# Modeling Enterprise Dependency Networks

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***Abstract***
*The term enterprise modeling, synonymous with enterprise engineering, often refers to methodologies, developed for modeling activities, states, time, and cost within an enterprise architecture. They serve as a vehicle for evaluating and modeling activities resources and so on. CIM - OSA (Computer Integrated Manufacturing Open Systems Architecture) is a methodology for modeling computer integrated environments, and its major objective is the appropriate integration of enterprise operations by means of efficient information exchange within the enterprise. Although there are other methodologies in the industry that serve the same purpose, most of them concentrate on the internal aspect of an enterprise. The paper is concerned with the modeling of the links between enterprises. The aim is to examine these relationships or links in detail and suggest a method for modeling enterprise networks drawing on the methodologies currently used in the industry and extending with the method proposed here.*

**Keywords : Enterprise modeling, Dependency Factors, CIM-OSA, TOVE**

### *Introduction*

Enterprise modeling methodologies like *CIM-OSA* or *PERA* focus on the modeling of activities, resources and labour within an enterprise. Their primary objective is to create a model of the tasks an enterprise *(in terms of functions)* performs, resources required for each function, and people allocated for each task. The majority of those methodologies were developed with a computer integrated manufacturing environment in mind and their aim is to assist in the modeling process of computer integrated manufacturing enterprises. Their success lies in their ability to develop an overall view of all three levels mentioned above (functions , resources, labor) as well as the interdependencies amongst them. The models present an enterprise from two different viewpoints. These are the functional view and the manufacturing view, presenting the tasks from a *data flow* perspective and a *resources* perspective respectively. The first one is dealing with information and data that are relevant for the performance of each task, whereas the later one deals with the equipment and the people related with each task or function.

However an enterprise is more than a set of activities, resources and people. It also consists of a set of links with the outside world. These links usually take the form of dependencies as they are established under a very competitive environment. The information that is passed to an enterprise, through these links, as well as the information that is propagated to others, has a direct affect to the way an enterprise operates.

### *Enterprise Modeling Scenario*

The operations of an enterprise are affected by the operations of other enterprises on a supply chain network. The links we're examining are of *demand-supply* nature. The affect they have on an enterprise operation, can be understood if one considers what happens when a company has a contract for an *x* percentage of goods by a supplier and the supplier fails to deliver. The company's operations will certainly be affected as their production levels will fall until they find a new supply to recover the missing supply. Suppose we're trying to model the following scenario. Assume that *Integrator a* and *Integrator b* both work in the same region serving the same purpose which is of course the production of cars. They are both supplied tyres by a major tyre manufacturer at the predetermined capacity *Ca,* for *Integrator a* and *Cb* for *Integrator b*. Let's also assume that the total capacity of the tyre company is *Ct*. Both *Integrator a* and *Integrator b* produce annually a number of cars. The number of cars both of them produce is depended on their suppliers' capacity. Figure 1. shows the dependencies between the car manufacturers and the tyre manufacturer.

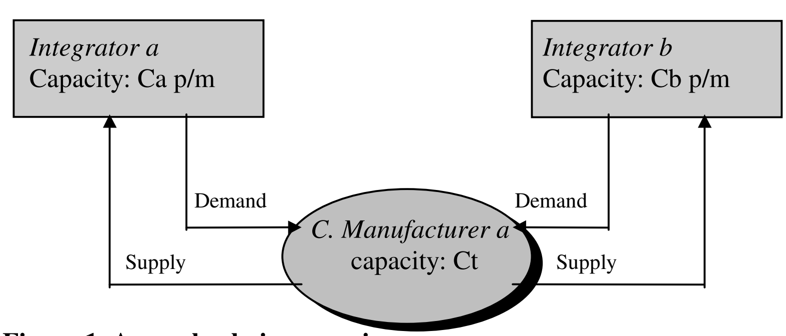


**Figure 1. A supply chain scenario**

Keeping this data in mind and using all data regarding the suppliers of the rest of the car components, we can create a model of the tasks that take place in each major car manufacturer.

