THE SIMULATION AND EVALUATION OF A PROPOSED MANAGEMENT SYSTEM WITH SHARED CONSTRAINED RESOURCES IN THE MULTI-PROJECT ENVIRONMENT

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PROJECT REPORT SUMMARY

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In a competitive environment management of organizations has to decide which the best opportunities are to pursue, as well as how to deliver faster and cheaper than their competitors on their commitments. This has to be done with limited resources to ensure profitability.

In this study a conceptual management model is proposed to serve as a management tool to help management of organizations choose the right amount of value opportunities entering the organization's value stream, managing the risks associated with the opportunities, and converting the opportunities into high-value adding realities as fast as possible.

The solution applies supply chain and constraint management principles to the proposed management model, assuming that Critical Chain multi-project management is in place. The conceptual management model also proposes a set of strategically placed buffers as an integral part of the process, which are the primary means of managing the whole system for increased productivity.

The TOC thinking processes is systematically employed to identify the core management problem for the study and also proposing a solution. The proposed solution was simulated and confirmed that it is indeed a valid way to increase organizational value in terms of amount and timing.

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I would like to convey my thanks to:

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TABLE OF CONTENT

CHAPTER 2: PAGE

CHAPTER 2: PAGE

CHAPTER 3: THE PROPOSED INJECTIONS PAGE

CHAPTER 3: PAGE

CHAPTER 4: PAGE

CHAPTER 5: PAGE

CHAPTER 6: PAGE

BIBLIOGRAPHY PAGE

APPENDICES PAGE

LIST OF FIGURES

CHAPTER 1 PAGE

CHAPTER 2 PAGE

CHAPTER 3 PAGE

CHAPTER 4 PAGE

CHAPTER 5 PAGE

CHAPTER 5 **PAGE**

LIST OF TABLES

LIST OF ABBREVIATIONS

CC	Critical Chain
CCPM	Critical Chain Project Management
CCMPM	Critical Chain Multi Project Management
EC	Evaporating Cloud
FRT	Future Reality Tree
I	Inventory
OE	Operating Expense
PERT	Programme and Evaluation and Review Technique
PMBOK	Project Management Book of Knowledge
TOC	Theory of Constraints
TV	Throughput Value
TVC	Truly Variable Cost
WiP	Work in Progress

"When I look back
I see the landscape
I walked through.

But it is different.
All the great trees are gone.
It seems there are remnants of them.

But it's the afterglow
inside of you
of all those you met
who meant something in your life."

Olav Rex, August 1977

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO THE RESEARCH

Since the existence of mankind, man has been faced with difficult decisions that could alter the course of his very existence. This is no different in the business environment. History is filled with examples of managers who have made the wrong decision that have had severe repercussions, to sometimes both the individual and the company as a whole.

In organizations such as consulting firms, product development divisions of companies, research and development organizations, laboratories and engineering departments of industrial companies, deliverables are supplied to clients through the execution of multiple projects with limited resources to ensure their profitability.

With the global and local economies in a state of very low growth, management in for-profit organizations that use projects to deliver value, has to act under the assumption that opportunities are limited and that competition will be extremely high in the pursuit of these opportunities. Therefore management has to decide which the best opportunities are to pursue, as well as how to deliver faster and cheaper than their competitors on their commitments.

To make trustworthy decisions regarding value opportunities as quickly and as early in the project life cycle as possible, management has to ensure that the necessary information is available, and that a process is established to analyze the opportunity information, reducing (as much as possible) any uncertainty and associated risk before they decide whether the opportunity should become a formal development project or not. In addition to this, management needs to ensure that once opportunities have been approved as formal projects they are delivered successfully – within time, budget and predetermined specifications.

1.2 THE CURRENT STATE OF THE INDUSTRY

Literature from leading local and international researchers was studied to determine the historical development and current state of organizations that deliver projects or products for value. During this study, it will be shown that a definite need exists to provide the management of organizations, which consists of limited resources, with a management tool that will serve as a “roadmap”.

This tool should help management to choose the right amount of value opportunities entering the organization's value stream, managing the risks associated with the opportunities, and converting the opportunities into high-value adding realities as fast as possible. This study will propose such a tool in the form of a new project management system, which will aim to address these issues.

1.3 THEORETICAL FRAMEWORK

1.3.1 THEORETICAL BOUNDARIES OF THE STUDY

The boundaries of the research are expressed in figure 1. The system to be researched, is the process of acquiring value opportunities, selecting the most promising opportunities, and the successful delivery of the chosen value opportunities.

This management system strives towards reducing associated risks with value opportunities, to an acceptable level as early as possible in the project life cycle. Achieving this will enable management to select only the most promising value opportunities to become formal development projects, with a sufficient degree of confidence that the project will deliver high value. The system also strives towards synchronizing the process of acquiring value opportunities with the value delivery process.

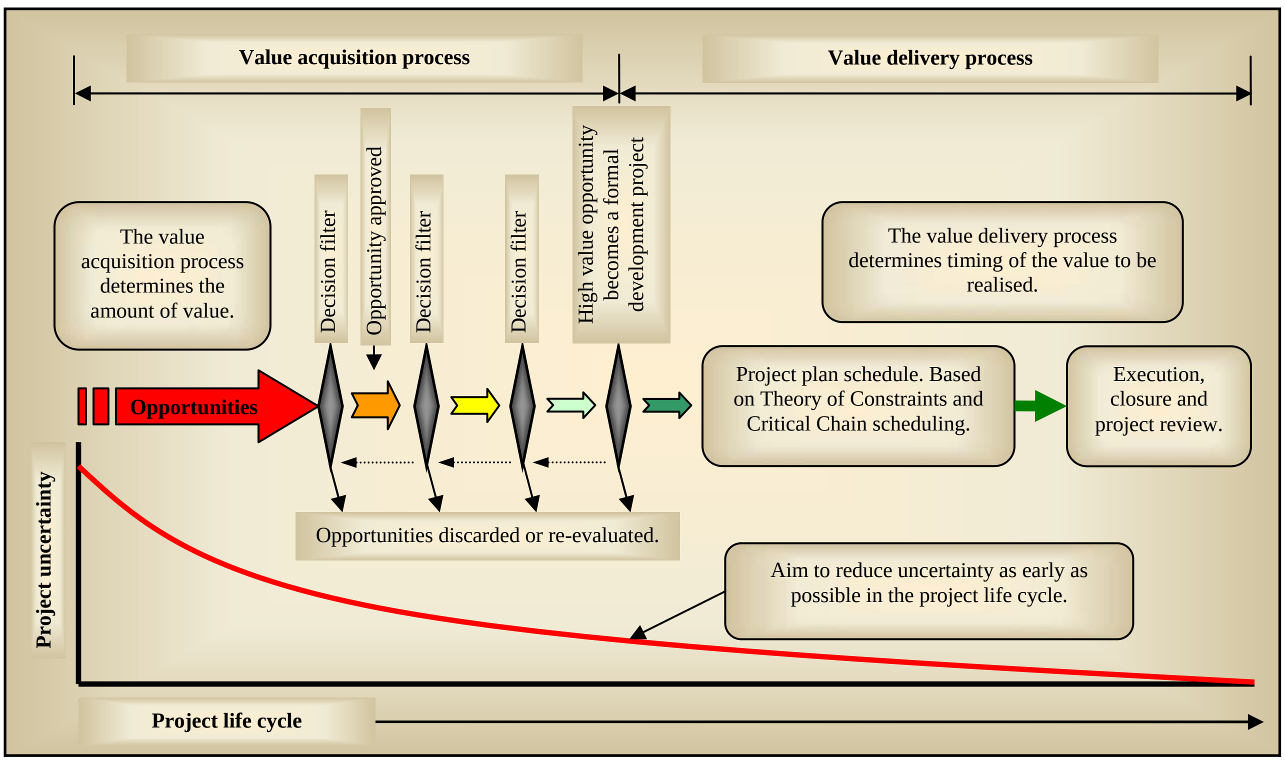

Figure 1: The theoretical framework of the study.

Value used in the context of this study can be seen as the difference between the money flowing into the organization and the money flowing out of the organization. However, to understand value in the context of the study completely, the concept of Throughput or Throughput Value (TV) has to be described.

Throughput Value is the rate at which a system generates money through sales. This is calculated by deducting direct project cost, known as Truly Variable Cost (TVC) from the sales achieved over a period of time (Goldratt [22]).

As mentioned, two dimensions of value exist – the amount of value, as well as the timing of the inflow and outflow of the money. These two dimensions are focused on the two different macro processes in the project life cycle – the value acquisition process and the value delivery process. The value acquisition process is the process that would determine the amount of the value entering the organization, while the value delivery process will determine the timing of the value to be realized.

1.3.1.1 THE PROJECT LIFE CYCLE

For this study the project life cycle will be broken down into two macro processes. As already established, they are:

1. The value acquisition process.
2. The value delivery process.

The value acquisition process

The value acquisition process will be defined as the process of opportunity initiation, development, evaluation, selection, planning and budgeting. Management's main goal with the value acquisition process is to increase shareholder value through portfolio management.

Cooper [10] states that in a well-defined portfolio approach, management should aim to achieve four goals when they review the project portfolio. They should:

1. Aim to maximize the value of the portfolio.
2. Seek the right balance of possible opportunities.
3. Ensure that the opportunities and the spending breakdown mirror the business strategy.
4. Ensure that the right number of projects is being worked on with the limited available resources.

According to Allen [1], to attain this, portfolio managers have to do the following:

1. Create opportunities that will ensure high value for the organization.
2. Estimate the value of the newly arriving opportunities.
3. Understand the risks involved in each opportunity.

Once these tasks are accomplished, management still needs a reliable framework for choosing high value opportunities and allowing them to successfully deliver the chosen opportunities. According to Viljoen [50], current tools that are being used in some companies to help them with the decision-making process on value opportunities, are strategy tables, influence diagrams and risk/reward bubble-diagrams where the organization's projects are plotted as bubbles on an X – Y plot in order to display balance.

Allen [1] argues in his book that value can only be found in good opportunities or ideas, and that creating opportunities requires two important things:

1. Processes that executives and employees can use to determine which opportunities are best, and how they can be most effectively pursued.
2. A culture that encourages people to seek out high-value alternatives.

Although an appropriate corporate culture is important to increase an organization's portfolio, this study's emphasis will be solely on the development of an embedded management process that will aim to serve as a tool for management to choose high-value opportunities and to successfully deliver on these value opportunities. For the management process to be successful, it will need to entail the concept of learning, knowledge management and the capability to integrate and to transform itself.

The value delivery process

For the purpose of the study, the value delivery process will consist of the project scheduling and the execution of the right projects based on Theory of Constraint (TOC) principles and its application to multi-project management known as Critical Chain multi-project management.

TOC is a management philosophy developed by Dr E M Goldratt, first published in his book *The Goal* [21]. It is a systems approach based on the assumption that every organization has at least one factor (the constraint) that inhibits the organization's ability to meet its objectives.

Goldratt [21] highlights that the normal objective for a business should be to make more money – now and in the future. To manage the capacity constraints of an organization and to improve the ability to make more money, he proposes a five-step process of on-going improvement.

The steps in this process are:

1. *Identify* the system's constraint(s).
2. *Decide how to exploit* the constraint.
3. *Sub-ordinate* everything else to the above decision.
4. *Elevate* the constraint.
5. If in a previous step a constraint has been broken, go back to step 1, but do not allow inertia to become a system's constraint.

TOC and its application to project management Critical Chain will be discussed in detail in chapter 2 of this study.

The main objective for management during the value delivery process can be seen as successful project performance, which is delivering the product on time and within budget and client specifications.

Typically the project scheduling predicts the timing of the value to be realized, while the execution realizes the value of an opportunity. The money generated in a timeframe is then typically used to cover expenses and to declare profits or reinvest (when the value is more than the expenses for the timeframe). The value delivery process also determines the cash available to make any payments at any point in time.

1.4 THE SCOPE OF THE RESEARCH

1.4.1 THE RESEARCH APPROACH

First the core management problem of the study will be identified and verbalized by making use of the Evaporating Cloud (EC) which is one of the tools in the Theory of Constraints (TOC) thinking processes. The Evaporating Cloud will be discussed in detail later on in this chapter.

After the management problem has been verbalized, the Future Reality Tree (FRT), which is also a tool of the TOC thinking processes, will be utilized to develop a future vision for a newly proposed project management system. In the FRT, "injections" or "interventions" will be proposed that will aim to invalidate the assumptions made during the construction of the EC, thus vaporizing the EC.

The main challenge of the study is to answer the research question: Is this proposed "injections" that will be presented in the FRT, indeed a valid way to vaporize the EC?

To answer the research question, a simulation model will be developed, based on the FRT and its proposed "injections". The validity of the new proposed future vision and its "injections" will then be tested by way of the simulation model.

The results obtained from the simulation will then be analyzed and tested against a set hypothesis.

1.4.2 USING THEORY OF CONSTRAINTS THINKING PROCESSES IN THE STUDY

The TOC thinking processes were originated by Dr Goldratt. The process uses a strict logical framework where causes and effects are carefully defined to ensure logical arguments and conclusions.

The question may arise why the TOC thinking processes are utilized during this research, rather than more conventional problem solving techniques. The answer lies mainly in the fact that conventional techniques often focus on incremental change, addressing symptoms of the problem as opposed to the deeper-rooted problems, which would demand fundamental changes to the current system.

This concept is supported by the following statement: "*The intent of the thinking processes was to provide a systematic approach to enable people to create and implement the kinds of change that can also be considered improvement"* (Scheinkopf [41]). As opposed to focusing on incremental change, the TOC thinking processes is a system level problem solving technique, which can be applied to any level of system, aimed at defining the core problem, which, if solved, will remove all of the undesired symptoms (Scheinkopf [41]).

1.4.2.1 ANSWERING THE RESEARCH QUESTIONS

The main challenge of the research is to test whether the proposed solution to vaporize the EC is indeed valid.

In order to arrive at a meaningful answer, and to propose an innovative solution for improvement in current project management processes, an attempt will be made to find answers to the following questions:

1. What is the core management problem within the multi-project environment?

To answer this question, the management problem in the multi-project environment for this study will be postulated by using one of the TOC thinking process tools - the Evaporating Cloud (EC).

2. What should current processes in the multi-project environment be changed to?

To find an answer to the second question the proposed solution to vaporize the EC will be presented by means of another TOC thinking process tool – the Future Reality Tree (FRT).

3. Is the proposed solution presented in the FRT indeed a valid approach to improve current project management models?

Question three is in fact the core research question that needs to be solved. To get to a meaningful answer, a simulation model will be conducted to validate the proposed solution to the proposed core management problem.

To find answers to the three questions highlighted above the sequence of the research will be as follow:

- Later on in this chapter, the Evaporating Cloud (EC) will be used to identify and verbalize the management problem.

- Chapter 2 in the study will explore necessary competitive factors in development and the strategies involved. Chapter 2 will also investigate processes to achieve a good value acquiring flow rate and the concept of Throughput Value and Critical Chain project management in the multi-project environment.

- In chapter 3, a vision will be created of the new state to which current project management processes should be changed. This new vision will be discussed from two viewpoints:

a) The "process" view (physical process) of the solution will be presented and discussed by means of structured English and illustrations.

b) After the "process" view of the solution has been discussed, the "systems" view (non-physical view) of the solution will be presented and discussed by means of one of the TOC thinking processes tools - the Future Reality Tree (FRT).

- The vision presented in chapter 3 will be scrutinized in the remainder of the study by building a simulation model to test whether the proposed "injections" presented in the FRT are indeed a valid way to vaporize the Evaporating Cloud. Figure 2 expresses how the two TOC thinking processes will be employed during the course of the study.

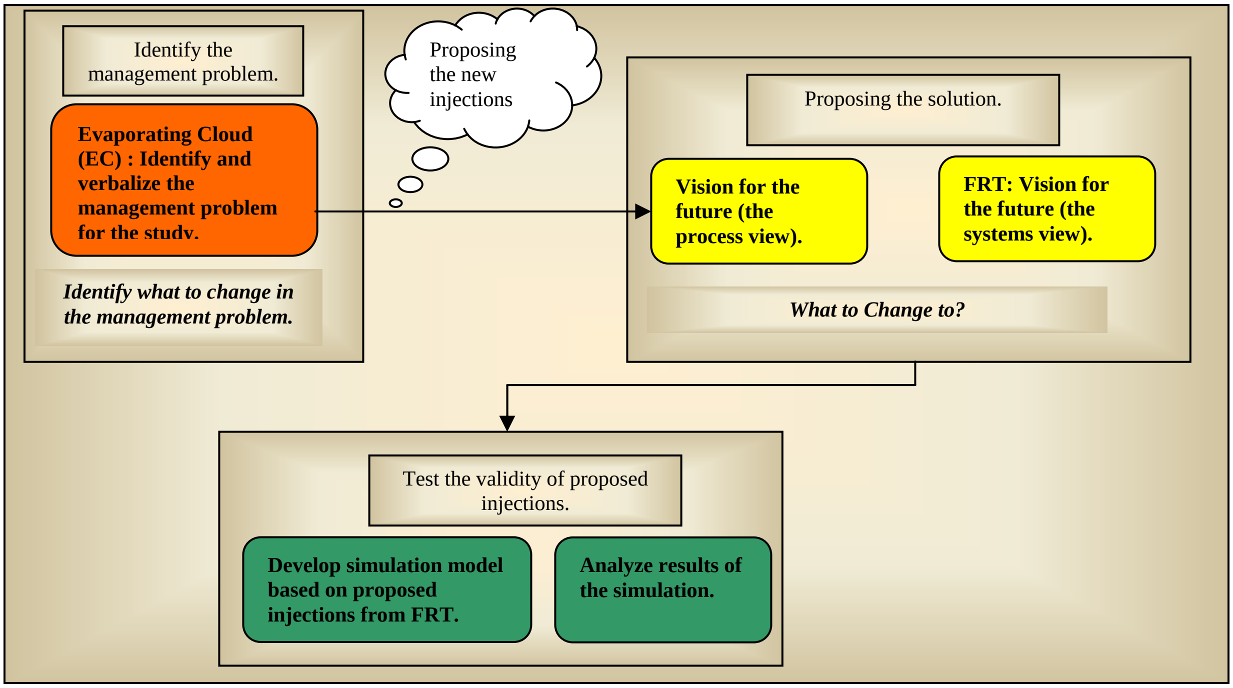

Figure 2: The Evaporating Cloud and the Future Reality Tree is the TOC thinking process tools that will be used in this study.

The use of the two TOC thinking process tools and the development of a simulation model, will enable the researcher to develop and investigate the validity and effectiveness of the proposed injections to invalidate the assumptions made during the construction of the Evaporating Cloud.

1.4.3 THE SIMULATION MODEL

As already highlighted, a simulation model will be developed, which will be based on the Future Reality Tree with its proposed "injections". The simulation model will aim to investigate whether the proposed injections to vaporize the Cloud are indeed valid.

As suggested by Kelton and Sadowski [27], the simulation will be dynamic, discrete and stochastic. The simulation model will be verified and validated before any runs are made.

The results of the simulation will be analyzed through standard data analysis procedures, and scrutinized and evaluated against the proposed future vision presented in the FRT (the systems view) and also in the "process view" of the model.

1.4.4 RESEARCH BREAKDOWN

The approach that will be followed in this study can be viewed in figure 3.

1. **Chapter 1 – Introduction to the research**
   - Background and state of the industry
   - Theoretical framework
   - Research approach and scope
   - Identify the research question
     - Present the Evaporating Cloud and identify the injection in order to evaporate the cloud
     - Hypothesis is stated
   - Possible benefit to the industry.

2. **Chapter 2 – In depth literature review**
   - Investigate necessary competitive factors in development and the strategies involved
   - Investigate processes to achieve a good value acquiring flow rate
   - Investigate the concept of Throughput Value and Critical Chain project management in the multi-project environment.

3. **Chapter 3 - Proposing the injection (What should processes be changed to?)**
   - Propose the "process" view of the injection in the form of structured English and illustrations - derived from current literature
   - Present the vision for the future - the FRT ("systems" view).

4. **Chapter 4 - The simulation model – testing the validity of the injection**
   - The Research methodology
   - The research simulation model, based on the FRT presented in Chapter 3
   - The simulation model will be
     - Dynamic
     - Discrete
     - Stochastic
   - Verification and validation of the simulation model.

5. **Chapter 5 - Data analysis**
   - Simulation runs for different scenarios will be made to test whether the proposed injections is a valid approach to evaporate the EC
   - The data obtained from the simulation run will be analyzed and discussed
   - The stated hypothesis will be re-evaluated and tested.

6. **Chapter 6 - Final conclusions**
   - Final conclusions
   - Possible future studies.

Figure 3: The breakdown structure of the approach.

1.5 IDENTIFYING THE MANAGEMENT PROBLEM IN THE MULTI - PROJECT ENVIRONMENT

In this section the Evaporating Cloud (EC) will be discussed and presented. Here the management problem will be verbalized. The proposed "injections", which will aim to solve the Evaporating Cloud will be discussed in chapter 3.

1.5.1 THE GENERIC EVAPORATING CLOUD

The EC is a tool in the TOC thinking processes and will be used to verbalize the management problem as a systemic conflict that is perpetuating the existence of undesirable effects for organizations in the multi-project environment.

During the construction of the EC the question "*What to change"* will be answered. The next step in the TOC thinking processes is to discover *"To what should processes in the multi-project environment be changed?".* In order to answer this question the Future Reality Tree (FRT) will be employed.

With the EC "injections" for a solution will be uncovered by verbalizing the assumptions supporting the necessary conditions defined in the cloud.

With this "injection(s)" in mind, the FRT will be applied (in chapter 3) to create a vision of the future and predict likely positive and negative effects of the "injection".

In the TOC approach to the Thinking Processes, the Evaporating Cloud (EC) is created by starting with the core problem and defining an effect that is its opposite. For this purpose the cloud takes on the following form as expressed in figure 4:

The EC is read as follows:

> In order to have objective A, we must have necessary condition B.
> In order to have necessary condition B, we must take undesirable action D.
> In order to have objective A, we must have necessary condition C.
> In order to have necessary condition C, we must take action D'.
> But actions D and D' are in conflict.

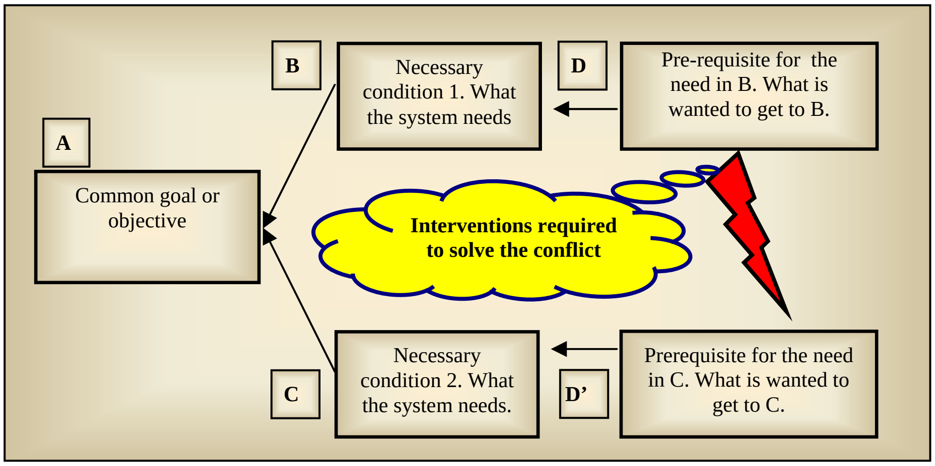

Figure 4: Generic Evaporating Cloud, adapted from Scheinkopf [41].

The arrows connecting the boxes represent necessary conditions. The perspective developed by using Goldratt's [20] EC, is one that draws attention towards the assumptions that underpin or give life to the problem – supporting the necessary conditions. The Evaporating Cloud requires the statement of assumptions made, then questions their validity to find a way to invalidate the assumptions and vaporize the cloud. According to Scheinkopf [41], TOC solutions arise in the main from invalidating the assumptions in the Evaporating Cloud by introducing an *"intervention"* or "*injection*".

1.5.1.1 THE EVAPORATING CLOUD FOR ORGANIZATIONS WITH LIMITED RESOURCES IN A COMPETITIVE ENVIRONMENT

The EC diagram will be constructed for multi-project-driven organizations with limited resources which function in a competitive environment.

The logic of the EC will be discussed in the following paragraphs and the discussions should be followed alongside figure 5.

In the first place entity A identifies the global objective of organizations that deliver value through the execution of multiple-projects. The objective is to deliver projects that will increase the value of the organization. This value can be measured in terms of throughput, as discussed earlier. The goal of delivering projects that increase the value of the organization depends on two necessary conditions:

1. Satisfy the demands of the clients (entity B). It is assumed that satisfying the demands of the customers increases their perception of value that could lead to increased sales through better prices and more orders.

2. Improving the productivity of the system (entity C). Increased productivity is fundamental to the throughput value of the organization.

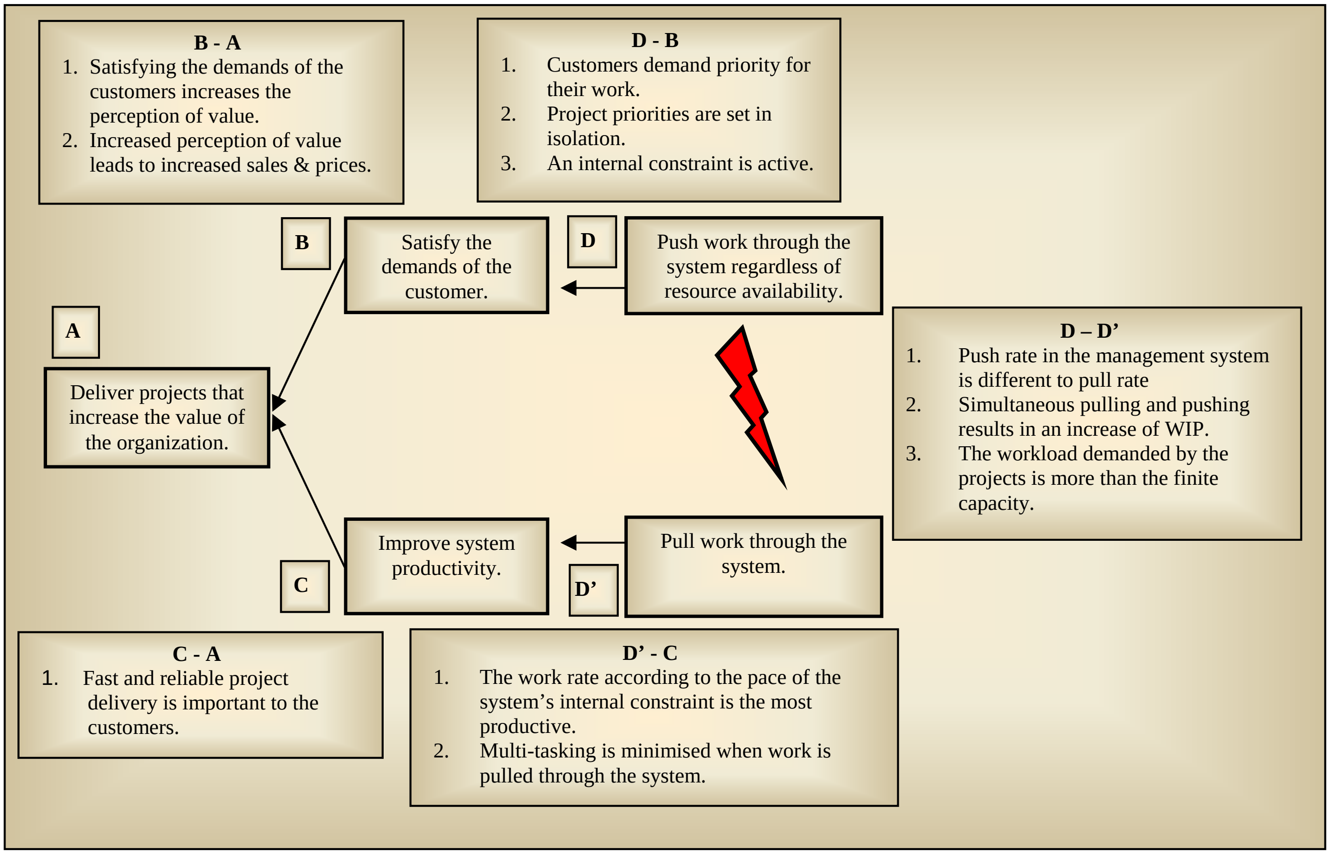

Figure 5: The Evaporating Cloud for organizations with limited resources in a competitive environment.

The next entity D, pushing work through the system, is the prerequisite for the first necessary condition B. Here management "pushes" work through the system regardless of the available resource capacity, as clients demand that their work is given priority. The priority work of the client is also usually set in isolation (and does not consider other projects) for the limited pool of shared resources.

Entity D', pulling work through the system, is the prerequisite for the second necessary condition. Here the view is followed that the organization should pull work through the system taking into account the limited resource capacity, as the assumption is made that the work rate according to the pace of the system's constraining resource is the most productive.

