Working paper

Organizing activities in industrial networks - The case of Volvo S80

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Abstract

Based on an efficiency model presented by Richardson (1972), this article addresses the efficiency and organizing of activity structures. While Richardson's model is activity based, it allows analysis of the efficiency in industrial networks where boundaries other than firm boundaries delimit the unit of analysis.

Richardson's model is used here for analyzing the activity structure created for the development and manufacture of the Volvo S80. More specifically, Volvo's relations with two of its module-/systems-suppliers were studied. The cases show that the actors involved strive to achieve efficiency through realizing scale benefits where possible. These potential scale benefits are, however, limited by the actors' striving to create unique end products. These contradictory efforts lead to a situation in which a number of different dependencies between various activities need to be coordinated. The characteristics of the activity dependencies thus have strong implications for the organizing of the activity structure.

In contrast to traditional economic theory, the present analysis shows that strong dependencies between activities need not necessarily be coordinated within the firm boundary, i.e. through hierarchy. Instead, the analysis reveals that both formal and informal organizational units, some temporary and others more long term, can be created to coordinate strong activity (inter-)dependencies through relationship exchange. It is also concluded that alternative organizational solutions always exist, thus generating dynamics that continuously develop the network. Each organizing mode thus creates new possibilities for technical and organizational innovations.

Introduction – A background to the Volvo S80

Volvo introduced the S80-model in the summer of 1998. The S80 was the first model based on Volvo's completely new platform P2, which forms the basis of a number of derivative car models. For the development of the P2-platform and the S80-model, Volvo altered its relations with a number of suppliers, and thereby its network.

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This development began in the crisis following Volvo’s and Renault’s break-up in 1994. Over a period of a little more than two years, the two companies had invested many resources in a joint platform. When the cooperation was terminated, Volvo had no platform of its own and very scarce financial resources. This situation was very serious in view of the car industry's requirement of frequent product renewal – especially since at that time, Volvo was among the smallest ”independent” car manufacturers in the world.

Volvo realized that a new way of working was required in order to develop a new platform within a reasonable time frame. Volvo therefore studied other car manufacturers’ recent changes in product architecture, internal organization and supplier relations. Volvo was especially inspired by Chrysler – a company that had recovered tremendously well after a severe crisis. The change undertaken by Chrysler was the division of the car into a number of building blocks, i.e. modules, the majority of which were developed and manufactured by suppliers. Their development work was organized in cross-functional teams, in which the module-suppliers played an important and active role.

These ideas formed the basis of the changes Volvo initiated regarding internal conditions and network characteristics, both in the areas of product development and manufacturing. By dividing the S80-model into a number of modules, Volvo could outsource some of them and thereby parallelize and shorten the product development work. The suppliers could then contribute time and financial resources and thereby reduce the pressure on Volvo. Another benefit was that Volvo could profit from experiences gained by the suppliers when working with other car manufacturers in other development projects. Volvo organized the development project in cross-functional teams, called module teams, in which the suppliers played an important role.

Manufacturing activities were changed in a similar way. The suppliers responsible for one or several modules established local module assembly units in Volvo’s proximity. In these module assembly units (MAUs), the suppliers assemble the product modules directly on Volvo’s orders and within a very short time frame.

A few of Volvo’s suppliers have thus taken a large measure of responsibility for the development and manufacturing activities related to product modules. Strong dependencies between the companies’ activities have therefore been created. This article discusses these activity (inter-)dependencies based on a theoretical model introduced by Richardson (1972). The aim is to analyze the efficiency and organizing of an activity structure with strong interdependencies that cross firm boundaries.

Frame of reference – Richardson’s efficiency model

Efficiency is a term that has been defined and used in many different situations (see Torvatn 1996). Regardless of the exact definition, efficiency is always based on a relationship between output and input. A system boundary that defines output and input is therefore always required when analyzing efficiency. Economic theory has traditionally used the firm boundary, which is assumed to separate the firm from supply- and demand-markets, as a system boundary. Contrary to this prevailing view, this article uses an activity-based efficiency model presented by Richardson (1972). Through its focus on activities, not actors or firms, this model can be used for analysis even where the firm boundary is not used for delimiting the unit of analysis.

Activities can, according to Richardson (1972), be coordinated through market exchange, internal coordination (hierarchy) or relationship exchange. The most efficient form of coordination is determined by the dependencies between the activities (and the resources they activate) inherent in each situation.

One type of dependency can be identified when activities can, at least to some extent, use the same type of resource when being performed. Such activities are labeled *similar activities* (ibid:889) and can give scale benefits. Activities can also be sequentially dependent, which means that they must be performed in a certain order. Such activities are labeled *complementary activities* (ibid:889). Moreover, if two complementary activities are specific in relation to each other, i.e. if they are qualitatively and/or quantitatively adjusted to each other, Richardson uses the term *closely complementary activities*.

Based on combinations of these types of activity dependencies, Richardson identifies appropriate forms of coordination (see Figure 1). *Market exchange* is appropriate when two activities are dissimilar (i.e. they cannot use the same type of resource) and complementary (but not closely complementary). *Internal coordination* through hierarchy is most efficient when activities are closely complementary and similar, or dissimilar when they are not related to scale benefits elsewhere. Finally, relationship exchange is an efficient coordination form when two activities are closely complementary and dissimilar (Richardson 1972).

