream (DS). Accumulating these lead-times the total lead-time for the flow i (F_i) is obtained, where: $FLT_i = USLT_i + HLT_i + DSLT_i$. The decoupling zone highlighted here is related to a decision domain and hence of type PB-DZ. The RB-DZ can be positioned in a similar way based on that the decoupling zone is related to an intersection of a set of flows. $DSL T$ would in this case correspond to $DSL T = \min_{i \in Flows} \{DSL T_i\}$ where $Flows$ is the set of all flows where the resource is involved. In a corresponding way the lead-time of the RB-DZ can be defined as: $HLT = \max_{i \in Flows} \{HLT_i + DSL T_i\} - DSL T$. $USLT$ can then finally be defined as: $USLT = \max_{i \in Flows} \{FLT_i\} - HLT - DSL T$.

Based on the argument earlier, where the second decoupling point was considered as of less interest, the decoupling point upstream of the hybrid decision domain is not analysed further. The positioning of the decoupling point is hence based on the lead-time of the downstream decision domain, $DSL T$, in relation to a reference lead-time such as the total flow lead-time, FLT . The position of the decoupling point can hence be expressed in two different ways:

- The lead-time $DSL T$, which is useful in e.g. analysis based on the time-phased bill-of-material to calculate the position of the decoupling point. This is the ‘absolute’ lead-time expressed in suitable time units.
- The ‘relative’ lead-time results in a percentage and expresses how long a lead-time is in relation to a ‘benchmark’ lead-time and in particular we are interested in the fraction of the benchmark lead-time that is related to downstream property. For positioning of the decoupling point the key lead-time is the relation between the lead-times $DSL T$ and FLT , which is called the $DSL T:FLT$ relation. If $DSL T:FLT = 1$ then the decoupling point is at the beginning of the flow. If $DSL T:FLT \ll 1$

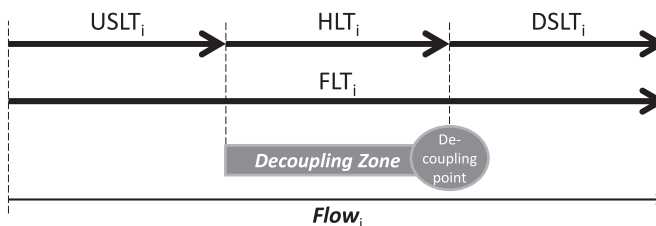


Figure 8. Decision domains and lead-times.

(or $DSL:FLT = 0$) then the decoupling point is at the end of the flow and finally if $DSL:FLT < 1$ the decoupling point is positioned within the flow.

The ‘relative’ lead-time is measured in relation to a reference value and is thus of more practical use in COBM. From a general perspective it can be defined as:

A *lead-time relation* is a ratio of two strategic lead-times.

Positioning of the decoupling point also provides information about the extension of the upstream and the downstream decision domains in case there is no hybrid decision domain. If also a hybrid decision domain is present additional lead-time analysis is required to position also this decision domain. This additional analysis can be based on either USLT or HLT. Once the decoupling point and decoupling zones are positioned, the different decision categories can be combined resulting in compounded decision domains.

4.5. Compounded decision domains

In an actual decision situation, multiple decision criteria may be important to consider at the same time. Still each decision criterion can be defined separately as in Figure 9 where this is illustrated on the left side with decision criteria 1 and 2. In most cases, the different decision criteria are independent of each other and capturing different aspects of the challenges facing the decision-maker. Therefore the two decision criteria may be modelled as two separate dimensions as shown on the right of Figure 9. The resulting four decision domains are referred to as compounded decision domains (CDD):

A *compounded decision domain* covers the intersection of two decision domains related to two separate decision criteria.

Each CDD is a combination of upstream (U) and/or downstream (D) decision domains based on decision criteria 1 or 2. For example, D1, D2 is a CDD where the decision criterion is a combination of decision criteria D1 and D2. Depending on the actual decision criteria used some of the combinations might not be possible, or at least not competitive, and hence a strategy for that CDD might not be necessary. However, from a generic point of view all CDDs are assumed to be valid and hence all possible CDDs are included.

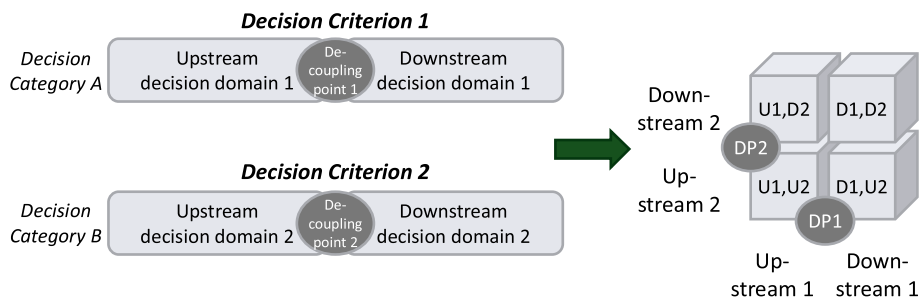


Figure 9. Example of compounded decision domains.

The CDDs add complexity since they introduce a multi-dimensional perspective on decision domains. The example in Figure 9 is based on two flows with decoupling points only. By also including decoupling zones there are some more challenging issues to consider.

4.5.1. *Compounded decision domains and process-based decoupling zones*

The concept of CDD can easily be expanded to also include hybrid decision domains and PB-DZs. The example of Figure 9 represents the possible combinations when no hybrid decision domains are included. By allowing hybrid decision domains each dimension would be extended to three blocks and in total nine CDDs would be included on the right in Figure 9. This scenario, with nine CDDs, is somewhat similar to the analysis of the resource-based decoupling zone of Table 1 (with seven possible combinations). It is however important to note that in this case the two dimensions are based on different criteria whereas in Table 1 the two dimensions were based on the same criterion. Since the CDD here is based on two criteria the type 7 case cannot occur and the criteria are different for types 4–6 which means that it would result in another three types (for example, U1, D2 does not correspond to D1,U2 when different criteria are used). In summary there would be four CDDs only involving upstream and downstream decision domains and an additional five that include at least one hybrid decision domain. This would result in three decision domains in each dimension of Figure 9 and, consequently, in total nine different CDDs (cf. Figure 16 for an example).

4.5.2. *Compounded decision domains and resource-based decoupling zones*

The CDDs creates additional complexity in terms of RB-DZs since the number of possible combinations increases significantly. The example of Figure 7 resulted in one additional scenario (totally three) compared to when one flow was analysed. The number of possible combinations of decision domains, $C(\text{Number of flows, Number of decision domains per flow})$ affecting a resource when each flow can be divided into n different decision domains is a combinatorial problem. For the case in Figure 7, which is based on that the decision domains belong to the same DC, the number of combinations would be: $C_{\text{One DC}}(2, 2) = 2 + 1 = 3$ different combinations of decision domains. In case each flow would contain a hybrid decision domain the number of combinations would be: $C_{\text{One DC}}(2, 3) = 3 + 3 + 1 = 7$ different combinations (as shown in Table 1). When the CDDs are introduced the possible combinations for a resource to be involved in more than one decision domain increases dramatically for RB-DZs. Consider, for example, the case introduced above in Figure 9 with two dimensions and two decision domains in each dimension resulting in a total of four CDDs. One case could be that a resource is acting in the CDD U1, U2 for one flow and the CDD D1, D2 in the other flow. By definition the RB-DZ is related to when a resource is involved in two CDDs of different properties which means that if a resource is involved in CDD U1, U2 of two different flows it is not defined as a RB-DZ. For this case with two flows with four CDDs each there are a total of $C_{\text{Two DCs}}(2, 4) = 12$ possible combinations. Introducing PB-DZs in each flow of course increases the complexity further and the number of combinations fast becomes hard to manage. It is therefore important to identify the critical intersections and to exclude the less important from the analysis.

4.6. Summary of framework for flow based decision-making

The generic framework for decoupling points and decoupling zones provides the means for identifying some key decision categories related to supply chain and operations management. In summary, the generic framework for flow based decision-making contains ten key concepts (which have been explicitly defined above):

- (1) *Logical entities* are the platform for decisions on flow based management.
- (2) *Flow* provides the point of reference for identifying lead-time based decision categories.
- (3) *Decision categories* are defined based on decision criteria.
- (4) *Decision criteria* are used to define decision domains within a decision category.
- (5) *Decision domains* for the same decision criteria are separated by decoupling points.
- (6) *Decoupling points* are positioned at the interface between two decision domains.
- (7) *Decoupling zones* correspond to mixed properties in a decoupling point scenario.
- (8) *Process-based or resource-based* perspective can be applied on decoupling zones.
- (9) *Lead-time relations* position decoupling points/zones and decision domains.
- (10) *Compounded decision domains* reflect the complexity of an actual decision problem.

The generic framework with these ten key concepts is next used to define three lead-time relations and thereafter four decision categories for COBM.

5. Lead-time based flow analysis

Lead-time analysis is used in different contexts to e.g. reduce lead-times, identify wastes or simply to identify the magnitude of the lead-times. This type of lead-time analysis can be categorized as ‘absolute’ lead-time analysis since focus is on the length of the lead-times. It is however ‘relative’ lead-time analysis that is of main interest as an indicator of positioning of decoupling points and decoupling zones since it involves the relation between different lead-times. Before these lead-time relations can be defined it is necessary to identify the key ‘strategic’ lead-times.

5.1. Lead-time definitions

Balancing the requirements and availability of material and capacity of operations are important challenges in logistics flow. Common to these challenges is that timing is of critical importance. The relationship between available capacity and capacity requirements should be investigated with respect to a timeline and also the balancing of demand and supply of materials requires a time-phased approach (however less significant in a rate-based context). The comprehension of lead-times and how they should be managed is therefore of utmost importance to enterprise management.

The standard item lead-times (L) are fundamental, but even more important from a competitiveness perspective are the five strategic lead-times (Wikner, 2011). From a

supply perspective the cumulative lead-time (Blackstone, 2008) is critical since it represents the lead-time of the product including all items. The cumulative lead-time is then split in two parts representing items provided by the logical entity in focus (internal lead-time) and items provided by the upstream logical entities (external lead-time). Another key aspect is the level of possible customization involved and this is here referred to as adapt from a supply perspective. Customization is based on customer requirements and adapt may hence also be seen as based on customer requirements from a demand perspective. Finally, a key aspect from a customer perspective is also the requested delivery lead-time as it also frequently defines a key characteristic of the order winners.

