Strategic supply chain management using simulation.

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ABSTRACT

STRATEGIC SUPPLY CHAIN MANAGEMENT USING SIMULATION

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In today's global economy the need for an efficient and optimised supply chain is increasing. Recent studies showed that supply chain management is one of the areas that have a great impact on the financial well being of an organization as well as customer satisfaction. The recognition of the importance of efficient and optimised supply chains has led to increasing investments in supply chain planning and execution systems. In order to compete in the global market place organizations want to develop systems that enable fast and effective on time delivery of products to customers. Therefore generating the necessary customer satisfaction.

Today there are APS (Advanced Planning & Scheduling) systems available to help "manage" the supply chains. These tools were specifically designed to have the ability to rapidly and simultaneously plan and schedule customer demand while considering material and capacity constraints. Not only does these systems provide the ability to increase revenues, but it can also increase the customer service and cut costs by synchronized management of the complete supply chain. Although these systems help to improve the system, it is restricted to the static part and it does not incorporate the dynamic part. The result therefore is that a lot of "noise" still exists within the system once the results are achieved. This opened the way for solutions that can provide insight to the uncertainty and interdependency of processes and customer demand within the supply chain. One way of gaining insight into the system variation and interdependencies is through the use of simulation technology. This type of technology allows organizations to predict future behaviour and test future designs or do redesigns of their current supply chains.

The scope of this dissertation is to develop a supply chain planning methodology, which will help to improve the understanding of the uncertainty and interdependency of processes within the supply chain.

To design this methodology different steps are taken in order to introduce the final solution. Therefore, four main methods were used; literature research, market research, supply chain planning methodology development and a case study.

The literature research brought to light the reasons for the inefficiencies and variations in supply chain planning and why the need for change exists. During the supply chain market research several supply chain planning and execution systems were under study.

From this it was quite clear that the only way that organisations can ensure one optimal answer is when the demand is constant and there is a zero percent chance that it could change. In real world systems it is virtually impossible to accurately predict future demand 100 percent of the time, and therefore variability and randomness cannot be excluded from a supply chain solution. This paved the way for the introduction of simulation technology as a possible solution for this variability and randomness. The market research was concluded with the analyses of the current simulation solutions in the market.

The next step in the design phase was the introduction of the new supply chain planning methodology. The main purpose of this new methodology is to use the power of modelling and simulation to improve the initial supply chain performance. This methodology focuses on initial supply chain design, analyses and optimisation. By introducing this methodology organisations are now able to compare current supply chains with an unlimited realm of possible future configurations.... and without disrupting the initial day-to-day operations of an actual supply chain. The methodology is also designed to help predict the supply chain performance in terms of **throughput, tardiness, utilisation, profitability, and other key performance indicators...**

In order to experience real-life supply chain problems a case study has been done. This case study is about the automotive industry, which will include the ordering of parts assembly of vehicles, warehousing and distribution of vehicles. Different problems and difficulties were experienced. In conclusion, this case study provided a better insight into the behaviour of a supply chain. The case study was used to evaluate the use of this new methodology and as a result certain inefficiencies were recognized. As a result of the evaluation certain improvements need to be made to the supply chain methodology in order to make it more suitable for the market. These improvements would focus on inventory planning, supply chain analysis as well as database integration.

The result of the case study also showed that the supply chain planning methodology is now set to develop a supply chain solution on the lowest level. There is however a need to be able to grow this supply chain methodology from a low level to a relatively high level. These functions are among others higher-level planning modules, which focus on transportation, production, demand and distribution and performance measurements. The focus will be to introduce these functions as objects. Every object will have the ability to design a supply chain solution on a high level or low level depending on the detail and requirements.

"...I also believe that the one who adapts his policy to the times prospers, and likewise that the one whose policy clashes with the demands of the times does not." Niccolo Machiavelli, 1525

OPSOMMING

STRATEGIC SUPPLY CHAIN MANAGEMENT USING SIMULATION

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In vandag se globale ekonomie is daar 'n toenemende behoefte vir 'n doeltreffende en meer effektiewe voorsieningsketting. Oor die afgelope jare het verskeie studies aangetoon dat die bestuur van voorsieningskettings 'n groot invloed het op die finansiële resultate van 'n organisasie so wel as op die gebied van kliënte tevredenheid. As gevolg van die toenemende belangstelling in die doeltreffende en effektiewe bestuur van voorsieningskettings het organisasies groot investerings aangegaan op die gebied van voorsieningsketting beplanning- en voorsieningsketting beheer stelsels. Om in die globale ekonomie te kan kompetteer wil organisasies self stelsels ontwikkel wat in staat is om produkte vinnig en optyd aan klante kan besorg. Daardeur kan die nodige kliënte tevredenheid gehandhaaf word.

Vandag bestaan daar sogenaamde gevorderde beplanning en skedulering stelsels wat kan help om voorsieningskettings te bestuur. Hierdie stelsels was ontwikkel om baie vinnig en gelyktydig te beplan en te skeduleer om sodoende aan die vraag van kliënte te voldoen deur te kyk na kapasiteit en materiaal beperkings. Hierdie stelsels besit nie alleen die vermoë om inkomste te verhoog nie maar dit kan ook kliënte tevredenheid sowel as koste besparings teweeg bring deur gesinkroniseerde bestuur van die totale voorsieningsketting. Hierdie stelsels besit die vermoë om 'n voorsieningsketting te verbeter maar dit is beperk tot die statiese deel en dit kyk glad nie na die dinamiese deel. Die gevolg hiervan is dat daar nog aansienlike "lawaai" binne die sisteem bestaan by aantoon van die resultate. Dit het die weg gebaan vir oplossings wat insig kan verskaf in die onsekerheid en interafhanklikheid van prosesse en kliënte vraag. Een manier om insig te verkry in die variasie en interafhanklikhede binne die sisteem is deur gebruik te maak van simulasie tegnologie. Hierdie tipe tegnologie help organisasies om gedrag van toekomstige sisteme te voorspel en om toekomstige ontwerpe te toets of met die herontwerp van bestaande voorsieningsketting.

Die doel van hierdie verhandeling is om 'n nuwe beplannings metodologie vir voorsieningskettings te ontwikkel, wat sal help om the om onsekerheid en interafhanlikheid van prosesse in die voorsieningsketting beter te verstaan.

Om hierdie metodologie te ontwerp is 'n aantal stappe gevolg om die finale oplossing aan te bied. In hierdie proses is vier stappe gevolg; literatuur studie, mark navorsing, ontwikkeling van die voorsieningsketting beplannings metodologie en 'n gevallestudie.

Die literatuur studie het die redes vir ondoeltreffenhede en variasie in voorsieningsketting beplanning aangedui sowel asdie redes vir verandering. Tydens die

mark analise van voorsieningskettings is daar na 'n aantal voorsieningsketting beplanning- en voorsieningsketting beheer stelsels gekyk. Aan die hand van die mark analise was dit duidelik dat die enigste manier waardeur organisasies 'n optimale antwoord kan kry is wanneer die vraag konstant is en wanneer daar geen kans bestaan vir verandering. In die hedendaagse wêreld is dit omtrent onmoontlik om toekomstige vraag na produkte honderd persent akkuraat te voorspel. Hierdeur is dit duidelik dat veranderlikheid en ewekansigheid nie buite rekening gelaat kan word by 'n voorsieningsketting oplossing nie.

Dit het dus die weg gebaan vir die introdusering van simulasie tegnologie as 'n moontlike oplossing vir veranderlikheid en ewekansigheid. Die mark analise was afgerond met 'n mark oversig van die bestaande simulasie oplossings in die mark.

Die volgende stap in die ontwikkelings fase was die bekendstelling van die nuwe voorsieningsketting beplannings metodologie. Die algehele doel van die nuwe beplannings metodologie is om gebruik te maak van modelering en simulasie sterk punte om sodoende die prestasie van voorsieningsketting te verbeter. Hierdie metodologie fokus op die aanvanklike ontwerp, analise en optimisering van 'n voorsieningsketting. Indien organisasies van hierdie metodologie gebruikmaak dan is dit moontlik om bestaande voorsieningsketting te vergelyk met onbeperkte aantal toekomstige konfigurasies... en dit sonder om die dag tot dag bewerkings van 'n voorsieningsketting te verhinder.

Hierdie metodologie is ook ontwikkel om die prestasie van voorsieningsketting te voorspel in terme van; *deurset, traagheid, benutting, winsgewendheid, en ander prestasie aanwysers...*

Om hedendaagse voorsieningsketting probleme te ervaar is daar 'n gevallestudie gedoen. Hierdie gevallestudie is gerig op die motorvoertuig industrie, en dit sluit in die bestelling van parte, vervaardiging van voertuie, berging en distribusie van voertuie. Verskillende probleme en moeilikhede was ervaar tydens die ontwikkeling van die gevallestudie. Die gevallestudie het wel beter insig verskaf om die gedrag van die voorraad ketting te verstaan. Die gevallestudie was ook gebruik om die toepassing van die nuwe metodologie te evalueer en as gevolg daarvan is daar 'n aantal ondoeltreffenhede bemerk. Na aanleiding van die evaluering moet daar 'n aantal verbeterings aangebring word om die metodologie meer aanvaarbaar te maak vir die mark. Hierdie verbeterings sal fokus op voorraad beplanning, voorsieningsketting analise en databasis integrasie.

Die resultate van die gevallestudie het aangetoon dat die nuwe metodologie vir voorsieningsketting beplanning geskik is om 'n voorsieningsketting op die laagste vlak te ontwikkel. Daar is egter 'n behoefte om om die voorsieningsketting metodologie te kan groei van 'n laer vlak na 'n hoër vlak. Hierdie groei moet kan gebeur deur sogenaamde hoër vlak beplannings modules wat fokus op, vervoer, produksie, vraag en distribusie asook prestaties aanwysers. Die fokus sal wees om hierdie funksies as objekte voor te stel wat tegelykertyd op 'n hoë vlak as 'n lae vlak kan funksioneer afhangend van die detail en verwagtinge.

"...Ek glo daaraan dat die een wat sy strategie voortdurend aanpas vooruitgaan, en die wie se strategie teenstrydig is met die vraag van die tye nie." Niccolo Machiavelli, 1525

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LIST OF ABBREVIATIONS

AC	– Air Condition
APO	– Advanced Planner and Optimiser
APS	– Advanced Planning and Scheduling
ARC	– Automation Research Corporation
ARENA BE	– Arena Basic Edition
ARENA PE	– Arena Professional Edition
ARENA SE	– Arena Standard Edition
AST	– Application Solution Template
ATP	– Available To Promise
BPR	– Business Process Reengineering
CAD	– Computer Aided Design
CAGR	– Cumulative Average Growth Rate
CIM	– Computer Integrated Manufacturing
CRP	– Capacity Resource Planning
CTP	– Capable To Promise
DRP	– Distribution Requirements Planning
EBPO	– Electronic Business Process Optimisation
EDI	– Electronic Data Interchange
ERP	– Enterprise Resource Planning
ETO	– Engineer To Order
FCS	– Finite Capacity Scheduling
GFSS	– Global Forecasting Supply System
IT	– Information Technology
IBIT	– Income Before Interest and Tax
IIE	– Institute of Industrial Engineers
MPS	– Master Production Schedule
MRP	– Material Requirements Planning
MTO	– Make To Order
Non-Ac	– No Air Condition
RCCP	– Rough Cut Capacity Planning
ROA	– Return on Assets
SCE	– Supply Chain Execution
SCM	– Supply Chain Market
SCOPE	– Supply Chain Optimisation Planning and Execution
SCOR	– Supply Chain Operation Reference
SCP	– Supply Chain Planning
TIP	– Truly Integrated Planning
TQM	– Total Quality Management
TMS	– Transportation Management Systems
VBA	– Visual Basic for Applications
WMS	– Warehouse Management System

LIST OF KEY TERMS

- ➢ Supply Chain Planning
- ➢ Supply Chain Management
- ➢ Advanced Planning and Scheduling (APS)
- ➢ Improving Supply Chain Performance
- ➢ Supply Chain Simulation
- ➢ Supply Chain Problems
- ➢ Simulation Technology
- ➢ Supply Chain Planning Methodology
- ➢ Behaviour of a Supply Chain
- ➢ Simulation Solutions

1   *Introduction*

Supply Chain Management can be defined as the process which enables the flow of goods all the way from raw material, to distributors and transporters, to retailers and finally to end customers. In essence it therefore manages the flow of materials and products from source to users.

Although it sounds simple it is quite a complex task due to all the interdependencies within a supply chain. It is not just about make and deliver, it also includes aspects of purchasing, manufacturing, planning, distribution system planning, transportation systems, warehousing and inventory systems, demand input from sales and marketing activities.

All of this can be the result of a single product line or production plant to a complex web or chain that includes multiple demand sources, suppliers, distribution means or factories. Clearly one can understand the complexity of managing such an operation...

Today there are APS (Advanced Planning & Scheduling) systems available to help "manage" the supply chains. These tools were specifically designed to have the ability to rapidly and simultaneously plan and schedule customer demand while considering material and capacity constraints. Not only does these systems provide the ability to increase revenues, but it can also increase the customer service and cut costs by synchronised management of the complete supply chain.

It is clear that core methodologies exist and that it can focus on specific problem areas within the supply chain. These methodologies are known as *"solver technologies"* which include: heuristics, constraint management, linear programming, mixed-integer programming and network programming. All of this can provide the results or outputs for the APS tools. Unfortunately there is one draw back of supply chain management at this stage and that is the understanding of variability within the supply chain. Although supply chain management helps to improve the system, it is restricted to the static part and it does not incorporate the dynamic part. The result therefore is that a lot of "noise" still exists within the system once the results are achieved.

The scope of this dissertation is to develop a supply chain planning methodology, which will help to improve the understanding of the variability and dynamics within the supply chain. By doing this, supply chain analysts will be able to define the system clearly and therefore minimise multiple (mis) interpretations as to the complexity and variability of the processes.

The methodology will help analysts to design the supply chain much better and do what if scenarios and it can further provide them with the necessary visibility, a 95% confidence interval, certainty, minimise the thinking process and help them with the analyses of the best rules before implementing the supply chain solution.

2 *Dissertation Goal*

The goal of the dissertation is to link supply chain concepts with simulation. By doing this a methodology will be designed which will allow one to design a total supply chain in a fairly short period of time.

This supply chain methodology will then be able to address the following issues:

- ➢ Randomness and variation in a supply chain.
- ➢ What-If scenarios before the final supply chain is developed.
- ➢ Modelling of the corporate dynamics throughout the supply chain.
- ➢ Reliably predict the effect of multiple changes in the supply chain.
- ➢ Visibility on the performance of the supply chain.
- ➢ Minimise multiple misinterpretations as to the complexity and variability of the processes.

3 Research Approach

This section presents the research approach and the outline of this dissertation. The research approach is characterised by an extensive desk research, several software developments, and a case study. The research is conducted by following the steps displayed in Figure 3.1.

Figure 3.1. Research Approach.
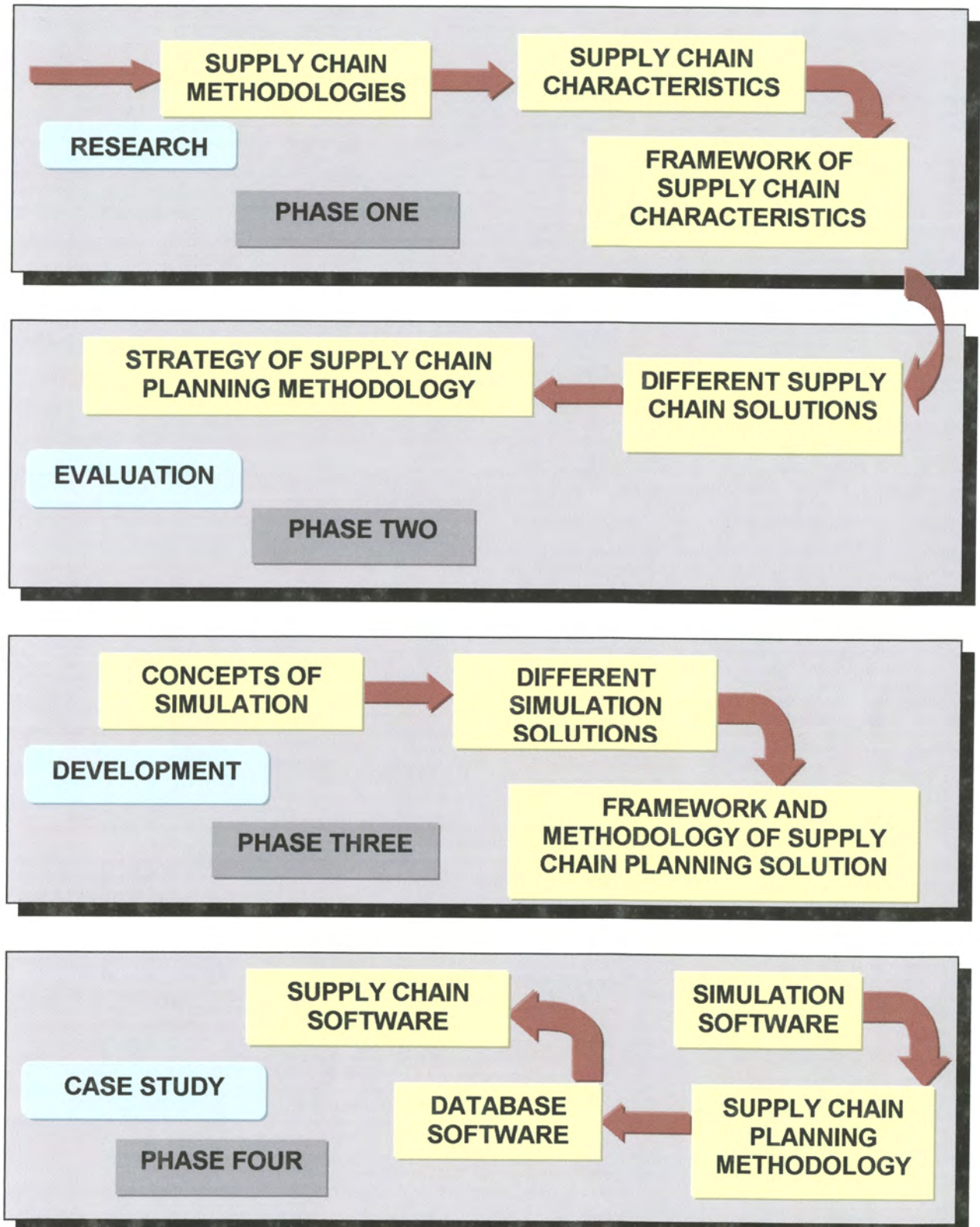
- Phase One: Research

Phase 1 is concerned with the identification and definition of supply chain management used to define the framework for the supply chain design methodology.

- Phase Two: Evaluation

Phase 2 uses this framework to evaluate current supply chain strategies in order to establish a strategy for the development of the supply chain methodology.

- Phase Three: Development

In Phase 3, the concepts of simulation will be introduced in order to establish the framework for the prototype methodology.

- Phase Four: Case Study

In phase four the methodology will be applied to a case study in order to demonstrate the capability of the methodology and this will conclude the development of the supply chain methodology.

3.1 Phase One: Establish the supply chain methodology

Before a problem can be solved an analyst first needs to understand the dynamics of the problem. During phase 1, a number of theories and methodologies will be researched in order to identify and define the process characteristics that will assist the analyst in understanding the problem. All of these process characteristics will be used to define the framework and guidelines for supply chain management.

3.2 Phase Two: Establish methods and techniques for supply chain management

While phase 1 produced certain guidelines that will assist the analyst in understanding the problem, phase 2 is used to produce solution methods and techniques to model the problem.

In this phase four companies are evaluated in order to develop a strategy framework for the supply chain planning methodology. This strategy addresses the issue of using existing methodologies. The methodologies that will be evaluated are:

> I2 Technologies
> SAP
> BAAN
> Manugistics

These four companies are at the forefront of technology and each one has a different solution for supply chain management.

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3.3 Phase Three: Establish methods and techniques for supply chain management and simulation.

In this phase the appropriate supply chain solution is mapped to the appropriate simulation solution.

During this phase different simulation solutions will also be evaluated.

The framework and methodology of the supply chain planning methodology will be shaped according to the supply chain and simulation solutions.

Different links between the solutions will also be investigated.

3.4 Phase Four: Apply supply chain methodology to a specific case study.

In this phase, the supply chain planning methodology will be applied to an industry specific case study.

This case study is about the automotive industry, which will include the ordering of parts assembly of vehicles, warehousing and distribution of vehicles.

4 *Phase One: Establish a Framework for the evolution of Supply Chain Management*

4.1 *Outlined introduction of phase one*

Figure 4.1. Phase One Approach.
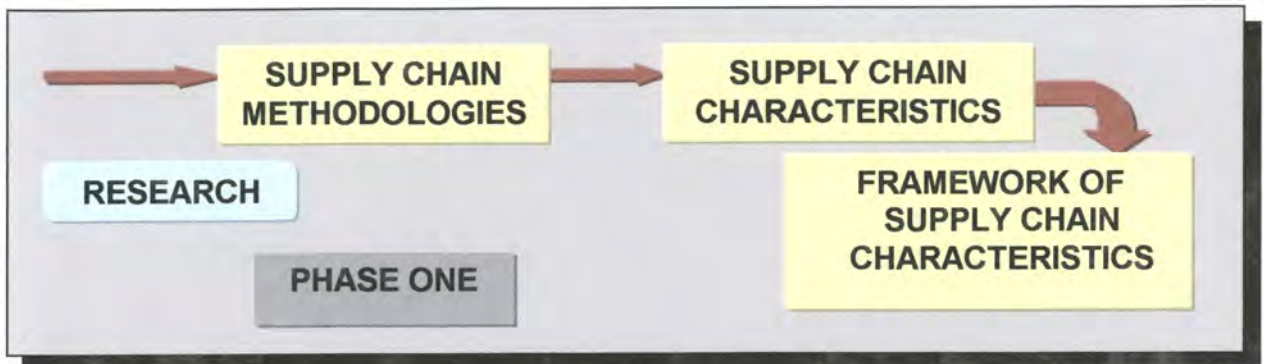
In order to become a competitive market player the business environment demands more responsive and integrated enterprise systems - ones that leverage real-time decision making for real time execution.

Strategic planning should no longer be seen as long term. The reason for this is that mergers, spin-offs, new entrants in the competitive arena, and the incessant drive to reduce cycle time and cost make strategic planning an immediate necessity. Nowadays global competition and global opportunities demand a new fitness level for an organisation's success.

Dramatic steps should be taken in order to become agile and to be able to be a manufacturing contender in the next century. Those steps include that organisations must focus on moving information and products quickly through the entire service chain: distribution, assembly, manufacture and supply. All the physical and logical events within the supply chain must be enacted swiftly, accurately, and effectively. The faster parts, information, and decisions flow through an organisation, the faster it can respond to customer needs.

Organisations must be market driven, with more product research and short development and introduction cycles. To compete at an increased pace depends on how well an enterprise integrates cross-functional processes. It is now essential for organisations to integrate business functions, which were once performed sequentially into multiple functions in order to be able to perform tasks simultaneously across the supply chain.

The customer now becomes the principle driver for determining how these business functions are to be performed. What emerges from this now is an increased emphasis on customers and this in effect is a de-emphasis on organisational boundaries. This means that there is no longer one company that is managing a customer order, and delivering finished goods, it is an entire supply chain.

Inside this new environment which focuses on the customer, planning and scheduling functions that were once the domain of manufacturing alone, have become processes

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that flow between multiple cells within an organisation and throughout that organisation's trading partners.

For an organisation that wants to move toward total integrated planning and scheduling, it is necessary to breakdown functional stovepipes and unites non-collaborative partnerships. This synchronous approach does not only enhances an enterprise's ability to meet customer demand, but it also enables the company to better understand change management and supply chain issues which need to be addressed. As early as 1525 Niccolo Machiavelli expressed his concern with the following statement,

> *"...I also believe that the one who adapts his policy to the times prospers, and likewise that the one whose policy clashes with the demands of the times does not."*

4.2 Logistics and Competitive Strategy

Throughout the history of mankind a lot of wars have been won and lost through logistics strengths and capabilities. The commanders of these wars clearly new that in order to succeed logistics should be well planned and coordinated. Only over the last decade organisations started to recognise the vital impact logistics management can have on the achievement of a competitive advantage. The lack of recognition can partly be blamed on the low level of understanding of how integrated logistics should function.

In 1915 Arch Shaw wrote the following:

> *" The relations between the activities of demand creation and physical supply... illustrate the existence of the two principles of interdependence and balance. Failure to co-ordinate any one of these activities with its group-fellows and also with those in the other group, or undue emphasis or outlay put upon any one of these activities, is certain to upset the equilibrium of forces which means efficient distribution.*
>
> *...The physical distribution of the goods is a problem distinct from the creation of demand... Not a few worthy failures in distribution campaigns have been due to such a lack of co-ordination between demand creation and physical supply... Instead of being a subsequent problem, this question of supply must be met and answered before the work of distribution begins."*[1]

The basic principles of Logistics Management took a further 70 or so years to be clearly defined. According to Martin Christopher there are many ways to define logistics but he defined it as follows:

> *"Logistics is the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and related information flows) through the organisation and its marketing channels in such a way that current and future profitability are maximised through the cost-effective fulfilment of orders."*[2]

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[1] A.W. Shaw, Some Problems in Market Distribution, Harvard University Press, 1915
[2] M. Christopher, Logistics and Supply Chain Management, Pittan Publishing, 1992

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One of the most significant changes that emerged in management thinking over the past 10 to 15 years was the decision to focus on the search for strategies that will provide superior value to customers. This paradigm shift was to a large extent caused by Michael Porter, a Harvard Business School Professor, who through his research and publications has alerted managers and strategists to the central importance of competitive relativity's in achieving success in the market place. One of his most valuable concepts was the concept of the *'value chain'*.

"Competitive advantage cannot be understood by looking at a firm as a whole. It stems from the many discrete activities a firm performs in designing, producing, marketing, delivering, and supporting its products. Each of these activities can contribute to a firm's relative cost position and create a basis for differentiation... The value chain disaggregates a firm into its strategically important activities more cheaply or better than its competitors."[3]

The value chain principal is mainly broken down into two categories: primary-, and support activities. Refer to figure 4.2

Figure 4.2. The Value Chain[4]
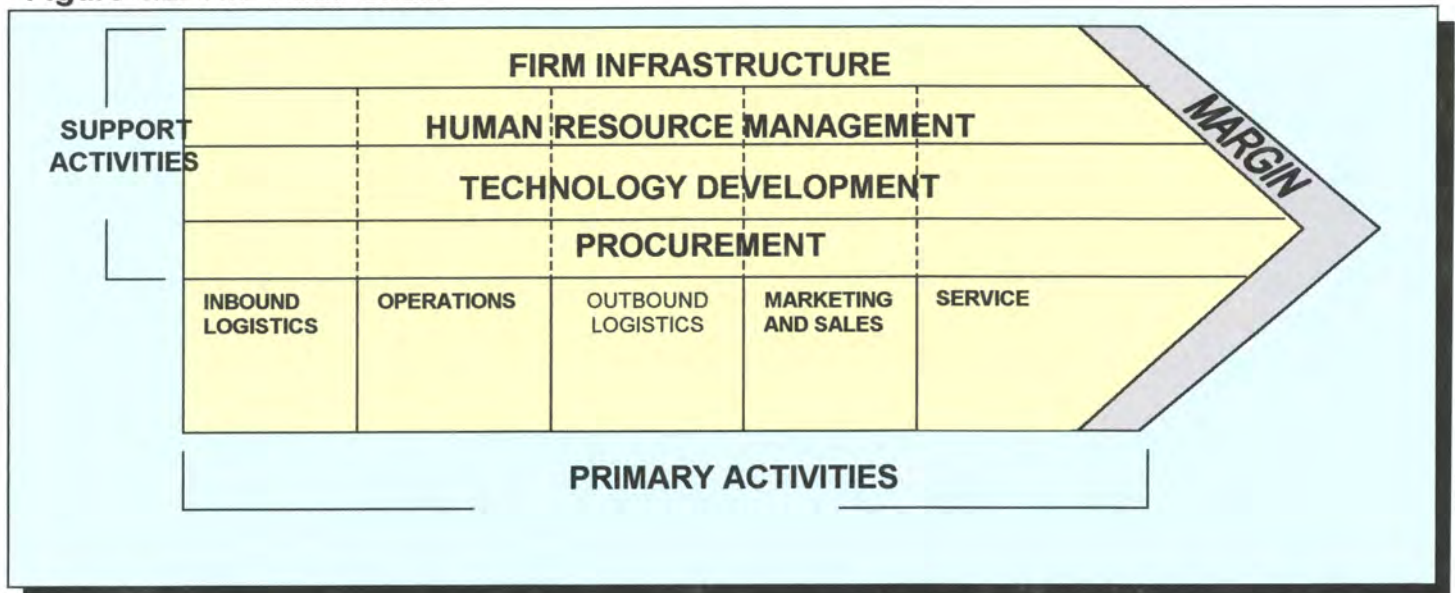
The primary activities are supported by means of the support activities, which are integrated through the organisation. Competitive advantage can only be gained by organising these discrete activities in the best possible way.

Figure 4.3 will show why logistics management has the potential to assist the organisation in the achievement of both a cost/productivity advantage and a value advantage.

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[3] M.E. Porter, Competitive Advantage, The Free Press, 1985
[4] M.E. Porter, Competitive Advantage, The Free Press, 1985

Figure 4.3. Gaining Competitive Advantage Through Logistics.[5]
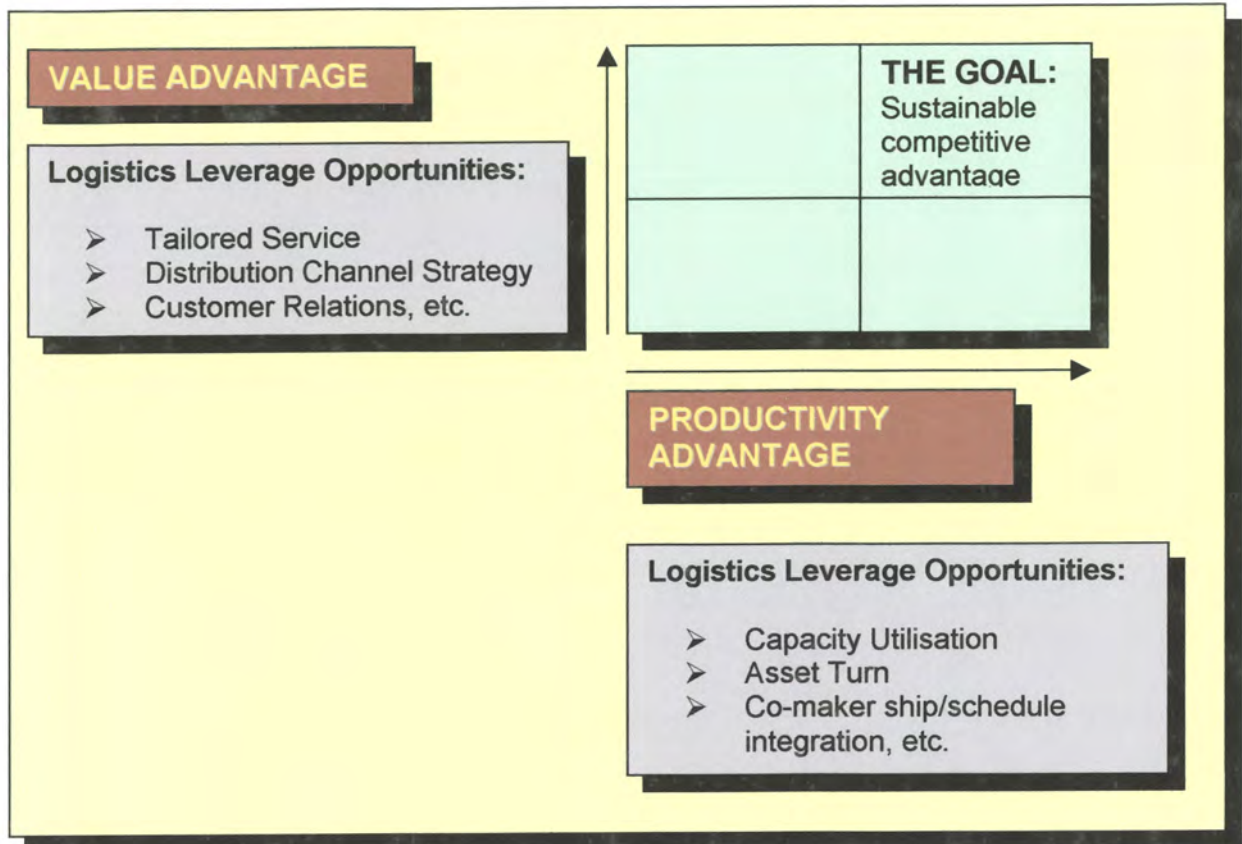
It is clear that customer service has become a vital means of differentiation. According to Martin Christopher organisations that want to be market leaders of the future need to seek and achieve the twin peaks of excellence: they have to gain both cost leadership and service leadership.

From the previous comments it is clear that the mission of logistics management is to plan and co-ordinate all those activities that are necessary to achieve desired levels of delivered service and quality at the lowest possible cost. Logistics as a whole can be seen as the link between the marketplace and the operating activity of the business.

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[5] M. Christopher, Logistics and Supply Chain Management, Pittan Publishing, 1992

The scope of logistics management is better described by figure 4.4.

Figure 4.4. Logistics Management Process[6]
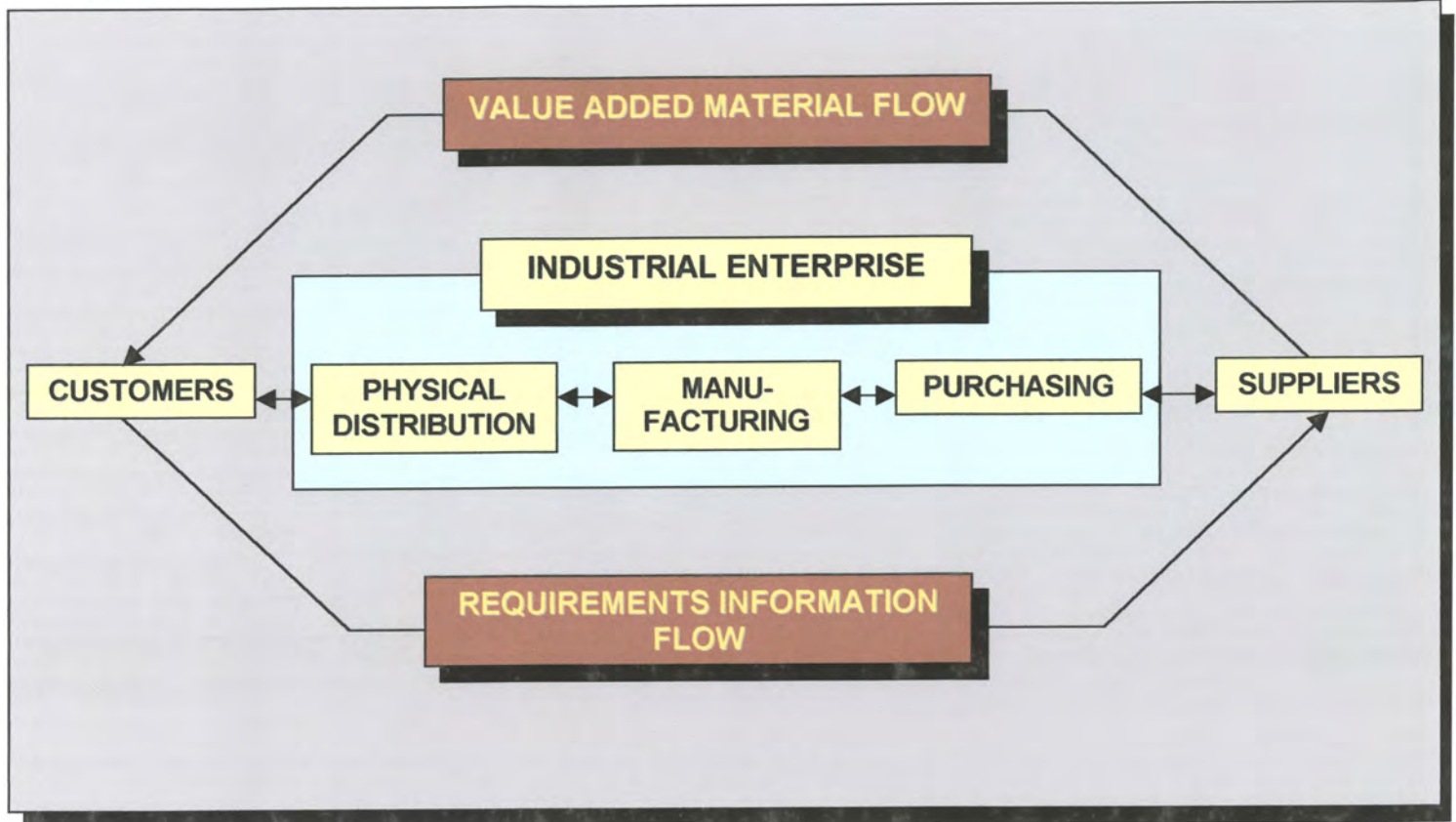
As the figure illustrates logistics spans the organisation from managing the raw materials right through to the delivery of the final product.

Martin Christopher described logistics management from this total systems viewpoint as follows:

" the means whereby the needs of customers are satisfied through the co-ordination of the materials and information flows that extend from the market place, through the firm and its operations and beyond that to the supplier."

In order to achieve this company-wide integration, a different orientation is required than that encountered in a conventional organisation.

The next part of this phase will focus on the analyses of why a different orientation is needed and the evaluation of what sort of methodology is needed to achieve this integration.

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[6] D.J. Bowersox, D.J. Closs, O.K. Helferich, Logistics Management 3rd edition, Macmillan Publishing Co, 1986.

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4.3 Reengineering the Planning Process

4.3.1 The Traditional divided Process

" We trained hard, but it seemed every time we were becoming to form teams we would be re-organised. I was to learn later in life that we tend to meet every situation by re-organising and a wonderful method it can be for creating the illusion of progress, while producing inefficiency, and demoralisation." Gaius Petronius Arbiter C AD 65.

Traditionally the planning process was divided a couple of times and there was no integration. During these traditional years simple software tools were created to help solve the different pieces of the planning problem. One of the first was material requirements planning (MRP), which computes time-phased material requirements. Other tools were then created around this tool, which addresses different issues of different levels of detail.

Because of these software tools, organisations followed a fragmented breakdown approach to problem solving. This in fact caused the creation of the composite arrangement of people around functions, processes, geography and classes. These arrangements have strangulated organisational efforts to adequately satisfy market needs. Traditionally a few exceptions did occur, where organisation's plants evolved by placing machines and equipment in location where space was available. The information systems were developed, as "islands" breaking down into accounting, inventory, purchasing, etc., with no overall plan to guide their interaction.

The people were structured and shuffled around classes: walls separated elite executives, middle management and hourly labour. These walls refer to the way planning occurred. Management wanted certain goals, and then every process was handled on its own, total visibility of the "big picture" was not known... or brought into the open.

Organisations tried to manage all of these changes by means of MRP, automation, algorithm, quality circles, cells group technology, TQM and CIM, and organisations only achieved limited results. It is no wonder that organisations experienced difficulty in getting products out the door!

So, by now the "big picture is beginning to show".... questions arise such as, *why didn't it work, where do organisations suffer the most* and many more....

According to I2 technologies the traditional process was divided into two major levels of detail: *master planning and execution planning.* The following paragraph will focus on the evolution of the traditional planning process as was defined by I2 Technologies. Figure 4.5[7] illustrates the traditional divisions in the planning.

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[7] *Rhythm® Supply Chain Planner Concept Manual, © 1996 i2 technologies, Inc. Proprietary Information*

Figure 4.5. The Traditional Divisions
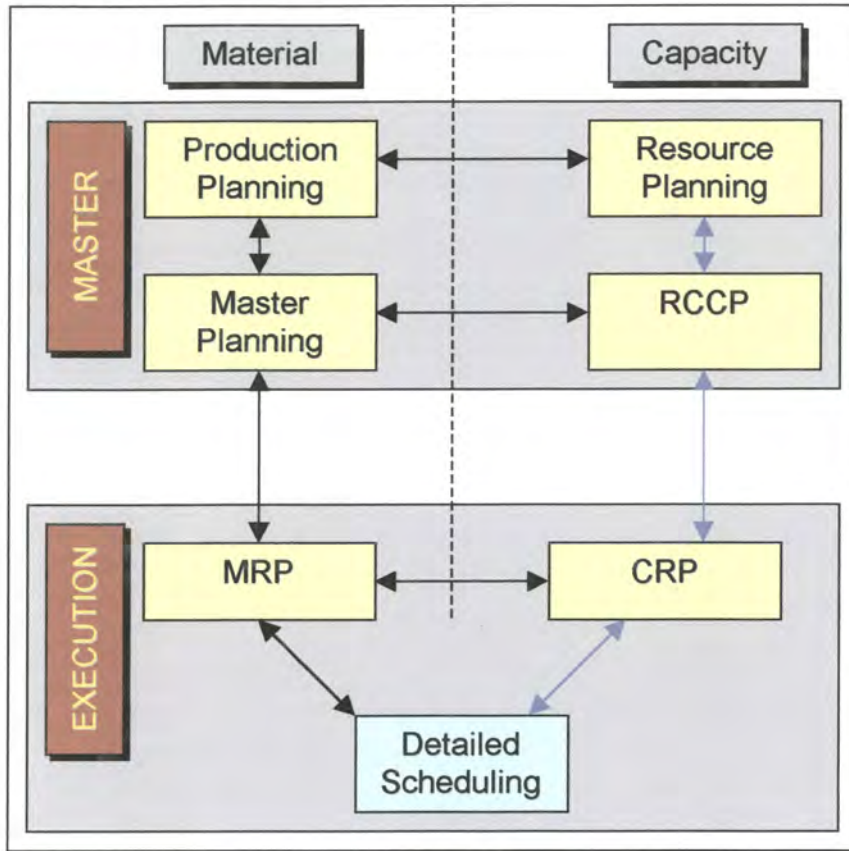
Master planning was about deciding what should be built, and then what should be sold. This process typically consists out of making long term planning decisions, thus causing longer time-horizons.

The execution plan on the other hand was about using and supporting detail information that was sufficient to drive the actual execution of the factory. This process however, was only needed for a short period of time resulting in short time-horizons.

From figure 4.5 it can be seen that the master and execution planning levels are split into different parts again. The first three levels are then split into material and capacity planning, depending on exactly what the focus area is.

The result is that the four different groups are divided into seven separate process steps, which need seven different software tools. It is clear that organisations with significant distribution networks between customer (demand) and the factory (master planning) need additional process steps as well as separate tools.

Distribution planning is quite similar to factory planning: demand orders need to be filled out, various inventory levels need to be managed and different lead times need to be met for all the different warehouses and distribution centres. In order to do all of this the MRP algorithm was reformed to a bill of distribution rather than a bill of material, the result was called distribution resource planning. The opinion arises that, because of the similarities between MRP and DRP activities, these activities are performed together, and this is actually not the case.

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The distribution plan interfaces with the master production schedule and provides demand orders as output which functions as an input to the master schedule. Master scheduling on the other hand outputs the master production schedule that specifies what to build. Figure 4.6[8] illustrates the traditional divisions in distribution planning.

Figure 4.6. Distribution Planning Division
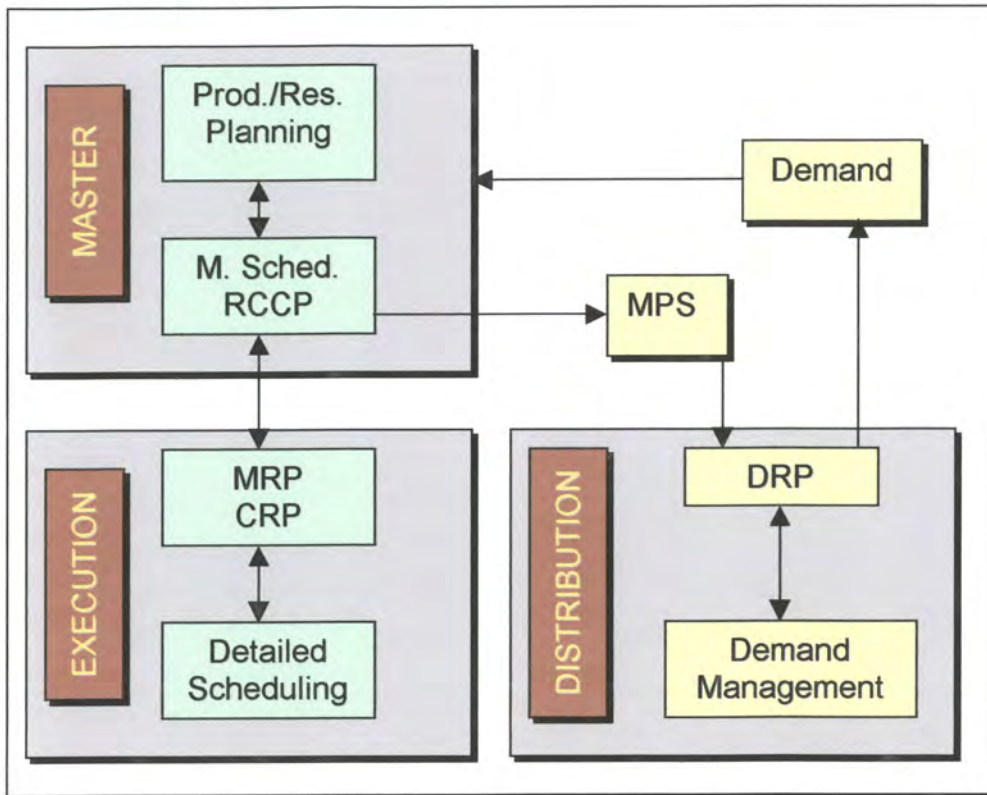
All of these divisions were developed in order to simplify the process. There were some significant advantages to divide the process, because manufacturing planning is a highly complex problem, and at the time there was no solution to address the problem as a whole.

The following paragraphs will explain the detail around the traditional planning process. The best way to illustrate the traditional approach is by the next figure.

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[8] *Rhythm® Supply Chain Planner Concept Manual, © 1996 i2 technologies, Inc. Proprietary Information*

Figure 4.7: The Traditional Approach
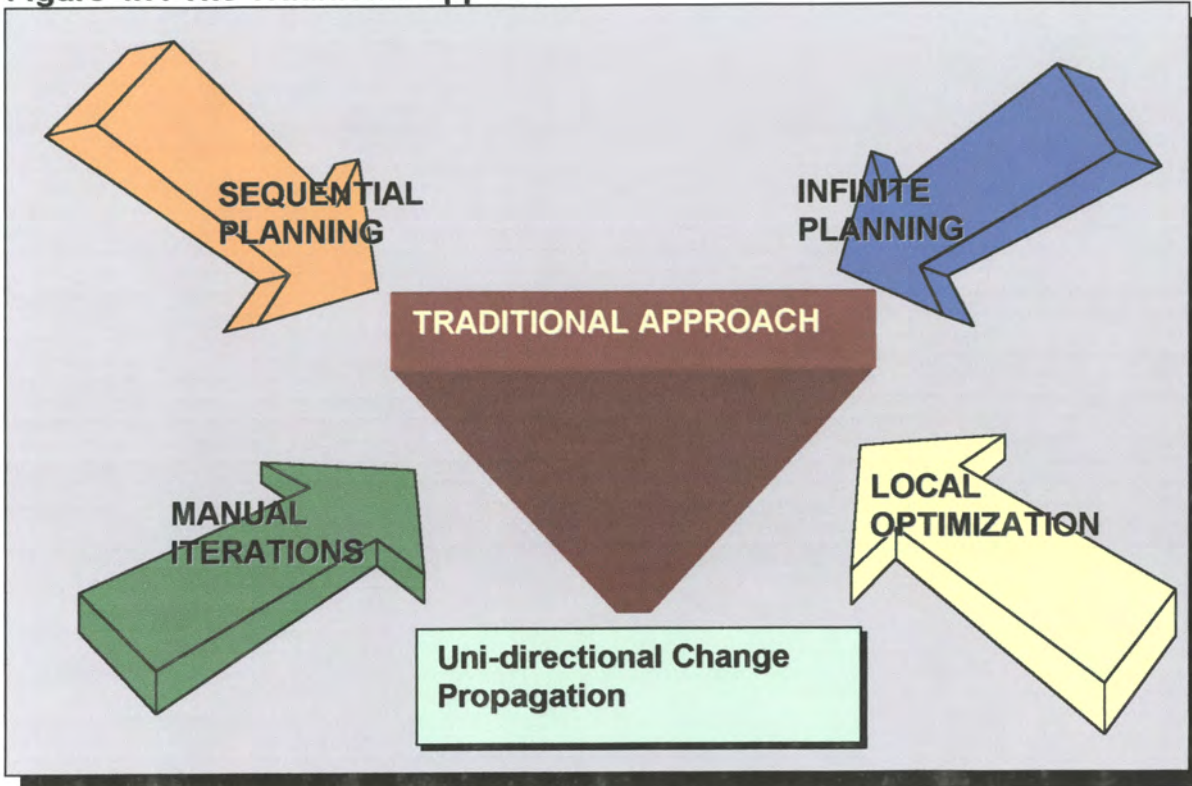
4.3.2 Sequential Planning

Sequential planning was about dividing the process into different specialised functions with dedicated personnel that did all the tasks of that specific function. This planning process did have some practical advantages, but in the end the simplification caused the burden to be shifted to the human planner. Figure 4.8 provides a schematic illustration of I2 Technologies view on sequential planning.

Figure 4.8 Sequential Planning[9]
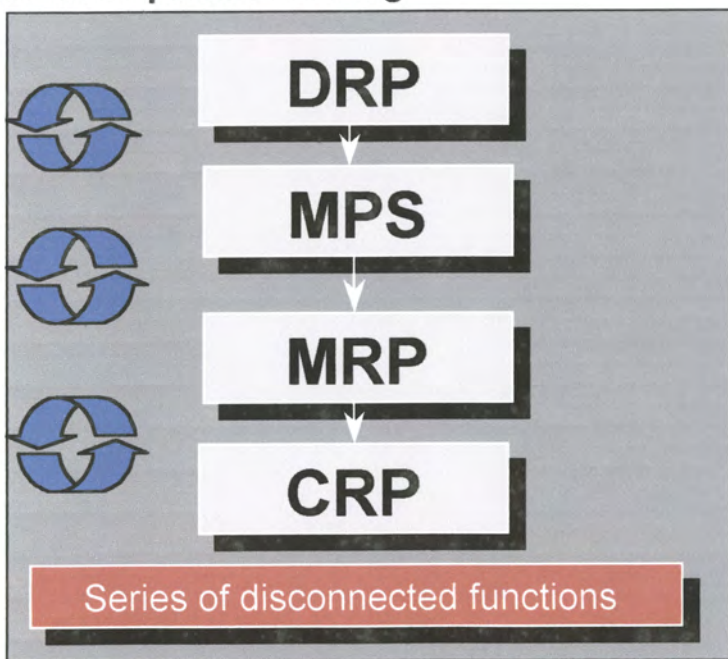
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4.3.3 Local Optimisation

According to I2 technologies local optimisation was a definite result of sequential planning. The divisions between the planning functions resulted in the local optimisation of tasks within the specified departments. It further resulted in a loss of visibility into the entire problem and it caused disruptions downstream in the facility. Each department or function was only concerned about its own local objectives and not about the global objectives, after optimisation problems occurred when interfacing with the other functional departments. Figure 4.9 provides a schematic illustration of local optimisation.

