The Expected Costs and Benefits of EDI in the Modular Supply Chain

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Abstract

In this paper we examine how the adoption of EDI can increase the flexibility of a modular supply chain of organisations to match customised demand, and how expected costs and benefits of such the adoption are distributed among these organisations. Within a modular supply chain, organisations form process module networks in response to customised demand. These networks indicate in what order process modules need to be operated, how they are linked to each other, and how many resources they use. We have developed the modular design approach to support the design of process module networks. By means of an automated tool, called Chain Moduling, costs and lead times of several designed networks can be computed and compared. The first application of Chain Moduling demonstrates how the adoption of EDI impacts a specific process module network. In this paper, the approach, the tool, the first application and future research are discussed.

1. Introduction to research problem

Organisations face the ongoing pressure of customised demand. The range of products and services should be increased, without creating longer lead times and higher costs. An increase of flexibility at the point of customer contact is needed to meet customised demand [8, 16, 19, 22, 33]. Flexibility in this context refers to the ability to quickly respond to customised demand. Bahrami [2] divides this ability into the following two distinct aspects: (1) agility, which refers to the ability to respond quickly, and (2) versatility, which refers to the ability to produce the required variety. Close co-operation is required within the supply chain in order to achieve the desired flexibility (see for instance [10]). The supply chain encompasses each element of the production and supply processes from raw material to the end-customer ([30],[32]).

In order to measure the current level of flexibility within the supply chain and to find ways to increase this flexibility, we model supply chain members, i.e. the organisations that form the supply chain, as modular entities. The modular supply chain consists of a large set of process modules of which relevant modules can be linked instantly in a process module network after a customer places an order [12, 19, 22]. A process module is the "smallest possible core unit at which production can be replicated and repeated" ([25]:67). The faster process modules can be linked (agility) in a large variety of combinations (versatility) the better the modular supply chain can match customised demand.

An increase of flexibility at the point of customer contact requires an optimisation of information exchange between the organisations that form the modular supply chain. Porter & Millar [23] argue that information technology (IT) can be an important enabler in optimising linkages between organisational units as well as links to the outside of the organisation. In particular, Electronic Data Interchange (EDI) can be useful for the optimisation of inter-organisational information exchange, because it enables information to be exchanged faster and more accurate [11]. Therefore, EDI may be considered as a key enabler to increase flexibility of the modular supply chain. Supply chains may benefit significantly from the adoption of EDI [9, 4, 28, 29]. However, expected costs and benefits of EDI still remain unclear. Moreover, it is expected that the distribution of these costs and benefits among supply chain members may be unbalanced [21, 27]. This may explain why organisations are still reluctant to implement EDI.

The adoption of EDI is expected to have the highest benefits when it is applied as an enabler for business process redesign (see for instance [3]). Several authors stress the capabilities of IT and EDI for redesigning business processes [7, 13]. This paper deals with EDI enabled business process redesign at the supply chain level. Venkatraman [32] calls this business network redesign. We propose an approach to determine how EDI could facilitate business network redesign by means of an increase of flexibility. This approach, which we refer to as the modular design approach, also allows us to assess expected costs and benefits and the way they are distributed among supply chain members.
To illustrate the approach we will focus in this paper on a case taken from the air cargo transportation sector. This case deals with a three-staged modular supply chain in which a forwarder, a road carrier and an air carrier fulfil air cargo transportation from shippers to consignees (see figure 1).

The paper is organised as follows. In section 2 the theoretical background of the research will be discussed. Next, the modular design approach is introduced, which is used to model modular supply chains (section 3). Also in this section, the automated tool Chain Moduling is introduced. This tool is based on the modular design approach and can be used to assess the expected costs and benefits of EDI at the supply chain level. In section 4 we elaborate on the different ways how EDI may be adopted in modular supply chain. In section 5 we illustrate the aforementioned approach and tool in a fictive example. In section 6 some conclusions are drawn and directions for further research are discussed.