Five strategic lead-times (referred to as SEIAD based on their variable names) are investigated here and further elaborated on below:

- Supply lead-time (S) is the cumulative lead-time for the product through the whole (extended) logical entity.
- External lead-time (E) can in many cases be seen as related to the (purchased) component and is therefore usually associated with purchase orders.
- Internal lead-time (I) corresponds to the controllable part of the bill-of-material and is usually associated with the own provisioning lead-time.
- Adapt lead-time (A) is related to the customer order but based on when the supply performed is actually customer order unique. The possible level of customization is related to a supply perspective (A_S) and the requested level of customization is related to a demand perspective (A_D). This lead-time could also be referred to as the customization lead-time but to avoid confusion with different types of customization strategies the more neutral term adapt is used. The adapt lead-time is important in e.g. the context of mass customization but it is also a key component in other cases such as e.g. postponement strategies.
- Delivery lead-time (D) is based on market requirements for delivery and directly associated with demand/customer order.

5.2. *Example: lead-times and time-phasing*

The different types of lead-times defined above are related to each other and a simple example is introduced as an illustration of the theory. Some of the concepts introduced here have also been applied on actual cases (Bäckstrand et al., 2013) but in general, actual bill-of-material that can be used as an illustration of several concepts are rather complex. The sheer complexity of the bill-of-material in these cases and their area of application diverge the focus from the illustration of the concepts. The example introduced below is therefore fictitious and designed to be simple but still sufficient to illustrate the key concepts used here. The example is shown in Figure 10 in terms of a traditional material based bill-of-material (product structure) to the left and a time-phased bill-of-material to the right (see e.g. Bäckstrand & Wikner, 2013; Clark, 1979; Wikner & Rudberg, 2005b). The material based bill-of-material includes where-used relations and lead-times. For example, item Y consists of item X and item U , and item Y has a lead-time (L_Y) of 3 periods. On the right in Figure 10 this bill-of-material is instead represented by a time-phased bill-of-material where the horizontal distance between two filled circles corresponds to each item's lead-time (L). In this case the supply lead-time $S=12$ periods (the cumulative lead-time for the bill-of-material) and

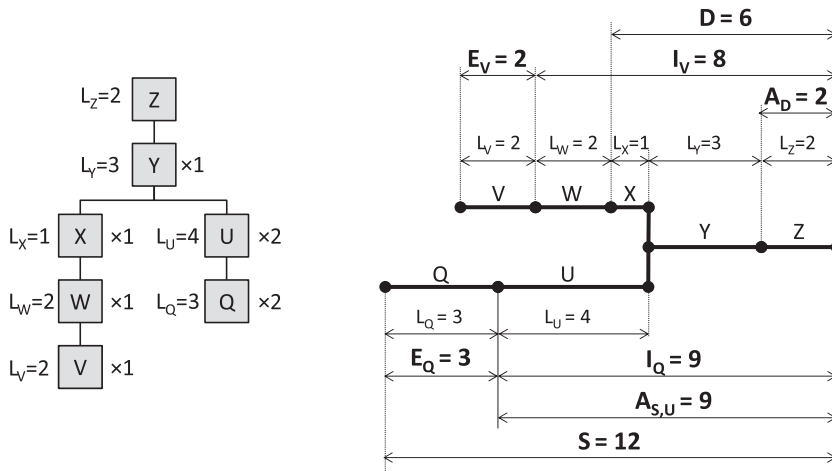


Figure 10. Example: Material-based and lead-time-based bill-of-materials.

the delivery lead-time to the customer is given as $D = 6$ periods. (The estimation of the delivery lead-time D will be more elaborated on later, see e.g. Figure 18). Since it is the adaptation of Z that constitutes a customer order unique solution, the demand adapts lead-time $A_D = 2$ periods and Y is customer unique. From an engineering and production perspective it would be possible to also make item U customer order unique which means that the supply adapt lead-time $A_{S,U} = 9$ periods. The items V and Q , finally, are purchased in a traditional way from suppliers. These two items represent the end of two branches with an external lead-time (E). An internal lead-time (I) can then be calculated for each branch of the bill-of-material. The set Leaf is assumed to contain all N items that are at the lowest level of each branch and would in many cases correspond to purchase items. In the example of Figure 10 it would mean that $N = 2$ and $\text{Leaf} = \{V, Q\}$. For the branch of item V the cumulative lead-time is $S_V = E_V + I_V = 2 + 8$ and for item Q the cumulative lead-time is $S_Q = E_Q + I_Q = 3 + 9$. The branch with the longest cumulative lead-time is also equal to the supply lead-time $S = \max_{n \in \text{Leaf}} \{S_n = E_n + I_n\}$. A more elaborate analysis can also be performed where a S is defined for each item in the bill-of-material (Bäckstrand & Wikner, 2013). This approach provides the opportunity to identify for each item if it is within D and can be customer-order-driven, or if it is longer than D and must be forecast-driven.

5.3. Lead-time context

If only one branch of the product structure in Figure 10 is considered, a network without different branches is obtained and this can be labelled as a ‘linear’ chain. Using the terminology introduced above the chain may be referred to as consisting of two logical entities, one focal entity (‘focal’ refers to the unit that is in focus for the analysis) and one supplying entity, i.e. two logical entities in sequence and with an implicit entity represented by a customer. The context of this analysis is therefore a triad consisting of a customer entity and two logical entities representing the supply. Each one of the logical entities can be illustrated with the entity’s strategic lead-times SEIAD resulting in

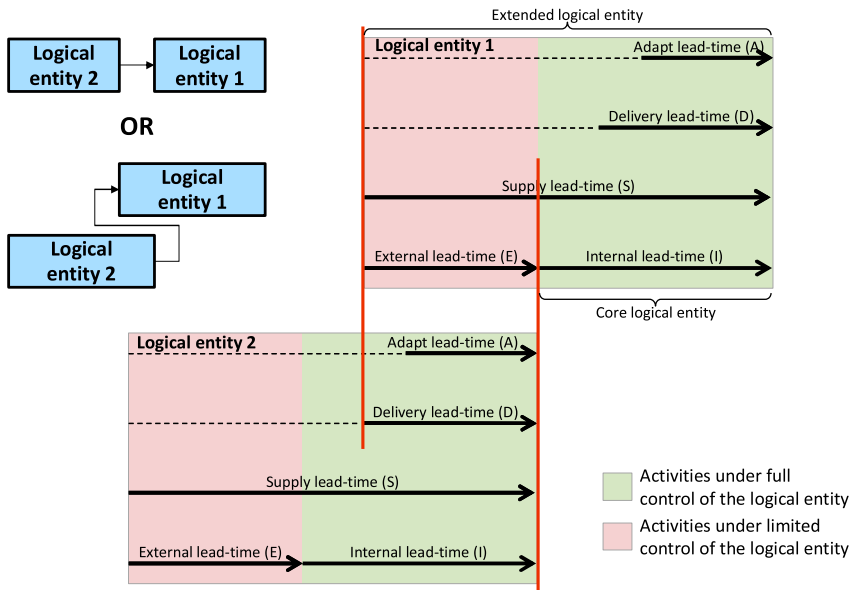


Figure 11. Dyad of two logical entities with no integration.

Figure 11. Logical entity 1 would then correspond to all activities required to supply with item *Z* in the example of Figure 10, i.e. the focal entity. Logical entity 2 is related to the supply of item *V* or *Q* (since $E + I = S$ in logical entity 1). These items may in turn consist of other items but that is not shown in the example but covered by other structures within the supplying logical entity (logical entity 2). The green part on the right of each logical entity represents the part of the flow that is controllable for the logical entity and the red part on the left represents the part that is not controllable for the logical entity. As shown in Figure 11 there is an overlap between the entities but in the overlap only one logical entity has the ability to control the activities (logical entity 2 in the overlap in Figure 11). This assumption is relaxed later in section 6.3.2. This type of overlap is illustrated in Figure 11 on the top left of the figure where two logical entities are in sequence with some overlap. The top entity-dyad illustrates in this way the core logical entities (green segment) while the lower entity-dyad illustrates the extended logical entity (which corresponds what is referred as a logical entity in the text unless otherwise stated).

The external lead-time (*E*) for logical entity 1 corresponds to the lead-time for a purchase order, e.g. for item *V* or item *Q* in Figure 10. From the supplying entity’s perspective (logical entity 2) it corresponds to the delivery lead-time (*D*) for a customer order. Hence, this is also an illustration of how a purchase order of the focal company is connected to a customer order at the supplier.

The strategic lead-times thus represent a link between different logical entities as exemplified by *E* for logical entity 1 and *D* for logical entity 2. Within each logical entity a number of important lead-time relations can be identified. In particular three lead-time relations are of key important to identify decision categories for COBM and related strategic choices in terms of positioning of decoupling points and decoupling zones.

Table 2. Lead-time relations.

| | S | E | I | A | D |
|----------|-------------------|----------|----------|----------|-------------------|
| S | - | n/a | × | × | × |
| E | n/a | - | n/a | n/a | n/a |
| I | <i>I:S</i> | n/a | - | × | × |
| A | A:S | n/a | A:I | - | <i>A:D</i> |
| D | <i>D:S</i> | n/a | D:I | × | - |

5.4. Lead-time relations

Five different strategic lead-times were identified above and referred to as SEIAD. In total 20 different lead-time relations, between two different lead-times, can be identified based on SEIAD as shown in Table 2 (based on Bäckstrand, 2012) (excluding the relation between lead-times of the same type, i.e. the diagonal of Table 2). There are some overlaps between these lead-times when a supply network is investigated since the delivery lead-time *D* for a supplier corresponds to the external lead-time *E* for that item at the customer. Note, however, that the analysis performed here is based on one logical entity. Since the focus here is on COBM the emphasis is on customer facing lead-times (see Figure 11), i.e. *A*, *D*, *S*, and *I* (lead-time relations related to *E* are therefore indicated with *n/a* in Table 2 and since $S = E + I$, the *E*-based relations may be derived based on *I*-based relations if necessary). The lead-time relations above the diagonal are the inverse of the lead-time relations below the diagonal and only one relation of each ‘pair’ is included. As a general rule the relation where we normally would expect the smaller value in the numerator is included and the other is indicated by a ‘×’ in Table 2. In total there are hence six potential lead-time relations left to investigate: *D:S*, *A:D*, *I:S*, *A:I*, *A:S*, and *D:I*.