Figure 4.9. Local Optimisation[10]
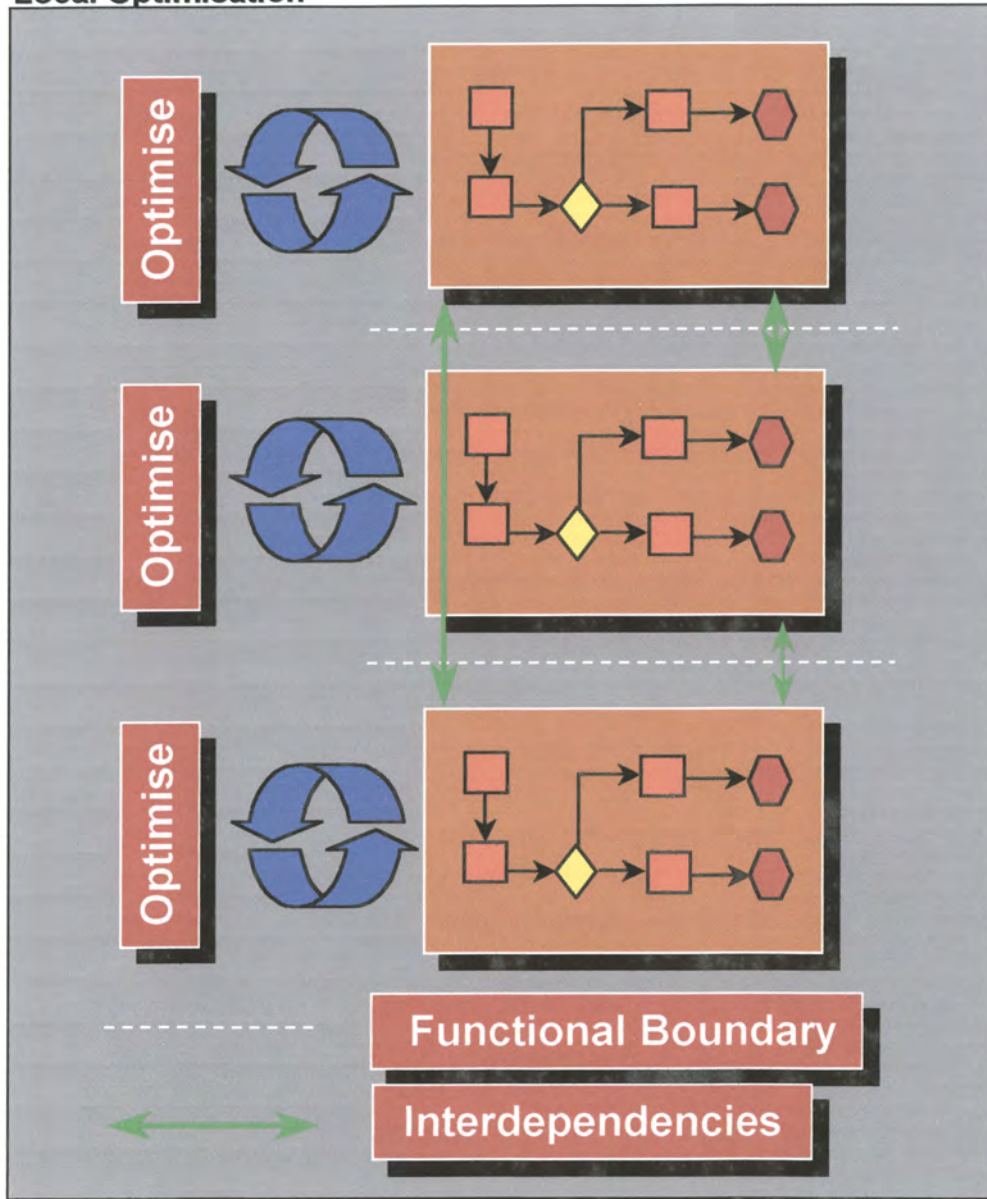
4.3.4 Manual Iteration

A further result of sequential planning was that the material tools largely ignored capacity constraints and the capacity tools largely ignored the material constraints. Distribution ignored what happened on the factory floor and factory planning ignored the distribution of demand.

One advantage was that the computational requirements were much smaller because each department/function only considered a part of the whole. This in return caused those undesirable decisions that were made with one tool cannot be detected until the results were propagated to the next tool.

Because of this iteration between the various tools was an essential part of the traditional planning process. Figure 4.10 provides a schematic illustration of I2 Technologies definition of manual iteration.

Figure 4.10. Manual Iteration[11]
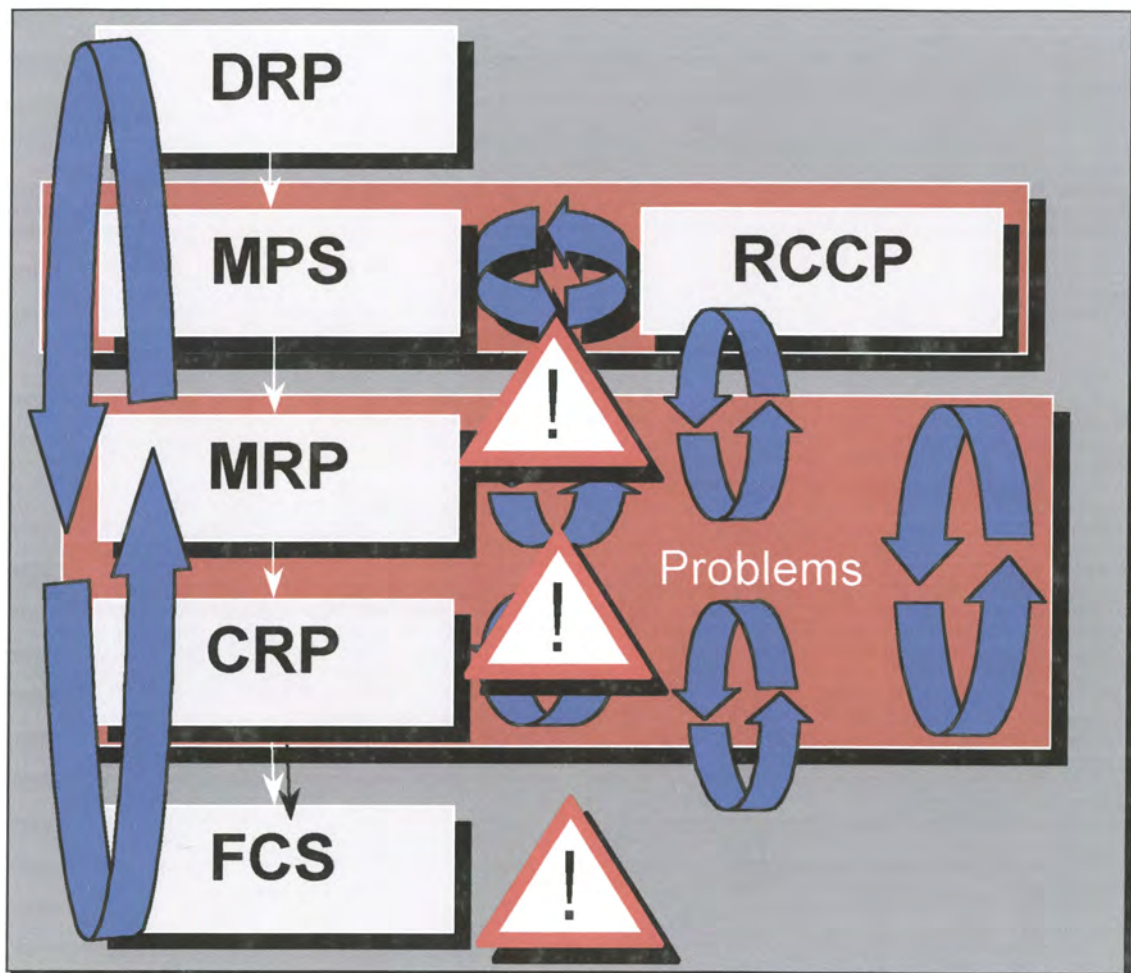
4.3.5 Infinite Planning

Infinite planning was about making high-level conservative decisions in order to reduce the iterative process. These decisions were made in the earlier stages of the planning process to be able to prevent the later tools (capacity or more detailed) from detecting problems that would require iteration.

These high level decisions were often made instead of making decisions that are most profitable to the company. It often happened in later stages of the planning that the planners had to work around poor decisions made in the earlier tools and they do not go back to correct the previous mistakes. This resulted in the creation of organisational constraints, because companies did not allow changes in the high level phases within the horizon of the more detailed tools.

For example, a material – constrained firm will do their material planning first and will devise plans that will avoid reaching any capacity constraints. One of the plans might be to purchase excess capacity in order to keep material usage low, in that way the capacity tools would not detect an overload.

The same can be explained for a capacity – constrained firm. They will do their capacity plans first and devise plans that would avoid reaching any material constraints. This typically can consist of higher inventory levels or stable material usage that effectively will relax the material requirements. Figure 4.11 provides a schematic illustration of I2 Technologies definition of infinite planning.

Figure 4.11. Infinite Planning[12]
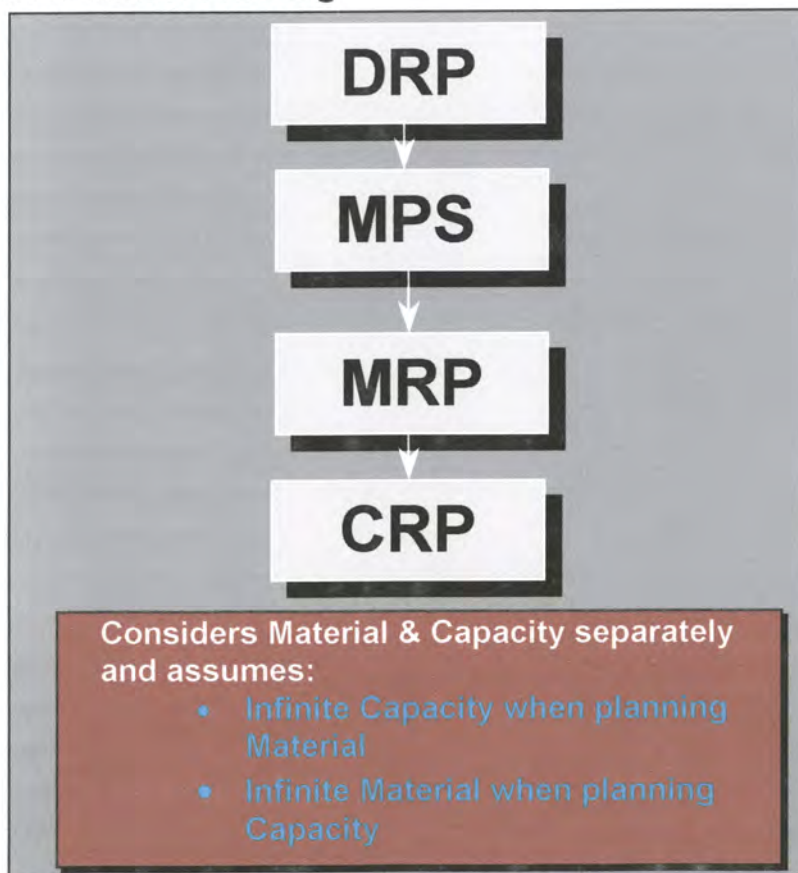
[12] *Rhythm® Supply Chain Planner Concept Manual, © 1996 i2 technologies, Inc. Proprietary Information*

4.3.6 Uni - Directional Change Propagation

Iterations between the different tools are cumbersome but it also has the effect of distorting the big picture. So the planner is restricted to the visibility of the software tool in use and therefore complicating the planning as the following statement from Peter Senge highlights:

"From a very early age, we are taught to break apart problems, to fragment the world. This apparently makes complex tasks and subjects more manageable, but we pay a hidden enormous price. We can no longer see the consequences of our actions; we lose our intrinsic sense of connection to a larger whole. When we try to "see the big picture," we try to reassemble the fragments in our minds, to list and organise all the pieces. …. the task is futile…. Thus, after a while we give up trying to see the whole altogether."[13]

It is still the responsibility of the human planner to create and maintain a good plan for the whole manufacturing environment even if the software tool is not considering the whole.

Dividing the problem did simplify the planning process but the burden of understanding and managing the whole was shifted to the human planner. Refer to figure 4.12.

Figure 4.12. Uni – Directional Change Propagation[14]

A Change anywhere requires a new planning iteration starting at the beginning of the planning process

Line 112
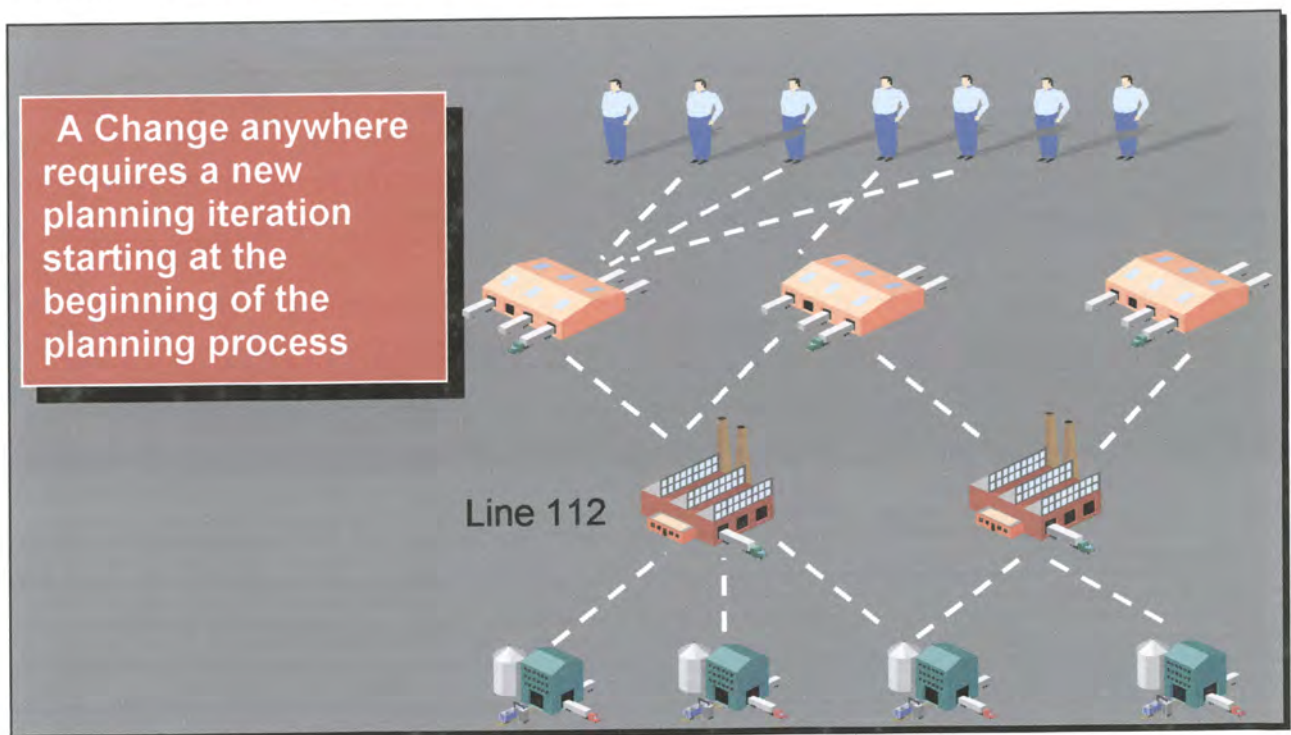
4.4 The Assumptions have changed

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[13] Senge, Peter M., The Fifth Discipline: The Art and Practice of the Learning Organization, Doubleday, NY, 1990
[14] *Rhythm® Supply Chain Planner Concept Manual, © 1996 i2 technologies, Inc. Proprietary Information*

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Since the design of the traditional planning process (and the software tools that embodied them) the assumptions that were made changed dramatically. Not only did computer power advanced tremendously but also the basic understanding of the manufacturing process underwent a "major overhaul".

Globalisation and a reengineered market place forced the planning problems to move. The changes in the assumptions called for a total rethinking of the traditional planning process and introduced some questions.

- What was the focus point of the rethinking?
- Where did organisations suffer the most?
- What is needed to solve this problem?

The first focus area was about the segmentation of the software, organisations tend to focus on only a part of the problem and this does not provide a total integrated solution, and secondly there is no visibility throughout the system.

Organisations suffered mostly in time and money. Organisations maintained long lead times in order capture and processing, engineering, purchasing, production planning etc. The results from the above were lost sales, higher inventory cost and excessive overheads.

The road ahead is steep, and to be able to compete in the global market place, which is extremely competitive, there is no place for a bronze or silver medal. You either win or you loose. This performance and ability do not simply happen, it requires years of commitment, conditioning, and a vision of a gold medal.

In conclusion the traditional planning process have to change and for that one need to have a vision, endurance, agility and speed.

4.5 The Innovative Approach: An Overview

I2 Technologies also saw that the traditional approach needed some reengineering and this translated or evolved into a new innovative approach to planning. This Innovative approach was the direct result of the inability of the traditional planning process to address the new market demands and globalisation of organisations.

I2 Technologies further defined five main areas for improving the inefficiencies of the traditional planning process. These five areas are:

- Concurrent Planning
- Global Optimisation
- Speed
- Constrained Based Planning
- Bi-directional change propagation

This planning approach is better illustrated by figure 4.13.

Figure 4.13. The Innovative Approach
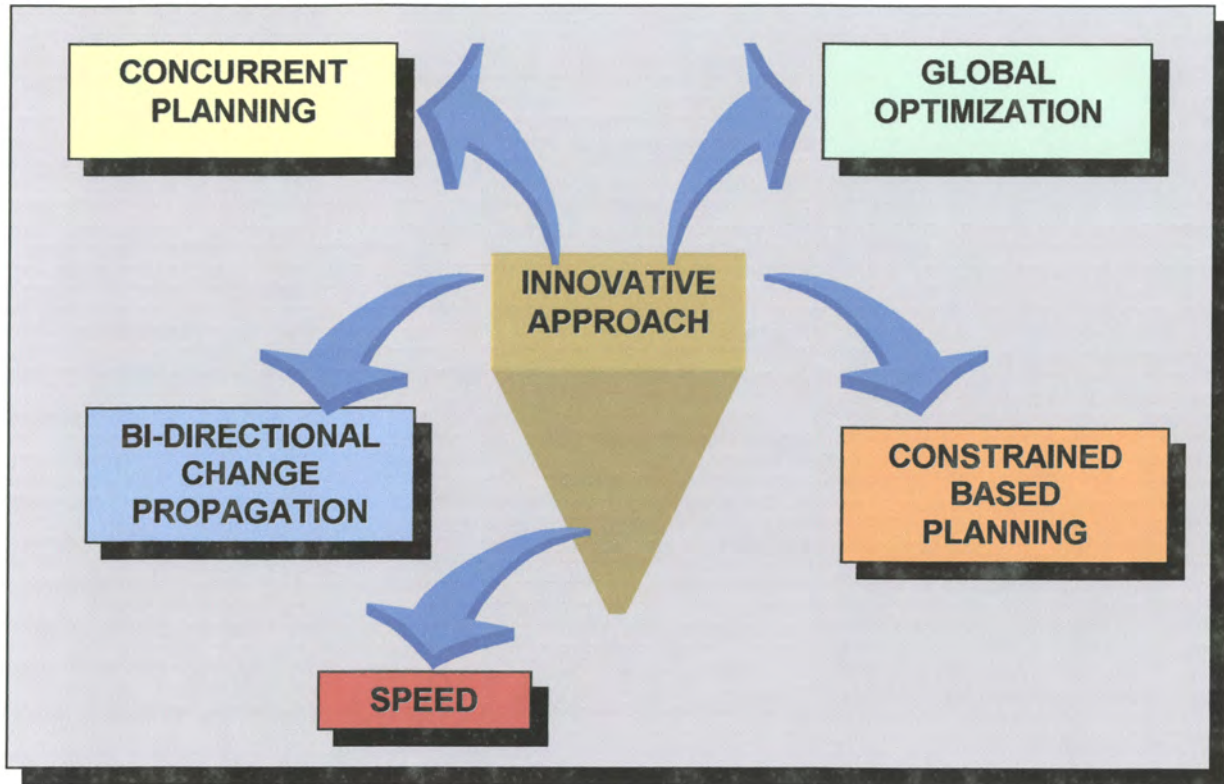
4.5.1 Concurrent Planning

I2 Technologies stated that the main focus of concurrent planning is that the problem needs to be addressed as a whole, this means that functional areas are not to be divided and planning should occur simultaneously. Figure 4.14 provides a schematic illustration of concurrent planning.

Figure 4.14. Concurrent Planning[15]

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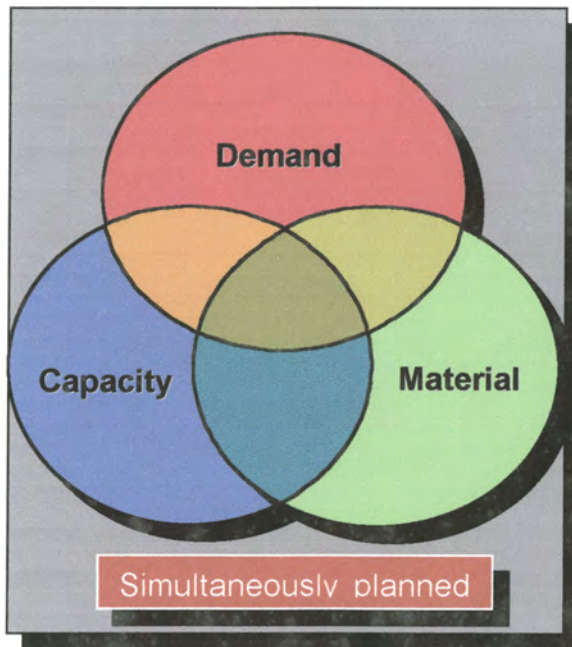
[15] *Rhythm® Supply Chain Planner Concept Manual, © 1996 i2 technologies, Inc. Proprietary Information*

Addressing these planning issues separately can indeed simply each problem, but the separation actually makes it more difficult to develop a good plan that considers all the relevant issues. Only by considering these planning issues simultaneously will one be able to have global visibility of the entire problem.

It can be concluded that without the direct visibility into the global result it is very difficult to make good enough decision from a global perspective.

4.5.2 Global Optimisation

I2 Technologies further realised that because of the globalisation of the marketplace, local optimisation can no longer be implemented. Relationships between the manufacturer, supplier and the market have changed tremendously because of this globalisation. Figure 4.15 provides a schematic illustration of global optimisation.

Figure 4.15. Global optimisation[16]
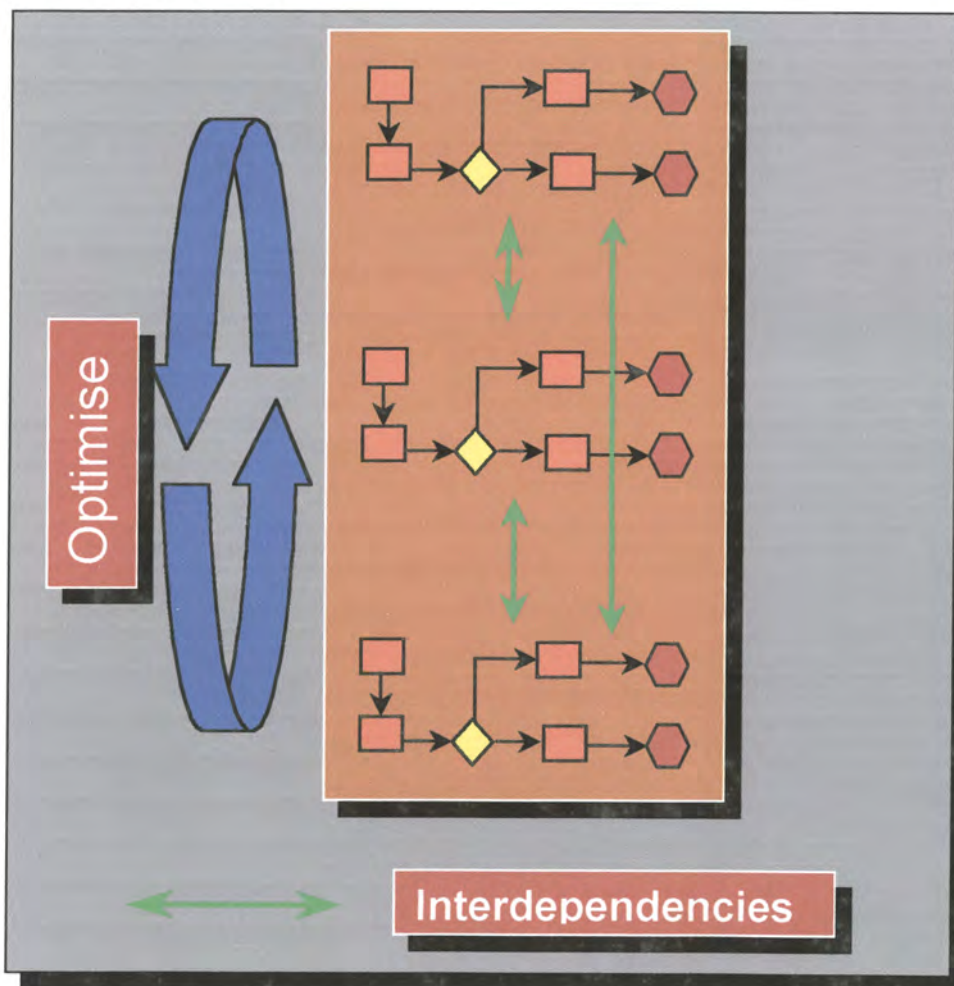
By optimising globally one will have the ability to visualise all the interdependencies within the organisation and its upstream and downstream supply chain. Functional divisions will no longer plan on their own, and a total integrated plan will be created.

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[16] *Rhythm® Supply Chain Planner Concept Manual, © 1996 i2 technologies, Inc. Proprietary Information*

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4.5.3 Speed

One of the key factors according to I2 Technologies is speed and they said that if organisations want to compete in the global marketplace organisations will need to provide speed, responsiveness and flexibility not only to their immediate customer but also to their entire supply chain. Figure 4.16 illustrates the impact of introducing speed into the planning process.

Figure 4.16. Speed[17]

Demand

Material

Impact of a change, internally or externally induced, in a supply chain is directly proportional to the propagation delay(of that change).
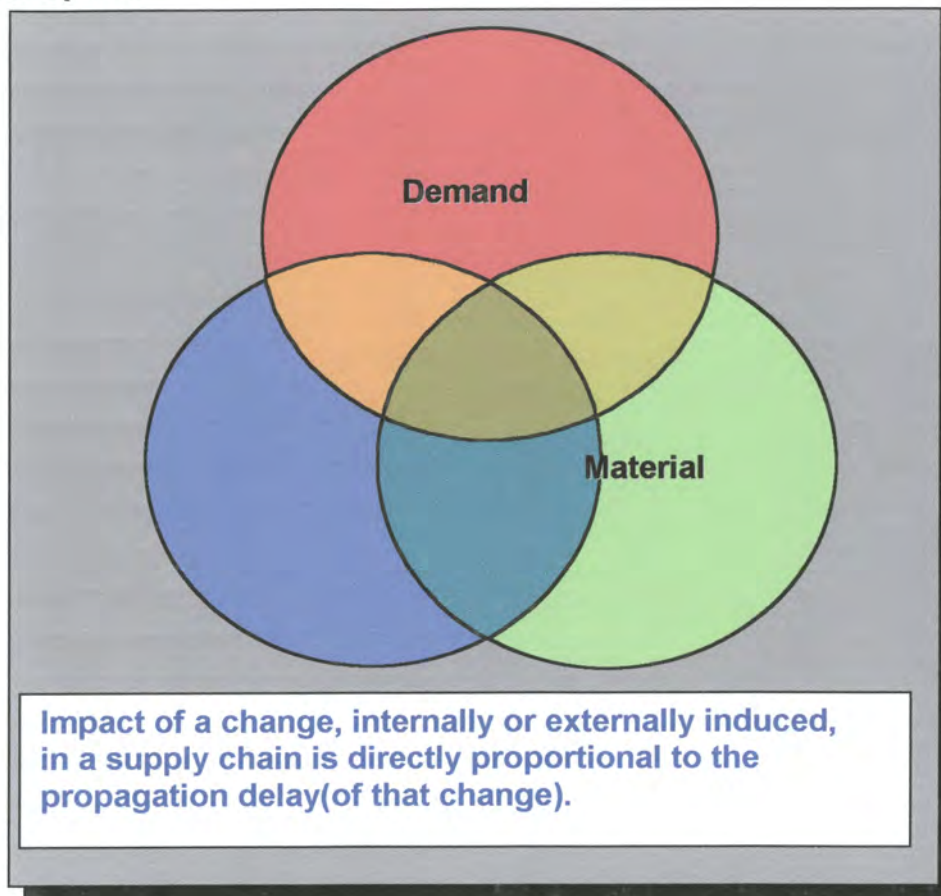
Concurrent, memory resident architecture enables rapid what-if scenarios and re-planning capabilities.

4.5.4 Constrained-Based Planning

Another main focus is of I2 Technologies constrained based planning. Constrained based planning is about deciding on what is the system's constraint and plan around it. In this case material and capacity constraint are considered simultaneously and not individually. By doing this, mistakes are reduced from the beginning and the entire planning process is integrated.

In Figure 4.17 an explanation is given on the main focus of constrained based planning.

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[17] *Rhythm® Supply Chain Planner Concept Manual, © 1996 i2 technologies, Inc. Proprietary Information*

Figure 4.17. Constrained- Based Planning[18]

Constraint

Flow ➡

(i) **Constraints determine the performance of the system; focus resources on managing constraints**

(i) **Planning system must both identify and respect all constraints in the Supply Chain automatically.**
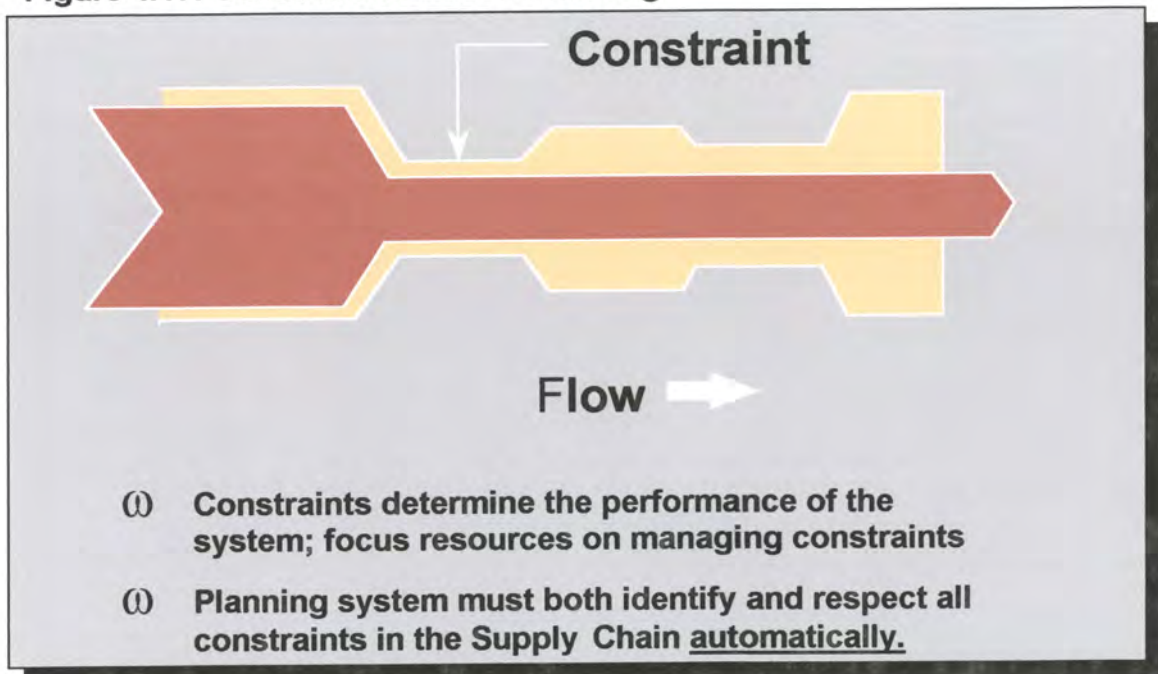
According to Vollmann, Berry and Whybark "Capacity plans must be developed concurrently with material plans if the material plans are to be realised."[19] Dividing these to issues is no longer acceptable and when companies push towards lower inventory levels and lower levels of excess capacity, the planning problems tend to increase exponentially in each area.

As material and capacity constraints interact with one another integrated software that can handle both becomes a necessity in any planning environment.

4.5.5 Bi-directional Change Propagation

I2 technologies also realised that the traditional uni-directional way of planning was not efficient and therefore introduced the bi-directional focus, which states that organisations should be able to integrate and make changes across multiple dimensions. When the problem occurs one needs to be able to propagate the necessary changes upstream and downstream from where the problem occurred.

By doing this the effect of this propagation can immediately be seen and thus providing one with global visibility.

It can now be concluded that in order to reengineer the planning process one would need to "overhaul" one's traditional process into an innovative approach, an approach that is integrated across multiple dimensions, where material and capacity planning is integrated into one problem and where production and distribution is integrated.

This approach also needs to provide one with the necessary flexibility, speed, visibility and quality. It is also essential that the planning should not be done as islands but must

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[18] *Rhythm® Supply Chain Planner Concept Manual, © 1996 i2 technologies, Inc. Proprietary Information*
[19] Vollmann, Berry, Whybark, Manufacturing Planning and Control Systems, Third ed.,Business One Irwin, 1992, p227.

be integrated into one single funnel with the detail varying over a combined planning horizon.

It is clear that one question is still left unanswered and that question is: how do one get to a solution to be able to provide all of this..?

4.6 Truly Integrated Planning

4.6.1 The Opportunity

According to the following statement from Richard G. Ligus it is clear that organisations need to change their way of thinking in order to stay competitive within a global market place.

"Becoming agile means competing and leading in the next century. Companies require an overhaul of their infrastructures to be able to introduce and build new products quickly and accurately, but also need an acculturation process fuelled by heavy involvement. It takes time to enact changes of major proportions…. and careful planning."[20]

Only the truly integrated planning process will be able to steer organisations to this objective. Truly Integrated Planning is the only process that directly addresses the planning problem as a whole. The opportunity to solve the needs of being able to truly integrate organisations processes is now emerging.

This opportunity will no longer allow; excess inventory, unused capacity, missed due dates or even un-synchronised distribution plans. It will even sort out conflicting objectives between manufacturing, sales, and distribution functions. This opportunity is not a "quick and dirty" solution. This opportunity is called effective **Supply Chain Management**[21], and businesses that can squeeze additional revenue from their supply chains will have a powerful competitive edge.

"Any cost savings through improved supply chain management… can go directly to the bottom line. In 1995, American Companies spent an estimated \$670 Billion on logistics alone… equal to over 10 percent of the Gross Domestic Product."[22]

It can be concluded that the need exist to find a way to exploit this opportunity and start to manage the billions of dollars of revenue, which lie trapped in all the inefficient supply chains. If organisations can start to exploit this opportunity to their own advantage, it will provide them with increased market share, cash flows and profits.

All of these measures – market share, cash flow and profits – will form part of the paved road on the way to become a truly integrated and competitive organisation.

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[20] Richard G. Ligus. President of Rockford Consulting Group ltd.
[21] Supply Chain Management - Managing the flow of materials and products from source to user.
[22] The Yankee Group.

4.6.2 The Challenge

Exploiting this opportunity is a challenge above imagination, but it is a challenge organisations dare not even to think of not accepting.

Managing an organisation's supply chain is not an easy task. It is quite complex. Organisations need to move and rearrange all the assets in such a way so that the "stakeholders" - customers, shareholders, employees, unions and regulators are satisfied.

During the years businesses have tried a lot to deal with the problem, by breaking it down into pieces, rigging up walls between different segments of the chain, which fragmented the responsibilities in different segments in the chain. In order to be able to cope with these pieces businesses used different tools, to track these data as illustrated in paragraph 5.1.

Because of this fragmentation there is no integration and organisations do not have the ability to see the "big picture" of what the effect of different decisions and actions is on the total supply chain and the bottom line.

This inability of no visibility makes decision making a slow and arduous task.

In today's highly competitive market organisations need to have the ability to make informal decisions rapidly, so responsiveness is the key measurement. The faster organisations can respond to their customer's needs the better, because the longer the delay the greater the cost of satisfying that need.

In other words organisations need something more than just a localised view, they need to be able to have visibility on a global scale. This means that traditional business systems are not the solution any more, because the assumptions have changed. Organisations no longer can afford to only view parts of the business puzzle, they need to see the whole puzzle....

4.6.3 What is needed to follow a Truly Integrated Supply Chain Solution?

➢ Develop a vision that is based on strategic objectives that will make one agile and take one to world-class status in terms of quality, delivery, cost and speed of new product introduction. This vision needs to be introduced throughout the entire organisation by developing tactical objectives and action plans for all the supporters of this vision.

➢ All the realities and constraints in terms of physical resources, capacities, human resources, resistance to change, etc., which prevents one from being where one wants to be, need to be considered. One needs to determine what it will take to overcome them.

➢ A master plan has to be devised which will fit the organisation's capability to progress. All the bases such as strategy, processes, structure, staffing/skills, organisational reward systems and culture have to be covered in this master plan.

➢ Reorganise the business to satisfy the supply chain - physically and logically. The physical operations need to be streamlined; the processes integrated and there must be a striving for velocity within the entire chain.

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➢ Information Systems must be streamlined all the parts of the supply chain must be linked electronically for fast communication and processing of transactions.

➢ Functional barriers need to be smashed by restructuring each part of the organisation to complete business cycles quickly. Manage change.

"In conclusion, those that successfully emerge from this radical transformation will be the winners and leaders: quick and resourceful enterprises."

4.7 What is the solution and new framework for Supply Chain Management

The question that keeps on appearing is; How in the world are organisations going to manage their supply chain differently or more efficient than traditionally...?

The solution is not simple! Businesses need the ability to instantly make intelligent decisions, which will provide them with the necessary knowledge to be able to understand the global consequences of each business option in order to solve complex real-world problems such as:

➢ Are materials and capacity being allocated among key customers and channels in the most effective manner?
➢ Which resources would be impacted most by revised forecast?
➢ What products are truly available-to-promise? On what date?
➢ How will a late supplier, plant, or distribution delivery impact customer orders, inventories, and transportation loads- as well as profitability

Only by having global visibility into total operations - from source to user - on a real-time basis one will have this ability and knowledge of solving the complex problems in time. The solution must consider real-world constraints as well as limitations. It also must provide management with the ability to make million dollar decisions quickly and swiftly, with a high level of confidence.

A tool that can do all of the above can help managers to transform their current supply chain into a swift, accurate and effective supply chain, which will most definitely provide them with a powerful competitive edge....

In conclusion organisations must be market-driven, with more product research and short development and introduction cycles. The focus must lie on quickly satisfying the supply chain, the chain from customer inquiry through complete customer satisfaction. Thus the solution must have the following characteristics:

➢ It must be able to address the problem as a single holistic[23] problem. Thus the ability to view the whole business puzzle as a whole and not only specific parts, therefore an integrated solution.

➢ Ability to make changes and thinks at an unparalleled speed.

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[23] System as a whole not only the components.

- Speed of response requires a highly intelligent system, which is able to predict, plan, change capacities, do "what-if" analyses and provide managers with informed options in minutes not in weeks.

- Enough speed to be able to make more of the right product at the right time, without wasting time on the shelf or in WIP queues, thus providing value added time.

- Co-ordinate all the phases of demand/fulfilment cycle concurrently at a high speed in order to make sure that the transportation and distribution is synchronised with production.

- Built-in intelligence to weigh thousands of variables and recommend "globally good" solutions for each component of the chain.

- To be able to consider real-world problems or constraints such as, capacity and material shortages, unexpected breakdowns, sudden shifts in distribution channels etc.

- Ability to do all of the above within context of the company's primary goals namely, making money and satisfying customers now and in the future.

By reviewing the above paragraphs it is clear that to have a tool is essential, but what is more essential is the fact of having the right tool which need to have the above characteristics. Only by having that tool with the predefined characteristics, one will be able to exploit the opportunity into a powerful competitive edge....

4.8 Detail description of the solution

During the past few decades, the rules of business have changed due to the increased needs of customers.

This is why today success depends upon responsiveness. Responsiveness can be defined as follows: an organisation's ability to react quickly to customers' needs by delivering the highest quality product on time, at the lowest cost.

Today, more and more companies start to realise that the new key to responsiveness is effective supply chain management. To be able to ensure good product quality, meet aggressive due dates, and keep prices low, businesses need to understand the opportunities and challenges within their supply chains, as well as the constantly changing dynamics at their markets.

Organisations need global visibility throughout the entire supply chain. The functionality of global visibility allows the planners to view all the constraints in the supply chain - as well as their impact on all the supply chain resources. Planners can then use this functionality to formulate plans that are inherently feasible.
The goal of supply chain management as the solution is to achieve maximum customer responsiveness at the least cost. Traditional planning solutions fragmented the problem and solved it sequentially, resulting in unresponsive supply chains.

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So in order to reach maximum customer responsiveness the breakthrough solution of Intelligent Supply Chain Management will focus on improving operation measures such as:

> Customer service level
> Cycle times
> Inventory levels
> Asset utilisation rates which influence ROA, profit contribution

Figure 4.18. The Goal of Intelligent Supply Chain Management[24]
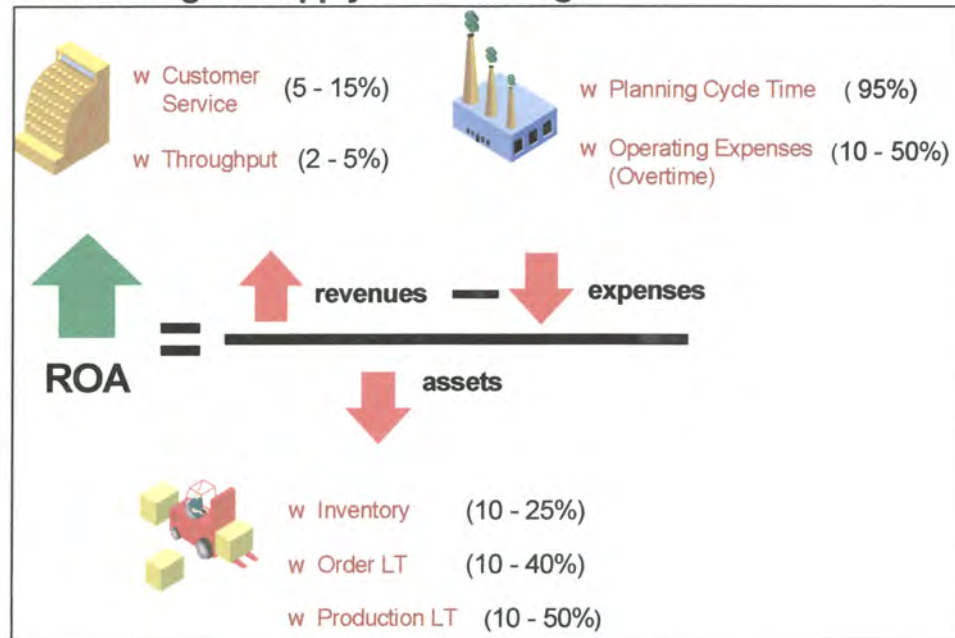
In conclusion Supply chain management will provide an organisation with the necessary improvements to become competitive.

" Quality is no longer a competitive edge – it's a given. Service is the arena where the battle for superiority is being fought. Success will go to those enterprises that can turn on a dime.

As businesses continue to downsize and re-invent themselves in their quest to remain competitive, they must relentlessly seek new ways to do more with less.

We see a day when Intelligent Supply Chain Management will become the new competitive edge.

And that day is now"[25]

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[24] *Rhythm® Supply Chain Planner Concept Manual, © 1996 i2 technologies, Inc. Proprietary Information*
[25] *Rhythm® Supply Chain Planner Concept Manual, © 1996 i2 technologies, Inc. Proprietary Information*

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4.9 Intelligent Supply Chain Management: How it works

The following diagram is an illustration of how intelligent supply chain management functions.

Figure 4.19. Planning funnel of Truly Integrated Planning. [26]
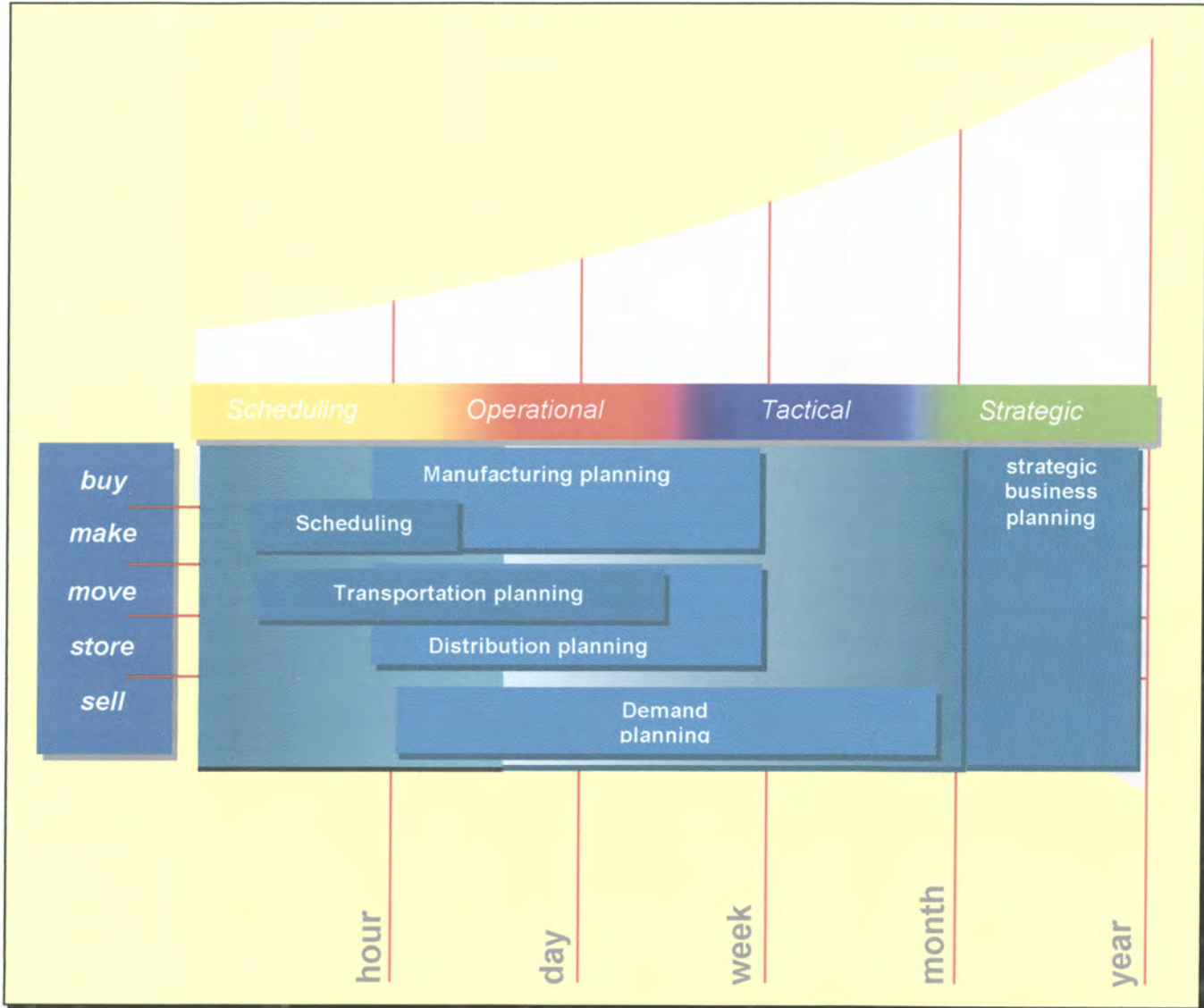
Traditionally the planning levels were divided and done separately (refer to paragraph 5.1) causing different plans and fragmented planning horizons to occur, there was no integrated planning horizon. Scheduling plans for instance is of great detail but only over a short time horizon while some of the other planning is done over a longer time horizon.

In the above diagram on can clearly see that as time passes the planning funnel gradually slides forward therefore increasing the detail of the plans.

When an activity enters the planning funnel for the first time, which is in the production-planning phase the planning is done very coarsely. This is because the future plans vary greatly from what happens in the original plans. As time advances and the funnel moves

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[26] *Rhythm® Supply Chain Planner Concept Manual, © 1996 i2 technologies, Inc. Proprietary Information*

forward, the plans are refined narrowing how much they vary from what actually occurs. In the end the plans reach the neck of the funnel where they are made in great detail. By this time it is hoped that the plans accurately reflect what happens.

4.9.1 Supply Chain Management Characteristics.

➢ Transportation Planning

Encompass the tactical, operational and execution needs for the supply chain. Enables you to:

Derive a demand-driven, feasible plan for transportation resources

➢ Advanced Scheduling

Bring all production operations into detailed synchronisation to meet customer goals and optimise resources. Enables you to:

Determine the optimal sequence of jobs, taking into account a wide variety of highly realistic and detailed constraints.

➢ Manufacturing Planning

Takes a global approach to intelligently optimise the performance of a manufacturing operation. Enables you to meet:

Customer delivery requirements and business objectives by simultaneously manage multiple and dynamic constraints

➢ Demand Planning

Reduce forecasting error; increase planning accuracy and link planning process directly to strategic goals. Enables you to combine:

Intelligent forecasting techniques and multi-dimensional data manipulation

➢ Distribution Planning

Enables logistics managers to:

Create an operating plan that meets the global objective of the Supply Chain

➢ Demand Fulfilment

Improves customer service levels. Enables you to make:

Delivery promises to your customer by providing visibility into complete demand/fulfilment cycle from sourcing through manufacturing, transportation and distribution

➢ Master Planning

Creates a master plan for the entire supply chain. Enables you to determine:

The quantity to produce, purchase, ship and store to meet customer demand. A balance between financial goals and customer service level against operational constraints

➢ Strategic Business Planning

Helps to design most optimal Supply Chain. Enables you to determine:

Where should we locate factories and DC's?
What modes of transport should we use?
How much Capacity is required?

4.10 Conclusion on the evolution of supply chain management

It can be concluded that a new direction is emerging for supply chain management, that direction is Truly Integrated Planning (TIP). Only by having a truly integrated system in place organisations will have global visibility of all the effects. TIP addresses the whole planning process directly, which provides the flexibility organisations need to really support on-going dynamic planning. TIP also integrates the whole planning process across several dimensions and therefore facilitates major leaps in planning capability.

Organisations can have a lot of planning tools in place but if there are no integration involved to allow for global visibility organisations will still be far from reaching business-engineering objectives.

The only way for organisations to get on the right track is to understand their supply chain and manage that supply chain to its optimum. In a supply chain there are five major activities which take place: buy, make, move, store and sell. It doesn't matter whether all of this occurs within a single enterprise or multiple enterprises; the same activities encompass the entire supply chain with planning data being seamlessly exchanged among them.

In order to have an effective supply chain in place organisations need to have an integrated plan with specific decision support capabilities. These capabilities will help organisations to determine when, where and what quantity to buy, make, move, store and sell in order to meet their customers requirements.

Supply Chain Management represents a breakthrough solution which focus on the improvement of operational measures such as customer service levels, cycle times, inventory levels and asset utilisation rates which directly influence return on assets (ROA) and profit contribution for the enterprise.

In the next phase the focus will be on producing solution methods and techniques to model the problem. In this phase different solutions will be evaluated in order to develop a strategy framework for the supply chain planning methodology. This strategy will be constructed from existing methodologies.

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5 Phase Two: Establish Methods and Techniques for Supply Chain Management

5.1 Outlined introduction of phase two

The supply chain management market is exploding and there are a lot of Supply Chain Solution providers that have tools in place with the ability to rapidly and simultaneously plan and schedule customer demand while considering materials and capacity constraints. They also provide the ability to increase revenues, improve customer service and cut costs by synchronised management of the complete supply chain.

Today there is a typical core methodology for each type of problem within the supply chain, which are better known as *"solver technologies"*. It is clear that constant changes and variability, at ever-increasing rates of speed define businesses, faster and faster. These systems although powerful are still working with static data and therefore do not take the randomness and dynamic variability of the entire supply chain in account.

It can be argued that these systems are in need of a tool, which will be able, to model or generate the required randomness and variability, thus providing dynamic capabilities to the planning function....

The technology that is able to provide this randomness and variability is dynamic discrete-event simulation. According to Ted Matwijec simulation (discrete event) can be defined as follows: *"creating a computer model of a real or proposed system and conducting experiments on the model to describe observed behaviour and/or predict future behaviour before investing any time or money. Because experimenting on a real system could be costly and/or impractical, simulation has become an extremely important tool for designing and analysing complex systems; it is a cost-effective way of testing proposed systems, plans, or policies before incurring the expense of prototypes, filed tests, or actual explanations."*[27]

Simulation however is not a *"solver technology"* it is a methodology to evaluate detailed solutions and alternatives in the supply chain.

Simulation can certainly compliment and enhance the planning and performance of a supply chain. In order to be able to provide a simulation solution for supply chain management a strategy is needed to develop the simulation solution.

While Phase One produced certain guidelines that will assist the analyst in understanding the problem, Phase Two is used to produce solution methods and techniques to model the problem. Figure 5.1 will provide an outline of phase two.

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[27] Using Simulation in Supply Chain Management, Ted Matwijec, VP International Operations, Systems Modeling Corporation, 1999.