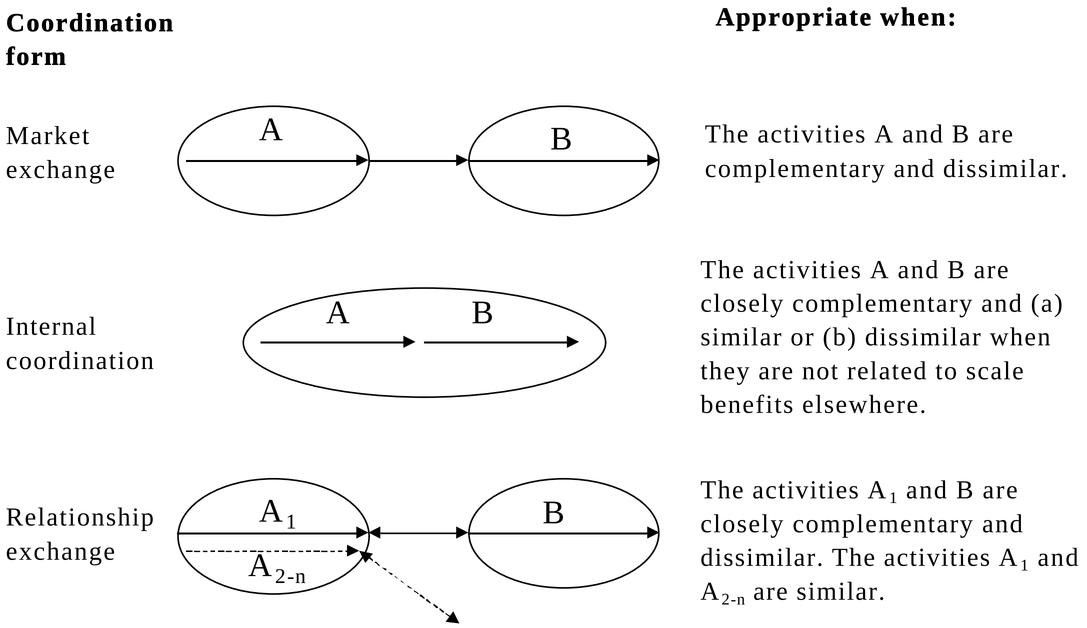

Figure 1. Three coordination forms according to Richardson (1972).

Coordination through relationship exchange implies that scale benefits can be achieved when performing activities, if similarities with activities in other activity chains are utilized. This is illustrated by the activities A_{2-n} in Figure 1. The company performing these activities also performs the similar activity A_1, which is directed to another customer, and can thereby increase resource utilization. In this way, firms can exchange products that are uniquely adapted to each other, while at the same time utilizing economies of scale. This is dramatically different when compared to market exchange, which assumes mass production of standardized products based on aggregated supply- and demand-situations. Relationship exchange is thus a coordination form that has a strong influence on the efficiency of industrial structures, but which has received too little interest from academia (Richardson 1972).

Richardson's model thus enables analysis of efficiency in an activity structure that crosses firm boundaries. This article uses Richardson's model when analyzing the way in which Volvo and its suppliers organized their product development and production activities for the Volvo S80-model.

Case description – The activity structure for the Volvo S80[3]

Volvo faced a very challenging situation at the start of the development of the Volvo S80. A new car model was not enough – a new platform was needed, from which a number of derivative products could be developed. In order to meet customer demands, it was also considered necessary to offer each car model in more variants than previously. Volvo's need for development and manufacturing resources was therefore immense, and new ways of working, both internally and with suppliers, were necessary.

The major changes were that the car was divided into a number of modules and systems, with suppliers assuming a more extensive responsibility. Volvo therefore co-operated with several suppliers during the development phase. The majority of these suppliers were global players who developed and manufactured modules for several other car manufacturers. Volvo's cooperation with these suppliers were by necessity far-reaching, and the suppliers were a natural part of Volvo's cross functional "module teams". The aim of the module teams was to integrate several different competencies (see Figure 2).

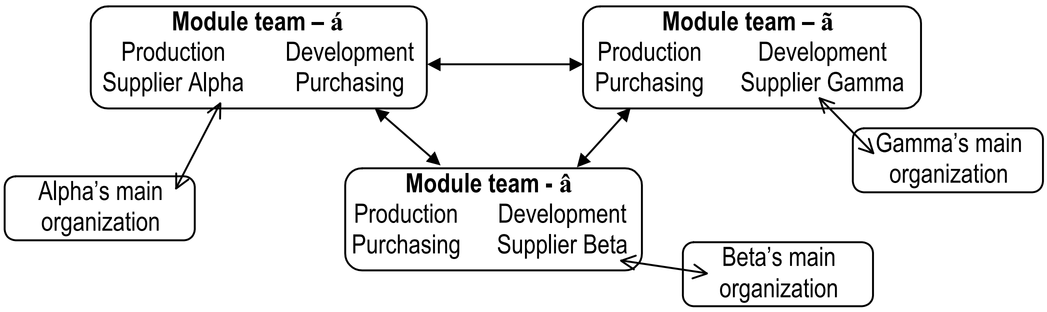

Figure 2. Illustration of three module teams and the suppliers' roles.