***Considerations before modeling***
We could create a hierarchical task model of the functions that take place, the information used, as well as the labor required. But would the model be precise and reliable? If the production of the tyre manufacturer goes down, below its control capacity level, then the model we had created would not be accurate. It would not be accurate because the information regarding the suppliers would not be precise. Both car manufacturers would have to decrease production until they find a new supplier. Until this happens they would also have to stop getting as many car components from the other suppliers as they would be unnecessary. Production would go back to normal if both found a new supplier or *Component manufacturer a* restored its initial capacity.

There are of course many questions that can be raised and many scenarios that be created. If for example, *Integrator a* has a stronger link with *Component manufacturer a* then *Component manufacturer a* may agree to keep *Integrator a* on the original supply level and deduct the level of supply from *Integrator b* only. *Component manufacturer a* may close down leaving both car manufacturers looking for a new supplier. On the other hand the car manufacturers themselves may decide to leave the region leaving the tyre manufacturer out of business. There are a number of scenarios or situations that can be created in order to illustrate how strong the need for modeling these network of dependencies are. On top of all that the example also illustrates how complex this modeling process can be, due to the complex nature of these links.

***The nature of dependencies***
In a previous publication, Periorellis[1997] we suggested an object oriented approach for modeling the links between enterprises. We declared the problem of enterprise modeling and suggested an O-O technique for developing a model of a particular sector, starting with the modeling of the enterprises in isolation and moving on to the modeling of their links.

Due to the complexity of the links and the enormous variety of the contracts that can be agreed between enterprises it would be very adventurous and over ambitious to claim that a model that caters for every link can be developed. The problem is that, in real life, if something like the situation described above had actually happened we wouldn’t be able to tell how would the major car manufacturers react. However we can develop a model and approximate their reaction by considering a number of facts.

**Status of an enterprise**
The status of an enterprise is a variable that indicates how smooth the company operates. There are different states a company may be in, when it takes the form of a player, in a supply chain network. Every company has a product capacity level and a control capacity level. The product capacity indicates how much the company produces annually and the control capacity indicates what is the maximum they can

produce. We've declared 3 different states a company can be in, matching the three types of *dependency factors* that can be assigned to its links. The three states are represented by colours on the prototype whenever a graphical representation of the supply chain network is drawn, although on the thesis they are indicated by symbols.

*Status of Component Manufacturers*
We've divided three states for each component manufacturer and we've assigned a special symbol to each one of them. The arrow pointing upwards '↑', shows that the component manufacturer supplies to various integrators most of its total product capacity and operates smoothly. The arrow pointing in both directions '↔' shows that the company supplies almost all of its total capacity and is in a state of investigating the possibilities of establishing a new link with another integrator for the rest of the capacity. Finally the arrow pointing downwards '↓', indicates that the company has a considerable amount of its total production capacity unwanted and has to do something to sort out the problem of the spare capacity immediately.

*Status of Integrators*
The integrators' state are indicated using two symbols omitting the intermediate state that was declared for component manufacturers. The symbol of equality '≡' indicates that the annual capacity reaches the pre determined levels, whereas the symbol of approximation '≅' shows that there is a lack of supply and further investigation has to be done on the supply chain network in order to cover that gap.

**Dependency factors**
The status of the company is the major criteria for determining the dependency factors. The status is an indication of the production levels as well as the demand on the company's product percentage wise. In order to assign a *dependency factor* and approximate the company's reaction to a new link being established or deleted we divide the type of factors into categories. Initially we divided the types of links into three categories; the strong ones the medium ones and the weak ones. We use the capitol letters *A,B,C* to indicate the links initiated by the higher level to the lower one; that is for example from the integrator to the component manufacturer. We also use the numbers *1,2* and *3* to indicate the strength of the link from the lower level to the higher or in other words from the component manufacturers point of view. Each one of these links regardless of the level for which they are defined shows the status of an enterprise at some point in time. The status of the enterprise –at least in the beginning- is determined by the capacity they produce and the capacity they supply. The strength of the link is determined by the percentage of supply an integrator gets from a component manufacturer. The two arrays show what the two sets of dependency factors indicate from the integrators point of view.