Here it is assumed that the work-in-progress (WiP) increases if work is pushed into the system. An increase in WiP will lead to limited resources doing (more) multi-tasking over the two macro processes.

It is assumed that multi-tasking adds significant waiting time that increases the elapsed time to complete a task. This leads to the fact that key tasks on the project takes a long time to complete, causing the system to become unproductive and bloated with project work.

Both prerequisites of pushing and pulling cannot be valid at the same time – this is the first major assumption when identifying the conflict.

The conflict is clear, but will only exists if available capacity is finite and when the workload demanded by the projects in the system, exceeds the finite capacity.

The organization needs to push work through the system, but at the same time needs to pull work through the system. When managers are confronted with this type of systematic conflict and no solution seems to be available, one side of the conflict usually wins. In reality, project work tends to be pushed through the system regardless of resource availability, because of the fear of losing business Cooper [9]. The existing conflict will be referred to throughout the study as the push problem.

Another assumption is that the existing conflict is primarily due to the fact that the push rate is different to the pull rate. This means that the value acquisition and the value delivery rates are determined by two totally independent factors, as suggested by Payne [36].

The value acquisition rate is determined by the amount of work that is available in the market. In other words push is determined by the amount of opportunities clients present.

The value delivery rate (pull rate) is driven by internal factors such as the availability of limited internal resources.

The identified conflict is further enlarged, due to a resource scheduling issue over the two macro processes. Many key resources are utilized in both the value acquisition and value delivery processes (Babcock [2]) and management is sometimes unclear on how to do the future scheduling of these resources over the two macro-processes. Limited key resources are used:

1. In the value acquisition process to identify new opportunities and to help with the associated decision making.
2. In the value delivery process to ensure that a high-quality product is introduced swiftly to the market.

1.6 HYPOTHESIS

In the view of the foregoing arguments and thoughts developed around the Evaporating Cloud shown in figure 5, the hypothesis is made that it should be possible for project-delivery driven organizations with limited resources, to acquire a project management system which will address the identified push problem. In other words, a tool that will synchronize the flow rate of the value delivery and value acquisition processes in such a way that the organization's value will be maximized in terms of amount and timing.

This would be possible provided that at least one of the assumptions supporting D – D' or D – B in the EC can be invalidated. This can be achieved by showing that the suggested interventions that will be discussed later on in this study are indeed invalidating at least one of the assumptions on the EC.

1.7 THE PROPOSED CONTRIBUTION

If the proposed injections are found to be valid tools to use in order to increase an organization's project value, the contribution towards scientific knowledge is an integrated model for the holistic management of multiple projects through the project life cycle. Therefore, industries that are employing project management to manage the delivery of their outputs can benefit.

1.8 CONCLUSION

Now that the research question has been identified and the core management problem verbalized, injections for the Evaporating Cloud will be presented in chapter 3. The injections will aim to invalidate the assumptions made in the arrow connecting D'–D and D-B. The injections will be presented from a "process" view which will be by means of structured English and illustrations and a "system's" view which will be in the form of a Future Reality Tree (FRT). These injections will propose an answer to the question *"To what should processes in the multi-project environment be changed?".*

But first a detailed literature study will be undertaken where the necessary competitive factors in development and the strategies involved will be presented. The processes to achieve a good value acquiring flow rate and the concept of Throughput Value and Critical Chain project management in the multi-project environment will also be discussed.

CHAPTER 2

LITERATURE STUDY

2.1 INTRODUCTION TO THE LITERATURE STUDY

This chapter prepares the background for the development and assessment of the proposed injection to the Evaporating Cloud by means of a comprehensive literature study. The chapter consists of three core issues that will be used as the building blocks for the new project management model.

The first section of the chapter will explore the key driving forces and the competitive essentials that play a part in the new product or process development world. The second section explores the literature on the value acquisition process and the last section describes the multi-project critical chain environment as the value delivery process.

2.2 COMPETING THROUGH DEVELOPMENT CAPABILITY

In a competitive environment that is global, intense and dynamic the development of new products and processes increasingly is a focal point of competition (Buggie, Scheuiing and Vaccaro, [4]). Firms that get to market faster and more efficiently with products that are well matched to the needs and expectations of target customers create significant competitive leverage (Kmetovicz, [28]). Firms that are slow to market with products that match neither customer expectations nor the products of their rivals are destined to see their market position erode and financial performance falter (Willis and Jurkis [53]). In a turbulent environment, doing product and process development well has become a requirement for being a player in the competitive game; doing development extraordinarily well has become a competitive advantage.

2.2.1 THE KEY DRIVING FORCES IN DEVELOPMENT

The key forces driving the development of new opportunities or products are as follow (Wheelwright and Clark [52]):

1. *Intense international competition.*

   The number of competitors capable of competing at a world-class level has grown. At the same time those competitors have become more aggressive in their pursuit of new opportunities. This has resulted in competition being more intense, demanding and rigorous, creating a less forgiving environment.

2. *Fragmented, demanding markets.*

   Customers have grown more sophisticated and demanding. Previously unheard of levels of performance and reliability are the expected standard today.

3. *Diverse and rapidly changing technologies.*

   The growing breadth and depth of technological and scientific knowledge has created new options for meeting the needs of an increasingly diverse and demanding market. The development of novel technologies and a new understanding of existing technologies increases the variety of possible solutions available to engineers and marketers in their search for new products. New technologies have the capacity to change the character of a business and the nature of competition.

Wheelwright and Clark [52] highlight that these forces are at work across a wide range of industries. They are central to competition to young, technically dynamic industries, but also affect mature industries where life cycles historically were relatively long, technologies mature and demands stable, as also highlighted by Cooper [8].

2.2.2 THE COMPETITIVE ESSENTIALS

Rigorous international competition, the explosion of market segments and niches, and accelerating technological change have created a set of competitive essentials for the development of new products and processes in diverse industries. Table 1 shows these essentials, as discussed by Willis and Jurkus [53], and suggests some of their implications.

Required capability	Driving force	Implications
1. Fast.	Intense competition; accelerating technological change.	Shorter development cycles.
2. Responsive to the client.	Greater client expectation and hearing the client's voice.	Better targeted products.
3. High development productivity.	Exploding product variety; sophisticated, discerning customers; technical diversity.	Leverage from critical resources; increased number of successful development projects per engineer.
4. Products with distinction and integrity.	Demanding customers; crowded markets; intense competition.	Creativity combined with total product quality, customers integrated with truly cross functional development process.

Table 1: The development essentials, adapted from Willis and Jurkus [53].

To succeed, firms must be responsive to changing customer demands and the moves of their competitors. This means that they must be fast (Kmetovicz, [28]). Willis and Jurkus [53] state that although quality, price and productivity are very important, the most important battleground is time-based competition.

Time-based competition is a competitive strategy that seeks to compress the time required in developing and delivering products (Thomas and Sadat-Hossieny, [48]). Willis and Jurkus [53] highlights that the organization that is most responsive to the customer's needs will be the winner. Blackburn [3] further points out that when customers are given a selection of similar products of high quality and cost, customers will gravitate toward the one that is delivered fastest.

Slow product developers face several disadvantages. To name one, they may be forced to use a riskier strategy by attempting to incorporate more modifications with each new product release, in order to keep abreast of the faster developers (Willis and Jurkus [53]). The organization with a fast development cycle can use a more incremental approach, with product releases occurring more frequently, and each release incurring less risk. Meyer and Purser [31] recommend six key steps to prepare the organization for minimizing product development cycle time. These are:

1. Recognize what the customer regards as added value in the product.
2. Focus the entire organization on those activities that add value to the end customer.
3. Flatten the structure of the organization by utilizing multi-functional teams to make the firm more flexible and responsive.
4. Pursue product development and process development to verify that production is capable of building proposed designs.
5. Set "stretch" goals of at least a 50% reduction in cycle time, and communicate progress publicly.
6. Create an environment that stimulates and rewards continuous learning and improvement.

But delivering products fast is not enough. Firms must also bring new products and processes to the market efficiently. Because the number of new products and new process technologies has increased while model lives and life cycles have shrunk, firms must mount more development projects than has traditionally been the case, utilizing substantially fewer resources per project.

Recent research has revealed that when time is compressed, productivity improves, risks are reduced, and market share is increased (Ellor D, Zahra S.A [17]). In terms of margin, customers are also willing to pay higher prices for quicker delivery and service, especially if those products or services are unique or custom-built to their needs (Willis and Jurkus [53]).

Michael Porter [39] has also developed a detailed and highly regarded paradigm of competitive strategy. Its entire structure is based on the proposition that business success rests on satisfying customer needs as explained by Nolte [35]. According to Nolte [35] the products and the processes that a firm introduce must meet client demands in terms of value, reliability and distinctive performance.

2.2.3 THE OPPORTUNITY AND THE CHALLENGE

Willis and Fulkus [53] highlights that firms that challenge and meet these competitive essentials enjoy a significant advantage in the market place. The development of successful products result in a happier, more satisfied customer. The organization itself benefits from successful development in terms of lower operating costs, shorter product development cycles, faster inventory turnover and greater market share. All of these factors enhance a firm's ability to compete. Successful new products also unleash a virtuous cycle in reputation and enthusiasm within and outside the organization. Inside, successful new products energize the organization; confidence, pride and morale grow. Outside, outstanding new products create broad interest in the firm and its products, enhance the firm's ability to recruit new employees and facilitate the building of relationships with other organizations.

While potential opportunities to be realized in developing new products and processes are exciting, making them happen is a demanding challenge (Cooper [8]). New product and process development entails a complex set of activities that cuts across most functions in a business, as suggested by figure 6, which lays out the phases of activity in a typical development project.

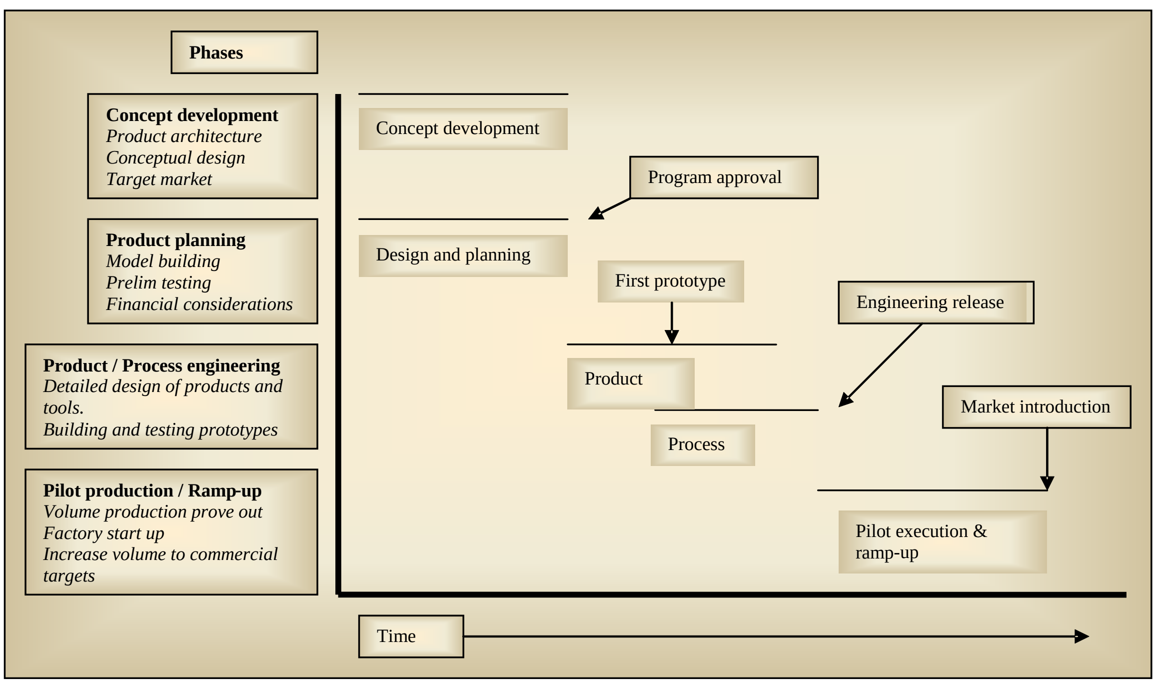

Figure 6: Typical phases of opportunity to product development, adapted from Wheelwright and Clark [52].

In the first two phases - concept development and product planning – information about market opportunities, competitive moves, technical possibilities and production requirements must be combined to lay down the architecture of the new product.

This includes its conceptual design, target market, desired level of performance, investment requirements and financial impact. Before a new product development project is approved, firms also attempt to prove out the concept through small-scale testing, the construction of models and, often, discussions with potential customers.

Once approved, a new project moves into detailed engineering. The conclusion of the detailed engineering phase of development is marked by an engineering “release” or “sign-off” that signifies that the final design meets its requirements. At this time the firm typically moves development into a pilot manufacturing phase. During pilot production many units of the product are produced and the ability of the new or modified manufacturing process to execute at commercial level is tested.

At this stage all commercial tooling and equipment should be in place and all part suppliers should be geared up and ready for volume production (Wheelwright and Clark [52]). This is the point in development at which the total system – design, detail engineering, tools and equipment, parts, assembly sequences, production supervisors, operators and technicians – comes together. The final phase is ramp–up, where commercial production begins.

An obstacle to achieving rapid, efficient, high-quality development is the complexity and uncertainty that confronts the organization (Chapman and Ward [6]). The problems that uncertainty creates – e.g., different views on the appropriate course of action, new circumstances that change the validity of basic assumptions, and unforeseen problems – are compounded by the complexity of the product and the production process.

Moreover, products may be evaluated by a number of criteria by potential customers. Thus the market itself may be complex with a variety of customers who value different product attributes in different ways.

This means that the organization typically draws on a number of resources with a variety of specialized skills to achieve desired, yet hard to specify, levels of cost and functionality. To work effectively, these skills and perspectives must be integrated to form an effective whole.

2.2.3.1 DOING THE RIGHT PROJECT RIGHT

Montoya-Weiss [32] states that there are two types of success factors that need to be present for organizations to deliver new projects fast and successfully. The first deals with doing the right projects; the second deals with doing the project right.

Doing the right project

According to Cooper [8] doing the right projects depends on a number of external or environmental success factors over which the project team has little control. These include characteristics of the new product's market, technologies and competitive situation, along with the ability to leverage internal competencies. Although not within the control of the team, these are nonetheless useful factors to consider when selecting or prioritizing projects.

Doing projects right

Doing the chosen projects right highlights the process factors or action items an organization could focus on. This would provide the project team or top management with things to do to ensure successful project development.

2.2.4 CHARACTERISTICS OF EFFECTIVE DEVELOPMENT

Outstanding projects							
Selected themes							
A unique, superior and differentiated product with good value for money for the customer.	A strong market orientation.	Sharp, early fact-based product definition before development begins	Solid up-front homework. Doing the front-end activities well.	Cross functional teams: Empowered, resourced, accountable, dedicated leader.	Leverage – where the project builds on business's technology and market competencies.	Quality of the product launch effort: Well planned and resourced	Technological competencies and quality of the execution.

Table 2: Selected themes in outstanding development projects, adapted from Cooper [10].

Table 2 highlights how important it is in successful development of new products for objectives and accountability to be clear. It is also necessary for the new product to be widely shared and important for the new product to stem from a concept and product planning process that brings marketing, engineering and execution together.

The next section of this chapter will focus on the front end of the development process – the value acquiring process.

The concept of development strategy, the creation of an aggregate project plan to guide a portfolio of development efforts, and two development processes that successfully initiate and select projects and focus on the organization's resources to bring the most attractive opportunities to the market rapidly and efficiently, will be explored.

2.3 THE VALUE ACQUISITION PROCESS

"Whether you think you can, or you think you can't, you are right" – Henry Ford.

2.3.1 THE CONCEPT OF DEVELOPMENT STRATEGY

As highlighted by Danielmeyer [13], there are four types of potential benefits of effective development:

- The elevation of the limited (constraining) resources in a company.
- The acceptance of more challenging and value-adding opportunities.
- More rewarding goals for the organization.
- An overall improved development process.

2.3.1.1 PROBLEMS IN NEW PROCESS DEVELOPMENT

To ensure that new product development is successful, it is useful to explore some ways in which development problems manifest themselves. Wheelwright and Clark [52] propose a few obvious pitfalls that emerge:

A moving target.

Too often the basic product or process concept misses a shifting technology or market, resulting in a mismatch.

Mismatches between functions.

Mismatches often occur within the organization. What one part of the organization expects or imagines another part can deliver, may prove unrealistic or even impossible.

Lack of product distinctiveness.

Often new product development terminates in disappointment because the new product is not as unique as the organization anticipated.

Problem solving delays.

Every new product development activity involves uncertainty, with regard both to specific problems and conflicts that will inevitably arise, and the resources required to resolve them. Too often organizations allocate all of their development resources to known project requirements, leaving little or no cushion for the unexpected.

Unresolved policy issues.

A number of very specific choices and decisions must be made during the product development process. If major policies have not been articulated clearly and shared, these choices often force a decision on the policy issue for the entire organization.

Much can and usually does go wrong during development projects. When things do go wrong, most often it is not because the project team was not smart or was unwilling to work. Usually the problem is a much deeper and more fundamental one. Table 3 expresses what Cooper [8] calls seven "blockers" for why success on projects is limited. The project performance "blockers" and each blocker's implication are shown.

Blocker	**Implications of Blocker**
1. Ignorance.	Don't know what should be done to properly execute the project.
2. Lack of skills.	Resources don't know how to do the tasks.
3. Misapplied new product process.	The process is missing key elements or it is laden with bureaucracy.
4. Organizations are too confident.	New products usually fail due to omission of key elements or sloppy quality of execution.
5. A lack of discipline.	No leadership.
6. Tight programme schedule.	Worked is rushed.
7. Too many projects and not enough resources.	1. Management doesn't provide the necessary resources to achieve the organization's new goals - implication to CC scheduling. 2. Too many projects are approved for the limited resources available.

Table 3. Problems in new product/project development, adapted from Cooper [8].

Cooper [8] highlights that managers of organizations are often too ignorant and overconfident. Managers often fail to plan sufficiently in advance to provide the requisite skills and resources, to define the project and its purposes appropriately, and to integrate the development project with other basic strategies. Rather, managers often seek to respond to problems as their importance becomes apparent; at that point they are unavoidable.

Therefore the need for managers exists to have a comprehensive approach in order to apply development resources, including management's time, in a manner that is preemptive, proactive and of maximum value.

2.3.1.2 A FRAMEWORK FOR A DEVELOPMENT STRATEGY

Wheelwright and Clark [52] proposes a framework for development strategy, depicted in figure 7, which creates a foundation for individual projects.

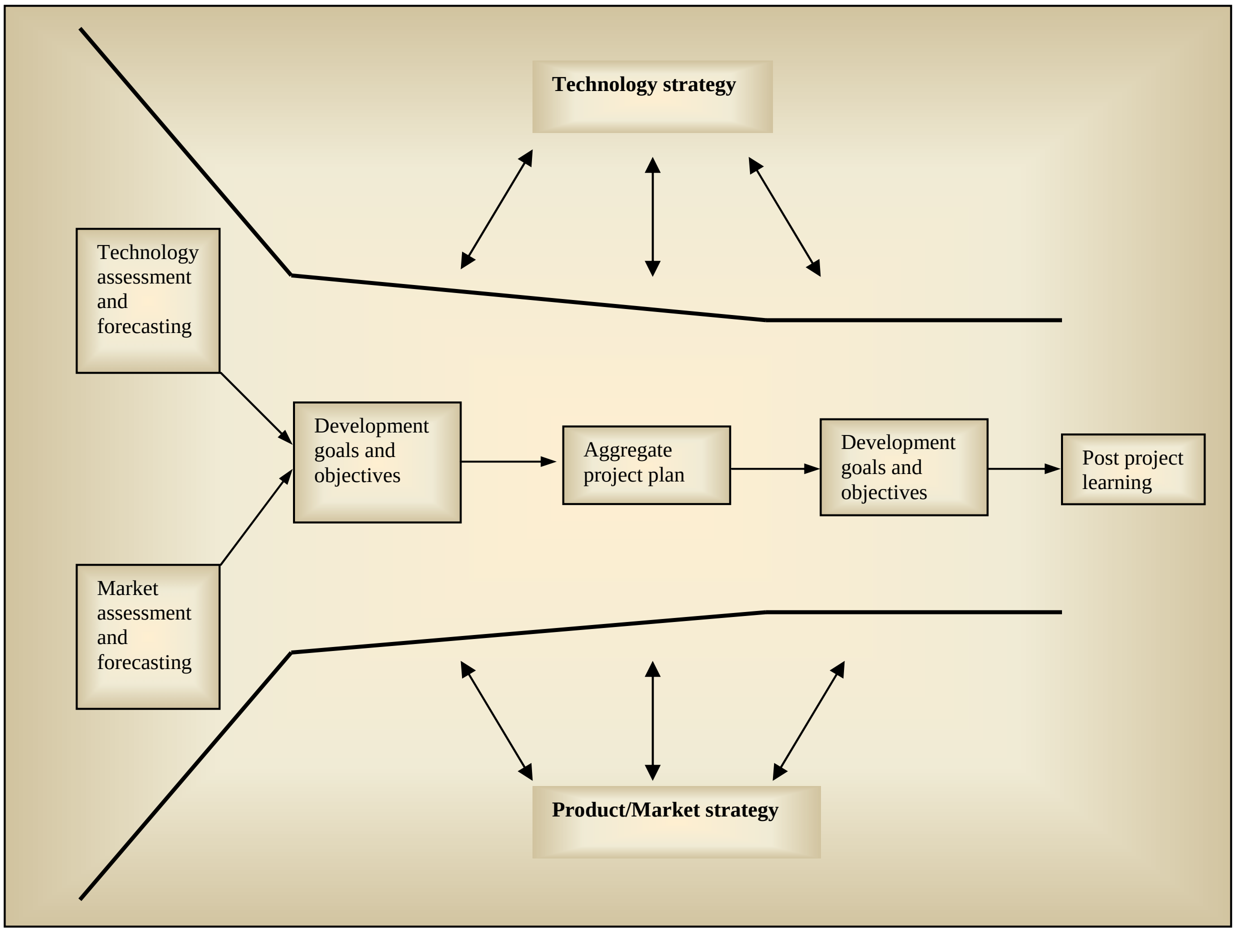

Figure 7: The development strategy adopted from Wheelwright and Clark [52].

This framework addresses the four main purposes of a development strategy:

1. Creating, defining and selecting a set of development projects that will provide superior products and processes.
2. Integrating and coordinating functional tasks, technical tasks and organizational units involved in development activities over time.

3. Managing development efforts so they converge to achieve business purposes as effectively and efficiently as possible.
4. Creating and improving the capabilities needed to make development a competitive advantage over the long term.

The framework proposed by Wheelwright and Clark [52] accomplishes these purposes by adding two pre-project focal points – developing goals and an aggregate project plan – where *technology strategy* and *product/market strategy* can be discussed and integrated. These explicit pre-project activities provide a way for managers to address policy issues and cross-project concerns, and to set bounds on individual projects. By limiting the scope of individual projects, senior management make projects more manageable and facilitate refinement and improvement of project management procedures. The framework thus recognizes the important need for ongoing learning, as suggested by Thiry [49], and provides mechanisms for capturing and applying learning beyond the efforts of individual team members. The framework provides much more robust phases for the necessary pre-project planning, as also suggested by Cooper [10], and post project learning that complement and support work on specific projects.

2.3.1.3 TECHNOLOGY PLANNING AND STRATEGY

The objective of technology strategy is to guide the organization in acquiring, developing and applying technology for competitive advantage (Wheelwright and Clark [52]).

A strategy for technology must confront, in the first instance, what the focus of technical development will be. As a first step in creating technology strategy, *focus* defines those capabilities where the firm seeks to achieve a distinctive advantage relative to competitors. Establishing *focus* defines targets for investment in technical capability, but leaves open the question of *source*. This is the second critical aspect of technology strategy. The key questions technology strategy must answer about *sources* are:

1. What roles will internal and external sources play?
2. How will they be integrated?

Having determined the *focus* of technical development and the *source* of capability, the organization must establish the *timing and frequency* of the implementation. Part of the timing issue involves developing technical capability, and part depends on introducing technology into the market.

2.3.1.4 PRODUCT/MARKET PLANNING AND STRATEGY

A product/market strategy for a business addresses four important questions:

1. What product will be offered?
2. Who will be the customers?
3. How will the products reach those customers?
4. Why will customers prefer our products to those of competitors?

2.3.1.5 DEVELOPMENT GOALS AND OBJECTIVES

A strategy for technology and for products and markets gives the development effort guidance and direction (Wheelwright and Clark [52]). To ensure consistency and coherence across these strategies and to link them explicitly to business as well as development objectives, a firm must define its basic development goals and objectives.

At the aggregate level, the goals and objectives need to be made explicit and then juxtapositioned to examine their compatibility and complementarity. The purpose of this process is to provide integration both in the aggregate and at the level of the individual project. Typically, these goals range from market share to revenues and profits, and from technology achievements to new product/process objectives. When effectively tied together, these goals provide an organization with confidence that their strategies will generate the business performance desired. They also can serve as a guide for investment decisions and a benchmark for monitoring ongoing progress.

For these goals to be credible, they must be linked directly to the set of development projects the firm intends to undertake. That is, the sum of the projects must provide the aggregate performance desired. In addition to meeting aggregate business goals, the collective set of projects must meet technical performance goals.

At the operating level, there is also a need for goals that can guide the individual project, yet connect its contribution to longer-term objectives. Typically, firms that measure development focus their attention on either resource productivity or design quality. According to Wheelwright and Clark [52] only recently time-to-market and production quality have gained attention as important measures for individual projects.

In most competitive environments, however, managers need multiple measures on all four performance dimensions. Moreover, the primary emphasis must be on improving all of the dimensions simultaneously. As part of development strategy, it is important to define what measures are to be used and why, and to apply them consistently in evaluating development performance. Table 4 presents examples of performance measures and their connection to competition.

Performance dimension	**Measures**	**Impact on competitiveness**
Time-to-market	1. Frequency of new product introductions. 2. Time from concept to market introduction. 3. Number of projects started and completed. 4. Percentage of sales coming from new product.	1. Responsiveness to customers/competitors. 2. Quality of design. 3. Frequency of projects – model life
Productivity	1. Key resource hours per project. 2. Cost of materials per project. 3. Actual versus plan.	1. Number of projects. 2. Frequency of projects.
Quality	1. Reliability in use. 2. Design – customer satisfaction. 3. Yield – factory and field.	1. Reputation – customer loyalty. 2. Market share – attractiveness to customers. 3. Profitability – cost of ongoing service.

Table 4: Performance measures for development projects, adapted from Wheelwright and Clark [52].

Management can use these performance measures as common reference points when making decisions during the development process and development strategy.

2.3.1.6 THE AGGREGATE PROJECT PLAN

The process of working out development goals and objectives integrates technology and commercial plans from the standpoint of purpose and intent.

The aggregate project plan brings a second stage of integration down to the level of specific projects and resources. The purpose of creating such a plan is to ensure that the collective set of projects will accomplish the development goals and objectives and also build the organizational capabilities needed for ongoing development success.

The aggregate project plan makes it possible to balance the demands of individual projects for critical development resources with existing capacity in the organization.

The aggregate project plan also lays out the sequence of projects the firm plans to undertake, as well as which will be actively supported at any one time. The planned project sequence establishes a framework for future decisions about adding new projects, and thus the demands on the organization's resources. It also makes explicit the kinds of capabilities the firm will be building over time. Development projects serve as a primary vehicle for building people and organizational skills. The aggregate project plan helps senior management ensure that, collectively, individual and group project assignments make sense over time, enhancing and expanding the organization’s critical capabilities.

Cooper [9] emphasizes that there is a general tendency to over-commit the development resources of a company, resulting in projects being late.

When the aggregate capacity of an organization is overcommitted, the constraining resources usually find themselves spread across several projects at a time. The justification offered for concurrent project assignments to constraining resources is that, in order for management to increase the profit of the entire organization, the constraining resources need to be exploited fully as suggested by Goldratt [21] when applying Critical Chain project management techniques.

In the multi-project environment it is usually the case that the introduction of project work that exceeds the organization's capacity will, in itself, lead to further capacity reductions because of an increase in bad multi-tasking and bad time management of the individual resources.

The development of an aggregate project plan can be broken down into three different steps (Wheelwright and Clark [52]). First, management has to ensure that the correct resources are applied to the appropriate type and mix of projects. By indicating the number and mix of the different project types, the aggregate project plan helps an organization to allocate its efforts in proportion to the need for, and benefits from, projects of each type.

Secondly management must develop a capacity plan. In most organizations the demands or opportunities for developing projects far exceed the capacity of available resources to work on them.

The final step in the aggregate project plan will be to examine the effects of the proposed projects on fundamental skills and capabilities required for future development projects. These include planning net additions to development resources, but more importantly, providing a set of projects with which project leaders and teams can sharpen their skills over time.

2.3.1.7 POST-PROJECT LEARNING

The final element of a development strategy is post-project learning. Its goal is to ensure that the lessons available from each project are identified, shared and applied throughout the organization. In doing so, it closes the loop on continuous improvement (Thiry [49]) by strengthening the foundation for the next iteration of the development strategy.