In a lead-time relation one lead-time is used as a point of reference and the relation then shows how long the other lead-time is in relation to the reference lead-time. The lead-time relations further investigated are mainly related to *D* since the delivery lead-time *D* is the fundamental lead-time from customers’ perspective. Note that the *I:S* relation and the *I:A*-relation are multiple relations since there are *N* pieces of *I* lead-times (one for each branch of the bill-of-material) and hence also *N* pieces of *I:S* relations. In case of the *A:I* relations it is even more complex since there may also be multiple *A* lead-times, and in addition *A* may be supply based or demand based. The *A:I* relation could be of some interest as it can be used to analyse if customization affects more than the focal entity. This information is, however, implicitly provided by the *I:S*-relation in combination with the *A:D*-relation when the compounded decision domains are introduced. In a similar fashion the *A:S* relation represents how customization affects supply but it is less exact compared to the *A:I*-relation and is hence not included. The *D:I* relation, finally, could provide some interesting information on if customer-order-driven flow impacts suppliers but this information can also be obtained from compounded decision domains which are described later. The three remaining lead-time relations are of key importance to identify important decision categories for COBM and they are highlighted in Table 2 as bold and italic. As a result there are three lead-time relations that connects the two aspects of supply (*I* and *S*), the two aspects of demand (*A* and *D*, in particular if *A_D* is assumed), and finally the key link between supply and demand (*D* and *S*).

5.4.1. *D:S-relation*

The fundamental lead-time relation is based on the delivery lead-time (D) in relation to the supply lead-time (S). If the customers can accept to wait longer than it takes the supplier to provide the product it becomes possible to perform all provisioning activities at the request of a customer. If, on the other hand, the customer cannot accept to wait the time it takes to perform the activities at least some of these activities must be performed on speculation about future customer orders. This lead-time relation has received relatively large attention in both practical application and literature (Shingō, 1989) (originally published in Japanese in 1981) and is usually seen as the earliest reference on this even if Shingō used the denotation ‘relation of $D:P$ ’. This relation was introduced to a broader audience by Mather (1984) who observed the potential of this concept. Mather did however note that $D:P$ could be mixed up with DP, which at that time was widely used as an acronym for ‘data processing’. To reduce the risk for this confusion he suggested that it would be better to call it the $P:D$ relation (or $P:D$ ratio as Mather called it). Unfortunately the numerical result of the $P:D$ relation does not provide an intuitive sense of how large part of P that is customer-order-driven. Due to this the original relation $D:P$, as defined by Shingō, is used here as a point of departure.

Initially (Shingō, 1989) referred to P as the product lead-time but it has also been associated with production lead-time. Today supply is used as a terminology for all types of activities related to the provisioning of goods and hence S is here used instead of P . Both Shingō (1989) and Mather (1984) used D as an abbreviation for delivery lead-time and this is also used here. Note that D implies that activities within D may be performed to customer order. It is, however, not a requirement but should be seen as an ‘option’ to provide to customer order. If the products are standardized and delivered frequently the activities may also be performed on speculation with reasonable risk taking. This option is sometimes not fully used by for instance production engineering reasons where it is suitable to produce a quantity that deviates from an individual customer order. Some standard examples of the $D:S$ -relation are:

- $D \ll S$: Basically all activities must be performed on speculation (corresponds to the strategy Make-to-Stock, MTS).
- $D < S$: Some activities are performed on speculation (corresponds to the strategy Assemble-to-Order, ATO).
- $D \approx S$: All activities can be performed on commitment (corresponds to the strategy Make-to-Order, MTO, Purchase-and-Make-to-Order, PMTO, or Engineer-to-Order, ETO, depending on if engineering activities are included or not).

5.4.2. *A:D-relation*

The relation between adapt lead-time (A) and delivery lead-time (D) is relating two aspects of demand to each other. The distinction made here is based on how large part of D that is actually related to a part of the lead-time that is customer order unique, A . This relation highlights that even if the flow is customer-order-driven it is not necessarily also tailor made for that particular customer. The $D:S$ relation shows what is customer-order-driven and therefore also that there is an ‘option’ for providing something customer order unique. A more detailed approach could also, as mentioned earlier, differentiate if A is what is actually possible from a supply perspective (A_S) or if A is related to what is required by the customer (A_D) (Bäckstrand & Wikner, 2013). From a

supply perspective the different branches of the bill-of-material may provide different opportunities for customization and hence A_s should also be defined for each and every branch of the bill-of-material. In summary A_D represent the market requirements and A_s the opportunities available from a supply perspective. Hence the difference corresponds to the options available for responding to new market requirements due to e.g. increasing competition. In this context A is however assumed to represent the customers' requirements. The $A:D$ relation shows to what extent the provider has decided to exercise the 'option' to provide something customer unique:

- $A \ll D$: Basically all activities are standardized.
- $A = D$: Customer-order-driven activities are also customized.
- $A > D$: Some forecast-driven activities are customer order adapted (a high risk strategy that usually should be avoided).

The connection between customer adaptation and customer-order-driven flow has many facets covering e.g. that it is not necessary for a product to first be completely engineered and then produced. It may also involve, for example, engineering adaptations where some semi-finished goods are in stock when engineering adaptations are made. This can be described as a two dimensional problem where engineering and production activities can be combined in different ways (Wikner & Rudberg, 2005a).

5.4.3. $I:S$ -relation

In contrast to the $D:S$ and $A:D$ relation, which are based on demand, the $I:S$ relation is completely based on the supply side. The internal lead-time (I) represents the lead-time performed within control of the focal logical entity and the supply lead-time (S) represents the cumulative lead-time of the system in question. In the case of traditional relations to the suppliers, where integration is low and purchase order and customer order are the foundation for cooperation, this means that if I is much smaller than S , basically all activities within S are performed by suppliers upstream in the flow. But, the supplier plays a less important role in the supply chain in case the total lead-time S is short and I therefore relatively long. Also here three cases are of particular interest and note that in this case there is a lead-time relation for each 'branch', cf. Figure 10:

- $I_k = S_k$: Basically all activities of the k -branch are performed by the core logical system.
- $I_k < S_k$: Some activities of the k -branch are outsourced to a supplier.
- $I_k \ll S_k$: Basically all activities of the k -branch are outsourced to a supplier (the extended logical entity).

Based on the three lead-time relations defined above it is possible to define and position three decoupling points and three process-based decoupling zones that constitute three decision categories and thus also the core of the flow based framework for COBM.

5.5. Example: Lead-time relations

Going back to the example of Figure 10 a set of lead-time relations can be calculated and used to classify both the whole product and the individual items. In this case the

Table 3. Example: Item-based $D:S$ relations.

| Item (k) | Make/buy | L_k | S_k | $D:S_k$ |
|--------------|----------|-------|-------|-----------|
| Z | Make | 2 | 2 | $6/2 = 3$ |
| Y | Make | 3 | 5 | 1.2 |
| X | Make | 1 | 6 | 1 |
| W | Make | 2 | 8 | 0.75 |
| V | Buy | 2 | 10 | 0.6 |
| U | Make | 3 | 9 | 0.67 |
| Q | Buy | 4 | 12 | 0.5 |

Table 4. Example: classification using item-based $D:S_k$ relations

| Category | Item |
|------------------------------|--------------|
| Requires speculation | W, V, U, Q |
| Possible to speculate on | X |
| Not suitable for speculation | Y, Z |

$D:S$ relation is analysed and in particular the item based $D:S$ relations are analysed. The indented bill-of-material of Table 3, based on Figure 10, includes the item based $D:S$ relations in the rightmost column. S_k is calculated for each item based on the cumulative lead-time for that particular item. For item X the cumulative lead-time $S_X = 2 + 3 + 1 = 6$ periods which is the same as the delivery lead-time according to Figure 10 ($D=6$). Consequently the item based $D:S_k$ relation is one which means that item X can be produced based on customer order.

According to the introduction of the example, item Z is customer order unique and Y is customer unique. Both of these items are within the delivery lead-time which means that they can be produced based on customer order. Since they are unique for the customer they are not suitable for speculation even if recurring customer orders would make it possible to speculate on Y since it is unique for the customer and is hence the same for different customer orders from the customer, The items $W, V, U,$ and Q all have a $D:S_k$ relation < 1 and must be made to forecast and thus requires speculation. Item X finally is interesting since it has a $D:S_k$ relations = 1 indicating that is should be customer order driven but at the same time it is a standard item used for all types of customer. In this case the $D:S_k$ relation should be interpreted as a standard item with an option to produce either to customer order or to forecast, i.e. on speculation. This discussion is summarized in Table 4.

6. Customer-order based management

The different lead-time relations introduced above each represents a way of dividing the flow into two parts with different preconditions. The interface between these two types of flow involves a discontinuity along the flow in the sense that the preconditions change significantly when the flow crosses that point, which also corresponds to the interface between two decision domains. Each one of the lead-time relations identified as important in Table 2 corresponds to such an interface and is of critical importance as decision support for COBM. The three decision categories covered by this analysis are flow driving, flow differentiation and flow delimitation. In addition the DC flow transparency, with a slightly different approach, is introduced below.

6.1. Decision category: flow driving

Flow driving refers to what it is that decides if a process should be initiated or not. In the case of *flow driving*, it is assumed that a high *level of certainty* of the driver is defined from a customer perspective. The decoupling point that separates certain from uncertain flow driving is referred to as the CODP (see e.g. Giesberts & van der Tang, 1992) and based on the *D:S*-relation, see Table 2. Downstream from the CODP demand is certain in terms of a ‘perfect’ customer order where what (in terms of form/place) the customer wants and when the customer wants delivery is determined. The hybrid decision domain here represents that there is some knowledge of what will be demanded but that some information is missing for complete certainty. This domain corresponds to the concept customer order decoupling zone (CODZ), introduced by Wikner & Rudberg (2005b). The starting point of the flow in Figure 12 is Source, which represents what is beyond the extended logical entity, and Sink, which is the end point (usually also corresponding to a customer) of the logical entity.