| *Dependency Factors* | *Percentage integrators demand by component manufacturer* |
|---|---|
| *Degree A* | *Strong Dependency i.e. ≥ 60%* |

| | |
|---|---|
| *Degree B* | *Medium strength dependency. Integrators have more suppliers for the same product* ≥ 20% < 60% |
| *Degree C* | *Weak dependency> integrator receives most of the supply from other resources* < 20% |

In a similar way the following table shows how the degree of dependency between a component manufacturer and an integrator is divided and what the numbers mean.

| *Dependency Factors* | *Percentage C.M. supplies to an integrator* |
|---|---|
| *Degree 3* | *Strong dependency most of its capacity* ≥ 60% |
| *Degree 2* | *Medium strength. They supply other integrators too.* ≥ 20% < 60% |
| *Degree 1* | *They only supply a small percentage. Most is supplied elsewhere* < 20% |

Both tables show what the degree assigned to a link indicate. When a new link is established on a supply chain network a pair of these degrees; that is one of each table, would be assigned to it, indicating how dependent they are upon each other. When a link breaks there are a set of alternatives associated with each one of these pairs. There are nine pairs that can be drawn from these two tables. The following table shows the pairs and what they indicate for both integrators and component manufacturers.

| *Dependency factors* | *Meaning* |
|---|---|
| *Degree A3* | *Integrator demands most of its total*<br>*Comp. Manufacturer supplies most of its total capacity* |
| *Degree A2* | *Integrator demands most of its total*<br>*Comp. Manufacturer supplies some, but there is a lot spare of its total capacity* |
| *Degree A1* | *Integrator demands most of its total*<br>*Comp. Manufacturer supplies a small percentage of its total capacity and has others demanding the rest* |
| *Degree B3* | *Integrator demands some of its total*<br>*Comp. Manufacturer supplies most of its total capacity* |
| *Degree B2* | *Integrator demands some of its total*<br>*Comp. Manufacturer some of its total capacity* |
| *Degree B1* | *Integrator demands some of its total*<br>*Comp. Manufacturer supplies a small percentage of its total capacity* |
| *Degree C3* | *Integrator demands a small percentage of its total*<br>*Comp. Manufacturer supplies most of its total capacity* |
| *Degree C2* | *Integrator demands a small percentage of its total*<br>*Comp. Manufacturer supplies some of its total capacity* |
| *Degree C1* | *Integrator demands a small percentage of its total*<br>*Comp. Manufacturer supplies a small percentage of its total capacity* |

The pairs on the table show how the *dependency factors* are translated. There is of course the other side of the coin. The table shows us what do these factors indicate as long as a link exists between the two enterprises. However, as it's been mentioned throughout the thesis, there is also a need to establish what the impact is, on the network of dependencies, should a link gets deleted.

Each one of these pairs is associated with a set of alternatives. These alternatives indicate the actions both enterprises may take should one of the links breaks. These actions are derived from past experiences with a particular supply chain network i.e. *automotive*, and are dependent upon the *dependency factor* applied to the broken link. The alternatives are showed in the following table starting with the component manufacturer.

| *Broken Link* | *Alternatives for Comp. Manufacturer* |
|---|---|
| *Degree 3* | *1. Check whether any integrators need more supply.*<br>*2. Leave region* |

| | |
|---|---|
| *Degree 2* | 1. *Check possibilities of supply to other integrators*<br>2. *Lower capacity level* |
| *Degree 1* | 1. *Establish link with other integrators*<br>2. *Lower production levels* |

If a *degree 3* link breaks it will a have a major impact on the component manufacturers operations as most of the product capacity won't be targeted by any other integrator. There will be a major impact on the company's cash flow as most of the supply will remain unwanted and the only alternatives in order to stay on the network will either be to establish a new link quickly, leave the region or go out of business.