Figure 5.1 Outline of Phase Two
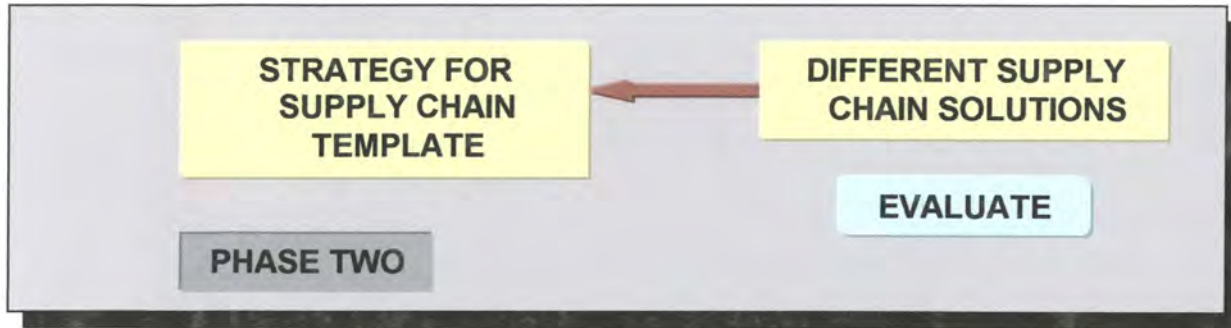
In this phase four companies are evaluated in order to develop a strategy framework for the Supply Chain Template. This strategy addresses the issue of using existing methodologies. As part of this phase a lot of focus will be on the movement in the Supply Chain Market in order to highlight the complexity and competitiveness of this market. The methodologies that will be evaluated are:

A. I2 Technologies
B. Manugistics
C. SAP
D. BAAN

These four companies are on the forefront of technology and each one has a different solution for Supply Chain Management.

5.2   Strategies for Supply Chain Management: An Overview.

According to a recent survey, there was a rapid slowdown in the Supply chain Management software market. Part of the blame can be the slower growth rate in the supply chain-planning end of the market, which only grew two thirds as fast as the year before, it slowed down to a **55%** in **1998** from **75%** in **1997.** The Supply Chain Execution Market also decelerated, but not as much as the **SCP, SCE** growth is estimated at **39%** in **1998**, it was **43%** in **1997**[28].

Some AMR research shows that the markets are going to be slow, but it will pick-up as soon as the **Y2K** bug vanishes and Supply Chain offerings from **ERP** vendors take shape. They projected that the **SCM** market will grow **50%** in **1999**, planning portion increasing **58%** and execution **42%.** Refer to Table 12.1. for a detail outline of the growth expectations.

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[28] AMR Research, 1999

Table 5.1. SCM Revenue by Application Segment[29]

TYPE	REVENUE 1997	EST REVENUE 1998	PROJECTED REVENUE 1998	GROWTH RATE 1997 - 1998	GROWTH RATE 1998 - 1999
SCP	829	1285	2030	55%	58%
SCE	962	1337	1889	39%	42%
TOTAL SCM	1791	2622	3929	46%	50%

AMR research showed that in *1997*, two major role players, i2 technologies and Manugistics dominated the *SCP* and *SCM* market. Each one of these companies had an annual growth rate of *90%*. They used their significant market capitalisation and operating margins to broaden product suites, through development, partnerships and acquisitions. In *1998*, they however took dramatically different paths. *I2* emerged as the market leader and grew steadily to gain an estimated *69%* of the market in *1998* while *Manugistics* took a nose dive with estimated losses of *25 million dollars* and a *11%* decrease in software license revenue.[30]

The rest of the SCP market was similarly tumultuous. ERP vendors entered the market, mergers, acquisitions and partnerships were on the order of the day.

5.2.1 Supply Chain Management Applications a Party of Two.

SCM vendors continued on their change campaign as they've done for the past five years. They kept on changing the incantation of integrated supply chain management, which is meant to be to more efficiently co-ordinate the flow of goods from material suppliers, to manufacturers to consumers. The vendors used internal development, partners, acquisitions, and merged with others to sew together a patchwork of once independent supply chain applications. Because of this transportation management systems *(TMS's)* virtually disappeared as stand-alone products due to buy-outs from *WMS-* and *SCP* vendors. Transportation Management Systems was not the only market that was assimilated, demand planning and forecasting markets became footnotes in SCP and ERP vendor's portfolios.

This resulted in a consolidated two-segment market; the major difference is the time frame in which users have to make decisions. Refer to figure 5.2 for the outline of SCM functionality.

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[29] Source AMR research, 1999 (Revenue figures are in millions of US dollars).
[30] Source AMR research, 1999.

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Figure 5.2. Supply Chain Management Functionality, AMR Research 1999

EXECUTION	**ORDER MANAGEMENT**
	INVENTORY MANAGEMENT
SCE	**INTERNATIONAL TRADE LOGISTICS MANAGEMENT**
OPERATIONAL PLANNING	**TRANSPORTATION MANAGEMENT**
	WAREHOUSE MANAGEMENT
TACTICAL PLANNING	**DISTRIBUTION MANAGEMENT**
	MANUFACTURING PLANNING & SCHEDULING
SCP	**SUPPLY PLANNING**
	DEMAND PLANNING & FORECASTING
STRATEGIC PLANNING	**SUPPLY CHAIN NETWORK DESIGN**

SECONDS/ MINUTES   HOURS/ DAYS   WEEKS/ QUARTERS MONTHS   YEARS

SCP – focus on getting ready for a job with decisions made from weeks to years.
SCE – focus on getting the job done hours and weeks in advance.

5.2.2 SCM looks beyond the Manufacturer

With the consolidation going on, two market forces unfolded to stretch Supply Chain beyond its traditional boundaries. SCM software vendors used their applications to share information and collaborate with others in order to go beyond manufacturing. Supply Chain collaboration became an integral part of the marketing message.

35

5.2.3 APS Technology lets users practice SCM

APS took shape and started to change significantly from the traditional perspective; production scheduling, supporting *MRP* and *FCS,* to a more enhanced APS application with additional business rules, optimisation and real-time "what-if" decision support functionality.

AMR research view APS as an umbrella technology that enables users to do advance Supply Chain Planning and Scheduling in SCP and SCE applications including real-time decision support, optimisation and cross-functional decision-making.

In short it means that APS technology is enabling companies to practice SCM. The following figure highlights the fact that APS technology enables Supply Chain Management Practices.

Figure 5.3. APS enables SCM practices, AMR Research 1999
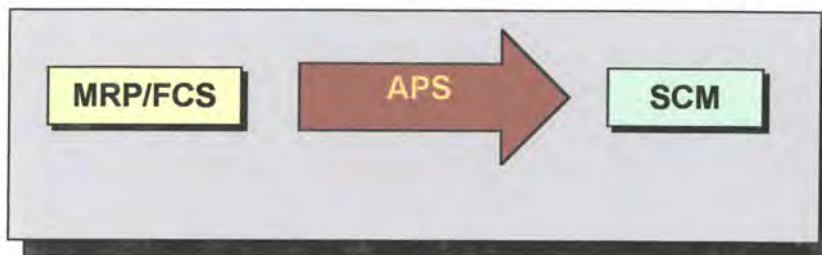
5.2.3.1 What Is APS Technology?

AMR research views APS technology as an umbrella technology that acts in the following ways:

> ➢ It considers a combination of material, plant and distribution resources and customer demand simultaneously.
> ➢ It provides a modelling environment to incorporate constraints, business rules, and goals in the planning process.
> ➢ It uses optimisation algorithms that incorporate business goals.
> ➢ It leverages memory resident programs and databases to provide real-time plan and schedule creation and regeneration.
> ➢ It supports real-time decision support with "what-if" analyses.
> ➢ It provides real-time *ATP/CTP.*

From the above-mentioned points it is evident that APS systems in contrast to ERP systems provide some "intelligence" to decision support, through its modelling and analysis capabilities. APS systems are quite fast but they are still hampered by their single-enterprise, and supply chain focus.

5.2.4 Enterprise Resource Planning Shortcomings

ERP systems did succeed in integrating data from multiple functional areas, which resulted in an incremental addition of value over previous "legacy" point solutions, but their scope is still limited to the single-enterprise and they are quite slow in their processing of data. ERP systems are not intelligent-based, they are transactional-based and therefore these systems do not provide for complexity, which in some cases are required where multiple courses of action are available.

The following table[31] reflects some of the shortcomings of ERP systems.

Table 5.2. Enterprise Resource Planning Shortcomings

Historically, Not Planning, Orientation	ERP systems are built for recording what already happened, rather than planning for what will be. These systems can process orders, but they do not analyse business situations to provide insight into future courses of action. Transaction systems are good at monitoring events, but do not take into account present and future constraints to aid in intelligent decision-making.
Rigidity	They allow an enterprise to design complex and sophisticated workflows, but are far too rigid in their ability to continually reshape and restructure workflows as business challenges and opportunities arise.
Lack of Scalability	They lack the ability to scale large numbers of users and transaction volumes. For example, if a company were to attempt to extend their ERP system's order taking capabilities to the internet, they would quickly find that the system is unable to handle the large volumes necessary.
Single-Enterprise Focus	While ERP systems integrate multiple business functions, they lack the ability to expand their scope to multiple enterprises. Clearly, in a business climate were collaboration with ones customers and suppliers is critical to success, this is a severe gap.
Not an Open Architecture	ERP companies have defined "open" as being able to run multiple hardware/ operating/ database configurations. Although important, this does not deliver openness of applications and data. For example, data models are different for each ERP system, so that integrating multiple ERP systems requires data transformations.

A company called i2 technologies that are on the forefront of supply chain management developed a new technology, which allows companies to leverage the strengths of APS and ERP systems, while mitigating their weaknesses. This initiative is called e-Business Process Optimisation (eBPO).

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[31] i2 eBPO Whitepaper, 1999.

5.2.5 A new solution called eBPO

eBPO can be defined as follows: *"ability to closely couple multiple functions across multiple enterprises through a set of high speed engines that manage complexity, and speed the ability of those companies to react to micro and macro changes in demand, supply, competition, and partner relationships", i2 eBPO Whitepaper, January 1999.*

In essence eBPO allows enterprises to achieve velocity in their operations in the following way:

➢ Maximises an enterprise's ability to execute its business processes more quickly (speed of processing).
➢ Through Intelligence (ability to compare and evaluate multiple courses of action.

The following figure is a graphical representation of the movement of enterprise information systems towards velocity.

Figure 5.4. Information Systems are moving towards Velocity[32]
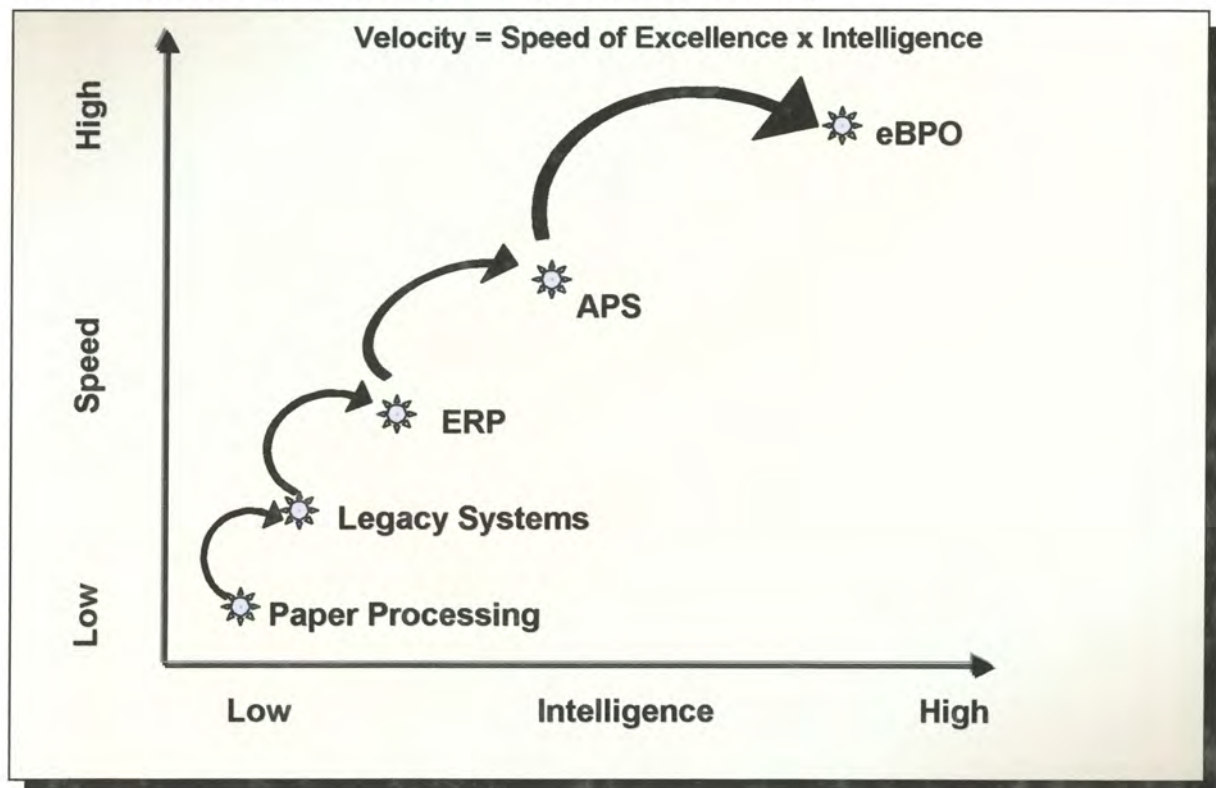
Through the evolution of enterprise software systems there has also been incremental increases in the speed of execution and intelligence. Significant gains were accomplished in the speed of execution, while the gains in intelligence were only marginal. To every rule there is always an exception, and in the case of the movement from ERP to APS the increase in intelligence was quite large. With the advent of eBPO the increase in intelligence and speed also took a significant leap.

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[32] I2, eBPO Whitepaper, January 1999

According to i2 technologies it is essential to have the right planning engine that is intelligent which can help to determine the best course of action in any situation. Whether it is to plan the introduction of a new product or need to consider the effect on existing customer, products and margins or a customer is inquiring about product availability.

5.3 Role Players in the Supply Chain Planning market

The following section is an overview of what happened in the Supply Chain Planning market.

According to reports from the Gartner Group many of the consumer-oriented SCP vendors, such as Manugistics, Logility and Numetrix, have suffered falling growth rates and financial difficulties due to a combination of internal execution problems and outside market conditions. Even the ERP vendors have seen growth rates tumbles for their transactional functionality, and now many are looking to SCP as an important future revenue stream.[33]

5.3.1 The Magic Quadrant Update

The updated Magic Quadrant from the Gartner Group, reflects the continuing execution challenges facing most vendors, but also, more encouragingly, an increase in visionary SCP products aimed at specific market segments.

Figure 5.5. The SCP Magic Quadrant[34]

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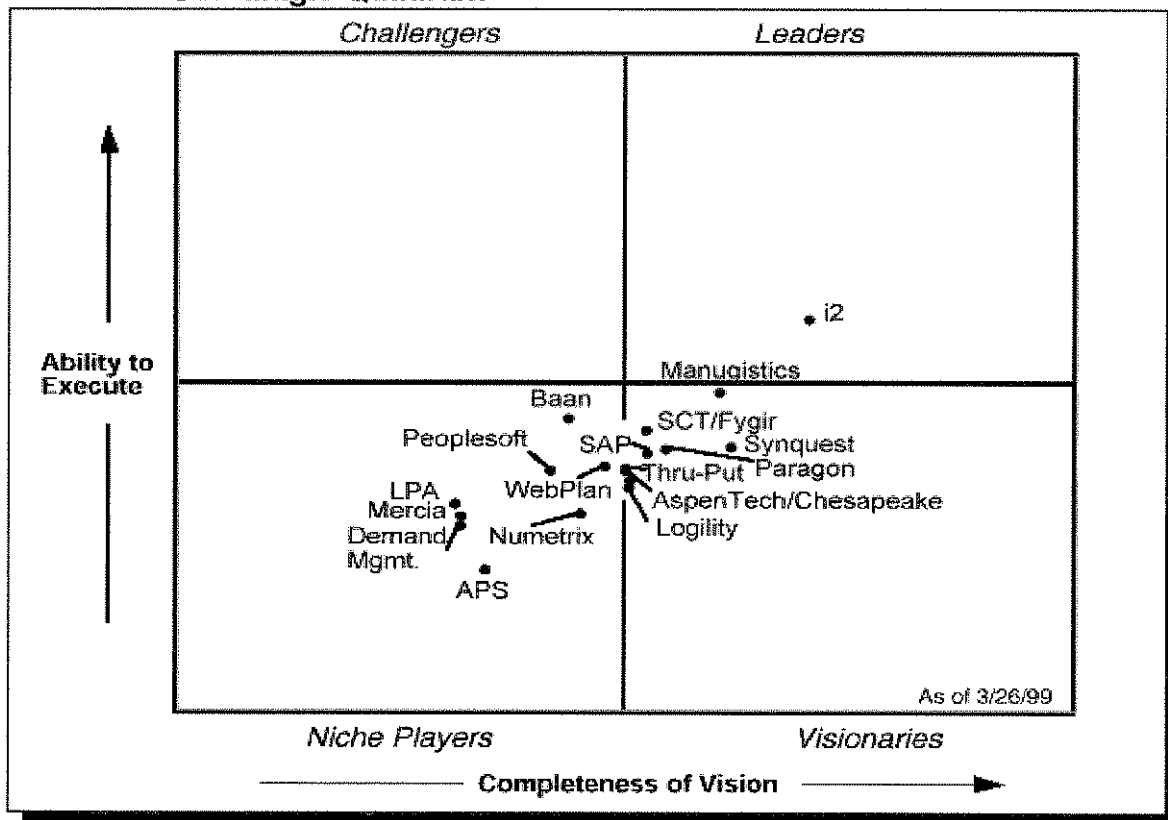
[33] Supply Chain Planning Magic Quadrant Update, Gartner Group, April 1999
[34] Supply Chain Planning Magic Quadrant Update, Gartner Group, April 1999

5.3.2 The Magic Quadrant Process

According to the Gartner Group, to be included in the SCP Magic Quadrant it is required that there is a (believable) vision for a multi- product SCP suite (e.g. Products that may include network planning, capacity planning, demand planning, manufacturing planning and scheduling, distribution and deployment planning or transportation planning) with an effective distribution channel.

The Magic Quadrant is a graphical representation of a vendors performance in a market segment.

There are four major areas around which the analysis is focused:

> *Viability*
> *Service/support*
> *Feature/functionality*
> *Technology*

The ability-to-execute axis is providing a Gartner Group view of how well a vendor performs today. The vision axis provides a Gartner Group view of how well a vendor will do in the future according to the Gartner Group's view on where a market is headed.

In essence the Magic Quadrant is a means to understand vendor positioning and to set performance expectations for vendors.

The Magic Quadrant is just showing that recommended vendors might be found in all quadrants, not necessarily in the leader's quadrant, and that vendors may be appropriate for only specific markets.

The Magic Quadrant Sectors can be defined as described in the following figure.

Figure 5.6. The Magic Quadrant Sectors.

Figure 5.6. The Magic Quadrant Sectors.

Speech bubbles in figure:
- Executes well today, may dominate large segments, but is not in svnch with market.
- Executes well today, well positioned for tomorrow.
- CHALLENGERS QUADRANT
- LEADERS QUADRANT
- NICHE QUADRANT
- VISIONARIES QUADRANT
- Either focus on a small segment of the market and does it well, or is unfocused and does not out-innovate or outperform others direction.
- Understands where the market is going or has a vision of changing market rules, but does not execute well yet.

1.   *The Leaders Quadrant:*

Manugistics is no longer part of the leader's quadrant and is now positioned in the visionaries' quadrant. Manugistics is the second largest SCP software vendor with estimated revenue of just over 200 million US dollars for the 1998 calendar year. The reasons for moving down to the visionaries' quadrant are because of major execution problems since Spring 1998 due to a lack of sales, and a lack of corporate focus on its core markets at a time of increasing ERP competition.

Manugistics has since returned its focus to consumer-oriented businesses. The leader's quadrant has now only one resident and that resident is I2 Technologies. The vision rating of I2 has increased because of its "eBPO" initiatives, however, because of execution challenges around eBPO, its ability to execute rating has not increased.

It is quite clear that the leader i2 is executing better than any other SCP vendor with total revenue of 362 million US dollars in 1998. Although i2 continues to deliver a differentiated vision to the market, it is believed that i2 will be challenged to sell and successfully implement eBPO in a mass-market fashion for the next two years. The results shows that i2's vision rating has increased while its execution rating hasn't moved significantly.

I2's sweet spot still remains discrete manufacturers especially high tech and electronics. I2 is also making a lot of progress in helping apparel and automotive customers address some SCP issues.

2.   *The Visionaries Quadrant*

Overall maturity of product direction and business models in the SCP market is reflected through the movement of many vendors to this quadrant. New entrants include AspenTech/Chesapeake, SCT/Fygir and SAP. Chesapeake and Fygir's have enhanced their ability to compete in their process-manufacturing target markets due to their sell out to larger and more-financially viable vendors.

Aspen/Chesapeake has differentiated itself for process manufacturers through its deep domain expertise, its comprehensive toolkit of planning applications, and its vision for closed-loop interaction with process control systems. SCT/Fygir on the other hand has been gaining momentum with its object-based process manufacturing, scheduling, planning and distribution software.

The reason for SAP's upliftment into the visionaries' quadrant is because of its clear commitment to SCP, its disciplined product delivery, organisation and functionality like supply chain cockpit. Nevertheless, SAP remains a SCP novice.

It is believed that its depth of functionality, scalability and performance, implementation methodology and training for APO remains immature, therefore degrading its time-to-value proposition.

Thru-Put, which specialises in solving complex manufacturing issues, especially *ETO/MTO*, has moved onto the visionary/niche dividing line due to its broader product suite and innovative customer support initiatives.

3. *The Niche Quadrant*

WebPlan has made the most progress, because of its innovative collaborative SCP Strategy orientated towards electronics, aerospace and industrial manufacturers. Numetrix has moved up a bit in its ability to execute.

Baan's supply chain group rose slightly in its execution ability with the acquisition of Caps Logistics, but is still constrained because of its financial position and integration issues.

The Magic Quadrant perspective is a Gartner Group initiative and their viewpoints are highly regarded. According to the Gartner Group the SCP market will continue its chaotic ways in 1999 and one can expect more acquisition activity as the ERP vendors jump-start their SCP capabilities.

5.4 Logistics Information Systems

"Information Technology (IT) is the thread running through the enterprise – the link that truly integrates manufacturing distribution and customer delivery. Its innovative use defines the competitive arena, and its role in integrated distributions is that of key enabler. In other words, it is an integral part of, not a support for, the process." Gopal & Cypress, Integrated Distribution Management, Business One Irwin, 1993, p. 145.

Before the different solutions can be evaluated it is essential to understand what is needed in such a solutions and how should it be integrated into the logistics channel.

Logistics are complicated and efficient planning thereof is only possible with the correct information. Enabling this information with technology provides a driving force for competitive logistics strategy.

From the Magic Quadrant update it is evident that there are a lot of integrated logistics systems in the market that link the operations of the business, such as production and distribution, with supplier's operations on the one hand and the customer on the other. It is also clear that *EDI*, which enables computer-to-computer ordering and transaction management, is now widespread.

A classic example of where EDI is used is the information system that drives the replenishment process for the clothing and apparel sold by Marks and Spencer through their UK stores[35]. Their replenishment requirements are determined by head office through daily information from the point of sale. Suppliers receive the transmitted information and package individual requirements into bar-coded parcels. Two logistics service companies then collect these parcels. From here on the bar-coded parcels are transported to transhipment centres where it is stored for store delivery. Through this function a just-in-time delivery is achieved which enables stores to carry only minimum stock and transportation costs are contained through the principles of consolidation. The following two figures (fig 5.7 and fig 5.8.) explain the above-mentioned process.

Figure 5.7. Daily Sales data drives the replenishment order system.[36]

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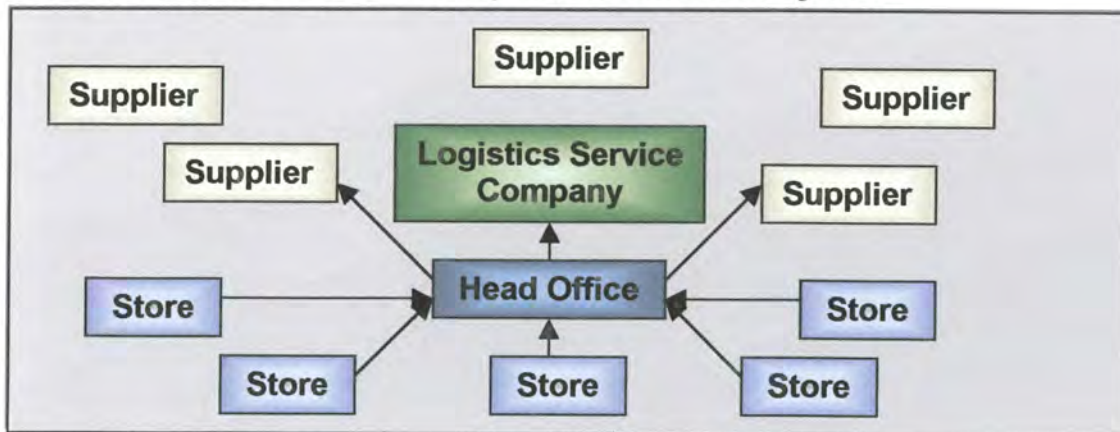
[35] Logistics and Supply chain Management, M. Christopher, 1992, p170
[36] Logistics and Supply chain Management, M. Christopher, 1992, p170

Figure 5.8. Acting on this information a consolidated pick-up and store delivery sequence is activated.[37]
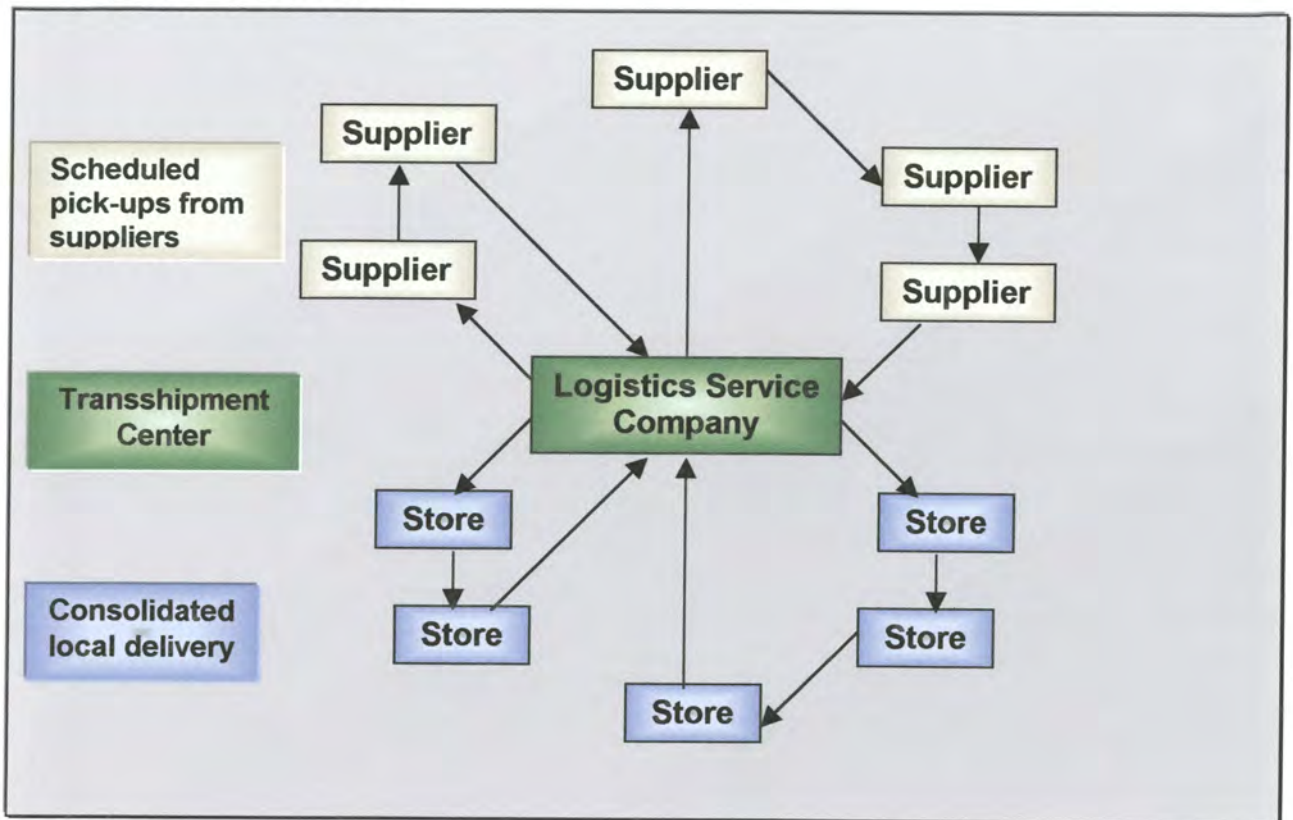
So, information is crucial and some organisations even found that they manage dispersed inventories as single inventories through the use of information. It can be argued that if inventory management is centralised and decisions on replenishment and order quantities are taken on the basis that it is a single stock, then only one safety stock instead of many is required. The stock therefore can be carried anywhere in the system, either near the point of production or the point of consumption. This whole concept is better known as **"virtual"** inventory management or electronic management.

SKF, the Swedish Bearing Company has established their own logistics planning systems better known as global forecasting and supply system (GFSS). This system is a demand management system that captures the demand as customers places their orders at the local SKF sales office or through EDI. The computer-based system determines in real-time where items that are required are held in stock, or, if they are not available, when and where are the next items scheduled for production. At the same time the customer's order is accepted and a delivery date is issued, because the system can schedule the transport concurrently.

This type of system is now becoming more and more popular as open system architecture enables easier computer-to-computer linkage.

Basically all of the organisations mentioned in the Gartner Group's magic quadrant update report (see par 5.3.1.) has some sort of system in place, which enables the process of computer-to-computer linkage.

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[37] Logistics and Supply chain Management, M. Christopher, 1992, p171

The following figure (see fig 5.9.) is a summary of the architecture of a system that was developed by the Digital Equipment Corporation. This is a general-purpose integrated logistics system that enables organisations to manage demand from one end of the pipeline to another.

Figure 5.9. An integrated logistics information system.[38]
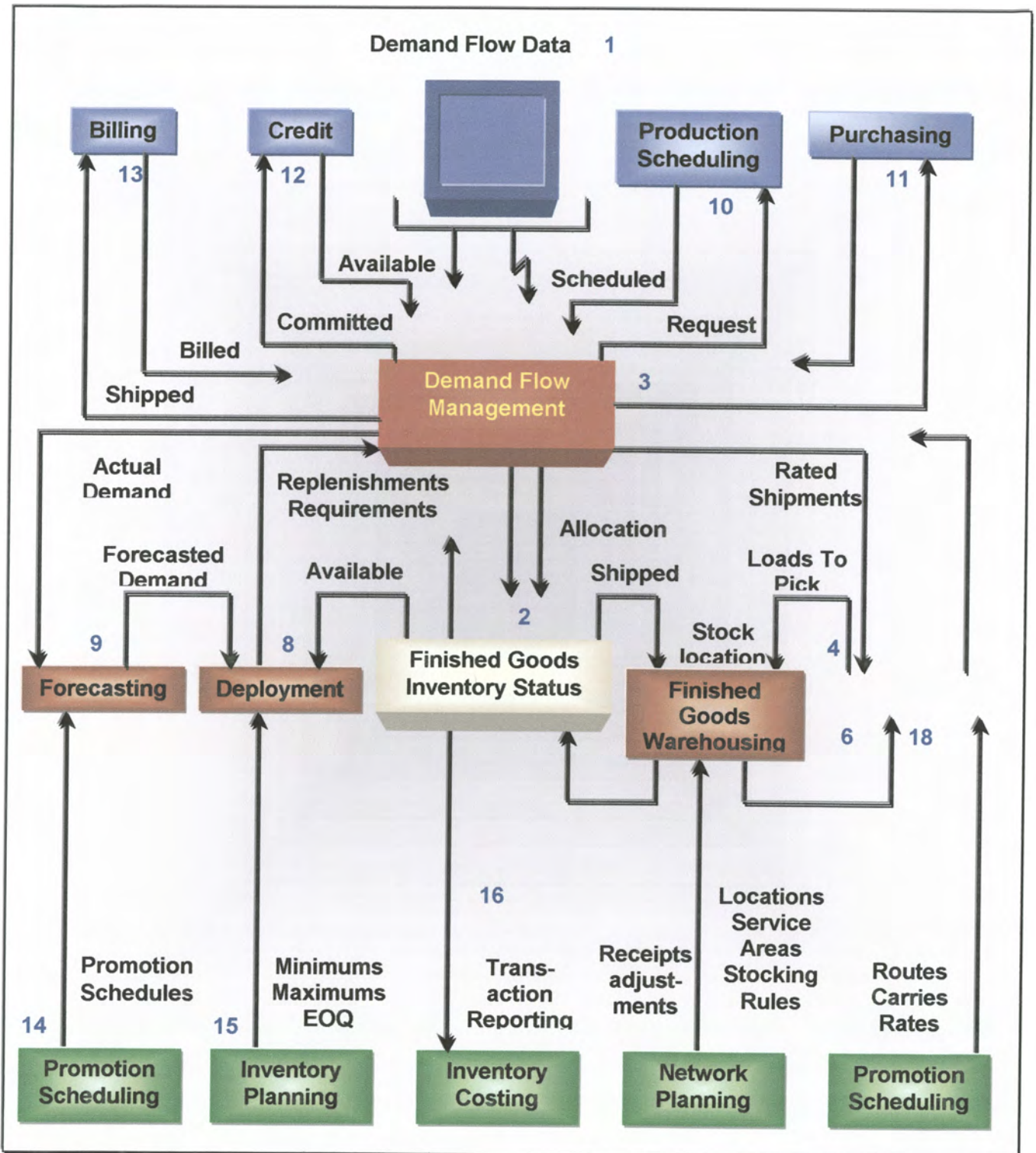
[38] Source, Digital Equipment Corporation.

The use of logistics information systems in the integration in the supply chain is crucial and planning, co-ordinating and controlling all the activities that are related to order fulfilment can greatly facilitate the internal management of a business. The following figure will show what the basic functions of a Logistics Information System is, and how it is possible from a common database to provide information to better manage each of the vital elements in the logistics process. (Refer to fig 5.10.)

Figure 5.10. Functions of a Logistics Information System.[39]

Planning Function
- **Stock Management**
  - By Product/ Customers
  - By Location
- **Demand Forecasting**
- **Strategy Planning**

Co-Ordination Function
- **Production Scheduling**
- **Materials Requirements Planning**
- **Sales/Marketing Planning**

DATABASE
- **External Data**
  - Customer Orders
  - Inbound Shipments
- **Internal Data**
  - Production
  - Inventory

Customer Service Communication Function
- **Customer Order Status**
- **Inventory Availability**
  - By Product
  - By Stock Location
- **Inbound Shipment Status**

Control Function
- **Customer Service Levels**
- **Vendor Performance**
- **Carrier Performance**
- **System Performance**

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[39] Logistics and Supply chain Management, M. Christopher, 1992, p173

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5.5 Evaluation of Supply Chain Solutions

In this section the focus will be on the different solutions currently available in the market today. From Gartner Group's Magic Quadrant update (par 5.2.1) it is quite clear that there are quite a lot of new players in the Supply Chain Arena. It was decided to analyse 4 of the major role players in the Supply Chain market. Two of the companies are traditional ERP solutions experts while the other two are traditional SCM solutions experts.

The purpose of this part is just to highlight the different solutions and to show how these solutions operate. It will appear that the solutions are very similar in their approach as well as what they sell. Although it seems as if these solutions are the same the opposite is true.

The explanation of these solutions will pave the way for the strategy for the Supply Chain Template.

The companies which solutions will be evaluated are:

> I2 Technologies
> Manugistics
> SAP
> BAAN

5.5.1 I2 Technologies

5.5.1.1 About I2 Technologies

I2 was founded in 1988 and is a leading provider of intelligent decision support and execution software for managing the global supply chain.

5.5.1.2 I2's Solution for Intelligent Decision-Making across the Enterprise

According to i2 technologies today's business landscape has become extremely variable and complex. It is believed that this has been the result of several major trends such as; globalisation, corporate consolidations and an explosion in Internet usage. In addition, there is an increased focus on a customer-centric business model with mass-customisation, customer-driven supply chains, and complete customer relationship management.[40]

I2 believe that the variability and complexity of businesses will increase with a factor 10 over the next couple of years.

In order to address this rapidly changing environment, i2 Technologies has pioneered a new category of software called: electronic Business Process Optimisation (eBPO).

So what is eBPO and how does it work?

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[40] eBPO Whitepaper, i2 Technologies, February 1999.

> electronic Business Process Optimisation

eBPO can be defined as follows: " *ability to closely couple multiple functions across multiple enterprises through a set of high speed engines that manage complexity, and speed the ability of those companies to react to micro and macro changes in demand, supply, competition, and partner relationships", i2 eBPO Whitepaper, January 1999.*

I2 believes that there are three ways to achieve a competitive advantage:

> *Operational Excellence with effective Supply Chain Management.*
> *Product leadership through Product Life Cycle Management.*
> *Customer Intimacy by means of Customer Management.*

The key to achieve this competitive advantage is to excel in all three processes, integrate them and provide the ability for a strategic long-term view.

The following paragraphs are an overview discussion of i2's eBPO solution. (Refer to fig 5.11)

Figure 5.11. electronic Business Process Optimisation[41]
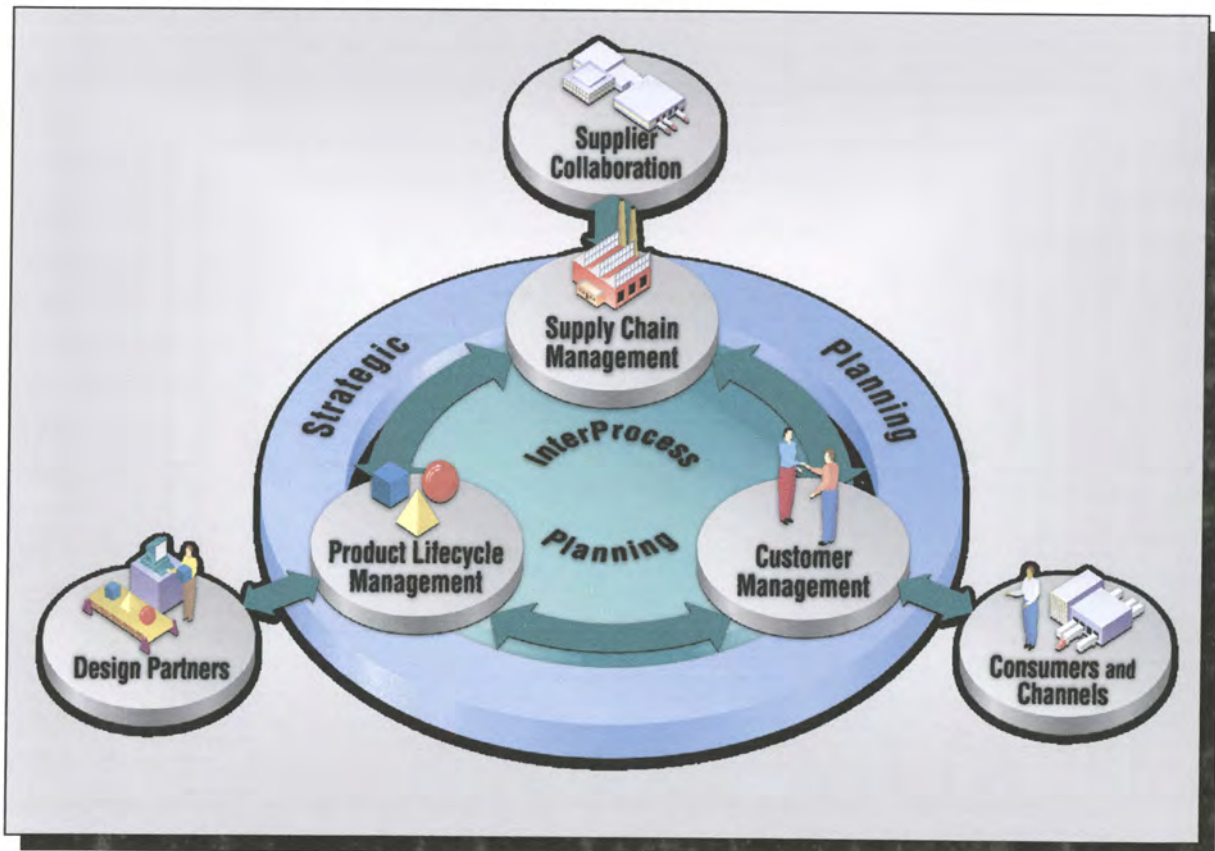
As the above figure shows it is clear that eBPO integrates the following core business processes for an enterprise and its value chain:

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[41] eBPO Whitepaper, i2 Technologies, February 1999.

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- ➤ Product Lifecycle Management
- ➤ Supply Chain Management
- ➤ Customer Management
- ➤ InterProcess Planning
- ➤ Strategic Planning

eBPO addresses each of these processes with both an internal focus on integration, and an external focus on electronic business (eBusiness) activities with customers, suppliers and trading partners.

According to i2 Technologies eBPO enables maximum velocity by optimising the core business processes that make up an enterprise. It is believed that this integrated
and optimised approach across multi-enterprise business processes is
what differentiates the eBPO solutions from previous generations of enterprise software.

5.5.1.3 eBPO Business Processes

- ➤ Supply Chain Management

    I2 Technologies defines supply chain management as follows:

    "The process of anticipating market demand, positioning enterprise resources to meet demand and fulfilling demand as it is realized."[42]

    According to I2 Supply Chain Management is composed out of three sub-processes: Demand planning for the effective anticipation of the market demand and trends, Supply planning for the optimal positioning of enterprise resources to meet the demand and Demand fulfilment for efficient fulfilment of demand as it is realised.

- ➤ Product Life Cycle Management

    I2 Technologies defines product life cycle management as follows:

    "The process of managing products from concept, design and test, to phase-out and replacement."[43]

- ➤ Customer Management

    I2 Technologies defines customer management as follows:

    "The process of maximising customer satisfaction and optimising return on sales, marketing and customer service investments"[44]

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[42] Dan Keelan, I2 Technologies, Executive Conference, 19 May 1999.
[43] Dan Keelan, I2 Technologies, Executive Conference, 19 May 1999.
[44] Dan Keelan, I2 Technologies, Executive Conference, 19 May 1999.

➤   <u>Inter Process Planning</u>

I2 Technologies defines inter process planning as follows:

"Process that balances resource requirements among processes to achieve enterprise-wide efficiency and responsiveness."[45]

➤   <u>Strategic Planning</u>

I2 Technologies defines strategic planning as follows:

"Process by which senior executives perform competitive analysis, set company objectives and make long-term financial, product portfolio and supply chain decisions."[46]

Figure 5.12. Customer-To-Supplier Integration with eBPO[47]

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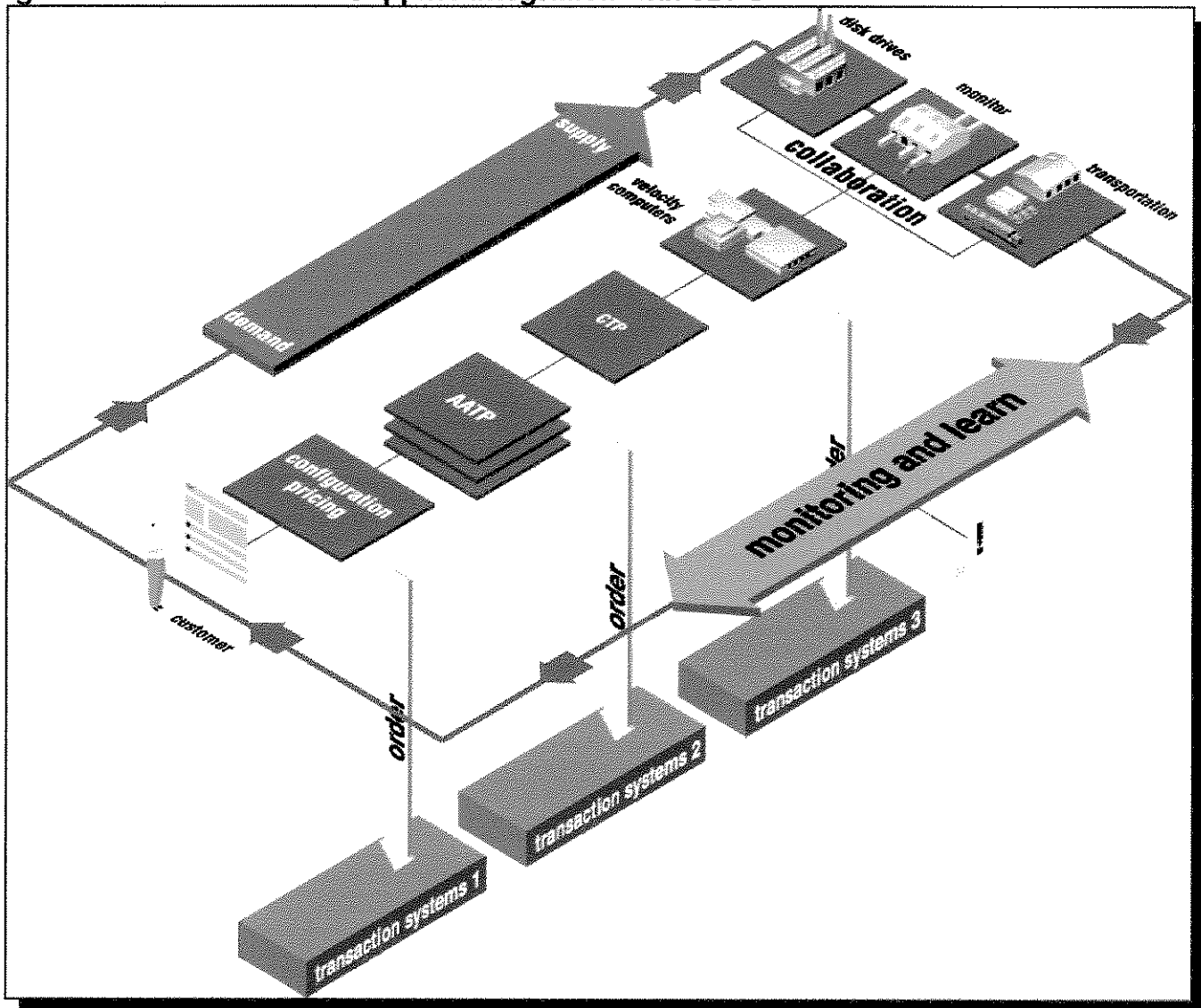
[45] Dan Keelan, I2 Technologies, Executive Conference, 19 May 1999.
[46] Dan Keelan, I2 Technologies, Executive Conference, 19 May 1999.
[47] eBPO Whitepaper, i2 Technologies, February 1999.

5.5.1.4 Conclusion of I2 Technologies' Solution

The I2 solution offers intelligent answers for decision-making across the entire enterprise. The Rhythm® software product suite optimises and integrates key business processes, while delivering intelligent e-Business through collaboration with trading partners. It also offers a complete solution through its optimisation, integration, and forward visibility functionality's.

5.5.2 Manugistics

5.5.2.1 About Manugistics

Manugistics, Inc. (Nasdaq: MANU) is a leading provider of customer-centric supply chain optimisation solutions.

5.5.2.2 Manugistics Solution for Supply Chain Management

Manugistics Supply Chain Solution is built around a customer-centric solution framework called ONEview™.

This framework is unlike internally focused systems; it provides a dynamic solution to accommodate the changing needs of customers.

Manugistics believes that in order to optimise your supply chain around your customers means making informed decisions along the entire spectrum- from product design and acquiring raw materials to manufacturing products and distributing finished goods to the customer. Refer to figure 5.12.

Figure 5.13. Manugistics' ONEview™
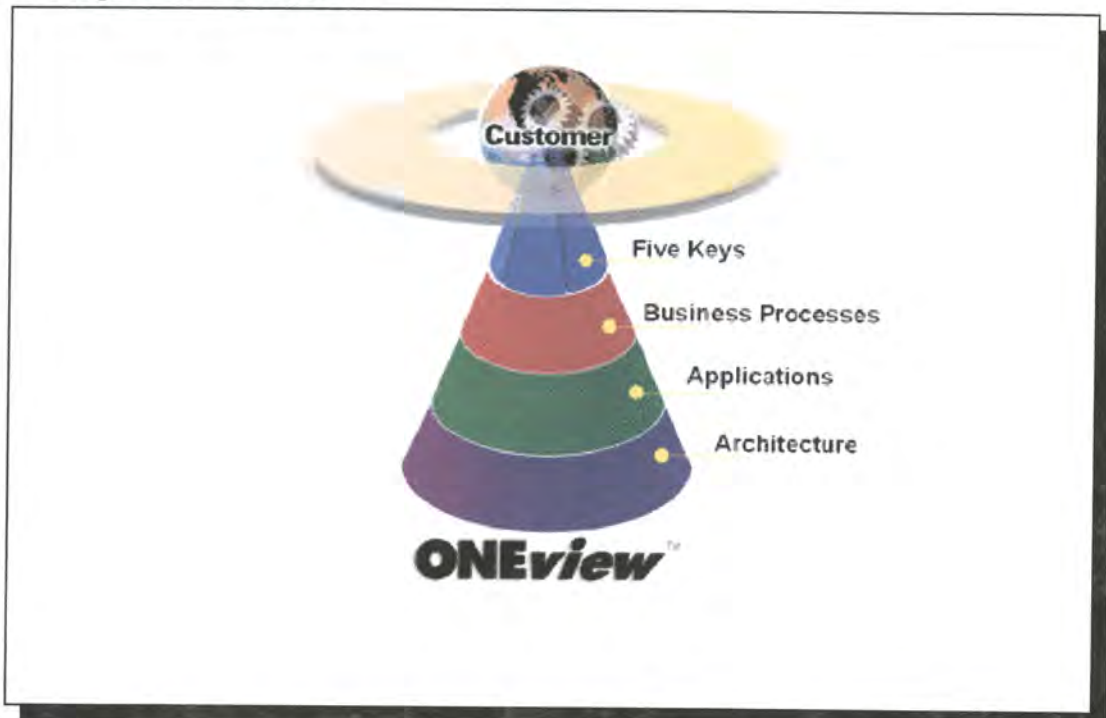
The following paragraphs are an overview discussion of Manugistics' ONEview™ solution.

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5.5.2.3 The ONEview™ Solution.

> ## The Five Keys

Manugistics believe that the following keys are essential requirements for delivering Customer-Centric Supply Chain Optimisation:

> - Integrate
> - Collaborate
> - Optimise
> - Real Time ATP
> - Profitable Mass Customisation

According to Manugistics in order to deliver on the promise of the customer-centric approach a fundamentally different kind of solution is required, a solution that leverages the end-to-end Supply Chain from the perspective of the customer. Without the five keys intact an optimised Customer –Centric Supply Chain cannot be enabled.

> ## Business Processes

Manugistics' ONE*view*™ business processes are uniquely focused on managing decisions, events and plans with the customer as the key focus. With ONE*view*™'s business processes efficient organisational deployment of Customer-Centric Supply chain Optimisation is ensured.

> ## Applications

To be results driven, it is important that best practice processes are enabled with applications. Manugistics believe that specific applications are needed to optimise each one of the key supply chain business process areas, design, buy, make, move, store, sell, collaborate, monitor and measure.

> ## Architecture

The Manugistics Supply Chain Architecture is the backbone that brings together all the necessary components in order to allow a business to focus on the needs of their customers.

The following figure is an outline of what Manugistics believes is their solution for truly customer centric supply chain optimisation.

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Figure 5.14. Manugistics' Solution for Customer-Centric Supply Chain Optimisation
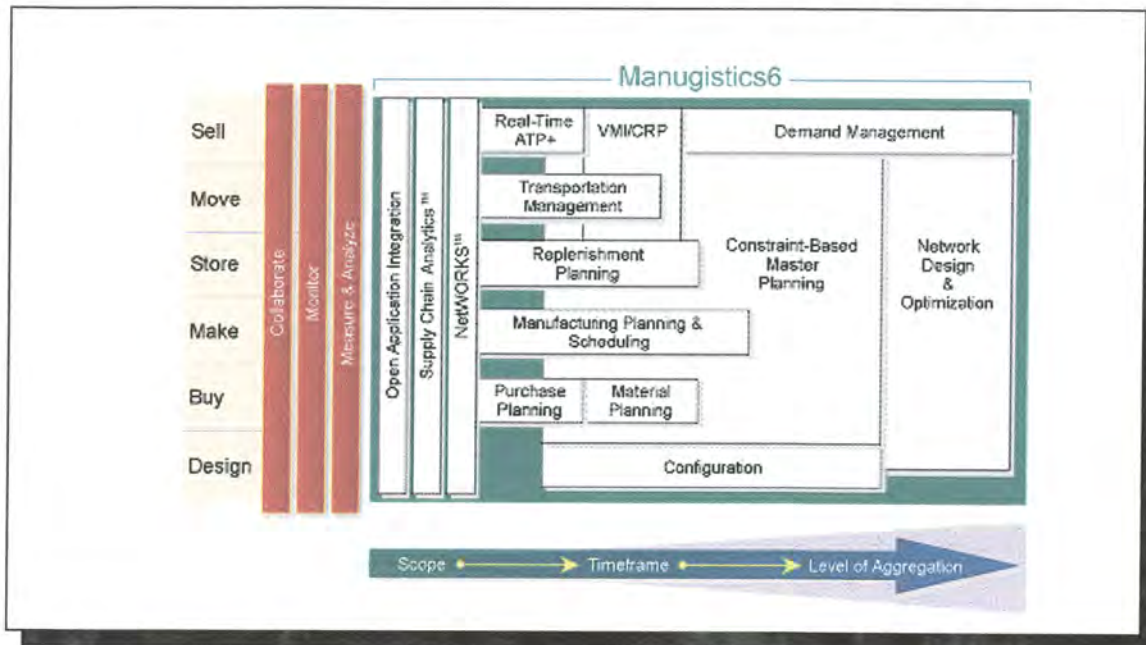
5.5.2.4 Conclusion of Manugistics' Solution

Manugistics enables a truly customer-centric approach for a business, and Manugistics6 is one of their newest generations of proven supply chain optimisation applications. Manugistics6 anticipates customer needs, orchestrates actions both within and across enterprises to meet those unique needs, and maximises customer satisfaction. It is also designed to optimise each one of the key supply chain business process areas – design, make, store, move, sell, collaborate, monitor, and measure & analyse.