6.1.1. Customer order decoupling point

The interest in the CODP gained ground when different so called hybrid strategies (see e.g. Sun, Ji, Sun, & Wang, 2008) came into focus. The pure make-to-stock (MTS) and make-to-order (MTO) strategies were employed in different companies, but as customer requested short delivery lead-times in combination with customization the assemble-to-order (ATO) strategy was highlighted (Wemmerlöv, 1984). The ATO strategy can be described as a combination of MTS with MTO where MTS is applied upstream from the CODP and MTO downstream. In this context, the CODP is usually seen as identical to a physical stock point. This material-based approach to decoupling points has a long tradition in the literature. There are a number of ‘local’ publications in e.g. industry magazines in different countries but the two publications usually quoted as the origins of this concept are Hoekstra & Romme (1992), originally published in 1985 in Dutch and Sharman (1984). Sharman referred to the concept as order penetration point (OPP) since it is a measure of how far deep into the supply process (from a lead-time perspective) that the actual customer order penetrates. The CODP has been used in many contexts and is also known as e.g. decoupling point (Hoekstra & Romme, 1992), customer order point (COP) (Mason-Jones & Towill, 1999; Olhager & Östlund, 1990), OPP (Sharman, 1984), supply stream decision point (Hines & Rich, 1997), material

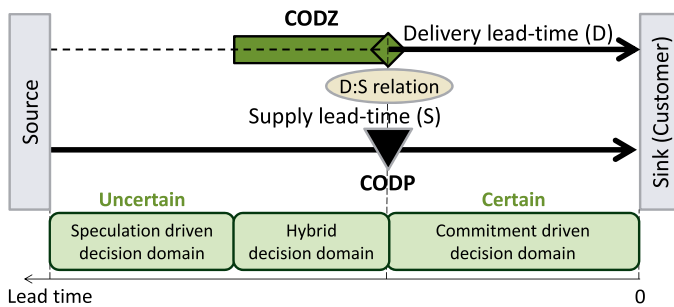


Figure 12. DC for customer-order based management – flow driving.

decoupling point (Mason-Jones & Towill, 1999) and push-pull boundary (Chopra & Meindl, 2004). In the postponement literature, the CODP corresponds to time postponement relating to the time when the customer order actually drives the activities (Pagh & Cooper, 1998). This explicit focus on the physical stock point (see e.g. Banerjee et al., 2011; Sun et al., 2008) as the CODP is the dominant perspective in the literature but here the CODP is first and foremost seen as something related to decision-making in line with Wikner and Rudberg (2005b) and the CODP is therefore defined as:

The *customer order decoupling point (CODP)* separates decisions about initiating flow based on speculation on future customer orders from commitment against actual customer orders.

The CODP is based on the *D:S*-relation, where *D* indicates the part of the flow where the (future) customer's demand is known. In Figure 12, the decision-based aspect of the CODP is indicated with a diamond (quadrangle). The stock point (black triangle in Figure 12) corresponding to the CODP constitutes a buffer between the speculation-driven decision domain and the commitment-driven decision domain. The CODP buffer is thus a safety stock for uncertainty in demand. The material in the CODP buffer is replenished based on speculation (forecast), i.e. an estimation of future demand for materials in the stock point has been done. The commitment-driven withdrawals represent real demand and the dimensioning of the CODP buffer is therefore based on the deviation between forecasted withdrawals and actual withdrawals which is in line with how safety stocks usually are calculated. It is however important to observe that the 'real' demand used in dimensioning should reflect the demand that the commitment-driven process can deliver. If there is capacity to handle variations in demand downstream, the pressure on the material availability in the CODP buffer increases, but if the capacity downstream is not that flexible it is also a constraint for how much the withdrawals can vary. The CODP hence play a critical role in order promising and this is further discussed in e.g. Fleischmann and Meyr (2004); Rudberg and Wikner (2004). Dimensioning of the CODP buffer should therefore be based on the flexibility that the flow downstream from the CODP can offer. Product mix variations can, however, increase demand on the buffer even if the volume is stable. Another interpretation of this scenario is that flow upstream from the CODP is goods based but downstream also can involve services (Fließ & Kleinaltenkamp, 2004). In this context, the CODP has also been called the service decoupling point (Wikner, 2012b).

6.1.2. Customer order decoupling zone

The CODZ involves a mix of uncertainty and certainty about customer orders' timing. Downstream from CODZ the flow is driven by customer orders and upstream from CODZ the flow is driven by a market-based forecast. Within the CODZ, the flow driver is uncertain to some extent depending on either partial customer order information (process-based CODZ) or aggregate capacity requirements for resources where some of the materials are forecast-driven and some are customer-order-driven (resource-based CODZ).

The *customer order decoupling zone (CODZ)* covers decisions about initiating flow based on a compromise of speculation and commitment on customer orders.

For process-based CODZ, the certainty increases along the flow (Wikner & Rudberg, 2005b) and the level of certainty can then be defined by two dimensions based on figure 6:

- Spatial dimension (what?): On a scale from uncertain to certain about what the customer wants (in terms of form and place).
- Temporal dimension (when?): On a scale from uncertainty to certainty of when the customer wants delivery.

Resource-based CODZ is based on that the level of certainty can vary depending on to what extent resources are involved in a combination of speculation-driven and commitment-driven decision domains. This type of CODZ has been noticed in different contexts such as the assortment hybridity (Giesberts & Tang, 1992). The mixed load on resources can be created both as a consequence of that customers with different demand in terms of D purchase the same product and that different products are loading the same resource but with different flow drivers. If the customers request different delivery lead-times, a backlog profile can be created where the resource-based CODZ represents the time horizon where some customer orders are known, but not all, and hence the resources performing the corresponding activities operate under mixed load. This could also be referred to as customer-based CODZ. Correspondingly, different products may create a mixed load on resources which means that the aggregate could be referred to as product-based CODZ. But, for simplicity, both these types of mixed load are associated with the concept resource-based CODZ. In both these cases, there is a challenge in terms of how to schedule the flow on the resources. For example, the forecast-driven flow can generate a levelled first loading and then being complemented with customer-order-driven load, or the customer-order-driven flow may be prioritized and first loaded on the resources and thereafter the forecast-driven flow can be used to level out the load on the resources.

6.2. Decision category: flow differentiation

Flow driving concerns the driver of the process but provides no information about the level of customization involved, which is a separate issue (see e.g. García-Dastugue & Lambert, 2007; Hoekstra & Romme, 1992; Mason-Jones, Naylor, & Towill, 2000; Olhager & Östlund, 1990; Wikner & Wong, 2007). For decisions about customization, the point of departure is *flow differentiation*, which means the *level of uniqueness* in terms of form and place. A completely unique process is adapted for a specific customer order and is limited, from a flow perspective, by the customer adaptation decoupling point (CADP) related to the $A:D$ -relation. Generic processes are upstream from CADP and provide standard products and therefore lack connection to specific customers in terms of form and place at this stage. The customer adaptation decoupling zone (CADZ) corresponds to some degree of adaptation, such as when the flow is customer unique, i.e. the product is customer unique, but not customer order unique, in terms of design (Wikner & Bäckstrand, 2012). The CADZ may hence extend upstream from the CODZ since speculation may be performed even on customer unique materials if the customer orders are recurring. A more comprehensive discussion on these issues, from a customization aspect, can be found in Graca et al. (1999). These concepts are illustrated in Figure 13.

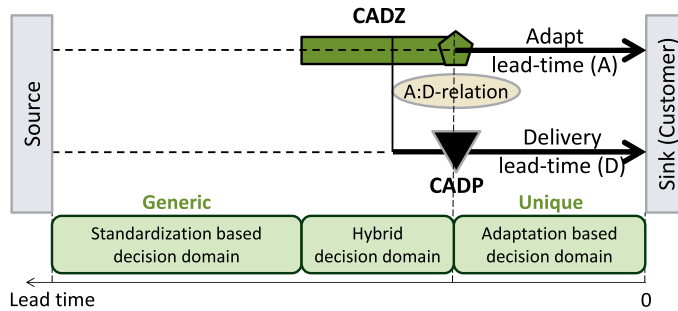


Figure 13. DC for customer-order based management – flow differentiation.

6.2.1. Customer adaptation decoupling point

The CADP is based on the $A:D$ relation (Bäckstrand & Wikner, 2013; Wikner, 2012a) and represents the interface between flow of standard products and customer order adapted products (indicated with a pentagon in Figure 13). As mentioned above, the $A:D$ -relation can be defined from a demand perspective or a supply perspective. When the decoupling point and decoupling zone for customer adaptation are defined, the demand perspective is assumed but in most cases the discussion is equally valid for the supply perspective.

The *customer adaptation decoupling point (CADP)* separates decisions about differentiating flow based on standardization for a market of different customers from adaptation against actual customer orders.

The requirement for a stock point positioned at the CADP is in this case not as obvious as in the case of the CODP. It is, however, important to note that upstream from CADP there is recurring need for the same product which enables some speculation (it is here assumed that CADP is positioned downstream from CODP since it otherwise would result in speculation on customer order unique products, which is not recommended). If it is possible to perform standard activities between the CODP and the CADP to customer order there might be a lot-sizing buffer of standard products positioned at the CADP as a stock point. This can be useful when it is preferable to supply with larger quantities (due to e.g. long set-up time) than the customer order that initiated the batch requires (a lot-sizing method other than lot-for-lot is used). This type of lot-sizing inventory replenishment can also be created in other places upstream from CADP but CADP indicates the last point in the flow where this type of inventory should occur.

6.2.2. Customer adaptation decoupling zone

The CADZ (Wikner & Bäckstrand, 2012) is a hybrid between what is generic from a customer perspective and what is unique from a customer order perspective. This compromise means that the flow is customer unique but not unique for a single customer order. This distinction between what is customer unique and what is customer order unique is in many cases of decisive importance when it is combined with the decision to speculate since it can be a reasonable decision for customer unique products but

basically not for customer order unique products. In general, the CADZ is based on the A:D-relation and can be defined as:

The *customer adaptation decoupling zone* (CADZ) covers decisions about differentiating flow based on a compromise of standardization and adaptation for customer orders.

As indicated in the general decoupling theory, the decoupling zones can be of two types: process-based or resource-based. Adaptation of a product can be performed in many different aspects related to both form properties of product, including the service performed, and the actual location, place, of the product. For process-based CADZ, two key dimensions for flow differentiation can hence be identified in line with Figure 6:

- Form dimension (product): On a scale from generic form (standard product) to unique form (customer order unique product).
- Place dimension (location): On a scale from generic place (e.g. central distribution site) to a unique place (e.g. the customer's site or a specific delivery point/site).

Within the process-based CADZ the product is not completely standard but has some characteristics that only is of interest to some customers which means that the product can be adapted in the meaning customer unique but not customer order unique (Wikner & Bäckstrand, 2012). The CADZ hence provides a more detailed view of customization where one level of customization is product related in the sense that it is unique for a particular customer, whereas customization for a particular customer order is unique for that particular customer order. In some cases, only the form dimension is applied since it could be argued that place is only unique once the product is in the hands of the customer. Unless form and place uniqueness are handled separately, the form uniqueness may then be dominated by the place uniqueness.

