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Typology for planning and control – Combining object type, mode type, and driver type

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Abstract Planning and control of manufacturing and logistics activities within a supply chain covers a wide range of scenarios and corresponding methods. Frequently the methods are classified based on the relation to different layouts and industries. The typology developed here is instead based on flow characteristics covering three main perspectives: object type, and hence also resource properties, related to the object being continuous or discrete; mode type related to if the flow is managed as continuous, intermittent or onetime; and driver type related to if forecast or customer order drives the flow. Hybrid systems are identified within each perspective and cross hybridity is identified by combining the three perspectives.

1. Introduction

Balancing supply with demand is the core theme of supply chain planning and control. The demand represents the challenges facing the supplying entity and from a logistics perspective this challenge can be divided into the dimensions "what", "where" and "when". "What" is defined by the customers in terms of the requested product. "Where" could for example be at the supply site or at some of the customers' sites. In this sense the "what" and "where" are defined by the customer's and from a logistics perspective they can therefore be considered as given preconditions. The third dimension, "when" is however where the real challenges rest from a logistics perspective. A requested delivery lead-time is usually provided but the different aspects of supply lead-time are in the hands of the supplying entity. The supply lead-times are a consequence of the time it takes to perform the supply processes involved in the flow that fulfils the customer requirements. Planning and control of the flow requires some kind of model that conveys the important characteristics of the flow and thus emphasises the key perspectives of the flow. Fundamental in this aspect is the type of objects exposed to the transformation. The object type is key in that it conveys the value to the customer and also defines the preconditions for the resources performing the transformation [1]. The second perspective involves the mode of the flow which highlights the flow behaviour from a dynamic perspective with emphasis on the repetitivity of the flow. Once the objects and mode are defined it is a question of when to actually perform the flow and this is the third perspective which here is referred to as the driver of the flow. These three perspectives are the cornerstones of the typology outlined here. In practice the three perspectives do not exist in isolation. The perspectives can be combined in different ways resulting in different cross hybrids as shown in Figure 1. The typology is based on the three perspectives in combination but as illustrated by the figure a first step is to investigate the three possible combinations of two perspectives and based on this to finally investigate the combination of all three, i.e. the cross hybridity OT-MT-DT.

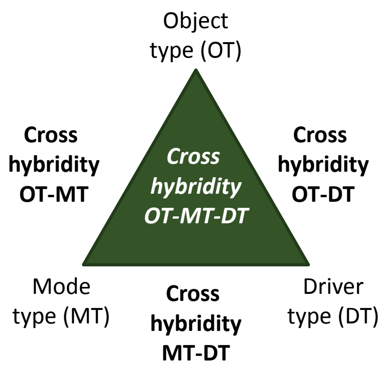

Figure 1 The four cross hybridities identified and analyzed.

The purpose of this paper is to identify a typology of key perspectives that are fundamental in the design of supply chain planning and control.

The method employed for the research is mainly based on logical reasoning using input from the literature in previous research related to decoupling theory [2], planning and control in process industry [3], and in particular sales and operations planning in process industry [4]. An important objective throughout the work has therefore been to integrate concepts from the discrete manufacturing industry with concepts from the process industry.

The paper is basically split into three parts and next each one of the three perspectives is investigated separately followed by analysis of hybrids between two of the perspectives. Finally all three perspectives are integrated as a typology for planning and control.

2. Frame of reference

As outlined above there are three perspectives that are of particular interest for supply chain planning and control. The customer requests a product and the product properties are key for the supply. In particular, the type of object being transformed is crucial since it also affects the type of resources being employed in the supply process [1] and therefore also how the supply process can be managed [5]. From a planning and control perspective the repetetivity of the supply process is critical. At one extreme the supply process is performed once and at the other it is performed more or less continuously [6]. In addition it can be performed intermittently and these aspects are covered by the mode type. Finally the actual trigger of the flow is crucial since this is what actually initiates the supply process. The driver type is typically in the shape of actual customer orders or in terms of speculation about future customer orders [7]. These three perspectives are each established in the literature and this is further outlined below. Thereafter they are combined to establish what here is called cross hybridity.