2.3.2 STRUCTURING THE DEVELOPMENT FUNNEL

The aim of any product or process development project is to take an idea or concept to reality by converging to a specific product that can meet a market need in an economical, manufacturable form.

As suggested by Wheelwright and Clark [52], the overall development process starts with a broad range of inputs and gradually refines and selects from among them, creating a handful of formal development projects that can be pushed to rapid completion and introduction. Wheelwright and Clark [52] present a converging funnel for symbolizing this process. Managing the development funnel involves three challenges:

To widen the mouth of the funnel

To be effective, the organization must expand its knowledge base and access the information in order to increase the number of new opportunities.

To narrow the funnel's neck

After generating a number of opportunities, management must screen them and focus resources on the most attractive opportunities. The challenge is to narrow the neck of the funnel while ensuring that a constant stream of good projects flows down it. The goal is to create a portfolio of projects that will meet the business objectives of the firm while enhancing the firm's strategic ability to carry out future projects.

Delivering value

The third challenge is to ensure that the selected project delivers on the objectives anticipated when the project was approved.

2.3.2.1 CREATING THE DEVELOPMENT FUNNEL

The nature of the development funnel is defined by the way the organization identifies, screens, reviews and converges on the content of a development project as it moves from idea to reality. The funnel establishes an overall framework for development: the generation and review of alternatives, the sequence of typical decisions and the nature of decision-making. In effect, the development funnel creates the architecture for the set of development activities that must occur as part of a successful development project. Wheelwright and Clark [52] lay out three sets of dimensions that define the choices firms make about the development funnel:

1. Its process for creating development projects – encouraging certain sources of new ideas and selecting which of those to support in the development projects.
2. Its means of achieving convergence to a focused product concept and detailed design through a set of decision-making, review and control procedures during project execution.
3. Its final commitment to the market through final testing, screening and market introduction plans.

In Figure 8 a graphical representation of the development funnel concept is shown and discussed accordingly.

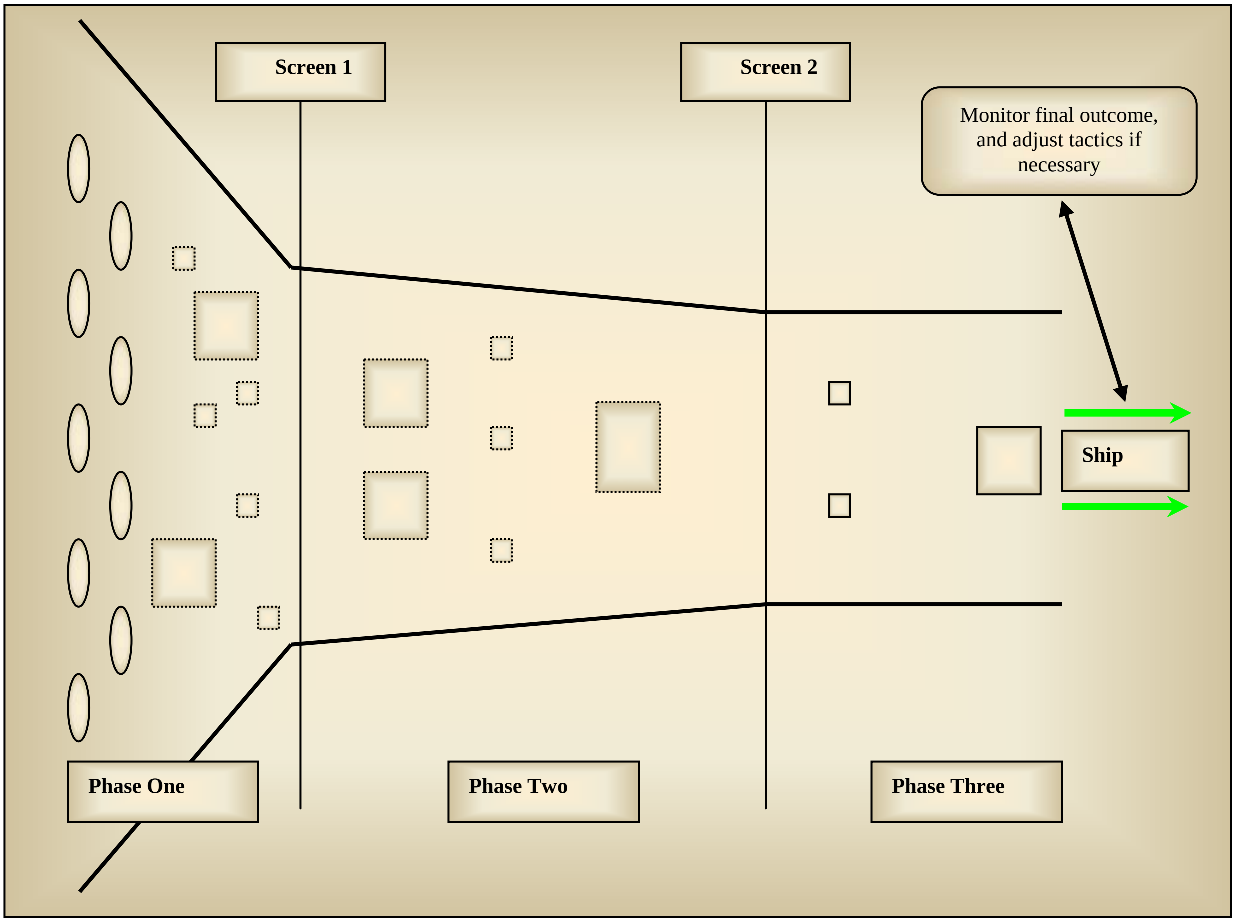

Figure 8: The development funnel adapted from Wheelwright and Clark [52].

Phase 1:

Phase 1 happens before any type of screening is done. The front end of the funnel is expanded to encourage as much idea generation and concept development as possible. This will help to encourage innovation and input from all parts of the organization as well as from customers, competitors and suppliers. To encourage resources to such a behavior, incentive schemes etc can be installed.

Screen 1:

At screen 1 a narrowing of the funnel occurs. This is at the end of the product/process concept development stage. Screen 1 can be thought of as a "completeness" or "readiness" review rather than as a no/go decision review.

According to Wheelwright and Clark [52] the intent is to periodically (quarterly or even monthly) review the status of those ideas in the concept development stage of the funnel. As part of this initial screen, ideas should be checked for their fit with technology and product market strategies, their potential role in executing the aggregate plan, and their appropriateness as an application of the firm's development resources.

If an idea is complete it can move on to the next phase. If it is found to be incomplete and not ready to move on, then the specific tasks needed to complete it so it meets the requirements of screen 1, can be agreed upon, assignments made for completing them, and the time established at which it will next be reviewed at a screen 1 meeting. Besides reviewing ideas for completeness, screen 1 carries out a second important function. It begins to identify competing concepts, ideas that might be integrated into platform development products and those that might be most effectively embedded in enhancement or derivative projects.

Phase 2:

Following the initial screening, the best of those ideas are then detailed and analyzed and put in a form that will enable management to evaluate proposed projects against competing and complementary projects under consideration, the functional strategy maps, the aggregate project plan and the resources available.

Screen 2:

Screen 2 is a no/go decision point. Senior management should review product and process development options, and select those that will become development projects. Any project passing the screen will be funded and staffed with every expectation that it will be carried through to market introduction.

Phase 3:

If approved, a project's bounds, and the knowledge required for its completion, becomes the starting point for rapid and focused development.

Having a well-functioning development funnel for the identification of new project or product ideas is of no use if the ideas are not implemented correctly. The only way to achieve this is to continuously monitor the final outcome of the funnel.

Wheelwright and Clark [52] emphasizes that these results should be critically compared with the expectations during the filtering phases of the funnel. This will enable management to use the funnel to adapt their criteria for choice to enable them to make better choices in future. In doing so, it closes the loop on continuous improvement.

2.3.3 THE STAGE-GATE DEVELOPMENT PROCESS

Very similar to the development funnel proposed by Wheelwright and Clark [52] is a generic stage-gate new product development process presented by Cooper [10]. This process is shown in figure 9.

The stage-gate system breaks down the new product project into identifiable stages. Each stage is designed to gather information needed to progress the project to the next gate or decision point.

According to Cooper [10] each stage should be multi-functional. In other words, each stage should consist of a set of parallel activities undertaken by people from different functional areas within the organization. These activities are designed to gather information and to drive uncertainties down.

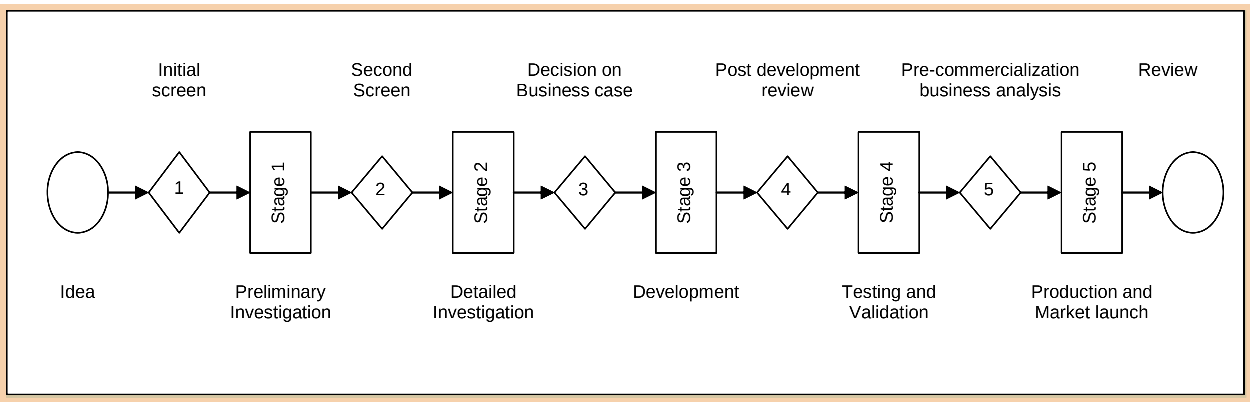

Figure 9: A generic stage-gate new product process, adapted from Cooper [10].

Cooper [10] emphasizes the fact that resource commitment in the various stages is incremental, and should become more intense as the process continues over time. Preceding each stage is a gate or a decision point. These gates are predefined and specify a set of deliverables, a list of criteria, both “must meet” and “should meet”.

The stage-gate system’s main goal is to reduce uncertainty during a certain stage to such an extent that an informed decision can be made at the next gate. To better understand Cooper’s [10] development process, a view of what is involved at each stage and gate is given below:

Gate 1: Initial screen:

Gate 1 is a very gentle screen and amounts to subjecting the project to a handful of key “must meet” and “should meet” criteria. These criteria often deal with strategic alignment, project feasibility, market attractiveness etc. If the decision is a Go, the project moves into the preliminary investigation stage.

Stage 1: Preliminary investigation:

This first stage has the objective of determining the project's technical and market place merits. The typical market assessment will determine if the proposed product has any commercial prospects such as:

1. The attractiveness and potential of the market.
2. Gauging possible product acceptance.
3. Sizing up the competitive situation.

The preliminary technical assessment will include key concerns such as:

1. What will the product requirements or specifications be?
2. How can these requirements be achieved technically?
3. What are the odds that it is feasible?
4. Can the product be manufactured?
5. What are the key technical risks?

This stage is a quick scoping of the project, and provides for the gathering of both technical and market information – at low cost and in a short time – to enable a cursory and first-pass financial analysis as input to gate 2. Cooper [10] suggests that this activity should not take longer than one calendar month.

Gate 2: Second screen:

The project is submitted to a second and somewhat more rigorous screen at gate 2. This gate is essentially a repeat of gate 1: the project is re-evaluated in the light of the new information obtained in stage 1. If the decision is Go at this point, the project moves into a heavier spending stage. At gate 2 the project is again submitted to the original set of "must meet" and "should meet" criteria used at gate 1.

Here additional "should meet" criteria may be considered, dealing with sales force and customer reaction to the proposed product, potential legal, technical and regulatory "killer variables" – all the result of new data gathered during stage 1. Again a checklist and a scoring model facilitate this gate decision.

Stage 2: Detailed investigation (Build the business case):

Stage 2 is where the business case is constructed: this stage is a detailed investigation stage, which clearly defines the product and verifies the attractiveness of the project prior to any heavy spending.

Stage 2 is also the critical homework stage which will include research on market needs and preferences, competitive analysis, concept testing and a detailed technical study which will focus on the "do-ability" of the project at stage 2. A detailed financial analysis is also conducted as part of the justification facet of the business case.

The result of stage 2 is a business case for the project: the project definition or protocol is agreed to, and a thorough project justification and detailed project plan are developed. Stage 2 involves considerably more work than stage 1, and requires the inputs from a variety of sources. According to Cooper [10] stage 2 is best handled by a team consisting of multi-functional members.

Gate 3: Decision on the business case:

This is the final gate prior to the development stage, the last point the idea can be discarded before it becomes an official project. Gate 3 subjects the proposed project once again to the set of "must need" and "should meet" criteria used at gate 2.

If the decision is Go, gate 3 sees commitment to the product definition and agreement on the project plan that charts the path forward. At this point the opportunity/idea become a formal development project and a full project team is designated.

Stage 3: Development:

Stage 3 is the implementation phase of the development plan and the physical development of the product. During this stage the emphasize is on technical work, but marketing and manufacturing activities also proceed in parallel. The deliverable at the end of this stage is a lab tested prototype of the final product. In stage 3 detailed test plans, market launch plans and production and operation plans are also developed. An updated financial analysis is prepared, while legal and patent issues are resolved.

Gate 4: Post-development review:

The post-development review is a check on the progress and the continued attractiveness of the product and project. This gate also revisits the economic question via a revised financial analysis based on new and more accurate data. The tests and validation plans for the next stage are approved for immediate implementation.

Stage 4: Testing and validation:

This stage tests and validates the entire viability of the project: the product itself, the production process, customer acceptance and the economics of the project.

Gate 5: Pre-commercialization business analysis:

This is the final point at which a project can still be discarded before full production starts. This gate focuses on the quality of the activities at the testing and validation stage and their results.

The criteria for passing this gate focus largely on the expected financial return and appropriateness of the launch of the product. The operations and marketing plans are reviewed and approved for implementation in stage 5.

Stage 5: Full production and market launch:

Stage 5 involves implementation of both the marketing launch plan and the production plan.

Post-implementation review:

Finally a post-audit – a critical assessment of the project's strengths and weaknesses, what was learned from the project, and how the next one can be better – is carried out.

Cooper [10] claims that this proposed stage-gate system as shown in figure 6 could be very successful due to the fact that it incorporates the following factors that are vital to the success and speed of a new product to the market:

1. The process places a lot of emphasis on the investigation of the pre-development activities.
2. It is a multi-disciplinary and multifunctional process.
3. There is a lot of parallel processing – which speeds up the process.
4. There is a strong market orientation in the process.
5. The gates or decision points establish a higher level of focus in the process.
6. Throughout the process there is a strong focus on quality of execution.
7. There is post-project learning – which closes the loop on continuous improvement during the project lifecycle.

2.3.3.1 ESTIMATION AND EVALUATION OF VALUE OPPORTUNITIES

Chapman and Ward [5] propose a minimalist "pass" approach in their paper where they write about the estimation and evaluation of value opportunities and their associated uncertainties.

The process concerns itself with the estimation and evaluation of value possibilities at decision points in order to optimize the overall management process.

The approach involves the following six steps:

1. Identify the different attributes to be quantified.
2. Estimate crude but credible ranges for probability of occurrence and impact.
3. Recast the estimates of probability and impact ranges.
4. Calculate expected values and ranges for composite parameters.
5. Present the results.
6. Summarize the results.

For step 1 shown above management could use the following attributes to help with the decision-making throughout the value acquisition process. The attributes present a combination of what Babcock [2] and Cooper [9] suggest. They are:

1. The technical relevance of the opportunity (availability of needed skills and facilities, the probability of technical success).
2. Research direction and balance of the organization (the compatibility with research goals and desired research balance).
3. Timing of R&D and market development relative to the competition.
4. Stability of the potential market to economic changes and difficulty of substitution.
5. Position factor relative to other product lines and raw materials.
6. Market growth factors for the product.
7. Marketability and compatibility with current marketing goals.
8. Producibility with the current production facilities and manpower.
9. The financial factors.

During the application of the first pass approach Chapman and Ward [5] mention that there is an underlying concern to avoid optimistic bias in the assessment of uncertainty, and a concern to retain simplicity with enough complexity to provide clarity and insight to guide uncertainty management.

After the organizations' aggregate project plan, goals and objectives have been set, and arriving opportunities have been approved for further development, the stage is set for the execution of the projects. The value delivery phase and in particular the Critical Chain Project Management principles as developed by Goldratt [18] will be discussed in the next section of this chapter.

2.4 THE VALUE DELIVERY PROCESS

The project delivery process has excellent project performance as the main objective - delivering the project on time, within the specified budget and with the required standard of quality and specifications. Achieving this objective is usually not an easy task, especially when taking into account that an organization has a limited amount of resources available to work on the value delivery process.

According to Chapmann and Ward [6] the successful delivery of projects is largely dependent on how uncertainty is managed during the early parts of the project life cycle. Cooper [9] also recognizes this problem and suggests that organizations need to ensure that they have a reliable and up to date product development process in place to help management choose the most promising value opportunities - as discussed in previous sections of this chapter.

2.4.1 PROJECT PERFORMANCE ISSUES

Cooper [8] further emphasizes that after the most lucrative opportunities have been chosen to become development projects (at the end of the value acquisition process) and project execution is about to start, organizations still find it difficult to deliver the project within the planned timeframe, budget and client specifications.

Leach [30] also highlights that delays in projects, especially construction projects, are still very common in most parts of the world, even with the introduction of advanced construction technologies.

Cooper [8] suggests reasons for unsuccessful project delivery could be that:

1. Management allows too many opportunities to become formal development projects for the capacity of the available resources in the organization.
2. Management allows for an unrealistic project programme, and is in general too confident with their anticipated delivery speed and quality of execution.
3. There is a lack of discipline and general leadership in the organizations.
4. Management underestimate the tasks involved in the delivery process.

Table 5 expresses solutions of what Cooper [8] suggests management could do to overcome the above-mentioned problems and obtain a high probability to achieve success during the project delivery phase – meeting the final project budget and specifications within the desired timeframe.

Problem	Solution (value acquisition)
Too many projects and not enough resources.	▪ Maximize value of portfolio. ▪ Seek right balance of projects. ▪ Ensure project falls within overall strategy. ▪ Carefully plan spending breakdown.
Problem	**Solution to achieve successful value delivery**
Unrealistic project programme task duration estimates. Underestimate tasks that are involved.	▪ Find a balance between task reduction time and quality of execution. ▪ Ensure all tasks with realistic time estimates are included and in order of dependence in the project programme. ▪ Develop cross-functional team.
No real discipline and drive to complete tasks.	▪ Identify leaders. ▪ Leadership training. ▪ Monitor delivery progress.

Table 5:Proposed solutions to achieve a successful project delivery process, adapted from Cooper [8].

To address the value delivery problems highlighted and to serve as a tool which can be applied to the "proposed value delivery solutions" shown in table 5, the Theory of Constraint (TOC) principles as developed by Goldratt [21] could be used. TOC and its direct application to project management, known as critical chain scheduling and buffer management address the issue of successful project delivery.

2.4.2 CRITICAL CHAIN PROJECT MANAGEMENT

TOC is an overall management philosophy developed by Goldratt [21] that has its basis in the manufacturing environment. TOC is a systems approach based on the assumptions that every organization has at least one factor (the constraint) that inhibits the organization's ability to meet its objectives. The normal objective for an organization should be to maximize profit (Goldratt [21]). TOC emphasizes the maximization of profit by assuring that the factor that limits production is used most efficiently.

In his book *The Haystack Syndrome* Goldratt [22] introduced 3 financial performance metrics. Goldratt distinguishes between Throughput or Throughput Value (TV), Inventory or Investment (I), and Operating Expenses (OE).

Throughput can be defined as the rate at which a system generates money through sales after the reduction of material costs, commissions and distribution costs (Goldratt [22]).

Inventory or investment is defined as all the money the system invests in purchasing things it intends to sell again, while operating expenses is defined as the money the system spends in turning inventory into throughput. Throughput value as defined can be calculated as:

TV = sales – totally variable costs (TVC).

The totally variable costs (TVC) and sales of a project are only recognized when the actual money flows in the organization are realized. TVC can for example be seen as payments to sub-contractors, materials used on the project, etc. Sales (money flowing into the organization) are realized when payments for completed work are received (time-based charge to client) or from the revenue earned by the project product.

Operating expenses (OE) on the other hand is another form of money flowing out of an organization. OE include expenses such as salaries, lease of the building, water and electricity, etc, (Viljoen, [50]). The expense of an internal resource working on a project is an organizational operating expense that is incurred whether the resource is working on the project or not.

Under TOC, the objective is to maximize throughput while minimizing operating expenses for labor, sales and administration and simultaneously minimizing investment outlays for inventory, plant, and equipment.

The first step in applying TOC is to *identify the constraint* of the system. For organization that employ skilled resources, and for many other service organizations, the constraint is often the time of one or a few employees.

Once the constraining factor has been identified, the next step is to determine the throughput per unit of the constraining factor. This is done by dividing the throughput per unit of product by units of constraining factor required to produce each unit of product. The key to maximizing profit is to concentrate on selling and producing products that provide the highest throughput per unit of constraining factor.

The primary message of TOC is focus. The five focusing steps of ongoing improvement introduced by Goldratt [20], which are applicable to any physical system, are listed below:

1. *Identify* the system constraint.
2. *Exploit* the system constraint.
3. *Subordinate* everything else around the system constraint.
4. *Elevate* the system constraint.
5. If, in the previous step, a new constraint has been uncovered, *repeat* the process.

The following sections of the chapter will discuss the above-mentioned five TOC focusing steps in detail.

2.4.2.1 IDENTIFY THE CONSTRAINT

The Critical Chain

TOC identifies the constraint of a project as the Critical Chain (Goldratt [18]). The lead-time of a project is determined by adding the durations of the different activities on the longest set of dependent tasks. This is known as the critical path. The critical path approach assumes that the resources to perform the activities are all available. The dependencies between activities are assumed to be technical dependencies only, although it may be as a result of resource dependencies.

Figure 10 illustrates a typical deterministic project schedule. The critical path activities are indicated in red.

Resource limitations are taken into account by the Critical Chain approach from the outset in the scheduling process. The Critical Chain is typically composed of sections that are dependent on precedence (technical) relationships and other sections that are dependent on resource availability.

For a project without resource constraints, the Critical Chain will be the same initial activity path as the critical path.

The PMBOK states that the critical path may change during the performance of the project. This occurs when other paths experience delay, and the 'zero–float' path to complete the project is recalculated. The Critical Chain, on the other hand, does not change during project performance. This is mostly as a result of the overall Critical Chain plan construction procedure.

The next step in the TOC approach is to exploit the constraint by focusing on getting the most out of a given length of schedule.

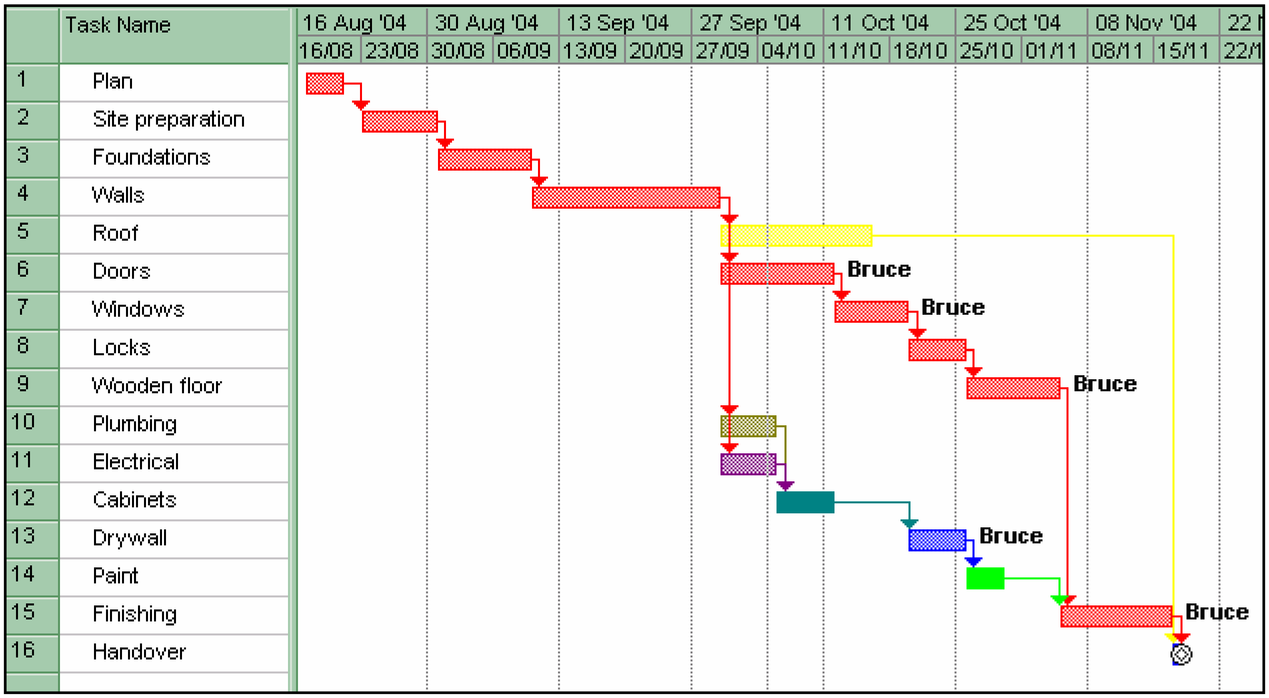

Figure 10: A deterministic project schedule.

2.4.2.2 EXPLOIT THE CONSTRAINT

Exploit common cause variation

Dr. W. Edwards Deming, the man credited with the postwar industrial revolution in Japan, stated "*It would be a mistake to export American management to a friendly country*".

According to Leach [30] Dr. Deming's reasons for this statement were grounded on the many mistakes management of organizations make in attempting to control the system of production. Two of these mistakes may be institutionalized in current methods of project delivery, and must be dealt with before project managers can significantly improve project performance. Dr. Deming included 'an understanding of variance' as one of his four points of profound knowledge in his book *Out of Crisis*.

He identified two points of variation:

1. *Common cause variation:* A cause that is inherent in the system and can be seen as the responsibility of management.
2. *Special cause variation:* A cause that is specific to some group of workers, or to a machine or specific local condition.

The problem with making the above-mentioned mistakes is that they both increase variation in the project. Dr. Deming notes that managers often make the system worse by not understanding the fundamentals between these two types of variation. He also suggests that an exceptionally large part of the variation in projects is inherited by the system itself (common cause variation), and to a lesser extent special cause variation. Leach [30] highlights that projects have a common cause variation in the performance of time of activities.

Although the time to perform individual project activities may be independent of each other, project activity networks define activity dependence. By the definition of project logic (Leach [30]), the successor activity can not start until the predecessor activity is complete (for the most frequent finish to start connection).

Goldratt's improvements for production take advantage of (exploit) the reality of statistical fluctuations and dependent events. Figure 11 illustrates a typical activity performance time distribution. The solid curve shows the probability of a given time on the abscissa. The dotted line shows the cumulative probability of completing the activity in a time less or equal to the time on the abscissa. The left skew of the distribution and the long tail to the right as shown in figure 11 is typical of the common cause variation for many project activities.

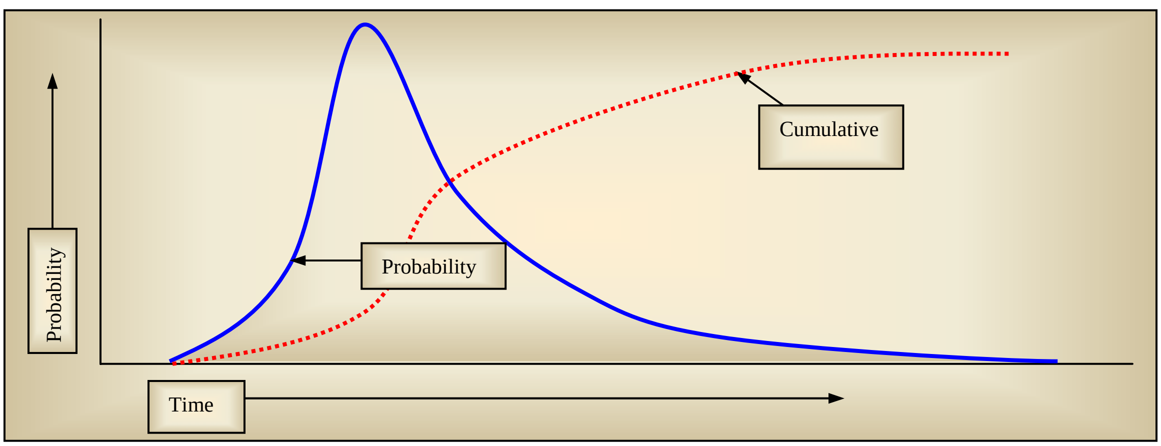

Figure 11: Typical project activity performance time probability distributions show a minimum time, left skew and long tail to the right, adapted from Leach [30].