2. Theoretical background

The research problem has been approached from the point of view of how economic activities can be best organised within an inter-organisational context. In this respect, the transaction cost economics approach, developed by Williamson [34, 35], considers two alternative forms to organise economic activities: markets and hierarchies (first introduced by Coase [5]). The unit of analysis is the transaction, which occurs 'when a good or service is transferred across a technologically separable interface' ([35]:1). Transaction costs are determined by three structural characteristics: asset specificity, uncertainty and frequency. Asset specificity refers to the degree to which an asset (like machinery, people, etc.) can be redeployed to alternative uses and by alternative users without causing significant additional costs and without losing its value. Uncertainty refers to whether one can exactly predict the outcomes of a transaction in advance. Frequency refers to whether a specific transaction occurs frequently or rarely. The general statement within the transaction cost economics approach is that the hierarchy as organisational form will be more beneficial than the market when production costs of a supplier combined with the costs of transacting with the supplier exceeds the costs of internal production.

Transaction cost economics considers only the market and the hierarchy as two extreme forms of organising economic activities. Recently, attention has been paid in literature to intermediate, or hybrid, organisational forms between, or next to, markets and hierarchies. One of these forms is the network [1, 6, 15, 20, 24, 31]. Different reasons are proposed why networks may outperform markets and hierarchies. For instance Antonelli [1] argues that when both the costs of using the market and the hierarchy are high and economies of scale are low, networks may emerge (p. 53). Jarillo [15] argues that the network may become economically feasible when specialisation of each supplier decreases total costs and when it can be sustained by closing long-term bonds that lower transaction costs (p. 39). In this respect a network should be able to find the 'optimal' allocation of activities (or: process modules) to be performed within the network. An allocation of activities among network members is cost optimal when production costs and transaction costs are minimised. Given certain constraints, like the availability of process modules, the optimal allocation can be approximated or realised. Miles & Snow [20] introduce the dynamic network in which optimal allocations of activities may change according to the nature of the end-customer's demand. They describe that 'for the dynamic network to achieve its full potential, there must be numerous firms (or units of firms) operating at each of the points at the value
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chain, ready to be pulled together for a given run and then disassembled to become part of another temporary alignment’ (pp. 66-67). Others describe this process as thinking in reverse [16] or customer-value networking [33].

It is expected that the adoption of EDI may change transaction costs, since it refers to the communication between organisations. However, how the adoption of EDI may facilitate either the market, hierarchy or network form as the most preferable one, still remains unclear. The rise of electronic markets is, amongst others, advocated by Malone et al. [18], while Antonelli [1] and Johnston & Vitale [17] argue that electronic hierarchies will become the economically feasible organisational form. Antonelli [1] argues that as long as no open EDI-networks exist, the investment in EDI will lead to an increase in asset specificity which contributes to the hierarchy as favourable organisational form (see also [14]:549, [26]).

All contributions discussed here, demonstrate that the question how activities (or process modules) should be allocated between supply chain members to minimise total costs (divided in production costs and transaction costs), still has not been answered satisfactorily. However, an important issue has been raised by a number of authors (amongst others [16, 20, 33] that supply chain members should be able to operate in dynamic networks in which they look for optimal coalitions in response to customer demands. The underlying premise is that any set of process modules can be produced (customisation) by any supply chain and that any allocation of process modules among the supply chain members is possible (economic optimisation). This paper elaborates on this premise. Our objective is to assess whether the flexibility of modular supply chains can be increased by adopting EDI in such a way that the optimal allocation of process modules between supply chain members can be chosen. Moreover, we want to assess the effects of such an EDI adoption on expected costs and benefits for each supply chain member. In the next section we introduce the modular design approach to find these allocations and assess the impact of EDI on these allocations.

3. The modular design approach

In this section the modular design approach will be described. The approach can be used (1) to translate an incoming order into a process module network and (2) to determine costs and lead time of this network.

Before the modular design approach can be applied, participating organisations have to identify which service elements they can deliver and which process modules produce these elements. Service elements are specific parts or characteristics of the total product and service range offered by an organisation or a supply chain. The identification of service elements should be conducted from the end-customer’s perspective. Service elements enable end-customers to describe their specific preferences as accurate as possible. Process modules can be identified by considering the primary production and information processes within an organisation or a supply chain.

In the modular supply chain a co-ordinator is required, responsible for the translation of an order into a process module network. This co-ordinator can be either: (1) the end-customer; (2) one of the participating organisations in the supply chain; or (3) a new organisation entering the supply chain (for instance a value adding services organisation).