2.1 Perspective 1: Object type (OT)

The object transformed in the flow, i.e. flow object, can be of different types which also affects the type of resources being used in the supply process. When discrete objects are transformed in manufacturing it is usually referred to as discrete manufacturing which is defined by [8] as “The production of distinct items such as automobiles, appliances, or computers.” Discrete manufacturing is performed in the discrete manufacturing industry (DMI). The other large type of industry related to manufacturing is usually referred to as the process industry (PI), which is defined by [8] as “The group of manufacturers that produce products by mixing, separating, forming, and/or performing chemical reactions.” In contrast to the DMI, the PI is not defined by the complete transformation process but rather that some part of it is of the type process manufacturing. “Process manufacturing adds value by mixing, separating, forming, and/or performing chemical reactions. It may be done in either batch or continuous mode” [8]. This means that the transformation object is of continuous type [1]. Cconsequently the object type can be either continuous object or discrete object, as shown in Figure 2.

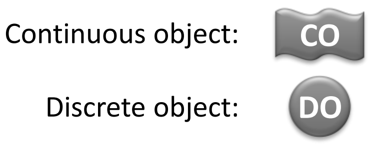

Figure 2 Perspective 1: Object type (OT)

Discrete object (DO) is basically defined as an object that can be counted in pieces [9]. This type of object is handled individually or in batches. These objects are usually transformed individually meaning that even if both manufacturing and transportation may be performed on batches the objects can be transformed one by one.

Continuous object (CO) cannot be counted in pieces but must be measured in terms of e.g. volume or weight [9]. This means that CO cannot be handled individually, such as transformed one by one. Instead they represent a "flow" and the flow rate times a time period represents a certain amount of the object.

Object hybridity with discretization point (DiPo) introduces an interface between the two types. Objects cannot by themselves be hybrid but from a supply chain perspective the flow may be based on both types of objects and this is here referred to as object hybridity. The object hybridity is based on the assumption that a physical entity [2], such as a manufacturing site, can be involved in the transformation of both COs and DOs [10] [11]. In general DOs are not transformed into COs [9]. One exception would be for example when containers, which are discrete objects, of liquids are received and emptied into a flow based on CO. Otherwise this would not occur and the most common scenario would be when COs are discretized and for example packaged to become DOs. The point where this transformation of CO into DO takes place is referred to as the discretization point (DiPo) [3] and this is illustrated in Figure 3. For the less common case of DO being transformed into CO this could correspondingly be referred to as a Continuization point (CiPo) but this is not further discussed here.

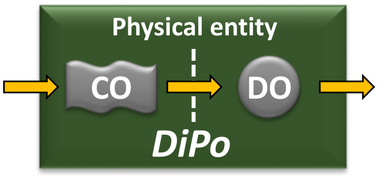

Figure 3 Object hybridity based on the DiPo

In general both form transformation (manufacturing), and place transformation (transportation) within a network may be applied on COs as well as DOs, see Table 1. In this context the network consists of physical entities as nodes, i.e. a network of manufacturing sites with transportation between the nodes of the network. Distribution nodes only performing stocking (time transformation) are not included and in case some kind of repackaging is taking place the distribution node is classified as a manufacturing node.

	Continuous object (CO)	Discrete object (DO)
Form transformation	Process manufacturing	Discrete manufacturing
Place transformation	Pipeline transportation	Vehicle transportation

Table 1 Transformation of CO and DO

2.2 Perspective 2: Mode type (MT)

The transformation can be performed in different modes ranging from a onetime occurrence to a continuous mode. A compromise is when recurring transformation is performed and this is referred to as intermittent mode. All three mode types are shown in Figure 4 where the frequency is an indicator of the level of repetitivity [6].