Fluctuations in the actual performance of unique project activities are likely to be much larger than fluctuations in the time it takes a production machine or person to repeatedly process a part. The project activity network expressed in figure 10 also clearly shows the many dependencies that exist in the project.

Therefore, if a project were compared to a production line it would become evident that even most moderate-sized projects have more dependencies than most production lines. These are the reasons behind the logic that improved production should also improve project management.

Leach [30] highlights that this common cause variation in activity performance is not an exceptional event, such as discrete project risk events. Leach [30] also states that PERT attempted to estimate the impact of this common cause variation by using three activity duration estimates, but for a variety of reasons did not succeed. PERT diagrams as referred to in many project management books are simply a way to show the project logic independent of the time scale; not an application of the three time estimates. Some projects use methods such as simulation and Monte Carlo analysis (Viljoen, [50]) to assess the impact of activity duration and cost uncertainty. While these methods propose a way to estimate uncertainty, they do not pose an effective systematic method to manage it.

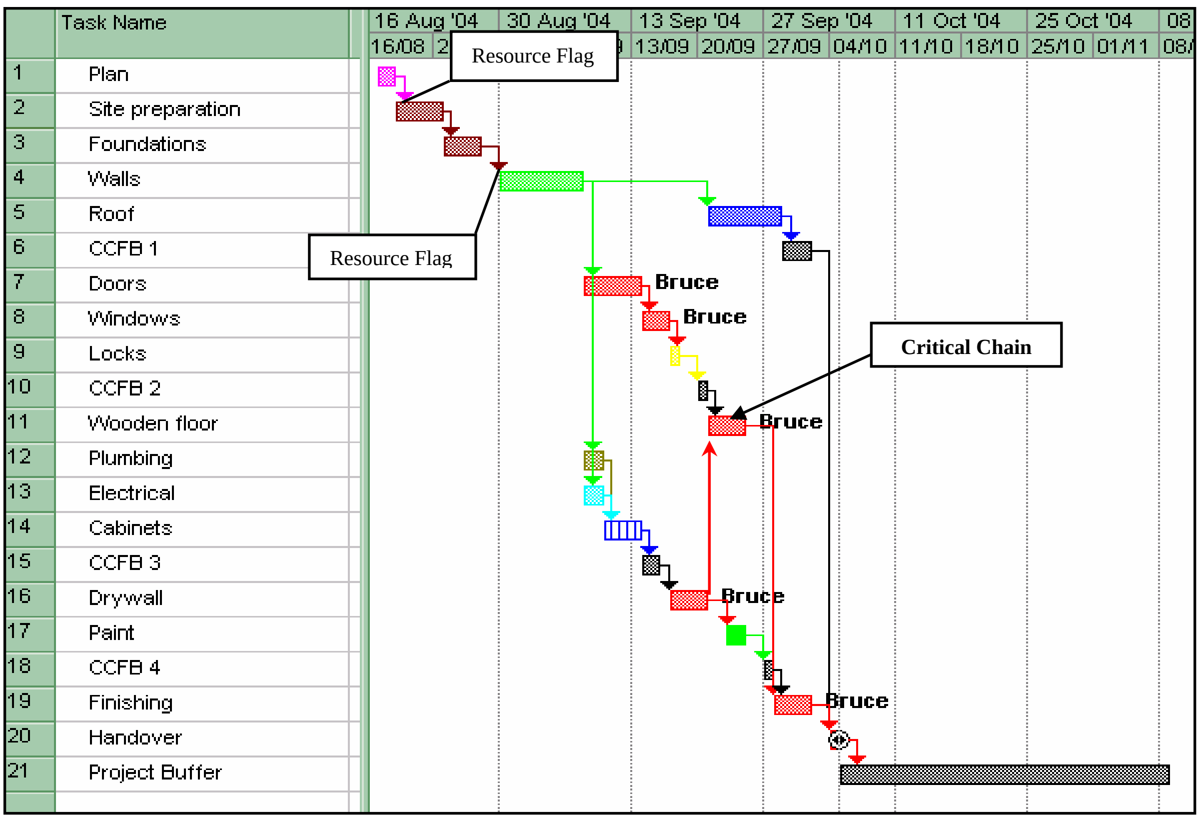

Figure 12: Critical Chain schedule identifies key features of the plan.

CCPM accounts for *common cause variation* as an essential element of the project management system. The process removes identifiable *special causes of variation*, including resource unavailability, and common resource behavior such as the student syndrome (which will be discussed later on in this section). Resource flags are also used to identify and ensure the availability of resources on the Critical Chain as indicated in figure 12.

Exploit project activity estimates

Resources estimating activity times usually do so believing that the project manager wants “low risk” activity times. The probability of a typical task duration estimate is illustrated in figure 13. For a resource to estimate the time it will take to complete a task, knowing that A will be possible only when everything goes right, that there is a 50% chance that *B* will be possible and that C will be the likely duration if something goes wrong, it is most likely for the resource to give a time estimate of C and more (Steyn [46]).

CCPM seeks to use 50% probable individual activity time estimates. The CCPM project manager recognizes that actual individual activity performance time include common cause variation, and therefore would not criticize resources if their tasks finish later that the 50% probable time estimates.

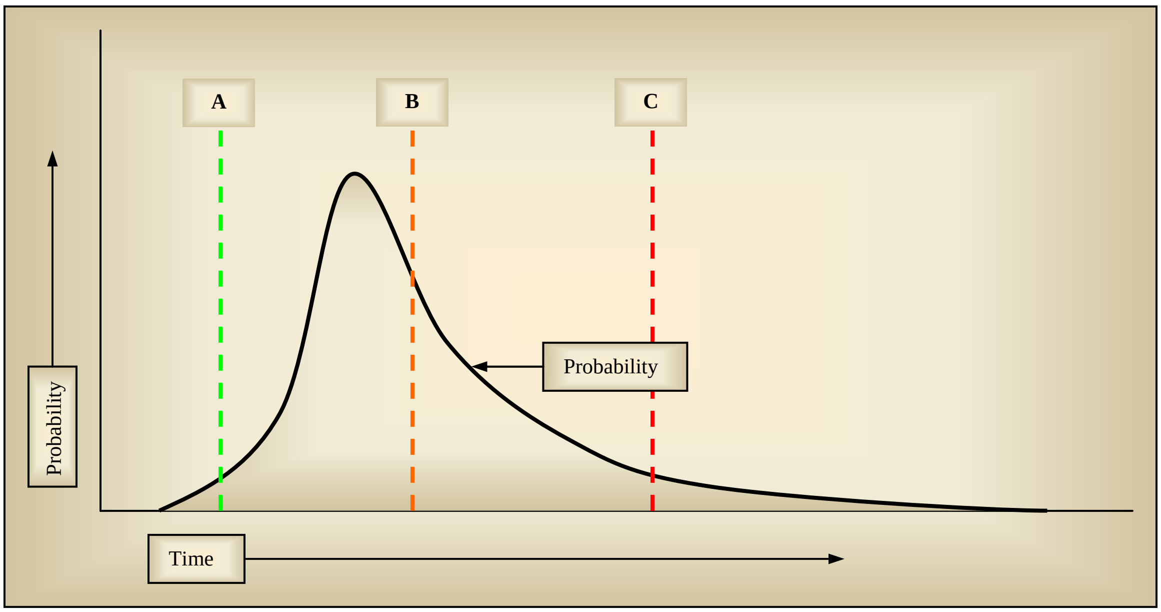

Figure 13: Probability profile of a typical project task.

Usually the reason for resources to build in a contingency reserve is due to the fact that there is very little incentive for a resource to finish his activity ahead of schedule. Not meeting the deadline (outside the CCPM environment) may also reflect negatively on the specific individual. To aggregate this problem, managers at each level of the organizational hierarchy tend to add their own precautionary measures on top of the estimates of managers reporting to them (Steyn [46]).

A project with a long lead time is the result of resources and managers adding contingency reserves to their tasks; in an attempt to ensure the project has a high probability of finishing on time. Still it often occurs that the project is not finished within time. The reason for this is that the activities of the project still don’t meet their due dates. One apparent reason for this is the student syndrome effect and “multi-tasking” which will be discussed later in this section.

Exploit statistical law governing common cause variation

Previous experience can also help management to estimate a better duration for the activity. Usually 50% of the safety that was removed from the activities is placed back onto the project as a project or feeding buffer. The buffer could be smaller than the sum of the individual reserves that have been removed from the lower level activities. This is made possible as a result of aggregation and applying the Central Limit Theorem.

The Central Limit Theorem states that, if a number of independent probability distributions are summated, the variance of the sum equals the sum of the variances of the individual distributions (Steyn [45]). Therefore if n independent distributions with equal variance V are summated it follows that:

$$V_{\Sigma} = n.V$$

Where V_{Σ} is the variance of the sum. The standard deviation (σ) can be used as an indication of risk. And since $\sigma^2 = V$ it follows that:

$$\sigma_{\Sigma} = (n)^{1/2} . \sigma$$

where σ_{Σ} is the standard deviation of the sum. Therefore:

$$\sigma_{\Sigma} < n.\sigma$$

This illustrates the reduction in overall risk when risks are aggregated. Because of the fact that $(n)^{1/2}$ is much smaller than n, the effect of aggregation of independent risks is significant, as discussed by Steyn [45]. The higher the number of risks that are being aggregated, the more marked the effect.

Thus the higher the number of activities on the critical chain of a project, the more the project buffer can be reduced. Buffer sizing and buffer management will be discussed in detail later on in the chapter.

2.4.2.3 SUBORDINATING MERGING PATHS

Most projects have multiple activity paths. All activity paths must merge into the critical path by the end of the project, if for no other reason but to create a milestone that identifies project completion.
Merging activity paths create a filter that eliminates positive fluctuations, and passes on the longest delay (Leach [30]). Tasks done in parallel don't allow benefit from tasks completed early due to the fact that the task following have to wait for all the tasks to be completed. Figure 14 demonstrates the impact merging activity paths could have on the project.

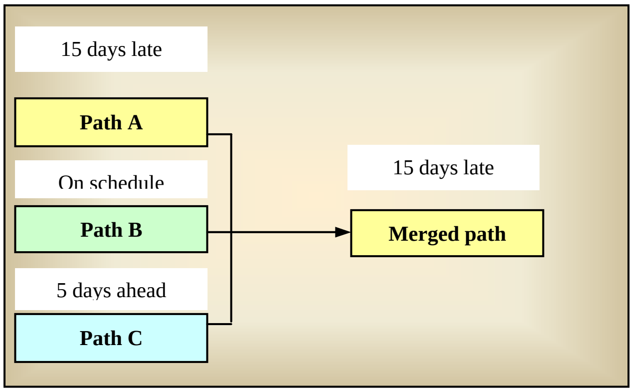

Figure 14: The impact of activity path merging.

CCPM protect the critical chain from potential delays by subordinating critical chain feeding paths; placing an aggregated feeding buffer on each path that feeds the critical chain. This includes paths that merge with the critical chain at the end of the project.

The feeding buffer provides a measurement and control mechanism to protect the critical chain (that will be discussed later in the chapter). Figure 15 illustrates how the buffers absorb the late paths. This innovation immunizes the critical chain from potential delays in the feeding paths. It also provides a means to measure the feeding paths, while keeping focus on the critical chain.

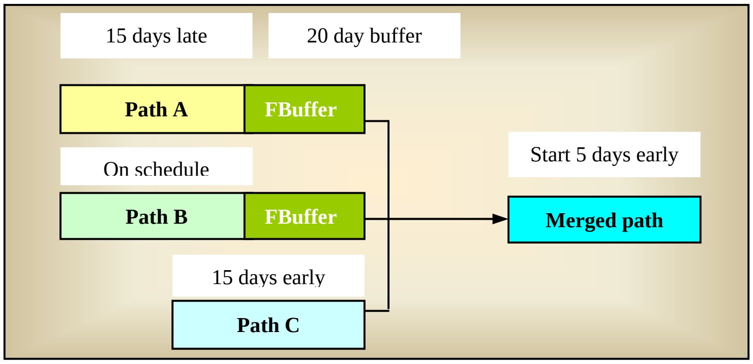

Figure 15: Critical Chain Feeding Buffers (CCFB) absorb delays from critical chain feeding paths.

2.4.2.4 ELEVATE THE CAPACITY - ACTIVITY PERFORMANCE

Elevate data-driven performance

According to Steyn [46] resources usually report most of the activities as done on the milestone date, and they report significant portions of the activities as late. One of the most important reasons for this is the fact that the resource doing the task is accountable for the quality of the task. He therefore tends to improve the quality by spending the time available (reducing the technical risk).

In any case, the resource normally does not get credit for finishing earlier than schedule. Another apparent reason for tasks not meeting their due dates is the student syndrome effect as highlighted by Newbold [33] and expressed in figure 16.

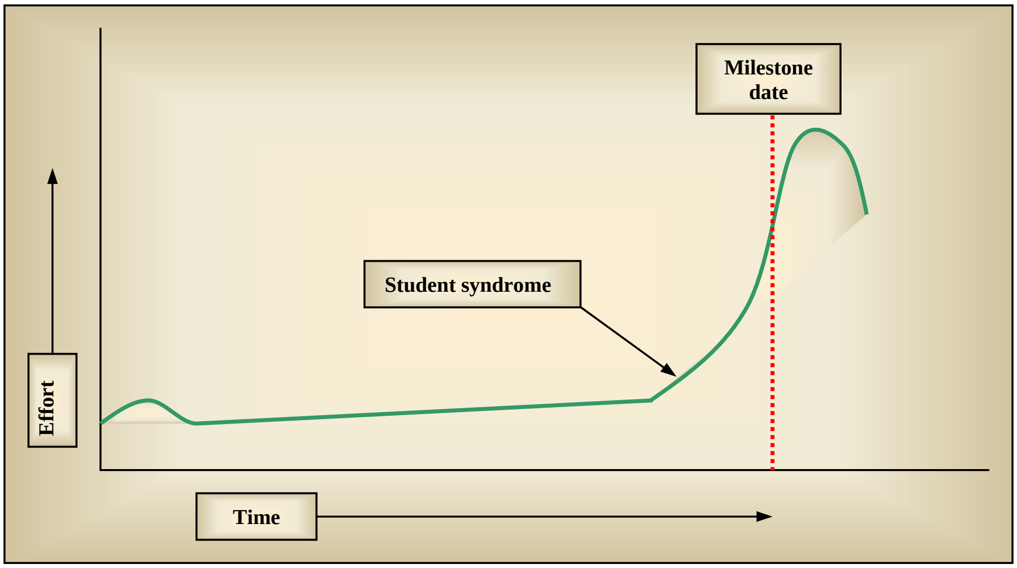

Figure 16: The student syndrome effect adapted from Newbold [33].

Leach [30] further highlights that Critical Chain project plans only provide dates for the start of activity chains and the end of the project buffer. For the rest of the project, the plan provides approximate start times and estimated activity duration. Critical Chain project managers should not criticize resources that overrun estimated activity durations as long as the resource started the activity as soon as possible, worked 100% on the activity (no multi-tasking), and pass on the activity as soon as it is completed. CCPM project managers expect 50% of the activities to overrun.

Elevate the activity performance by eliminating multi-tasking

A second way time reserve is wasted on task durations is by means of multi-tasking, the effect of which is illustrated in figure 17. Multi-tasking can be seen as the performance of multiple project activities at the same time. In an attempt to keep a project on track, a resource does half of task A, then half of task B, then half of task C, then finishes task A, then B, then C.

The result is that the lead-time was much longer than it could have been and that the reserve was wasted. CCPM seeks to eliminate multi-tasking by drawing 100% focus on the project activity at hand by all resources supporting the project. Thus eliminating “fractional head counts” is a primary consideration in planning a Critical Chain project.

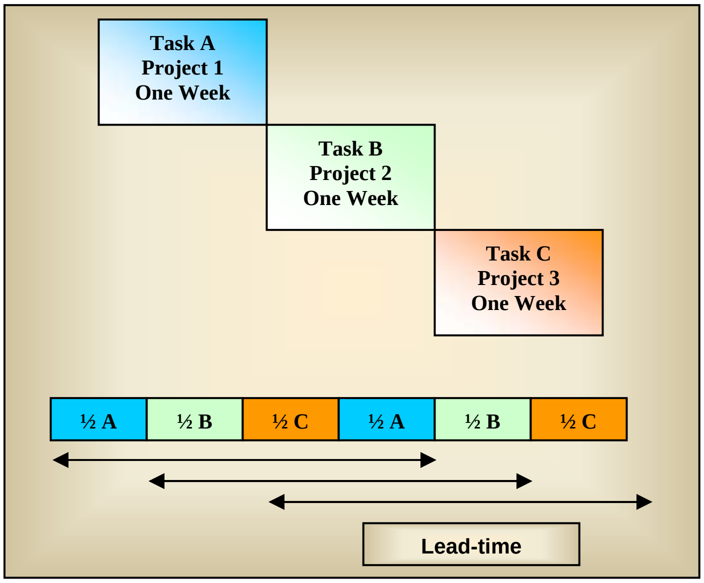

Figure 17: The effect of multi-tasking.

Early start vs. late finish (exploit)

Extensive studies have evaluated the desirability of using early-start schedules or late-finish schedules. According to Leach [30] project managers believe that early-start schedules reduce project risk by getting things done early, and that there is a believe that late-finish schedules:

1. Reduce the impact of changes on work already performed.
2. Delay the project cash outlay.
3. Give the project a chance to focus by starting with fewer simultaneous chains, allowing the project team and processes to come up to speed.

CCPM uses a late-start for all project activities, which will give more urgency to resources working on the tasks (counteracting the student syndrome effect). The feeding buffers provide an explicitly-sized buffer to protect the overall project from late completions in the feeding paths. This maximizes the advantages of the project, while ensuring project schedule protection.

2.4.2.5 EXPLOIT THE PROJECT PLAN USING BUFFERS AND BUFFER MANAGEMENT

Buffers are an extremely valuable tool for monitoring the status of projects and determining whether drastic actions are required. Buffers that are used in the multi–project environment are discussed below and an example of how to use the buffers is shown in the next section of this chapter.

Project buffers:

Project buffer protects the overall delivery time with a buffer at the end of the Critical Chain. This exploits the statistical law of aggregation by protecting the project from common cause uncertainty of the individual activities in an activity path using buffers at the end of the path. Buffers appear as activities in the project plan, but they have no work assigned to them. Goldratt [18] suggests a very simple method to size these buffers: for a 95% chance for the events being ready on time, use one half of the sum of the unpadded activity durations in the chain of activities that precedes the buffer. The project buffer is the single most important buffer to determine if the progress of a project is still on track.

Critical Chain feeding buffers:

A feeding buffer protects the critical chain from potential delays by subordinating critical chain feeding paths, placing an aggregated feeding buffer at the end of each path that feeds the critical chain. This includes paths that merge with the critical chain at the end of the project. The feeding buffer provides a measurement and control mechanism to protect the Critical Chain. It also provides the chance for early-start, if the critical chain tasks are ahead of schedule (Newbold [33]).

The sizing of these buffers is similar to that of a project buffer. A 95% chance of being ready on time will most likely be sufficient, setting the buffer size at half of the padding saved in the path leading to the feeding buffer.

Resource buffers:

Resource buffers protect the Critical Chain from unavailability of resources. They ensure that resources are ready to work on Critical Chain activities as soon as the activity input is ready. Because it is nothing more than a "wake–up" call, these buffers are easy to size. It could for an example be two weeks long. Then, based on how the Critical Chain schedule goes, management would make sure the resources are notified at appropriate times before they are needed.

Drum/strategic resource buffer:

Drum buffers are placed on the project schedule before the drum (key) resource in order to make sure that the drum resource has work, and can therefore keep its schedule. In other words, it protects the throughput of the organization. (Key resources are finite and are those resources that personify the organizations competitive advantage).

Capacity buffers:

Capacity buffers ensure that the drum resource is protected between different projects, ensuring that the drum is available for the subsequent project. The drum resource's work on different projects is thus efficiently staggered on its schedule.

Buffer management

The critical chain project management process, introduced by Dr. Goldratt, uses buffers to measure the activity chain performance. Buffers are sized-based on the activity chain they protect. In this buffer management process Leach [30] highlights that certain explicit action levels were set to make the necessary decisions.

The decision levels are in terms of the buffer size, measured in days. The buffers are divided into three sections as shown in figure 18 and managed as follow:

1. Within the first third of the buffer (the green zone) the system is deemed still under control and no action is to be taken.
2. When penetrating the middle third of the buffer (the amber zone), the system might be unstable. Management must assess the problem and plan for the future.
3. When the buffer consumption is in the last third (red zone), the system is unstable and the project is at risk. Action has to be taken and sustained until buffer consumption has returned to the green zone.

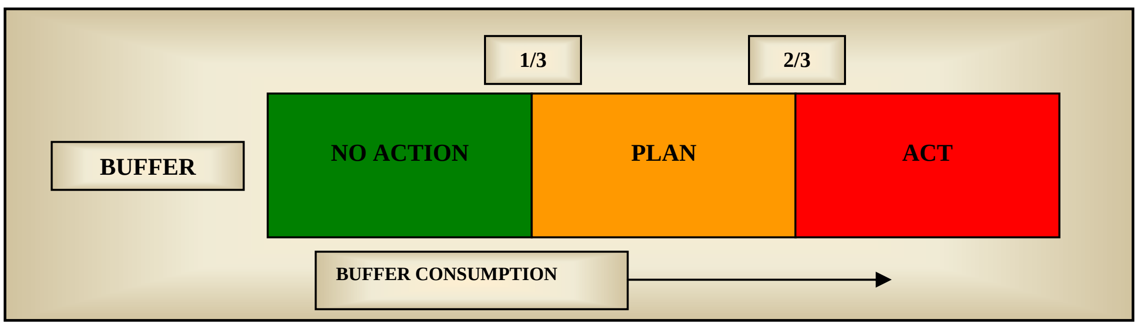

Figure 18: Using buffer management, adapted from Steyn [47].

Without buffers, there is frequently no good way to tell when a late task is a serious problem. Consequently a project manager is likely to under- or overreact. The project manager also has no good way of justifying a feeling that perhaps he needs the resources that are being moved elsewhere.

2.4.3 THE MULTIPLE-PROJECT ENVIRONMENT

The impact of multi-tasking on a single project is significant. In a multiple-project environment, it is even worse. The impact mounts as managers push more projects into the project performance system. CCPM project managers work to eliminate multi-tasking, and aim to create a pull system for the multi-project environment (Leach [30]). Figure 19 gives an example of a critical path multi-project environment scenario. The colours on the bars represent different resources. Using conventional low-risk activity estimates, and considering two-project multi tasking, the activity duration is 30 or 40 days, as indicated.

In the multi-project environment a company first has to identify the capacity constraining resource. The selection criteria such as cost of the resource and the scarcity of the skill can typically be included in the selection process.

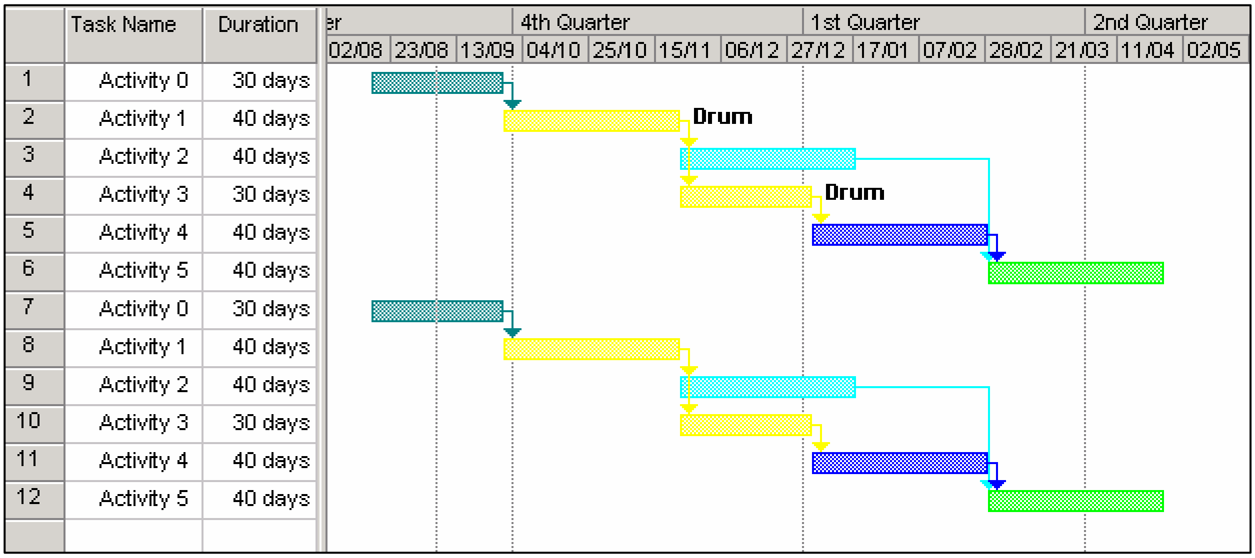

Figure 19: Example of critical path multi-project schedule.

The company's constraining resource then becomes the "drum" for scheduling multiple projects. This terminology comes from Goldratt's production methodology, where the drum sets the beat for the entire factory. In this case the drum sets the beat for all the company projects, just like the drummer in a galleon.

Goldratt [18] also suggests that non-critical path tasks should be started as late as possible. Non critical paths feeding into the critical chain should have feeding buffers to protect the critical chain incase the tasks are delayed. The project system becomes a "pull" system because the drum schedule determines the sequencing of the projects. Management pulls projects forward in time if the drum completes project work early.

Figure 20 illustrates the CCPM method. It reduces each activity time by eliminating the two times multi-tasking, and using 50% probable duration estimates. The resource supplying activities 2 and 3 is the capacity constraining resource (the drum). The plan exploits the resource by synchronizing the projects using the constraining resource as the drum. The schedule subordinate to this resource, by adding capacity buffers between the projects (Leach [30]). The capacity buffers ensure that the capacity constraining resource is available for the subsequent project.

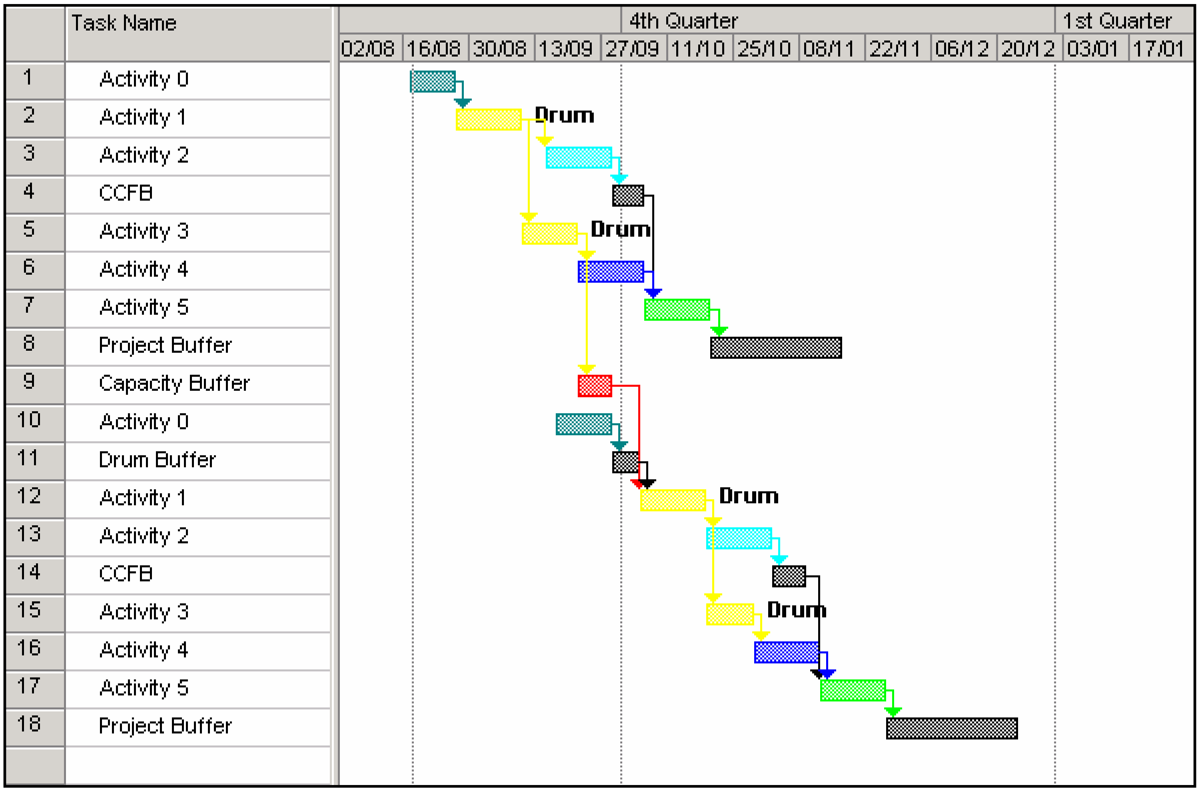

Figure 20: The CCPM multi-project plan synchronizes the projects.