5.5.3 SAP

5.5.3.1 About SAP

SAP (Systems, Applications and Products in Data Processing) was founded in 1972, and it is one of the leading ERP software solution providers.

5.5.3.2 SAP's Solution for Supply Chain Management

According to SAP today's global business environment has become increasingly competitive and fast moving and they believe that in order to be competitive, it is important to have an information infrastructure that enables quick response to changing market dynamics, and still maintaining profitability.

SAP traditionally a transactional software vendor is now realising the need for supply chain management, and states that integrated supply chain management and real-time decision-making are crucial in order to keep pace with the rapid changes in supply and demand[48].

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[48] SAP APO: Advanced Planner and Optimiser

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To be able to meet these challenges SAP launched the SAP SCOPE® (Supply Chain Optimisation Planning and Execution) initiative.

SAP SCOPE® provides new generation solutions that integrates information and decisions across the entire supply chain into a seamless, automated and optimised information infrastructure. SAP APO is a central component of the SCOPE® initiative and provides a complete suite of supply chain planning tools for real-time planning and decision support.

The following figure highlights SAP's APO process. (Refer to figure 5.15.)

Figure 5.15. SAP's Advanced Planner & Optimiser
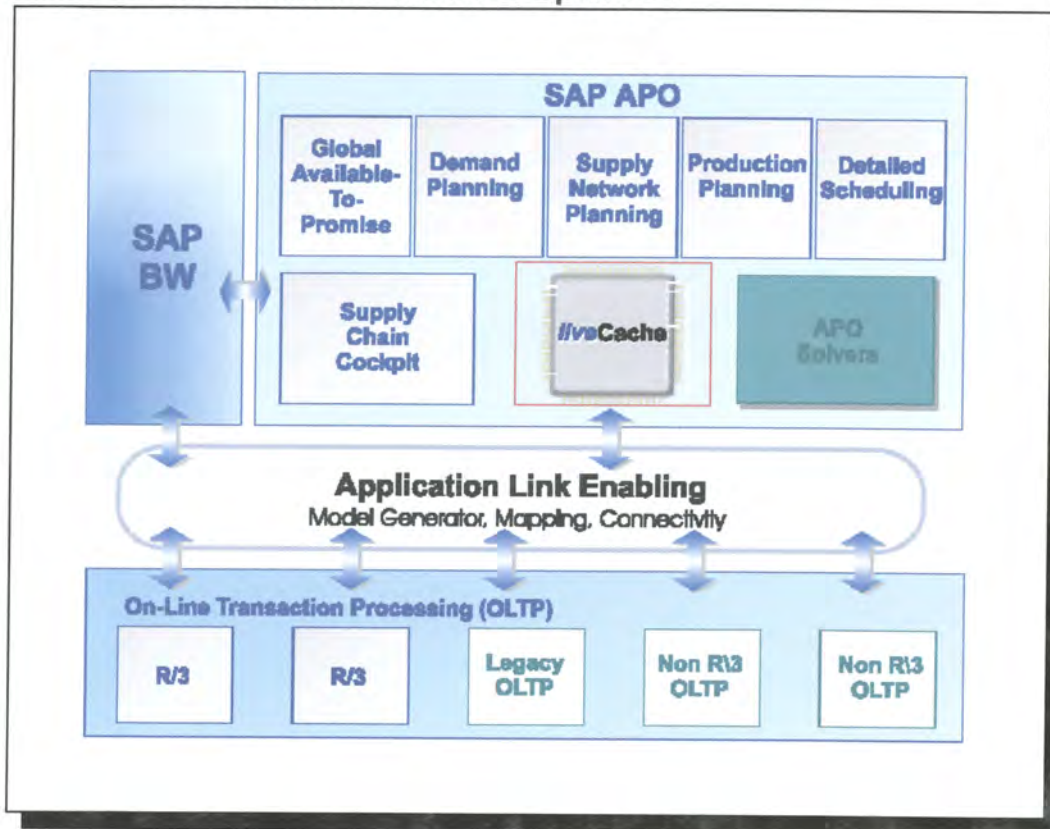
5.5.3.3 Conclusion of SAP's Supply Chain Solution

SAP is still in the beginning stages of Supply Chain Management but they are quickly catching up. (Refer to the Gartner Group's Magic Quadrant Update on Supply Chain Management.)

SAP APO is a new generation of advanced planning, optimisation and scheduling software that provide clients with a solution that will enable close interaction and synchronised planning between all the participants within the supply chain and therefore increasing competitiveness and enhancing customer service.

5.5.4 BAAN

5.5.4.1 About Baan

Baan Company is a leading provider of enterprise business software that enhances the processes common to businesses of all sizes and industries.

5.5.4.2 Baan's Solution for Supply Chain Management

Baan is also an ERP solution provider and emerged on the Supply Chain Market with the acquisition of Caps Logistics.

At this stage it is still a new beginning for Baan so the level of detail available is just about the different tools that can assist organisations in the optimisation of their supply chains.

The following figure is an outline of the existing Baan Solution for Supply Chain Management. (Refer to fig. 5.16.)

Figure 5.16. Baan's Supply Chain Planning Suite.
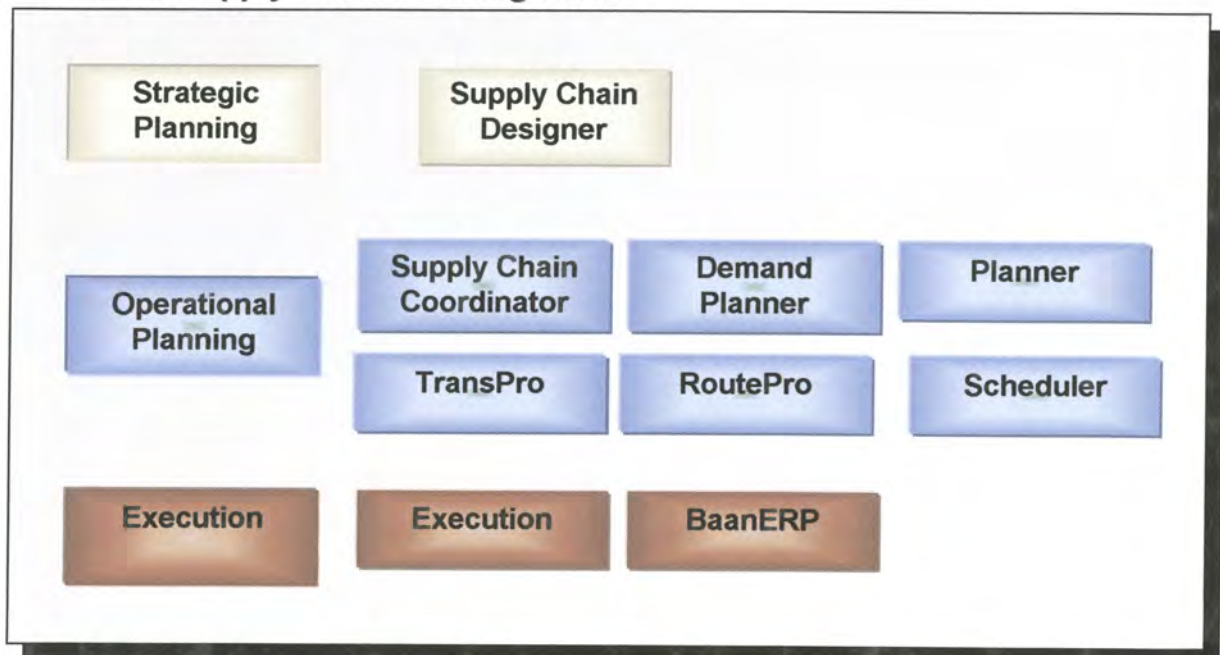
5.5.4.3 Conclusion of Baan's Supply Chain Solution

Baan is still in the beginning stages of Supply Chain Management but they are quickly catching up. According to the Gartner Group's Magic Quadrant update on Supply Chain Management Baan's execution ability increased with the acquisition of Caps Logistics, but they are still constrained because of their financial ability and integration issues.

5.6   Conclusion on Supply Chain Solutions

From the above mentioned paragraphs it is clear that the supply chain solution providers have tools in place with the ability to rapidly and simultaneously plan and schedule customer demand while considering materials and capacity constraints. They also provide the ability to increase revenues, improve customer service and cut costs by synchronised management of the complete supply chain.

Today there is a typical core methodology for each type of problem within the supply chain, which are better known as *"solver technologies"*. Examples of the solver technologies that provide the results or outputs of the advanced planning and scheduling tools are:

> Heuristics
> Constraint Management
> Linear Programming
> Mixed Integer Programming
> Network Programming

Over the years it was proved that companies which followed a classical approach to logistics was more vulnerable to change than the ones that didn't.

The only real method of demonstrating this vulnerability to poor management of change is through models in which the techniques of systems dynamics are applied to the industrial environment.

Companies generally increase their vulnerability themselves by inducing unreal business cycles and even further amplify them by localised protective policies. According to John B. Houlihan, A company's vulnerability can be considered in a dual context - the context of its external placement in a global supply chain and the context of its internal supply systems. In the case of the placement within the global supply chain, the further a company is from its end users of its products the greater are the demand swings.

The effects experienced by this company are the cumulative results of time delays, planning distortions and inventory shake-ups in preceding links of the chain.

Constant changes and variability, at ever-increasing rates of speed define businesses, faster and faster. The Supply Chain Solution tool's function is to find the interdependency of the system constraints that minimises cost and maximises profit.

Within these tools there exist a "Critical Path" and a "Shortest Path", that achieve the min/max idea while looking at the variability behind production allocation, expansion, consolidation and resource planning. But the question that organisations can ask now is whether there exists only one answer to the problems...? The only way that one can ensure one optimal answer is when the demand is constant and there is a zero percent change that it could change.

In real world systems it is virtually impossible to accurately predict future demand 100 percent of the time, and therefore variability and randomness cannot be excluded from a supply chain solution. Say for instance that demand is set to be a constant value and it ends up being too high, unnecessary costs would've been added to the system and the

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ever lurking possibility of higher inventory levels will leave one with no place to put the final product. On the other hand if demand ends up being too low, there will most certainly be dissatisfied customers and therefore stock prices will go down, earnings will be overestimated, and there can even be a loss in market share.

These systems although powerful are still working with static data and therefore do not take the randomness and dynamic variability of the entire supply chain in account. Experimentation is performed on the live business therefore increasing an organisation's vulnerability. With a Supply chain planning system in place it is relatively easy to change global inventory settings, but what to...?

Visibility is still limited in some key issues, which lead to companies treating the effect not the cause, wasting limited resources and therefore only achieving incremental improvements, and investing inappropriately.

 So when considering a supply chain solution the solution needs to include randomness and variability, which will provide the dynamic capabilities to the planning function....

The technology that is able to provide this randomness and variability is dynamic discrete-event simulation. Simulation (discrete event) can be defined as follows: *"creating a computer model of a real or proposed system and conducting experiments on the model to describe observed behaviour and/or predict future behaviour before investing any time or money. Because experimenting on a real system could be costly and/or impractical, simulation has become an extremely important tool for designing and analysing complex systems; it is a cost-effective way of testing proposed systems, plans, or policies before incurring the expense of prototypes, filed tests, or actual explanations.*[49]

Simulation however is not a *"solver technology"* it is a methodology to evaluate detailed solutions and alternatives in the supply chain.

5.7   Why Use Simulation?

It has been proven that those companies that do not want to change to improve – eventually did go out of business or lost some market share in some way. Simulation can certainly be an insurance policy in change management and can capture the randomness of systems. Meaning that simulation can model the corporate dynamics in the complete supply chain, from source to the user in throughout the Plan, Source, Make, and Deliver process. So how can simulation capture variability...?

Variability is mainly a function of the statistical nature of simulation tools. The output from a simulation model is not only statistical data but it also consists out of performance animation through which the system dynamics can be viewed. Simulation can reliably capture and predict the effect of multiple changes in corporate systems.
Simulation gives companies a visual presentation of their systems performance and provides the ability to *"test drive"* the system before it is implemented.

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[49] Ted Matwijec, VP International Operations, Systems Modeling Corporation. Using Simulation in Supply Chain Management, 1999

Supply Chain Management is difficult and the key to any supply chain performance is to understand the variability of the processes of the system. All the items mentioned above (refer to par. 5.6) clearly affect the efficiency with which a supply chain functions. Simulation can help companies to gain knowledge of the system dynamics by making better evaluations test-drive or perform what-if analyses of the supply chain in order to improve the performance. When conducting a simulation project it forces companies to re-evaluate their way of thinking, and their understanding of system operations and thus defines the system clearly and therefore minimises multiple (mis) interpretations as to the complexity and variability of the processes. It can be argued that by understanding the supply chain dynamics and variability behaviour, better performance can be expected from the supply chain (e.g. lower inventories, better customer service).

5.7.1 Examples of System randomness and variability

From the above paragraphs it is clear that there is much change in the business environment today. The Decision making process is becoming more and more complex due to the fast changing information that are put before management. The next couple of points highlight some of the problems that are critical in supply chain planning.

> *Manufacturing:*

- Stock out situations.
- Parts not arriving on time for subassembly operations.
- Machines breaking and disrupting production.
- Labour problems
- Machine set up/retooling.
- New product line introductions.

> *Warehousing/Distribution:*

- Automated material handling systems broken.
- Trucking/Shipping/Air/Rail systems deliver late.
- Labour problems.
- Spacing constraints.

> *Information Technology:*

- Changing business processes due to mergers/acquisitions
- Constantly changing business computer systems

> *Market Conditions:*

- Customer changing demand.
- Economic conditions.
- Currency conditions.

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5.7.2 What can Simulation do to improve Supply Chain performance?

When managing a supply chain there are a lot of areas to consider where simulation can be introduced to enhance the performance of the supply chain.

According to Ted Matwijec, VP International Operations, Systems Modeling Corporation one of the first view points to consider is a key question in supply chain management that ask the following: *"What are the tradeoffs to achieve high customer service levels vs. associated costs (and related profits) to provide this service?"* He further states that a high-level simulation model consisting out of many parameters in the various supply chain links with appropriate statistical data will provide valuable insight into this question.[50] By means of this simulation model companies will be able to "test-drive" their policies of distribution/transportation rules, manufacturing rates, inventory levels, etc. to see the effect on the complete system.

Secondly, the typical key components of a supply chain comprise of the following[51]:

> *Forecasting* – predicting the levels of activity that will effect product demand.
> *Advanced Planning* – sets production over time horizons of months and years using constraint models that treat both material and capacity.
> *Dynamic scheduling* – deals with the daily and weekly planning of production, take information from ERP, APS systems and generate a detail schedule for the shop floor.
> *Demand/Distribution planning* – determines optimal quantities of each product to make at each plant to be distributed to each warehouse so that manufacturing and distribution costs are minimised and customer demand is met.
> *Transportation management* – optimises assignments from plants to distribution centres then to retail centres.
> *Warehouse and Inventory management* – integrates work performed evaluating the stocking levels.

It is evident that in each one of these areas there exist an opportunity where a simulation model can be used to test different scenarios and consider multiple solutions quickly for purposes of resource capacity planning, bottleneck analysis, cycle-time reduction process (cost cutting), etc.

The final consideration is the one of benchmarking. When implementing supply chain management there exits a tendency to benchmark the system. So what better way to indicate performance of a supply chain than by building a benchmark simulation model and using the model operationally to compare the performance over a period of time...?

In essence simulation can certainly compliment and enhance the supply chain management department's ability to improve the planning and efficiency of the supply chain.

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[50] Ted Matwijec, VP International Operations, Systems Modeling Corporation.Using Simulation in Supply Chain Management, 1999
[51] Ted Matwijec, VP International Operations, Systems Modeling Corporation.Using Simulation in Supply Chain Management,1999

5.8   Strategy for Supply Chain Solution

The following strategy as outlined in figure 5.16 will be followed to develop a generic simulation solution for supply chain management.

Figure 5.16. Strategy for Supply Chain Simulation Solution
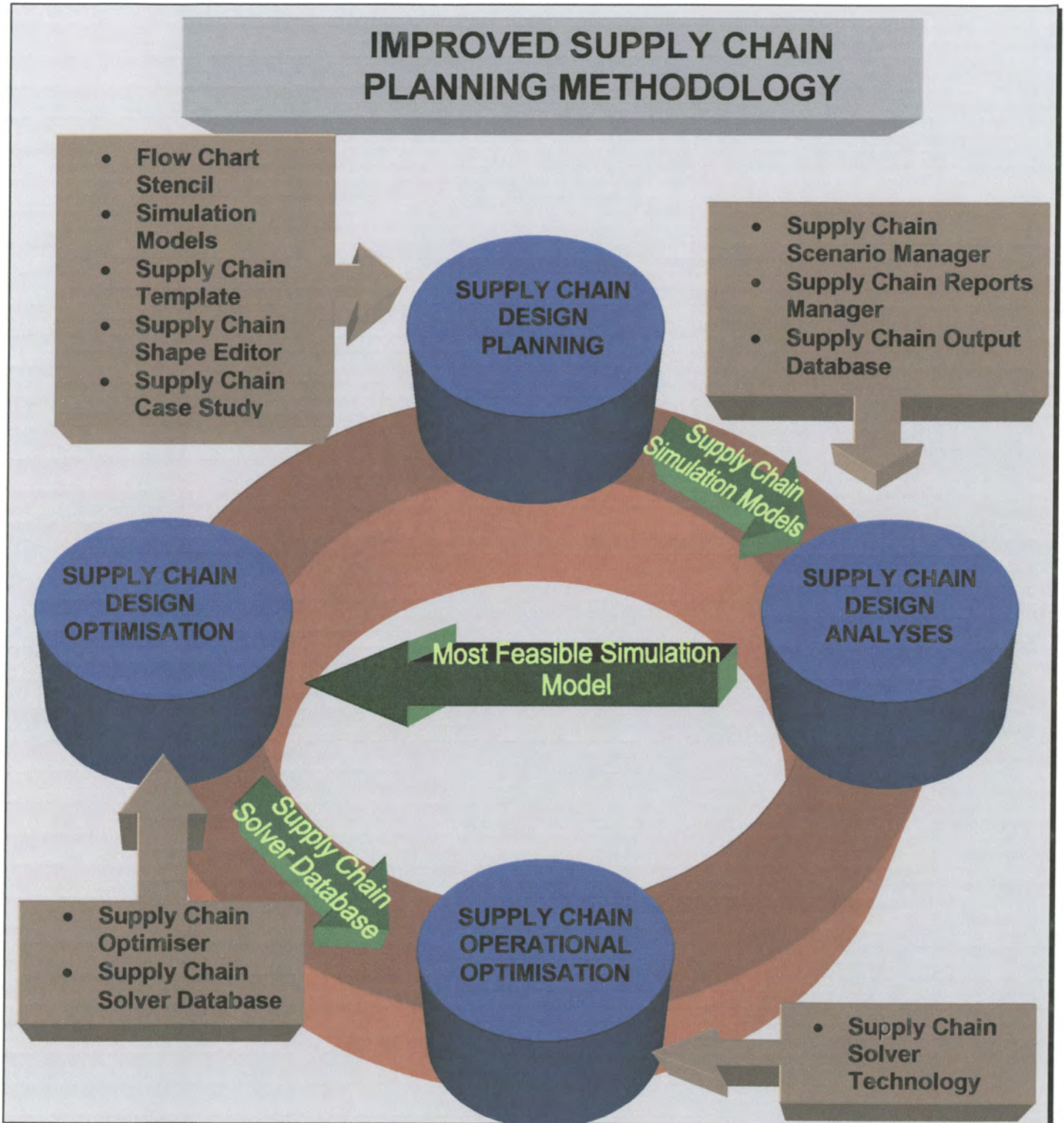
This strategy is only a high level overview and will be discussed in detail within phase three. In phase three the focus point will be to establish methods and techniques for supply chain management and simulation.

6 Phase 3: Establish methods and techniques for Supply Chain Management and Simulation.

6.1 Outlined Introduction of phase three.

The improved supply chain planning methodology lets organisations bring the power of modelling and simulation to improve the initial supply chain performance.

This methodology will allow supply chain analysts to compare current supply chains with an unlimited realm of possible future configurations.... and without disrupting the initial day-to-day operations of an actual supply chain. The methodology is designed to predict the supply chain performance in terms of **throughput, tardiness, utilisation, profitability, and other key performance indicators...**

Supply Chain analyst can now quickly evaluate the impact of proposed changes, such as **adding additional buffers, increasing or decreasing inventory, changing the product mix, or incorporating supply chain policies/strategies...** Another advantage of using this methodology is that it will help to remove the initial **"noise"** and provide a more accurate input to the supply chain solver technology.

All the information regarding the supply chain is stored within a central supply chain database. This database makes it possible to directly share supply chain data between different supply chain solver technologies. For example you can design a supply chain by using the supply chain template and export the data to the supply chain database and then use the data to interface with other supply chain technologies.

The methodology will further help a supply chain analyst to understand how to make fundamental changes to a supply chain in order to improve your input accuracy to the supply chain solver technology over the long term. In the following chapter it will be illustrated that this supply chain methodology can also be used to help with short-term tactical questions, such as predicting the impact of change in the product supply and demand mix. By adding this methodology to an organisation's supply chain planning toolbox more accurate decisions can be achieved both on the short term and long term for improving the supply chain performance.

In this phase the appropriate supply chain solution is mapped to the appropriate simulation solution.

During this phase different simulation solutions will also be evaluated.

The framework and methodology of the supply chain planning methodology will be shaped according to the supply chain and simulation solutions.

Different links between the solutions will also be investigated.

Figure 6.1. Outline of Phase Three.
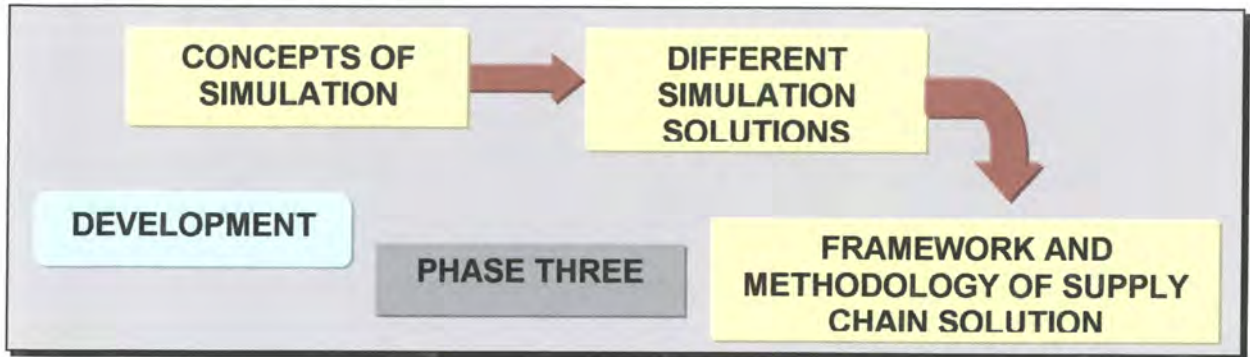
6.2 Concepts of Simulation

As previously defined in paragraph 5.5. Simulation (discrete event) can be described as follows:

"creating a computer model of a real or proposed system and conducting experiments on the model to describe observed behaviour and/or predict future behaviour before investing any time or money. Because experimenting on a real system could be costly and/or impractical, simulation has become an extremely important tool for designing and analysing complex systems; it is a cost-effective way of testing proposed systems, plans, or policies before incurring the expense of prototypes, filed tests, or actual explanations."[52]

Simulation is often used to study fairly simple systems, but the real power of this method can only be realised and appreciated when analysing complex systems.

Many analysts will argue that simulation is not the only tool that can be used to evaluate this system, but why is it frequently the method of choice...?

The answer to this is that simulation allows the analyst to represent the system faithfully and to the finest detail, thus capturing the complexity of the system with the added ability of what-if analysis into one model. Other systems on the other hand may require stronger simplifying assumptions about the system to enable analysis, therefore questioning the validity of the model.

Simulation models can be classified in a lot of different ways, but the most useful way is along the following three dimensions:

➤ Static vs. Dynamic:

Within Static models time is of no importance while in a dynamic model it is extremely important. Almost all the operational models are dynamic.

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[52] Ted Matwijec, VP International Operations, Systems Modeling Corporation. Using Simulation in Supply Chain Management, 1999.

> ## Continuous vs. Discrete

Continuous models are defined as continuous because the state of the system can change continuously over time; an example would be the level of a lake as water flows in and out, and as precipitation and evaporation occur. In discrete models on the other hand, change can occur only at separated points in time, such as a manufacturing systems with parts arriving and leaving at specific times, machines going down and coming back up at specific times, and breaks for workers. A system can consist out of elements with continuous-, and discrete change within the same model and can then be referred to as mixed continuous-discrete models; for example a refinery with continuously changing pressure inside vessels and shutdowns which occur at specific points in time.

> ## Deterministic vs. Stochastic

Deterministic models are models that have no random input; an operation with fixed service times would be a good example. Stochastic models operate on random inputs – like a bank with randomly arriving customers in a bank that require varying service times. In a simulation model there can be both deterministic and stochastic data inputs.

6.2.1 Deciding on how to carry out the Simulation.

When it is decided to simulate it is important to know what the different methods and techniques of simulations are. In this section the focus will be on specific options for running a simulation as well typical simulation software.

> ## Simulating by Hand

The following example is an example of an experiment that was done in the 17th century by a person named George Louis Leclerq (who was later referred to as Le Compte de Buffon). This experiment is an early example of simulation and is better known as the Buffon Needle Problem. If you toss a needle of length l onto a table painted with parallel lines spaced d apart (d must be $\geq l$), it turns out that the needle will cross a line with probability $p = 2l/(\pi d)$.[53] So figure 18.2 represents a simulation experiment to explanation to estimate.

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[53] W. David Kelton, et al, Simulation with Arena 1998.

Figure 6.2. The Buffon Needle Problem[54]

Get the needle and paint the lines on the table. →	**Decide how many times _n_ you're willing to toss the needle.** →	**Set the counter to 0.**

Toss the needle "randomly" onto the table.

Do these steps _n_ times.

If it crosses one of the lines, add 1 to the counter. (If it doesn't cross a line, leave the counter alone.)

Provided that $\hat{p} > 0$, estimate p by $\dfrac{2l}{\hat{p}d}$ ←

Compute the proportion $\hat{p}$ times the needle crossed a line:

$$\hat{p} = \frac{\text{final value of the counter}}{n}$$

The purpose of this experiment is to estimate the value of π, the estimated value in the end would not be exactly right and there will be an error margin associated with it. The ultimate goal is to know how large the error is, and to reduce this error by making more tosses with the needle. The smaller the error is likely to be the better the estimated value of π. One can continue this experiment by tossing the needle until the margin of error is small enough to make a good estimate instead of deciding on the number _n_ of tosses beforehand.

> Programming in General-Purpose Languages

According to W.D. Kelton analysts began writing computer programs with general-purpose procedural languages like FORTRAN to do simulations of more complicated systems with the appearance of digital computers in the 1950's and 1960's.

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[54] W. David Kelton, et al, Simulation with Arena 1998.

This approach provided the analyst with customisation and flexibility, but it was also painfully tedious and error-prone since models had to be coded almost from scratch every time.

> ➤ Simulation Languages

Analysts started to develop special-purpose simulation languages like GPSS, SIMSCRIPT, SLAM and SIMAN, which provided a much better framework for their typical simulations. And, in order to understand any one of these languages a lot of time had to be spent on learning the features and functions, and it all depended on the user interface provided.

6.3 Role Players in the Discrete Event Simulation World

Currently there are as many as 30 different Software Companies with products based on discrete event simulation technology sold into a wide variety of different industries. Some of the industries are listed below:

- ➤ Automotive
- ➤ Electronics
- ➤ Government
- ➤ Aerospace
- ➤ Machinery
- ➤ Food and Beverage
- ➤ Pharmaceuticals
- ➤ Chemicals
- ➤ Banking and Finance

The traditional hotbed of simulation software and services activity has been in manufacturing applications. Since most of the vendors evolved to serve the manufacturing market, competition in the manufacturing space is extremely intense with a large number of competitors with very little feature differentiation vying with each other to win business.

In recent years simulation solutions have been widely accepted and experienced rapid growth in markets associated with delivering service - either directly to customers, or to businesses. (Health care, business processes, supply chain/logistics systems, and call centers).

According to Vivek Bapat the Product Manager of Rockwell Software's Arena Simulation Suite of products, these new emerging markets have been the launching pad for many new entrants thereby introducing new competition to the older players. Some of the newer entrants have a technology advantage and consequently are faster and nimbler in reacting to market requirements. Both long-term vendors, as well as newer entrants have developed viable products for new and emerging markets.

According to a 1998 Automation Research Corporation (ARC) report on the Global Outlook for Market Analysis and Forecast for Discrete Event Simulation Product, the cumulative average growth rate (CAGR) for total revenues (software and services) for simulation applications is approximately 14 % in North America (58% of the total market

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space). Similarly, the European market, the second largest market (29% of total market space) for simulation products will grow at a rate of 14 %. While the credibility of this report is debatable, it is the only independent source that provides information on the market.

The simulation software marketplace is characterized by a large number of competitors, offering a wide variety of products at significantly different prices ranging from $500 to $40,000. Windows has become the dominant platform of choice for most simulation developers accounting for more than 80 % of units sold. This trend is expected to continue over the next few years.

The competitive map shows the position of some of the leading vendors in the current simulation market space.

Figure 6.3. Discrete Event Simulation Competitive Map
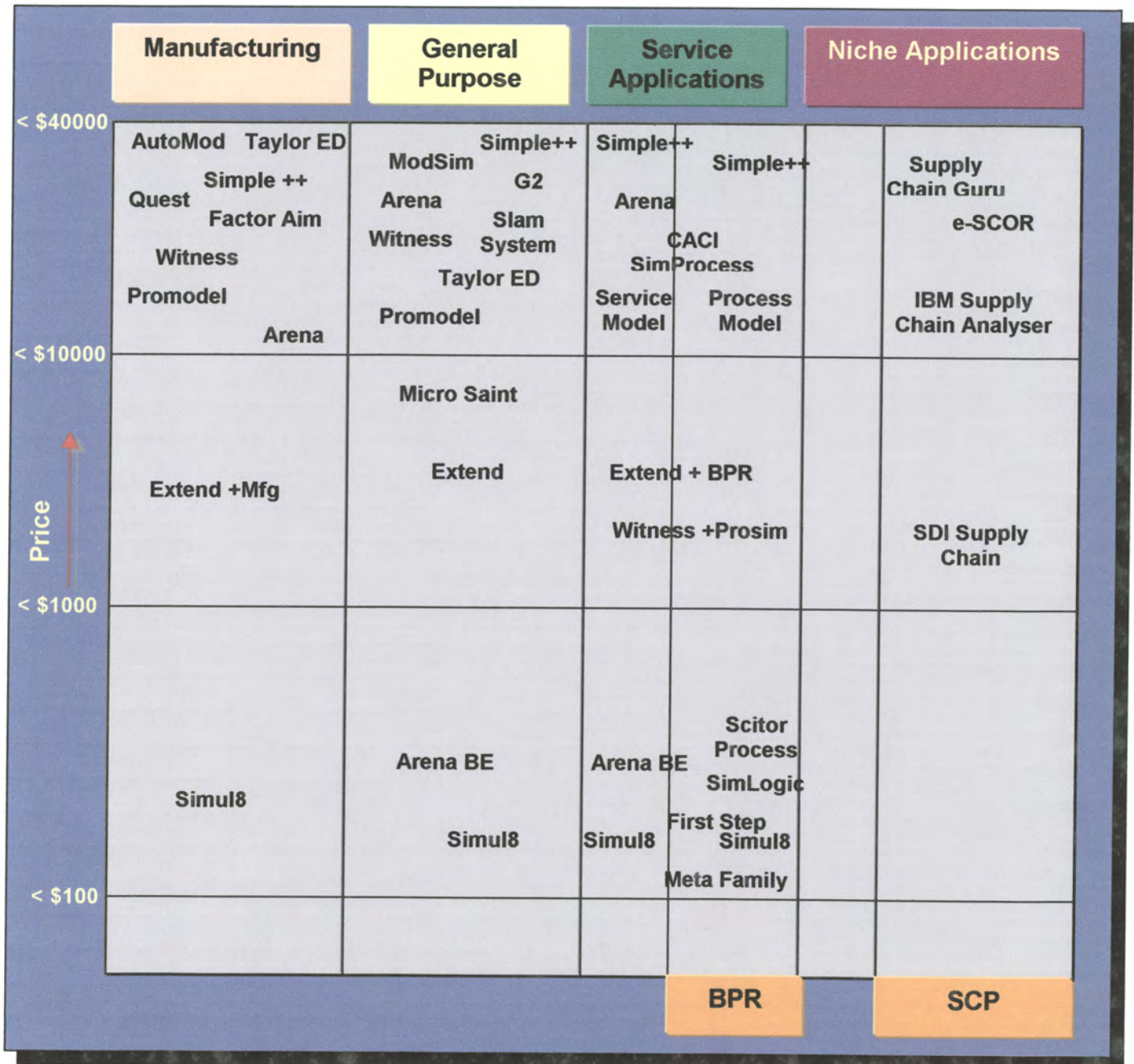
Many of the products available today, are technically sound and have adequate features required for typical modelling problems. Given the current depth of programming technology, and the knowledge and skill required to make product enhancements, it is becoming increasingly difficult for vendors, especially in the general purpose modelling area to differentiate on the basis of "feature-functionality", in contrast to conditions a few years ago.

According to recent surveys done by AMR Research The SCM market will pick up this year after having slowed down the past two, having only experienced 20% revenue growth in 1999. The market will grow 42% in 2000 to $4.5B[55].

All of this bodes very well for simulation technology in the supply chain market. Until now, most of the buzz around supply chain planning has been about "optimisation" technologies. The inherent weakness in these analysis methods is that they fail to include randomness and variability in their methodology. Although, this major weakness in analysis has been identified by a very small percentage of the market, it is a gap that can be widely exploited. Some major SCP and SCE players have announced partnerships with simulation vendors in some niche markets (I2 –Auto Simulations in the Wafer Fabrication and Semi Conductor Market), but in general most of the significant vendors SCP vendors have held simulation vendors at bay.

There are only a few competitive products in this space from the simulation perspective. E-SCOR, and Supply Chain Guru are two players at the higher end of the market. The market for simulation-based tools in this area is up for grabs since both these products are fairly new and not yet proven. The low-end space is wide open.

6.4 Evaluation of Simulation Solutions

In this section the focus will be on three of the most prominent simulation software packages in South Africa available today. The names of the packages are:

- Arena ® , developed by Systems Modeling in the United States
- Simple++ , developed by AESOP in Germany
- G2 , developed by Gensym.

Rockwell Automation, a business of Rockwell (NYSE:ROK), has acquired the assets of Systems Modeling Corp. in April 2000. The transaction gives customers additional flexibility in integrating information throughout the enterprise and provides additional products and expertise for the Rockwell Automation Manufacturing Business Ware initiative.

6.4.1 Overview of Arena®

The following explanation is an abstract of the following article: The Arena Product Family: Enterprise Modeling Solutions, by Vivek Bapat, Glenn Drake and Deborah Sedowski of Systems Modeling. *The Proceedings of the 1998 Winter Simulation Conference*

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[55] Source AMR research, 1999

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The Arena product suite (Figure 6.4) is designed for use throughout an enterprise, from strategic business decisions, such as locating capacity in a supply chain planning initiative, down to operational planning improvements, such as establishing production line operating rates. All Arena products share a common software foundation so that integrated organizations can establish a common methodology using a scaleable tool, leveraging product knowledge throughout diverse business entities.

Figure 6.4. Arena Product Suite
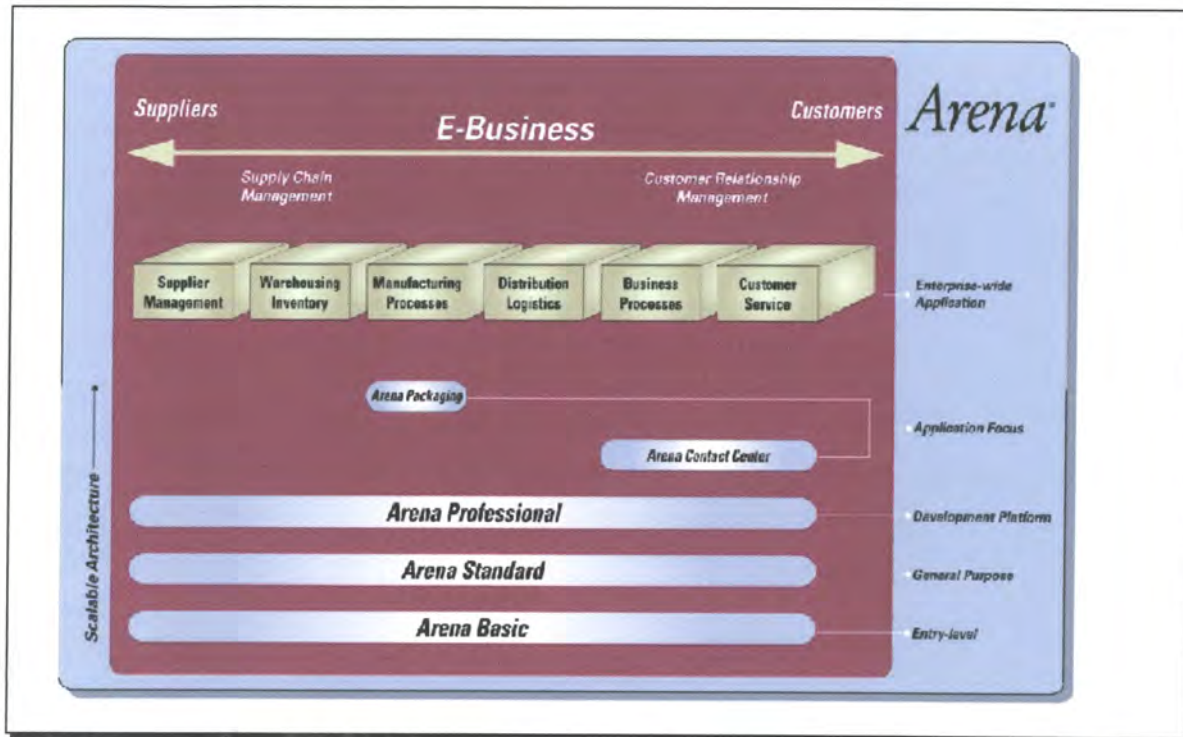
The Arena® product offerings begin with the Basic Edition (Arena BE), which is targeted both at modelling business processes and at simulating other systems (e.g., manufacturing, service) in support of high-level analysis needs. For more detailed models of discrete and continuous systems, the Arena Standard Edition (Arena SE) provides complete modelling flexibility, enabling analysts to capture the dynamics of a system at any required level of precision. The Arena Professional Edition (Arena PE) enhances Arena SE with the capability to craft custom simulation objects that mirror components of the real system, including terminology, process logic, data, performance metrics, and animation.

Arena® is designed in such a way that it is easy to learn and use and it also provides robust modelling and integration capabilities. Arena® is fully compatible with Microsoft® Windows 95/NT® and Microsoft® Office 97, and this gives new users a familiar and inviting interface. With Arena's robust modelling constructs analyst can build complex and detailed systems with confidence. Arena® also has an extended ability to integrate with other technologies, such as databases, drawing/modelling products, or spreadsheets. One of the newest additions to the Arena® products is the ActiveX® and Visual Basic® for Applications (VBA), Microsoft's key technology backbone for desktop application integration. These additions enables Arena® to utilise existing enterprise models and data hosted in applications such as Microsoft Office, Visio®, Oracle®, etc.

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After an overview of the Arena® product family the next section will describe the detail software architecture as well as the role and value of using Arena®.

Arena products utilise a core software engine (Figure 6.5) that is designed with the following objectives:

- Ease-of-use and rapid mastery.
- Power for complex system modelling.
- Modelling objects that closely fit the target systems.
- Built-in integration with leading applications.
- Open architecture to leverage corporate information and support custom applications.

Figure 6.5. Arena Software Engine.

Higher

User-Created Templates
Commonly used constructs.
Company-specific processes.
Company-specific templates etc.

Application Solution Templates
Arena Contact Center Edition.
Arena Packaging Edition.
Arena Basic Edition

Vertical Solutions

Level of Modeling.

Basic Process Panel
Basic modeling constructs that can be used in Arena Business-, Standard-, Professional edition.

Advanced Process Panel
Access too more detailed modeling for greater flexibility.

Advanced Transfer Panel
Access to more detailed modeling for the physical movement of entities.

Blocks, Elements Panels
All the flexibility of the SIMAN Simulation language.

User-Written Visual Basic, C/C++, FORTRAN Code
The ultimate in flexibility C/C++ and FORTRAN requires compiler.

Lower

Arena Template

SIMAN Template

Arena Standard Edition

Arena Professional Edition

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6.4.2 Overview of Simple++

The following explanation is an abstract of the information available on the World Wide Web[56]. SIMPLE++ provides a set of tools to design, simulate, visualize and optimise production systems and processes. The software helps you to develop optimal systems and processes for different levels of engineering: global production network, local plants, lines, and shops. It is a tool, which is built around an object-orientated environment that uses a lot of programming.

SIMPLE++'s hierarchical and scalable enterprise models and simulation capabilities enable you to evaluate different scenarios of global production networks and make fast and reliable decisions on relocation or closure of a plants and warehouses. Thus, SIMPLE++ supports supply chain planning of global production networks.

One level below, SIMPLE++ enables you to optimise the layout, capacity and performance of a single plant. The software's object-oriented technology enables you to create well-structured hierarchical plant models and re-usable line objects taking into account the external and internal supply chain, production resources and all related production and business processes.

Further down the hierarchical, simultaneous engineering process, SIMPLE++ supports the optimisation of production lines. As a result of simulation, charts and graphs help you to analyse the utilization of buffers, machines, containers, transportation systems and workers, to identify bottlenecks. By removing bottlenecks and harmonizing the utilization of resources, you will get flexibly designed and high performance lines and shops.

Some of Simple++ functionalities are as follows:

- Hierarchical and scalable factory model.
- Application Object Libraries for modelling assembly lines, body-in-white shops, paint shops, and job shops.
- Re-use of objects (Application Objects) for designing lines, robot cells, and assembly stations, thereby supporting standardisation of systems and manufacturing processes.
- Object-oriented user environment to efficiently build, update and maintain models in an iterative engineering process.
- Built-in Dialog Manager to design and customize easy-to-use and easy-to-learn user interfaces
- Multiple visualisation facilities to meet different user requirements: Model Browser, 2D Schematic, 2D/3D CAD, and true 3D. All are fully integrated to provide animation online to simulation.
- Real time communication and integration to CAD, ERP, and database systems.

Simple++ developed a strategic business evaluator for the complete supply chain and can be used to investigate different scenarios of possible future structures, facility portfolios and situations. This evaluator links directly with other data systems in order to extract current data to effectively evaluate possibilities and plans.

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[56] www.technomatix.com

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The Strategic Business Evaluator is developed to assist an analyst with the following:

- Evaluation of production, transportation and warehousing options.
- Evaluation of Make or Buy as well as Site Shutdown or Opening Ideas.
- Evaluation of the optimisation of resource utilisation, performance and inventory control.

The evaluator will therefore assist the analyst to optimise the current allocation of resources based on fulfilling customer demand.

6.4.3 Overview of G2

The following explanation is an abstract of the information available on the World Wide Web[57]. G2 is a comprehensive, object-oriented environment for building and deploying mission-critical, intelligent applications that dramatically improve complex business operations.

G2's proven technology provides a competitive advantage by helping analyst to:

- Optimise operating efficiencies
- Improve asset and service availability
- Better manage complex, time-critical operations
- Build and deploy operations management applications dramatically faster
- Minimise the costs of maintaining operations management applications
- Preserve, enhance, and leverage operations knowledge

With G2, analysts can apply knowledge to operational data to reach conclusions, provide advice, and execute decisions - all in real time.

G2 is a knowledge-based system and enables developers to represent knowledge as objects, rules, methods, and procedures using graphics and structural natural language. This allows applications to be readily understood, tested, and modified.

G2 is a highly interactive and visual development environment that simplifies and speeds the prototyping, development, and on-line deployment of intelligent systems. The object-oriented environment of G2 is divided into different objects that are powerful and can intuitively represent the physical and abstract aspects of applications. These objects are organised in a hierarchical class structure, and G2 provides the flexibility of multiple inheritance so that an object inherits properties and behaviours from multiple object classes. Once an object - or class of objects - is defined, the work is immediately reusable. Any object or group of objects can be cloned repeatedly, and each cloned copy will inherit all the properties and behaviours of the original object. Objects, rules, and procedures can then be grouped into library modules that are shared by all G2 applications, allowing streamlined development of new applications.

G2's graphics represent much more than pictures - they represent the properties and behaviours of objects and the relationships among them. Developers can quickly model an application by graphically representing and connecting objects. These connections

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[57] www.gensym.com

can be dynamically created, modified, and deleted even while G2 is on line. Connected objects form powerful models that visually represent application processes - such as material flows, industrial processes, communication networks, transportation and logistics networks, information routings, and even logic flows.

G2 graphics also include built-in dialogs, graphs, charts, dials, tables, sliders, bitmaps, and meters to speed up the development of user interfaces.

Expert knowledge is expressed using G2 rules, which work in real time and can mimic the human ability to focus on specific problems while maintaining a general awareness. These rules capture an expert's knowledge of how to reason about and respond to a given set of conditions.

G2 rules reason about real-time data and histories for time-critical analysis and action. They can be event-driven (through forward chaining) to automatically respond whenever new data arrives. These rules can also be data-driven (through backward chaining) to automatically invoke other rules, procedures, or formulas. And G2 can automatically monitor situations by regularly invoking rules that scan for possible circumstances and then take actions when defined thresholds are reached.

G2's procedures work in real time and can be scheduled to the millisecond for non-stop execution. Procedures, rules, and models execute concurrently based on priorities. The G2 procedures can also be linked to object classes as methods to help developers effectively represent object behaviours. Wait states and parallel execution threads can be specified in any procedure.

As a result, organisations can build powerful real-time applications that are far more robust than those built with traditional programming tools. G2 has the ability to execute procedures that can link with other G2 applications throughout an enterprise or for creating interfaces to other real-time systems, databases, or applications.

G2 can also work efficiently and reliably in real time so that operational decisions and responses can be made quickly. G2 applications can process thousands of rules per second and concurrently execute rules, procedures, and models based on defined priorities. Variables are time-stamped for storing histories of data and events and for reasoning about behaviour over time.

For real-time execution in response to unexpected disruptions such as power failures, G2 saves snapshots of the status of a production application and "warm boots" to the latest saved condition.

6.5 Conclusion of Modern Simulation Tools

In order to determine a the best simulation solution for proposed supply chain planning methodology the following criteria were used to evaluate the three simulation solutions:

Figure 6.6 Evaluation Criteria for Discrete Event Simulation Software
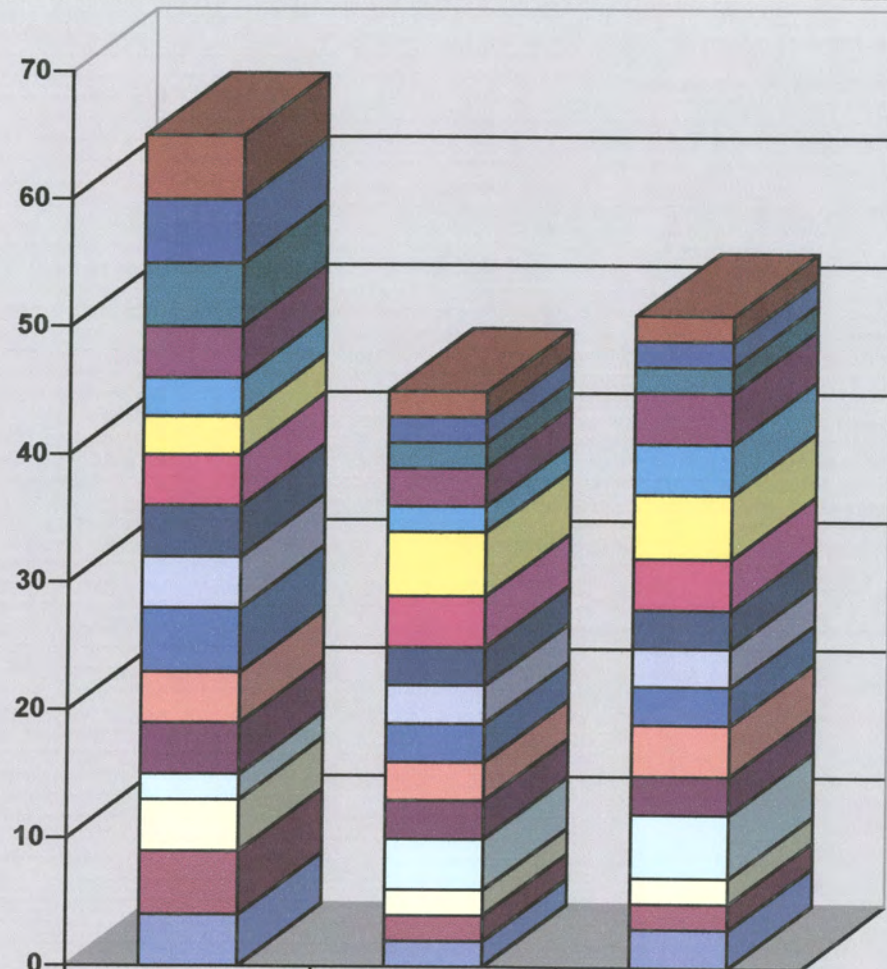
	ARENA	G2	SIMPLE ++
■ Visio Integration	5	2	2
■ Price	5	2	2
■ Technical Support	5	2	2
■ Reporting Capability	4	3	4
□ Animation	3	2	4
□ Level of Programming	3	5	5
■ Modeling Capability	4	4	4
■ Data Integration	4	3	3
□ Modeling Flexibility	4	3	3
■ Distribution	5	3	3
■ Business Reporting	4	3	4
■ Industry leading Technology	4	3	3
□ Scalability & Extensibility	2	4	5
□ Ease of Use - Model Validation	4	2	2
■ Ease of Use - Modeling Methodology	5	2	2
□ Execution Speed	4	2	3

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The three software packages were evaluated against the following factors on a scale of 1 to 5, were the higher the value the more capable the simulation solution. The evaluation criteria are as follows:

- Visio Integration
- Price
- Technical Support
- Reporting Capability
- Animation
- Level of Programming
- Modeling Capability
- Data Integration
- Modeling Flexibility
- Distribution
- Business Reporting
- Industry leading technology
- Scalability & Extensibility
- Ease of Use – Model Validation
- Ease of Use – Modeling Methodology
- Execution Speed

From the previous paragraphs it is quite clear that one will be able to model any type of situation or process with different levels of complexity. All of these packages are good packages, but one tend to stand out, that is the Arena® product for its easy to use flow chart concept. A low level of programming (building blocks) is needed and it is a look and feel environment that provides the user with a comfortable feeling when it is used. The other two packages do have their strong points but one still needs to do a lot of programming in certain natural computer languages such as C++ or visual basic.

It is very difficult to compare software packages (G2) with simulation ability with an actual simulation software package (Arena®). G2 is an expert system, which main purpose is to be used as a process control system, but it can also do a lot of other intelligent functions, but only by means of programming and it can take a lot of programming code to construct a simple model. Simple++ is also programming code, and it can also be a lot of work for a simple model, but once the objects are defined a model can be developed without a lot of effort.

Based on the points achieved on evaluation criteria and the current knowledge of the software a decision was made to use Arena as the simulation design tool for the new supply chain planning methodology. Overall Arena® seems to be suitable for various types of environments but still lack the ability to be fully object orientated. This factor was seen as an initial qualifier but the overall scorecard showed that Arena® passed with more than 70%.