The changes in the industrial structure were also evident. A large number of suppliers have, traditionally, delivered one or a few components each to Volvo, who, in turn, has assembled these components at a pre-assembly station or on the main assembly line. The establishment by the module suppliers of local module assembly units (MAUs) that pre-assemble components into modules, changed this structure. One of the most noticeable advantages in this more parallel structure is that modules, and thereby cars, can be efficiently adjusted to customer requirements. Pre-assembling modules in separate flows also allows for modules to be tested before being fitted into the cars.

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[3] The case study was performed during 1997 and 1999 and included a total of 113 interviews with different managers at Volvo and at twelve different suppliers. Nine interviews were conducted with representatives from the supplier Alpha and twelve with representatives from the supplier Beta.

Due to the large number of possible variants of each module, it is not efficient to keep buffers of finished modules. Instead, each module is assembled and delivered just-in-sequence to Volvo's final assembly line when that specific module is ordered. The modules are assembled and delivered within tight time constraints, since Volvo knows the exact sequence of cars to be assembled, and therefore, what modules are needed when cars are put on the assembly line (see Figure 3). The MAUs that deliver modules to the first assembly station have an order-to-delivery time of only four hours, while the MAUs delivering to the final assembly station have about 20 hours at their disposal.

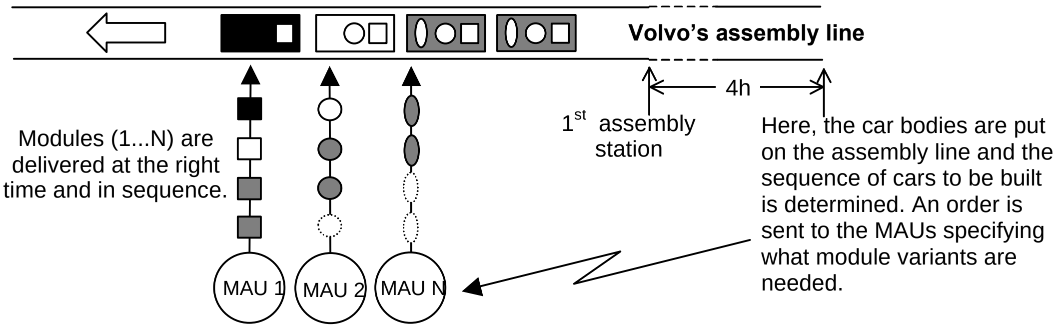

Figure 3. Illustration of modular supply to Volvo.

Two of the suppliers who assumed a far-reaching responsibility for developing and manufacturing different modules are Alpha and Beta. Alpha and Beta are two of the biggest suppliers globally within the automotive industry and they deliver components and modules to a large number of car manufacturers. Both suppliers had resources in Volvo's module teams during the development of the S80-model, and they both established a MAU in Volvo's proximity. The following sections describe the relations between Volvo and Alpha and Beta respectively, in more detail.

The relation between Volvo and Alpha – Product development

Alpha assumed a significant responsibility for the development of Module A_1 for the S80-model and also, to some extent, for Module A_2. Alpha was thereby responsible for activities traditionally performed by Volvo and strongly linked to Volvo's core values. Both Modules A_1 and A_2 are vital for, for example, safety and quality. These links between Alpha's responsibilities and the characteristics that make a Volvo car unique had major implications for the conduct of the development work.

Alpha had many years of experience, gained from developing A_1-modules for other car manufacturers. Volvo could therefore benefit from Alpha's expertise when developing Module A_1 for the S80-model. Alpha also had existing technical solutions and technologies that could enable shorter development time and lower cost per unit, if properly used. Volvo regarded these potential time and cost benefits as important, but had to continuously and carefully weigh them up against the aim of developing a car with unique characteristics.

Volvo's strive to develop a unique car, and thereby a unique Module A_1, required intensive communication between Alpha and Volvo. However, Alpha had no development resources in close proximity to Volvo at the start of the development project. Alpha's development resources were concentrated in one of their plants that already developed and manufactured A_1-modules for another car manufacturer. Although Alpha had a representative at Volvo for coordinating the development of Module A_1, they performed the main part of the development work at this other plant. One of Alpha's advantages was that one of their manufacturing units had been acquired from Volvo and had over 30 years experience of manufacturing A_1-modules for Volvo. This promoted a good relationship between the product development and manufacturing departments.

While most parts of the car were developed in parallel, it was difficult for Volvo to specify the function and appearance of Module A_1 in detail to Alpha. The design and engineering of Module A_1 needed to be continuously adjusted to other parts of the car, e.g. the electrical system. Unexpected problems occurred from time to time, which resulted in changed specifications. One such example was when engine vibrations spread to Module A_1. The development cooperation between Volvo and Alpha was therefore far from linear.

Alpha had a less extensive responsibility for the development of Module A_2, which needs to be adjusted to several other parts in the car. Module A_2 also has a major influence on the "look and feel" of the finished car. Volvo therefore retained a large part of the development responsibility for Module A_2 in house. Alpha's role was primarily to develop technologies enabling them to manufacture the geometrically complex basic component in Module A_2.

The relation between Volvo and Alpha – Production

Alpha had supplied different components and modules to Volvo for several years prior to the S80. For the S80, Alpha and Volvo agreed that Alpha's existing plant should continue to deliver A_1-modules to Volvo. Although this plant assembled A_1-modules in sequence, it was not, however, a strict module assembly unit (MAU). Instead, it was a complete plant in the sense that it not only assembled A_1-modules but also manufactured some of the components. The other components were purchased from other suppliers, some of which were chosen and quality-certified by Volvo.