The synchronization of the projects in this way has the effect that the work of non-constraining resources is also staggered more effectively. This reduces the need for multi-tasking overall - reducing the probability that delays on projects will occur.

2.5 THE EXISTING GAP IN THE LITERATURE

During the literature study, it became evident that the need exists for management of project-delivery driven organizations to have a tool, which will enable them to manage the value acquisition process and the value delivery process as a whole, taking into account management's limited availability of resources.

In other words, the need exist for management to have a tool which will synchronize the value acquisition flow rate with the value delivery flow rate around the schedule of the constraining (drum) resource, assuming these organizations have limited resources to their availability and uses CCPM techniques in the value delivery process. The proposed vision for the future presented in the next chapter will aim to fulfill this need.

2.6 CONCLUSION

This chapter has provided some insights into how to successfully acquire value opportunities through the introduction of various value flow processes and discussions around relevant organizational strategies, which proposes various ways for management to make decisions on value opportunities faster and with more certainty. The chapter also presented an in-depth look into CCPM which addresses the issue of swift project delivery for organizations with limited resources in the multi-project environment.

The proposed vision for the future with its injections, which will be presented in terms of a Future Reality Tree (FRT), will be presented in the next chapter. This vision will propose an answer to the question: *"What should current processes in the multi-project environment be changed to?".*

CHAPTER 3

THE PROPOSED INJECTIONS

3.1 BACKGROUND

Now that an in-depth literature study was presented, which evolved around competitive factors in the development environment, value acquiring processes and an in-depth look at Critical Chain Project Management, this chapter will present the proposed "injections" that will aim to vaporize the EC presented in chapter 1.

First, the rationale for developing an injection will be highlighted again. The new solution or "injections" will then be proposed. These "injections" will be obtained from the literature presented in chapter 2 and will be discussed from two viewpoints: The "process" view of the solution and the "systems" view of the solution. The "process" view will be discussed by means of structured English and illustrations and the "systems" view will be discussed by making use of another TOC thinking process tool – the Future Reality Tree (FRT). This injection proposes an answer to the second question presented in chapter 1 – *"What should current processes in the multi-project environment be changed to?"*.

3.2 RATIONALE FOR THE PROPOSED 'INJECTIONS'

The motivations that underpin the development of a new project management system, was discussed in chapter 1 and 2 of this study. The rationale for proposing a new project management system, can again be summarized by the following main points:

1. The synchronization between inflow and outflow of value – addressing the push problem.
2. Better resource allocation over the value acquisition and the value delivery process.
3. Ensuring that only the most promising value opportunities are chosen.
4. Ensuring the financial viability of the projects.
5. Better and faster quality of execution of key tasks in the project.
6. Ensuring the delivering of more projects in the same period of time.
7. More structure is necessary. A road map or layout of the key tasks, will ensure nothing was left out until too late.

3.3 THE PROPOSED INJECTIONS TO THE EVAPORATING CLOUD

The EC, presented in chapter 1, is vaporized if the proposed injections invalidate one or more of the assumptions supporting it. The proposed injections, that will aim to invalidate some of the assumptions, are listed below in table 6.

Proposed injection	Assumption in the EC to be invalidated by the proposed injection.
• Strategically placed value buffers are introduced in the stage gate management process as presented by Cooper [10].	• Push rate in the management system is different to the pull rate.
• The sizing of the value buffers.	• The workload demanded by the projects is more than the finite capacity.
• Value buffer management techniques to ensure the future work and WiP are kept within the value buffer limits.	• The project priorities are set in isolation

Table 6: The proposed injections that aims at invalidating some assumptions in the EC.

The proposed injections, as highlighted above, are aiming to invalidate the indicated assumptions supporting the necessary conditions D-D' and also D-B, as expressed in figure 21.

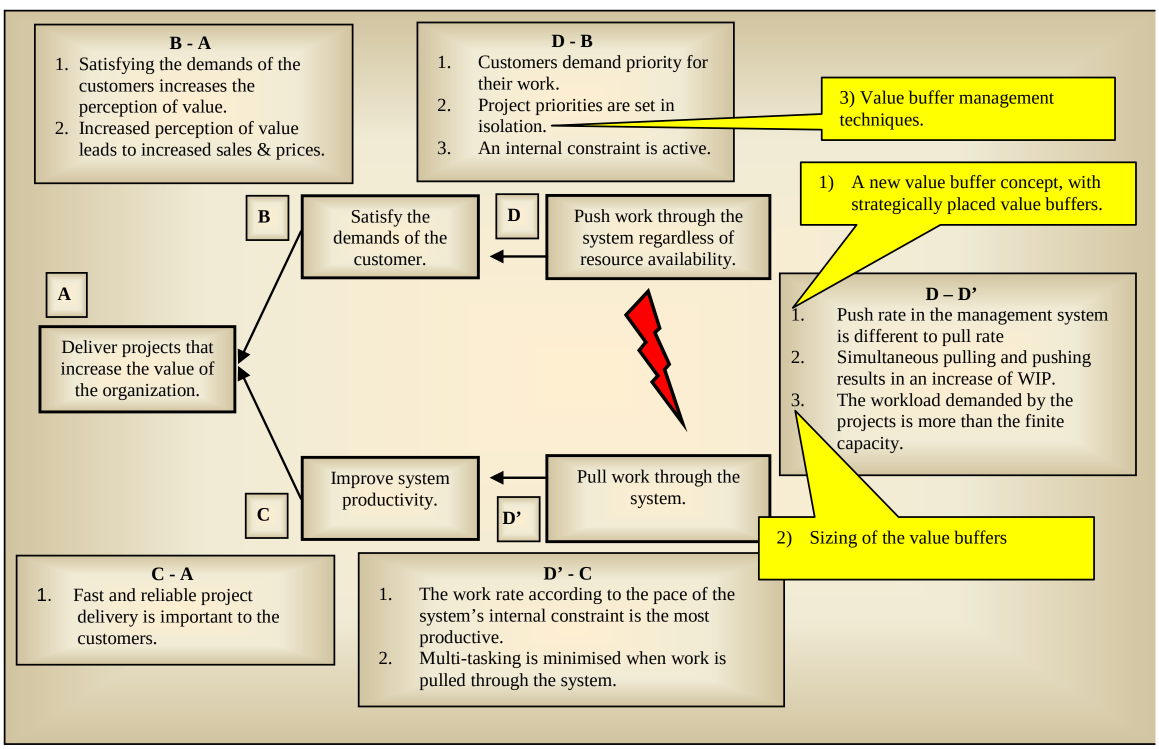

Figure 21: The proposed injections that aim at invalidating some assumptions in the EC.

In the following sections of this chapter the "process" and "systems" view of the proposed injections will be discussed in detail.

The proposed injections will then be scrutinized in the remainder of the study by building a simulation model to test whether the proposed injections presented from the "system's view" (the FRT) are indeed a valid and effective way to invalidate one or more of the assumptions supporting the EC, thus vaporizing the EC.

The reasons why the injections could invalidate the assumptions, supporting the EC, will become apparent during the course of this chapter and will be further illuminated in chapter 5, after the simulation results have been presented.

3.4 THE 'PROCESS' VIEW OF THE PROPOSED INJECTIONS

In the next sections of the chapter the "process" view (or the physical process) of the injections highlighted above will be discussed. The proposed injections will aim at resolving the conflict in the EC by invalidating some of the assumptions supporting the necessary conditions in the EC. These injections will be expressed within a new project management model.

This proposed management system will provide a channel for delivering the following:

- New products to be sold or added to an organization's product portfolio
- New major markets to be entered
- New services to be sold
- Major feature requests to be developed (customer demands)
- Strategic initiatives
- Engineering projects
- Maintenance projects.

Before the proposed management model with its proposed injections is presented, background needs to be provided on flow through a system. This is important as the proposed project management model will emulate flow through a system.

3.4.1 FLOW IN A SYSTEM

Project portfolio management and multi-project management are in essence about managing flow in a system, as was highlighted in chapter 2 of the study when Coopers' [10] stage-gate model and Wheelwright and Clark's [52] development funnel was discussed. The sought after effect of a well managed flow system is that a high quality product is delivered at the due date with a short lead time.

It was shown in chapter 2 that a project (or a flow system) is made up of various independent tasks (or sub-systems).

These sub-systems are very often managed as if it is independent, because of the fact that different departments of the organisation are responsible for different sub-systems. For example – the research department is responsible for the identification of new opportunities, while the design department is responsible for the final design of the product. The project management division on the other hand is responsible for the successful delivery of the project. In most instances each of these departments tries to optimise their own sub-system, which will not necessarily optimise the system as a whole. To optimise the system, management of the system must take the dependence of the sub-systems into account.

As was highlighted in chapter 2, each of these tasks (subsystems) has common cause variation inherent to it. A characteristic of such a system which consists of dependent subsystems with their own variation is the fact that this variation accumulates as one move further down the flow chain.

The Critical Chain multi-project scheduling approach as introduced by Goldratt [18] will therefore be applied in the solution to the push problem, as it has been developed to manage variation in this environment.

3.4.1.1 CRITICAL CHAIN MULTI-PROJECT MANAGEMENT (CCMPM) APPLIED IN THE PROPOSED SOLUTION

It was discussed in chapter 2 that the CCMPM methodology has been developed to successfully manage variation within flow systems and between different flow systems. The CCMPM deals with the accumulation effect of variation with the introduction of time buffers which form part of the project (flow system) schedule. This implies that task durations on the project are scheduled with aggressive lead times, and that protection against the cumulative effect of variability is provided in the form of project buffers and feeding buffers. To protect projects against the variability of other projects, capacity buffers are included between the work of the different projects. A detailed discussion around this topic was done in chapter 2. CCMPM thus allows for projects to be staggered on a time line with aggressive lead time estimates for the activities (subsystems) which is scheduled around the constraining (drum) resource, implying that the drum resource will serve as a “gate” through which project work will be released. This concept will be further illuminated later in the chapter.

3.4.1.2 THE STAGE-GATE MODEL AND THE DEVELOPMENT FUNNEL

What will set the proposed solution apart from any current project management model within the multi–project environment, is the introduction of the new value buffer concept within Cooper’s [10] stage-gate process.

The management model will also incorporate a funnel as was highlighted in chapter 2 when Wheelright and Clark’s [52] development funnel was discussed. Having a funnel in a flow system implies that the later the project is in its life cycle, the fewer projects should be worked on. The reason for this is that the selection criteria become more strict, and information becomes less uncertain, as the project moves down the value chain.

To ensure that the rate of value delivery (the final design and execution) is maximised, a number of projects (at different stages in their life cycle) should be worked on at any point in time throughout the value chain. This requires a number of projects to be maintained throughout the value chain, which can also be seen as managing a supply chain. This concept will be discussed in the following section.

3.4.2 BACKGROUND TO GIVE FOCUS TO THE INJECTION

To develop a theoretical background to the solution, the analogy of the supply of bread to the consumer will be used.

The supply of a loaf of bread to a consumer in an ideal setting can also be viewed as a supply chain or flow in a system. For this example the whole supply chain will belong to one owner. The supply chain will consist out of the following sub-systems:

1. The wheat stored in silos on the owner’s farm.
2. The mill which will supply flour to the various regional flour suppliers.
3. The regional suppliers of flour.
4. A number of bakeries within different regions which will order and receive flour from the regional supplier.

The consumer takes pleasure in perfect service, knowing that bread will always be available whenever he wants it. All he has to do is walk to the bakery and buy a loaf of bread. This scenario is of course only valid if the assumption is made that enough wheat has been harvested earlier in the year, and that it went through the various processes in the supply chain to end up as bread in the bakery. The analogy serves to highlight four principles that a supply chain must comply with. These are:

1. All parts in the supply chain are connected. In an ideal situation all the relevant role players in the supply chain will have just enough wheat or flour available in their inventory to satisfy the demands of their downstream branches of the supply chain. For example, the regional flour supplier should always have flour available on request from any bakery in the region.
2. Most of the inventory is kept as far upstream in the supply chain as possible. In this instance, most of the wheat should be kept in the silos, and should only move down the value chain when it is needed. The flour will only be distributed to the regional supplier when the regional supplier has distributed flour to the bakeries in the region. The reason why inventory should be kept as far upstream as possible can be explained as follow: Inventory held at a supply point should be equal to the maximum consumption within the replenishment time of the inventory. The maximum consumption is a future estimate made by management, usually based on statistical data and past experience. This future estimate has a lot of attributes influencing it, and is therefore subject to variability. In this example, the variability of consumption at the regional flour supplier (supply point) will be much lower than at one bakery (consumption point). This is as a result of the fact that the demand from a supply point is the aggregated consumption of all the points it feeds. Statistical fluctuations average out as was explained in chapter 2. Thus the relative variability of demand at the regional supplier is much lower than at a consumption point such as a bakery. In doing this the overall inventory in the system will be reduced, which could save the management of the value chain money. Holding the inventory upstream has another positive effect, in the sense that it reduces the replenishment time to the next sub-system in the supply chain. The replenishment time will now only be a function of transportation time and how long it takes to place the order by the downstream sub-system, as the flour can now be delivered immediately. A fast replenishment time has a knock-on effect in the sense that forecasted consumption accuracy deteriorates with the length of time forecasted. This has the effect that the replenishment time to the consumer is reduced as well as the maximum forecasted consumption.
3. The flour will only be distributed as a result of a trigger initiated at the end of the process. In this instance, enough bread is sold at all the bakeries in one instance that results in an order for additional flour from the regional supplier. In other words some kind of pull trigger is initiated to activate parts of the upstream supply chain. In the case of this example the status of the inventory level at the sub-systems upstream of the bakery will be such that the effect of this pull trigger only stops when the first storage facility is reached. In this case it can be seen as the harvested wheat in the silo of the supplier.
4. The excess capacities of the upstream dependent sub-systems in the value chain (in this case it is the regional flour supplier, the mill and the wheat in the silo) are sufficient to maintain the

demand for flour in every bakery. Excess capacity needs to be built into the upstream sub-systems of the supply chain. This is necessary to ensure that flour could be provided to all the bakeries in the region if the maximum forecasted amount of bread is bought in all the bakeries. The "perfect performance" of the supply chain (a 100% guarantee that there will always be bread available) can only be guaranteed if the required capacity of the last sub-system (the bakeries) is used as the finite capacity. In other words, the bakeries should serve as constraint that determines the capacities of the upstream subsystems of the supply chain.

Because the proposed solution to the push problem will enable the continuous delivery of high value projects, the solution has to:

- Ensure that the constraint in the system is in the last stage of the system;
- Operate as a pull system with pull triggers situated in the last stages of the value chain;
- Ensure that there are strategically placed value buffers upstream of the constraint to cope with any variation that may occur in the supply chain and manage flow of projects.

Before the management model is discussed in detail, the following assumptions and definitions need to be highlighted:

1. Work done in any stage of the project lifecycle can be seen as a project on its own. For example, the conceptual design phase and final design phase could be scheduled as two separate projects within a new product development process.
2. All the projects in the different stages of the project life cycle (not only the value delivery phase) are scheduled according to the Critical Chain multi-project scheduling methodology. This means that the work on each project is scheduled with aggressive duration estimates and that a project is scheduled with protection against the effect of variability in the form of various buffers as was discussed in chapter 2 of the study.
3. Key (constraining) resources are those resources that personify the organization's competitive advantage. These resources are finite and their productivity needs to be maximized in order to achieve the maximum system productivity.
4. Using CCPM techniques, will imply that built into the model is the theory that projects and key tasks are staggered around the schedule of a key resource (constraining resource). The schedule of the constraining resource will therefore be used as the definition of the internal system capacity and the whole system will be synchronised to this capacity.
5. Key resources will be needed in the different phases throughout the project lifecycle, not only the value delivery process.
6. As part of the CCPM techniques a well-managed work buffer will be in place at all times for the constraining resources.

The conceptual model within Wheelwright and Clark's [52] development funnel, as discussed during this section of the chapter, is shown in figure 22.

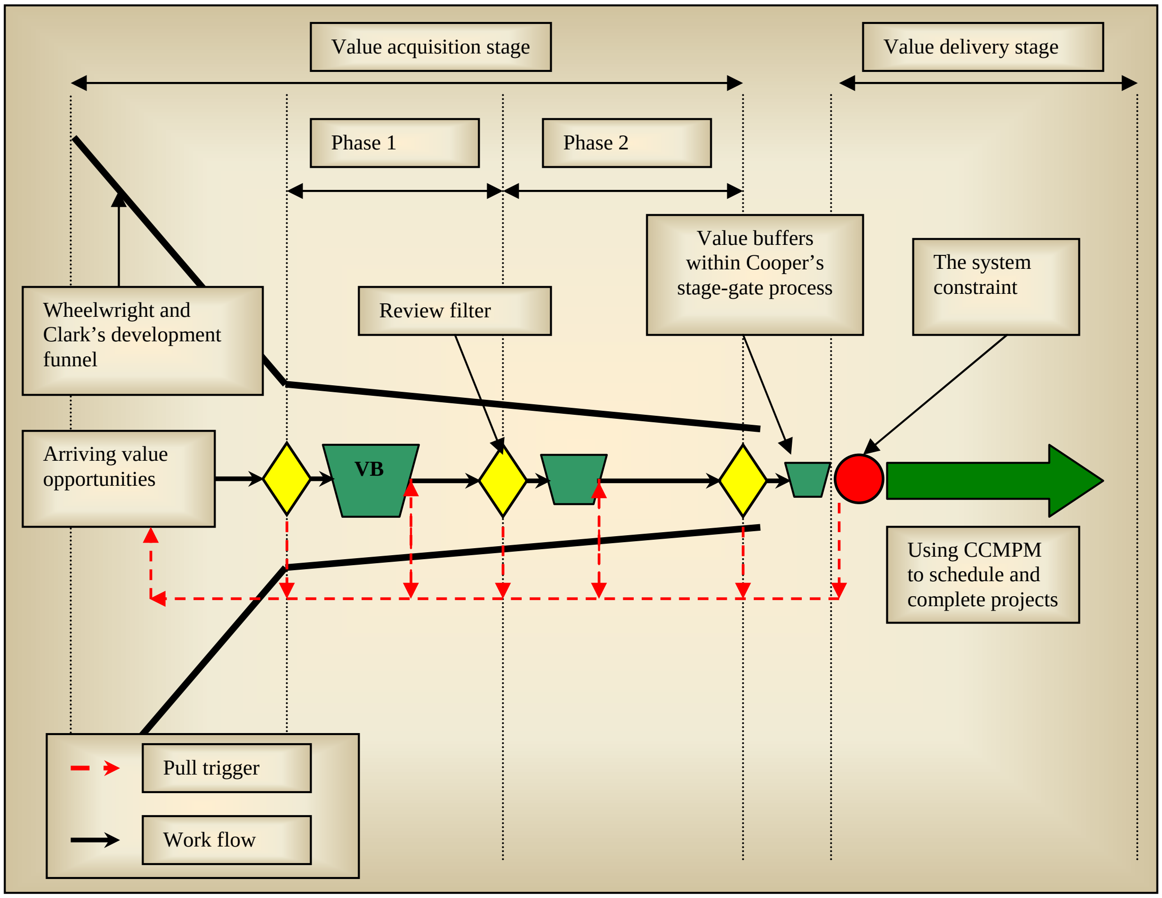

Figure 22: The conceptual model within Wheelwright and Clark's development funnel.

The boundaries for the proposed management model are the two different processes that are evident throughout the project life cycle – the value acquisition and the value delivery process, and are discussed accordingly.

3.4.3 THE VALUE ACQUISITION PROCESS

The value acquisition process of the proposed management model is shown in figure 23 (a).

The following elements will form an integral part of the value acquisition process:

1. Three value buffers, which will protect the system against any variability in terms of availability of work that may occur.
2. Three decision filters which are situated before the value buffers.
   - The initial filter – situated before phase 1 of the value acquisition process, before value buffer 1.
   - Decision filter 2 – situated between phase 1 and phase 2 of the value acquisition process, before value buffer 2.
   - Decision filter 3 – situated at the end of the value acquisition process, before the final value project work buffer.
3. The different project stages within the value acquisition process.

Figure 23(a) depicts the value buffers within the stage-gate funnel, with value buffer 1 being the largest and therefore proficient to maintain availability of project work to the next value buffer and therefore all the way through the value chain to the final value buffer.

Individual projects in the value chain are scheduled by making use of the Critical Chain project management approach. This project scheduling approach defines the workload of all the resources in the system, as was discussed in detail in chapter 2. In order to ensure a final value buffer of available project work, from which the constraining resource can pull work into the value delivery process, the workload on key resources are used to synchronize approved projects relative to each other by taking into account the inter project dependencies (The Critical Chain concept in the multi-project environment was explained in chapter 2.) The project work in the final value buffer is therefore only released according to the schedule of the constraining resource.

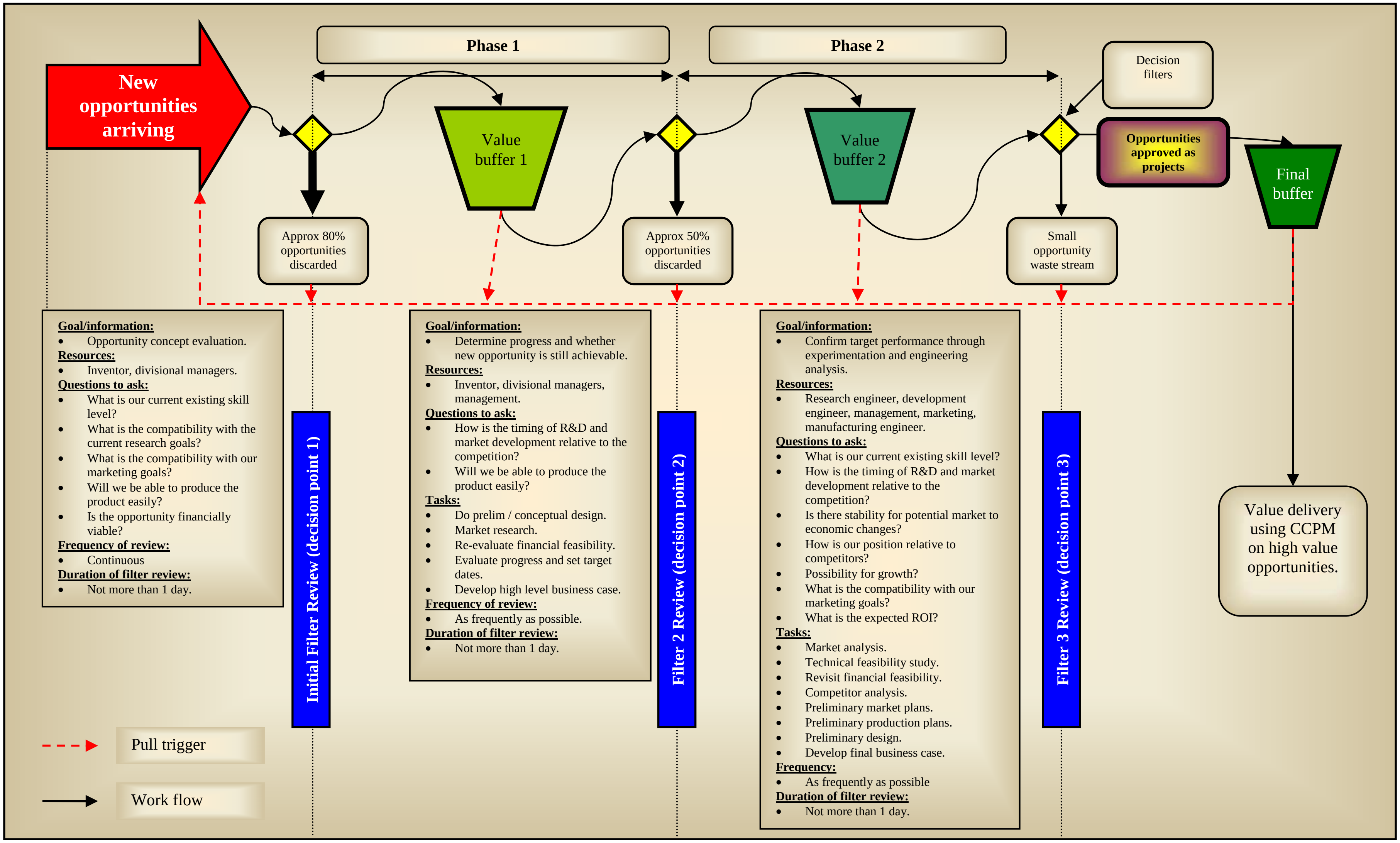

Figure 23 (a): The proposed management model – The value acquisition process.

The flow in the proposed project management system is controlled by pull triggers downstream in the value chain. As work is pulled from the final value buffer according to the schedule of the constraining resource, a pull trigger is generated that releases an opportunity from value buffer 2, which is situated upstream in the process, as shown in figure 23 (a). Various necessary tasks will be done on the opportunity (which has been released from value buffer 2), and it will be evaluated by a filter review team, before it moves into the final value buffer or be discarded. If the opportunity is discarded, another pull trigger is generated to release the next opportunity from value buffer 2, because no replenishment of work has occurred. The concept is the same for the flow between the other value buffers.

The decision-making criteria at the decision filters should be of such a nature that only the most promising value opportunities are selected. This implies that the management system will act as a funnel which will dilute the incoming opportunities to such an extent that only the most promising opportunities remain in the system. This is to reduce the risk of a key resource doing excessive work on an opportunity, which will eventually be discarded by management. In order to ensure that the right project is released from the value buffers when a pull trigger is signaled from downstream in the value chain, the review filter team need to prioritize opportunities (entering and already in the next value buffer) according to the opportunity's own individual project buffer status and the "weight" it carries for the organization. The value buffer time allows for management to do the reprioritization of these projects. How opportunities are prioritized in a value buffer will not be covered in this study and could form part of a future study.

All the decision filters will be preceded by a stage that will provide enough information to make the necessary decisions at the different filters. The details pertaining each stage and decision filter will be discussed in the following section of this chapter.

3.4.3.1 DIFFERENT PROJECT STAGES AND DECISION FILTERS

Decisions at the review filters will be made by means of rating the opportunity against the various attributes as proposed by Babcock [2] and Cooper [9] (presented in chapter 2) and by using the proposed scoring model (presented later in the section), in which each attribute is scored on a scale from 0–3.

A relative weight representing the importance of each attribute can be used as a multiple at each decision point. The weighted scores for all the attributes can then be added for a specific decision point. Each opportunity should comply with a minimum "must meet" score to move on to the next phase in the value acquisition process.

It is for management to decide what the minimum "must meet" score and representing weights for each attribute should be. The detail covering each specific decision filter and work phase will be discussed in accordance.

The initial filter:

The proposed project management model starts off by acquiring all the possible value opportunities that are available to the organisation. When these opportunities arrive at the initial filter, a cross-functional peer committee screens the possible value opportunities. The screening of the value opportunities will happen as these new opportunities are explored within the organisation.

The first filter is a very gentle screen and amounts to subjecting the project to a handful of key "must meet" and "should meet" criteria for the new opportunity. The criteria summarized in table 7 will deal with:

- The technical merit of the opportunity.
- The business relevance of the opportunity.
- The financial viability of the final product.
- The marketability of the final product.

	Scoring Scale			
Attributes	**0**	**1**	**2**	**3**
Technical relevance	No existing skill level. No facilities to produce product. Probability of success extremely low.	Low existing skill level. Current facilities not up to standard. Probability of success low.	Existing skill level is good. Very good facilities. Probability of success is good.	Existing skill is excellent. Excellent facilities. Probability of success is extremely high.
Research direction and balance	No compatibility with the research goals and desired research balance.	Little compatibility with the research goals and desired research balance.	Compatibility with research goals and research balance are very good.	Compatibility with the research goals and research balance excellent.
Marketability and compatibility with current marketing goals.	No compatibility with current marketing goals.	Little compatibility with current marketing goals.	Good compatibility with current marketing goals.	Excellent compatibility with current marketing goals.
Producibility	Production will be impossible with the current production facilities and manpower.	Production will be low with the current production facilities and manpower.	Production will be high with the current production facilities and manpower.	Excellent production with the current production facilities and manpower.
Financial factors	Expected inflow of money > 5 years.	Expected inflow of money 2–5 years.	Expected inflow of money 0.5–2 years.	Expected inflow of money < 6 months.

Table 7: Attributes to be considered using the proposed scoring scale at the initial filter.

From the initial opportunities, managers should be very selective in their choice of potential projects. Only those opportunities with the highest probability to succeed which will offer the highest financial reward, should be given approval.

Being very selective at the initial filter, will imply that a very large initial waste stream will exist. Resources involved at the initial filter meeting, are the inventor (resource who initiated the opportunity) and the relevant divisional manager, who will do a brief check on the appropriateness of the opportunity.

Phase 1:

At the initial filter, the opportunity can either be approved or it can be rejected. In the case where it is rejected, the opportunity could be re-evaluated later on, or it can be totally discarded - depending on its specific criterion. If the opportunity has been given the Go decision by the divisional managers or committee at the initial filter, it will move further down the value stream into phase 1. During phase 1 the main objective for the inventor and key marketing personnel is to:

1. Determine the project's initial technical feasibility
2. Determine the project's market place merits
3. Do a financial feasibility exercise.