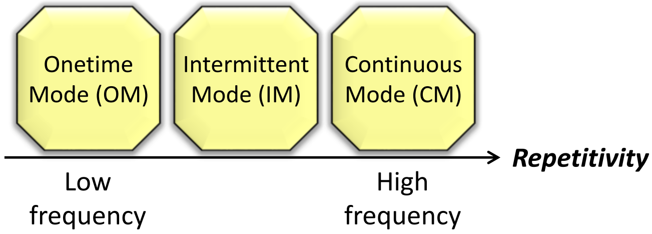

Figure 4 Perspective 2: Mode type (MT)

Onetime mode is when a unique transformation is being performed. By definition this type of transformation is performed once. Once is however a relative concept here and is defined in relation to what is known at that particular moment. The same transformation may be performed later but then it is related to demand that was not known, or expected, at the previous occasion. It is also important to note that onetime does not imply anything about if one or more objects are being transformed at that time. It only implies that the transformation is taking place at one particular time instant.

Intermittent mode is applied when demand is recurring and continuous mode is not applicable. In most cases this is due to setup times that inhibit transformation in continuous mode. By transforming batch-wise the setup time can be shared across the units in the batch to reduce the capacity required per unit, and consequently also the unit cost. This is maybe the most complex mode and two sub types, in particular, may require differentiation even if they still are classified as IM. The basic case “closed batch” is when the complete batch is transformed by a resource before anything of the batch continues to the next resource. The second case “open batch” relaxes this constraint and enables a smoother flow between the resources. In DM this is referred to as overlapping and in CM it is related to the use of campaigns.

Continuous mode is sometimes also referred to as one-piece transformation in DMI. The continuous mode is usually applied on flows of only one object or on a group of objects acting as one virtual object where no setup time is required for changing between objects within the group.

Mode hybridity with mode interface point (MiP) separates segments of the flow with different flow modes. Transformation is performed in one mode only and therefore the MiP must be situated at an intermediate flow point usually referred to as a stock point or decoupling point. As shown in Table 2, there are nine possible MiP scenarios when an upstream mode is combined with a downstream mode. The three scenarios on the diagonal are void since they do not represent an interface between two different mode types and are hence categorized as No MiP. Note however that if the subclasses of closed batch and open batch are covered explicitly, the case of intermittent would be more complex but this is not included here. The remaining six scenarios all represent possible configurations. The two scenarios OM-IM and OM-CM both represents that upstream onetime mode would change into a flow of higher level of frequency downstream. It might be possible to identify some instances of these combinations but in general they are unusual wherefore they are put in brackets in the table. Scenario IM-OM corresponds to when objects are produced using IM and then used in OM for e.g. providing something unique for a particular customer. This could e.g. be that subcomponents are produced under IM and then the final assembly is produced under OM. Scenario CM-OM represents a similar hybridity but then the subassembly can be produced in a continuous manner. The two remaining scenarios can frequently be found in different industries. The scenario IM-CM is frequently used in different lean settings where some kind of final transformation such as final assembly is performed in CM within a product family on an assembly line. Some of the parts are provided using processes that requires setup times such as pressing or forming and hence acting as “monuments” using batch production in IM [12]. Scenario CM-IM finally is common in process industry where the initial transformations are performed as CM on some raw materials and then the final stages, including CO as well as DO, are performed as IM in e.g. packaging.

	Downstream OM	Downstream IM	Downstream CM
Upstream OM	*No MiP*	(OM-IM)	(OM-CM)
Upstream IM	**IM-OM**	*No MiP*	**IM-CM**
Upstream CM	**CM-OM**	**CM-IM**	*No MiP*

Table 2 Mode hybridity based on the MiP

2.3 Perspective 3: Driver type (DT)

The MT defines the key flow characteristics once the flow is activated. The actual activation of the flow is however not covered by MT. The activation is here referred to as the driver of the flow, i.e. the flow driver, and from a customer perspective there are basically two possible types of activation based on speculation on future customer orders, usually in terms of forecasts, or commitment to actual customer orders [13] [7] [14]. The type of driver is decided based on the relative length of the delivery lead-time and the supply lead-time as shown in Figure 5, based on [2]. Due to the driver of the flow the related processes can be associated to decisions based on speculation or commitment and the interface between these domains is the customer order decoupling point (CODP) [13].