For resource-based CADZ, it means that one resource is involved in multiple processes that have different characters in terms of differentiation. This can create a number of challenges from a capability perspective since standard products usually have cost as an order winner, and customer order adapted products usually have order winners related to delivery speed or delivery precision. This of course also affects the loading challenge indirectly since products with focus on delivery precision have other requirements on the process compared to products of standard character which can be kept in inventory.

6.2.3. Product differentiation

Customer adaptation (or customization) as a concept is part of the wider concept of product differentiation since the latter by definition is not explicitly connected to customer demand but covers products in general, including customer generic products. Also for the flow upstream from the CODZ, a number of important decisions may be made related to what in the TOC (see e.g. Blackstone, 2008) are known as control points related to diverging flows which means that one particular material or component may be used for different purposes due to supply-based differentiation. A set of standard components can be assembled to a wide range of products based on forecast and available inventory for each product. Hence, the decision to use the components for a particular product is in this case also resulting in differentiation since different variants could be created by the standard components (see e.g. Hoekstra & Romme, 1992). Note

however that the differentiation in this case is based on supply aspects and not related to a particular customer. The subject can therefore be divided into demand-based and supply-based differentiation:

Demand-based differentiation is based on customer requirements as above, which means that the product (the result from a process) in some sense is customer adapted. The customer unique flow is related to the CADZ in Figure 13 and the customer order unique flow is related to the flow downstream from the CADP.

- Customer adaptation type A: Customer order unique product: Properties are related to requirements that are unique for a specific customer order of one-time character, wherefore the product is difficult, and maybe even impossible, to sell at a later time.
- Customer adaptation type B: Customer unique product: Properties that are related to requirements that are unique for a particular customer but covered by recurring customer orders. This type of products provide some opportunity for speculation since it is a recurring customer.

Supply-based differentiation is independent of specific customer requirements and is therefore only related to customer generic product (standard products). In Figure 13, this corresponds to the flow upstream from the CADZ but may in some instances also be an additional cause of differentiation in the CADZ due to the design of the product in terms of the process-based CADZ or due to mixing different flows in terms of resource-based CADZ. Note that $CADP_S$ represents potential customer-based differentiation, whereas supply-based differentiation is independent of customer requirements. Supply-based differentiation is therefore an important concept, but not in focus for COBM as outlined here.

- Standard products can be sold to a market consisting of multiple customers. Product differentiation in this case is related to that material changes in terms of form or place to be part of different types of customer generic products.

6.3. Decision category: flow delimitation

The third flow-based DC complements the other two in the sense that flow driving is related to why and when a flow is initiated and flow differentiation is related to decisions about the uniqueness of the flow. The remaining issue, according to the analysis of Table 2, is how the flow is managed and this DC is here referred to as *flow delimitation*. This DC is based on the extension of the logical entities and is related to the *I:S*-relation and the *level of finiteness* that can be applied in managing the flow. The decoupling point is defined from a control perspective but is despite this referred to as the purchase order decoupling point (PODP), (Wikner et al., 2009). Since the PODP is related to the *I:S*-relation it is important to remember that since there might be multiple *I:S*-relations, there might correspondingly also be multiple PODPs related to one product (see e.g. Figure 10 with I_V and I_Q). The background to this name is that what is referred to as ‘external’ and ‘uncontrollable’ frequently is also related to suppliers and hence related to purchase orders (note that this is however not necessary). The analogy with CODP and customer order also supports the naming of the decoupling point in the framework. Somewhat simplified, processes performed by the focal company (same as

focal logical entity in this case) can be considered as controllable as only own resources are involved. Processes performed by suppliers can in a corresponding fashion be considered as uncontrollable. In some cases, the customer can control parts of the supplier’s resources (for example, when capacity is ‘purchased’) or depending on divided responsibility so that all the own resources can be controlled as one entity. Correspondingly, a supplier may have influence on some of the customers flow through vendor-managed inventory (VMI), which would move the PODP downstream compared to the situation before VMI was implemented. Wikner and Bäckstrand (2011) provide an overview of different configurations. Since controllability cannot unambiguously be related to customer/supplier interface the controllable decision domain is referred to as ‘Internal’ and the uncontrollable decision domain as ‘External’.

Also in this case, a hybrid decision domain can be identified. Supply of material and capacity can vary between finite and infinite. If material and capacity can be analysed as finite resources there is full controllability but this is not always possible to achieve. The hybrid decision domain, where resources to some extent can be managed as finite, are in Figure 14 represented by the purchase order decoupling zone (PODZ).

6.3.1. Purchase order decoupling point

The PODP is indicated with a hexagon in Figure 14 and is based on the *I:S*-relation. The interface between the decision domains is in this case based on the controllability of the process which means that the PODP can be defined in line with CODP and CADP:

The *purchase order decoupling point (PODP)* separates decisions about delimiting flow based on what is external to the logical entity from what is internal and hence controllable.

The PODP is based on the *I:S* relation and the interface is in this case based on the flow delimitation and therefore also the controllability. Upstream from PODP is another logical entity that ‘owns’ the controllability but downstream the flow is controllable from the focal logical entity’s perspective. Since the flow upstream from the PODP is not controllable for the focal entity, it can also involve some uncertainty considering the supply to the stock point indicated in Figure 14 at the PODP. To handle this uncertainty, either safety lead-time is used, which results in some stock since materials are delivered

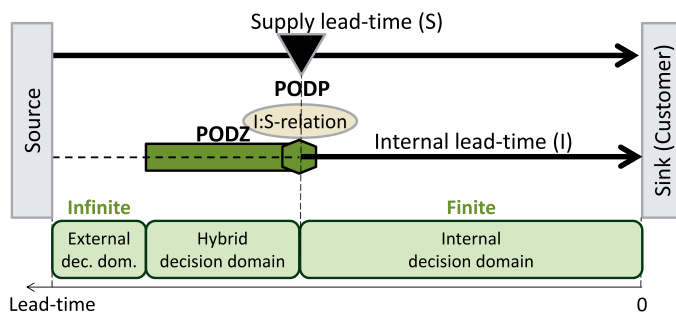


Figure 14. DC for customer-order based management – flow delimitation.

before there is a requirement, or a traditional safety stock is used with a physical quantity. In combination with CODP, the PODP creates different preconditions for supplier interaction (Wikner & Bäckstrand, 2011).

6.3.2. Purchase order decoupling zone

Planning and control of materials flow has traditionally been divided into planning and control for manufacturing and for materials supply (basically purchased materials). This delimitation along the flow is becoming less significant and focus is more and more on creating a holistic and integrated management approach to the whole flow independent of, if it covers one department or multiple integrated actors in a supply network. In this context, the logical entities play a crucial role since they are defined from a management and control perspective. The activities that are included in the core logical entity, see Figure 11, are controllable and finite principles considering resource constraints can be applied. The upstream activities are considered as non-controllable which means that infinite control principles can be applied where a lead-time is given but the availability of resources in terms of materials and capacity is unknown to the core logical entity. The delimitation between these domains is not always that obvious but different degrees of finite can exist, which is also what defines the PODZ.

The *purchase order decoupling zone (PODZ)* covers decisions about delimiting flow based on a compromise on what is external and what is internal to the logical entity.

Two key dimensions for flow control can be identified and they are applied in many contexts related to planning and control. For example, in MRPII, materials are planned using a time-phased approach and then a capacity evaluation is performed based on these plans (Wight, 1984). In rate-based approaches, capacity is usually planned first through e.g. line balancing and then the product mix and required materials are scheduled as needed and replenished using pull systems (see e.g. Duggan, 2012). At an overall level, most techniques for planning and control are emphasizing these two dimensions:

- Material dimension (transformed resources): On a scale from infinite to finite materials and with focus on availability of materials at stock points.
- Capacity dimension (transforming resources): On a scale from infinite to finite capacity and with focus on availability of capacity at resources.

For CODZ and CADZ, it is obvious that there is a process-based and a resource-based variant of the decoupling zone. For PODZ, it is however not as intuitive to identify these two perspectives since resources play such a key part in this DC on controllability. But, also in this case the two types of decoupling zones can be identified.

Process-based PODZ represents a scenario where the possibility to apply finite techniques gradually increases along the flow. In general, it is assumed that the more downstream the more information about the resources is available to the logical entity. It is, for example, possible to apply finite scheduling in the own production (at least in theory, in practice all information might not be available due to e.g. technical reasons) but in the parts that involve suppliers, the information about availability might be limited and the only given information might be the planned lead-times. For the receiving logical entity, it means that the supplier is upstream from PODP and hence classified as

infinite. It could however be that the availability of some of the capacity at the supplier is known and hence it would be possible to consider as finite, which would correspond to being inside a process-based PODZ, where some of the capacity can be finite scheduled or that the capacity can be finite scheduled to some degree.

The resource-based PODZ is an aggregate of multiple flows that consumes the same resource. In most cases, all load would be treated in the same way meaning for instance that if a resource is scheduled using finite capacity all load would have to compete for this capacity using some kind of priority as a base line but when the maximum capacity is reached more capacity is only added as an exception. An example of this scenario is when different customers have different priority. Normally, the resources are finite scheduled but in some cases fast delivery is highest priority and by using, e.g. overtime the extra capacity can be provided to secure delivery reliability. In this way, the resource is managed as finite for some flows/customers and as infinite for other flows/customers.