6.6   Framework and Methodology of Supply Chain Solution

This methodology was developed around four corner stones:

➢ Supply Chain Design Planning
➢ Supply Chain Design Analyses
➢ Supply Chain Design Optimisation
➢ Supply Chain Operational Optimisation

The blue circle containers in figure 5.16 illustrate the cornerstones. A brown circle connects the cornerstones to symbolise the connectivity between them. The brown arrowhead boxes illustrate the core inputs and constructs of the cornerstones, while the green arrows illustrate the information link between the cornerstones. The following paragraphs will explain each cornerstone in detail.

6.6.1 Supply Chain Design Planning

The supply chain design-planning cornerstone is the first cornerstone in the methodology and this forms the foundation of the other cornerstones. In this phase the supply chain planner will design or map out the entire supply chain process. The following figure will highlight the various steps within the planning phase and will be followed by an explanation of the different steps.

Figure 6.7. Cornerstone One: Supply Chain Design Planning

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> Step 1: Supply Chain Flow Chart

The supply chain planner will first create a high level flowchart of the appropriate supply chain, by using a custom designed supply chain stencil within Visio® a flowchart package from Microsoft®. There are seven flowchart modules in the stencil:

- Batching
- Buffer
- Decision
- Location
- Operation
- Supply Plan
- Transportation

As soon as the supply chain planner has finished the supply chain flowchart, it can export the flowchart to Arena® by using the process simulation macro. The supply chain stencil only allows high-level process information and the detail process information must be changed or developed in Arena® with the supply chain template. Figure 6.8 illustrates an example flowchart of a supply chain process for a car manufacturer. Refer to Appendix A for explanation of flowchart modules.

Figure 6.8. Flowchart example of a Supply Chain Process
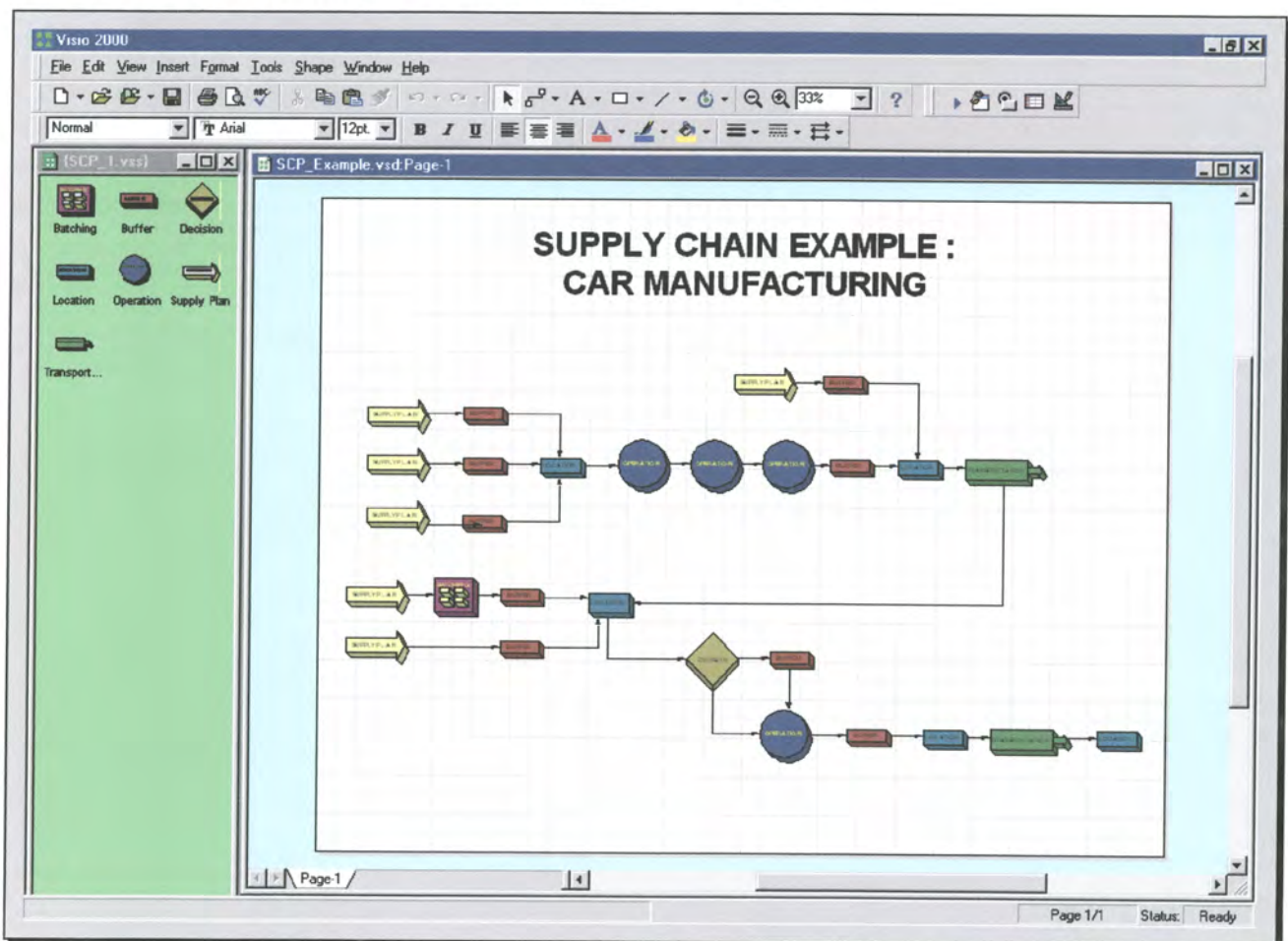
> ➤   <u>Step 2: Supply Chain Simulation Models</u>

The next step of the supply chain design-planning cornerstone is to develop the supply chain simulation model. By using a custom designed supply chain template a simulation model can be developed. This template was developed with the Arena® Professional Edition. If the flowchart was used to develop the initial supply chain process the process simulation macro will import the flowchart into the Arena® environment.

The supply chain planner can now start to configure the detailed supply chain simulation model by using the supply chain template. The template consist out of the following building modules:

Table 6.1. Supply Chain Template Modules

Batching	Items
Buffer	Location
Conveyor	Moving Vehicle
Customer	Operation
Decision	Resources
Demand Plan	Supply Chain Analyses
Distribution Paths	Supply Plan
Inventory Plan	Transportation

It is clear that there are more building modules available within the template than in the flowchart stencil. The reason for this is that the simulation environment is the heart of the planning process. The functionality's of the supply chain template helps the supply chain planner to configure a specific supply chain in as much detail as possible. The supply chain template and simulation model is not there to replace the supply chain solver technology it is there to aid in the initial design of the supply chain.

Once the supply chain planner is satisfied that the supply chain model is valid and rigid the Information link can be passed to the next cornerstone, the supply chain design analyses cornerstone. Refer to Appendix B for explanation of supply chain template modules.

6.6.2 Supply Chain Design Analyses

The supply chain design analyses cornerstone is the second cornerstone in the methodology. In this phase the supply chain planner will validate and test various scenarios of the supply chain process. Figure 6.9 illustrates the various steps within the analyses phase and will be followed by an explanation of the different steps.

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Figure 6.9. Cornerstone Two: Supply Chain Design Analyses
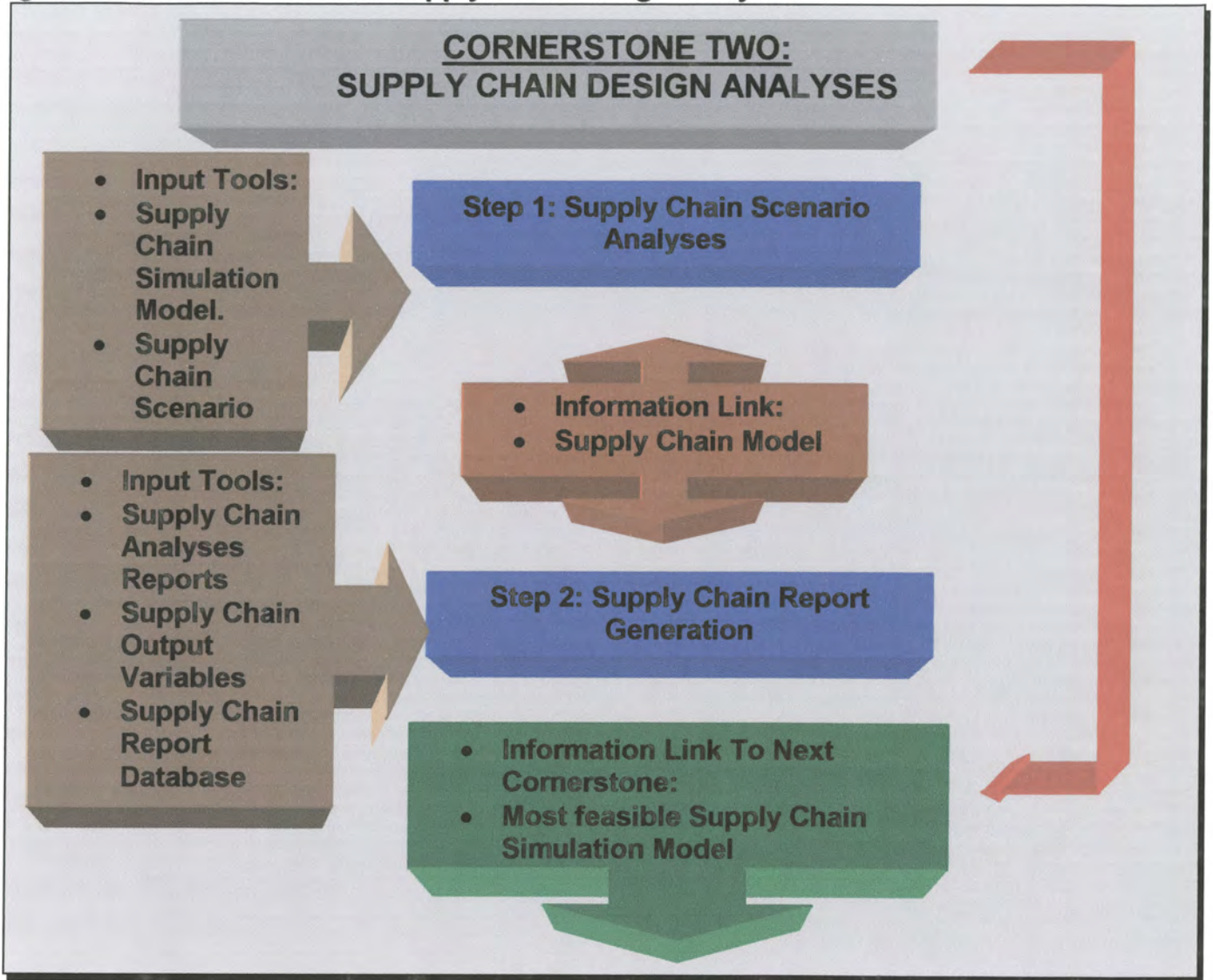
> ➢   Step 1: Supply Chain Scenario Analyses

In this phase the supply chain planner will start to evaluate the various scenarios. The process analyser of Arena® will be used to analyse the various scenarios. The process analyser uses a control/response approach in combination with a spreadsheet-style (or grid) interface; one can quickly set up your scenarios, focusing only on what's important, for easy viewing and comparison of alternatives. This allows decision-makers to easily set up and find what they are looking for- results.

The role of the process analyser is to allow for comparison of the outputs from validated models based on different model inputs. Possible inputs, called controls, are variable values and resource capacity. The outputs, called responses, can be variables, or any type of Arena statistic (i.e., Dstats, Tallies, Counters, and Outputs).

The supply chain planner can also create various charts of the results, including 3-D charts.

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The process analyser has a feature that automatically identifies the scenarios that are statistically better than the others therefore allowing the supply chain planner to assess the results and draw conclusions this is a standard add-in function to Arena® Simulation Software.

➤ Step 2: Supply Chain Reports Generation

The supply chain planner needs to have customised reports in order to speed up the analyses phase and therefore Excel from Microsoft® is used as the supply chain reports generator. This generator will use the outputs of the Simulation Model and generate customised charts and tables. Figure 6.10 illustrates an example of an output chart. For more information on the supply chain reports generator refer to Appendix E.

Figure 6.10. Customised Output Chart from the Supply Chain Reports Generator
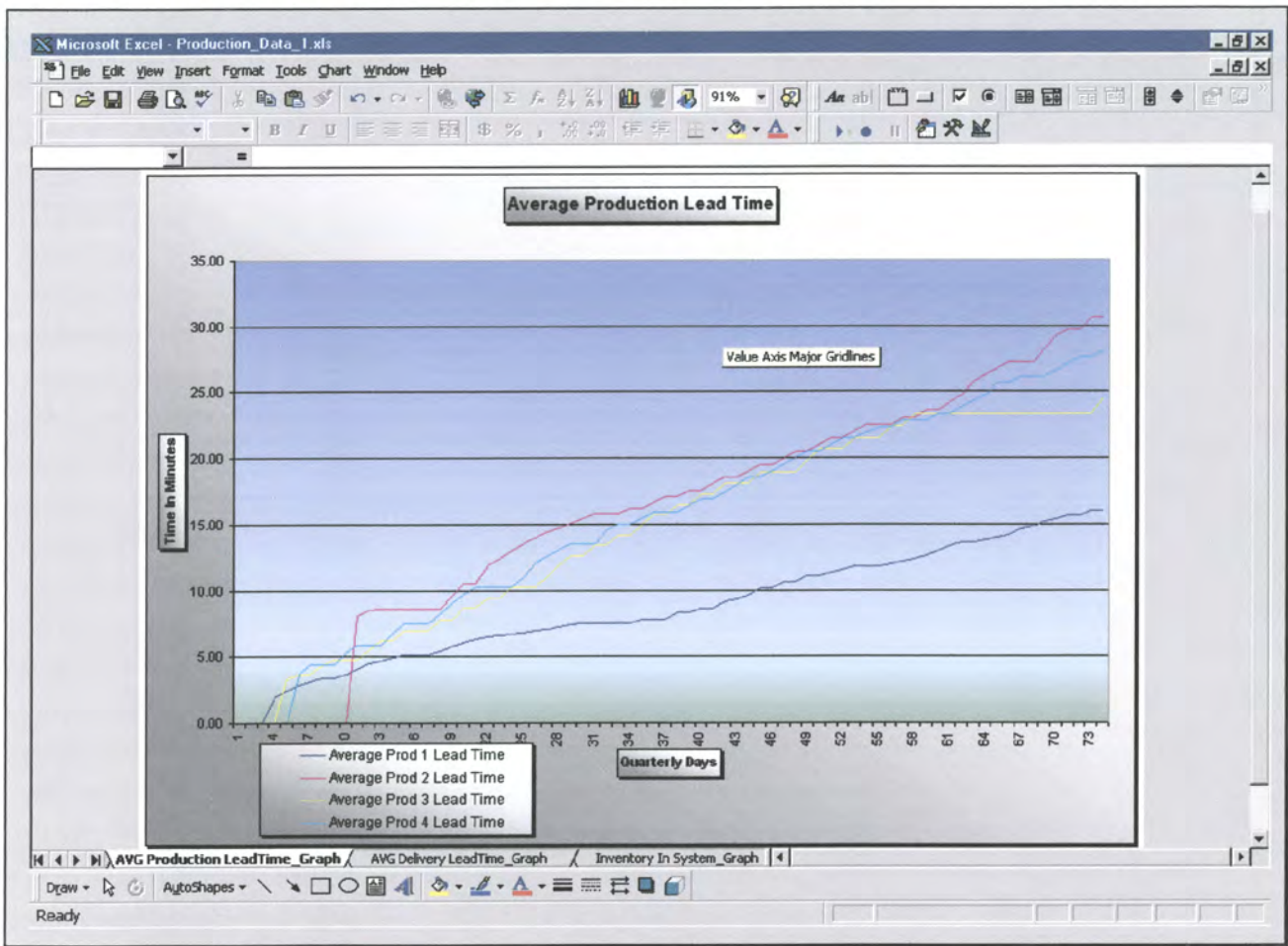
Once the supply chain planner is satisfied with the results the most feasible solution can be passed to the supply chain design optimisation cornerstone.

6.6.3 Supply Chain Design Optimisation

The supply chain design optimisation cornerstone is the third cornerstone in the methodology. In this phase the supply chain planner will optimise the most feasible supply chain simulation model by means of Optquest® for Arena®.

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Figure 6.11 illustrates the various steps within the optimisation phase and will be followed by an explanation of the different steps.

Figure 6.11. Cornerstone Three: Supply Chain Design Optimisation
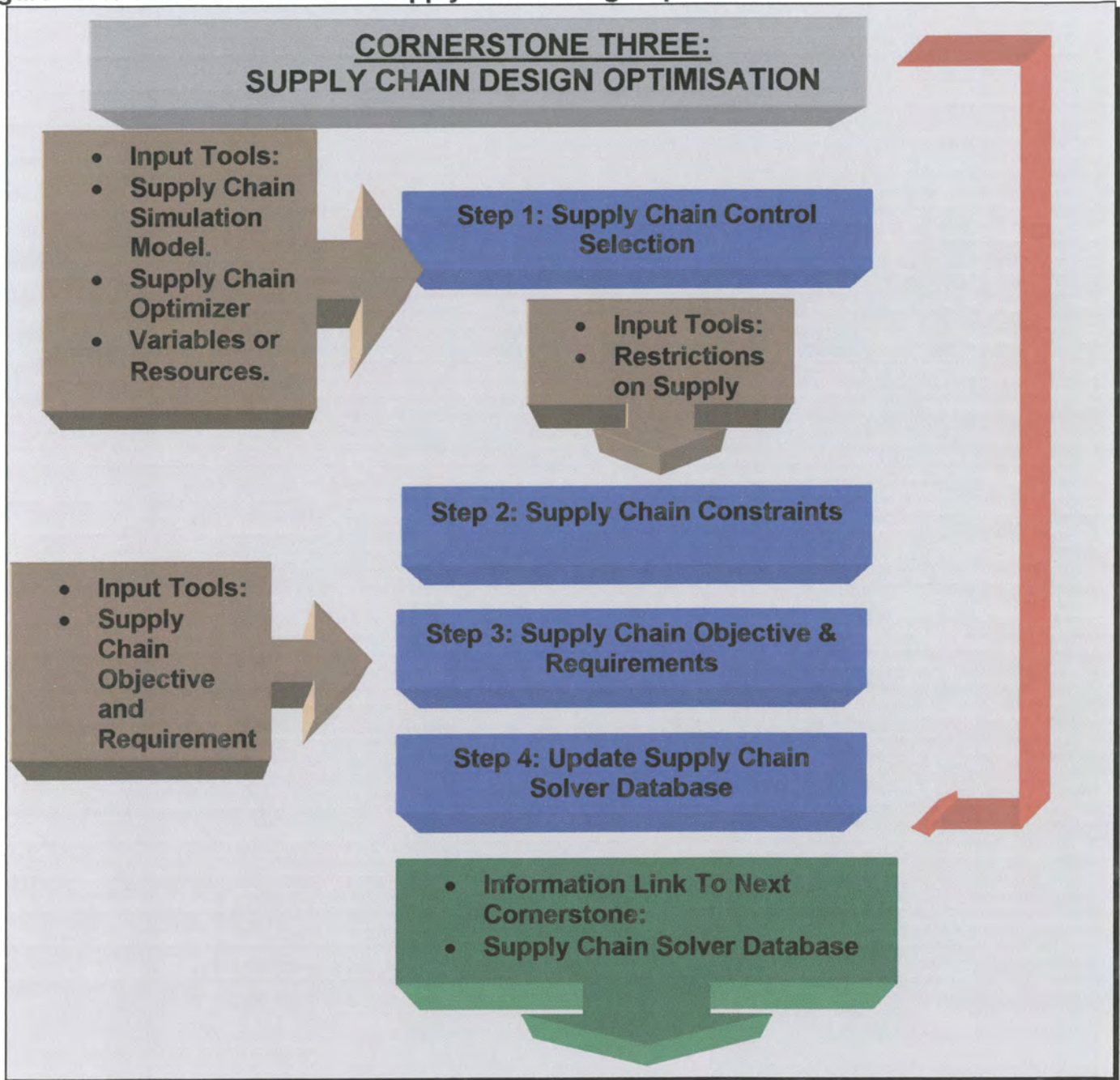
> ➢ Step 1: Supply Chain Control Selection

In this phase the supply chain planner will start to optimise the most feasible supply chain model. Optquest® for Arena® will be used for the optimisation.

In today's highly competitive global environment, supply chain planners are faced with many difficult decisions, such as allocating financial resources, building facilities, managing inventories, determining product mix strategies, and more. Modelling a supply chain problem by means of the supply chain template will tell the supply chain planner what performance measures can be expected by using a certain strategy.

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A strategy can be defined as a certain set of values for the controls. In other words a strategy includes a scenario and solution. Note that "solution" refers to the control values (inputs to the supply chain simulation model), not to the resulting values of the performance measures (responses, or outputs from the Supply Chain Simulation Model).

The controls can be variables or resources in the supply chain model. After the definition of the controls in the supply chain simulation model, a selection can be made of which controls to optimise in OptQuest®. The values of these controls will change with each simulation until OptQuest® finds values that yield the best objective. For some analyses, it might be better to fix the values of certain controls and optimise the rest.

> ## Step 2: Supply Chain Constraints

The next step is to define the supply chain constraints. These constraints restrict the controls by defining relationships among them. For example, if the total budget for scanners ($20,000 each) and printers ($10,000 each) is $50,000, you can define this as:

20000*scanners + 10000*printers <= 50000

Supply Chain constraints can narrow the search for the optimal solution, thus improving OptQuest's performance. Solutions that violate a constraint are constraint-infeasible; OptQuest® does not send them to Arena® for evaluation.

> ## Step 3: Supply Chain Objective Requirements

The next step is to define the supply chain objective and requirements. The following paragraphs explain the meaning of an objective and requirement.

An objective can be defined as a response in the Arena model that represents the model's objective function.

Requirements are restrictions on the values of responses. These differ from constraints, since constraints restrict controls. When an analyst defines a requirement, the analyst also needs to give it an upper bound, a lower bound, or both (a range). Like constraints, requirements must be satisfied for a solution to be considered feasible.

A feasible solution is one that satisfies all constraints and requirements. Each time OptQuest® generates a new set of values for the supply chain controls, it tests the solution for supply chain constraint feasibility. Only constraint-feasible solutions are sent to Arena® for evaluation. OptQuest® then uses the responses from Arena® to determine if an evaluated solution is requirement-feasible.

After solving an optimisation problem with OptQuest® the supply chain planner will run a sensitivity analysis to determine the robustness of the results. The sensitivity analysis is a report that assesses the sensitivity of the objective function value to changes in the values of the controls. It does this by compiling solutions that are within a specified percentage of the best solution and then calculating statistics for the control values of those solutions.
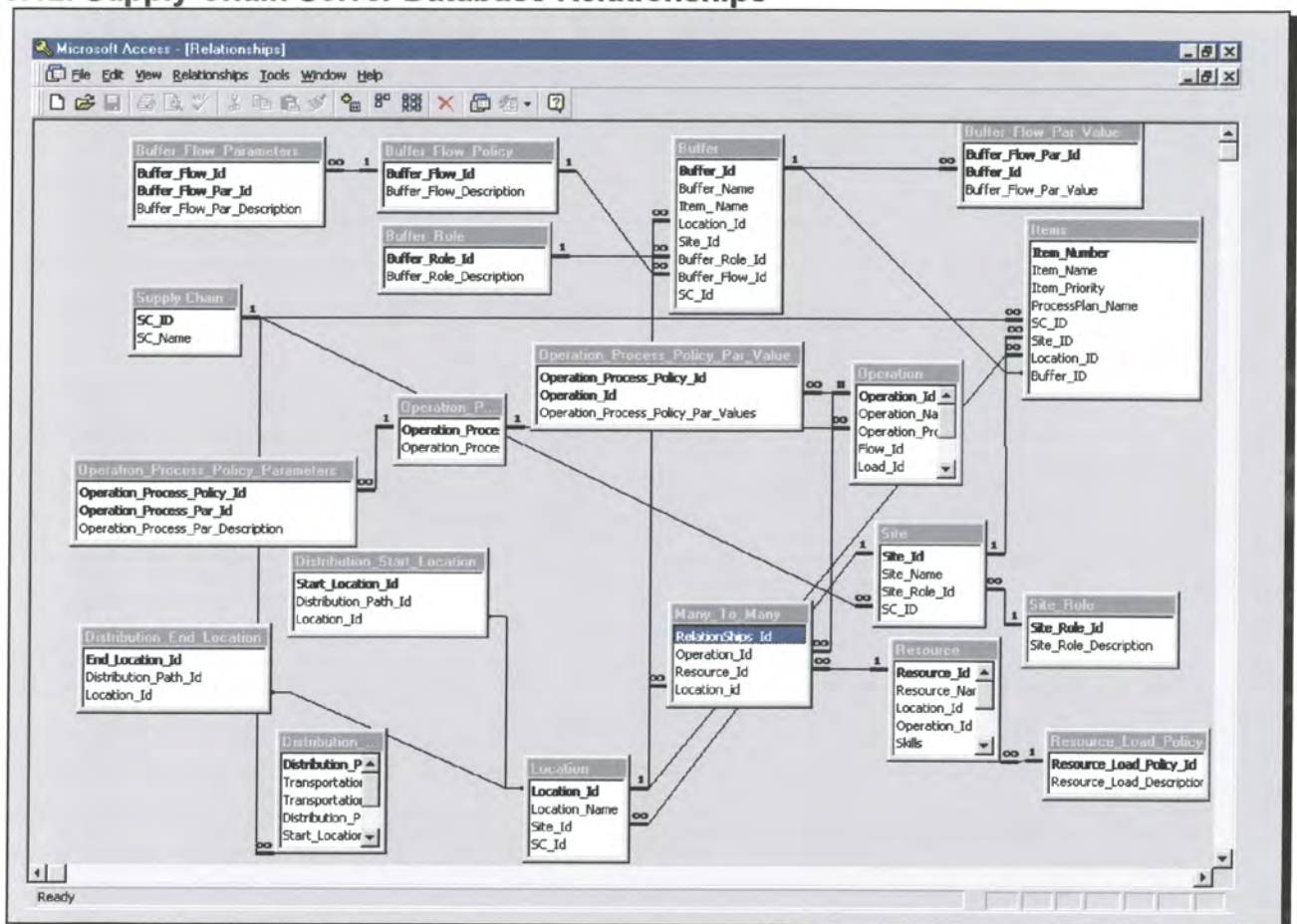
> ➤   Step 4: Update Supply Chain Solver Database

Once the supply chain planner is satisfied with the results of the optimised solution the results can be transferred to the supply chain solver database. The supply chain solver database will be used as the input for the next cornerstone supply chain operational optimisation.

6.6.4 Supply Chain Operational Optimisation

The supply chain operational optimisation cornerstone is the fourth cornerstone in the methodology. In this phase the supply chain planner will use the supply chain solver database as the input for the supply chain solver technology. Figure 6.10 illustrates the relationships between the various tables within the supply chain solver database.

Figure 6.12. Supply Chain Solver Database Relationships

The purpose of this database is to capture all the results of the optimised supply chain simulation solution. The results will then be used as the initial inputs in the supply chain solver technology. For example if the optimised supply chain simulation solution shows that the maximum capacity of a buffer is 5 units then this value will be used as the maximum capacity for the buffer in the solver technology database.

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7 *Phase Four: Apply Supply Chain Planning Methodology to a Case Study*

7.1 *Outlined Introduction of Phase Four.*

In order to experience real-life supply chain problems a case study has been done. This case study is about the automotive industry, which will include the ordering of parts assembly of vehicles, warehousing and distribution of vehicles. The focus of the case study is to illustrate how the new supply chain planning methodology can be applied.

This case study involves the design of a supply chain solution by using the new planning methodology. The following steps will be followed in order to design the supply chain of New Cars:

> ➤ Supply Chain Design Planning
> ➤ Supply Chain Design Analyses
> ➤ Supply Chain Design Optimization
> ➤ Supply Chain Operational Optimization

The first focus will be on the actual design of the supply chain process. After this the analyses and optimisation will follow.

Experiences and conclusions that are derived from this case study are presented in this chapter.

Figure 7.1. Outline of Phase Four.
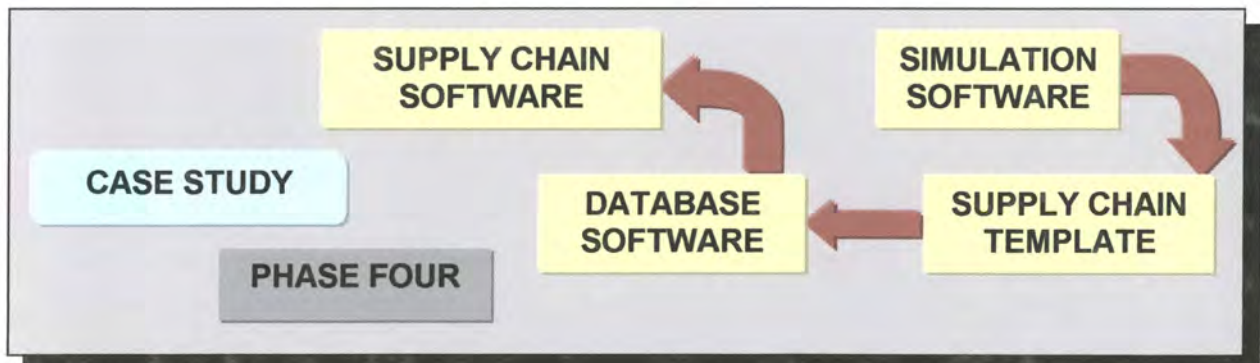
7.2 Case Study: Car Manufacturer

Figure 7.2. Schematic Overview of the Supply Chain: NewCars
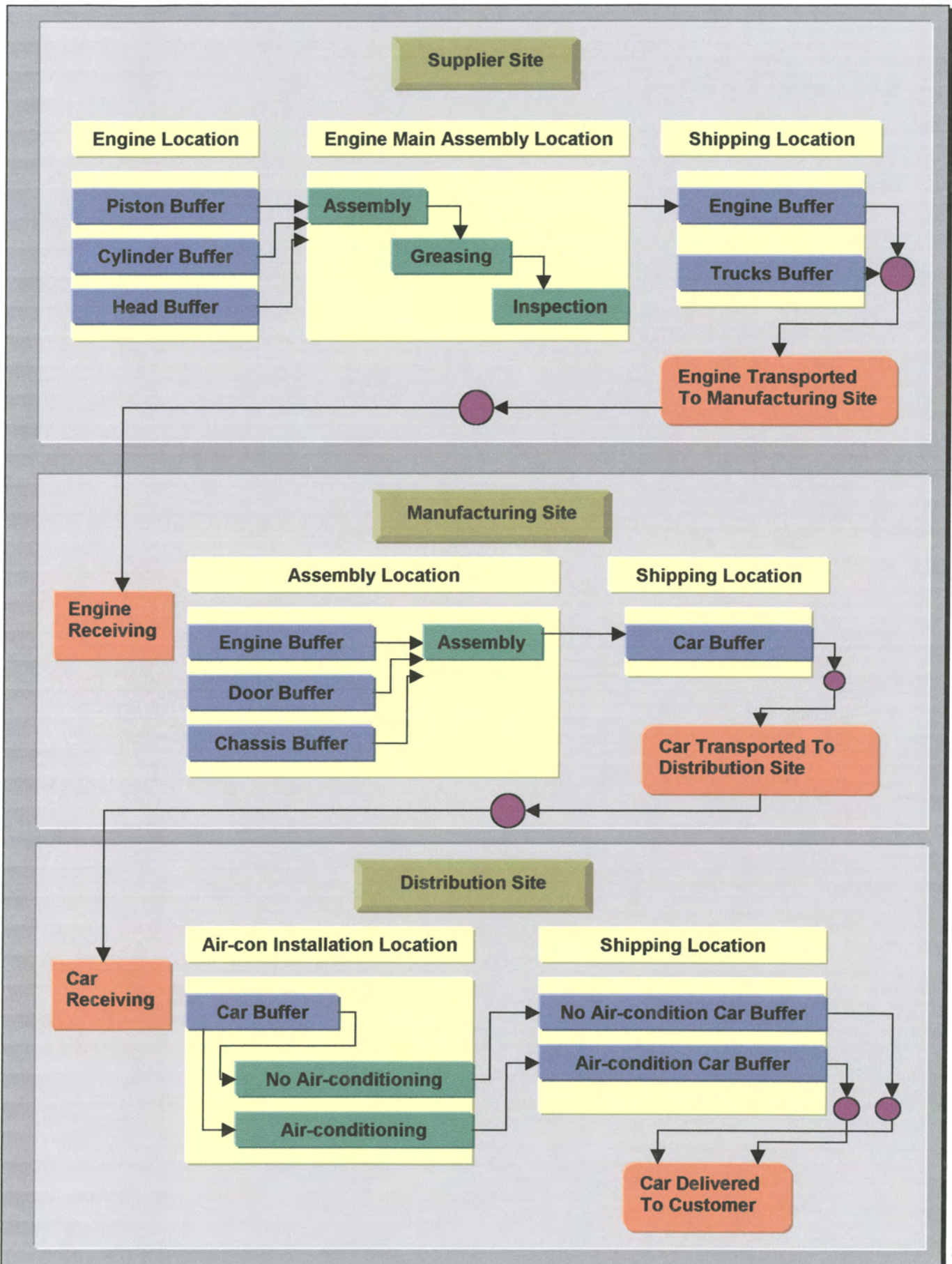
7.2.1 Background of New Cars

The car that NewCar manufactures is assembled in 30 minutes at an Assembly location by putting together a chassis, an engine and four doors.

It takes one day to set-up the Assembly operation and one assembler to perform the operation. The NewCar manufacturing site regards all of the items (chassis, engine, and doors) as raw material and their inventory is managed via a reorder point.

Upon completion, the finished car is taken to a delivery location where it is stored until it is time to ship to the distribution site. It takes one week to ship cars to the distribution site. No resource is needed for this operation.

The finished goods stocking point requires a minimum of 100 units on-hand but cannot exceed 200 units total. Additionally, the stocking point requires 7 days of cover. The NewCars Supply chain produces two types of cars: Non Air-conditioned and Air-conditioned. The NewCars manufacturing site however, only produces a generic "bare bones" car that lacks any Air-condition functionality.

The distribution site processes the generic car sent from NewCars manufacturing into either a Non Air-conditioned or Air-conditioned car based on demand. NewCars distribution consists of a storage area for new cars, a processing area where the cars are organised into a Non Air-conditioned and Air-conditioned car operations, and end item buffers for delivery. In more detail, the receiving operation at Newcars distribution takes one day. After a car is received from the NewCars manufacturing site, it is taken to an Air-condition installation location where it is stored until it is time to install, if necessary, the Air-conditioned unit.

The Air-conditioned stocking point requires a minimum of 100 units on-hand but not to exceed 200 units in total. It also requires 7 days of cover. If the car does not require an Air-conditioned unit, it goes through an operation where a faceplate is installed to cover where the Air-conditioned unit goes. The installation of the faceplate takes one day. If a car requires an Air-conditioned unit it goes to an Air-condition installation procedure that takes two days.

Once the car goes through the Air-condition installation it goes to a delivery location where it waits until it is time to deliver it to the customer. The finished goods stocking point requires a minimum of 100 units on hand but not more than 200 units in total. It also requires 7 days of cover. It takes one day to deliver cars to customers and no resource is needed for this operation.

NewCars supplier builds the engines using three parts (one of each) kept in an Engine Assembly location: a piston, cylinder and a cylinder head. A main assembly operation builds the engines. The process includes assembly, greasing, and inspection sub operations. In this assembly, there are no restrictions on the supply of components that constitute the engine. Furthermore, each of the individual operations is independent of the lot sizes.

To clarify, the time taken to complete the process remains the same regardless of the number of units being processed. The main assembly operation uses an assembler to perform the assembly and greasing sub operations. The assembler and the inspector

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are skilled resources with 100% availability. Also the assembler can handle a load from either the assembly or greasing sub operations, and the inspector can only handle a load from the inspection sub operation.

Once NewCars supplier assembles the engine it stores them in a shipping location until it is time to deliver them to NewCars manufacturing. The stocking point requires a minimum of 100 units on hand but not more than 200 units in total. It also requires 7 days of cover. Although NewCars supplier can produce many engines there is a constraint on the delivery trucks that deliver the engines to NewCars manufacturing. Assume that one truck can deliver no more than one engine, and you have 50 trucks on any given day.

7.2.2 Designing the Supply Chain of New Cars

7.2.2.1 Application of the Supply Chain Design Planning Cornerstone

The first cornerstone in the new supply chain planning methodology is the Supply Chain Design Planning cornerstone. This cornerstone focuses on the entire process design of the supply chain. The first step in this cornerstone is to map out the new cars supply chain by means of the Supply Chain Stencil.

> ➤　Step 1: New Cars Supply Chain Flowchart

During the design of New Cars supply chain it was found that some logic wasn't captured in the supply chain template, therefore two stencils were used to design the entire supply chain process. One of the stencils the supply chain stencil was designed and the other, the process simulation stencil is a standard stencil supplied by Rockwell Software. It will also be possible to only use one of these stencils and then do all the other additions within the modelling environment of Arena®. For the case study the entire process was illustrated in Visio®. The New Cars flowchart consist of the following illustrations:

- ➤ Piston Site
- ➤ Cylinder Site
- ➤ Head Site
- ➤ Engine Site
- ➤ Door Site
- ➤ Chassis Site
- ➤ Car Site
- ➤ Car Distribution Site
- ➤ Customer Sites
- ➤ Customer Orders
- ➤ Financial Calculations

There are six supplier sites that supply products to the car site. Each one of these sites is represented on a separate page within Visio®. Figure 7.3 will illustrate the detail flow chart of one of the sites within the supply chain. For further detail on this flowchart refer to the compact disc attached at the end of this document.

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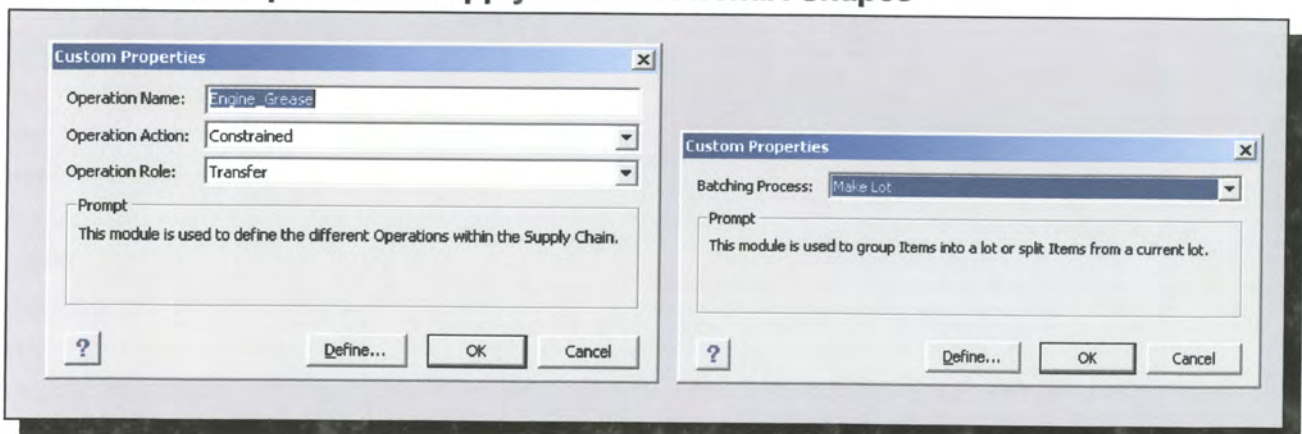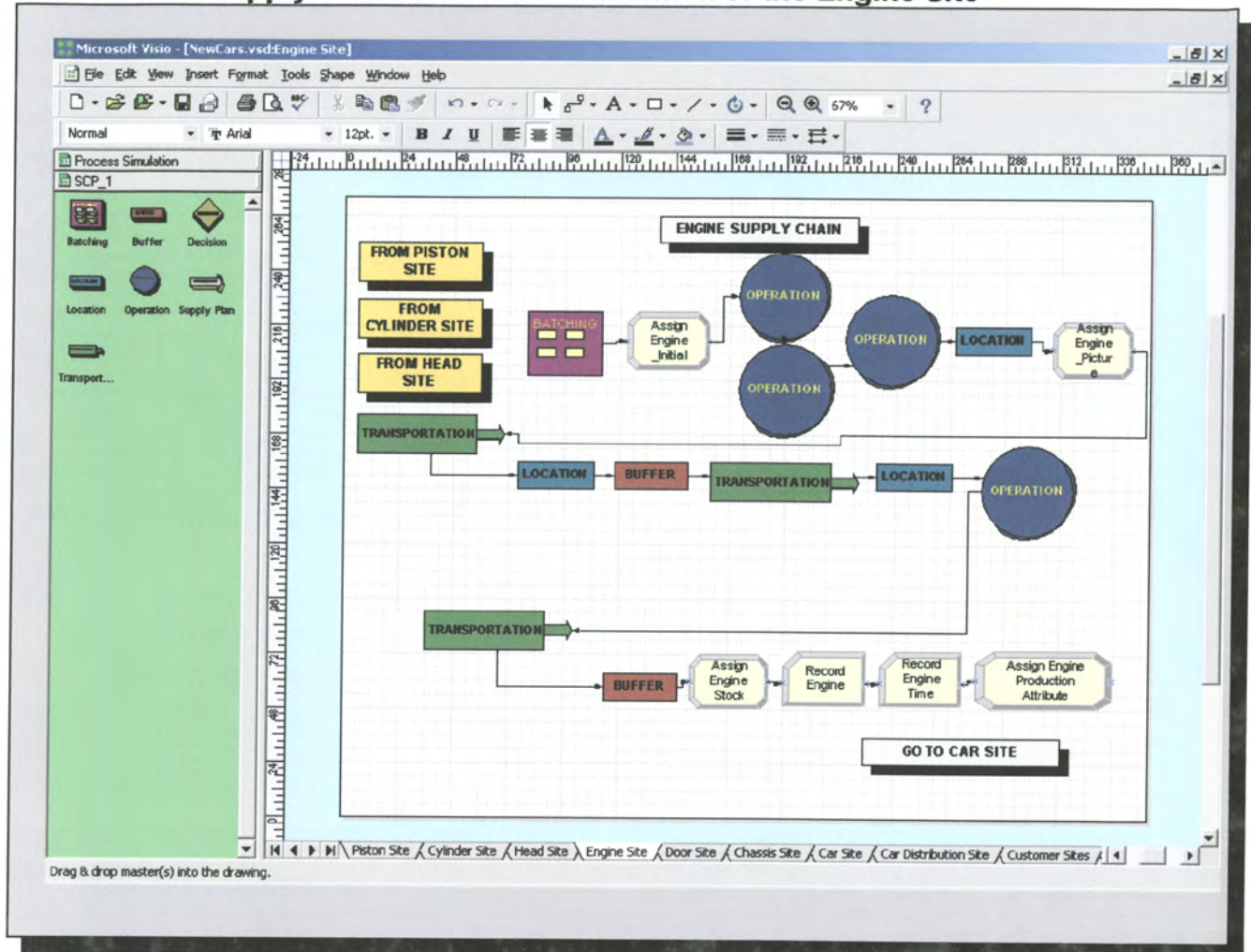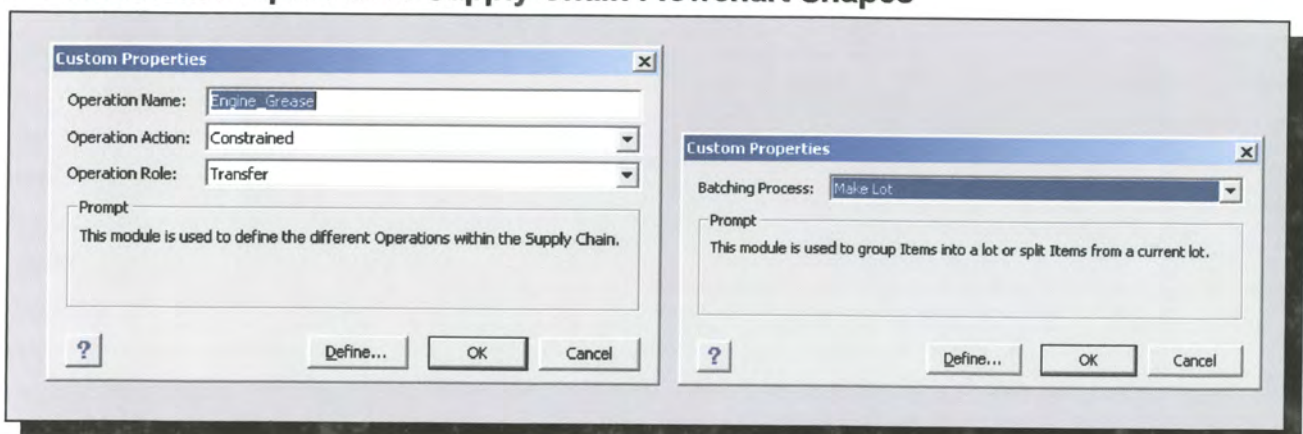UNIVERSITY OF PRETORIA
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Figure 7.3 New Car Supply Chain Flowchart illustration of the Engine Site

This flowchart illustration clearly shows the use of process simulation modules and supply chain modules. This is one of the advantages of using software that incorporates an open and scalable architecture. Due to the complexity of certain supply chains it sometimes very difficult to just use an AST and with a scalable architecture it is possible to incorporate different types of building blocks into one simulation model.

Initial configuring of data can be done within the flowchart module as illustrated in figure 7.4.

**Figure 7.4. Custom Properties of Supply Chain Flowchart Shapes**

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Figure 7.3 New Car Supply Chain Flowchart illustration of the Engine Site

This flowchart illustration clearly shows the use of process simulation modules and supply chain modules. This is one of the advantages of using software that incorporates an open and scalable architecture. Due to the complexity of certain supply chains it sometimes very difficult to just use an AST and with a scalable architecture it is possible to incorporate different types of building blocks into one simulation model.

Initial configuring of data can be done within the flowchart module as illustrated in figure 7.4.

Figure 7.4. Custom Properties of Supply Chain Flowchart Shapes

The next step is to make sure that all the Visio® shapes used in the New Cars Supply chain flowchart are mapped against Arena modules. Arena® uses an active map file when a new model is created from a Visio drawing. This map file decides which Arena® module to place for each Visio® shape. A map file is simply a list of Visio shapes and Arena® modules, along with a detailed mapping from one to the other, including the mapping of Visio® shape custom properties to Arena module operand values.

The default map file used by Arena® is called Arena Basic. map. This pre-defined map file links Visio® shapes in the Process Simulation stencil (provided by Rockwell Software) to Arena® modules in the Basic Process template. Thus, one can use the Process Simulation stencil to map and define business processes in Visio drawing files, and then easily export these drawings to Rockwell Software's Arena® software for dynamic simulation. In addition to the Arena Basic map file, one can create other map files to serve as blueprints for the transfer of shapes and data from other Visio stencils (e.g., the Basic Flowchart stencil).

In the case study two Visio® stencils were used to create the map file. This map file maps the process simulation stencil with the Arena Basic template and the supply chain stencil with the supply chain template. Figure 7.5 illustrates the mapping file. For more information on the mapping file refer to Appendix C.

Figure 7.5. Illustration of mapping Visio® shapes against Arena® modules.
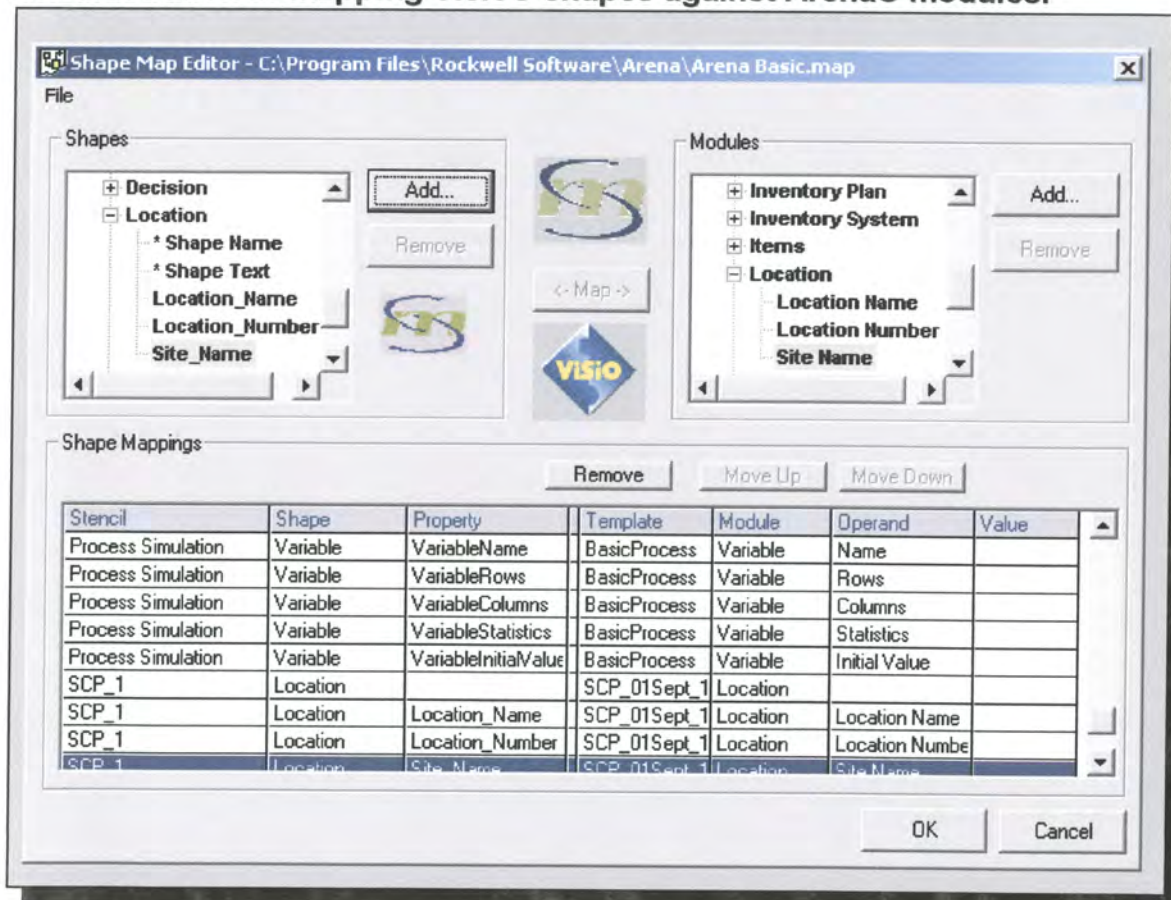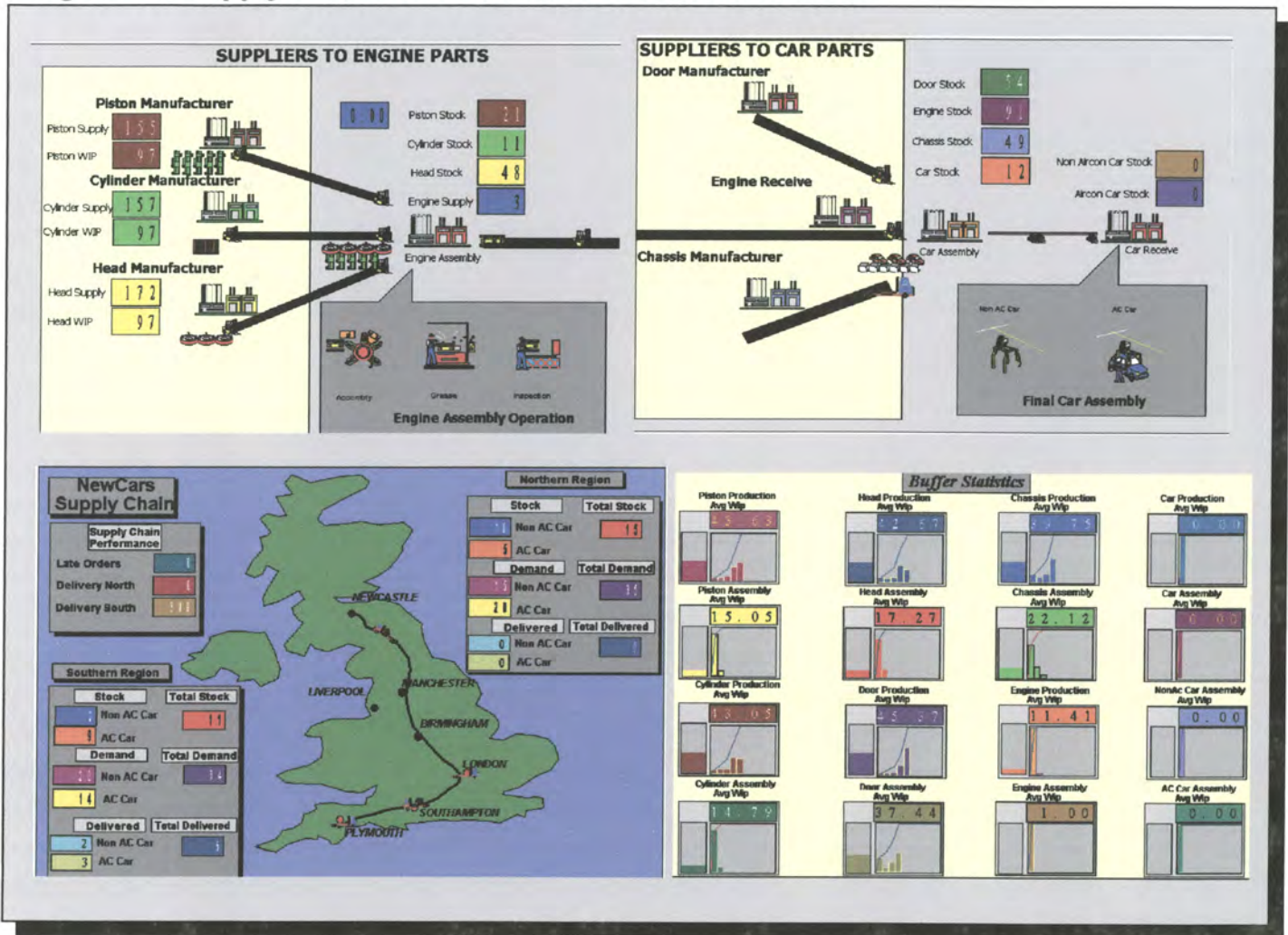
> ➢ Step 2: Supply Chain Simulation Models

The second step in the Supply Chain Design Planning cornerstone is to map out the new cars supply chain by means of the supply chain template. This template was developed with the Arena® Professional Edition. As previously explained in paragraph 6.4.1Arena PE enhances Arena SE with the capability to craft custom simulation objects that mirror components of the real system, including terminology, process logic, data, performance metrics, and animation.