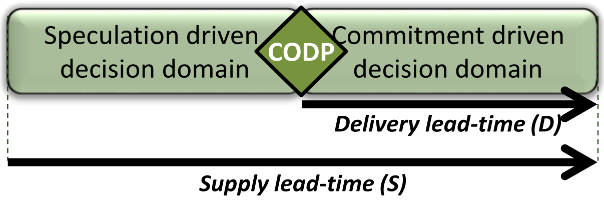

Figure 5 Perspective 3: Driver type (DT)

Forecast driven flow is performed when the customers are not willing to wait for the delivery object. The supply flow is therefore driven by a forecast that is an estimate of future customer orders [7]. The flow is performed on speculation about future customer orders and as in all types of speculation this involves taking a risk. The risk here is to not being able to deliver at the customers' request and this is handled by a stock point at the end of the speculation driven flow. Risk management in this case is based on balancing availability with requirements for delivery objects, i.e. items to be delivered.

Customer order driven flow is easier to manage in the sense that the customer orders are known when the flow is performed. The requested objects are therefore known but in this case the risk is related to the resources that are used in the object transformation taking place in the flow. Risk management is therefore related to balancing availability with requirements for capacity of resources involved in transformation to generate the delivery objects.

Driver hybridity with customer order decoupling point (CODP) is obtained when a complete flow is managed and a set of flow configurations can be defined as in Figure 6. In general there is always some part that is commitment driven and based on customer order. In make-to-stock (MTS) scenarios only pick and pack activities are performed to customer order but in other cases all form and place transformations take place based on a customer order and this is usually referred to as make-to-order (MTO), even if also non-manufacturing activities are involved. In some cases also engineering activities are performed to customer order which is known as engineer-to-order (ETO) (not included in Figure 6). As a compromise between MTS and MTO the flow is decoupled internally and this is usually referred to as assemble-to-order (ATO).

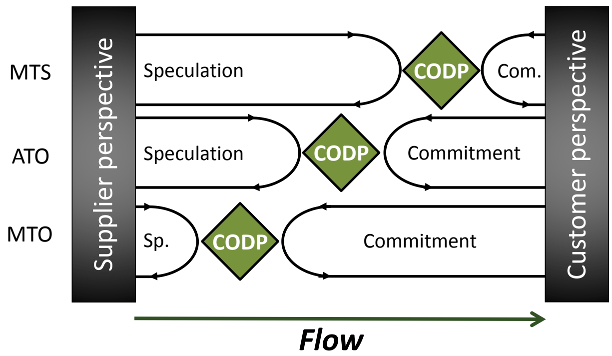

Figure 6 Driver hybridity based on the CODP

3 Cross hybridity of object type and mode type (OT-MT)

The flow mode represents the repetitivity of the flow and is very important to consider when selecting planning and control method. All three mode types are suitable for DO and are frequently used but as shown in Figure 7 only two modes are usually used in relation to CO.

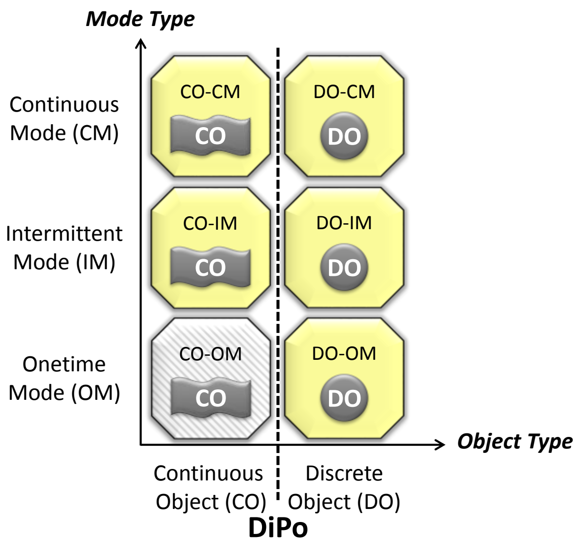

Figure 7 Cross hybridity of object type and mode type (OT-MT)