6.4. Decision domains for customer-order-based management

With flow-based decision-making as a point of departure, three different decision categories have been identified above with support from analysis of lead-time relations. Three different sets of decision domains have been identified together with three decoupling points and related decoupling zones. The four strategic lead-times *S*, *I*, *A*, and *D* have been used to position the decoupling points and therefore also decoupling zones from a flow perspective. To be able to decide the starting point of the zones require further information which either can be based on the first decision domain in the flow or simply the length of the decoupling zones, which is included in Figure 15 as CODZ lead-time, CADZ lead-time or PODZ lead-time. From a planning and control perspective, it can also be observed that the supply lead-time *S* corresponds to the planning time fence (PTF) if master scheduling (Blackstone, 2008) is applied at the level of the delivery object and defines how far into the future that flow is a constraint according to planned lead-times. Note however that sometimes a master schedule is used at lower levels in the flow such as at the CODP, and in this case the PTF would cover the time

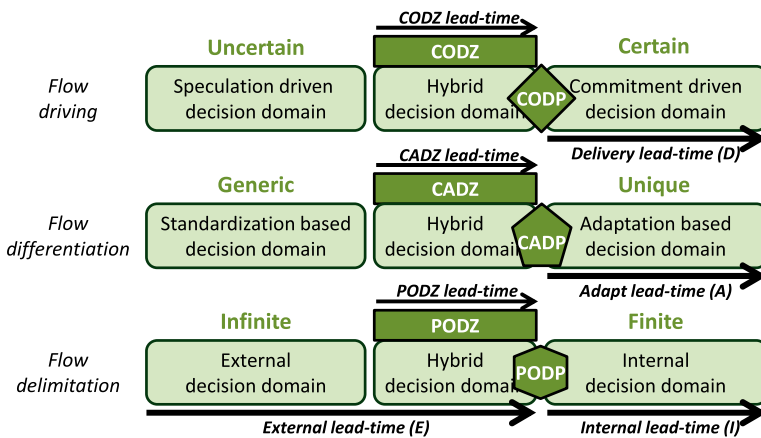


Figure 15. Decision domains for three decoupling points and three decoupling zones.

span from the CODP to the beginning of the flow, i.e. the PTF would at the CODP be set to $PTF = S - D$. If there are several branches in the product structure, such as in the example of Figure 10, PTF is related to the longest branch in terms of lead-time. PTF is also referred to as frozen time fence, since firm planned order is used within PTF. Correspondingly, the demand time fence (DTF) that also can be used for planning and control of delivery objects (Blackstone, 2008) is associated with the CODP since DTF indicates the part of the flow that, from a lead-time perspective, is customer-order-driven with no respect to forecast. DTF is also used in master scheduling. All deliveries within DTF must be related to customer order to make it possible for all customer-order-driven activities to be performed within the delivery lead-time. In case master scheduling is applied at the CODP, the DTF would be positioned at time zero since the master schedule then would be applied in a MTS-scenario.

The three decoupling points and the three decoupling zones can therefore be summarized as:

- CODP: *D:S* relation, safety stock for uncertain demand, DTF.
- CODZ: Process-based: Different levels of certainty between uncertain and certain for the attributes what and when. Resource-based: Mixed load for resources based on forecast-driven and customer-order-driven flows.
- CADP: *A:D* relation, last point in flow with lot-sizing inventory.
- CADZ: Process-based: Different levels of uniqueness between customer generic and customer order unique for the attributes form and place. Resource-based: The same resource is involved with different levels of customization.
- PODP: *I:S* relation, safety stock for uncertain supply.
- PODZ: Process-based: Different levels of controllability between infinite and finite for the attributes material and capacity. Resource-based: Different levels of finiteness are applied to different load-generating activities for the same resource.

Decoupling points thus mean that the preconditions for decision-making can vary depending on which part of the logical entity that is considered. This more sophisticated description of the decision problem is modelled in Figure 15 in terms of three decision categories with three decision domains each. The resource-based decoupling zones are however not explicitly illustrated in Figure 15.

So far the three decision categories have been analysed individually, but in practice a combination of multiple decision categories are usually relevant and the compounded decision domains are suitable to use for this purpose in COBM.

6.5. Compounded decision domains for customer-order-based management

The three decision perspectives related to flow driving, flow differentiation and flow delimitation are important but do not exist in isolation from each other. In some decision situations, one of these could dominate the others which may then be less important and therefore neglected. From a more general perspective, the context of the decision in a specific situation is based on a combination of different decision domains. A flow decision may, for example, be based on a certain requirement (flow driver is a customer order) for a standard product (flow uniqueness is standard in terms of standard product from stock) and own resources are used (flow control can be performed in terms of finite material and finite capacity for delivery from finished goods inventory).

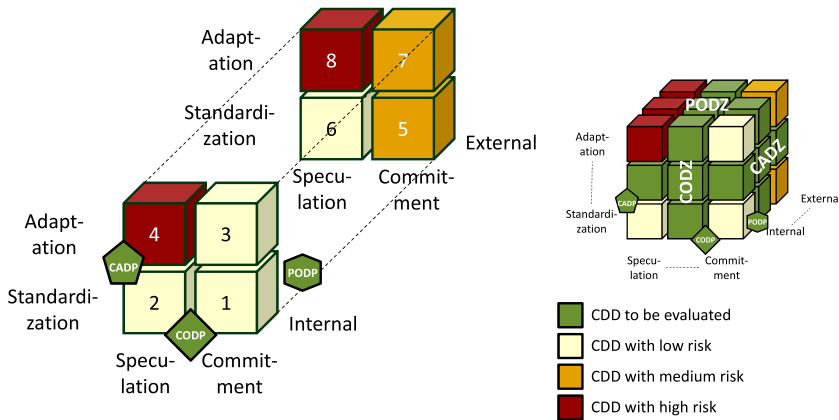


Figure 16. Compounded decision domains.

Since the three different types of decision domains, based on lead-time relations, are not mutually dependent, in terms of what they represent, they can be considered as three separate dimensions as shown in Figure 15. By combining these three dimensions of decision domains, eight compounded decision domains (CDD) can be identified if only decoupling points are included (on the left of Figure 16) or a total of 27 CDD if also decoupling zones are included (on the right of Figure 16). This approach is based on Figure 9. A CDD can be used to identify risk levels for different process configurations. In the case with eight CDD, the CDDs 1, 2, 3 and 6 (as indicated in Figure 16), represent scenarios that are well-established scenarios with relatively low risk. CDDs 5 and 7 represent a slightly higher level of risk when uncontrollable parts of the flow (e.g. a traditional supplier) are involved in the customer-order-driven part of the flow (which also can be customer order unique). CDDs 4 and 8, finally, have high risk since a customer order unique flow is performed on speculation.

To make it easier to reference to individual CDDs in the more complex model with 27 CDDs, to the right in Figure 16, a typology is introduced to be able to refer to one individual CDD where the first dimension (x -axis, to the right) represents flow driving, the second dimension (y -axis, upwards) flow differentiation and the third dimension (z -axis, outwards) flow delimitation. The example above with a certain demand for standard products supplied by own resources would then be represented by CDD (3,1,3), i.e. the cube to the right, furthest down and at the front, which is a CDD with low risk.

The three light yellow CDDs correspond to the standard cases with own production of standard products to forecast (1,1,3) and customer order (3,1,3), respectively, and to make something customized to customer order (3,3,3). The slightly darker CDDs at the back on the right (3,1,1) and (3,3,1) are CDDs with medium risk in the sense that this is about standard products but the supply is performed by resources that are outside the control of the logical entity (e.g. being performed by a supplier). CDDs (1,3,1), (1,3,2) and (1,3,3) are CDDs with high risk since they involve customer order unique production under speculation, which obviously should be avoided. The remaining CDDs include one or more zones and require a more thorough analysis to be evaluated. The present knowledge about these CDDs is simply not so developed in neither the literature nor in practical application. A further complicating factor is that the decoupling zones

can be of two types, i.e. process-based or resource-based. Above the decoupling zones included were process-based. As discussed in the section on CDDs and RB-DZs, the complexity would increase even further if RB-DZs were included since intersections of the 27 different CDDs would then be involved.

6.6. Decision category: flow transparency

The lead-time-based decoupling points define different decision categories in terms of decision domains as outlined above. A complementary type of DC is based on the sharing of information. This type of decoupling point does not define the decision situation or how the information may be used but indicates if a specific type of information is available as decision support. If there is a need for information that the owner of the information cannot, or does not want to, share this is indicated in the flow by an information-based decoupling point. From a flow perspective, there are in particular two types of information that are in focus: information about demand and information about supply.

Sharing of demand information upstream in the flow is sometimes associated with sharing sales information such as point-of-sales data. From a more general perspective, all types of sales information are involved related to, e.g. customer orders, direct sales, delivery schedules and call-offs. The sharing of demand information upstream is limited by the demand information decoupling point (DIDP), which corresponds to information decoupling point according to Mason-Jones and Towill (1999). The DIDP should be positioned upstream from the CODZ, or upstream from the CODP if no CODZ is present (Olhager, Selldin, & Wikner, 2006), as shown in Figure 17.

The demand information decoupling point (DIDP) constrains the transparency upstream of demand information.

If DIDP was positioned downstream from the CODP, it would mean that parts of the customer-order-driven flow would not have access to information about the customer order which would obviously be problematic. This could, however, occur if the CODP is positioned at a supplier who is not allowed to take part of the customer order information directly but only after it has been ‘filtered’ by the logical entity in direct contact with the customer. Considering also the CODZ, the DIDP should be positioned upstream of CODZ, if it is included in the analysis, since the CODZ indicate that some

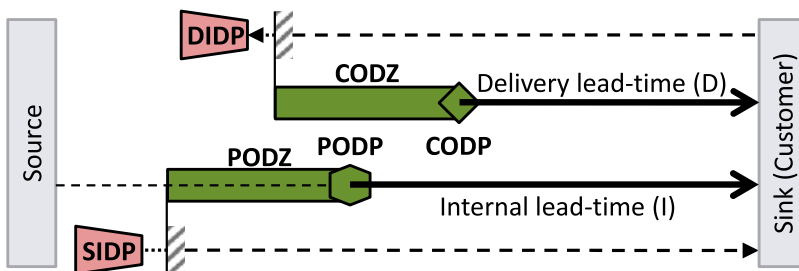


Figure 17. DC for customer-order-based management – flow transparency.

of the process driving is based on customer order. DIDP therefore highlights the interface between the part of the flow where all requested demand information is available and the part where different types of filter have been applied to the demand information.

Sharing of supply information downstream, i.e. downstream units having access to information of an upstream state, in the flow, enables for decision-makers to have information available regarding supply resources, such as available capacity and/or the usage of capacity. The will to share information may also in this case be limited. The user requesting the information is sometimes not allowed to take part of it and this constraint in information sharing is indicated by the supply information decoupling point (SIDP), see Figure 17.

The *supply information decoupling point (SIDP)* constrains the transparency downstream of supply information

Since PODP marks a limit in the flow what concerns the possibility to control the flow, it also means that SIDP cannot be positioned downstream from PODP as indicated in Figure 17. If PODZ is also considered, the SIDP should be positioned upstream of PODZ since the PODZ indicates that some information on availability is required. Also note that since the general case can consist of multiple PODPs there would also be corresponding multiple SIDPs.