The modular design approach consists of four steps (see figure 2). In consultation with the supply chain members the supply chain co-ordinator can execute all these steps or only parts of them.

The first step consists of the translation of a customer order into a set of service elements.

Figure 2: The modular design approach
The second step is the translation of the selected set of service elements into a set of process modules. Relationships between service elements and process modules can be either fixed or variable in terms of costs and times that accrue. In the case of the air cargo transportation sector, an example of a fixed relationship is the preparation and sending of a facsimile message 'confirmation of order' in response to an incoming order. The preparation and sending of this message will usually take the same time and incur the same cost, regardless whether the order deals with perishables (e.g. flowers), special cargo (e.g. living animals) or commodities (goods with no special attributes or characteristics). An example of a variable relationship is the translation of the service element 'way of delivery' into the process module 'intake of goods'. Goods can be either delivered loose, palletised or on a Unit Load Device (ULD). Since delivered goods need to be packed into ULDs before they enter the plane, the process module 'intake of goods' will differ in costs and times depending on the service element selected (loose, palletised or ULD) and the amount of goods delivered.

The third step is to link the set of process modules in a network. This network indicates in what order the process modules need to be performed in order to fulfill the customer's order. The network can be designed after dependencies between process modules have been defined. For instance, the process module 'intake of goods' at the air carrier's site can only be performed after the goods have been transported from the shipper's site to the air carrier.

The fourth step is the computation of operating costs, operating time and lead time. Operating costs are those costs which are directly related to the fulfillment of an order, such as production costs and information processing costs. Operating time refers to the total time needed to perform a process module network regardless the critical path within the network. Lead time is the net time span between the order placed and the order fulfilled and corresponds with the critical path within the process module network. Lead time can be computed when the selected process modules are linked in a network.

The modular design approach enables us to design several different process module networks which refer to the same order. The differences between such networks, for instance a network based on EDI versus a network not based on EDI, may demonstrate either a change in operating costs (showing an additional cost in case of increased operating costs, or a benefit in case of decreased operating costs) or a change in lead time (which is an indicator of agility). Alternative process module networks can be compared with the process module network which represents the current way of working, and can be classified in a 2x2 matrix as indicated in figure 3.

4. The role of EDI in process module networks

The first experiences with applying Chain Moduling indicate that EDI can be used to (1) increase efficiency by decreasing operating costs of process modules; (2) increase effectiveness by reducing lead time of a process module network; (3) change organisational boundaries within a process module network by moving the execution of a certain process module to another organisation in the supply chain (strategic issues). In table 1 these categories of effects are summarised. A simplified process module network depicted in figure 4 will serve as an example to clarify these three categories of EDI effects.

The first category of EDI effects (efficiency) refers to the decrease of costs and time incurred to operate a process module, regardless whether the module is part of the critical path. The module 'send notification of departure' is an example of a process module of which cost can be decreased when EDI is used, and which is not part of the...
Table 1: Three categories of EDI effects on process module networks

<table>
<thead>
<tr>
<th>category of EDI effect</th>
<th>efficiency</th>
<th>effectiveness</th>
<th>strategic</th>
</tr>
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<tbody>
<tr>
<td>operating cost reduction</td>
<td></td>
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<tr>
<td>operating time reduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lead time reduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>change in process module network design?</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>change in the roles organisations play?</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

Figure 4: A simplified example of a process module network

The module is executed after the plane has departed and therefore runs parallel with the module ‘air transport goods’. Through the adoption of EDI, the message can be sent electronically which will save a large part of the operating costs made.

The second category of EDI effects (effectiveness) refers to the reduction in costs and times of those process modules which are part of the critical path or those that will be removed from the critical path. In this case, not only costs but also lead time can be reduced, which is considered as an increase of agility. For instance, the process module ‘customs clearance’, which was formerly executed after goods have been transported by road, can now be executed concurrently with ‘road transport of goods’ when an EDI-message ‘pre-arrival notification of goods’ has been sent by the road carrier (see figure 5(a)).

The third category of EDI effects (strategic) refers to the re-allocation of process modules, by means of EDI, among supply chain members, regardless whether these process modules have been altered as discussed before. In this case, organisational boundaries will shift in the process module network, because EDI changes transaction costs and, possibly, also production costs. A possible reallocation is given in figure 5(b). In this alternative a bigger rule has been assigned to the road carrier. To find better allocations of process modules among supply chain members, transaction costs have to be included in the analysis. This is one of the issues discussed in section 6.