For DO some examples of methods for planning and control are different types of network based methods for OM, time phased approaches such as MRP for IM and rate based techniques used in e.g. some lean systems for CM. Onetime mode is by definition not as suitable for continuous objects [15] [5] since they cannot be counted easily and due to the characteristics of the process the repetitivity is of necessity for establishing a competitive process. Batch processing (IM) is however also commonly used for CO and of course the CM is used in many process industries where one single product is produced over an extensive time period.

4. Cross hybridity of object type and driver type (OT-DT)

The driver type defines the flow driver and the CODP separates the speculation driven flow from the commitment driven flow. Since speculation involves risk a stock point will be positioned at the CODP [7] [16]. In summary this means that the CODP is located between transformation points for form and/or place. From a logical entity perspective [2] multiple CODP in sequence cannot occur in the same flow. The object type, on the contrary, can only be changed at a transformation point [9] such as packaging. In general a physical entity only has one DiPo in a particular flow. Figure 8 is based on that a flow may only contain one CODP and one DiPo, and that the CODP is positioned at a stock point and DiPo at a transformation point. As a consequence the configurations on the diagonal are not possible (CODP and DiPo positioned at the same place). The encircled configurations are the same in terms of that they have one differentiation point internal, if it is positioned early or late is insignificant here. Consequently there are eight possible cross hybridities OT-DT.

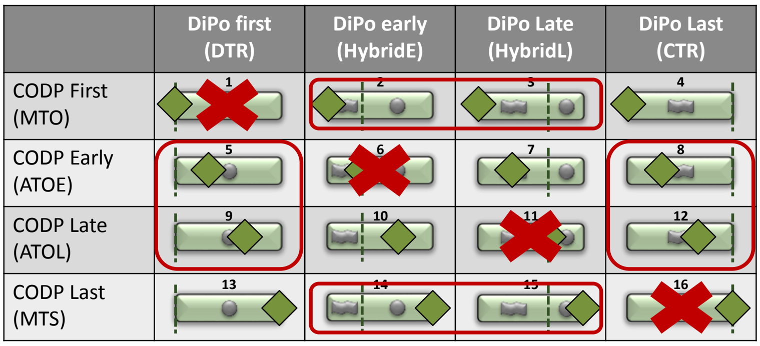

Figure 8 Cross hybridity of object type and driver type (OT-DT)

5. Cross hybridity of mode type and driver type (MT-DT)

The combination of mode type and driver type is a baseline for planning and control. The mode type defines the basic planning and control approach and the driver type defines how forecast and customer orders are combined in e.g. master scheduling to define the total requirements. OM is with few, if any, exceptions only used for customer order based flows (CD) and therefore the two additional configurations at the bottom of Figure 9 are dashed. IM can however be combined with all three possible positions of the CODP as IM can be applied on SD as well as CD flows. It is however important to note that in the case of IM it is usually assumed that batches are used which means that standard products or customized products for recurring customer orders are involved. If the products are unique for a customer order the OM-CD hybrid would be applied. CM finally can be applied for any position of the CODP. In the two cases where some or all flow is based on customer orders it is a necessary requirement that the products belong to a product family where there are no changeover time between the different variants in the family. In Figure 9 the mode types represent the flow where the transformation takes place. The arrow from the driver type symbolizes that it provides the trigger signal to the flow. For SD it is usually a forecast or some kind of plan and for CD it is directly or indirectly actual demand in terms of for example a customer order or a firm delivery schedule.