Figure 7.6 illustrates some of the different animation views inside the simulation model. For more detail on this simulation model refer to the compact disc attached at the end of this document.

Figure 7.6. Supply Chain Simulation Model: Animation Views

In the supply chain simulation model some of the standard Arena® modules were used in order to create the correct animation and statistical results. The initial design of the supply chain modules only focused on the collection of statistics inside a specific model, for example the time spent inside a buffer. The purpose of the supply chain analyses module was to incorporate results between different modules in the simulation model, but some errors forced the use of standard Arena modules. Arena's open architecture and development platform allows for module interaction between different templates, therefore allowing more flexibility when modelling.

Figure 7.7 illustrates the logic view of some of the supply chain sites inside the simulation model.

Figure 7.7. Supply Chain Simulation Model: Logic
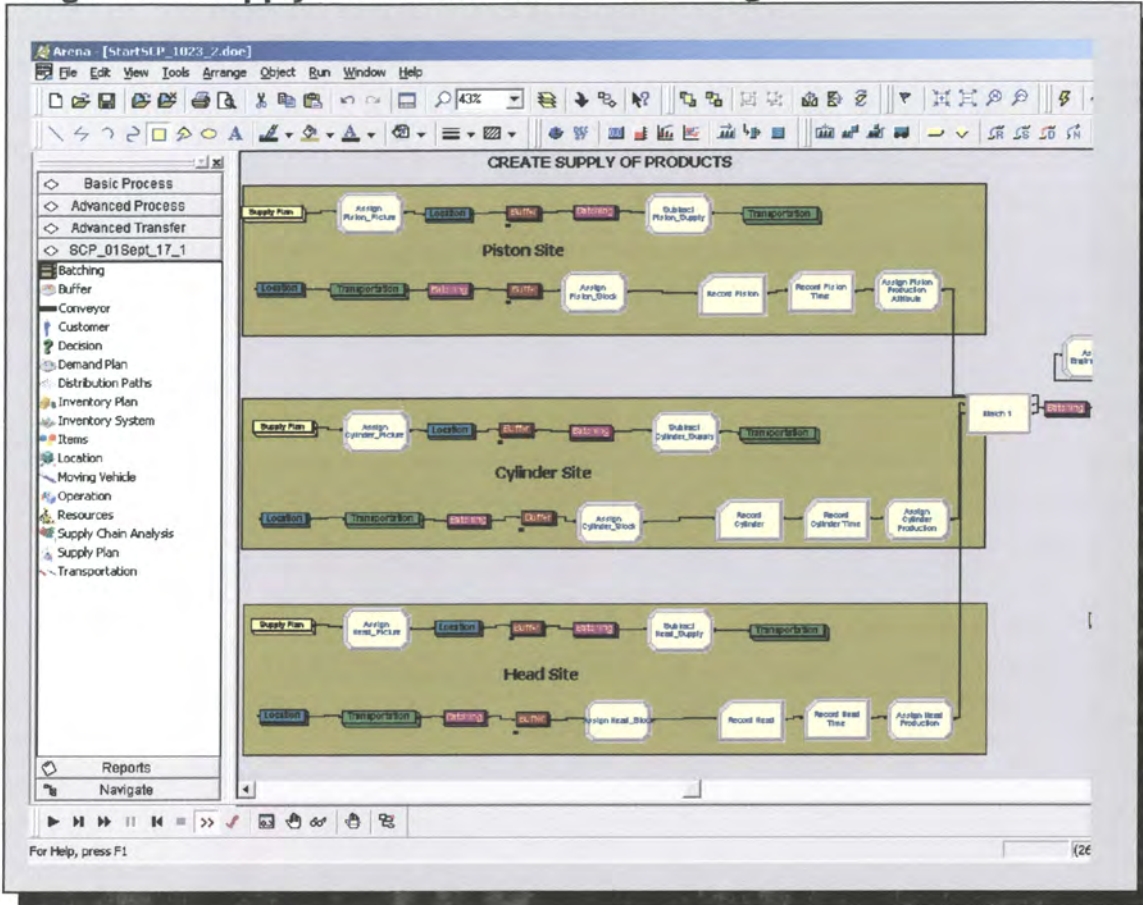
### 7.2.2.2 Application of the Supply Chain Design Analyses Cornerstone

The second cornerstone in the new supply chain planning methodology is the Supply Chain Design Analyses cornerstone. This cornerstone focuses on the analyses of the supply chain. The first step in this cornerstone is to define and compare the various scenarios of the New Car supply chain.

> Step 1: Supply Chain Scenario Analyses

During the initial validation of the supply chain simulation model the engine buffer at the engine site was identified as the bottleneck. In Scenario 1 the demand strategy of the engine buffer is defined as pull and is only allowed to transfer engines to the next process when it receives the downstream signal. Refer to figure 7.8.

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Figure 7.8. Demand Strategy of Engine Buffer
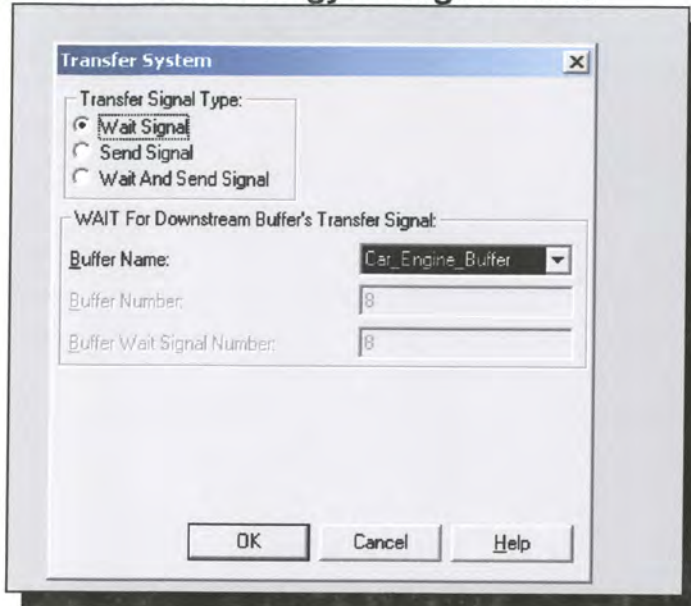
In order to define a suitable alternative scenario the demand strategy of the engine buffer was changed to a push system therefore eliminating the need for any downstream signal to transfer products. Both Scenario 1 and 2 includes variability, meaning that the processing times are represented by statistical distributions.

Two other scenarios were defined were the focus was to use scenario 1 and 2 but removing the variability in the system. In scenario 3 the demand strategy of the engine buffer is set to a push system while in scenario 4 it is set to pull. All the time functions were changed to constant values. Figure 7.9 illustrates a typical scenario run.

Figure 7.9. Scenario Analyses of the New Car Supply Chain
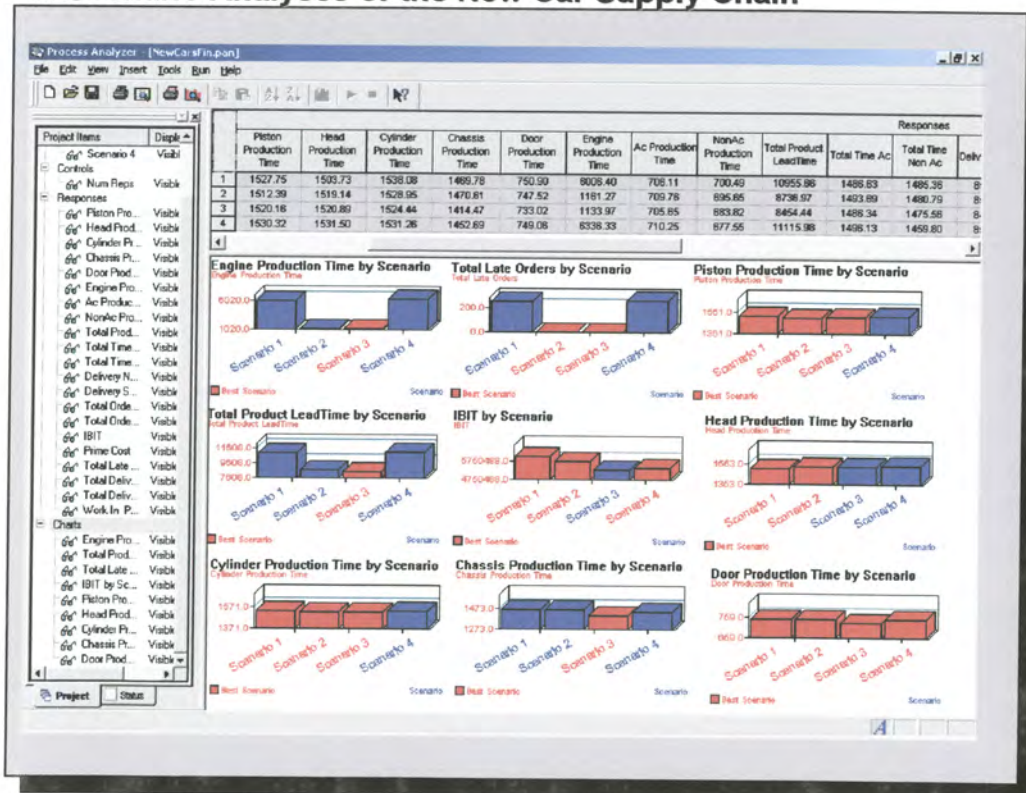
The following table illustrates the responses used and results achieved from the scenario analysis.

Table 7.1.Responses and Results from Scenario Analysis

Response	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Piston Production Time	1527.75	1512.39	1520.16	1530.32
Head Production Time	1503.73	1519.14	1520.89	1531.50
Cylinder Production Time	1538.08	1528.95	1524.44	1531.26
Chassis Production Time	1469.78	1470.61	1414.47	1452.69
Door Production Time	750.90	747.52	733.02	749.06
Engine Production Time	6006.40	1161.27	1133.97	6336.33
Ac Car Production Time	706.11	709.76	705.65	710.25
Non Ac Production Time	700.49	695.65	683.82	677.55
Total Product Lead Time	10955.66	8736.97	8454.44	11115.98
Total Lead Time Ac Car	1486.63	1493.69	1486.34	1496.13
Total Lead Time Non Ac Car	1485.36	1480.79	1475.56	1459.80
Delivery Time Northern Region	851.64	850.18	849.43	850.84
Delivery Time Southern Region	599.33	601.82	601.45	599.69
Total Cars Delivered To Northern Region	645	652	665	657
Total Cars Delivered To Southern Region	673	666	660	663
Total Ac Car Orders	200	337	330	198
Total Non Ac Car Orders	212	327	329	204
Total Late Orders	256	0	0	257
IBIT	5995120	5735180	5278320	5400920
Prime Cost	18469080	18380020	18231880	18222280
Work In Process Cost	21090	31810	32020	32440

➤   Step 2: Supply Chain Reports Generation

The second step in the supply chain design analyses cornerstone is generation of custom reports. The reports generator is divided into two parts financial data and production data. Appendix E provides a more detail explanation on the available reports. Figure 7.10 illustrates a sample report of the Supply Chain Reports Generator. For more detail on this reports generator refer to the compact disc attached at the end of this document.

Figure 7.10. Supply Chain Reports of the New Car Supply Chain
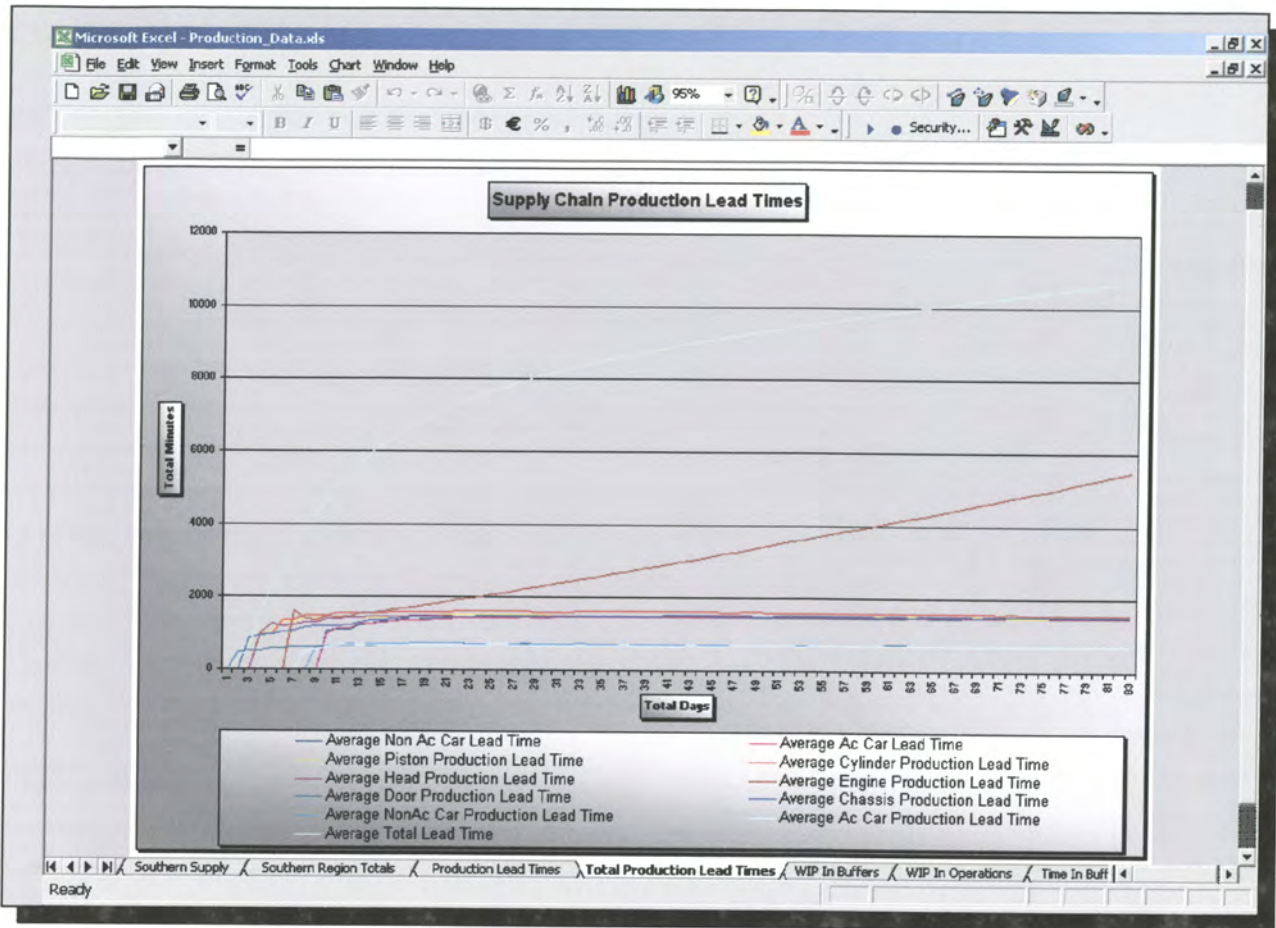
7.2.2.3 Application of Supply Chain Design Optimisation Cornerstone

The supply chain design optimisation cornerstone is the third cornerstone in the methodology. This phase will focus on the optimisation of scenario 2, which was defined as the most feasible solution for New Car.

> ➤ Step 1: Supply Chain Control Selection

The first phase within the supply chain design optimisation cornerstone is to specify the controls to optimise for New Car. Table 7.2 provides a list of all selected controls, which will be used in the optimisation. For more detail on this optimisation file refer to the compact disc attached at the end of this document.

Table 7.2. List of Optimisation Controls

Control Name	Control Type	Control Value
R_Car_Engine_Receive	Resource	1
R_Cylinder_Assembly	Resource	1
R_Cylinder_Production	Resource	1
R_Car_Buffer	Resource	1
R_Ac_Buffer	Resource	1
R_Piston_Assembly	Resource	1
R_Ac_Car	Resource	1
R_Non-Ac_Buffer	Resource	1
R_Car_Assembly_Buffer	Resource	1
R_Engine_Buffer	Resource	1
R_Car_Engine_Buffer	Resource	1
R_Head_Production	Resource	1
R_Chassis_Buffer	Resource	1
R_Car_Assembly	Resource	1
R_Engine_Inspection	Resource	1
R_Engine_Grease	Resource	1
R_Head_Assembly	Resource	1
R_Door_Production	Resource	1
R_Non-Ac_Car	Resource	1
R_Piston_Production	Resource	1
R_Chassis_Production	Resource	1
R_Engine_Assembly	Resource	1
R_Car_Receive	Resource	1
R_Door_Buffer	Resource	1
IBIT	Variable	60000000
Customer Interarrival	Variable	60

The controls need initial values in order to start the optimisation. The initial values of these controls will change with each simulation until OptQuest® finds values that yield the best objective.

> Step 2: Supply Chain Constraints

The next step is to define the supply chain constraints of New Car. These constraints restrict the controls by defining relationships among them. Table 7.3 provides a description and meaning of the supply chain constraints.

Table 7.3. List of Supply Chain Constraints

Constraint	Description
R_Engine_Inspection + R_Engine_Grease + R_Engine_Assembly <= 10	Restriction on the total amount of operation resources in Engine Site
R_Ac_Car + R_Non-Ac_Car + R_Car_Receive <= 7	Restriction on the total amount of operation resources in Car Distribution Site
R_Piston_Assembly + R_Piston_Production <= 4	Restriction on the total amount of buffer resources in Piston Site
R_Head_Production + R_Head_Assembly <= 4	Restriction on the total amount of buffer resources in Head Site
R_Cylinder_Assembly + R_Cylinder_Production <= 4	Restriction on the total amount of buffer resources in Cylinder Site
R_Door_Production + R_Door_Buffer <= 5	Restriction on the total amount of buffer resources in Door Site
R_Chassis_Buffer + R_Chassis_Production <= 4	Restriction on the total amount of buffer resources in Chassis Site
R_Car_Buffer + R_Ac_Buffer + R_Non-Ac_Buffer <= 5	Restriction on the total amount of buffer resources in Car Distribution Site
IBIT >= 5000000	Restriction on the total amount of Income earned.
Customer Interarrival <= 70	Restriction on the average time between Customer Order arrivals.

> Step 3: Supply Chain Objective Requirements

The next step is to define the supply chain objective and requirements of New Car. Table 7.4 provides a description and meaning of the supply chain objective and requirements. As previously explained in paragraph 6.6.3 an objective can be defined as a response in the Arena® model that represents the model's objective function. Requirements on the other hand are restrictions on the values of responses. These differ from constraints, since constraints restrict controls. When an analyst defines a requirement, the analyst needs to give it an upper bound, a lower bound, or both (a range). Like constraints, requirements must be satisfied for a solution to be considered feasible.

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Table 7.5. Optimisation Statistics of the New Car Supply Chain

	Sim 1	Sim 2	Sim 3	Sim 4	Sim 5	Sim 6
Objective: Total Product Lead Time	8707	8760	8700	8562	8540	8642
Ac Production Time	712	705	693	703	708	700
Car Lead Time	1486	1487	1486	1484	1482	1489
Chassis Production Time	1457	1465	1459	1447	1444	1440
Cylinder Production Time	1527	1546	1533	1538	1519	1516
Door Production Time	751	740	757	712	710	757
Engine Production Time	1158	1178	1162	1103	1141	1195
Head Production Time	1517	1537	1516	1500	1509	1514
Piston Production Time	1513	1549	1528	1540	1486	1496
Total Time Ac	1494	1493	1480	1487	1492	1494
Total Time Non Ac	1478	1479	1491	1482	1473	1485
IBIT	5286220	900387	5080720	1008703	6235020	1555020

The sensitivity analyses were based on the value changes of the controls defined in table 7.2. This generated an optimisation log file, which in turn provided the source data for the Sensitivity.xls Excel spreadsheet. For more information on the sensitivity spreadsheet refer to Appendix F. Figure 7.13 provides an illustration of the four feasible solutions referenced in table 7.5. In table 7.5 a list of the optimisation statistics provide some insight into the feasibility of the various solutions. From the sensitivity analyses simulation 4 and 6 was found to be infeasible due to a very low IBIT value.

Figure 7.13. Feasible solutions for the optimisation of the New Car Supply Chain
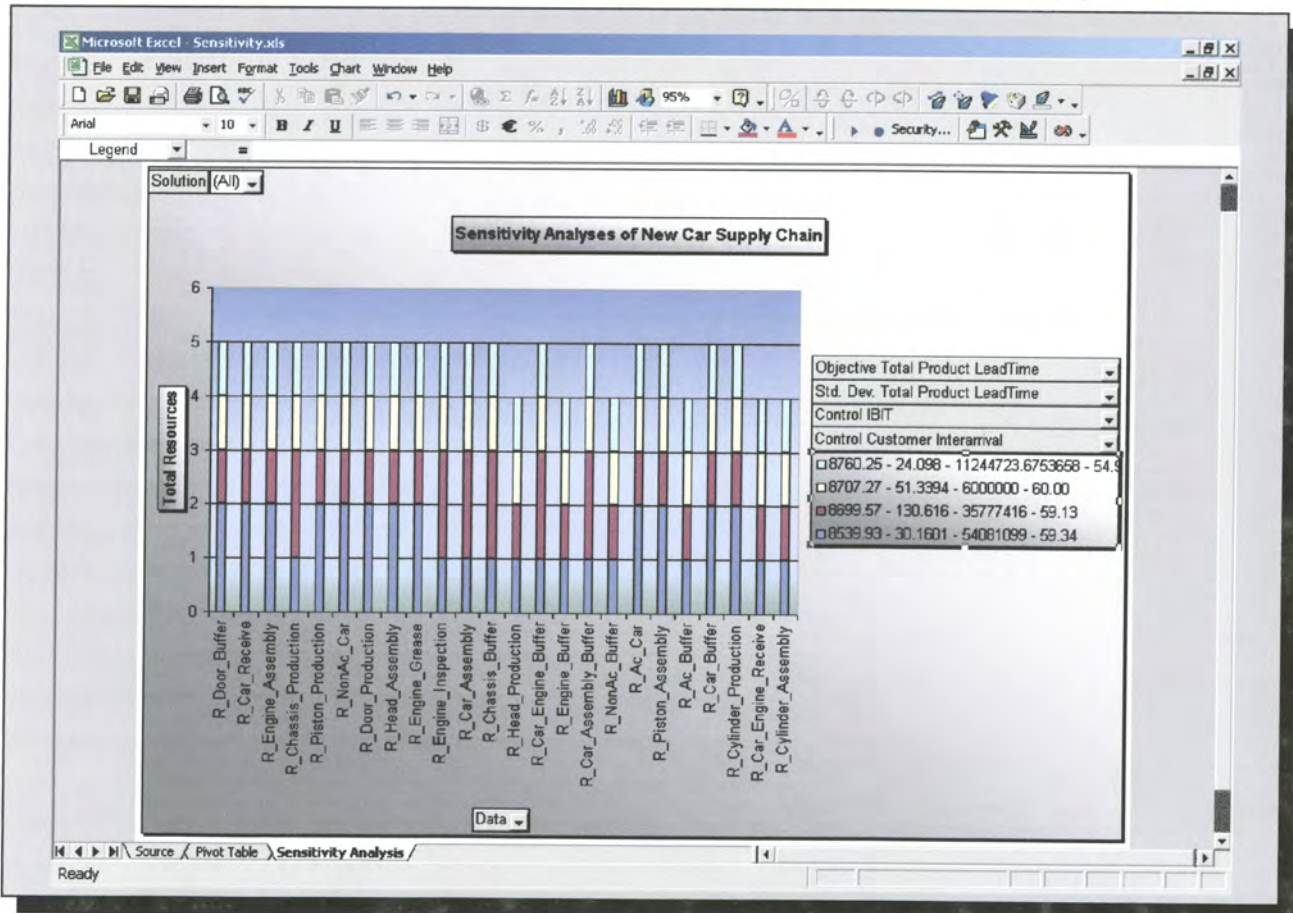
The optimised solution for New Car is simulation two. This solution was optimised with all the resource controls set to one. Table 7.6 provides a summary of the results and figure 7.14 a graphical representation.

Table 7.6. Results of Optimised Solution for New Car

	Value
Number of Replications	3
Objective Total Product Lead Time	8760.25
Std. Dev. Total Product Lead Time	24.10
Control IBIT	11244724
Control Customer Inter arrival	54.90

Figure 7.14. Most feasible solution for the New Car Supply Chain
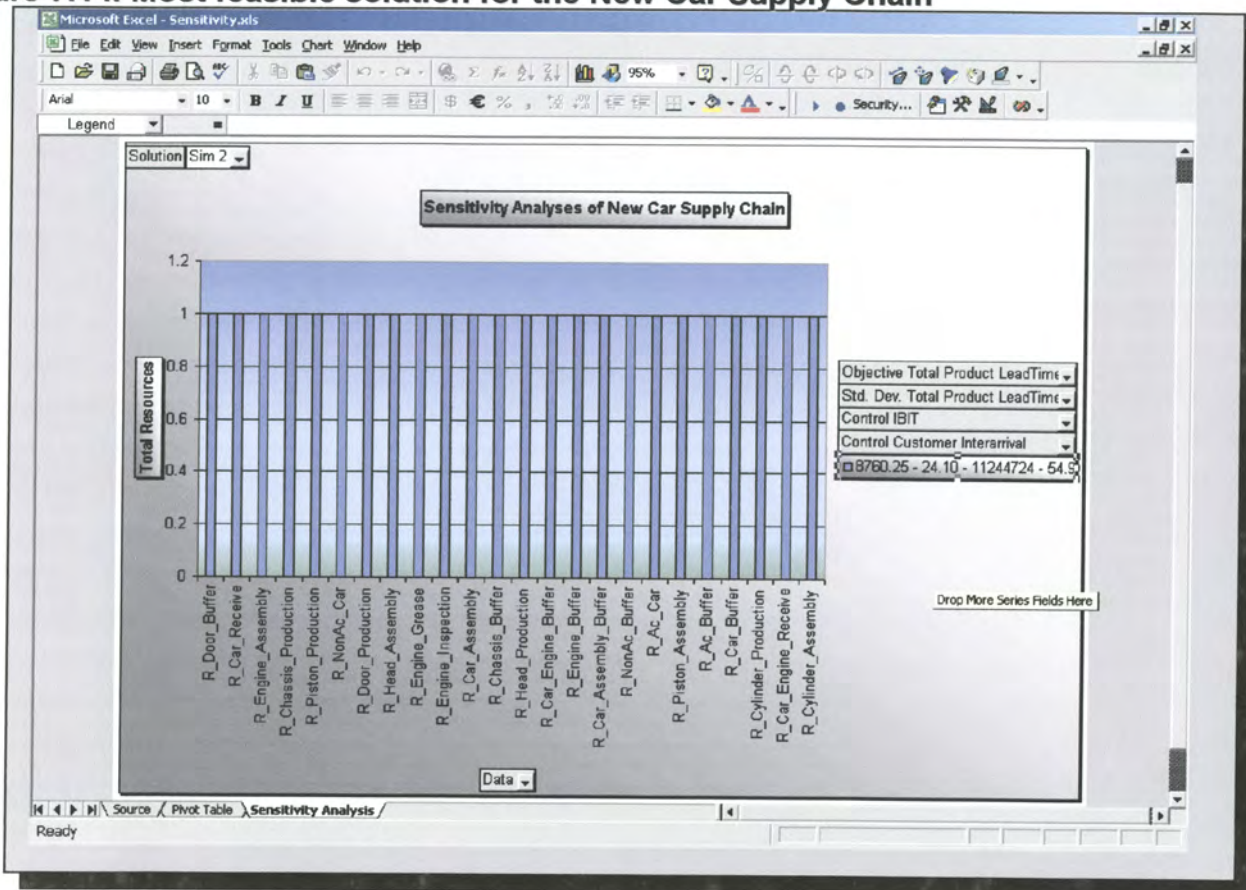
> ➢   Step 4: Update Supply Chain Solver Database

The results of optimised solution of the New Car supply chain can now be transferred to the supply chain solver database. The supply chain solver database will be used as the input for the next cornerstone the supply chain operational optimisation cornerstone.

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7.2.2.4 Application of the Supply Chain Operational Optimisation

The supply chain operational optimisation cornerstone is the fourth cornerstone in the methodology. In this phase the supply chain solver database will be used as the input for the supply chain solver technology. For more information regarding the supply chain solver database refer to Appendix D.

Figure 7.15. Illustration of the Buffer Detail Form from Supply Chain Solver Database

The supply chain solver technology can now make use of the stored data inside the supply chain solver database.

This step concludes the new supply chain planning methodology. The next chapter will focus on some adaptations and new developments for the supply chain planning methodology.

8 _Epilogue_

This chapter will focus on what was proposed and actually delivered with this dissertation. The main idea behind this was to bring all the elements into perspective and finalise all outstanding thoughts.

8.1 _Introduction_

The scope of this dissertation was to develop a supply chain planning methodology, which will help to improve the understanding of the uncertainty and interdependency of processes within the supply chain.

To design this methodology different steps were taken in order to introduce the final solution. The following steps were followed:

> ➢ Research
> ➢ Evaluation
> ➢ Development
> ➢ Case Study

8.2 _Research phase revisited_

The idea behind the research phase was to explain why a new way of thinking was unavoidable in supply chain planning. During this phase the focus was entirely on traditional planning methods and what problems or inefficiencies organisations experienced. It became evident that traditional planning had to change in order to be able to compete in the global market place.

This change brought about the introduction of a new planning solution, now widely accepted by organisations. It was believed that this new planning solution would solve all the problems of traditional planning and more. The research phase also focused on the characteristics of this new planning solution better known as supply chain management.

The research phase was concluded with some new thoughts on how supply chain management need to be integrated. These new thought showed that truly integrated supply chain planning is the answer for global visibility.

The conclusion of the initial research phase is that it did provide sufficient background on the topic of supply chain evolution.

8.3 _Evaluation phase revisited_

The reason for the evaluation phase was that based on the research phase a new planning solution was introduced. This planning solution had to be evaluated for strengths and weaknesses. During this phase the focus was first to provide an overview of the supply chain market and secondly on the role players.

The overview of the supply chain market focused on how the supply chain planning and execution market evolved over the years. It also showed that there are two types of

players in the supply chain market. The one is called supply chain execution and the other supply chain planning. A brief description highlighted the differences between these two. At this point the evaluation phase made a turn towards the supply chain planning role players. A detail analysis followed on what these solutions consisted of.

During this evaluation of it was found that all these applications lacked the basic ability to understand the variability within the supply chain. Although these solutions can help to improve the system, it is restricted to the static part and it does not incorporate the dynamic part. The result therefore is that a lot of "noise" still exists within the system once the results are achieved. This opened the way for solutions that can provide insight to the uncertainty and interdependency of processes and customer demand within the supply chain. Simulation technology was introduced as a solution of gaining insight into the system variation and interdependencies.

This phase was concluded with the explanation on why simulation technology can help to improve supply chain planning and this generated the initial strategy for the new supply chain planning methodology.

The conclusion of this evaluation phase was that it did provide insight into the inefficiencies of the current supply chain solution providers and how it can be solved.

8.4 Development phase revisited

The development phase main focus was to introduce the details of the new supply chain planning methodology. Before the development could start an evaluation of the simulation solution providers was done. This was done to provide more insight into the new proposed solution for understanding the uncertainty and interdependency of processes and customer demand within the supply chain.

The simulation solutions were evaluated against certain criteria. Based on this a solution was selected to for the development of the new supply chain planning methodology.

The main focus of this methodology was to provide a new framework for supply chain planning build around the following cornerstones:

- ➤ Supply Chain Design Planning
- ➤ Supply Chain Design Analyses
- ➤ Supply Chain Design Optimisation
- ➤ Supply Chain Operational Optimisation

This phase produced a new methodology, which makes use of different tools. These tools were developed with available software.

The initial design planning phase focused on the actual design of a supply chain based on some building blocks in Visio®. These building blocks were designed to incorporate the basic building blocks and functions of a supply chain. There is a need to have a set of some high-level building blocks that will make use of the lower level building blocks if needed. For a market solution some development needs to be done on the expansion of the Visio® building blocks.

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The initial result of the supply chain is captured in a Visio® flowchart. This flowchart will be the input for supply chain simulation model. In order for this input to work the Visio® shapes had mapped against the supply chain template modules. This was done by using the shape map editor which is part of the Arena® software. This seems to work fine but it can be improved with extra development. In order to gain the full advantage of the higher-level building blocks it should also be migrated to the supply chain template. One such building block is the inventory-planning module. This module would be used to introduce global inventory planning across the supply chain per item. Figure 8.1 provides an illustration of such a module.

Figure 8.1. Future building block for Inventory Planning
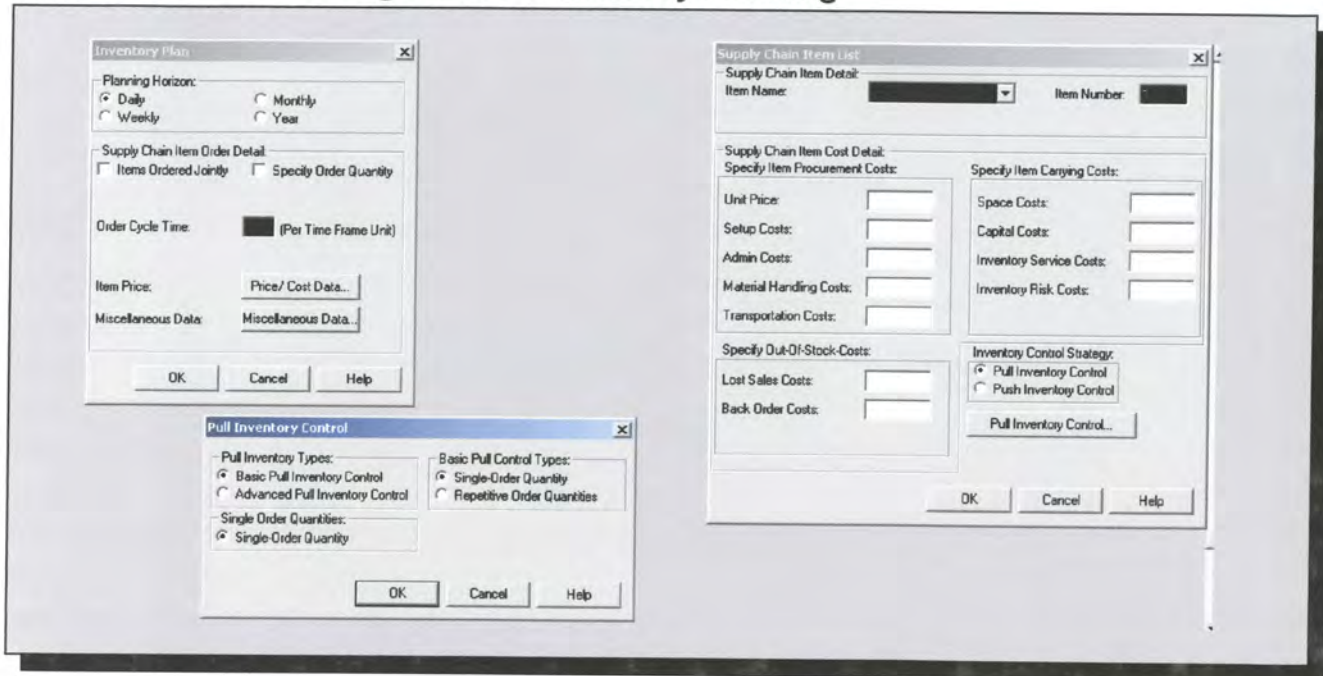
The design analyses phase provided some functionality, which can be used in the evaluation of scenarios. The only change here might be to introduce industry defined supply chain performance indicators. By doing this the evaluation of supply chain performance will be easier accepted in the market.

The optimisation phase allows for a detail analysis on how sensitive a certain solution is for changes. The only need here is to have industry defined requirements, controls, and constraints.

The operational optimisation phase is seen as one of the phases, which needs a lot of input from the market. This can actually be an entire different project just to define what is needed in such a database. For the purpose of the dissertation the database will only incorporate some of the basic building blocks that are referenced in the supply chain stencil.

The conclusion of the development phase is that this new supply chain planning methodology can be used to model supply chains but there still needs to be some development in certain aspects to make it more robust.

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8.5 Case Study phase revisited

In order to know whether this technology will work it had to be tested on a real life example. During the initial design some inefficiencies and needs started to emerge.

One of those was the need to expand the functionality of the demand strategy between buffers and operations. The demand strategy only focuses on a one-to-one relationship between a downstream and upstream buffer/operation. This means that only one upstream buffer/operation can wait for a downstream buffer/operation at a time. The demand strategy should be able to handle multiple upstream and downstream buffers/operations.

On the result side the need exist to have some industry standard of performance indicators. The supply chain council did provide a performance model for supply chain planning this is called the SCOR model. For future development it will be advisable to introduce some of the SCOR model's performance indicators. Figure 8.2 provides an illustration of the main supply chain performance indicators.

Figure 8.2. SCOR model: Supply Chain Scorecard[58]

Supply Chain Scorecard v. 3.0			Performance Versus Competitive Population			
Overview Metrics	SCOR Level 1 Metrics	Actual	Parity	Advantage	Superior
EXTERNAL Delivery Performance/ Quality	Delivery Performance to Commit Date	50%	85%	90%	95%
	Fill Rates	63%	94%	96%	98%
	Perfect Order Fulfillment	0%	80%	85%	90%
	Order Fulfillment Lead Times	7 days	7 days	5 days	3 days
Flexibility & Responsiveness	Production Flexibility	45 days	30 days	25 days	20 days
INTERNAL Cost	Total Logistics Management Costs	19%	13%	8%	3%
	Warranty Cost	NA	NA	NA	NA
	Value Added Employee Productivity	$122K	$156K	$306K	$460K
Assets	Inventory Days of Supply	119 days	55 days	38 days	22 days
	Cash-to-Cash Cycle Time	196 days	80 days	46 days	28 days
	Net Asset Turns (Working Capital)	2.2 turns	8 turns	12 turns	19 turns

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[58] Supply Chain Council, www.supply-chain.org

The SCOR model has divided the performance indicators into four categories. In addition to these four categories a fifth category is distinguished that includes the financial performance indicators.

The five categories are: financial statement, delivery reliability, supply chain flexibility and responsiveness, costs, and assets. One way of introducing this into the supply chain template is to have a supply chain analyses module. Figure 8.3 provides an illustration of such a module.

Figure 8.3 Supply Chain Performance Module
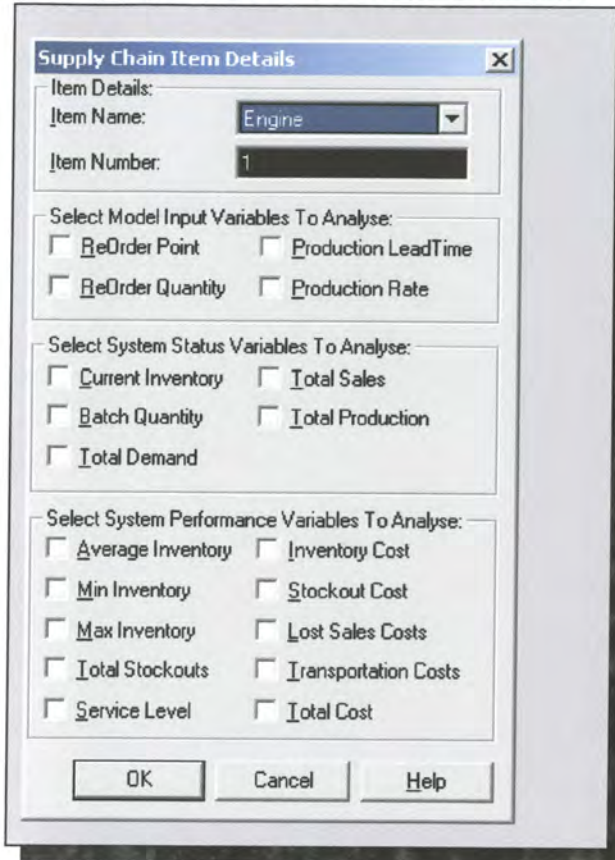
For future market acceptance it is important to introduce some higher-level modules that can make use of the lower level building blocks like buffer and operation. These building blocks should focus on transportation, production, demand and distribution and performance measurements. A good benchmark to use for these higher-level modules is the SCOR model. Figure 8.4 provides an illustration of some of the high level SCOR modules.

Figure 8.4. Illustration of High Level SCOR modules.
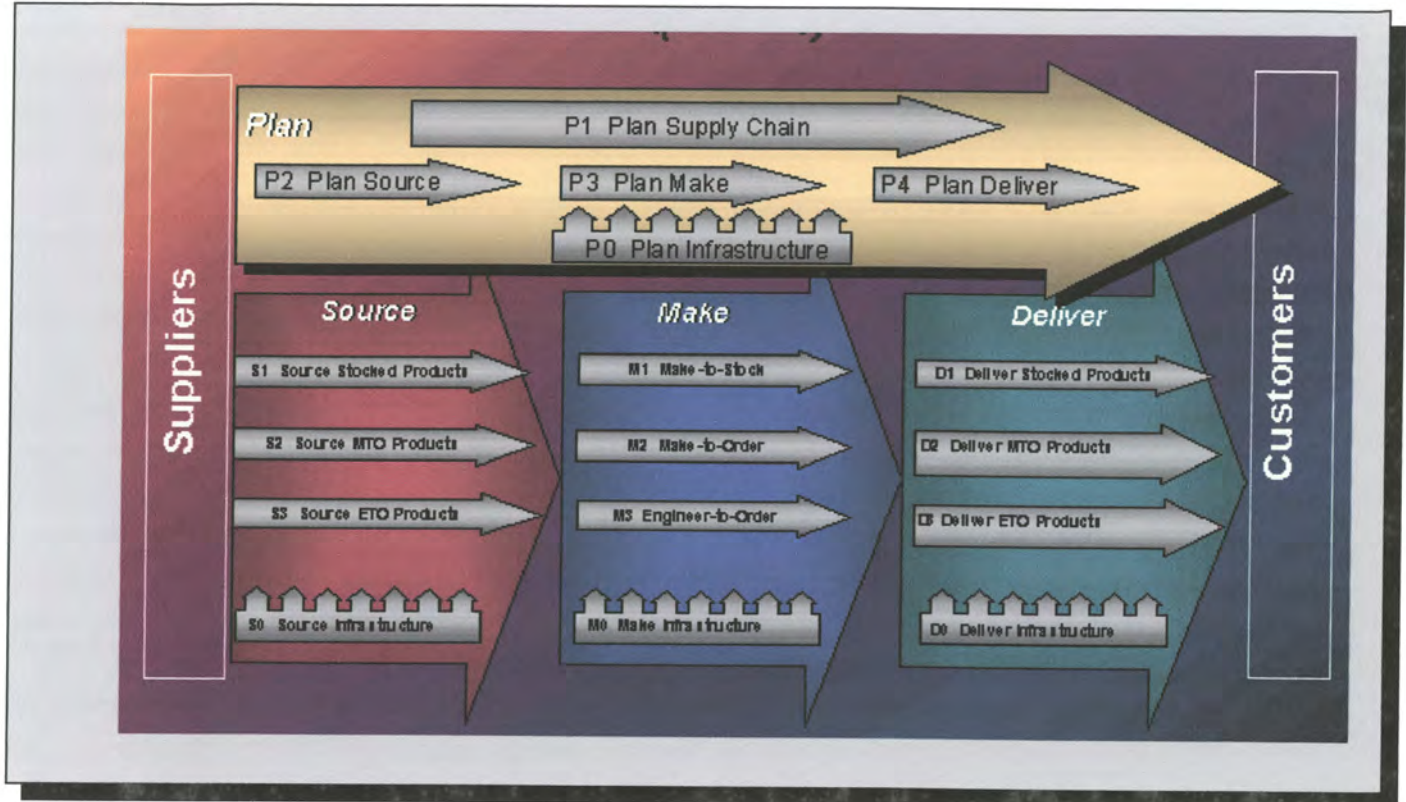
The following building blocks can be introduced into the existing supply chain template:

> Production Planning

This building block can either be used as a stand-alone process or as a sub model. If it is used as a sub model it will then make use of lower level modules such as buffers and operations. This module will then fit into the initial planning module of the SCOR model.

> Supplier Planning

Extend the functionality of the current supply plan building block, by introducing different source type products such as, stock products, MTO products, ETO products and infrastructure supply. This module will then fit into the initial source module of the SCOR model.

> Manufacturing

This building block can either be used as a stand-alone process or as a sub model. If it is used as a sub model it will then make use of lower level modules such as buffers and operations. If it is used as a stand alone it should be able to introduce different manufacturing strategies for the different supplier products such as stock products, MTO products, ETO products. This module will then fit into the initial make module of the SCOR model.

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➢ Transportation Planning

Extend the functionality of the current transportation module. This building block can either be used as a stand-alone process or as a sub model. If it is used as a sub model it will then make use of lower level modules such as transportation, moving vehicle, conveyor and distribution paths. If it is used as a stand-alone then it should be able to make use of different transportation policies for the different types of products such as stock products, MTO products, and ETO products. This will then fit into the initial delivery module of the SCOR model.

➢ Demand Planning

Extend the functionality of the current demand-planning module by introducing different demand type products such as, stock products, MTO products, ETO products and infrastructure demand. This building block can either be used as a stand-alone process or as a sub model. If it is used as a sub model it will then make use of lower level modules such as buffer and operations.

From the case study it is quite clear that some development is still needed in some areas of the new supply chain planning methodology. The case study however showed that it is possible to improve the initial supply chain design with simulation. It also helped to understand what is needed in a supply chain planning methodology.

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10 *Appendixes*

Appendix A: Overview of Flowchart Shapes
Appendix B: Overview of Supply Chain Template Modules
Appendix C: Overview of the Supply Chain Mapping File
Appendix D: Overview of Supply Chain Solver Database
Appendix E: Overview of Supply Chain Reports Generator
Appendix F: Overview Of Sensitivity Analysis

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1 *Appendix A: Overview of Flowchart Shapes*

1.1 *Introduction*

Microsoft Visio® was used to develop the flowchart modules. Arena uses an active map file when a new model is created from a Visio drawing. This map file decides which Arena module to place for each Visio shape. A map file is simply a list of Visio shapes and Arena modules, along with a detailed mapping from one to the other, including the mapping of Visio shape custom properties to Arena module operand values.

The default map file used by Arena is called Arena Basic. map. This pre-defined map file links Visio shapes in the Process Simulation stencil (provided by Rockwell Software) to Arena modules in the Basic Process template. Thus, one can use the Process Simulation stencil to map and define business processes in Visio drawing files, and then easily export these drawings to Rockwell Software's Arena software for dynamic simulation.

In addition to the Arena Basic map file, one can create other map files to serve as blueprints for the transfer of shapes and data from other Visio stencils (e.g., the Basic Flowchart stencil). It was decided that the initial design of the Supply Chain would be done by means of a flowchart. The map file links the Supply Chain shapes within the flowchart with the Supply Chain Modules within the Supply Chain Template.

1.2 *Basic Flowchart Shapes*

1.2.1 Batch Shape

1.2.1.1 Batch Shape Description

This shape is used to group items into a lot or split items from an existing lot. The only option available is to specify the batching process. All the other detail regarding the batching process will be defined within the Supply Chain template.
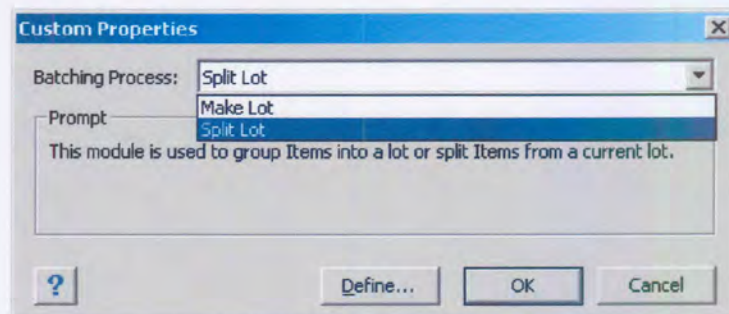
1.2.1.2 Batch Shape Prompts
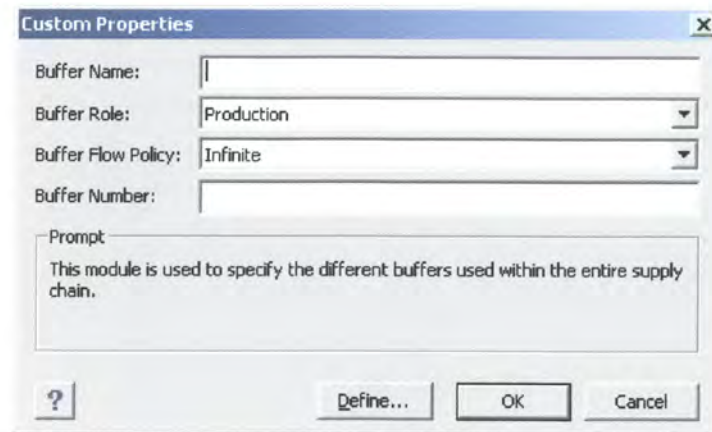
> Batching Process

The Batching Process can either be specified as Make Lot or Split Lot. When Make Lot is selected it means that items will be grouped together. If Split Lot is specified it means that Items from an existing batch will be split up /ungrouped.

1.2.2 Buffer Shape

1.2.2.1 Buffer Shape Description

This shape is used to specify the different Buffers used within the Supply Chain. The Buffer Shape allows one to specify the name, the Buffer Role, Buffer Flow Policy and the Buffer Number. All the other detail will be defined within the Supply Chain template.
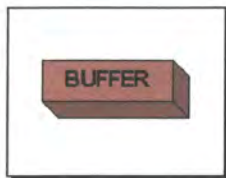
1.2.2.2 Buffer Shape Prompts

> Buffer Name

This prompt is used to name the Buffer Process.

> Buffer Role

This prompt allows the Supply Chain Analyst to specify what sort of role the Buffer will play. It can be **Transfer, Production or Customer Driven**.

> Buffer Flow Policy

There are two types of flow policies, Infinite and Constrained. If Infinite is selected it means that the Buffer can hold an infinite number of items. If constrained is selected it means that for some reason there are certain constraints within this Buffer.

> Buffer Number

This operand only allows for a unique number for a Buffer.

1.2.3 Decision Shape

1.2.3.1 Decision Shape Description

This shape allows for decision-making processes in the system. It includes options to make decisions based on one or more conditions (e.g., if entity type is Gold Card) or based on one or more probabilities (e.g., 75% true; 25% false). It is only possible to specify the decision type. All the other detail will be defined within the Supply Chain template.

1.2.3.2 Decision Shape Prompts
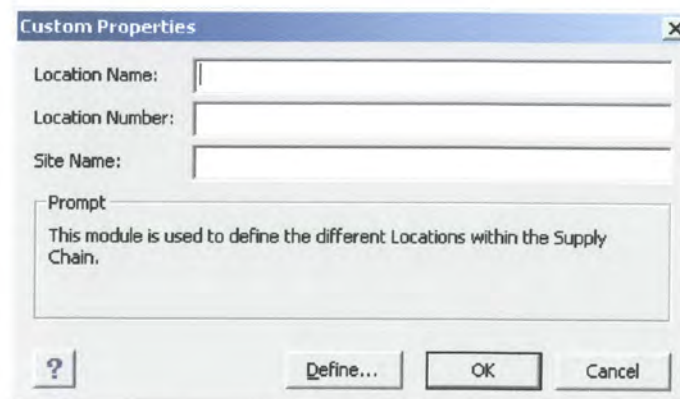
> ➢ Decision Type

Indicates whether the decision is based on a condition (if X>Y) or by chance/percentage (60% yes, 40% no). The type can be specified as either Condition or Probability.