The situation regarding Module A_2 was slightly different. The A_2-modules were assembled in a MAU located very close to Volvo (at a driving distance of 10 minutes). This MAU also assembled and delivered A_3-modules. Alpha became responsible for this MAU when they acquired the supplier that was responsible for the A_2- and A_3-modules.

The main component in Module A_2 is manufactured in one of Alpha's plants, which also manufactures the main component in A_2-modules for another car manufacturer. Some potential synergies thus exist in Alpha's manufacturing plant, even though the total volume is rather low. The other components that are pre-assembled in Alpha's MAU are delivered from external suppliers. Volvo designs most of these components, and Volvo also determined which suppliers should supply them.

When Alpha's MAU has finished the assembly of an A_2-module, it is loaded onto a special carrier for transportation to Volvo. The A_2-module is then pre-assembled, together with a few other components, into a higher-level module (Module V_2), which is one of the few modules that Volvo assembles in house. Volvo's internal MAU that assembles V_2-modules shares the building and several other types of resources with the main assembly shop. The A_2-modules are thus not delivered directly to the main assembly line, but to an internal MAU integrated into Volvo's ordinary assembly organization.

About a year after the start of production for the S80-model, Alpha moved its assembly operation for A_1-modules to a building located within Volvo's plant area. As space was available in the new building, Alpha also moved the assembly of A_2- and A_3-modules from the existing MAU. Although the potential synergies between the three modules are limited, Alpha could spread some administrative costs over a larger output. Additional synergies were exploited, as Alpha utilized skilled people from its other MAUs supplying A_1-modules to other car manufacturers.

The relation between Volvo and Beta – Product development

Volvo chose a rather novel technology for the development of System B, which is dispersed to several parts of the car and is therefore vital for the car's characteristics. Volvo needed help to use this novel technology and began cooperation with Beta, after a thorough comparison of different suppliers. Although Beta was a new supplier to Volvo, they were regarded as having the necessary developmental resources and technological skills. Beta also had internal component plants and a large number of suppliers and was therefore expected to contribute production aspects to the development project. Moreover, Volvo valued Beta's existing development projects with other customers.

Volvo invited Beta to participate during the pre-study phase of the complete P2-project, which was very early compared to Volvo's traditional practices. Since Volvo and Beta were new to each other, they perceived the cooperation as slow and hard-worked in the beginning. Much time was spent determining who should do what, and when etc. To solve these and any other problems early on, Volvo and Beta had special meetings, held in an atmosphere characterized by frankness and directness. These meetings resulted in a very "open" relationship between Volvo and Beta, who also made joint evaluations of their relationship. Due to these and other activities aimed at improvement, Volvo and Beta quickly acquired a common view both on their relationship and the project.

It was also important for Beta to fit into Volvo's development teams. Volvo therefore arranged special seminars and workshops for Beta's personnel. However, Beta initially had problems in increasing their development capacity in Sweden. Beta therefore hired people previously employed by Volvo and in this way they were integrated with Volvo's organization while at the same time increasing their capacity. Another consequence was, however, that Volvo occasionally felt that Beta's competence was too similar to their own.

Volvo had great difficulties in specifying in detail the function of System B. This was due to the novel technology used and the parallel development of the car, implying that new functions were added and existing ones changed. Several of these functions were developed by other system- and module-suppliers, which made it difficult for Beta to get a holistic view of all of the requirements of System B. The development of System B was therefore highly iterative and performed in close cooperation between Volvo and Beta. The co-location of engineers in the module team and their mutual efforts to get to know each other proved very valuable during this process.

The relation between Volvo and Beta – Production

The modules realizing System B exist in a large number of variants. Beta therefore established a MAU in close proximity to Volvo. During the establishment of the new MAU, Beta deployed project leaders from its other plants to help the local and recently employed management team.

Beta's MAU supplies Volvo with five modules, Modules B_{1-5}, that realize System B. Module B_1 is delivered in batches, and Modules B_{2-5} are delivered in sequence. Module B_2 is purchased from another supplier in batch, reloaded in the right sequence in the MAU and then delivered to Volvo. Modules B_{3-5} are pre-assembled in Beta's MAU and delivered in sequence to Volvo. The MAU also delivers a few modules to Volvo Trucks, thus allowing the MAU the possibility of spreading some administrative costs over a larger volume.

Beta's MAU has three small assembly lines, one each for Modules B_{3-5}. The equipment used in the lines is in many ways unique when compared to the equipment used in Beta's other MAUs. This is obviously due to the unique characteristics of the products delivered by Beta to Volvo, but it is also dependent on Volvo's influence on the design of Beta's assembly process.

To maintain a high level of service to Volvo, one of Beta's employees works full-time as a customer support. His role is to solve all problems related to the delivered modules that are found at Volvo's assembly line, and, to give feedback to the MAU. The customer support person therefore spends most of his time at Volvo.