After these tasks have been completed, the opportunity will wait to be evaluated at the filter 2 review meeting.

Filter 2:

A difficult situation arises when definitive results are slow to develop, often because of difficulties in developing experimental or analytical techniques that produce meaningful, reproducible results. Therefore another criterion is the evidence of progress that suggests a successful product is still attainable. The attributes that could be considered during the decision making process at the end of phase 1 are listed in Table 8.

	Scoring Scale			
Attributes	**0**	**1**	**2**	**3**
Timing	Timing of R&D and market development relative to the competition is very poor.	Timing of R&D and market development relative to the competition is not too bad.	Timing of R&D and market development relative to the competition is very good.	Timing of R&D and market development relative to the competition is excellent.
Producibility	Production will be impossible with the current production facilities and manpower.	Production will be low with the current production facilities and manpower.	Production will be high with the current production facilities and manpower.	Excellent production with the current production facilities and manpower.

Table 8: Attributes to consider at filter 2, using the proposed scoring scale.

Usually at this early stage, nature itself is the best filter. Most bright ideas will turn out not to work or to produce uninteresting results or to exhibit other undesirable results that make further effort unattractive. Fortunately, activities at this level are very small in scale and require a very modest (an estimated 10% - 20%) commitment of limited resources (Babcock [2]). The initial filter and filter 2 can be seen as a format/readiness filter preparing the proposals for filter 3. Resources responsible for making a decision at this point could be divisional managers and some directors (Wheelwright and Clark [52]).

Phase 2:

As in the case of the initial filter, the opportunity can either be approved or rejected at filter 2. In the case where it gets rejected, the opportunity could again be re-evaluated later on or it can be totally discarded. When an opportunity has been approved at filter 2 it moves into the second value buffer, where it waits until being pulled into phase 2 of the value acquisition process. In phase 2 all the relevant information needed to make a final decision on the opportunity is prepared by the "opportunity scanning team", consisting of key marketing personnel, researchers, manufacturing and development engineers. This is also shown in figure 22(a).

Typical work during phase 2 will include the following:

- A thorough market analysis
- Technical feasibility studies
- Financial viability studies
- Competitor analysis
- Preliminary market plans
- Preliminary production plans
- Preliminary design.

The amount of information prepared during this stage, depends on the size of the investment required to implement the project and the morphological distance from the core business of the organization. An increase in any of these two factors leads to increased risks (Wheelwright and Clark [52]), requiring more detailed information before making the final Go/No–go decision at filter 3 on the proposed opportunity. After the tasks on each opportunity during phase 2 have been completed the opportunity will be evaluated at the next review meeting, that of filter 3.

Filter 3:

Filter 3 is where the final Go/No–go is given to the opportunity. The decision on an opportunity is made by the directors of the organization. This decision is based on all the information that is gathered during phase 2 of the process. The attributes that should be under consideration at this decision point is presented in table 9.

	Scoring Scale			
Attributes	**0**	**1**	**2**	**3**
Technical relevance	No existing skill level. No facilities to produce product. Probability of success extremely low.	Low existing skill level. Current facilities not up to standard. Probability of success low.	Existing skill level is good. Very good facilities. Probability of success is good.	Existing skill is excellent. Excellent facilities. Probability of success is extremely high.
Timing	Timing of R&D and market development relative to the competition is very poor.	Timing of R&D and market development relative to the competition is not too bad.	Timing of R&D and market development relative to the competition is very good.	Timing of R&D and market development relative to the competition is excellent.
Stability	The potential market has no stability to economic changes. Product will be easy to substitute.	Stability exists for potential market to economic changes. Possibility will exist to substitute product.	Stability for potential market to economic changes is good. Substitution of product will be difficult.	Stability for potential market to economic changes is excellent. Substitution of product will be almost impossible.
Position factor	Very poor position relative to competitors and other product lines.	Following the competitors and other product lines.	Leading the competitors and other product lines.	In another class relative to the competitors and other product lines.
Market growth factors for the product.	No possibility for growth.	Low growth factor.	Good possibility for growth.	Excellent possibility for growth.
Marketability and compatibility with current marketing goals.	No compatibility with current marketing goals.	Little compatibility with current marketing goals.	Good compatibility with current marketing goals.	Excellent compatibility with current marketing goals.
Financial factors	Expected money inflow > 5 years.	Expected money inflow 2–5 years.	Expected money inflow 0.5–2 years.	Expected money inflow < 6 months.

Table 9: Attributes to consider at the 3rd filter using the proposed scoring scale.

As in the case of the previous review filters, the opportunity can either be approved or rejected at filter 3. In the case where it gets rejected, the opportunity could again be re-evaluated later or it can be totally discarded. If an opportunity is given the Go-decision at decision filter 3, it becomes a formal development project and waits in the final value buffer until it gets pulled into the value delivery process by the relevant limited resources.

3.4.4 THE VALUE DELIVERY PROCESS

The typical value delivery process of the management model is shown in figure 23 (b) and will be discussed in the following narrative.

For the purpose of the study the value delivery process will consist of issuing the final design, doing the project scheduling and the execution of the projects based on TOC principles and its application to multi-project management, known as Critical Chain multi-project management.

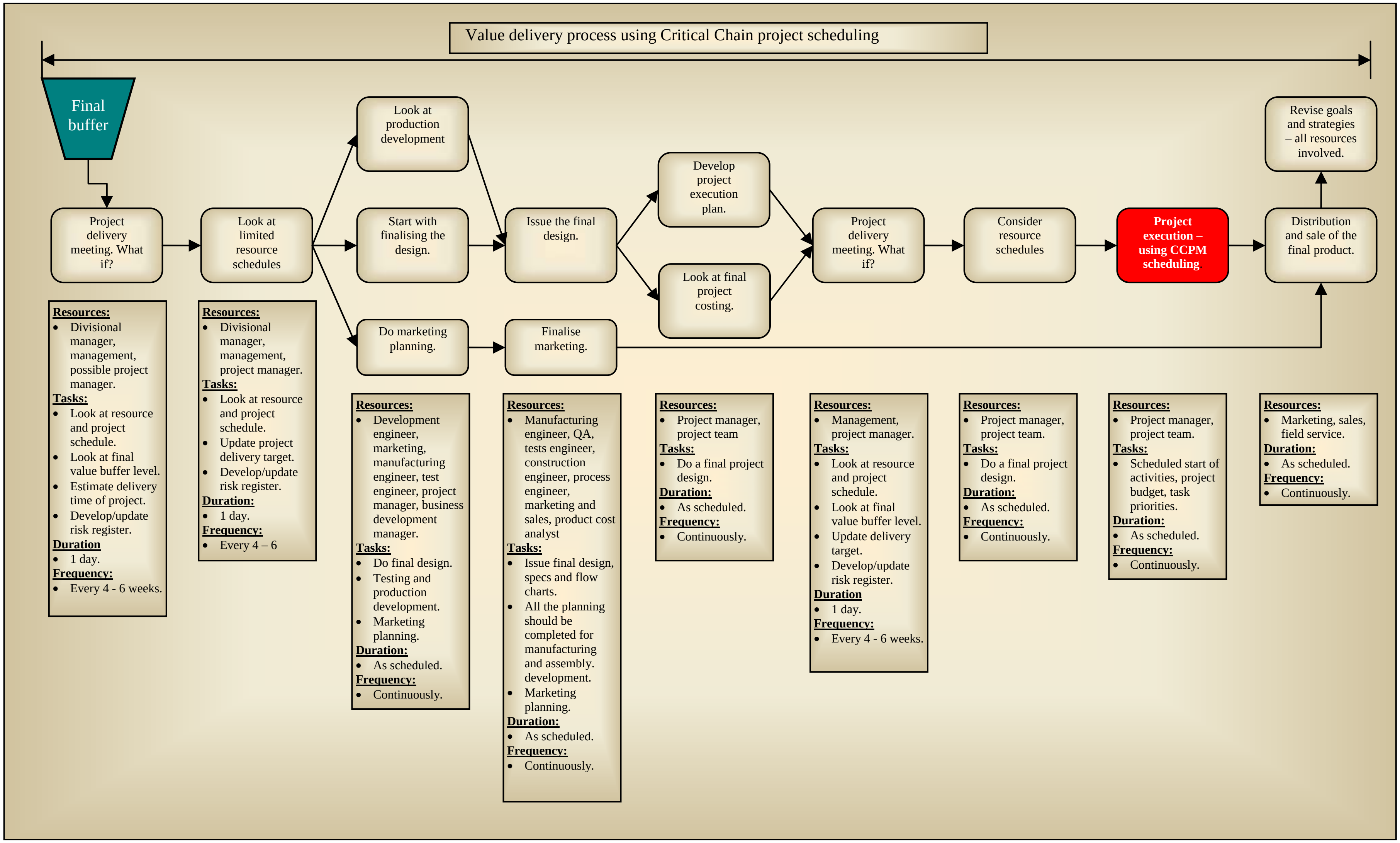

Figure 23 (b): The proposed management model – The value delivery process.

As highlighted earlier, the approved projects waiting in the final value buffer are staggered on a time line and are scheduled to the schedule of the constraining resource. These projects will therefore wait in the final value buffer until it gets pulled into the value delivery process by the constraining resource.

It is at this stage that the organization formally commits itself to the project. This is associated with the investment of money. It is therefore important that a high quality product is delivered on the due date with a short associated lead time.

Successful delivery of a project in a shorter period of time will result in earlier inflow of money into the organization. Earlier inflow of money will allow management to pursue and invest earlier in new projects. Fast and successful project delivery is also important from the viewpoint of the customers as they demand priority of their work. Fast product delivery will result in an increase in the customers' perception of the final product value.

It should be noted that review meetings are held throughout the value delivery process. Here questions are asked regarding the different delivery projects and their progress. Typical activities would be to monitor the buffer status protecting the Critical Chain of the delivery projects and also monitoring the status of the value buffers upstream from the value delivery phase.

Figure 23 (a) and (b) shows a typical spread of resources (Ramsey [40], Wheelwright and Clark [52]) involved in the different processes during the project life cycle. Most of the key resources are involved in both the value delivery and value acquisition processes. It is for this reason that the schedule of resources, (as highlighted by Wheelwright and Clark [52] when they discussed the project aggregate plan) is one of the most critical data sets for decision-making, as the availability of resources can determine the new project's lead time and therefore also the inflow of money.

3.4.5 THE IMPORTANT CHARACTERISTICS OF THE PROPOSED MANAGEMENT MODEL

To highlight the key features of the proposed management model, the important characteristics of the system could be summarized as follow:

1. New value opportunities and projects are pulled from a value buffer to the next phase of the system by a pull trigger when opportunities are released from the downstream value buffer.

2. An opportunity being discarded at a review filter acts as another pull trigger for the opportunities waiting upstream in the value buffer.
3. The initial waste stream for value opportunities will be large, becoming smaller further down the value chain.
4. Work will not be pushed to the next stage without a pull trigger.
5. The value buffers are preceded by review filters, which will ensure that an opportunity will only enter the value buffer if it has a very high probability to become a high value project.
6. The review filter meetings should be done on a high frequency, by the relevant resources as outlined in the previous sections of this chapter.

To complete the solution to the described push problem, two aspects of the proposed management model still have to be introduced – the sizing of the value buffers and the management of these buffers.

3.4.6 SIZING OF THE VALUE BUFFERS

The sizing of the value buffers is the second injection as indicated in section 3.3 of this chapter. The buffer sizes in the proposed management model are determined by the lead-time of projects between the buffers. In the supply chain analogy described in the previous sections of the chapter, the buffer size of the regional flour supplier would be equal to the rate of consumption of flour for all the bakeries being served by this regional supplier (rate of release or consumption from the buffer) multiplied by the time it takes to replenish the regional supplier's buffer from the mill.

Replenishment of the value buffer will be a function of the following:

1. The order frequency of flour
2. The frequency of transporting the flour
3. The transportation time.

The size of any buffer in a supply chain is therefore a function of the downstream rate of consumption and the upstream replenishment lead-time of the value buffer.

In the context of the proposed management model the final buffer size will be determined by the rate at which projects are worked on downstream of the value buffer (determined by the Critical Chain multi-project schedule of the constraining resource), multiplied by the time it takes for a project to go through the last project stage in the value acquisition process and also being approved.

The size of the second value buffer is determined by the rate of release from the final value buffer as well as the rate at which projects are abandoned at the final filter, which is situated just before the final value buffer multiplied with the time it takes to do the preliminary design and financial feasibility of a project (as highlighted in figure 23 (a)).

The first value buffer should be sized in a similar way. The sizing of the buffers and the factors that influence the buffer sizes as discussed in the previous paragraphs, can also be expressed as shown in figure 24.

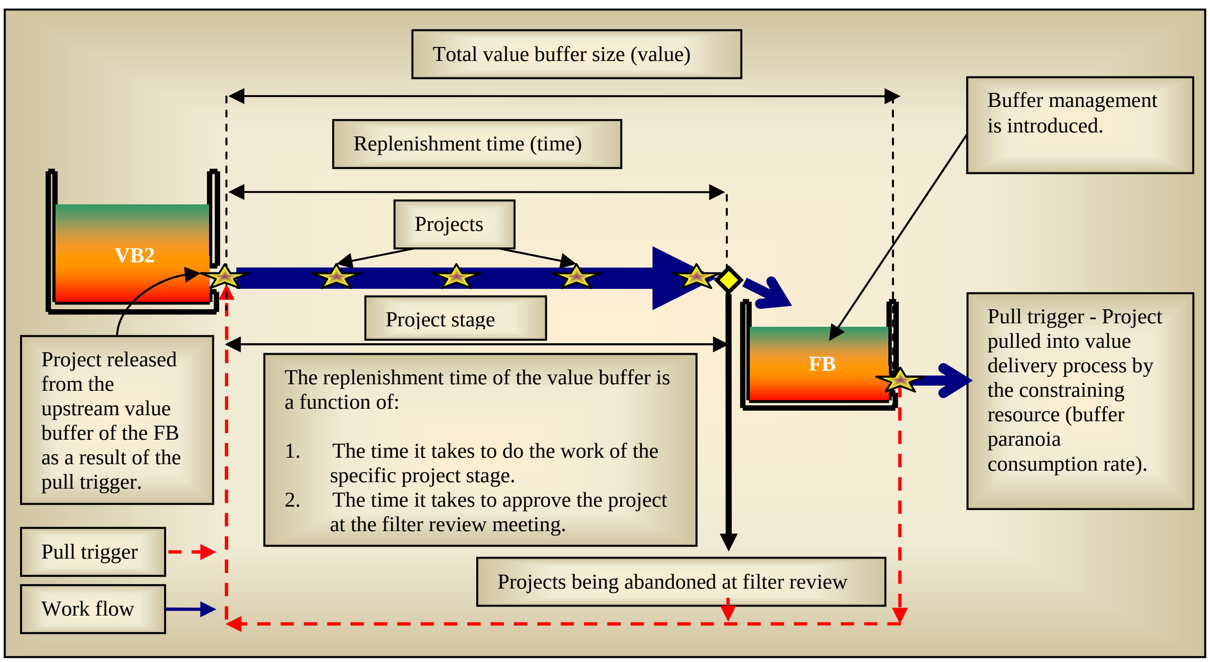

Figure 24: The sizing of the value buffers.

It is important to note that the replenishment of a value buffer, which will happen as a result of a downstream pull trigger, will only maintain the amount of work in the stage that is equal to that of the downstream value buffer.

When a project is abandoned at a decision filter, or pulled from a value buffer, a project is immediately pulled from an upstream value buffer, as described earlier in the chapter. In the case of the proposed management model, the project being pulled from the downstream value buffer, and being released from the upstream value buffer will never be equal in size. This will cause the value buffer to fluctuate around its maximum level. It is therefore imperative that organizations that apply the proposed management system implement projects that are phased similarly. This will be further discussed when value buffer management is introduced in the next section

Because of the fact that project value is measured in terms of throughput, the units used to express the size of the approved projects within the value buffer should be a financial unit. The value buffers could therefore be managed in terms of value status. The complete buffer management process will be discussed in the following section.

The size of the value buffers would also be dependent on the following factors inside of the organization:

1. The amount of available money in the organization.
2. The type of projects of the organization – some type of projects takes longer to design and to research. This will influence the replenishment time of the value buffers.
3. Financial targets set by management at the end of each financial year.
4. Desired project response rate to customers.
5. Limited resource loading.

3.4.7 VALUE BUFFER MANAGEMENT

The management of the proposed value buffers, is the third injection introduced.

In the Critical Chain multi-project environment, buffers are used to protect the project performance. In this buffer management process certain explicit action levels were established to make the necessary decisions. For the proposed management model action levels will also be used to manage the value buffers.

In the proposed project management model the value buffer status indicates the overall health of the model and will be the input for buffer management. The proposed value buffers will fluctuate in time as the consumption and replenishment rates vary, as described in the previous section. The effect is that when a photograph is taken of buffer content at a point in time, some of what is expected to be there would not have arrived and others would be in the buffer although it was expected later.

After the value buffer has been sized, the value buffer is divided into three equal zones and labeled red, yellow and green and managed to these zones (as also expressed in figure 24). The value buffer management process can be expressed as shown in figure 25, and will also be discussed in the following narrative.

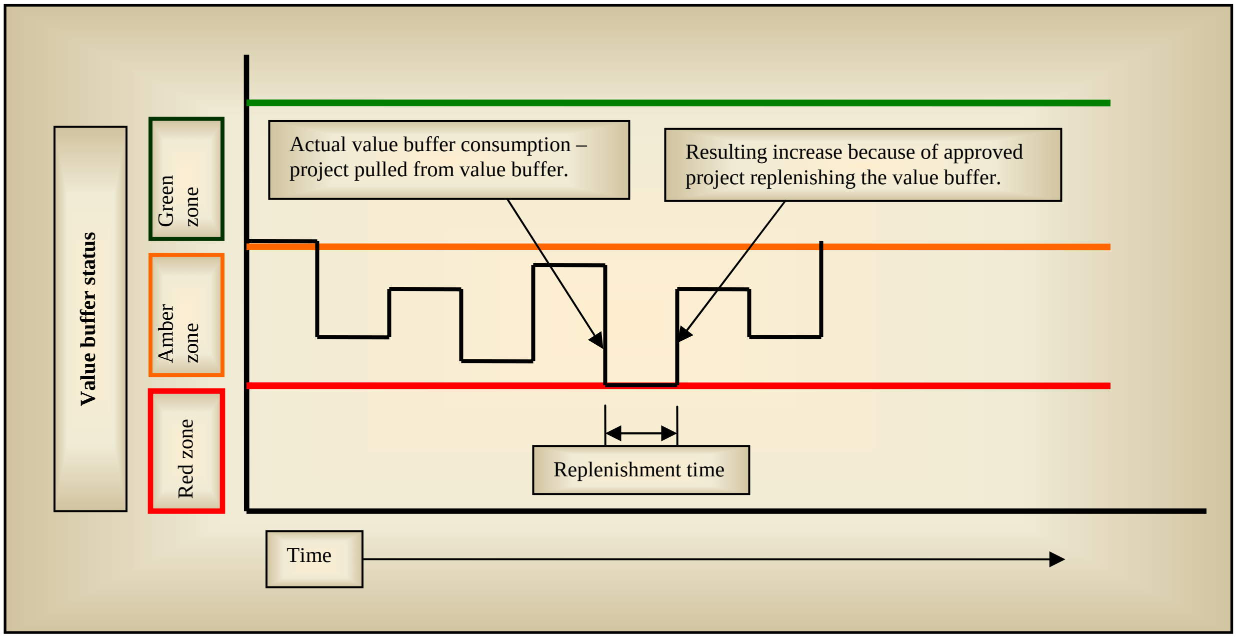

Figure 25: The value buffer management

In managing the value buffers in the project management system, the decision levels are in terms of the buffer size and the buffer status:

1. If the value of the projects that are approved for further processing is more that the yellow line, then the buffer status is green. No action is to be taken. The system is in control and it is assumed that because of variation in the system the work has been completed fast through the previous stage.
2. If the value of the projects that have been approved is between the yellow and the red line then the amber zone is penetrated. There is still enough work in the value buffers for the constraining resources to draw work from. The system is still in control, but management must plan how the project work in the work stage preceding the value buffer could be expedited to ensure quicker flow to the value buffer.
3. When the level of the value of projects approved is less than the red line level, then there is not enough project work in the value buffers and the key resources might be starved for work and become idle. Management has to take expediting decisions to speed up the flow to the value buffers in order to ensure that the key resources will not become idle.

3.4.8 SUMMARIZING THE PROPOSED PROJECT MANAGEMENT MODEL

The proposed project management system can now be summarized as follows:

- The flow in the system will be synchronized to the work rate of the constraining resource. The work rate of the constraining resource will therefore represent the productivity of the system.
- Projects are designed for all stages and scheduled with Critical Chain multi-project scheduling according to the work rate of the key resources as scheduled with aggressive duration estimates.
- Value buffers are introduced between review filters and project stages of Coopers [10] traditional stage-gate process.
- The high value projects waiting in the final value buffer ensures that key resources are productively busy with high value project work.
- The two value buffers situated upstream maintains the final value buffer.
- Project work are released from an upstream buffer when a downstream pull trigger is received from a downstream value buffer.
- All the value buffers in the system are appropriately sized and managed by applying the principles discussed in the previous section. Too large value buffer sizes will result in long project lead times which are undesirable if the organization wants to improve project value.

3.5 THE ‘SYSTEMS’ VIEW OF THE PROPOSED INJECTIONS - THE FUTURE REALITY TREE

In the next section the “systems’ view (or the non-physical view) of the injections will be presented and discussed by making use of the 2nd TOC thinking process tool to be used in this study – the Future Reality Tree (FRT).

The FRT creates a vision for the future, which aims to invalidate the assumptions made during the construction of the Evaporating Cloud (EC) in Chapter 1. The FRT proposes an answer from a “systems” view to question 2 of the research presented in chapter 1: *“What should current processes in the multi-project environment be changed to?”.* It is important to note that only the envisaged outcomes are explored in this section. The question whether the proposed injections are indeed valid will be answered by conducting a simulation model based on the FRT. This will be done in the next chapter.

Firstly, in order to understand the FRT fully, the *cause–effect* relationship and categories of legitimate reservation will be explored next.

3.5.1 CONSTRUCTING THE FRT

Cause-effect diagrams

The FRT consists of the following unique parts:

1. Entity – an entity can be seen as a *cause* or an *effect* of the *cause.*
2. Arrows – that is an indicator of the relationship between the two entities. The entity at the base of the arrow is the *cause.*
3. And-connectors – An and-connector is an ellipse that groups entities to present "logical and".

The way to read the diagram is to precede to the box on which the arrow originates with the word "if" and the box at the tip of the arrow with "then".

Categories of legitimate reservation

The relationship between the different entities can be diagrammed by using sufficient cause thinking techniques.

This means that one proves that something is the inevitable result of the existence of something else by drawing on experience, intuition, common sense and fact (Scheinkopf, [41]). In the absence of anything that proves the opposite, the premise has to be accepted.

In order to test the validity of the relationships provided in the FRT, the categories of legitimate reservation are employed. The legitimate reservation process is a systematic approach to challenge the assumptions while using sufficient cause thinking. The basic reservations deal with entity existence, causality existence and clarity, as indicated in figure 26.

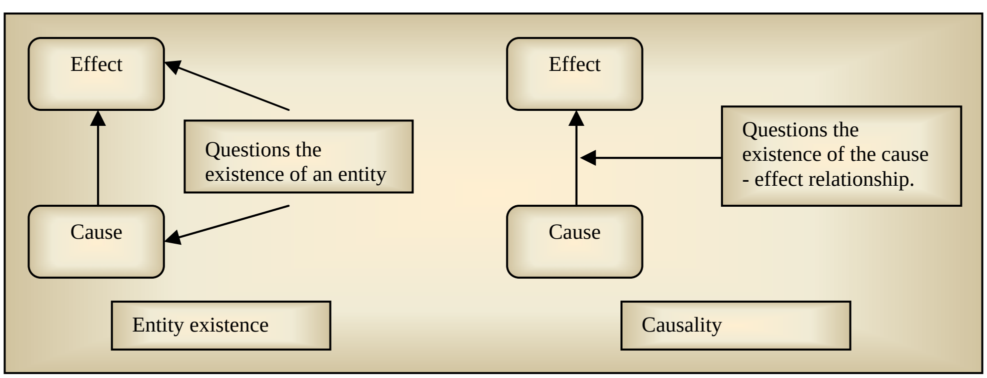

Figure 26: Basic categories of legitimate reservation, adapted from Scheinkopf [41].

The validity of these items can be verified by asking 3 fundamental questions:

1. Do the entities exist?
2. Is the cause-effect relationship between the entities valid?
3. Is the diagram communicating what we intended it to do?

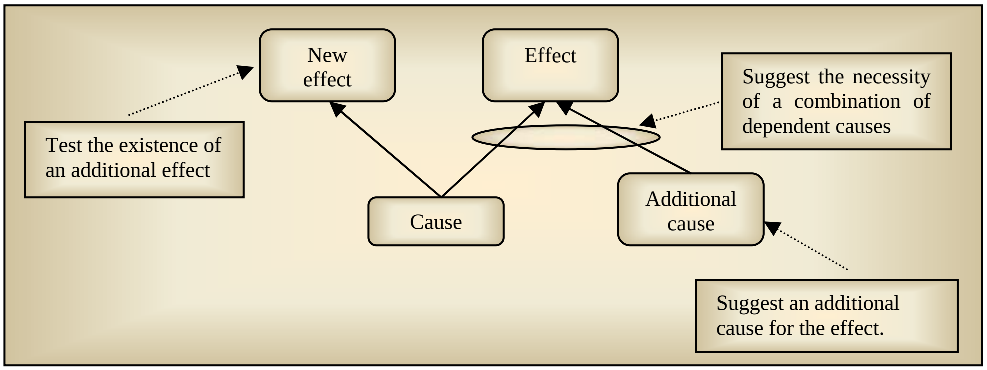

Figure 27: Additional conditions for legitimate reservation, adapted from Scheinkopf [41].

If the questions posed with the entity or causality existence reservations remain unanswered the following steps are followed to ensure any doubt about the validity of the system is removed, as also expressed in figure 27:

4. *Additional cause* – examine the causality existence by looking for additional independent causes for the given effect.
5. *Cause insufficiency* – further examine the causality existence by looking for missing dependent elements of the cause.
6. *Predicted effect* – is finally used to examine either causality or entity existence by utilizing the scientific method of effect-cause-effect.

3.6 THE FRT FOR THE PROPOSED PROJECT MANAGEMENT MODEL

The FRT is discussed in the following narrative and should be followed next to figure 28 (a) and (b). The different steps in the FRT are numbered (numbers are indicated in brackets) to make it easier for the reader to follow.

If the stage gate system and funnel concept with strategically placed value buffers is introduced (301), and any flow of project work from the value buffers is initiated by a key resource made possible by the Critical Chain multi-project management approach (302), then the effect will be that all project work wait in the value buffers, before being worked on by key resources (303).

If all project work wait in the value buffers before being worked on by key resources (303), and these projects in the value buffers are seen as monetary value (305), together with the injection that management review the status of these value buffers (304), it will lead to the result that all the project value in the system is known (306).

At this stage the assumption is made that in the Critical Chain environment, the work rate according to the system's constraint is the most productive (309). Furthermore, the value buffers are sized to ensure that these key resources are not starved for work, taking into account the estimated value buffer consumption and replenishment time (308). In addition to this, management also does resource scheduling across the two macro processes of the project life cycle (307). The foregoing causes will then have the effect that enough project work in value buffers is available to ensure that the key resources always have project work in the near future (310).

If CCMPM allows for approved projects in the value buffer to be staggered on a time line with aggressive lead time estimates for activities and these activities are scheduled around the key resource (311), and a pull trigger is introduced which is initiated by the key resource drawing work from the final value buffer (312), then the effect will be that project work is pulled from the final value buffer by the key resources; and a pull trigger is initiated (313).

If project work is pulled from the final value buffer by the key resources (313) and a project from the upstream value buffer is released as a result of downstream pull trigger (314), then the result will be that the replenishment of the value buffer as a result of the pull trigger only maintain the amount of work in the project stage equal to the size of the downstream value buffer (315).