1.2.4 Location Shape

1.2.4.1 Location Shape Description

This shape is used to specify a physical location within a supply chain. It consists of a geographical description but it can also be a description such as a loading dock in a warehouse.

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1.2.4.2 Location Shape Prompts

> ➤ Location Name

This prompt is used to name the Location.

> ➤ Location Number

This prompt only allows for a unique number for the Location.

> ➤ Site Name

This prompt is used to name the Site to which the location belong. The Site could correspond to a plant, to a portion of a plant, to distribution centres, warehouses, or stores.

1.2.5 Operation Shape

1.2.5.1 Operation Shape Description

An Operation is used to define a process, activity, or action that transforms or moves intermediate or final goods (items) through the supply chain. Operations may cause material to flow from certain buffers and, after transformation, to flow to other buffers. All the other detail will be defined within the Supply Chain template.
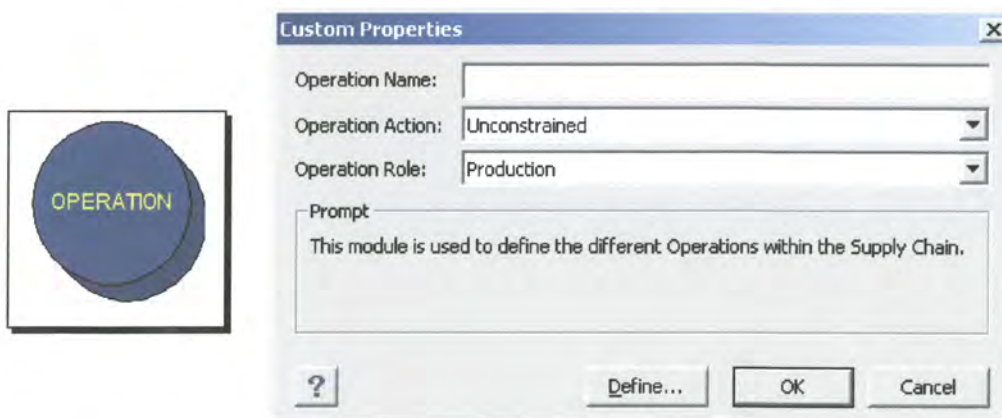
1.2.5.2 Operation Shape Prompts

> ➤ Operation Name

This prompt is used to name the Operation.

> ➤ Operation Action

There are two types of operation actions, Unconstrained and Constrained. If Unconstrained is selected it means that the Operation can hold an infinite number of items. If constrained is selected it means that for some reason there are certain constraints within this Operation.
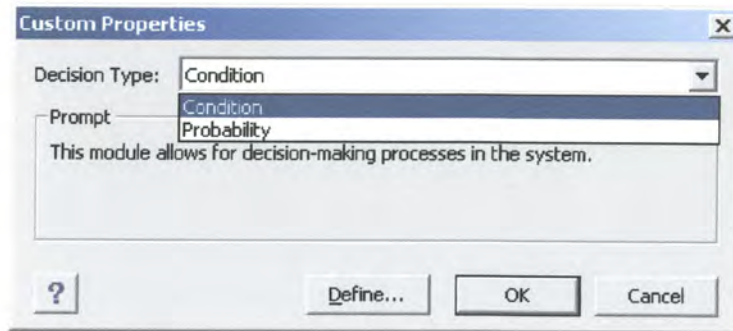
4
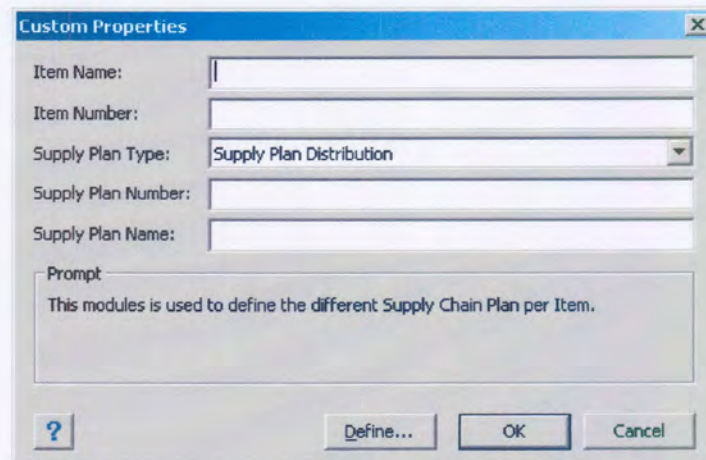
> ➤ Operation Role

This prompt allows the Supply Chain Analyst to specify what sort of role the Operation will play. It can be **Transfer, Production or Customer Driven**.

1.2.6 Supply Plan Shape

1.2.6.1 Supply Plan Shape Description

This module is used to specify the hourly demand of an item. By using different Planning Horizons the Supply Chain Analyst can specify the supply plan of an item on a hourly bases.

1.2.6.2 Supply Plan Shape Prompts

> ➤ Item Name

This prompt is used to specify the name of the Item, which will be linked to this specific supply plan.

> ➤ Item Number

This prompt is used to specify the unique number of the Item to be used.

> ➤ Supply Plan Type

There are two types of supply plans, supply plan distribution or a Specified Planning Horizon. If the Supply Plan Distribution is selected the supply of an Item will be based upon a specified Statistical distribution or expression. If the Supply Plan Horizon is selected it means that the supply of an item will be based on a predefined planning horizon.

> ➤ Supply Plan Number

This prompt is used to uniquely identify the Supply Plan.

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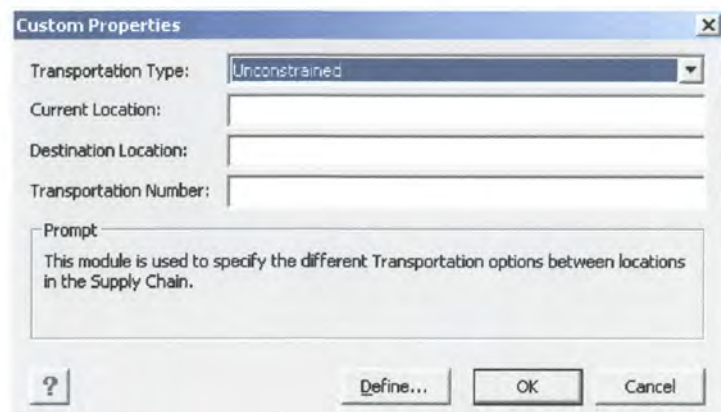
> Supply Plan Name

This prompt is used to name the Supply plan.

1.2.7 Transportation Shape

1.2.7.1 Transportation Shape Description

This shape is used to specify the different transportation methods between the various locations. The transportation type can either be constrained or unconstrained between different locations.
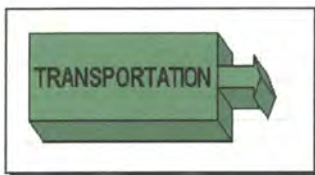
1.2.7.2 Transportation Shape Prompts

> Transportation Type

There are two types of transportation types unconstrained or constrained. When Unconstrained is selected it means that the Item does not need any transportation device between its current location and its destination location. If the transportation type is selected as constrained it means that the item need some sort of transportation device, which may be constrained.

> Current Location

This prompt is used to specify the current location of the item.

> Destination Location

This prompt is used to specify the destination location of the item.

> Transportation Number

This prompt is used to uniquely identify the transportation method.

2 Appendix B: Overview of Supply Chain Template Modules

2.1 Introduction

Arena Professional Edition, which is an advanced simulation system, was used to develop the Supply Chain template modules. The Professional Edition of Arena works with the Standard Edition principles and it provides an interactive environment for building, graphically animating, verifying, and analysing simulation models.

Professional edition allows one to develop a unique Arena template that is specific to a particular project, company, and industry. The Professional Edition builds on Arena's natural hierarchical structure enabling one to create new simulation tools, in a graphical, easy-to-use environment.

The Professional Edition is a development tool, and it can be used to create complete simulation blocks called modules. These modules may be very simple, such as one that calculates the amount of products in a buffer, or one can develop a complex module that captures all the activities associated with an advanced inventory system. In fact Arena's hierarchy encourages one too decompose the system under study into the most critical and basic elements.

2.2 Supply Chain Modules

This section will highlight all the detail information regarding the Supply Chain Modules. Every module will be explained in detail. The Supply Chain Modules are divided into two types, basic Supply Chain Modules and High Level Data Modules. The following table illustrate the different modules within the supply chain template

Basic Supply Chain Modules	High Level Data Modules
Batch Module	Conveyor Module
Buffer Module	Demand Plan Module
Decision Module	Inventory System
Location Module	Inventory Plan
Operation Module	Items
Site Module	Moving Vehicle
Supply Plan Module	Resources
Transportation Module	Supply chain Analyses

2.2.1 Basic Supply Chain Modules

These modules are used to model basic operation within a Supply Chain in a lot of detail. The modules within this section are mapped with the Supply Chain Shapes within Visio. The exact mapping by means of the Visio Shape editor will be explained in Appendix C.

2.2.1.1 Batch Module

2.2.1.1.1 Batch Module Description

This module is intended as the grouping mechanism within the simulation model. Batches of entities can be permanently or temporarily grouped. Specifying the Batch Process, as split lot will allow one to split temporary batches.

Batches may be made with any specified number of entering entities or may be matched together based on an attribute.

Entities arriving at the Batch module are placed in a queue until the required number of entities has accumulated. Once accumulated, a new representative entity is created.

Within the Batch Module there are some Statistics that can be recorded to analyse the performance of the batching process.
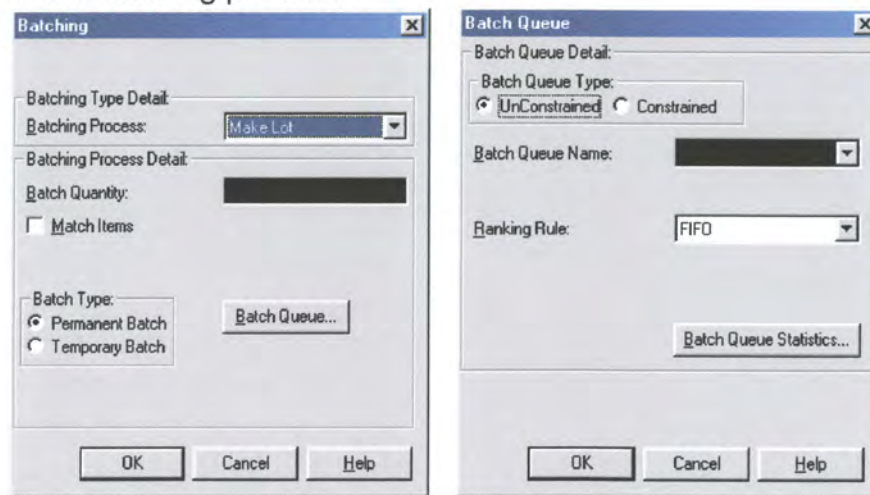
2.2.1.1.2 Batch Module Prompts:

Prompt Name	Prompt Name
Batching Process	Send Balked Items To
Batch Quantity	Queue Output Statistics
Match Items	Time In Queue Statistics
Match Criteria	Number In Queue Statistics
Batch Type	Minimum Time In Queue
Batch Queue Type	Average Time In Queue
Batch Queue Name	Maximum Time In Queue
Batch Queue Capacity	Minimum Number In Queue
Ranking Rule	Average Number In Queue
Dispose Balked Items	Maximum Number In Queue

➢ Batching Process

This prompt allows one to specify whether to make a lot or to split a previous batched lot. Only batches with the batch type set to temporary may be split.

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➢ Batch Quantity

This operand allows one to specify the number of entities to be batched.

➢ Match Items

The match Item check box allows makes it possible to synchronizes the advance of two or more entities. When operand Match Attribute is specified, the Match Item operand synchronizes the advance of entities with matching values of Match Criteria.

➢ Match Criteria

Match Criteria specify what attribute should be used to match entities. When the Batch Module has one or more entities (based on Batch Quantity) with the same match code, these entities are released to the next module. It further signifies that the values of the specified attribute must match for entities to be grouped. For example, if Match Criteria is Colour, all entities must have the same Colour value to be grouped. Otherwise, they will wait at the module for additional incoming entities.

➢ Batch Type

The Batch Type allows one to specify what method to use when batching entities together. The Type can either be permanent or temporary. If the batch is defined as **permanent**, the representative entity permanently replaces the members of the batch. If the Batch is defined as **temporary**, the representative entity temporarily replaces the members of the batch.

➢ Batch Queue Type

The Batch Queue Type allows one to specify whether the queue is constrained or unconstrained. When it is specified as unconstrained it means that there is no limit in the amount of entities that can wait in this queue. If constrained is specified is means that there can only be a limited amount of entities waiting in the queue.

➢ Batch Queue Name

This specifies the name of the queue each Batch queue has its own unique name.

➢ Batch Queue Capacity

If Queue is specified to be constrained the maximum capacity for this queue should be specified. This means that if a queue can only hold 5 units the Batch Queue Capacity should be set to 5.

➢ Ranking Rule

Ranking Rule specifies the order for a single queue and can be one of the following:

FIFO: First In, First Out. The entities are ranked based on their time of insertion in the queue. SIMAN inserts each arriving entity as the last entity in the queue until the next arrival.

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LIFO: Last In, First Out.   The entities are ranked based on their time of insertion in the queue. Each arriving entity is inserted as the first entity in the queue.

LVF (Rule expression): Low Value First of Rule expression. The entities are ranked in the queue low value first, based on the value of the specified expression.

HVF (Rule expression): High Value First of Rule expression. The entities are ranked in the queue high value first, based on the value of the specified expression.

> Dispose Balked Items

If this modifier is specified all the balked entities in this queue will be disposed.

> Send Balked Items To

This label specifies to which label the balked entity is sent.

> Queue Output Statistics

If this modifier is selected it will allow the Supply Chain Analyst to select various statistics associated with the queue. There are two types of statistics Time in Queue Statistics and Number In Queue Statistics.

> Time In Queue Statistics

This modifier allows the Supply Chain Analyst to select various statistics associated with the how much time an entity spends in a queue.

> Number In Queue Statistics

This modifier allows the Supply Chain Analyst to select various statistics associated with the how much entities are in the queue during the Simulation Run.

> Minimum Time In Queue

If this modifier is selected the Minimum Time spent in the Queue will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Average Time In Queue

If this modifier is selected the Average Time spent in the Queue will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Maximum Time In Queue

If this modifier is selected the Maximum Time spent in the Queue will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Minimum Number In Queue

If this modifier is selected the Minimum Number in the Queue will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Average Number In Queue

If this modifier is selected the Average Number in the Queue will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Maximum Number In Queue

If this modifier is selected the Maximum Number in the Queue will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

2.2.1.2 Buffer Module

2.2.1.2.1 Buffer Module Description

A Buffer models the management of flow (movement) of items, which are transformed to meet the customer demand. Buffer handles most of the material/inventory planning functionality. A Buffer typically only models the flow of items at a specific location. A Buffer is Item Specific so for each Item there might be a Buffer some where in the Supply Chain. The Buffer Module manages safety stocks, safety times, and lot sizing constraints.

Prompt Name	Prompt Name
Buffer_Name	Demand Strategy Types
Buffer Role	Types of Pull Systems
Transfer Buffer Name	Transfer Signal Type
Production Buffer Name	Buffer Name
Customer Driven Buffer Name	Buffer Number
Buffer Flow Policy	Buffer Wait Signal Number
Buffer Constrained Type	Upstream Buffer
Buffer Number	Buffer Send Signal Number
Min On Hand	Production Signal Type
Excess On Hand	Production Buffer
Buffer Wait Time	Production Buffer Number
Output Buffer Statistics	ProdBuffer Wait Signal Number
Time Spent In Buffer	Upstream Production Buffer
Items Into Buffer	Buffer SendSignal Number
Items Out Of Buffer	Customer Driven Data
WIP In Buffer	Time Between Orders
Minimum Time Spent In Buffer	Downstream Customer Buffer
Average Time Spent In Buffer	Cust_Buffer WaitSignal Number
Maximum Time Spent In Buffer	Cust_Buffer SendSignal Number
Items Into Buffer Per Hour	Reorder Signal Type
Total Items Into Buffer	Reorder Buffer Name
Items Out Of Buffer Per Hour	Reorder Buffer Number
Total Items Out Of Buffer	Reorder Buffer Level
WIP In Buffer Per Hour	Reorder Buffer Quantity
WIP At End Of Simulation	ReorderB WaitSignal Number
Strategy No	Upstream Reorder Buffer
Item Name	ReorderB SendSignal Number
Item Number	

> Buffer Name

This operand is used to name the Buffer Process. The Buffer Name is further used to specify the Buffer Queue in front of the Buffer.

> Buffer Role

This operand allows the Supply Chain Analyst to specify what sort of role the Buffer will play. It can be **Transfer, Production or Customer Driven**. When an item enters a Buffer there is a specific waiting time associated with this Buffer. The Buffer Role specifies what should happen when the Buffer waiting time has expired.

> Transfer Buffer Name

This Operand specifies the name of Transfer Buffer, if the transfer option is selected under the Buffer Role Policy.

> Production Buffer Name

This Operand specifies the name of Production Buffer, if the transfer option is selected under the Buffer Role Policy.

> Customer Driven Buffer Name

This Operand specifies the name of Customer Driven Buffer, if the transfer option is selected under the Buffer Role Policy.

> Buffer Flow Policy

There are two types of flow policies, Unconstrained and Constrained. If Unconstrained is selected it means that the Buffer can hold an infinite number of items. If constrained is selected it means that for some reason there are certain constraints within this Buffer.

> Buffer Constrained Type

This operand allows the Supply Chain Planner to specify what sort of flow policy should be used. For the time being there are only one type of policy called Basic Flow.

> Buffer Number

This operand only allows for a unique number for a Buffer.

> Min On Hand

This operand specifies what the minimum amount of items should be within the Buffer. For instance if the Min On Hand is 5 it means that the "safety stock" within this Buffer can never be less than 5 units.

> Excess On Hand

This operand specifies what the maximum amount of items should be within the Buffer. For instance if the Excess On Hand is 15 it means that the capacity of the Buffer can never be more than 15 units.

> Buffer Wait Time

This operand specifies what the minimum time an item has to wait in a Buffer before it can move to the next process.

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> Output Buffer Statistics

If this modifier is selected it will allow the Supply Chain Analyst to select various statistics associated with the Buffer. There are two types of statistics Time in Buffer Statistics and Number In Buffer Statistics.

> Time Spent In Buffer

If this modifier is selected the Supply Chain Analyst will be able to select various statistics about the amount of time an item spends in the Buffer.

> Items Into Buffer

If this modifier is selected the Supply Chain Analyst will be able to select various statistics about the amount of items that entered into the Buffer.

> Items Out of Buffer

If this modifier is selected the Supply Chain Analyst will be able to select various statistics about the amount of items that exited out of the Buffer.

> WIP In Buffer

If this modifier is selected the Supply Chain Analyst will be able to select various statistics about the Work In Process of items in the Buffer.

> Minimum Time Spent In Buffer

If this modifier is selected the Minimum Time spent in the Buffer will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Average Time Spent In Buffer

If this modifier is selected the Average Time spent in the Buffer will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Maximum Time Spent In Buffer

If this modifier is selected the Maximum Time spent in the Buffer will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Items Into Buffer Per Hour

If this modifier is selected the Total Number of Items per hour that entered the Buffer will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

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➢ Total Items Into Buffer

If this modifier is selected the Total Number of Items that entered the Buffer will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Items Out Of Buffer Per Hour

If this modifier is selected the Total Number of Items per hour that exited the Buffer will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Total Items Out Of Buffer

If this modifier is selected the Total Number of Items that exited the Buffer will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ WIP In Buffer Per Hour

If this modifier is selected the Work In Process in the Buffer per hour will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Wip At End Of Simulation

If this modifier is selected the Total Work In Process in the Buffer will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Strategy Number

This operand only allows for a unique number for the Demand Strategy.

➢ Item Name

This operand allows the Supply Chain Analyst to specify which Item should be used in this Demand Strategy.

➢ Item Number

This operand only allows for a unique number for the Item.

➢ Demand Strategy Types

This operand only allows the Supply Chain Analyst to select between three types of Demand Strategies, *Push System, Pull System or Reorder System*. If the *Push System* is selected all the items within the Buffer will be pushed forward into the next processes. If *Pull System* is selected a specific control logic will be used to allow the items in the Buffer to advance to the next processes. If *Reorder System* is selected a

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specific control logic will be used to allow the items in the Buffer to advance to the next processes.

> Types Of Pull Systems

There are three types of Pull Systems, Transfer Kanban, Production Kanban, and Customer Driven.

Transfer Kanban System means that the item will wait in a separate holding area next to the Buffer for a signal of the Downstream Buffer. Once the signal is received the item can be transferred to the Downstream Buffer. The transfer option allows for other items to enter the Buffer, because the item in transfer released some capacity.

Production Kanban System means that the item will wait in the Buffer for a signal of the Downstream Buffer. Once the signal is received the item can be transferred to the Downstream Buffer. The production option does not allow for other items to enter the Buffer, because the item in cannot transfer until the signal from the Downstream Buffer has been received. All incoming items will have to wait in front of the Buffer for available capacity.

Customer Driven System means that the item will wait in a separate holding area next to the Buffer for a signal of the upstream Buffer based on a specified Customer driven Signal. The Signal is send on a time bases and not by a downstream buffer. The Customer Driven option allows for other items to enter the Buffer, because the item in transfer released some capacity.

> Transfer Signal Type

This Operand allows the user to specify what sort of Signal type should be used at this Buffer. The Buffer can either Wait for a Signal from a Downstream Buffer, Send a Signal to an Upstream Buffer or Wait and Send a Signal at the same time.

> Buffer Name

This operand specifies the name of the Downstream Buffer that needs to send the signal to this Buffer.

> Buffer Number

This operand specifies the unique number of the Downstream Buffer that needs to send the signal to this Buffer.

> Buffer Wait Signal Number

This operand specifies the unique number of the Signal the Downstream Buffer needs to send to this Buffer.

> Upstream Buffer

This operand specifies the name of the Upstream Buffer that waits for the Signal from this Buffer.

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> Buffer Send Signal Number

This operand specifies the unique number of the Signal that this Buffer needs to send, in order to release items in an Upstream Buffer.

> Production Buffer Signal Type

This Operand allows the user to specify what sort of Signal type should be used at this Buffer. The Buffer can either Wait for a Signal from a Downstream Buffer, Send a Signal to an Upstream Buffer or Wait and Send a Signal at the same time.

> Production Buffer

This operand specifies the name of the Downstream Buffer that needs to send the signal to this Buffer.

> Production Buffer Number

This operand specifies the unique number of the Downstream Buffer that needs to send the signal to this Buffer.

> ProdBuffer Wait Signal Number

This operand specifies the unique number of the Signal the Downstream Buffer needs to send to this Buffer.

> Upstream Production Buffer

This operand specifies the name of the Upstream Buffer that waits for the Signal from this Buffer.

> Buffer SendSignal Number

This operand specifies the unique number of the Signal that this Buffer needs to send, in order to release items in an Upstream Buffer.

> Customer Driven Data

This operand specifies what type of Customer Data will be used to complete this demand strategy.

> Time Between Buffers

This operand specifies what the item release frequency from this Buffer will be.

> Downstream Customer Buffer

This operand specifies the name of the Downstream Buffer that needs to send the signal to this Buffer.

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> Cust_Buffer WaitSignal Number

This operand specifies the unique number of the Signal the Downstream Buffer needs to send to this Buffer.

> Cust_Buffer SendSignal Number

This operand specifies the unique number of the Signal that this Buffer needs to send, in order to release items in an Upstream Buffer.

> Reorder Signal Type

This Operand allows the user to specify what sort of Signal type should be used at this Buffer. The Buffer can only Wait and Send a Signal at the same time.

> Reorder Buffer Name

This operand specifies the name of the Downstream Buffer that needs to send the signal to this Buffer.

> Reorder Buffer Number

This operand specifies the unique number of the Downstream Buffer that needs to send the signal to this Buffer.

> Reorder Buffer Level

If the Buffer Level drops below the Reorder Buffer Level a Signal will be sent to an Upstream Buffer from which items for this Buffer are replenished.

> Reorder Buffer Quantity

This Operand specifies what the reorder quantity should be. If the Reorder Quantity is specified as 5 units every time the Buffer Level drops below the Reorder Level the Buffer level will be replenished with 5 units.

> ReorderB WaitSignal Number

This operand specifies the unique number of the Signal the Downstream Buffer needs to send to this Buffer.

> Upstream Reorder Buffer

This operand specifies the name of the Upstream Buffer that needs to wait for the Replenishment signal to this Buffer.

> ReorderB SendSignal Number

This operand specifies the unique number of the Signal that this Buffer needs to send, in order to release items in an Upstream Buffer.

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2.2.1.3 Decision Module

2.2.1.3.1 Decision Module Description

This module allows for decision-making processes in the system. It includes options to make decisions based on one or more conditions (e.g., if entity type is Gold Card) or based on one or more probabilities (e.g., 75% true; 25% false).
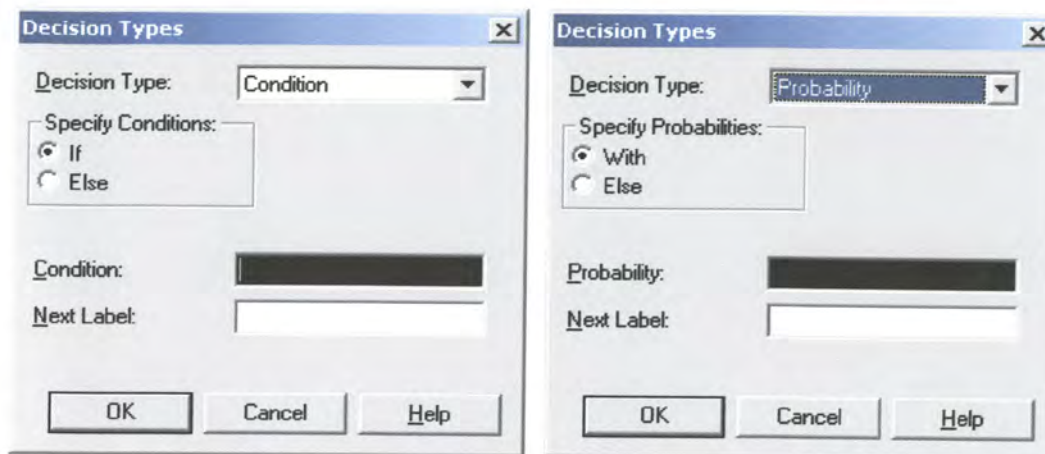
2.2.1.3.2 Decision Module Prompts

Prompt Name	Prompt Name
Decision Type	Next Label
Specify Conditions	Specify Probabilities
Condition	Probability

> Decision Type

Indicates whether the decision is based on a condition (if X>Y) or by chance/percentage (60% yes, 40% no). The type can be specified as either Condition or Probability. This allows for any number of conditions or probabilities to be specified as well as an "else" exit.

> Specify Conditions

This operand is used to specify what type of condition will be used in the decision making process.

> Condition

This operand is used to specify the expression or condition for evaluation.

> Next Label

This operand can be used if the decision module is not connected via the connection module. This label will specify the module to which the item will be routed.

➢ Specify Probabilities

This operand is used to specify what the type of probability will be for making a decision.

➢ Probability

This operand is used to specify what the probability value will be for making a decision.

2.2.1.4 Location Module

2.2.1.4.1 Location Module Description

This module is used to specify a physical location within a supply chain. It consists of a geographical description but it can also be a description such as a loading dock in a warehouse.

2.2.1.4.2 Location Module Prompts

Prompt Name	Prompt Name
Location Name	Location Number
Site Name	

➢ Location Name

This prompt is used to name the Location.

➢ Location Number

This prompt only allows for a unique number for the Location.
➢ Site Name

This prompt is used to name the Site to which the location belong. The Site could correspond to a plant, to a portion of a plant, to distribution centres, warehouses, or stores.

2.2.1.5 Operation Module

2.2.1.5.1 Operation Module Description

An Operation models a process, activity, or action that transforms or moves intermediate or final goods (items) through the supply Chain. Operations cause material to flow from certain Buffers and, after transformation, to flow to other Buffers.
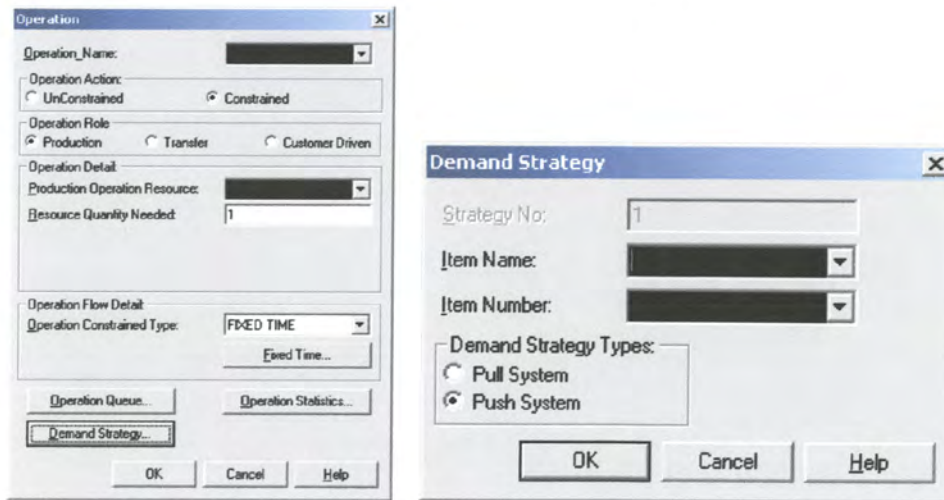
2.2.1.5.2 Operation Module Prompts

Prompt Name	Prompt Name
Operation Action	Min Time Spent In Operation
Operation Role	Avg Time Spent In Operation
Transfer Operation Resource	Max Time Spent In Operation
Production Operation Resource	Items Into Operation Per Hour
Customer Driven Operation	Total Items Into Operation
Operation Process Time	Items out of Operation Per Hour
Operation Setup time	Total Items Out of Operation
Operation Constrained Type	WIP In Operation Per Hour
Operation Name	WIP at end of Simulation
Fixed Process Time	Strategy Number
Fixed Setup Time	Item Name
Finish Time	Item Number
Operation Queue Type	Demand Strategy Types
Operation Queue Name	Types of Pull Systems
Queue Capacity	Operation Name
Ranking Rule	Operation Number
Dispose Balked Items	Operation Wait Number
Queue Output Statistics	Upstream Operation
Time In Queue Statistics	Operation Send Signal Number
Number In Queue Statistics	Transfer Signal Type
Min Time In Queue	Production Signal Type
Avg Time In Queue	Production Operation Name

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Max Time In Queue	Production Operation Number
Min Number In Queue	PropOper Wait Signal Number
Avg Number In Queue	Upstream Production Operation
Max Number In Queue	Operation SendSignal Number
Operation Output Statistics	Customer Driven Data
Time Spent In Operation	Time Between Orders
Number Into Operation	Downstream Customer Operation
Number Out of Operation	Cust_Oper WaitSignal Number
WIP In Operation	Cust_Oper SendSignal Number

> Operation Action

This operand specifies what type of action will be performed within this operation. There are two types of action Unconstrained and Constrained. If Unconstrained is selected it means that the operation does not have any constraints and that the capacity is unlimited. If Constrained is selected it means that for some reason there are a constraining factor within the Operation.

> Operation Role

This Operand appears as soon as the Operation Action is specified as constrained. This operand allows the Supply Chain Analyst to specify what sort of role the Operation will play. It can be **Transfer, Production or Customer Driven**. When an item enters an Operation there is a specific waiting time associated with this Operation. The Operation Role specifies what should happen when the Operation waiting time has expired.

> Production Operation Resource

This Operand specifies the name of Production Buffer, if the transfer option is selected under the Buffer Role Policy.

> Transfer Operation Resource

This Operand specifies the name of Transfer Operation Resource, if the Transfer option is selected under the Transfer Role Policy.

> Customer Driven Operation

This Operand specifies the name of Customer Driven Operation, if the transfer option is selected under the Operation Role Policy.

> Resource Quantity Needed

This operand is used to specify what quantity of the Resource is needed when an item enters an operation.

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➢ Operation Process Time

This operand appears if the Operation action is set to Unconstrained. It is further used to specify the amount of time the item need to spent within the operation.

➢ Operation Setup Time

This operand appears if the Operation action is set to Unconstrained. It is further used to specify the amount of time the item need to spent before entering the operation. Typically this will be a set-up time used to make sure that all the necessary preparations has been completed before the actual operation starts.

➢ Operation Constrained Type

This operand appears as soon as the Operation Action is specified as constrained. Only one option is available at this time, the option of fixed time. Fixed time means that there are specific times for finishing the operation.

➢ Operation_Name

This operand is used to specify the name of the operation.

➢ Fixed Process Time

This operand is used to specify the amount of time the item need to spent within the operation.

➢ Fixed Setup Time

This operand is used to specify the amount of time the item need to spent before the operation starts.

➢ Finish Time

This operand is used to specify the amount of time the item need to spent after the operation has finished.

➢ Operation Queue Type

This operand specifies what type of queue will be associated with the operation. There are two types of queues Unconstrained and Constrained. If Unconstrained is selected it means that the queue does not have any constraints and that the capacity is unlimited. If Constrained is selected it means that for some reason there are a constraining factor within the queue.

➢ Operation Queue Name

This operand is used to specify the name of the Queue.

➤ Queue Capacity

If Queue is specified to be constrained the maximum capacity for this queue should be specified. This means that if a queue can only hold 5 units the Operation Queue Capacity should be set to 5.

➤ Ranking Rule

Ranking Rule specifies the order for a single queue and can be one of the following:

FIFO: First In, First Out. The entities are ranked based on their time of insertion in the queue. SIMAN inserts each arriving entity as the last entity in the queue until the next arrival.

LIFO: Last In, First Out.   The entities are ranked based on their time of insertion in the queue. Each arriving entity is inserted as the first entity in the queue.

LVF (Rule expression): Low Value First of Rule expression. The entities are ranked in the queue low value first, based on the value of the specified expression.

HVF (Rule expression): High Value First of Rule expression. The entities are ranked in the queue high value first, based on the value of the specified expression.

➤ Dispose Balked Items

If this modifier is specified all the balked entities in this queue will be disposed.

➤ Queue Output Statistics

If this modifier is selected it will allow the Supply Chain Analyst to select various statistics associated with the queue. There are two types of statistics Time in Queue Statistics and Number In Queue Statistics.

➤ Time In Queue Statistics

This modifier allows the Supply Chain Analyst to select various statistics associated with the how much time an entity spends in a queue.

➤ Number In Queue Statistics

This modifier allows the Supply Chain Analyst to select various statistics associated with the how much entities are in the queue during the Simulation Run.

➤ Minimum Time In Queue

If this modifier is selected the Minimum Time spent in the Queue will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Average Time In Queue

If this modifier is selected the Average Time spent in the Queue will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Maximum Time In Queue

If this modifier is selected the Maximum Time spent in the Queue will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Minimum Number In Queue

If this modifier is selected the Minimum Number in the Queue will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Average Number In Queue

If this modifier is selected the Average Number in the Queue will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Maximum Number In Queue

If this modifier is selected the Maximum Number in the Queue will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Operation Output Statistics

If this modifier is selected it will allow the Supply Chain Analyst to select various statistics associated with the Operation. There are two types of statistics Time in Operation Statistics and Number In Operation Statistics.

> Time Spent In Operation

If this modifier is selected the Supply Chain Analyst will be able to select various statistics about the amount of time an item spends in the Operation.

> Number Into Operation

If this modifier is selected the Supply Chain Analyst will be able to select various statistics about the amount of items that entered into the Operation.

> Number Out Of Operation

If this modifier is selected the Supply Chain Analyst will be able to select various statistics about the amount of items that exited out of the Operation.

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➢ WIP In Operation

If this modifier is selected the Supply Chain Analyst will be able to select various statistics about the Work In Process of items in the Operation.

➢ Min Time Spent In Operation

If this modifier is selected the Minimum Time spent in the Operation will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Avg Time Spent In Operation

If this modifier is selected the Average Time spent in the Operation will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Max Time Spent In Operation

If this modifier is selected the Maximum Time spent in the Operation will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Items Into Operation Per Hour

If this modifier is selected the Total Number of Items per hour that entered the Operation will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Total Items Into Operation

If this modifier is selected the Total Number of Items that entered the Operation will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Items OutOf Operation Per Hour

If this modifier is selected the Total Number of Items per hour that exited the Operation will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Total Items Out Of Operation

If this modifier is selected the Total Number of Items that exited the Operation will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> ➢ WIP In Operation Per Hour

If this modifier is selected the Work In Process in the Operation per hour will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> ➢ WIP At End Of Simulation

If this modifier is selected the Total Work In Process in the Operation will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> ➢ Strategy No

This operand only allows for a unique number for the Demand Strategy.

> ➢ Item Name

This operand allows the Supply Chain Analyst to specify which Item should be used in this Demand Strategy.

> ➢ Item Number

This operand only allows for a unique number for the Item.

> ➢ Demand Strategy Types

This operand only allows the Supply Chain Analyst to select between two types of Demand Strategies, *Push System and Pull System*. If the *Push System* is selected all the items within the Buffer will be pushed forward into the next processes. If *Pull System* is selected a specific control logic will be used to allow the items in the Operation to advance to the next processes.

> ➢ Types of Pull Systems

There are three types of Pull Systems, Transfer Kanban, Production Kanban, and Customer Driven.

Transfer Kanban System means that the item will wait in a separate holding area next to the Buffer for a signal of the Downstream Buffer. Once the signal is received the item can be transferred to the Downstream Buffer. The transfer option allows for other items to enter the Buffer, because the item in transfer released some capacity.

Production Kanban System means that the item will wait in the Buffer for a signal of the Downstream Buffer. Once the signal is received the item can be transferred to the Downstream Buffer. The production option does not allow for other items to enter the Buffer, because the item in cannot transfer until the signal from the Downstream Buffer has been received. All incoming items will have to wait in front of the Buffer for available capacity.

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Customer Driven System means that the item will wait in a separate holding area next to the Buffer for a signal of the upstream Buffer based on a specified Customer driven Signal. The Signal is send on a time bases and not by a downstream buffer. The Customer Driven option allows for other items to enter the Buffer, because the item in transfer released some capacity.

➤ Operation Name

This operand specifies the name of the Downstream Operation that needs to send the signal to this Operation.

➤ Operation Number

This operand specifies the unique number of the Downstream Operation that needs to send the signal to this Operation.

➤ Operation Wait Number

This operand specifies the unique number of the signal for which the Operation waits.

➤ Upstream Operation

This operand specifies the name of the Upstream Operation that sends a signal to another operation.

➤ Operation Send Signal Number

This operand specifies the unique number of the signal that will be sent from this operation.

➤ Transfer Signal Type

This Operand allows the user to specify what sort of Signal type should be used at this Operation. The Operation can either Wait for a Signal from a Downstream Operation, Send a Signal to an Upstream Operation or Wait and Send a Signal at the same time.

➤ Production Signal Type

This Operand allows the user to specify what sort of Signal type should be used at this Operation. The Operation can either Wait for a Signal from a Downstream Operation, Send a Signal to an Upstream Operation or Wait and Send a Signal at the same time.

➤ Production Operation Name

This operand specifies the name of the Downstream Operation needs to send the signal to this Operation.

➤ Production Operation Number

This operand specifies the unique number of the Downstream Operation that needs to send the signal to this Operation.

➢ ProdOper Wait Signal Number

This operand specifies the unique number of the signal for which the Operation waits.

➢ Upstream Production Operation

This operand specifies the name of the Upstream Operation that sends a signal to another operation.

➢ Operation SendSignal Number

This operand specifies the unique number of the signal that will be sent from this operation.

➢ Customer Driven Data

This operand specifies what type of Customer Data will be used to complete this demand strategy.

➢ Time Between Orders

This operand specifies what the item release frequency from this Operation will be.

➢ Downstream Customer Operation

This operand specifies the name of the Downstream Operation that needs to send the signal to this Operation.

➢ Cust_Oper WaitSignal Number

This operand specifies the unique number of the Signal the Downstream Operation needs to send to this Operation.

➢ Cust_Oper SendSignal Number

This operand specifies the unique number of the Signal that this Operation needs to send, in order to release items in an Upstream Operation.

2.2.1.6 Site Module

2.2.1.6.1 Site Module Description

The Site defines all those assets of the Supply Chain used in manufacturing, and distribution that are controlled by one team of decision makers. The Site can correspond to a plan, to a portion of a plant, to distribution centres, warehouses, or stores. The Site should not be viewed as a physical division at a particular location. Within a Site there will be multiple locations.
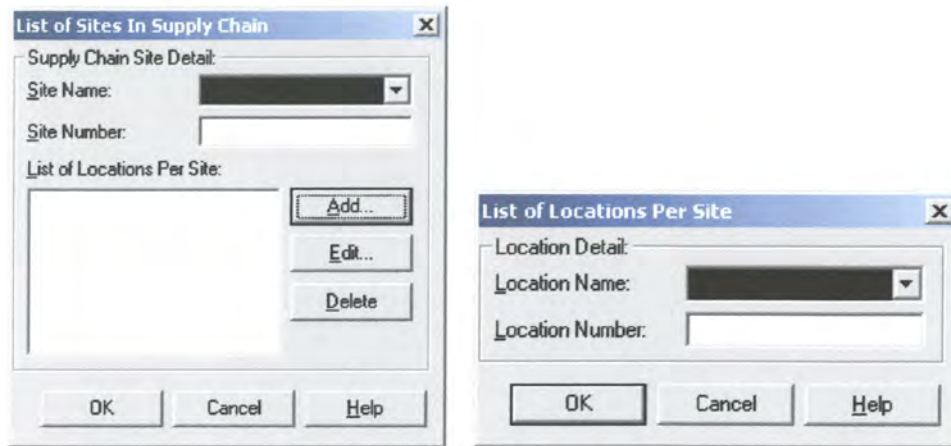
2.2.1.6.2 Site Prompts

Prompt Name	Prompt Name
Site Name	Location Name
Site Number	Location Number

> Site Name

This operand is used to specify the name of the Site.

> Site Number

This operand is used to uniquely identify the Site.

> Location Name

For each Site there will be some Locations, and this operand is used to specify the name of the Location.

> Location Number

This operand is used to uniquely identify the Location.

2.2.1.7 Supply Plan Module

2.2.1.7.1 Supply Plan Module Description

This module is used to specify the hourly supply of an item. By using different Planning Horizons the Supply Chain Analyst can specify the supply plan of an item on a hourly bases.
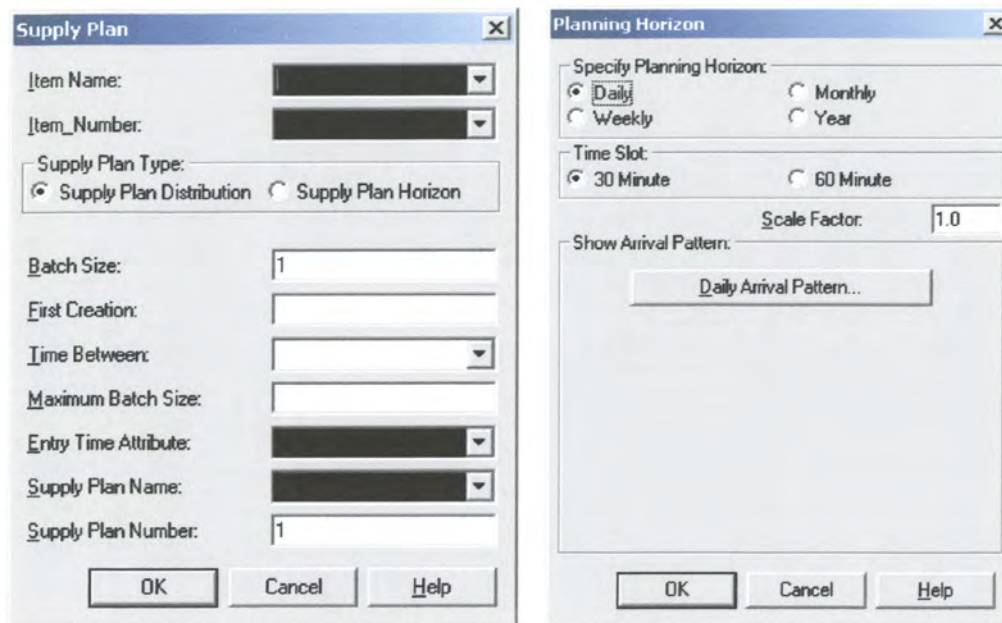
2.2.1.7.2 Supply Plan Prompts

Prompt Name	Prompt Name
Item Name	Entry Time Attribute
Item_Number	Supply Plan Name
Supply Plan Type	Supply Plan Number
Batch Size	Specify Planning Horizon
First Creation	Time Slot
Time Between	Scale Factor
Maximum Batch Size	

> Item Name

This operand is used to specify the name of the Item, which will be linked to this specific supply plan.

> Item_Number

This operand is used to specify the unique number of the Item to be used.

> Supply Plan Type

There are two types of Supply plans, Supply Plan Distribution or a Specified Planning Horizon. If the Supply Plan Distribution is selected the supply of an Item will be based upon a specified Statistical distribution or expression. If the Supply Plan Horizon is selected it means that the Supply of an item will be based on a predefined planning horizon.

> Batch Size

This operand is used to specify the number of items in each batch creation.

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> First Creation

This operand is used to specify the simulation time at which the first batch creation should occur (in base time units).

> Time Between

This operand is used to specify the Time between batch creations in base time units.

> Maximum Batch Size

This operand is used to specify the maximum number of batches to be created.

> Entry Time Attribute

This operand is used to mark the entity when it enters the system for the first time.

> Supply Plan Name

This operand is used to name the Supply plan.

> Supply Plan Number

This operand is used to uniquely identify the Supply Plan.

> Specify Planning Horizon

This operand is used to specify what planning horizon should be used. There are four types of Planning Horizons, Daily, Weekly, Monthly and Yearly.

> Time Slot

This operand is used to specify what the time slot of supply should be; at this moment there are two types of time slots 60 minutes and 30 minutes. When the time slot is selected the entire day will be divided into the equal timeslots for the entire day.

> Scale Factor

This operand is used to specify what the increase of the supply should be based on. If the scale factor is specified as 1.0 and the supply in the timeslot from 08:00 to 09:00, 50 then the supply will be 50. If the scale factor increase then the supply will also increase by that factor.

2.2.1.8 Transportation Module

2.2.1.8.1 Transportation Module Description

The transportation module is used to specify what type of transportation is needed between different locations. At this point the transportation can either be constrained or unconstrained. Constrained means that the transportation between two different locations is dependent on some sort of material haling equipment or material operator.

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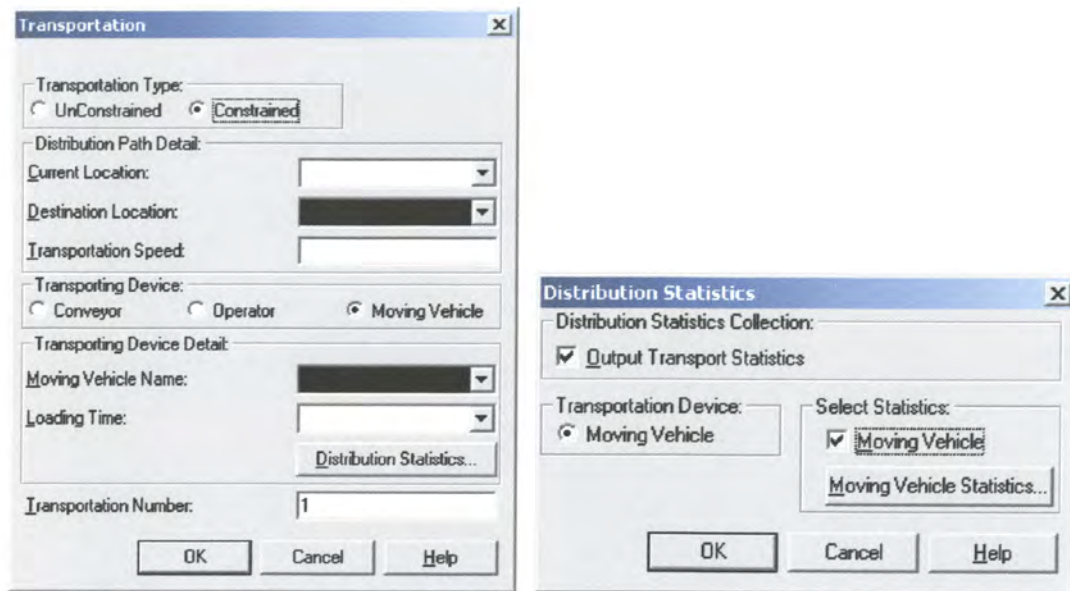
2.2.1.8.2 Transportation Prompts

Prompt Name	Prompt Name
Transportation Type	Transportation Speed
Current Location	Output Transport Statistics
Destination Location	Conveyor
Transportation Time	Operator
Route Time	Moving Vehicle
Transporting Device	Items Waiting For Conveyor
Loading Time	Time Waiting For Conveyor
Moving Vehicle Name	Items Waiting For Vehicle
Conveyor Name	Time Waiting For Vehicle
Operator Name	Items Waiting For Operator
Transportation Number	Time Waiting For Operator

> Transportation Type

This operand defines what type of transportation will be used. There are two types of transportation constrained and unconstrained. Constrained means that the transportation between two different locations is dependent on some sort of material haling equipment or material operator. If it is specified as unconstrained it means that there are no limit on the transportation.

> Current Location

This operand specifies the name of the current location from where an item will be transported.

> Destination Location

This operand specifies the name of the destination location to where an item will be transported.

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➤ Transportation Time

This operand is visible when the transporting device is specified as an Operator. If Operator is selected then transportation time is the time associated with the time it will take an operator to take the item from on location to another.

➤ Route Time

This operand is visible when the transportation type is specified as unconstrained. The Route time is the time associated with the time it will take an item to go from on location to another.

➤ Transporting Device

This operand will be visible if the transportation type is specified as constrained. There are three types of transporting devices, moving vehicle, conveyor and an operator.

➤ Loading Time

This operand is used to specify what the loading time will be if loading needs to be performed before transportation.

➤ Moving Vehicle Name

If the Transporting Device is specified as a Moving Vehicle one will need to specify the name of the Moving Vehicle that will be used.

➤ Conveyor Name

If the Transporting Device is specified as a Conveyor one will need to specify the name of the Conveyor that will be used.

➤ Operator Name

If the Transporting Device is specified as a Operator one will need to specify the name of the Conveyor that will be used.

➤ Transportation Number

This operand is used to uniquely identify the Transportation.

➤ Transportation Speed

This operand is visible if the transporting device is either a Moving Vehicle or a Conveyor. It is further used to specify at what speed the Transporting device should transport the item.

➤ Output Transport Statistics

If this modifier is selected it will allow the Supply Chain Analyst to select various statistics associated with the Conveyor. There are different types of Statistics if the Transportation

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Type is specified as constrained, so for one will have statistics for conveyors, moving vehicles and operators.

> Conveyor

This modifier is highlighted if the Transporting Device is specified as a Conveyor. If the Transporting Device is specified as a Conveyor there are two types of statistics that can be recorded, average number of Items waiting in front of the Conveyor and average time an item wait in front of a Conveyor.

> Operator

This modifier is highlighted if the Transporting Device is specified as an Operator. If the Transporting Device is specified as an Operator there are two types of statistics that can be recorded, average number of Items waiting for the Operator and average time an item wait for an Operator.

> Moving Vehicle

This modifier is highlighted if the Transporting Device is specified as a Moving Vehicle. If the Transporting Device is specified as a Moving Vehicle there are two types of statistics that can be recorded, average number of Items waiting for the Moving Vehicle and average time an Item wait in front of a Moving Vehicle.

> Items Waiting For Conveyor

If this modifier is selected the Average Number of Items waiting in front of the conveyor will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Time Waiting For Conveyor

If this modifier is selected the Average Time that Items wait in front of the conveyor will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Items Waiting For Vehicle

If this modifier is selected the Average Number of Items waiting for a Moving Vehicle will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> Time Waiting For Vehicle

If this modifier is selected the Average Time that Items wait for a Moving Vehicle will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Items Waiting For Operator

If this modifier is selected the Average Number of Items waiting for an Operator will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Time Waiting For Operator

If this modifier is selected the Average Time that Items wait for an Operator will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

2.2.2 Advanced Supply Chain Modules

These modules allows the user to specify more details about the type of Material handling equipment, Demand plan, Inventory System and Supply Chain Analyses.

2.2.2.1 Conveyor Module

2.2.2.1.1 Conveyor Module Description

The Conveyor module allows the definition of either an accumulating or non-accumulating conveyor for unit movement between locations within a Supply Chain.

When using a conveyor to transfer between locations within a Supply Chain, the conveyor must be defined using the Conveyor module.