There are basically two main components in Modules B_{3-5}. These are manufactured and delivered by two other Beta plants. Even if these components are uniquely adapted for Volvo, the plants can still use some of the equipment and working processes used for other products. Scale benefits can thereby be achieved in the component plants. This is especially evident in one of Beta's manufacturing plants, which manufactures a huge amount of main components for B-modules delivered to a number of different car manufacturers. The assembly activities performed in this plant are further rather similar to the ones performed in Beta's MAU dedicated to Volvo. The activities in the manufacturing plant are, however, not unique for each individual car and must not be performed in sequence, which enables scale benefits to be attained. Beta also achieves economies of scale when purchasing standard components for B-modules that are delivered to several car manufacturers.

Beta has several MAUs that deliver B-modules to different car manufacturers. In order to transfer improved ideas and working practices, Beta tries to standardize the operation of its MAUs. Beta also tries to standardize the relationships between its main plants and the different MAUs, for instance in terms of the ordering systems and procedures used. In this way, Beta tries to achieve scale benefits wherever possible, with the additional aim of being a full-service supplier of B-modules.

Analyses of activity dependencies

The case shows that the network encompassing Volvo and the module suppliers is complex and includes several different types of activity dependencies. The illustrated activity structure is analyzed in this section based on Richardson's efficiency model from 1972.

Adjustments give closely complementary activities

Some of the components in a Volvo S80 are standardized and can be found in other car models**,** as well as in other types of products. An evident example is nuts and bolts, which are designed and manufactured independently of Volvo's production of cars. The related activities do not need to be coordinated before they are performed. The activities are thus only *complementary* (Richardson 1972).

A majority of the activities undertaken by Volvo and the module suppliers are, however, adjusted to each other, as illustrated in the case. Alpha for instance, adjusted the development activities for Module A1 according to Volvo's unique requirements on quality and safety. Beta also adjusted their development activities due to Volvo's unique requirements on the functions implemented by the System B. These adjustments resulted in unique products and processes, and the related development and manufacturing activities were uniquely adapted to Volvo. Volvo's and the module suppliers' activities are in this way qualitatively and quantitatively adjusted to each other, and the output from the activities cannot be used elsewhere. The activities must therefore be coordinated before they are performed, and they are therefore *closely complementary* (Richardson, 1972).

Some of the activities undertaken in the module supplier's main plants are thus completely adjusted to Volvo. Another aspect of *close complementarity* emerges when analyzing the activities in the module assembly units (MAUs), i.e. activities are not only specific for the Volvo S80 but also specific to individual cars. This stronger and more precise dependence was not only related to the product design, but also to time.

The case also reveals that several of the second tier suppliers' activities are *closely complementary* to Volvo's activities. Several of their products were dedicated to Volvo, and the output of their design and manufacturing activities could not be used elsewhere. It is thus clear that the car design influences the activity structures far beyond the single company and its relationships with direct parties.

Similar activities enable economies of scale

Volvo's requirements on unique products and technical solutions made it difficult for the suppliers to always use existing competencies, products and processes when undertaking activities. The *similarity* between the activities was thus reduced, which meant that the possibilities of achieving economies of scale were also reduced (Richardson, 1972). It would have been cheaper and the development cycle shorter if Volvo had bought the suppliers' existing products. One of Volvo's ambitions was therefore to utilize *similarities* between activities by encouraging suppliers to use their existing products and technical solutions where possible. Both Alpha and Beta used some standard components in all their modules. In this way, Volvo achieved a product that the customers perceived as unique, while at the same time, the suppliers could benefit from some economies of scale.

Moreover, activities can be *similar* and enable scale benefits, even if their undertaking requires different physical resources, as long as they require the same intangible resources – e.g. knowledge and skills. Alpha for instance, could benefit from their previous experiences of the development and manufacture of A_1-modules for other customers. Beta was in a slightly different position due to the novel technology used in System B. Beta had no existing solutions to refer to during the development phase.

Both Alpha and Beta had, however, experience of operating MAUs. These intangible resources in terms of MAU-operation, gained in other customer relations, could be utilized in their relationship with Volvo.

A supplier can also achieve scale benefits when developing and manufacturing several products for one customer. Alpha could, for instance, assemble the Modules $A_{1\text{-}3}$ in one MAU. Although the equipment used when assembling the different modules differs, at least administrative activities, like information handling for instance, are similar. The purchasing company can gain similar scale benefits when utilizing the similarities between activities undertaken for the different modules but directed towards one supplier. Volvo therefore tried to standardize, i.e. increase the similarity between, different contacts with the MAUs.

Similarities can also be found between activities that are parts of the same activity chain. One example from the case is that almost the same type of resources could be used for Alpha's assembly of Module A_2 as for Volvo's internal assembly of the V_2-module. The Beta-case shows that activities can be similar in some dimensions but dissimilar in other dimensions. Beta's equipment is very different from Volvo's equipment. However, some similarities do exist due to the fact that Volvo assisted Beta in the process design.

The case thus clearly demonstrates that the actors involved strive to create unique products and thereby creates closely complementary activities, while at the same time trying to find new, as well as utilizing existing, similarities between activities. The results from these efforts, in terms of the dependencies between production activities, are summarized in Figure 4.