In both the case with demand information and the case with supply information, it is about the availability of information. The actual use of information is instead related to the decision domains or CDDs in combination with resource-based decoupling zones.

6.7. Example: decision categories

A fictitious product Z was introduced in Figure 10 in terms of a time-phased bill-of-material. Strategic lead-times were identified for the product and later some of the lead-time relations were analysed, see e.g. Table 3. Continuing on this example, some aspects of COBM can be illustrated. As a first step, a representative order book is assembled. In this example, the representative order book consists of 15 customer orders. The order book is sorted according to the requested delivery lead-time and illustrated as a time-phased order book in Figure 18. An alternative would be to use the promised delivery lead-time but to actually reflect the market requirements the requested delivery lead-time is preferable. The customer orders are positioned horizontally, where the requested delivery lead-time corresponds to the orange part at the right of each bar. The delivery lead-times vary between 6 periods and 10 periods. Consequently, all activities during the last 6 periods of the supply lead-time can be customer-order-driven and the CODP is positioned at $D=6$ periods. During the time from 6 periods to 10 periods before delivery, the activities can be based on a compromise of forecast and actual customer orders. This corresponds to a resource-based CODZ which extends from the CODP and $10-6=4$ periods upstream. Production of V , W and U may hence be produced/purchased based on a combination of forecast and customer orders.

Product Z is customized for individual customer orders at the last stage which means that $CADP_D$ is positioned two periods upstream. In addition, Y is unique for different customers which means that a $CADZ_D$ is positioned across the item Y . Items V and Q are purchased items, which here corresponds to the respective PODP since the product is assumed to be produced in one logical entity. The information about the activities

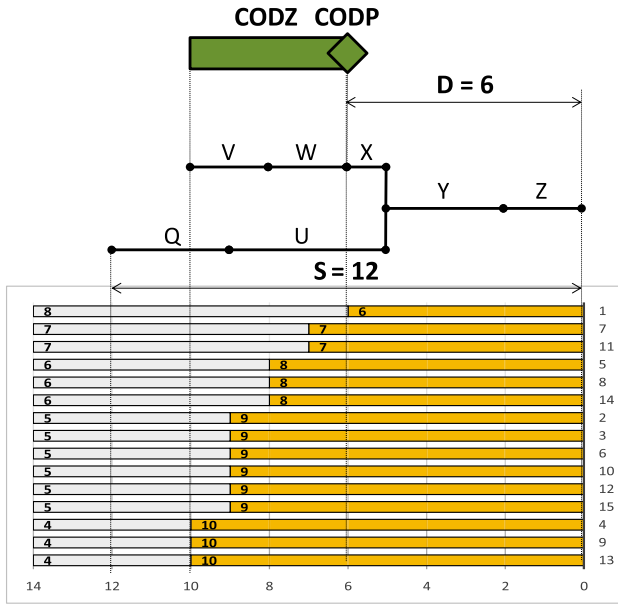


Figure 18. Example: the time-phased bill-of-material in relation to the time-phased order book.

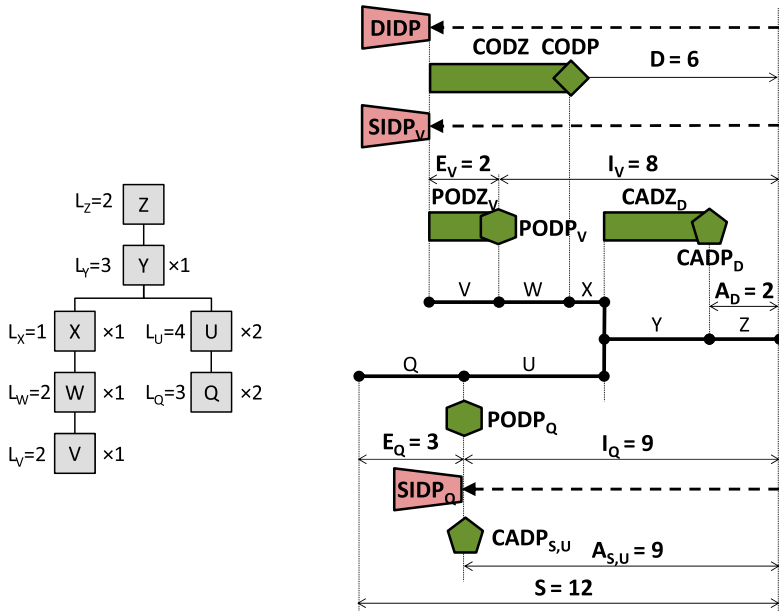


Figure 19. Example: the time-phased bill-of-material with decoupling points and decoupling zones.

and resource load at the supplier of Q is limited, wherefore the $SIDP_Q$ is positioned at the $PODP_Q$. The supplier of V provides load information but still is independent, wherefore this supplier is positioned within $PODZ_V$. Demand information (i.e. point of sales

Table 5. Example: CDD classification of the items (columns ordered in line with Figure 20).

| Item (<i>i</i>) | Driving | Differentiat. | Delimitation | CDD | SIDP | DIDP |
|-------------------|----------------|----------------|--------------|---------|------|------|
| <i>Z</i> | Customer order | Customer order | Internal | (3,3,3) | DS | DS |
| <i>Y</i> | Customer order | CADZ | Internal | (3,2,3) | DS | DS |
| <i>X</i> | Customer order | Standard | Internal | (3,1,3) | DS | DS |
| <i>W</i> | CODZ | Standard | Internal | (2,1,3) | DS | DS |
| <i>V</i> | CODZ | Standard | PODZ | (2,1,2) | DS | DS |
| <i>U</i> | CODZ | Standard | Internal | (2,1,3) | DS | DS |
| <i>Q</i> | Forecast | Standard | External | (1,1,1) | US | US |

data) is provided to the supplier of *V* which is indicated by the position of DIDP which is upstream from *V*. The supplier of *Q* does however not receive demand information as the DIDP is positioned downstream from the supplier. In this case, only one DIDP is used but in some cases it might be necessary to have multiple DIDP depending on how the provision of demand information is differentiated between different suppliers. Using the notation introduced above, the example could be illustrated as in Figure 19.

At this stage, it is also possible to categorize all items according to CDDs. Based on Figure 19, each item can be categorized in relation to the decoupling points as shown in Table 5. Item *Y* for instance is positioned downstream from the CODP and is hence customer order driven. It is also customer unique which corresponds to a position within the CADZ and finally it is manufactured and downstream of the PODPs which correspond to internal supply. In summary, this corresponds to CDD (3,2,3). It is important to note that each item is classified based on the most upstream position of the item and how it is related to the decoupling points. Finally, the information decoupling points are included in the two columns on the right. Each item is then categorized as being upstream (US) or downstream (DS) in relation to SIDPs and DIDP.

7. Framework for customer-order-based management

Decision categories with decision domains related to lead-time relations and also decoupling points and decoupling zones are the core elements of the framework for COBM. This type of components of a strategy framework is usually referred to as the *content* (Leong, Snyder, & Ward, 1990). To operationalize the content, it is necessary to identify how the content is supposed to be applied and this is usually referred to as the work process or simply *process*.

7.1. COBM framework: content

The framework’s different decision categories, i.e. its content, have been defined and exemplified above. Figure 20 summarizes the most important elements of the four decision categories. Three of the decision categories in Figure 20 are decision based and of similar structure. The DC Flow transparency is of information character and has in this way a more supportive function, but nevertheless it is covering decisions about level of transparency and hence also about positioning of two decoupling points. Flow transparency is also absolute in the sense that it is based on lead-times, whereas the other decision categories are relative since they are based on lead-time relations.

The four decision categories of Figure 20 represent the core aspects of the COBM framework as it is defined here. The purpose of the approach is to highlight that by

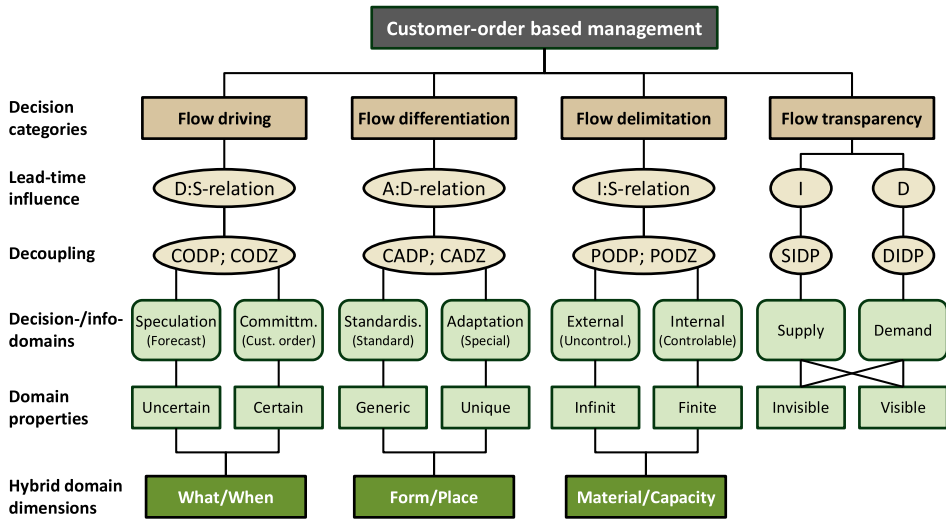


Figure 20. Key content in the framework for customer-order-based management.

identifying the different decision domains, positioning decoupling points and decoupling zones, and consequently identifying the CDDs, an appropriate approach to flow management can be outlined. The procedure for applying this type of approach is then referred to as the process of the framework.

7.2. COBM framework: process

A complete process for analysing COBM is relatively comprehensive with a large number of alternative activities depending on the specific circumstance in the particular case. The processes below are only outlined to provide the general idea and are based on Wikner (2012a). A more comprehensive process for supplier interaction applied in industrial cases is presented in (Bäckstrand, 2012; Bäckstrand et al., 2013). There are mainly two scenarios that are of interest and they are based on the analysis of a present state and the design of a future state, respectively. In both cases, the point of departure is usually the analysis of one product family, i.e. one value stream, at a time.

7.2.1. Analysing a present state

When analysing a present state, the objective is usually to investigate if the used control model is suitable for the present preconditions. The process can be summarized in seven steps:

- (1) Identify the strategic lead-times S , A_s , D and the relevant I_s .
- (2) Analyse lead-time relations.
- (3) Position the strategic decoupling points and use decoupling zones when suitable.
- (4) Analyse the positioning of the information decoupling points SIDP and DIDP.
- (5) Identify which CDDs that are applicable.
- (6) Evaluate the concerned supplier/customer relations from a CDD perspective.