2.2.2.1.2 Conveyor Module Prompts

Prompt Name	Prompt Name
Conveyor Name	Number Conveying
Conveyor Segment Set	Number Accumulated
Conveyor Velocity	Length Accumulated
Conveyor Cell Size	Length Conveying
Maximum Cell Size	Utilization
Item Size	Select Conveyor Failure
Conveyor Status	Time Between Conveyor Failures
Conveyor Type	Conveyor Downtime
Output Conveyor Statistics	Specify Conveyor
Accumulating Conveyor	Restart Velocity
Non-Accumulating Conveyor	

➢ Conveyor Name

This operand defines the name of the conveyor.

➢ Conveyor Segment Set

This operand determines the name of the segment set that is associated with the specified conveyor. The segment set defines the locations between which the conveyor transfers items.

➢ Conveyor Velocity

This operand specifies the initial speed at which items move along the conveyor in length.

➢ Conveyor Cell Size

This operand specifies the length of each conveyor cell.

➢ Maximum Cell Size

This operand specifies the maximum number of conveyor cells that any given entity will access at a time.

➢ Item Size

This operand specifies the size of an Item.

➢ Conveyor Status

This operand specifies the Initial status of the conveyor.

➢ Conveyor Type

There are two types of conveyors, accumulating and non-accumulating.

➢ Output Conveyor Statistics

If this modifier is selected it will allow the Supply Chain Analyst to select various statistics associated with the Conveyor. There are different types of Statistics for the two types of Conveyors.

➢ Accumulating Conveyor

Accumulating conveyors always move - loading or unloading of an item creates local blockages only. Items not affected by the local blockages continue to move on the conveyor.

➢ Non-Accumulating Conveyor

Non-accumulating conveyors completely stop to allow an item to get on or off the conveyor. These stops cause each item on the conveyor to stop until the conveyor starts again.

➢ Number Conveying

If this modifier is selected the Total Number of Items conveying on the conveyor the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Number Accumulated

This applies only to accumulating conveyors and returns the total number of entities that are accumulated at all accumulation points on the conveyor. If this modifier is selected the Total Number of Items accumulated on the conveyor will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Length Accumulated

This applies only to accumulating conveyors and provides the total length occupied by accumulated entities at all accumulation points on the conveyor. If this modifier is selected the total length occupied by accumulated items on the conveyor will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Length Conveying

Provides the length of cells occupied by all items that are in a conveying state. It does not include accumulated entities. If this modifier is selected the total length occupied by all the items conveying on the conveyor will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Utilization

If this modifier is selected the utilization of the conveyor will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

> ➤ Select Conveyor Failure

This operand specifies the name of the Conveyor Failure.

> ➤ Time Between Conveyor Failures

This operand specifies the time between conveyor failures, also called the uptime.

> ➤ Conveyor Down Time

This operand specifies the time to repair a conveyor failure, also called the repair time.

> ➤ Specify Conveyor

This operand specifies the name of the conveyor that will fail.

> ➤ Restart Velocity

This operand specifies what the restart velocity should be after a conveyor failure.

2.2.2.2 Demand Plan Module

2.2.2.2.1 Demand Plan Module Description

This module is used to specify the hourly demand of an item. By using different Planning Horizons the Supply Chain Analyst can specify the demand plan of an item on a hourly bases.

2.2.2.2.2 Demand Plan prompts

Prompt Name	Prompt Name
Item Name	Entry Time Attribute
Item_Number	Demand Plan Name
Demand Plan Type	Demand Plan Number
Batch Size	Specify Planning Horizon
First Creation	Time Slot
Time Between	Scale Factor
Maximum Batch Size	

➢ Item Name

This operand is used to specify the name of the Item, which will be linked to this specific demand plan.

➢ Item_Number

This operand is used to specify the unique number of the Item to be used.

➢ Demand Plan Type

There are two types of Demand plans, Demand plan distribution or a Specified Planning Horizon. If the Demand Plan Distribution is selected the demand of an Item will be based upon a specified Statistical distribution or expression. If the Demand Plan Horizon is selected it means that the demand of an item will be based on a predefined planning horizon.

➢ Batch Size

This operand is used to specify the number of items in each batch creation.

➢ First Creation

This operand is used to specify the simulation time at which the first batch creation should occur (in base time units).

➢ Time Between

This operand is used to specify the Time between batch creations in base time units.

➢ Maximum Batch Size

This operand is used to specify the maximum number of batches to be created.

➢ Entry Time Attribute

This operand is used to mark the entity when it enters the system for the first time.

> ➤ Demand Plan Name

This operand is used to name the Demand plan.

> ➤ Demand Plan Number

This operand is used to uniquely identify the Demand Plan.

> ➤ Specify Planning Horizon

This operand is used to specify what planning horizon should be used. There are four types of Planning Horizons, Daily, Weekly, Monthly and Yearly.

> ➤ Time Slot

This operand is used to specify what the time slot of demand should be at this moment there are two types of time slots 60 minutes and 30 minutes. When the time slot is selected the entire day will be divided into the equal timeslots for the entire day.

> ➤ Scale Factor

This operand is used to specify what the increase of the demand should be based on the scale factor. If the scale factor is specified as 1.0 and the demand in the timeslot from 08:00 to 09:00, 50 then the demand will be 50. If the scale factor increase then the demand will also increase by that factor.

2.2.2.3 Distribution Paths Module

2.2.2.3.1 Distribution Paths Module Description

This module is used to specify all the different Distribution paths within the Supply Chain. There are basically four types of distribution paths, a path where no material handling equipment is needed, a path where an Operator is needed to move the items, a path for Conveyors and a path for Material Handling Equipment.
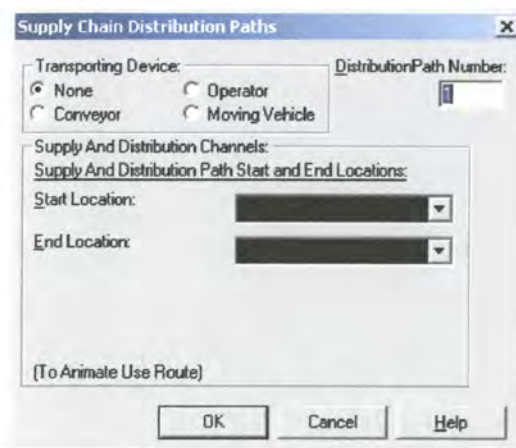
2.2.2.3.2 Distribution Path Prompts

Prompt Name	Prompt Name
Distribution Path Number	Segment Length
Transporting Device	Operator Start Location
Start Location	Operator End Location
End Location	Vehicle Start Location
Conveyor Start Location	Vehicle End Location
Conveyor End Location	Distance Name
Segment Set Name	Distance Length

> ➢ Distribution Path Number

This Operand is used to uniquely identify the Distribution Path.

> ➢ Transporting Device

This operand is used to specify what sort of transporting device will be needed for this distribution path. There are for types, none, operator, conveyor and transporter.

> ➢ Start Location

This operand is used specify the start location from where the item will be routed if the transporting device is set to none.

> ➢ End Location

This operand is used specify the end location to where the item will be routed if the transporting device is set to none.

> ➢ Conveyor Start Location

This operand is used specify the start location from where the item will be conveyed by the conveyor if the transporting device is set to conveyor.

> ➢ Conveyor End Location

This operand is used specify the end location to where the item will be conveyed by the conveyor if the transporting device is set to conveyor.

> ➢ Segment Set Name

The Segment module defines the segments that make up the path of the conveyor. A conveyor path is represented as a series of connected segments where each segment is a directed link between two locations. A beginning station and a set of next location-distance pairs define the conveyor path.

> Segment Length

This operand is used to specify the distance from the previous location.

> Operator Start Location

This operand is used specify the start location from where the item will be routed if the transporting device is set to Operator.

> Operator End Location

This operand is used specify the end location to where the item will be routed if the transporting device is set to Operator.

> Vehicle Start Location

This operand is used specify the start location from where the item will be transported by the Moving Vehicle if the transporting device is set to Moving Vehicle.

> Vehicle End Location

This operand is used specify the start location to where the item will be transported by the Moving Vehicle if the transporting device is set to Moving Vehicle.

> Distance Name

The Distance module defines the distance between two locations in the distance set of a free-path Moving Vehicle device. The beginning location, ending location, and distance are used to create the appropriate distance set, which is used during the simulation run by the Moving Vehicle moving between the specified locations.

> Distance Length

This field specifies the travel distance between the Beginning location and Ending location. This distance should be specified in length units consistent with the length units used in the transporters velocity.

2.2.2.4 Inventory System

2.2.2.4.1 Inventory Module Description

This module is used to provide the organisational structure and the operating policies for maintaining and controlling goods to be stocked. It further provides a guideline to the Supply Chain Analyst on what the order quantity and reorder point should be. There are two types of inventory systems: fixed order quantity models and fixed time period models.
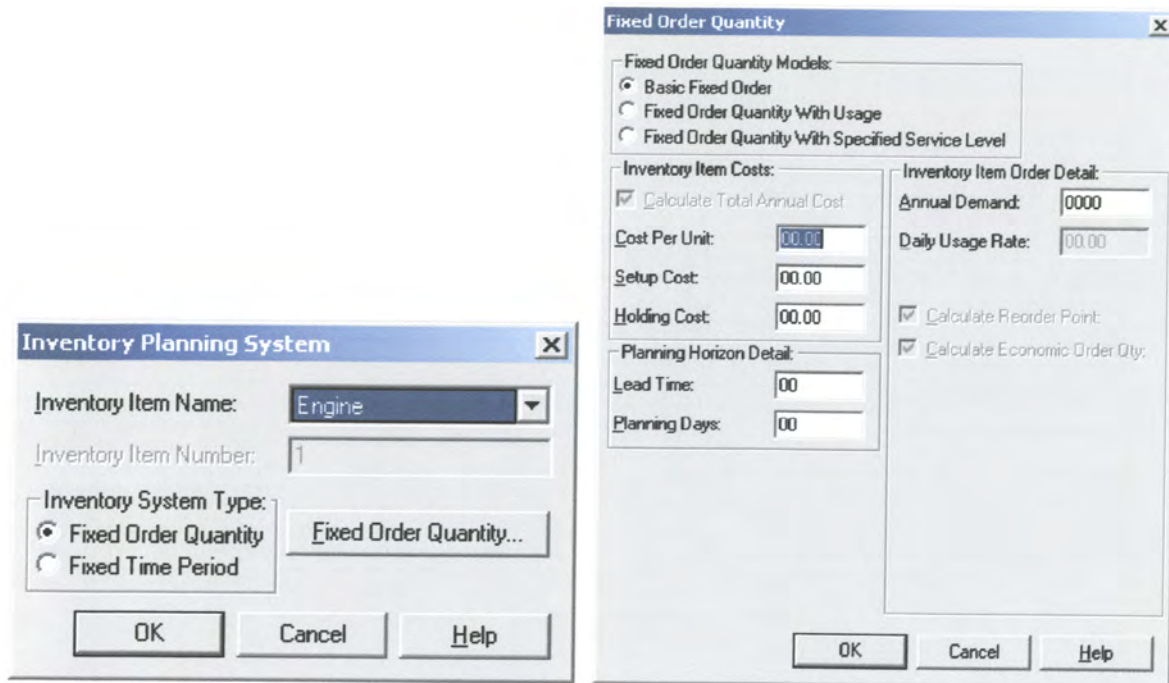
2.2.2.4.2 Inventory Module Prompts

Prompt Name	Prompt Name
Inventory Item Name	Daily Production
Inventory Item Number	Safety Stock
Inventory System Type	WIP
Fixed Order Quantity Models	Calculate Reorder Point
Fixed Time Period Models	Calculate Economic Order Qty
Calculate Total Annual Cost	Std Avg Demand
Cost Per Unit	Std Usage Lead Time
Setup Cost	Service Level
Holding Cost	Unsatisfied Demand
Lead Time	Calculate Orders Short
Annual Demand	

> Inventory Item Name

This operand is used to specify what Item will have what Inventory Plan. This allows for every item to have its own inventory Plan.

> Inventory Item Number

This Operand is used to uniquely identify an Inventory Plan. This number is based on the unique number of the Item specified in the Inventory Item Name Field.

➤ Inventory System Type

This operand allows the Supply Chain Analyser to specify what type of Inventory System will be used. There are two types of inventory systems: fixed order quantity models and fixed time period models. Fixed Order Quantity Models attempt to determine the specific point at which an order will be placed and what the size of that order should be. The Inventory system was designed based on work done by Chase and Aquilano on Inventory systems.[1]

➤ Fixed Order Quantity Models

Fixed Order Quantity Models attempt to determine the specific point at which an order will be placed and what the size of that order should be. In this application the focus will be on three different types of Fixed Order Quantity Models; Basic Fixed, Fixed Order Quantity with Usage and Fixed Order Quantity with Service Level. According to Chase and Aquilano, the following assumptions are made when looking at fixed order quantity models:

- Demand Constant
- Lead Time
- Price Per Unit of product is constant
- Inventory Holding cost is based on average inventory
- Ordering or setup costs are constant
- All demands for the products will be satisfied. (No backorders are allowed)

Basic Fixed is used where it is expected that all the quantity ordered will be received within one lot and this is frequently not the case.

Fixed Order Quantity with Usage is used where it is assumed that the lot sizes are not fixed and that the order will be deliver based on a predefined production rate.

➤ Fixed Time Period Models

➤ Calculate Total Annual Cost

If this module is selected by default and it will calculate the Total Annual Cost and record it in Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➤ Cost Per Unit

This operand specifies the total cost per unit of product.

➤ Setup Cost

This operand specifies the Set-up Cost or the cost to place an order.

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[1] Production And Operations Management: Manufacturing Services 7th edition, Richard B. Chase and Nicholas J. Aquilano, 1995.

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➢ Holding Cost

This operand specifies the Annual holding cost and storage cost per unit of average inventory.

➢ Lead Time

This operand specifies the average lead-time per product in days.

➢ Annual Demand

This operand specifies the annual demand of a product.

➢ Average Demand

This operand specifies the average daily demand per product.

➢ Daily Production

This operand specifies the daily production rate per product. Not visible if Basic fixed model is selected.

➢ Safety Stock

This operand specifies the safety stock per product. Not visible if Basic fixed model is selected.

➢ WIP

This operand specifies the current inventory on hand per product. The operand will only be visible for fixed time period models.

➢ Calculate Reorder Point

If this module is selected by default and it will calculate the Reorder Point and record it in Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Calculate Economic Order Qty

If this module is selected by default and it will calculate the Economic Order Quantity and record it in Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Std Avg Demand

This operand is used to specify the standard deviation of demand over lead-time if the demand is not constant.

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➢ Std Usage Lead Time

This operand is used to specify the standard deviation of usage during lead-time if the usage is not constant.

  ➢ Service Level

This operand refers to the number of units that can be supplied from stock currently on hand. For example, if annual demand for an item is 1000 units, a 95 percent service level means that 950 units can be supplied immediately from stock and 50 units are short.

  ➢ Unsatisfied Demand

This operand is equal to 1- the service level. So this will show what percentage of the stock will not be available for supply.

  ➢ Calculate Orders Short

If this module is selected by default and it will calculate the Total quantity of orders short and record it in Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

2.2.2.5 Items Module

2.2.2.5.1 Items Module Description

An Item models a kind of material, part, component, subassembly, assembly, or goods that have particular characteristics that define how it can be built, stored, processed, or used.
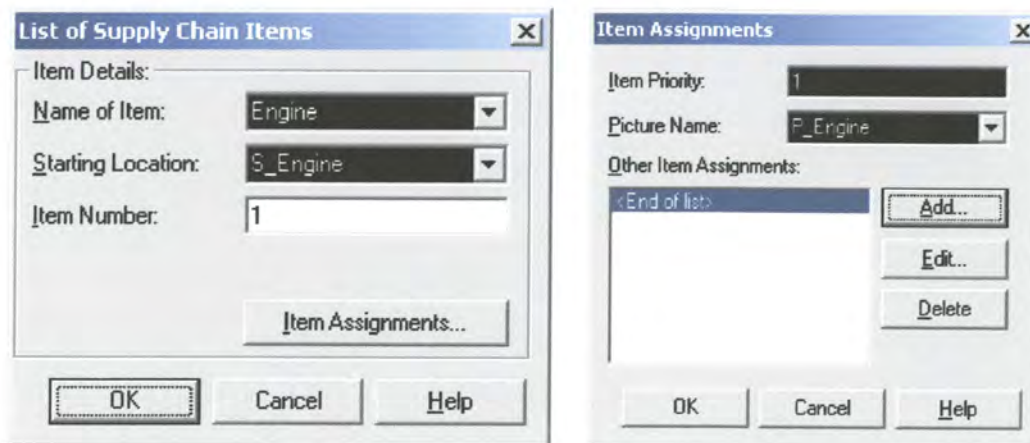
2.2.2.5.2 Items Prompts

Prompt Name	Prompt Name
Name of Item	Attribute Name
Starting Location	Variable Name
Item Number	Row
Item Priority	Column
Picture Name	Variable Value
Assignment Type	Value

> Name of Item

This prompt is used to specify the name of material, part, component, subassembly, assembly, or goods.

> Starting Location

This operand is used to specify where the Item will be located when the simulation starts.

> Item Number

This operand is used to uniquely identify the Item.

> Item Priority

This operand is used to specify the Priority of an Item if it exists.

> Picture Name

This operand is used to specify a picture for the animated item.

> Assignment Type

This operand is used to specify a type of assignment. The type can either be an attribute, or a variable.

> Attribute Name

This operand is used to specify the name of the attribute.

> Variable Name

This operand is used to specify the name of the variable.

> Row

This operand is used to specify the First index of the named variable array. For example if you have a variable named Test and with Row value 5, it means that this Variable consist out of 5 variables.

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> Column

This operand is used to specify the Second index of the named variable array. This is used for multiple dimensional arrayed variables.

Inventory (2,3)

This element defines a two-dimensional array named Inventory. Note that the initial values are entered one column at a time; that is, the first index increments through its entire range before the second index increments.

> Variable Value

This operand is used to specify the Variable Value to be assigned.

> Value

This operand is used to specify the Attribute Value to be assigned.

2.2.2.6 Moving Vehicle Module

2.2.2.6.1 Moving Module Description

The Moving Vehicle Module moves freely between locations and is not influenced by other Moving Vehicle traffic. They usually represent trucks, forklifts, and other mobile equipment.
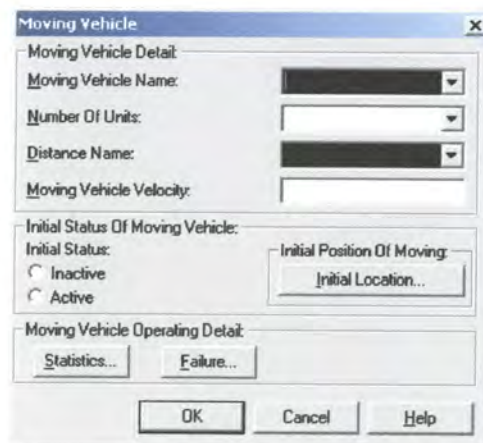
Prompt Name	Prompt Name
Moving Vehicle Name	Moving Vehicle Idle
Number Of Units	Moving Vehicle Utilization
Distance Name	Moving Vehicle Inactive
Moving Vehicle Velocity	Select Moving Vehicle Failure
Initial Status	Specify Moving Vehicle
Location Name	Time Between Vehicle Failures
Moving Vehicle Output Stats	Moving Vehicle Downtime
Moving Vehicle Unit	Vehicle Downtime Location

> ➤ Moving Vehicle Name

This is the name of the Moving vehicle that will be used to transport items from one location to another.

> ➤ Number Of Units

This operand defines how many individual moving vehicle units of a moving vehicle set are available. No more than this number of individual units may be used during the simulation run.

> ➤ Distance Name

This operand defines the distribution path that the transporters are to follow when transporting an item or groups of items.

> ➤ Moving Vehicle Velocity

This operand defines the initial velocity of the moving vehicles in this set.

> ➤ Initial Status

The Initial Status operand establishes the initial status, Active or Inactive, of each moving vehicle unit.

> ➤ Location Name

The Initial Position operand defines the initial location of the moving vehicle.

> ➤ Moving Vehicle Output Stats

If this modifier is selected it will allow the Supply Chain Analyst to select various statistics associated with the Moving Vehicle.

➢ Moving Vehicle Unit

This operand allows the Supply Chain Analyst to specify what unit's statistics will be recorded.

➢ Moving Vehicle Idle

If this operand is selected it will provide statistics regarding the idle state of the Moving Vehicle.

➢ Moving Vehicle Utilization

If this modifier is selected the utilization of the Moving Vehicle will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Moving Vehicle Inactive

If this operand is selected it will provide statistics regarding the inactive state of the moving vehicle.

➢ Select Moving Vehicle Failure

This operand specifies the name of the Moving Vehicle Failure.

➢ Specify Moving Vehicle

This operand specifies the name of the moving Vehicle that will fail.

➢ Time Between Vehicle Failures

This operand specifies the time between Moving Vehicle failures, also called the uptime.

➢ Moving Vehicle Downtime

This operand specifies the time to repair a Moving Vehicle failure, also called the repair time.

➢ Vehicle Downtime Location

This operand specifies the Location were the Vehicle would be repaired.

2.2.2.7 Resources Module

2.2.2.7.1 Resource Module Description

A Resource models the capacity that needs to perform the operation. Examples of Resources include assets such as machines, tools, fixtures, labour, trucks, moulds, etc and other things that are used in the Supply Chain that transform an Item to make it more valuable to the customer.

2.2.2.7.2 Resource Prompts

Prompt Name	Prompt Name
Resource Type	Resource Inactive
Resource Number	Number Of Resources Busy
Resource Capacity Type	Resource Utilization
Resource Capacity	Select Resource Failure
Schedule	Resource Failure
Rule	Failure Based On
Capacity	Failure Rule
Capacity Duration	Time Between Failures
Resource Output Statistics	Count
Number Of Resources Available	Time To Repair

> Resource Type

This operand allows the Supply Chain Analyst to specify the type of Resource. There are various types of resources: Customer Driven Buffer, Production Buffer, Reorder Buffer, Transfer Buffer, Customer Driven Operation, Production Operation, Transfer Operation and Other.

➢ Resource Number

This operand is used for the unique identification of a Resource.

➢ Resource Capacity Type

This operand specifies the method for determining the capacity for a resource. Fixed Capacity will not change during the simulation run. Based on Schedule signifies that a Schedule module is used to specify the capacity and duration information for the resource.

➢ Resource Capacity

Number of resource units of a given name that are available to the system for processing. Applies only when Resource Capacity Type is Fixed Capacity.

➢ Schedule

Based on Schedule signifies that a Schedule is used to specify the capacity and duration information for the resource.

➢ Rule

This Operand dictates when the actual capacity change is to occur when a decrease in capacity is required for a busy resource unit. Applies only when Resource Capacity Type is Schedule. There are three types of rules: Ignore, Wait and Pre-empt.

IGNORE   the schedule/failure ignores the entity controlling a busy resource. The value of the resource capacity (schedule) or the state (failure) will change at the scheduled time, but the resource itself will not actually change capacity or become failed until after the current entity finishes processing and releases the resource. The time duration of the schedule/failure begins immediately as scheduled, but the actual downtime may be reduced.

WAIT   the schedule/failure waits until the entity controlling a busy resource releases the resource. At the time of release, the value of the resource's capacity is changed or the failure begins for the duration of the schedule/ failure. This ensures a full duration (but possibly postponed) downtime.

PREEMPT   the schedule/failure pre-empts the controlling entity of a busy resource. The timing and duration of the schedule/failure occurs as scheduled unless the controlling entity is unable to be pre-empted, in which case the WAIT rule is used.

➢ Capacity

Number of resource units of a given name that are available to the system for processing. Applies only when Resource Capacity Type is based on Schedule.

- ➢ Capacity Duration

This operand specifies the time duration for which a specified capacity will be valid.

- ➢ Resource Output Statistics

If this modifier is selected it will allow the Supply Chain Analyst to select various statistics associated with the Resource.

- ➢ Number Of Resources Available

If this modifier is selected the total amount available of the specified Resource will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

- ➢ Number Of Resources Busy

If this modifier is selected the busy state of the specified Resource will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

- ➢ Resource Utilization

If this modifier is selected the utilization of the specified Resource will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

- ➢ Resource Inactive

If this modifier is selected the inactive state of the specified Resource will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

- ➢ Select Resource Failure

This operand allows the Supply Chain Analyst to add a failure to a Resource.

- ➢ Resource Failure

This operand is used to name the failure associated with one or more resources.

- ➢ Failure Based On

This operand determines if the failure is time-based or count-based.

- ➢ Failure Rule

This operand allows the Supply Chain Analyst to select how the failure operates if the resource is busy at the time the failure is initiated. There are three types of rules: Ignore, Wait and Pre-empt.

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IGNORE the schedule/failure ignores the entity controlling a busy resource. The value of the resource capacity (schedule) or the state (failure) will change at the scheduled time, but the resource itself will not actually change capacity or become failed until after the current entity finishes processing and releases the resource. The time duration of the schedule/failure begins immediately as scheduled, but the actual downtime may be reduced.

WAIT the schedule/failure waits until the entity controlling a busy resource releases the resource. At the time of release, the value of the resource's capacity is changed or the failure begins for the duration of the schedule/ failure. This ensures a full duration (but possibly postponed) downtime.

PREEMPT the schedule/failure pre-empts the controlling entity of a busy resource. The timing and duration of the schedule/failure occurs as scheduled unless the controlling entity is unable to be pre-empted, in which case the WAIT rule is used.

> Time Between Failures

This operand defines the time between failures for time-based failures.

> Count

This operand defines the number of resource releases for count-based failures. Valid when the Type is Count.

> Time To Repair

This operand defines the duration of the failure.

2.2.2.8 Supply Chain Analyses

2.2.2.8.1 Supply Chain Analyses Module Description

This module is used to select the variables for Supply Chain Analyses that will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface. These variables are based upon the current inventory, cost and revenue generated within the Supply Chain.

2.2.2.8.2 Supply Chain Analyses Prompts

Prompt Name	Prompt Name
Item Name	Total Production
Item Number	Average Inventory
Reorder Point	Min Inventory
Reorder Quantity	Max Inventory
Production Lead-Time	Total Stock outs
Production Rate	Service Level
Current Inventory	Inventory Cost
Batch Quantity	Stock out Cost
Total Demand	Lost Sales Costs
Total Sales	Transportation Costs
Total Cost	

➤ Item Name

This operand allows the Supply Chain Analyst to specify the name of the item that needs to be analysed.

➤ Item Number

This operand is used to uniquely identify the Item.

➤ Reorder Point

If this operand is selected the reorder point of the item recorded in the Simulation Model will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Reorder Quantity

If this operand is selected the reorder quantity of the item recorded in the Report will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Production Lead-Time

If this operand is selected the production lead time for an Item generated by the Simulation Model will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Production Rate

If this operand is selected the production rate for an Item generated by the Simulation Model will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Current Inventory

If this operand is selected the work in process for an Item generated by the Simulation Model will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Batch Quantity

➢ Total Demand

If this operand is selected the Total Demand for an Item generated by the Simulation Model will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Total Sales

If this operand is selected the Total Sales for an Item generated by the Simulation Model will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Total Production

If this operand is selected the Total Production for an Item generated by the Simulation Model will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Average Inventory

If this operand is selected the Average Inventory for an Item generated by the Simulation Model will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➤ Min Inventory

If this operand is selected the Minimum Inventory for an Item generated by the Simulation Model will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➤ Max Inventory

If this operand is selected the Maximum Inventory for an Item generated by the Simulation Model will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➤ Total Stock outs

If this operand is selected the Total Stock outs for an Item generated by the Simulation Model will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➤ Service Level

If this operand is selected the Service for an Item generated by the Simulation Model will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➤ Inventory Cost

If this operand is selected the Inventory Cost of an Item generated by the Simulation Model based on the Inventory Plan will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➤ Stock out Cost

If this operand is selected the Stock out Cost of an Item generated by the Simulation Model based on the Inventory Plan will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➤ Lost Sales Costs

If this operand is selected the Lost Sales Cost of an Item generated by the Simulation Model based on the number of Products Lost will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➤ Transportation Costs

If this operand is selected the Transportation Cost of an Item generated by the Simulation Model based on the Transportation will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

➢ Total Cost

If this operand is selected the Total Cost of an Item generated by the Simulation Model based on the Total Cost will be recorded in the Report Database as well as in the Reports Generator, which is an Excel Spreadsheet Interface.

3 Appendix C: Overview of the Supply Chain Mapping File

3.1 Introduction

When the Supply Chain Template within Arena creates a new model from a Visio drawing, it uses the Supply Chain map file to decide which Arena Supply Chain module to place for each Visio Supply Chain shape. A map file is simply a list of Visio Supply Chain shapes and Arena Supply Chain modules, along with a detailed mapping from one to the other, including the mapping of Visio Supply Chain shapes custom properties to Arena Supply Chain module operand values.

The Shape Map file (with the extension *". map"*) is used to configure the mapping between Arena Supply Chain modules and Visio Supply Chain shapes, and between module operands and shape custom properties.

3.2 Description of the Supply Chain Map File

3.2.1 Shape Map Editor View
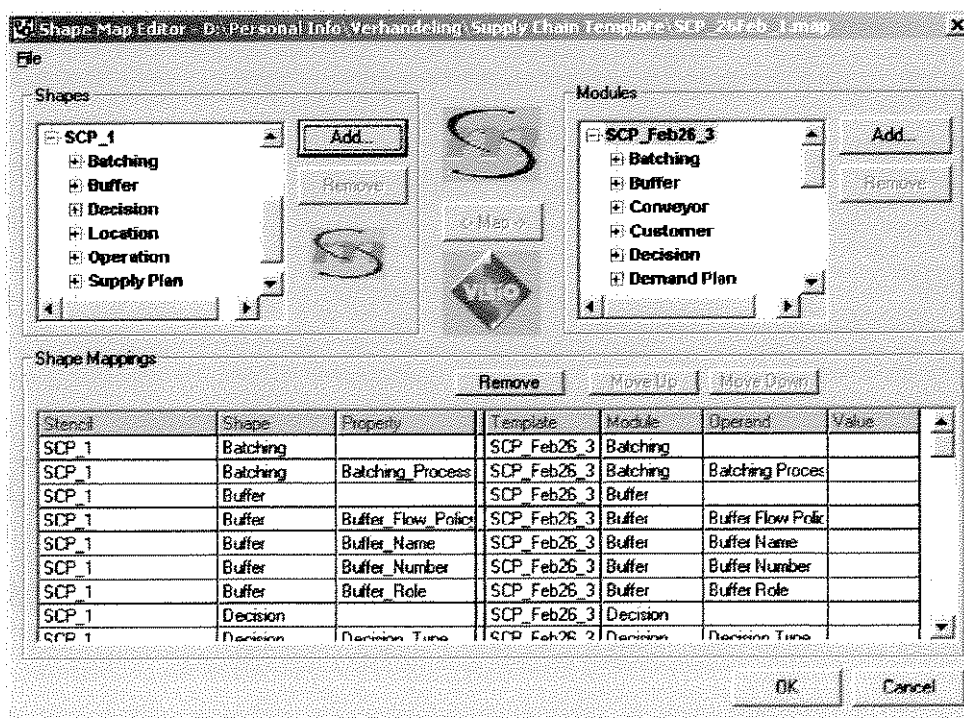
3.2.2 Shape Map Definition Tables

3.2.2.1 Shape Mapping of the Batching Process

Visio Supply Chain Shape Name	Batching	Arena Supply Chain Module Name	Batching
	Operand Name		**Operand Name**
	Batching Process		Batching Process

3.2.2.2 Shape Mapping of the Buffer Process

Visio Supply Chain Shape Name	Buffer	Arena Supply Chain Module Name	Buffer
	Operand Name		**Operand Name**
	Buffer Flow Policy		Buffer Flow Policy
	Buffer Name		Buffer Name
	Buffer Number		Buffer Number
	Buffer Role		Buffer Role

3.2.2.3 Shape Mapping of the Decision Process

Visio Supply Chain Shape Name	Decision	Arena Supply Chain Module Name	Decision
	Operand Name		**Operand Name**
	Decision Type		Decision Type

3.2.2.4 Shape Mapping of the Location Process

Visio Supply Chain Shape Name	Location	Arena Supply Chain Module Name	Location
	Operand Name		**Operand Name**
	Location Name		Location Name
	Location Number		Location Number

3.2.2.5 Shape Mapping of the Site Process

Visio Supply Chain Shape Name	Site	Arena Supply Chain Module Name	Site
	Operand Name		**Operand Name**
	Site name		Site Name

3.2.2.6 Shape Mapping of the Operation Process

Visio Supply Chain Shape Name	Operation	Arena Supply Chain Module Name	Operation
	Operand Name		**Operand Name**
	Operation Action		Operation Action
	Operation Name		Operation Name
	Operation Role		Operation Role

3.2.2.7 Shape Mapping of the Supply Plan Process

Visio Supply Chain Shape Name	Supply Plan	Arena Supply Chain Module Name	Supply Plan
	Operand Name		**Operand Name**
	Item Name		Item Name
	Item number		Item number
	Supply Plan Name		Supply Plan Name
	Supply Plan Number		Supply Plan Number
	Supply Plan Type		Supply Plan Type

3.2.2.8 Shape Mapping of the Transportation Process

Visio Supply Chain Shape Name	Transportation	Arena Supply Chain Module Name	Transportation
	Operand Name		**Operand Name**
	Current Location		Current Location
	Destination Location		Destination Location
	Transportation Number		Transportation Number
	Transportation Type		Transportation Type

4   Appendix D: Overview of Supply Chain Solver Database

4.1   Introduction

The purpose of this database is to capture all the results of the Optimised Supply Chain Simulation Solution. The results will then be used as the initial inputs in the Supply Chain Solver Technology. For example if the Optimised Supply Chain Simulation Solution shows that the maximum capacity of a buffer is 5 units then this value will be used as the maximum capacity for the buffer in the Solver Technology Database.

This Database will be linked to the Output Database of the Supply Chain Model.

4.2   Description of Supply Chain Solver Database Object Model

In the object model the different objects that can be defined in the Supply Chain Solver Database are stated. The objects are Buffer, Operation, Resource, Location, Site, and Item. These object classes can be specified for every supply chain. In order to achieve this the different attributes will have to be specified. The different objects are related to each other and this will be displayed.
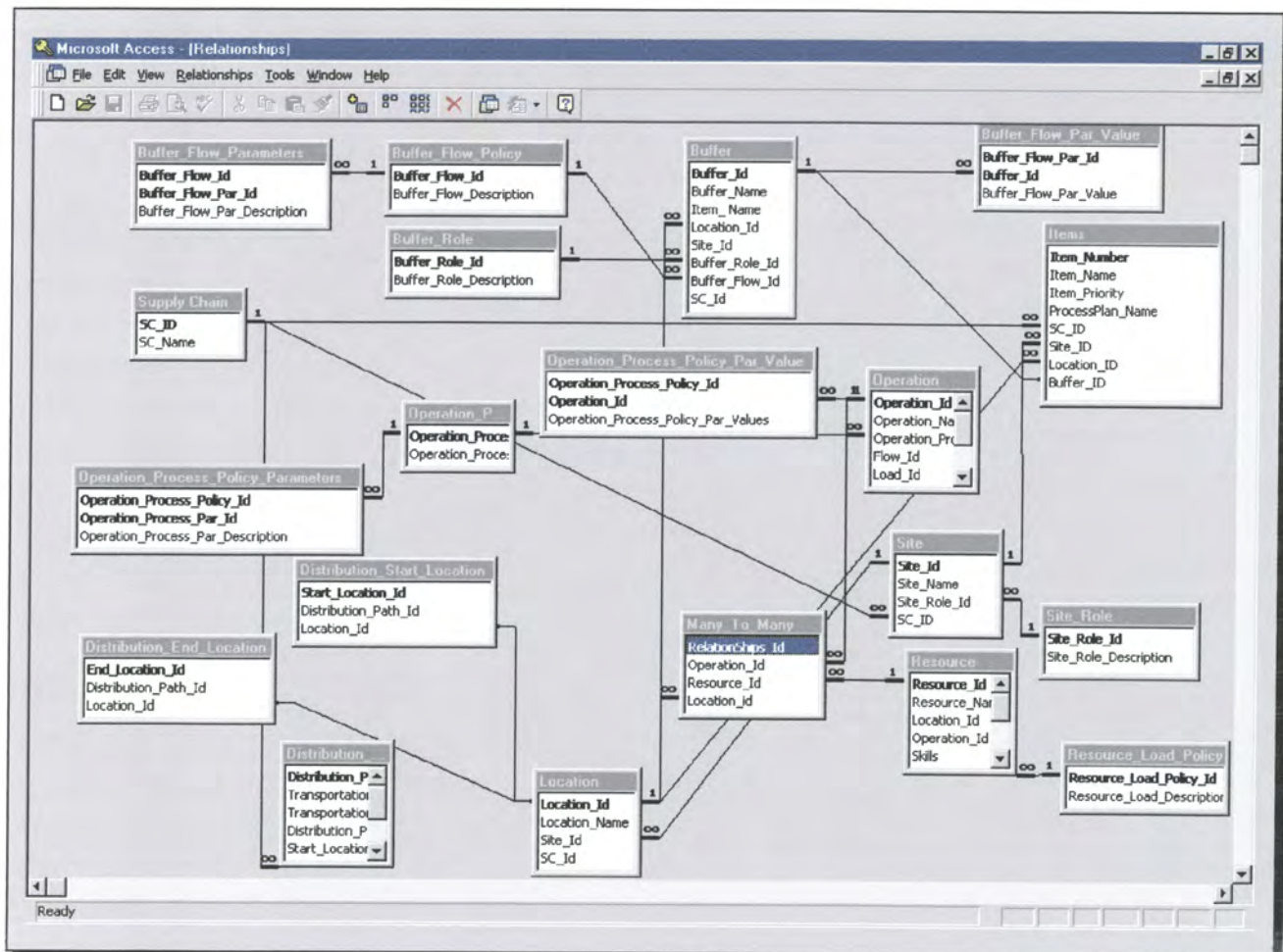
> Buffer

The Buffer object is used to store information regarding the Buffers within the Supply Chain. The Buffer is linked to a specific *Site* and *Location* and it is also *Item* specific. The Buffer allows the Supply Chain Analyst to specify the *Buffer Flow Policy* as well as what sort of role the Buffer will play. The following information will be stored: Buffer Number, Buffer Name, Item Name, Location Name, Buffer Flow Policy, Buffer Flow Parameters and Buffer Flow Parameter Values.

> Operation

The Operation object is used to store information regarding the Operations within the Supply Chain. The Operation is linked to a *Location* and it needs a *Resource* to complete the Operation. The Operation allows the Supply Chain Analyst to specify the *Operation Process Policy* as well as all the parameters associated with the Process Policy. The following information will be stored: Operation Number, Operation Name, Location Name, Operation Process Policy, Resource Name, Operation Process Policy Parameter and Process Policy Parameter Values.

> Item

The Item object is used to store some information about the Items within the Supply Chain. The following information will be stored: Item Name, Priority, Location, Site and Buffer.

> Resource

The Resource object is used to store information about the Resources within the Supply Chain. The following Information will be stored: Resource Name, Operation Name, Resource Efficiency, Resource Variability, Resource Capacity and Resource Load Policy.

> Location

The Location object is used to store information of all the Locations. The Location is linked to a Site and all the Buffers and Operations linked to a Location will be shown. The following Information will be stored: Location Name, Site Name, List of Buffers, and List of Operations.

> Site

The Site object is used to store information of all the Sites. The Site is linked to the Supply Chain and all the Locations linked to a Site will be shown. The following Information will be stored: Site Number, Site Name, Site Role, Supply Chain Name and List of Locations.

4.3   List of Supply Chain Database Tables

> Buffer
> Buffer Flow Parameters
> Buffer Flow Par Value

- ➢ Buffer Flow Policy
- ➢ Buffer Role
- ➢ Items
- ➢ Link Role
- ➢ Location
- ➢ Many To Many
- ➢ Operation
- ➢ Operation Process Policy
- ➢ Operation Process Policy Parameters
- ➢ Operation Process Policy Par Value
- ➢ Resource
- ➢ Resource Load Policy
- ➢ Site
- ➢ Site Role
- ➢ Supplier Role
- ➢ Supply Chain
- ➢ Switch Bord Items

Figure 4.2. Buffer Table

4.4 List of Supply Chain Database Forms

- ➢ Buffer Detail
- ➢ Buffer Detail Subform
- ➢ Buffer Flow Parameters
- ➢ Buffer Flow Par Entries
- ➢ Buffer Paremeter Values
- ➢ Item Detail
- ➢ Location Detail
- ➢ Location Site Subform
- ➢ Main Menu
- ➢ Operation Detail
- ➢ Operation Detail Subform
- ➢ Operation Process Policy Parameters
- ➢ Operation Process Policy Par Entries
- ➢ Operation Process Policy Par Values
- ➢ Operation Resource Subform

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- ➤ Report Main Menu
- ➤ Resource Detail
- ➤ Site Detail
- ➤ Site Detail Subform
- ➤ Supply Chain Detail

Figure 4.3. Buffer Detail Form

4.5   List of Supply Chain Database Queries

- ➤ Buffer Lookup
- ➤ Operation Resource Link
- ➤ Qrycombo1
- ➤ Site Supply Chain Link

Figure 4.4 Buffer Lookup Query

4.6 List Of Supply Chain Database Reports

- ➢ Buffer Subreport
- ➢ Buffer Detail Report
- ➢ Buffer Flow Parameters Subreport
- ➢ Buffer Flow Par value Subreport
- ➢ Item Detail Report
- ➢ Location
- ➢ Location Subreport
- ➢ Loaction Detail Report
- ➢ Operation Subreport
- ➢ Operation Detail Report
- ➢ Operation_Process_Policy_Parameters_Subreport
- ➢ Operation_Process_Policy_Par_Value_Subreport
- ➢ Resource_Report
- ➢ Site_Detail_Report
- ➢ Site_Subreport
- ➢ Supply_Chain_Detail_Report

Figure 4.5. Detail Site Report

DETAIL SITE REPORT

Supply Chain Name:	Motor Car_SC
Site Name:	Car_Manufacturing
Site Role :	Link

Location Names:

S_Engine_Receive
S_Car
S_Door_Buffer
S_Chassis_Buffer

5 Appendix E: Overview of Supply Chain Reports Generator

5.1 Introduction

The supply chain planner needs to have customised reports in order to speed up the analyses phase and therefore Microsoft® Excel is used as the supply chain reports generator. This generator will use the outputs of the Simulation Model and generate customised charts and tables. The reports generator is divided into two sections production and financials. For more information on the Reports generator refer to the Output_Interface.xls spreadsheet on the compact disc at the end of this document.

5.2 Production Data In Reports Generator

- Production Throughput
- Prodcution Inventory
- Prodcution WIP
- Supply Chain WIP
- Regional Demand
- Regional Delivery
- Orders Profile
- Northern Region Demand vs Inventory
- Northern Supply
- Northern Region Totals
- Southern Region Demand vs Inventory
- Southern Supply
- Southern Region Totals
- Production Lead Times
- Total Production Lead Times
- WIP in Buffers
- WIP in Operations
- Time in Buffers
- Total Buffer Times
- Time In Operations
- Total Operation Times
- Utilisation Profile Buffers
- Total Buffer Utilisation
- Utilisation Profile Operations
- Total Operation Utilisation

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Figure 5.1. Graphical Representation of Supply Chain Production Lead times

Figure 5.1. Graphical Representation of Supply Chain Production Lead times
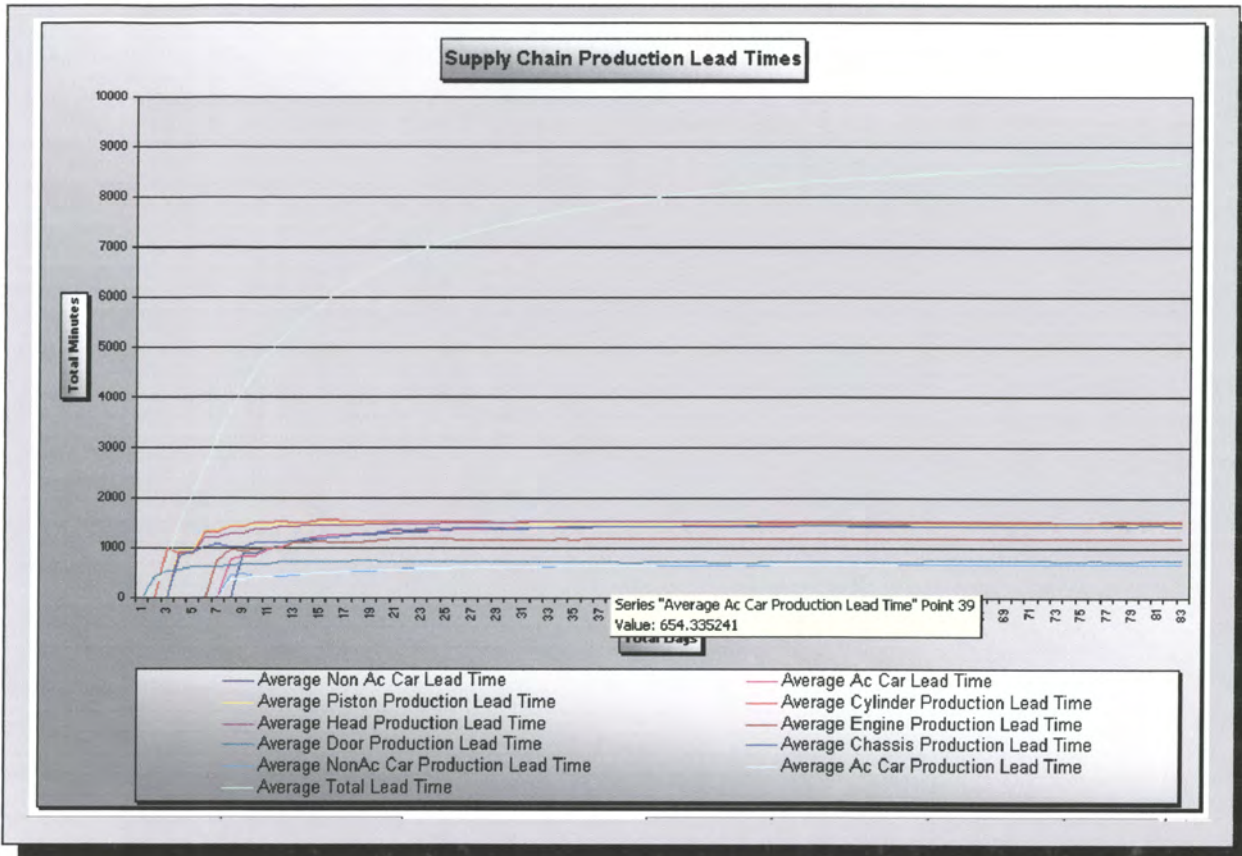
5.3 Financial Data In Reports Generator

The financial data is divided into two sections Income Statement and QPI Performance. When the simulation run ends the IncomePerformance.xls spreadsheet will be updated. During the simulation run various calculations updates the information in the Income Statement and QPI Performance.

Figure 5.2. Illustration of The Supply Chain Income Statement

Figure 5.2. Illustration of The Supply Chain Income Statement

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Figure 5.3. Illustration of The Supply Chain QPI Performance

| FIRST QUARTER QPI PERFORMANCE		
ALLOCATED BUDGET	700000	
BUDGET USED	50556780	
REMAINING BUDGET		-49856780
% YEAR COMPLETE	27.59	
FORECAST BUDGET EXPENDITURE YTD		193128
QPI	261.78	
ANTICIPATED ACTUAL EXPENDITURE		183245422

6 _Appendix F: Overview of Sensitivity Analysis_

6.1 Introduction

The purpose of the sensitivity analyses is to assess the sensitivity of the Total Production Lead Time to value changes in the values of the controls. The optimisation log file generated by Optquest® was copied to Microsoft® Excel. In this spreadsheet a sensitivity analyses table and graph represents the results of the four feasible solutions. For more information on the sensitivity analyses refer to the compact disc at the end of this document.

This spreadsheet makes use of pivot tables. A PivotTable report is an interactive table that you can use to quickly summarize large amounts of data. You can rotate its rows and columns to see different summaries of the source data, filter the data by displaying different pages, or display the details for areas of interest.

Figure 6.1. Illustration of Sensitivity Graph
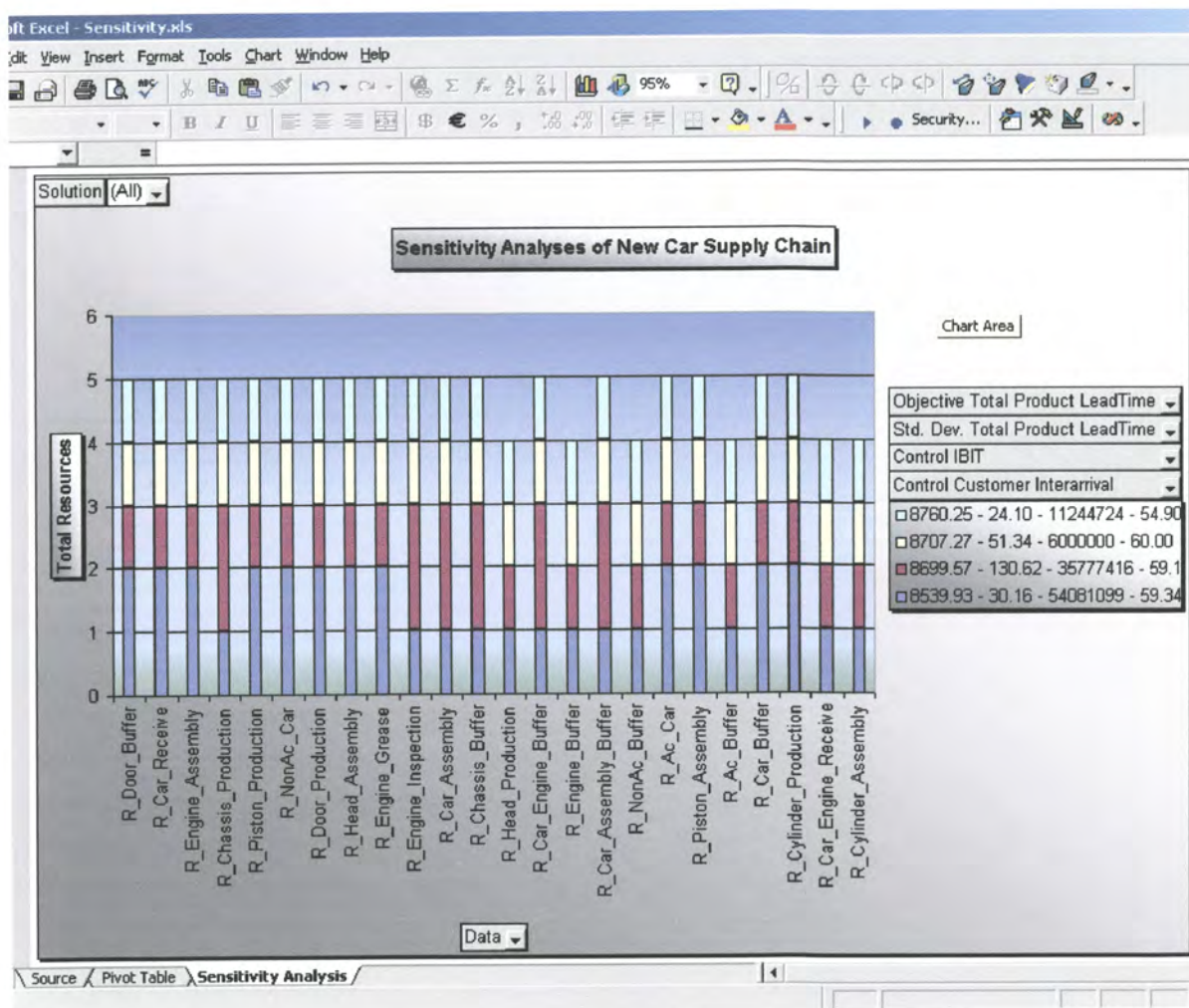
7 *Compact Disc Contents*

7.1 *Introduction*

Attached to this document is a compact disc, which features all the necessary documentation. In order to avoid any problems with macros the following directory should be on the destination hard drive: C:\My Documents\NewCars\NewCars_Sce_2

All the data should be copied to this directory. Do not make separate directories on the hard drive. Copy everything to same directory on the hard drive.

7.2 *List of Contents*

- ➢ Supply Chain Stencil
- ➢ Supply Chain Flowchart
- ➢ Suplly Chain Template
- ➢ Supply Chain Model
- ➢ Supply Chain Map File
- ➢ Supply Chain Output Files
- ➢ Supply Chain Manual
- ➢ Supply Chain Output Database
- ➢ Supply Chain Solver Database
- ➢ Supply Chain Report Spreadsheets
- ➢ Supply Chain Optimisation Log File
- ➢ Supply Chain Optimisation File
- ➢ Supply Chain Sensitivity Analyses