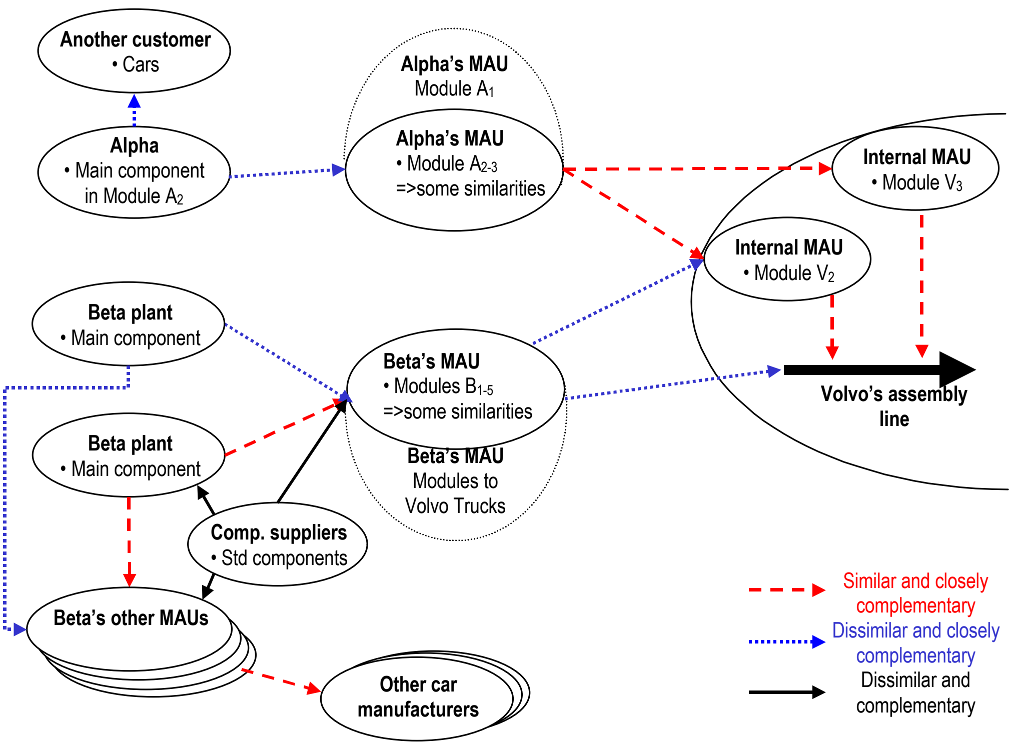

Figure 4. Illustration of the dependencies between the manufacturing activities in the cases.

Complex dependencies give systematic complementarity

The analysis has so far been based on the terms and concepts presented in Richardson (1972), i.e. (*closely*) *complementary* and *similar* activities. The cases revealed, however, situations of activity dependencies that were difficult to analyze and explain with these concepts. One further step is therefore taken here, based primarily on an article published by Richardson (1998).

Additional complexity in activity dependencies is found when several of the activity chains resulting in an end-product (e.g. a car) are included in the unit of analysis. Richardson (1998:10) claims that activities can be regarded as *systematically complementary* when '*…a large number of closely complementary activities or investments have to be coordinated … where coordination will not develop spontaneously … but requires design and direction*'. Systematic complementarity thus exists when a number of closely complementary activities cannot be coordinated by cooperation, but rather, requires top-down direction**.**

Volvo's and all the MAUs' activities can thus be regarded as *systematic complementary*. This is especially evident when situations occur that deviate from the plans. A good example of this is when Volvo changes its production plan, which is done for example, when the paint shop cannot paint car bodies in a certain color. When this problem occurs, Volvo must produce cars in other colors. Every MAU has, however, a number of restrictions that make it impossible to change the production plan in certain ways. Most restrictions are due to the fact that the MAUs cannot acquire new variant-specific components without a certain lead-time, which is often too long when a change of plan is done. While the MAUs and Volvo's different restrictions are more often than not contradictory, this situation cannot be solved by means of cooperation between the parties involved. Someone, in this case Volvo, needs to make decisions about which cars and thus which modules should be built, i.e. which manufacturing and assembly activities are to be undertaken.

Systematically complementary activities are more prominent during the development phase, since the final result is unknown, several different technologies and sub-systems should work together, and specifications are continuously changed and upgraded. The case description showed, for instance, how Module A_1 was continuously adapted to other sub-systems and modules, and vice versa. By cooperation, the parties involved can occasionally coordinate two activities embedded in such a complex network of interdependencies. The technical dependencies are, however, more often than not, too numerous and too far-reaching to be coordinated by the co-operation of the parties involved. This is especially the case when any of the involved actors also needs to consider the requirements of several other parties who are not directly involved in the specific situation, e.g. the suppliers' other customers.

The development activities can thus be regarded as *systematically complementary* since they are interdependent on a large number of other activities and cannot be delimited in a simple way. This situation relates to what Thompson (1967) refers to as the most complex form of dependence, i.e. reciprocal dependence between activities, which means that one activity's input is another activity's output and vice versa. The output from each activity requires adjustment when undertaking the other activities, which in turn requires that the first activities are adjusted and so on. These *systematically complementary* activities must be coordinated through direction, or direct supervision, which in our case was done continuously by Volvo.

Organizing activities in industrial networks

Based on Richardson (1972, 1998), the above analyses show different types of dependencies between activities in terms of *similarities* and different types of *complementarities*. When it comes to the second part of this article's aim, the central question is how the involved actors can organize these different dependencies. Organizing is here defined as the division and coordination of activities between different organizational units (Mintzberg 1979).