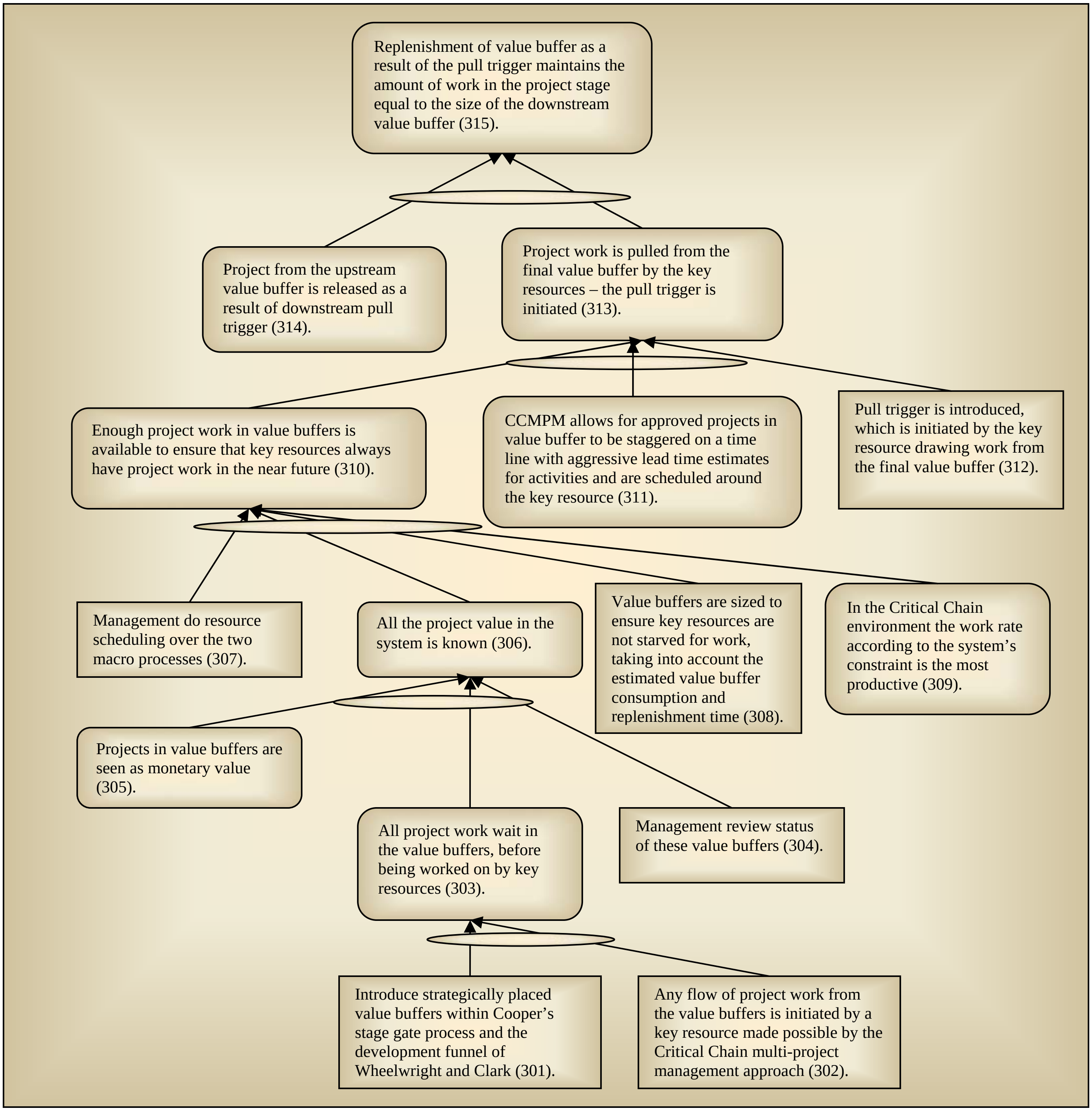

Figure 28 (a): The Future Reality Tree.

At this stage, if the assumption is made that the projects in the management system is phased similarly (319) and, if management find it necessary, the work stage preceding value buffer could be expedited, in order to shorten replenishment time of value buffer (316), then it will lead to the effect that the available project work for key resources will fluctuate around the maximum level of the value buffers (320). This in turn will have the effect that the project value in the whole system is known to management (306).

If project priorities determine the sequence of release for the next project stage (318), and the buffer time allows for project reprioritization (317), then organizations will be able to respond better to changed priorities in project work (321).

If the project work for key resources fluctuates around the maximum level of the value buffer (320) and organizations are able to respond better to changed priorities in project work (321), then the result will be that the reliability in production for the system increases (325).

At this stage, if CCMPM allows for approved projects in value buffer to have aggressive lead time estimates for activities and these activities are scheduled around the key resource (323) and the assumption is made that multi-tasking in the multi-project environment is minimised when Critical Chain multi-project scheduling is used (322), then the effect will be that the overall project lead time will decrease (324).

Project lead time decreasing and the reliability in production increasing will then lead to the result that productivity of the system increases (326).

An increase in the productivity of the system (326) will result in the throughput value of the projects increasing (332). An increase in productivity will also result in another positive effect - a faster client response rate (327). If a fast client response rate (327) is present and the assumption is made that clients demand priority of their work (328), then the result will be that clients will be happy (330). The foregoing will have another positive effect in the sense that the clients have an increased perception of value for the product (329).

If clients are happy (330) and an increased perception of value is present (329), then more sales and higher prices will be at the order of the day (331). More sales and higher prices will then increase the throughput value of the projects (332).

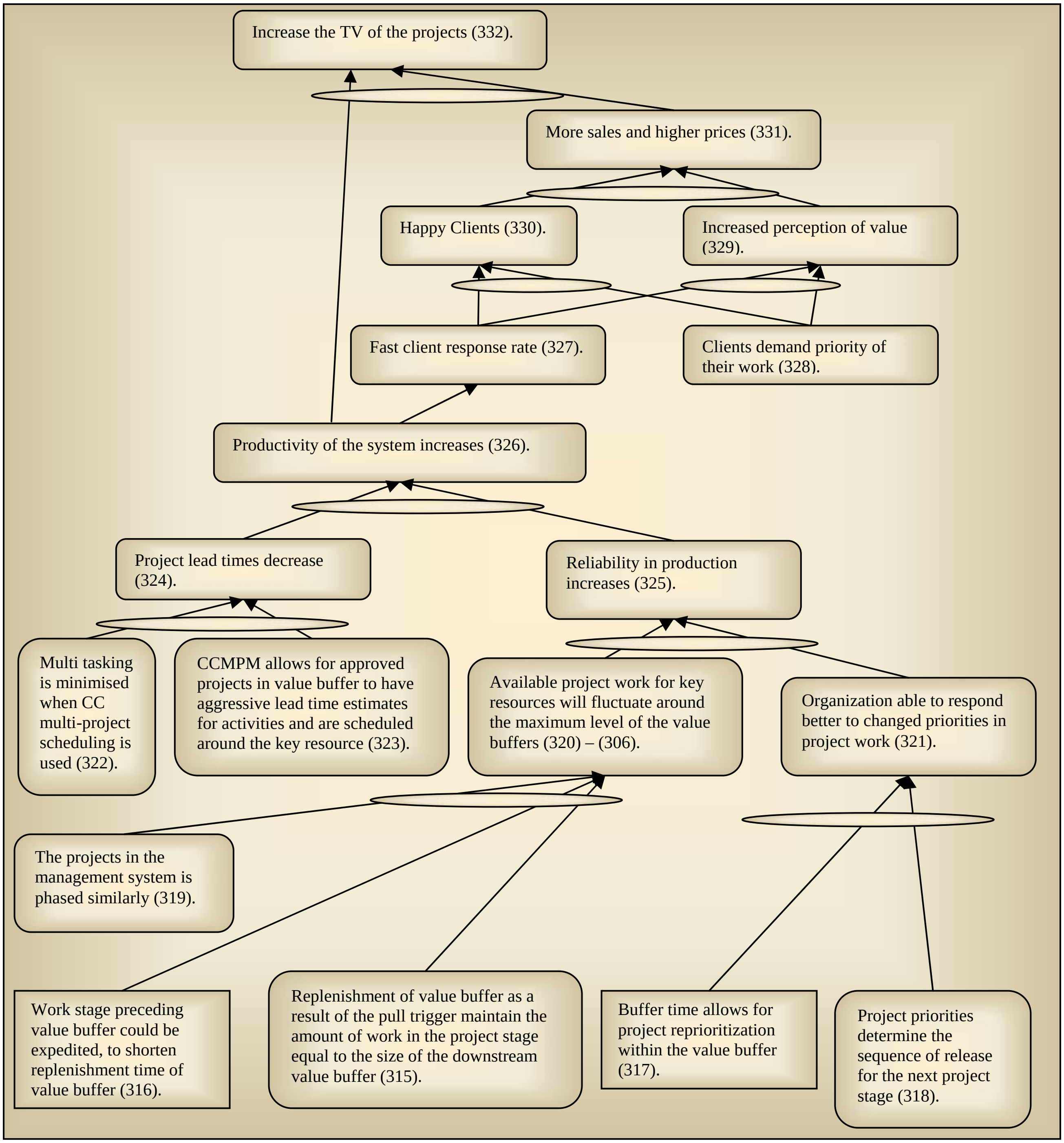

Figure 28 (b): The Future Reality Tree (continued).

3.7 CONCLUDING THE PROPOSED VISION FOR THE FUTURE

It is important to realize that the proposed project management model with its unique value buffer concept and the management thereof, are "injections" which aims at challenging and invalidating the assumptions made that supported the necessary conditions and requirement D-D' and D-B in the EC presented in chapter 1.

The proposed project management model aims at challenging these assumptions, especially the issue of push and pull, by the introduction of a unique value buffer concept, which can serve as a management tool through normal buffer management, as discussed throughout this chapter.

Now that the answer to the question *"What should current processes in the multi-project environment be changed to?"* has been proposed, a simulation model will be conducted in the next chapter. The simulation model will be based on the FRT with its proposed "injections" presented earlier in this chapter. The simulation model will aim at investigating whether the proposed injections to vaporize the EC are indeed valid.

CHAPTER 4

THE SIMULATION MODEL FOR THE PROPOSED INJECTIONS

4.1 BACKGROUND

The next step in the study is to answer the main research question as discussed in chapter 1: *"Is the proposed solution as presented in the FRT indeed a valid approach to improve current project management models?"* In order to answer this question, a simulation model will be developed, which will be based on the Future Reality Tree (FRT) with its proposed "injections". The simulation model will aim at investigating whether the proposed injections to vaporize the Evaporating Cloud (EC), are indeed valid. The simulation model will be presented conceptually in this chapter. Only in the next chapter will simulation runs be made. The main objective of this chapter is to provide the reader with some understanding of the logic behind the simulation model and why it responds the way it does. The validation of the simulation model will also be presented, but first of all the research methodology and tools that will be followed and used in order to investigate the validity of the proposed injections, and their benefits as shown in the FRT, will be discussed.

4.2 THE RESEARCH METHODOLOGY

The rationale behind the study was discussed in chapter 1 and in chapter 3. The main research question was summarized as the challenge to prove that the proposed injections with their benefits as presented in the FRT, are indeed valid interventions to invalidate at least one of the assumptions supporting the EC (especially the assumptions supporting D-D'), thus vaporizing the EC.

The proposed injections and vision for the future were presented and discussed in chapter 3 by providing the "process" and "system's" view of the management model. This vision was derived from the literature as presented in chapter 2. Now that the proposed project management model and the new injections have been presented, it will be developed into a simulation model. The simulation model will test various scenarios for the proposed project management system.

The results obtained from the simulation (which will be shown in chapter 5) will be analyzed through standard data analysis procedures. The results of the simulation will investigate whether the proposed injections are invalidating at least one assumption of the EC, which supports D-D' or D-B of the EC (as was shown in chapter 3). The results obtained will provide an answer to the main research question highlighted earlier in this study and also in this chapter.

The proposed management model will be validated if it can be shown that it solves the push problem and could lead to eliminating the negative effects stemming from it and replacing them with the positive effects shown in the FRT. In the terminology of the TOC thinking processes, it means that the push-don't push dilemma must be vaporized and that the desired effects must be caused by the proposed project management model.

Finally, conclusions on whether the proposed injections are indeed a valid approach to vaporize the EC will be given in the remainder of chapter 5. Chapter 6 of the study will provide the reader with a short summary of the findings obtained in this study and also some additional recommendations. In the next section of this chapter the simulation software that will be used in the study, as well as the type of simulation that will be executed, will be briefly discussed.

4.3 RESEARCH INSTRUMENTS

4.3.1 CONDUCTING A SUCCESSFUL SIMULATION STUDY

Firstly, having the appropriate simulation software, and secondly, having a definitive approach to conducting the simulation study, is critical to the study's success in general and in developing a valid model in particular. A seven-step approach for conducting a successful simulation study proposed by Law and McComas [29], is shown in Figure 29.

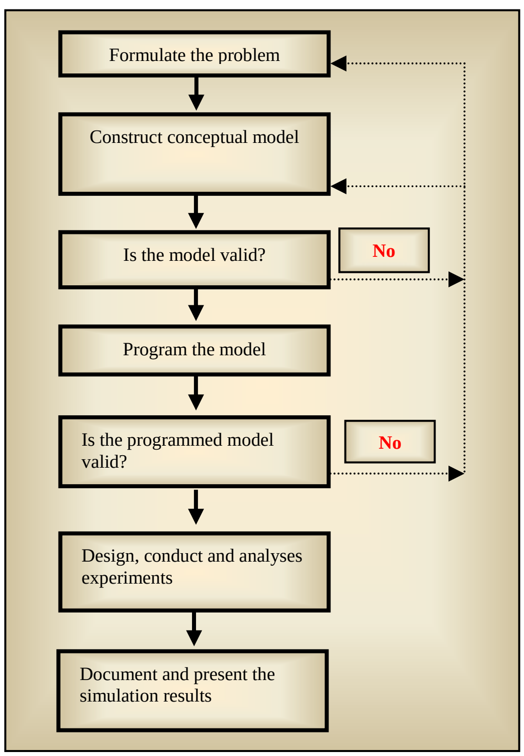

Figure 29: A seven-step approach for conducting a successful simulation study.

From figure 29 it is evident that the first step to achieve a successful simulation study is to formulate the research problem and goal. This has been achieved in the previous three chapters of this study. The next step is to create a conceptual model, making use of the simulation software, after which the model needs to be verified and validated.

Verification and validation is necessary to ensure that the results obtained from the simulation runs are accurate and trustworthy. The verification and validation of the model will be shown later in this chapter.

4.3.2 THE SIMULATION SOFTWARE

For this study, Arena will be used as the chosen simulation tool. The reason behind this choice is that Arena combines the ease of use found in high-level simulators with the flexibility of simulation languages. It does this by providing alternative and interchangeable templates of graphical simulation modeling and analysis modules, that can be combined into building a very wide variety of simulation models.

4.3.3 THE TYPE OF SIMULATION

According to Kelton and Sadowski [27] most simulations can be classified as either in a terminating or steady state. This is primarily an issue of intent or the goal of the study, rather than having much to do with internal model logic or construction.

A terminating simulation is one in which the model dictates specific starting and stopping conditions, as a natural reflection of how the target system actually operates. For example, the simulation of a project through to its completion.

A steady state simulation, on the other hand, is one in which the quantities to be estimated are defined in the long run (over a theoretically infinite time frame). In this particular study, a continual management process is being modelled and a steady state simulation is therefore appropriate.

In principle, the initial conditions for the simulation don’t matter. The problem is that a steady state simulation has to stop at some point, and it is crucial that the simulation run is long enough to capture enough data. The determination of an accurate run length will be discussed later in this chapter. To ensure that the relevant data of the simulation is captured, the simulation will be classified into three different dimensions as proposed by Kelton and Sadowski [27].

These dimensions are:

1. Dynamic – The lead time is a key variable in the model.
2. Discrete – The entities flowing through the process are discrete. Change will only occur at separate points of time, such as entities arriving and leaving at specific times.
3. Stochastic – The model operates with a random input (where the opportunities will arrive randomly and will require varying service times) defined as a probability distribution.

Before any simulation run is made, it is necessary to define and briefly discuss the key input parameters and conceptual logic for the simulation model.

4.4 THE INPUT PARAMETERS

4.4.1 THE INPUT SHEET AND LOGIC OF THE SIMULATION MODEL

To change key parameters in order to create different scenarios, an input sheet was developed for the simulation model. An example of the complete input sheet is shown in table 10. The most important input parameters and also the most important conceptual logic of the simulation model will be discussed in the following narrative.

Attributes:

In order to ensure total randomness in the simulation of the proposed management model, a probability distribution for a possible score (0-3) was assigned to the applicable attributes for any given arriving opportunity. Throughout the simulation, a relative weight representing the importance of each attribute can then be used as a multiple at each decision filter. The weighted scores for all the attributes are then added for a specific opportunity.

The value of an opportunity is then compared to the cut-off limit for the specific review filter (cut-off limits are discussed later in this section). The score of the value opportunity will determine whether it will move into the next value buffer or be discarded. Table 10 shows all the attributes used during the simulation and an example of the weight each attribute could have at each filter review.

Time between ideas and idea value:

The input sheet has the option to assign different triangular distributions to the arriving rate of opportunities and the value of the opportunities at the start of the simulation run. Hours were used as constant time metric throughout the simulation process.

As was highlighted in chapter 3, the frequency of key events upstream of the value buffers will have a significant impact on the time it takes for the value buffers to replenish lost value. During a simulation run the model will manipulate replenishment time according to the status of the value buffers.

	Attributes	0	1	2	3	Weight filter 1	Weight filter 2	Weight filter 3	Prelim
1	Technical relevance	0.05	0.1	0.2	0.65	0.2		0.14	0.33
2	Research direction and balance	0.05	0.15	0.2	0.6	0.2			
3	Timing	0.1	0.6	0.25	0.05		0.5	0.14	0.33
4	Stability	0.35	0.3	0.2	0.15			0.14	
5	Position factor	0.15	0.3	0.5	0.05			0.14	
6	Market growth	0.1	0.1	0.75	0.05			0.14	
7	Marketability	0.1	0.3	0.5	0.1	0.2		0.14	
8	Producibility	0.05	0.15	0.65	0.15	0.2	0.5		0.33
9	Financial	0.1	0.6	0.25	0.05	0.2		0.14	

	min	mode	max
Initial time between ideas	8	24	145
Idea value	0	70000	100000

Changes time between ideas	Yes

Filter review 1 cut-off limit	2.3
Filter review 2 cut-off limit	1.8
Filter review 3 cut-off limit	1.5

	As proportion of maximum idea value
Final buffer - critical limit	0.5
Final buffer - lower limit	1
Final buffer - upper limit	2

	min	mode	maks	Percentage active resource participation
Filter 3 prep activity delays	80	100	160	10%
Filter 2 & 3 meeting frequency	170	176	200	
Review meeting 1 frequency	170	176	200	
Review meeting 2 frequency	170	176	200	
Execution delay	1080	2160	3240	90%

Table 10: The input sheet developed for the simulation model.

Cut-off limits at decision filter meetings:

Each decision filter has a cut-off limit assigned to it. Any given opportunity's score will be judged against the assigned cut-off limit for that specific filter review. If the value of the opportunity is less than the chosen cut-off limit, the opportunity will be discarded. If the value of the opportunity is greater than that of the cut-off limit, the opportunity will proceed onto the next value buffer and stage. This process will continue until the opportunity is given the final Go decision for project development, where it will move into the final value buffer waiting to be pulled into the value delivery process by a key resource.

The value of the cut-off limits during all the simulation runs were set in such a way that the waste stream at the initial filter review is very high (not less than 80%) as suggested by Wheelwright and Clark [52] when they discussed their development funnel concept. At the next filter review, the waste stream decreases dramatically. At the final filter, the cut-off limit is such that the failure of an opportunity would be the exception. The value of the cut-off limits in this study will be kept the same throughout the analysis process.

Buffer sizing and buffer management:
The importance of proper buffer sizing and the management of these buffers for a productive management system came to the fore during the discussion of the process view and system's view for the management model in chapter 3.

The simulation model is developed in such a way that the final value buffer can be sized as a proportion of the maximum value for an arriving opportunity. It is important to do active value buffer sizing (over various simulation runs) in order to achieve the optimum value buffer size, as the size of the final value buffer will most certainly have an influence on the lead time of the projects in the management system and also play a role in the reliability of production. It is therefore a very important parameter to change.

The areas for buffer management (red/amber/green zone) can also be sized by the simulator. The management of the value buffers is a built-in feature of the simulation model.

It should be noted that the reprioritization of projects within the value buffers are not part of this simulation model and could form part of a future study. In this simulation model projects are pulled from the downstream value buffer and then immediately released from the upstream value buffer on a first-in-first-out basis, as a result of the pull trigger as described in chapter 3. In the simulation model, once a project is pulled from the final value buffer, the value in the buffer will only drop once the specific project has been realized at the end of the value delivery process.

The replenishment time of the value buffers is a function of the frequency and speed of key events upstream of the value buffers. Short lead times for events and a high frequency of decision filters upstream of the value buffer, shorten the time to replenish the lost value of the value buffer. This will have the effect that a smaller value buffer would be appropriate. This concept was also discussed in chapter 3.

Frequency of key meetings:
By changing the relevant triangular distribution, the frequency of the key meetings can be changed as desired.

This is one of the most crucial parameters, as the frequency of events taking place can have a significant influence on the replenishment time of the value buffer and the availability of project work in the value buffers, to ensure the key resources are not starved for work.

Resource scheduling - Percentage active participation:

The percentage active limited resource participation in the value acquisition and value delivery phase will hold the key for increasing the system's productivity as discussed in chapter 3. Therefore it is important that this parameter can also be changed to create different scenarios.

The most important resource to monitor during a simulation run, is the constraining (key) resource. In this study, the development engineer has been identified as the constraining resource and will therefore determine the capacity of the whole system. The resources utilized in both the value acquisition and value delivery process and their tasks are shown in table 11.

ASSIGNED TASKS TO RESOURCES		
Resources	**Value acquisition phase**	**Value delivery phase**
Development engineers	Technical feasibility	Production development
Divisional manager 1, 2, 3, 4, 5	Filter review 1 & 2	1st & 2nd review meetings
Management	Filter review 1 & 2	1st & 2nd review meetings
Manufacturing engineers	Competitor analysis, financial viability	Conceptual and final designs
Marketing personnel	Pre-lim marketing	Marketing

Table 11: Limited resources working on both the value acquisition and value delivery process.

After the input parameters have been defined, it is crucial that the data obtained from the steady state simulation run is accurate and representative of what truly happens during the project management process. To ensure this, the warm up and run length of the steady state simulation should be characterized in such a way that the output analyzer of Arena will only contain relevant data of the simulation run.

4.5 THE WARM UP AND RUN LENGTH OF THE SIMULATION

4.5.1 SIMULATION AT AN IDLE STATE

Before a simulation run is made, the management model is initially in an empty, idle state. This means that the model starts out empty of entities and all resources are idle. Realizing that this is unrepresentative of a steady state, the model is given a warm up period of 1 056 hours (half a year).

This period is sufficient, for the effect of the artificial initial conditions have worn off. At this time, the data accumulators of the output analyzer are cleared, and is therefore only gathering data after that. This ensures that the data being used for the analysis is "decontaminated" from the biasing initial conditions. The Arena output analyzer is used to capture data from the simulation runs.

A run time of 6 336 hours (three years); repeating each run twenty times (126 720 hours), was specified for the steady state simulation. In figure 30, a plot of the marketing resource's utilization is given during a "test" simulation run. The resource is busy when the value is 1 and idle when the value is 0.

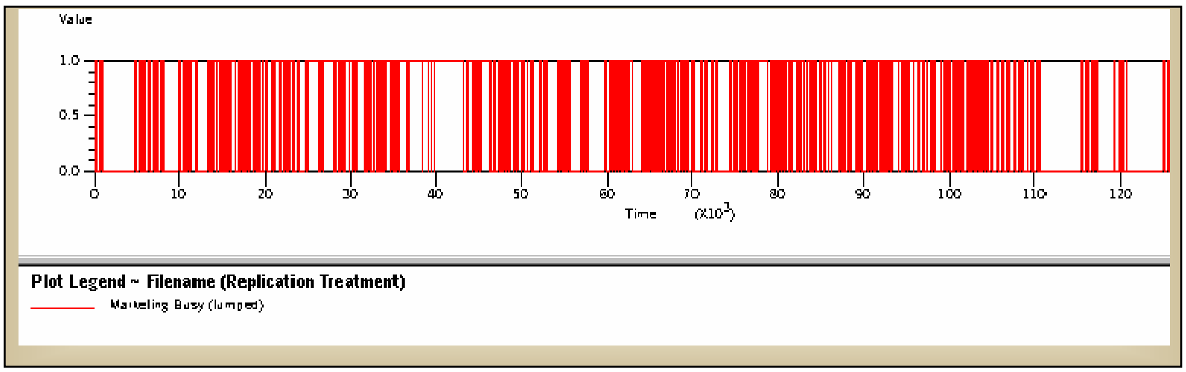

Figure 30: The utilization for the marketing resource for a test simulation run.

In figure 31, the value in the final buffer over the time horizon is shown for the same simulation run.

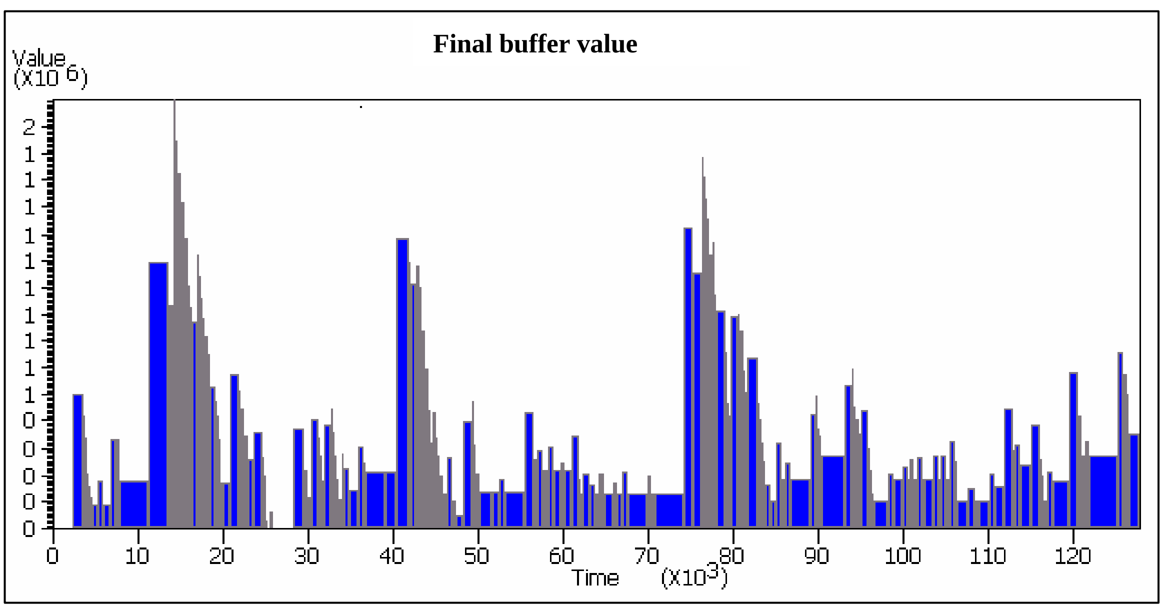

Figure 31: Value in final buffer for a test simulation run.

From figure 30 and figure 31 it is clear that the running length of three years (the first 6 336 hours), is enough for the model to have settled and to capture the relevant data.

4.6 DATA GATHERING PROCESS

As was shown in the previous section of the chapter, the run length of the steady state simulation is quite lengthy (6 336 hours), in order to allow the model to settle and allow the simulation to capture enough data. Because of the long simulation run, there are more opportunities for the simulation to sequence its internal operations a little differently, causing the random number stream to be used differently (Kelton and Sadowski [27]).

This doesn't make the management model in any sense invalid, but it has to be taken into account that it can affect the numerical results, especially when the model, as in the case of this study, has a lot of statistical variability inherent to it.

For this study, independent and identically distributed replications were made for the steady state statistical analysis as suggested by Kelton and Sadowski [27]. This implies that the simulation run was replicated a specified twenty times, with each replication starting afresh and using separate basic random numbers to drive the simulation. For each replication, a separate summary report was generated in the output file of the Arena output analyzer. Each output file contains the relevant data for each replication. This data was exported and summarized in a spread sheet format and are presented visually by means of graphs and discussed in accordance.

4.6.1 CONFIDENCE LEVELS THROUGHOUT THE SIMULATION

Throughout the simulation analyses a confidence level of 95% was used to obtain results from the simulation runs. This was achieved by making use of Arena's output analyzer function.

A confidence level is the probability value associated with a confidence interval (Kelton and Sadowski [27]).

The confidence interval (for example that of a mean (μ)) specifies a range of values within which the expected mean (μ) may lie. To explain confidence levels and intervals in another way, consider a confidence level of 95% and a confidence interval of 5%. If it is calculated that i.e. the mean for the "value executed" after a period of time is R100.00, the true value would be between R105 and R95 with a 95% confidence level.

Figure 32 illustrates confidence levels and confidence intervals. For a 95% confidence level the red dots mark the sample mean (μ). The lines on each side of the dot span the confidence interval. The red sample's confidence interval did not contain the mean.