5. An example

In this section we discuss a fictive example to demonstrate how Chain Moduling can be applied to assess the impact of EDI on process module networks. The application discussed here is based on fictive data and encompasses the supply chain introduced in the first section (see figure 1). The forwarder acts as the supply chain coordinator and arranges road and air transportation on behalf of the shipper.

After the service elements have been selected, the supply chain co-ordinator allocates subsets of the set of elements to participating organisations, i.e. the forwarder, road carrier and air carrier. Note that the forwarder, in the role of supply chain co-ordinator, allocates part of the order to himself as being a participant of the supply chain.
Figure 5: Example of how EDI may alter process module networks

Participant translates the subset of elements into a set of process modules which together form a process module network. Figure 6(a) depicts the process module network. The thick marked boxes represent process modules which are part of the critical path. This network represents the current way of working, in which EDI is not used.

Once the process module network without EDI has been designed, alternative networks can be defined in which EDI is used. We have defined an alternative in which EDI is used for: (1) allocating suborders (i.e. the subsets of the selected service elements) by the supply chain co-ordinator to the participants; (2) invoicing and payment activities; (3) customs clearance; and (4) sending the air waybill. The first two changes can be denoted as first category EDI effects, while the last two changes belong to the second category of EDI effects (see previous section). The new process module network is depicted in figure 6(b).

After both process module networks have been designed, we can compare them on operating costs, operating times and lead time. The relative improvements made with the EDI based network compared with the network not based on EDI, are depicted in figure 7. This figure indicates that this particular alternative process module network fits in the lower left quadrant of figure 3. It appears that:

1. lead time can be decreased using EDI and therefore contributes to the increase of (end-customer) flexibility;
2. every participant benefits of EDI (although EDI investments have not been included in the analysis);
3. benefits are not equally distributed (in percentages);
4. the forwarder enjoys the highest relative benefits, which is not surprising because his main activity is information processing (both as forwarder and as supply chain co-ordinator).

We now can repeat the procedure to evaluate other alternative process module networks. Other process module networks may be based on a different supply chain co-ordinator, a different use of EDI, etc. We can even apply the modular design approach to analyse the use of other enablers than EDI, such as mobile satellite communications, teleconferencing and electronic markets.
6. Conclusions and directions for further research

In this paper we have introduced the modular design approach. The approach is used to analyse how the adoption of EDI enables modular supply chains to match customised demand by increasing its flexibility in terms of reduced lead times (agility) and increased variety (versatility). Moreover, the approach also can be used to assess whether operating costs can be reduced by the adoption of EDI and how a cost reduction is distributed among modular supply chain members. The modular design approach is automated in a tool called Chain Moduling.

An application of Chain Moduling illustrated how flexibility in terms of agility can be increased by decreasing the lead time of the process module network. It also showed a reduction in operating costs and the way this reduction is distributed among the modular supply chain members. The versatility aspect of flexibility was not included, because this aspect refers to the total number of different customer orders which can be handled by a modular supply chain. The current approach only considers one order at the time. In order to analyse multiple orders at the same time the approach has to be extended with an analysis of all relevant subsets of service elements (and corresponding process module networks) organisations and/or modular supply chains can produce. Relevant subsets are those subsets which match the preferences of end customers and which modular supply chains are able to produce. An increase in versatility (for instance by means of EDI) is realised when the number of relevant subsets of service elements has been increased.

An other issue which remains to be addressed is how modular supply chains are formed within dynamic networks. A dynamic network encompasses a set of organisations which form different modular supply chains
to perform different process module networks. The adoption of this dimension in the modular design approach will raise complexity significantly, because: (1) all organisations within the network should be modelled in terms of service elements supported, process modules supported and their operating costs and times; (2) all transaction costs per relevant combination of organisations (one-to-one relationships) have to be known; and (3) all switching costs, which are costs of switching from for instance a road carrier to another road carrier, have to be known. Further research is required to analyse this additional dimension.

After resolving these issues, we should be able to assess the impact of EDI in a modular dynamic network in terms of increase of flexibility, costs and benefits and possible shifts in organisational boundaries.

References

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