Organizing production activities

The case description and the analyses discussed activities that were *complementary* and *dissimilar*. One example given here was the manufacturing of standard components purchased by Beta for assembly into Modules $B_{1\text{-}5}$. The component manufacturing and Module $B_{1\text{-}5}$ assembly activities require different resources for their undertaking and they do not need to be coordinated before being performed. In line with Richardson (1972), these activities were organized by means of market exchange as the form of coordination.

Another type of activity dependence found in the case was *closely complementary* activities. Two different types of close complementarity were identified. One type was activities that were unique to the Volvo S80 as a whole, and another type was the activities that were unique to each individual car. The former activities do not need to be performed in Volvo's proximity. They could therefore be performed in the suppliers' main plants, where other *similar* activities are performed that are destined for other customers. The suppliers (and Volvo) could thereby benefit from economies of scale in these main plants, as the activities were coordinated through hierarchy.

Due to some activities in the suppliers' main plants being unique to the Volvo S80, and thereby *closely complementary* to the activities in the MAUs, extensive coordination was required. Market exchange was therefore not an efficient alternative, and either internal coordination or relationship exchange was the most preferable form of coordination. However, coordination and organization of activities between the main plant and the MAU cannot be studied in isolation. If these plants are coordinated through hierarchy, it is evident that the MAUs and Volvo's activities will be coordinated through relationship exchange, and vice versa. The *close complementarity* between each MAU and Volvo's activities must also be considered. This is especially the case insofar as the activities in each MAU are dedicated to each individual car.

The most preferable coordination form (relationship exchange or hierarchy) in this situation depends, according to Richardson (1972), on the potential *similarities* that can be utilized. The case showed that both the buying firm and the supplier could perform activities in other parts of their organizations that are similar to those undertaken by the MAU, some of which may be purely administrative. The buying firm's and the supplier's possibilities to exploit such *similarities* between the *closely complementary* activities must thus be considered when organizing, i.e. when determining the form of coordination (see Figure 5).

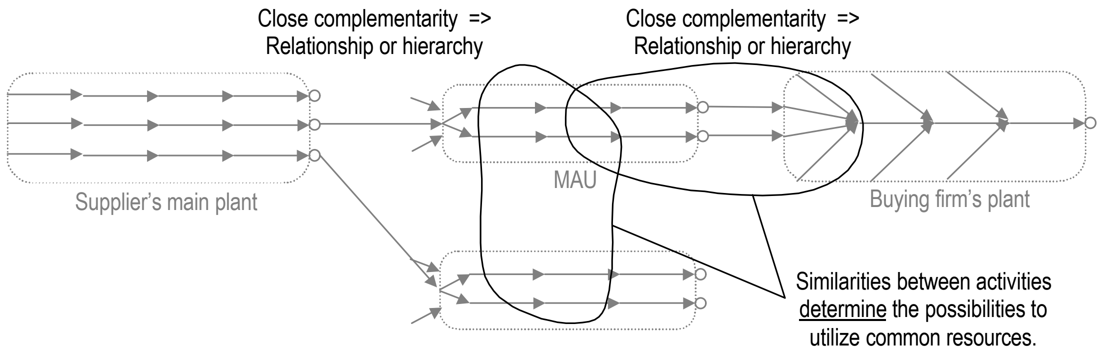

Figure 5. The choice of coordination form depends on similarities.

Regardless of what coordination form is chosen in such situations (i.e. relationship exchange or hierarchy), it is clear that the organizational boundaries created will internalize some activity dependencies and externalize others. Volvo could, for instance, internalize the closely complementary activities in a MAU within the hierarchy. This would, however, externalize the dependence between the MAU and the supplier's main plant. The actors performing the divided manufacturing activities must therefore utilize coordination mechanisms that correspond to the coordination requirements (Thompson 1967) – which are determined by the dependencies between the activities – regardless of the extension of the firm boundaries. Figure 6 illustrates how different coordination mechanisms (see Mintzberg 1979) cross different coordination forms in the network. The conclusion is therefore that the actors need to create formal and informal organizational units, some temporary and others more long term, that are based on one or more coordination mechanisms that internalize some activity dependencies.

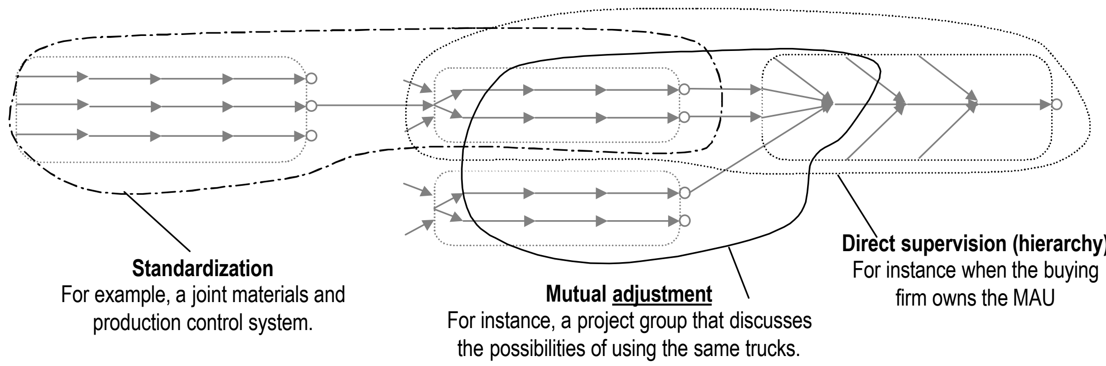

Figure 6. Different coordination mechanisms cross the coordination forms.