Links of *degree 2* also have a major impact but we assume that the company could recover if they take immediate action. The action would be to find an integrator or a set of integrators and allocate the remaining capacity or temporarily lower the capacity level so no major amounts of money will be wasted. Links of *degree 1* indicate that a small percentage of supply; i.e. less than 20%, needs to be supplied to a new integrator which the company has to find.

From the integrators point of view the situation is slightly different as they have more options to recover a situation like that. The table below shows the alternatives assigned to its type of broken links.

| *Broken Link* | *Alternatives for Integrators* |
|---|---|
| *Degree A* | 1. *Establish new links with other suppliers*<br>2. *Make new contracts with suppliers.*<br>3. *Ask other suppliers to increase their capacity*<br>4. *Fund new supplier*<br>5. *Leave Region* |
| *Degree B* | 1. *Establish new links with other suppliers*<br>2. *Make new contracts with suppliers.*<br>3. *Ask other suppliers to increase their capacity* |
| *Degree C* | 1. *Find a new supplier*<br>2. *Ask suppliers to increase their capacity* |

The table shows that the integrator due to its position on the supply chain network will manage to find another supplier willing to recover the damage the broken link caused. It would not leave the model unless all the alternatives have failed. In most cases the remaining suppliers could be asked to raise their current capacity, or find a new supplier in some other region that would be willing to cover that percentage, or even fund to build a new supplier.

The model should take into account all these scenarios above as well as the information related to each enterprise and produce a *dependency factor* for each link between. The *dependency factor* would indicate how strong the relationship is between the two parties. On top of all that it also needs to be shown what happens, or what the implications are there on the model, in case any of the above scenarios takes place. If *Component manufacturer a* suddenly stopped supplying *Integrator a* and *Integrator b* then the alternatives would be either to look for some other supplier. This is assuming that they both have the same *dependency factor* upon *Component manufacturer a*. If *Integrator a* had a stronger *dependency factor* then their would be another alternative for *Integrator a*. *Integrator a* could still be supplied the same demand whereas *Integrator b* with the lower *dependency factor* would only have one (*look for other suppliers*). If a new supplier joined the model, both *Integrator a* and *Integrator b* would have the same chances of getting the demanded supply.

There are of course a number possible scenarios to be taken into account. However, assuming that an enterprise has good knowledge of the industry, the model could be developed and the impact of changes on it could be predicted relatively to some probability factor, which would be derived by the experience the enterprise has on scenarios and situations that took place in the past.

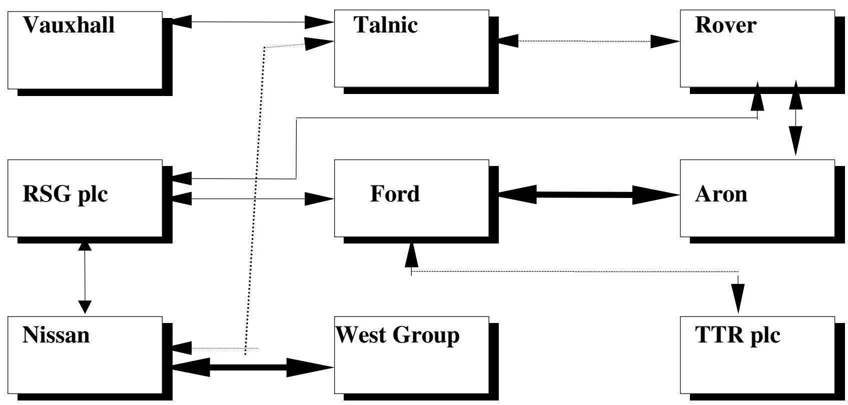


**Figure 2. The styles denote the different DF's assigned to each link**

The diagram indicates the strength of the dependencies in a supply chain scenario. The solid line indicates a strong dependency whereas the doted line that there are alternatives in case the component manufacturer leaves.