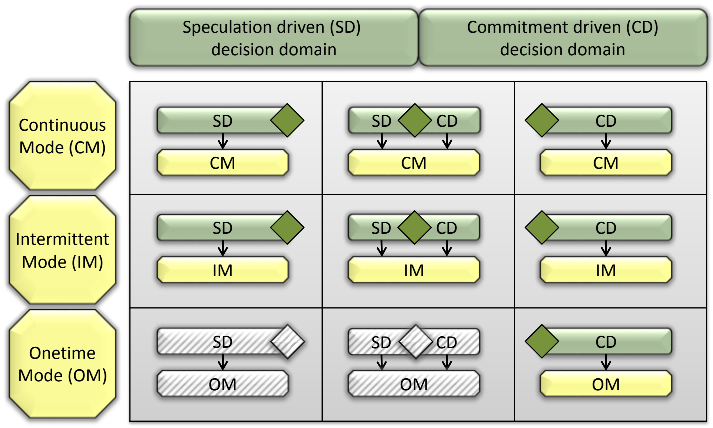

Figure 9 Cross hybridity of mode type and driver type (MT-DT)

6. Three dimensional typology for planning and control (OT-MT-DT)

Planning and control in practice involves consideration of all three perspectives outlined above. The object type is a precondition in the sense that the characteristics of objects, i.e. products, and the resource requirements are related to the physical entity's characteristics. The flow mode selected is related to the object type in combination with the volumes required and the timing across the time line. Finally based on the customers' requirements the driver type can be identified for the different parts of the system. Note that Figure 10 also includes flow with a combination of forecast and customer orders related to the SCD. This is referred to as a customer order decoupling zone [2] [16] and is included here for completeness even if this combination was not included above. This three dimensional representation of the planning and control challenge is illustrated in

Figure 10. As discussed above the OM is mainly applicable in CD scenarios and for DO and therefore the other OM-bricks are dashed. This is also obvious by combining Figure 7 and Figure 9 where the corresponding configurations are dashed. Figure 10 also includes an example of an application of the typology. The example is from PI where the flow is split in CM and IM where CM is applied upstream and IM downstream from the DiPO. The DiPo is positioned where packaging creates DOs. Further downstream the packages are labelled based on the particular customer order and this coincides with the CODP. In summary the flow consists of three different segments based on combining DiPO and CODP and can be classified as: CO-CM-SD; DO-IM-SD; DO-IM-CD. This flow setting is related to the three blue intersections and illustrated in Figure 10.

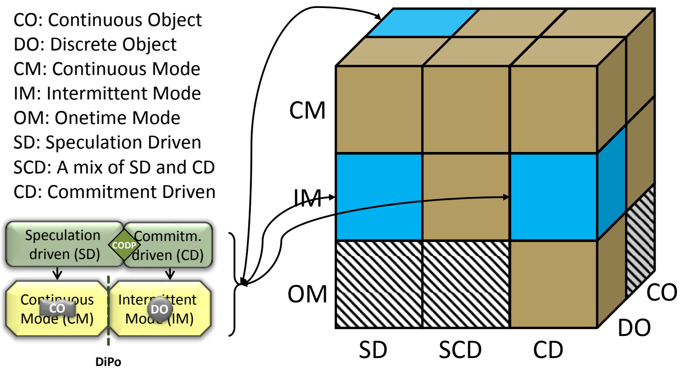

Figure 10 Typology for planning and control (OT-MT-DT) with example

7. Conclusions

The flow objects represent materials and the transformation performed by services and therefore also the response to the voice of the customer. Implicitly the object type also implies which type of resources that can be employed in the flow. CO requires certain properties of the process related to that no individual objects can be identified. DO on the other hand is by definition individuals that can be handled one by one in both form and place transformation. The flow mode represents the opportunities available for managing the flow due to, in particular, preconditions related to setup time. In this context it is important to again note the implicit resource perspective as different objects that can be transformed in arbitrary sequence, meaning no setup time is necessary, on the resources can be performed in CM. The final perspective included here is the actual trigger of the transformation which is here referred to as the flow driver. This represents why the transformation is taking place whereas the flow mode represents the conditions for the transformation and the object type what is being transformed. An obvious extension of this typology would be to also explicitly include level of customization as a separate perspective.

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