On a more general level though, it is clear that the organizing of activities by means of MAUs enhances Volvo's aim of achieving efficiency through both scale and product uniqueness. The MAUs' role in the overall system is to decouple the plants that manufacture components from Volvo's requirements on sequence deliveries. In this way the plants that manufactures components can really exploit the *similarities* between activities destined for different customers. Parallel to this decoupling role, the MAUs also need to perform the paradoxical task of integrating the plants manufacturing components with Volvo. A MAU thus performs a very important task in the overall system, i.e. it enhances efficiency through the utilization of similarities in the component plants, while at the same time ensuring the delivery of unique modules to the customer. A MAU could therefore be inefficient in itself while still contributing to the efficiency of the total industrial network.

Organizing product development activities

The analysis established that dependencies between development activities are very complex, leading to a situation that Richardson (1998) labels *systematic complementarity*. Richardson claims that systematically complementary activities must, by necessity, be coordinated by hierarchy and thereby internalized within the firm boundary. This is a plausible conclusion considering that the firm boundary is the most prominent (and important) boundary in traditional economic theory. The case showed, however, that systematically complementary activities could be organized through relationship exchange.

The division of the product into modules delimits the extension of the complex dependencies that would result in systematic complementarity. Systematic complementarity was accepted within the modules, but an effort was made to minimize the dependencies between the modules. Each module interface was therefore designed to be as simple as possible in order to achieve as few crossing interdependencies as possible. The modules thus limited the extension of systematic complementarity across the product, which enabled more dependencies to be coordinated by mutual adjustment.

In this way the module teams constituted an important organizational mechanism in cooperation between Volvo and the suppliers. The module teams constituted a forum where suppliers could share their knowledge about their current resources (and how the modules could be designed to enhance the utilization of similarities) and their experiences of working with other car manufacturers. Volvo-employees from different functions could consider this input while also creating product characteristics that were unique to a Volvo-car. The module teams thus reduced the extension of dependencies between activities and facilitated coordination through mutual adjustment between team members and direction by team leaders.

The module teams did not, however, cover all the strong dependencies. Strong dependencies, and in some cases systematic complementarity, existed between activities performed in different teams. System B is a good example, since it cuts across most parts of a car. The related dependencies could not be coordinated by cooperation between all the concerned individuals in the different teams. Instead, direction was required, which was provided by project leaders who chaired meetings between the different module teams at different levels. By creating formal and informal organizational units in this way, Volvo and the module suppliers could coordinate the reciprocal dependencies through the module teams (see Figure 7).

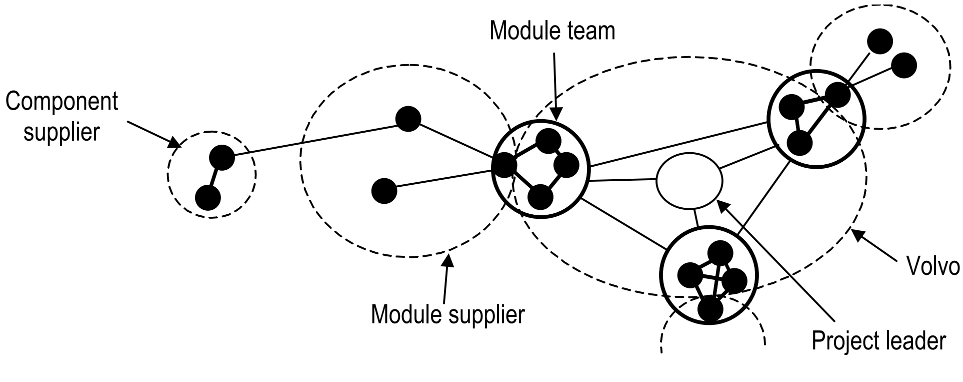

Figure 7. Organizing of the development work in module teams.

The division of the car into modules thus enhanced the coordination of development activities between Volvo and the suppliers. In other words, the module teams enabled coordination of systematically complementary activities across organizational boundaries.

Organizing implies dynamics in the activity structure

The analysis showed that the actors organized the activity structure to deal with the paradox between efficiency (through scale) and uniqueness. The product was divided into modules that could easily be adapted to different customers' requirements without changing all the components. The suppliers' establishment of MAUs was also a step in this direction since they linked the component plants that utilized similarities to Volvo's unique requirements.

It was also argued that regardless of how companies choose to organize these product development and manufacturing activities, strong activity dependencies cutting across firm boundaries would exist. The actors involved must therefore create (overlapping) formal and informal organizational units to internalize and coordinate the activity dependencies that are externalized by the firm boundaries.

There will, however, be no single way of coordinating all the dependencies. Alternative organizing methods will always exist and be utilized when the actors strive for a better balance between efficiency and uniqueness. Each form of organizing leads to new possibilities for technical and organizational innovations, which, in turn, implies new organizing methods. The relationships and the wider network will thus be continuously changing, a fact further emphasized by the actions of the suppliers' other customers, in their efforts to increase efficiency and uniqueness.

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