***How DF's for Bi-directional Links are determined***

The links between enterprises on a supply chain network are always bi-directional. In other words if Nissan is dependent on SR Tyres then they are dependent on Nissan too. The *dependency factors* may of course be different, as they are determined by different information. Producing the *dependency factor* for each link is very tricky.. If for example, in the scenario above there were other tyre manufacturers in the industry that either Nissan or Rover are unaware of, then of course the *dependency factor* between them and the tyre manufacturer would be very strong. However if they were aware of the industry and they knew that other tyre manufacturers did exist then the *dependency factor* they would assign on the links would be smaller. The same, of course, applies for the tyre manufacturer. The factors that determine the strength of the links between the tyre company and the car manufacturers depend on whether other car manufacturers exist in the region or not.

The approach for producing a *dependency factor* starts with the definition of the links between the enterprises themselves. The steps are presented below in order of their execution in Figure 3.

1. Define links between enterprise being modeled and the outside world
2. For each link consider an *outgoing dependency factor* and an *incoming dependency factor*
3. Examine industry for other possible links of the same type and possibility of linkage in the future
4. Produce *dependency factor.* Establish alternatives

**Figure 3. Establishment of DF's**

Step one suggests to identify all the links the enterprise has with the outside world. At this stage only the 1st tier *(demand-supply)* relationships need to be defined. When this phase is finished the enterprise will be in a position to know the dependencies, regardless of their strength, it has with other enterprises.

The second phase suggests to divide each dependency into two categories. The first one *(outgoing)* carries the *dependency factor* of the enterprise upon the external company. In the scenario above, assuming that we're modeling Nissan, the *outgoing dependency factor* would show how dependent Nissan is, upon the existence of SR Tyres supplies. The *incoming dependency factor* shows how dependent the supplier is on Nissan.

The following phase suggests to examine the industry in order to find other links of the same type that may be available. Using the same example as above Nissan would have to find whether there are other tyre manufacturers in the industry and their willingness to establish new links. This of course would depend on the company's control capacity. Other car manufacturers would also be examined in order to determine how dependent the tyre manufacturer is upon Nissan. If there are no other car manufacturers in the model then a maximum *dependency factor* can be assumed.

Each factor will be associated with a number alternatives. The alternatives represent the actions an enterprise may take, should any of the described situations took place. The success or failure of the model to establish a clear picture of the impact, relies on some probability factor. The degree of either success or failure is really determined by the amount of experience the modeled enterprise has about the industry. If for example, during phase three it has been found that no other tyre manufacturer exist and an event like the one described above took place, then the alternative actions associated with the *dependency factor* will be something along the lines of *'Buy tyre manufacturer'*, so all the capacity production is delivered to Nissan. There will of course be a number of actions associated with each link starting with the more practical ones and gradually moving to more extreme measures like *'Move to some other region'* etc.

***Conclusion***

The problem we're trying to tackle is the modeling of the behavior of enterprises when external events affect their operations. The solution we're proposing here is only related to integrators and their dependencies upon the component manufacturers. However there are other levels of dependency that need to be considered when a model is developed i.e. a component manufacturer is strongly dependent on the second tier companies that provide them with rubber. If a second tier company goes bankrupt, then this event will certainly have an effect not only on the component manufacturer that used the rubber to create tyres but also on the integrator. Taking the top down approach suggested here for modeling dependencies, by starting investigating the links between integrators with the first tier companies, an overall picture would gradually be developed and the model would become more concrete. The probability factor that determines the success of the model will always be there. However the more experience an enterprise has about the industry, the more concrete the model will be, decreasing at the same time the risk for a false prediction.

We've assumed during the production of these figures, that an integrator has more chances of immediately recovering a situation like this because of its position in the hierarchy. As it is at a higher level it is more likely to find more players at the level below ready to serve its needs, rather than a component manufacturer to find integrators to supply its product. If for example an integrator somehow losses 30% of its supply it is more likely to find other suppliers ready to cover that gap, or ask the remaining suppliers to increase their capacity until a new supplier is found. On the other hand a component manufacturer will probably find it harder to recover a 30% gap of its supplies straight away.

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