- (7) Decide/evaluate the appropriate approach for managing the flow based on identified CDDs and resource-based decoupling zones.

When this process is finished, a set of CDDs have been identified for the logical entity. This output supports the decision-maker in applying the appropriate approach for managing the enterprise. Each CDD has its particular characteristics and hence require a particular management approach. In this sense, the output can be seen as a foundation for ‘plan for every CDD’ in a similar fashion as ‘plan for every part’ that is frequently applied to select the appropriate approach for planning and control.

7.2.2. Example: analysing a present state

The fictitious example used above can be seen as representing a present state and hence also matching the outlined process for analysing a present state.

- (1) The strategic lead-times were identified and illustrated in Figure 10.
- (2) Lead-time relations were analysed in Tables 3 and 4.
- (3) Position of the strategic decoupling points and decoupling zones was illustrated in Figures 18 and 19.
- (4) SIDPs and DIDP were positioned in Figure 19.
- (5) CDDs were identified in Table 5.
- (6) The relation with the two suppliers were briefly discussed based on Figure 19 and Table 5.
- (7) The CDDs were identified in Table 5 and provides the foundation for managing flow since items are categorized according to driving, differentiation and delimitation of flow. The details of flow management are however not within the scope of this paper.

7.2.3. Designing a future state

Design of a future state involves a completely different challenge compared to analysis of a present state. Instead of focusing on a present state this process is about innovatively designing a future flow in the best possible way. This can of course involve many types of scenarios, such as designing new flows when new products are introduced, which involves the largest degrees of freedom, to designing a desired future state for an existing value stream with existing products and resources. At an overall level, the process has similar properties for most alternative scenarios. Also, in this case, the process can be summarized in seven steps:

- (1) Identify customer value and requirements on the delivery lead-time D and customizations (related to A_D).
- (2) Position the CODP and decide the length of CODZ to handle variations in the requirement(s) for D .
- (3) Position CADPs and decide the length of CADZs to highlight potential differences between standard, customer unique and customer order unique.
- (4) Position the PODPs that are required to identify where the control possibilities are limited, e.g. supplier interfaces.
- (5) When required, decide on the length of the respective PODZs.

- (6) Position the information decoupling points SIDP and DIDP.
- (7) Decide on the appropriate approach for managing the flow based on identified CDDs and resource-based decoupling zones.

Designing a future state obviously provides more degrees of freedom. It is a great opportunity to balance efficiency and effectiveness and consequently to establish competitive advantage by carefully positioning decoupling points and decoupling zones.

8. Discussion

Producing standard products to a mass market is still the main business for many companies. In these cases, the main competitive advantage is through cost efficiency and this has accelerated the trend for outsourcing based on finding the supplier that can provide the lowest possible cost. An alternative avenue is to differentiate the offering to the market. Differentiation can be based on increasing the variety of standard products but unless the variety is large the possibility of fulfilling individual customer needs is limited. Instead, different approaches for customization and servitization have developed over time to support this type of agility. Some activities are performed in the time span between the customer order is received and the delivery is performed and this is the target scenario for the framework developed here. Strategic decoupling points are an important concept for understanding the implications of these trends but so far the different perspectives have mainly been covered separately in the literature. In most cases the focus has been on the process driver which also can be seen as the origin of decoupling point analysis. The interest in a more integrated approach has however increased and in particular ‘multiple decoupling points’ (see e.g. Banerjee et al., 2011; Sun et al., 2008) has been used as a keyword. In addition, a number of CODP-based extensions have evolved over time. The most extensively explored is the different aspects of customization. Even in the early literature on CODP, such as Hoekstra and Romme (1992), this aspect was thoroughly investigated and many have followed. In parallel, the postponement literature provided an integrated approach to these two perspectives (see e.g. Pagh & Cooper, 1998). The CODP itself has been extended with the introduction of CODZ (Wikner & Rudberg, 2005b). Engineering has mainly been seen as occurring upstream from manufacturing but later these were treated as two separate dimensions (Giesberts & Tang, 1992; Wikner & Rudberg, 2005a). In addition, purchasing has been suggested as an additional dimension (Wallin, Rungtusanatham, & Rabinovich, 2006; Wikner & Bäckstrand, 2011). The resources and planning & control and order promising perspective has also been used in some cases (Giesberts & Tang, 1992; Rudberg & Wikner, 2004), and also implications for reverse logistics (Wikner & Tang, 2008) and services (Fließ & Kleinaltenkamp, 2004) have been included. The list above is not all-inclusive but still all these aspects are introduced more or less separately and not based on an integrative approach and on a common platform.

The frameworks outlined here provide both a common platform, in terms of the framework for flow-based decision-making, which is a general framework that can be used for many purposes, and the COBM framework, which provides an integrated approach to all these aspects of extending the CODP in terms of, e.g., multiple decoupling points. The generic framework for flow-based decision-making is related to the first research objective and outlines the fundamental aspects of COBM in terms of 10 key concepts. The concepts provide the building blocks of the decision categories for COBM. The second research objective resulted in the identification of SEIAD, the five

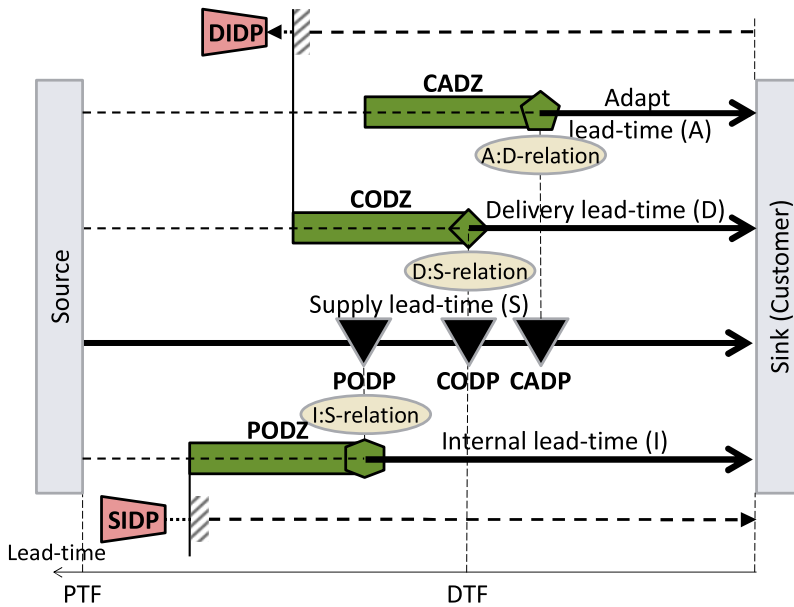


Figure 21. Lead-time-based summary of content for customer-order-based management.

strategic lead-times. Three of the decision categories are defined based on these strategic lead-times and each involves a lead-time relation, a decoupling point, decoupling zones and a strategic stock point. In addition, a DC related to transparency is included which resulted in a total of four decision categories which correspond to the third research objective. Figure 21 provides a lead-time-based overview of these four decision categories. Note however that the compounded decision domains and the resource-based decoupling zones are not explicitly represented in Figure 21. These two aspects are related to the intersection between multiple flows and different decision categories, respectively.

In addition to supporting the design of the flow, the COBM framework has also proved itself to be very useful for communication between different functions within a company and for communication with suppliers. Financial information is readily expressed using cost accounting terminology, engineering information in terms of product design and material selection, quality information in six sigma-based terminology, etc. Logistics have however had more difficulties in providing a comprehensive picture of the implications of different types of decisions on logistics-related issues (also including manufacturing). The COBM framework highlights strategic lead-times and strategic decoupling points and decoupling zones based on a time-phased bill-of-material and a time-phased order book. In combination they provide a comprehensive picture that highlights implications of lead-times. For example, a lead-time reduction that moves the CODP upstream in the bill-of-material has more important implications than a lead-time reduction that does not affect the position of the CODP. In a similar way, the procurement of focusing on low cost might extend the lead-time and thus changes a purchase-to-order to a purchase-to-forecast scenario. If this is also within the CADZ, it will be even more critical since customer unique material should preferably not be purchased to forecast.

The COBM framework rests on a generic foundation independent of, e.g., industry and product portfolio. Some level of customer order influence on the flow obviously makes the approach more relevant. The application can, however, be demanding during some circumstances. An important challenge is if the context is very dynamic, the strategic lead-times and consequently the position of decoupling points and decoupling zones may be dynamic, i.e. their position may change over time. In this type of situation, it would be necessary to either re-evaluate the positioning according to the decision categories, or to prepare for a number of scenarios with predefined configuration of COBM for each scenario. Another challenge is when the demand is not easily classified as customer order or forecast. In some cases, the contracts may stipulate some flexibility for the customer depending on the time horizon. The PB-CODZ might be suitable to handle this but still it can be difficult to actually position the CODP. This is even more accentuated in rate-based environments where the rate is set for an extensive time period.

9. Conclusions

The COBM framework has been derived using a three-layer approach, where the generic framework consisting of 10 key concepts provides the foundational constructs. The first level of instantiation is represented by the COBM framework consisting of content (see Figure 20) and process. The second level of instantiation is represented by the example used throughout the text, which is an instantiation of the COBM framework. The example highlights some detailed aspects of the framework but the implications of applying the framework are important also at a more general management perspective. Enterprise development with emphasis on operational efficiency has played a central role for many years in improving industrial productivity. Lean production has been a key enabler in this context and also introduced more emphasis on the customer. A cost efficient internal flow is however only the first step towards improved competitiveness. To reach a higher level of competitiveness, it is important to also develop the effectiveness, which is here referred to as the strategic efficiency, to provide the right preconditions for the operational flow through improved interaction. The flow-based COBM framework introduced here can hopefully provide increased understanding of, and support for, how strategic efficiency may be established.

The suggested COBM framework provides numerous opportunities for further research related to theory development, as well as industrial applications. In particular, three areas are being developed further:

- *Strategic decoupling and supply chain strategies* connects the logical entities to the physical entities and focus on how common supply chain strategies can be interpreted in terms of the COBM framework.
- *Strategic decoupling points and supplier/customer interactions* connects the logical entities to the legal entities and focuses on how supplier/customer interactions can be interpreted in terms of the COBM framework.
- *Strategic decoupling points and implementation* establishes a method for how to implement competitive COBM and thus also how to best position decoupling points and decoupling zones.

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