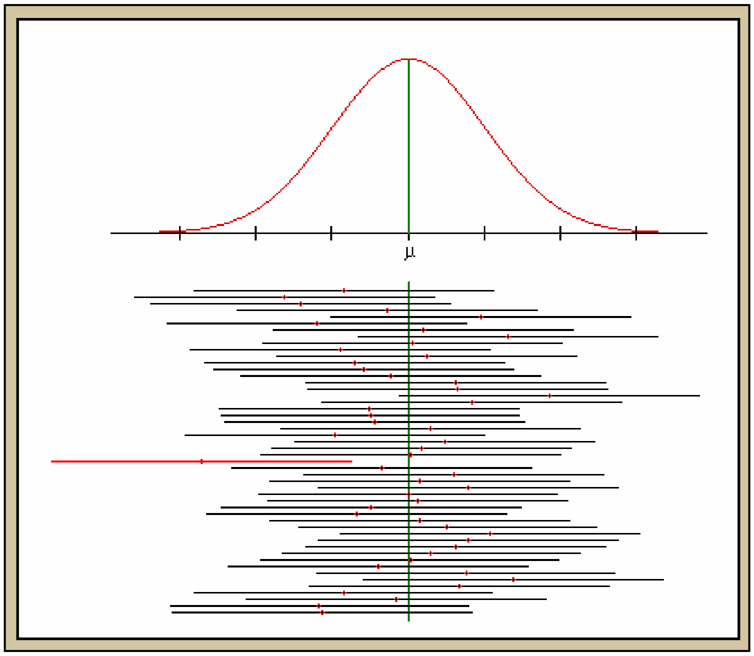

Figure 32: Confidence interval for the mean (μ) of a population.

It is important to note that confidence levels and confidence intervals are related. When all other values remain the same, the higher the confidence level, the larger the confidence interval.

During this study each replication in the simulation run produces an average value (μ), and due to random inputs these values will vary across different replications. The mean of 20 replications (as provided during a simulation run in this study), will therefore be a better indicator of what value to expect than a single run.

To use the simulation results with confidence, the simulation model has to be verified and validated (Law and McComas [29]). This is necessary to ensure that the model reacts the way it was intended to according to the modeling assumptions made, and that the results obtained are trustworthy and accurate.

4.7 VERIFICATION AND VALIDATION

The verification process

"The verification process is commonly known as 'debugging" of the model' - Law and McComas [29]. This is a crucial process, ensuring that all conclusions made are valid. Verification is easy compared to the validation process, which is the process of ensuring that the model really captures and predict the events of the real system.

The simulation model was successfully verified by means of tracking a single entity through the whole value chain of the model after a run has been completed, ensuring the model logic is as desired. This was done for different simulation scenarios.

The validation process

The validation process is the process of ensuring that the model captures and predicts the events of the real system (Law and McComas [29]). The following are some general perspectives on validation (Law and McComas [29]):

1 A simulation model of a complex system can only be an approximation of the actual system; no matter how much time and money is spent on model building.
2 If a simulation model is "valid", it can be used to make decisions about the system similar to those that would be made if it were feasible and cost effective to experiment with the system itself.
3 Validation of a model should always be done.

To explain how the simulation model was validated, the analogy can be used of an experienced structural engineer designing a simple steel beam which spans a fixed distance being suppressed by a normal point load. Before making use of his structural analysis software, the experienced engineer would (drawing from previous experience) have a good idea of what size and type of beam would be able to withstand the load for the particular scenario. Turning to his structural analysis software for the answer, the answer obtained validates the engineers' initial so-called "nudge".

The same approach can be followed when validating the simulation model. The simulation model was validated in 2 ways. From chapter 3 it is clear that there should exist a link between the project value waiting in the final value buffer and the value realized at the end of the value delivery process.

It is expected that once value is added (for the simulation it happens after project completion), the value in the final value buffer would drop with the same amount.

For a test run, figure 33 shows the difference between the value executed and the value of the opportunities waiting in the final value buffer after the simulation run. It is clear that there is a link between the value in the final buffer and the value executed during a simulation run.

Evaluating figure 33 at approximately 63 000 hours, it is apparent that as soon as the projects are completed and value are realized, the value in the final buffer drops at exactly the same time with exactly the same amount. This behavior of the simulation model is as expected and therefore validates the simulation model.

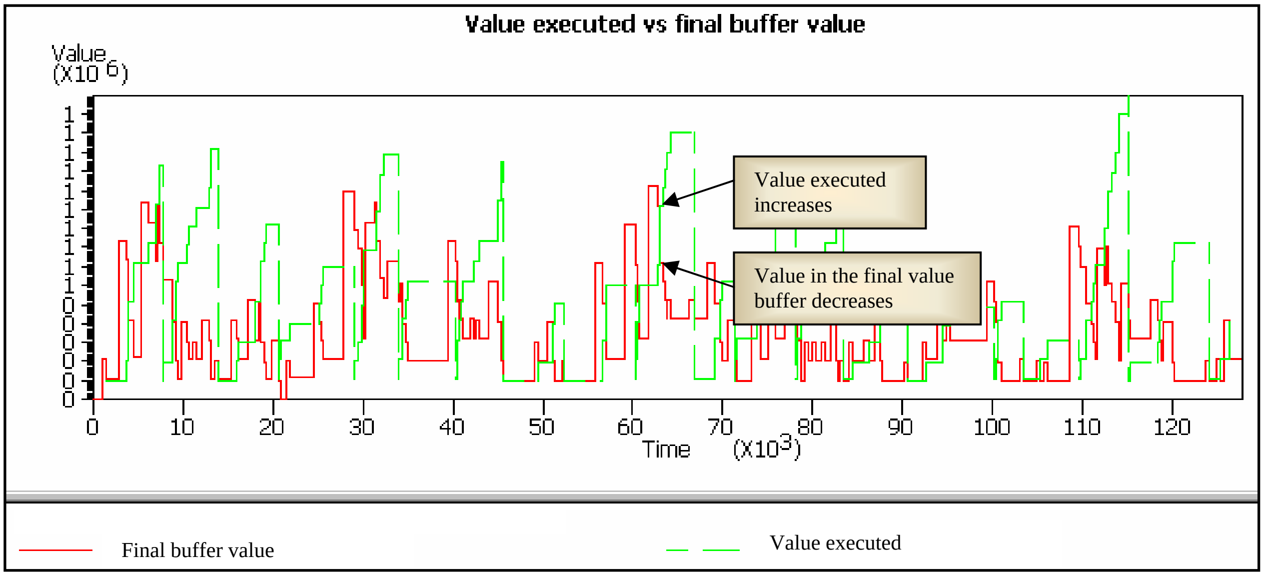

Figure 33: Value executed vs. value in the final buffer during a simulation run.

The simulation model was validated in a second way by means of looking at the final buffer value status and comparing it to the replenishment time of the value buffer.

The peak in value in the final buffer as shown in figure 34 (at approximately 27 000 hours), is due to the increase of the replenishment time of the value buffer (as shown in figure 35) because of the critical limit the buffer had at approximately 22 000 hours.

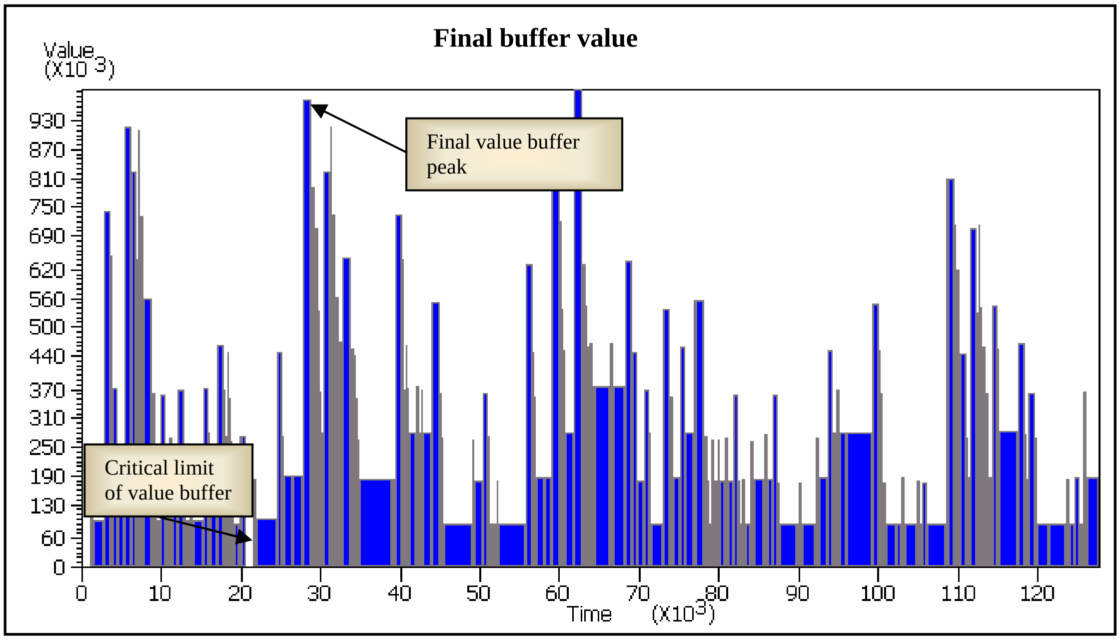

Figure 34: The critical limit and peak value of the final value buffer.

The arriving opportunities/projects at this point of time had “exceptional” long delay times and large associated value, thus causing the buffer value to create a spike at 27 000 hours. Trying to restore a normal buffer value, the system dramatically decreases the buffer replenishment time as shown in figure 35 (24 000 hours), just when the value of the projects were realized. Thus leading to the dramatic drop in the final buffer value.

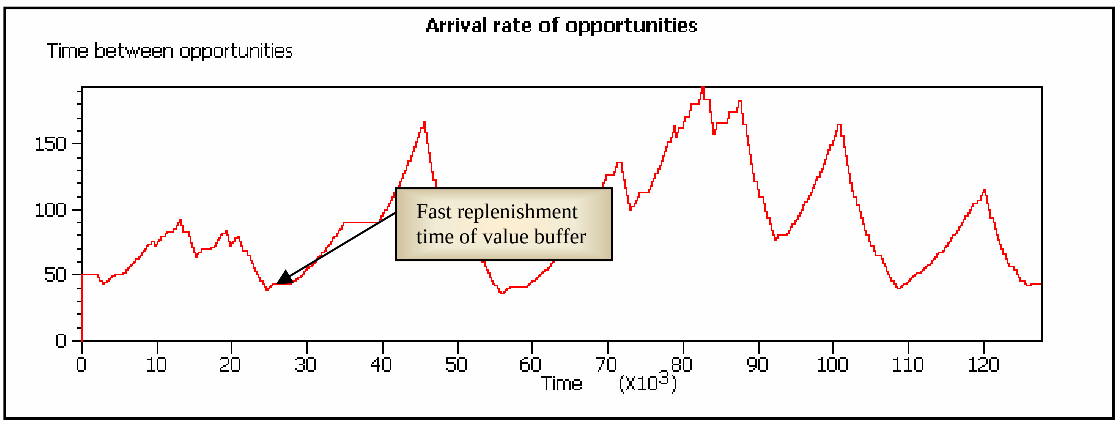

Figure 35: Maximum number of idea arrivals.

The expected link that exists between the final buffer value, value executed and the replenishment time of the value buffer, confirms that the model is indeed valid.

4.8 CONCLUDING THE SIMULATION MODEL

Now that the model logic has been described and the model has been verified and validated, runs for different scenarios will be made in the next chapter.

The data obtained from these runs will be presented and discussed in chapter 5. The results of the simulation will be analyzed through standard data analysis procedures, and scrutinized and evaluated against the proposed future vision.

CHAPTER 5

DATA ANALYSIS

5.1 BACKGROUND

In chapter 5, the proposed project management model will be simulated. The results obtained from the simulation runs will be presented and discussed. The ultimate aim of the chapter is to find an answer to the main research question: "*Is the proposed solution as presented in the FRT indeed a valid approach to improve current project management models?"*

In other words, the aim of this chapter is to test whether the proposed vision for the future is a valid approach to solve the identified push problem, therefore vaporizing the EC. After the appropriate data has been gathered and discussed, the assumptions supporting the necessary conditions in the Evaporating Cloud will be tested. The set hypothesis will then also be tested. The chapter will further aim to present a system with parameters that will optimize its performance in terms of value and time.

5.2 DATA GATHERED

The different input parameters that could be used for a specific simulation scenario were discussed in chapter 4.

Changing system parameters

The following parameters on the input sheet will be changed to create new simulation scenarios, as indicated in table 12. Results obtained by changing the different parameters will be presented in the following sections of this chapter. The parameters that will be changed are:

1. The percentage active resource participation in the value acquisition and value delivery phases.
2. The frequency of the 2nd and 3rd filter review meetings.
3. The value buffer size.

	Attributes	0	1	2	3	Weight filter 1	Weight filter 2	Weight filter 3	Prelim
1	Technical relevance	0.05	0.1	0.2	0.65	0.2		0.14	0.33
2	Research direction and balance	0.05	0.15	0.2	0.6	0.2			
3	Timing	0.1	0.6	0.25	0.05		0.5	0.14	0.33
4	Stability	0.35	0.3	0.2	0.15			0.14	
5	Position factor	0.15	0.3	0.5	0.05			0.14	
6	Market growth	0.1	0.1	0.75	0.05			0.14	
7	Marketability	0.1	0.3	0.5	0.1	0.2		0.14	
8	Producibility	0.05	0.15	0.65	[illegible]	[illegible]	[illegible]	[illegible]	0.33
9	Financial	0.1	0.6	0.25	[illegible]	[illegible]	[illegible]	14	

Changes as a result of value buffer management.

	min	mode	max
Initial time between ideas	8	24	145
Idea value	0	70000	100000

Changes time between ideas: Yes

Proper value buffer management was applied.

Filter review 1 cut-off limit	2.3
Filter review 2 cut-off limit	1.8
Filter review 3 cut-off limit	1.5

Cut-off limits were kept constant.

	As proportion of maximum idea value
Final buffer - critical limit	0.5
Final buffer - lower limit	1
Final buffer - upper limit	2

Value buffer size changed.

% active key resource participation changed.

Filter review meeting frequency changed.

	min	mode	maks	Percentage active resource participation
Filter 3 prep activity delays	80	100	160	10%
Filter 2 & 3 meeting frequency	170	176	200	
Review meeting 1 frequency	170	176	200	
Review meeting 2 frequency	170	176	200	
Execution delay	1080	2160	3240	90%

Table 12: Input parameters for the analysis.

The system's final performance will be judged on the following outputs to make the necessary conclusions for the study:

1. The average monetary value in the final buffer after a simulation run.
2. The value realized after a simulation run.
3. The utilization of the key resources, especially the development engineer (key resource), which is working on both the value acquisition and the value delivery phase.
4. The time it took for a project to move through the management system – the project lead time.

The data obtained from changing the above-mentioned parameters will be presented in the following sections of this chapter.

5.3 THE DATA ANALYSIS

5.3.1 CHANGING THE PERCENTAGE ACTIVE LIMITED RESOURCE PARTICIPATION IN THE VALUE ACQUISITION PROCESS

The limited (key) resources working on both the value acquisition and value delivery process were presented in chapter 4. While keeping all other input parameters the same, the percentage active limited resource participation in the value acquisition process was increased with increments of 10%. It was indicated in the previous chapters that typically, limited resources will not only work in the value delivery process, but will also need to acquire and evaluate opportunities and to a certain extent be involved with the preliminary design and delivery of an opportunity. Figure 36 shows the value executed and the value in the final buffer after each simulation run for the different scenarios.

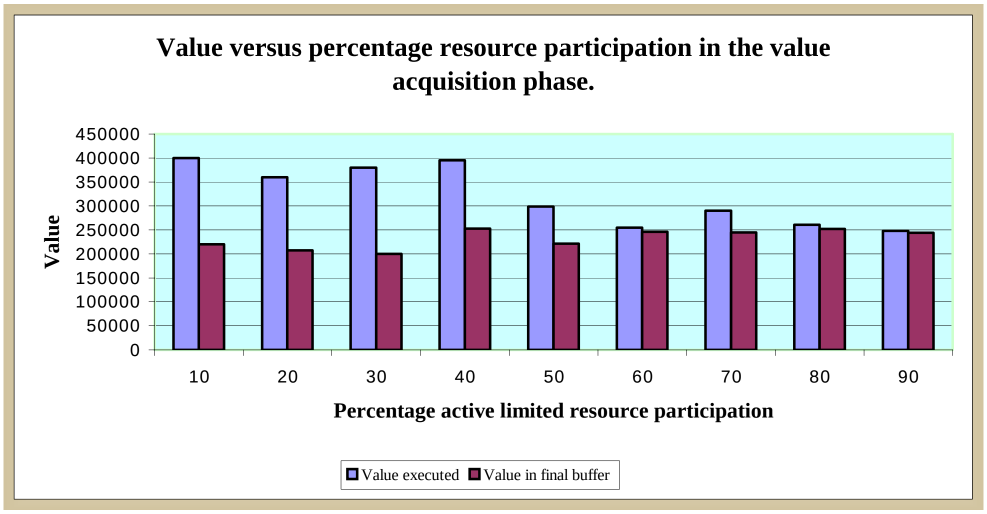

Figure 36: Value versus percentage active limited resource participation in the value acquisition phase.

From figure 36 it is clear that the value executed decreases at a rapid rate as the percentage active limited resource participation increases in the value acquisition process. In contrast, the value in the final value buffer stays more or less constant regardless of the percentage limited resource participation in the two macro processes. The percentage difference between the value executed and the value in the final buffer is expressed in figure 37.

Figure 37 shows that for a small percentage of limited resource participation in the value acquisition process the percentage difference between the value executed and the final buffer value are high and decreases dramatically as the percentage limited resource commitment increase in the value acquisition process.

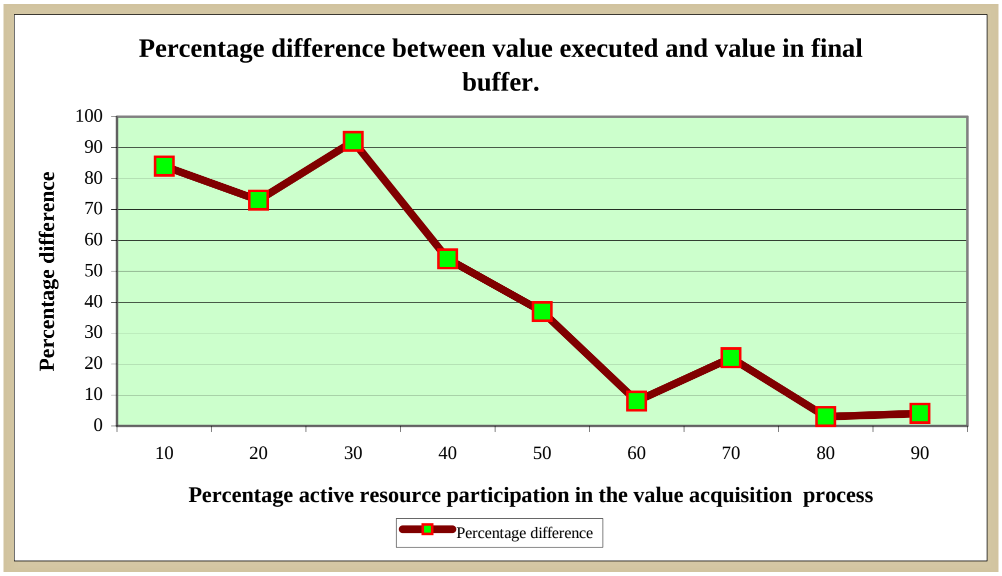

Figure 37: Percentage difference between the value executed and final buffer value.

During the construction of the EC in chapter 1 it was discussed that the common objective for any project-delivery driven organization is to deliver high value projects. One assumption, that supported the necessary condition D-D', was concerned with the value delivery and the value acquisition process having different value flow rates – the pull versus the push of work through the system. A problem that gave emphasis to this identified dilemma was the scheduling issue of limited resources over the two macro-processes. From figures 36 and 37 it is evident that the smaller the limited resource commitment in the value acquisition process is, the more value will be realized over a period of time.

Recalling from chapter 3, when the analogy of the supply chain was discussed, it was explained that the constraint of this particular system needs to be in the last stage to ensure value delivery and therefore the throughput value of the system is optimised.

As was highlighted in chapter 3, the project management model is based on CCPM principles and was designed in such a way that tasks of other resources are scheduled around the constraining (key) resource, implying that the key resource will serve as a "gate" through which project work will be released. The whole system will therefore operate as a pull system with the pull triggers situated in the last stages of the value chain. The key resource will therefore also be an indication of the system's capacity. It is consequently necessary that the throughput value per day for the constraining resource in the organization be maximized.

The tool that holds the key during this simulation is the proposed value buffer concept built into the management model. As described in previous chapters of the study, the value buffer concept in the system copes with any variation that may occur in the system and acts as an early warning device for management, when possible value opportunities and project work exceeds or drop below the predefined value buffer limits. This value buffer concept ensures the key resource of immediate future work and also helps the organization to plan their future required opportunity arrival rate and their resource scheduling over the two macro processes.

Figure 38, together with the foregoing data and arguments, confirms that the throughput value of an organization decreases as the percentage limited resource commitment to the value acquisition process increases. Throughput value rate can be seen as the total throughput value divided by the total time of the simulation run.

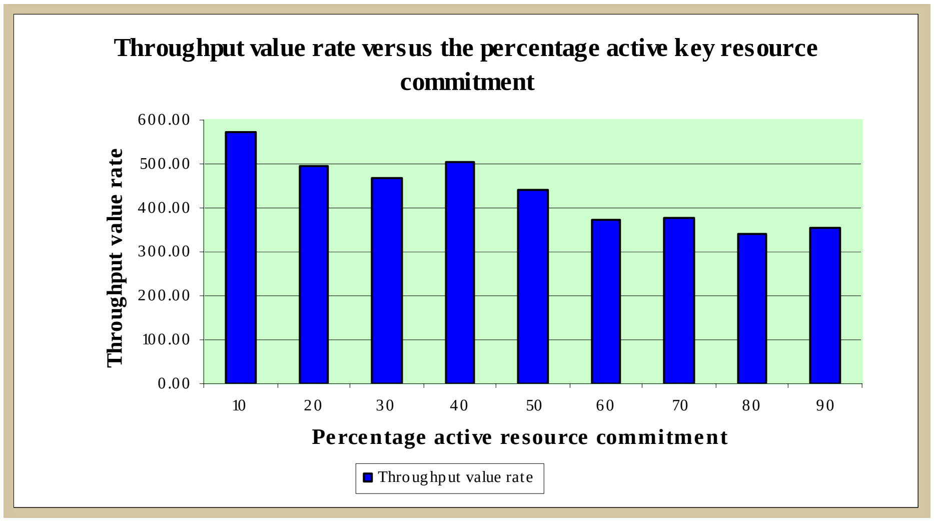

Figure 38: Throughput value rate versus percentage active key resource commitment in the value acquisition process.

The decrease in throughput value rate as the percentage active limited resource participation in the value acquisition phase increases, is a result of the increase of the project lead time. The increase in project lead time is due to the fact that key resources are spending unnecessary time in the value acquisition phase and therefore not pulling the available project work from the final value buffer as soon as possible.

From this section the conclusion can be made that one prerequisite for project-delivery driven organizations to increase their project value, would be to ensure that the organization's constraint (the key resource) is kept internal and to ensure that work is pulled through the system to the work pace of this constraint, which should be situated in the final stages of the value chain.

The organization should therefore ensure that the key resources are working in the value delivery process and only used in the value acquisition process when the need presents itself to acquire more value. The proper management of the value buffers and in particular the final value buffer can help management to estimate this future necessary value acquiring rate.

5.3.2 DIFFERENT FILTER REVIEW MEETING FREQUENCIES

In this section of the chapter, the frequency of the 2nd and 3rd filter review meetings (decision meetings in the value acquisition process) will be changed in increments of one week - from a low frequency of four weeks to a high frequency of one week. This is an important parameter to change due to the fact that the frequency of key events happening upstream from a value buffer play an important role in the time it takes for the value buffer to replenish the lost value.

The change in filter review frequency is done for a very high percentage limited resource participation in the value delivery process. Figure 39 shows the value executed and the value in the final buffer for different filter review meeting frequencies, after the simulation runs were completed.

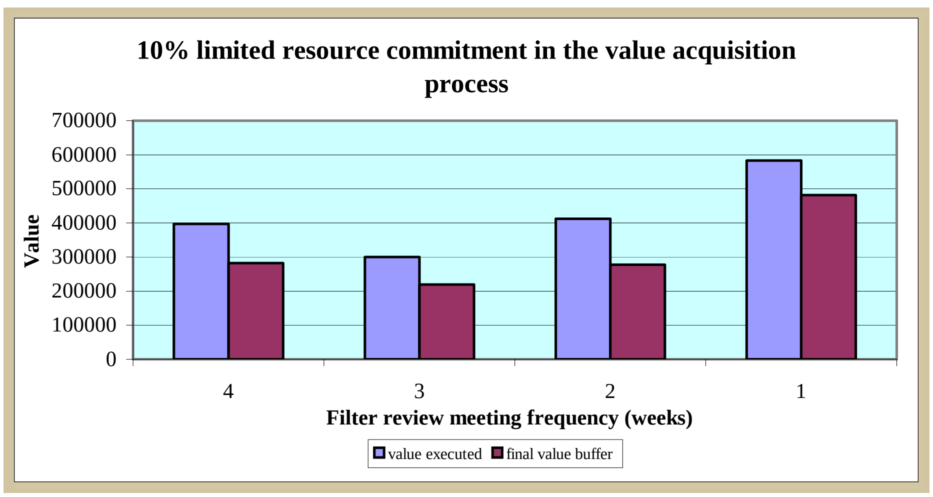

Figure 39: Filter meeting frequency versus value for different percentage resource participation in the value acquisition phase.

Figure 39 shows that as the filter review meeting frequency increases, there is an upward trend for value executed. The value buffer size also slightly increases. It was highlighted in chapter 3 that the sizing of the value buffers would be dependant on, amongst other things, the frequency of key events happening upstream of the value buffers. In this instance, value opportunities are more frequently reviewed, therefore the buffer replenishes its lost value quicker.

Figure 40 shows the percentage difference between the final buffer value and value executed for different filter meeting frequencies. It shows that for a low filter review frequency the percentage difference between final buffer value and the value executed is quite low and that it peaks when the filter review meeting frequency is at its highest.

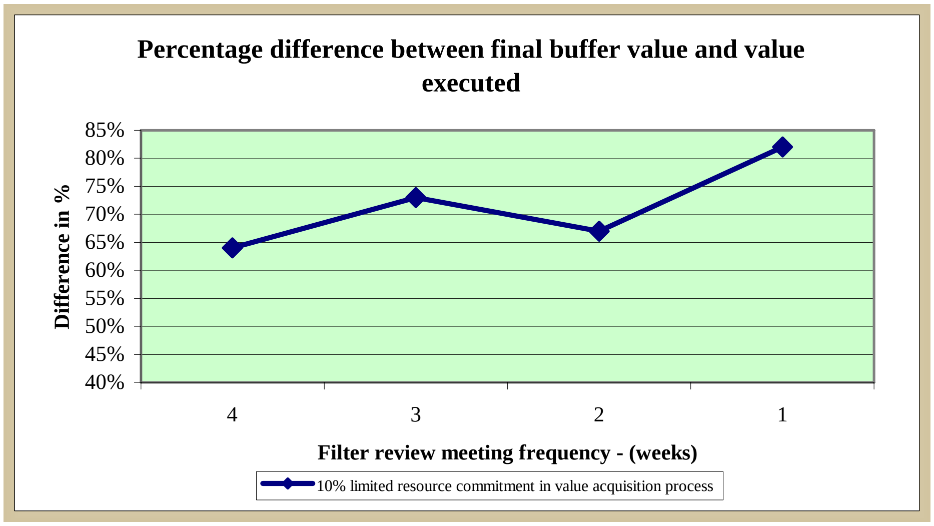

Figure 40: Percentage difference between final buffer value and value executed.

The increase in value executed, as the filter meeting frequency increases, can also be subscribed to the management of the final value buffer level.

Up to date information on the value buffer status provides management with the opportunity to make decisions on relevant value information in the system.

A higher filter review meeting frequency will lead to all the value buffers being kept more up to date with the most recent and relevant project value. Instead of value flowing into a value buffer every four weeks, new value can now possibly flow into the buffer every week (or practically as soon as a project is completed on a particular stage). More up to date information in the value buffers will allow management to make more accurate approximations of what the future value acquiring rate for the organization should be. This in turn should help management to make better estimates on what the future resource commitment and scheduling over the two macro processes should be.

It was also discussed in chapter 3 that the forecasted accuracy of consumption of the value buffers deteriorates with the length of time the maximum consumption of the value buffers have been forecasted.

This concept was highlighted during the discussion of statistical variation in chapter 3. Therefore, reducing the replenishment time of the value buffers will lead to the effect that the maximum forecasted consumption will also be reduced. This in turn will lead to the effect that the value buffer sizes can be smaller, which will result in shorter project lead times.

5.3.3 ACTIVE FINAL VALUE BUFFER SIZING

Changing the value buffer sizes is the last parameter that will be changed to create new scenarios for the simulation model.

The size of the final value buffer has been changed to create two scenarios. A simulation run for a large final value buffer limit and an optimum final value buffer limit (small as possible final value buffer while ensuring available project work for the key resource which is situated in the value delivery process) has been performed. Figure 41 expresses the comparative project lead times for a large final value buffer and optimum value buffer size over the simulation runs.

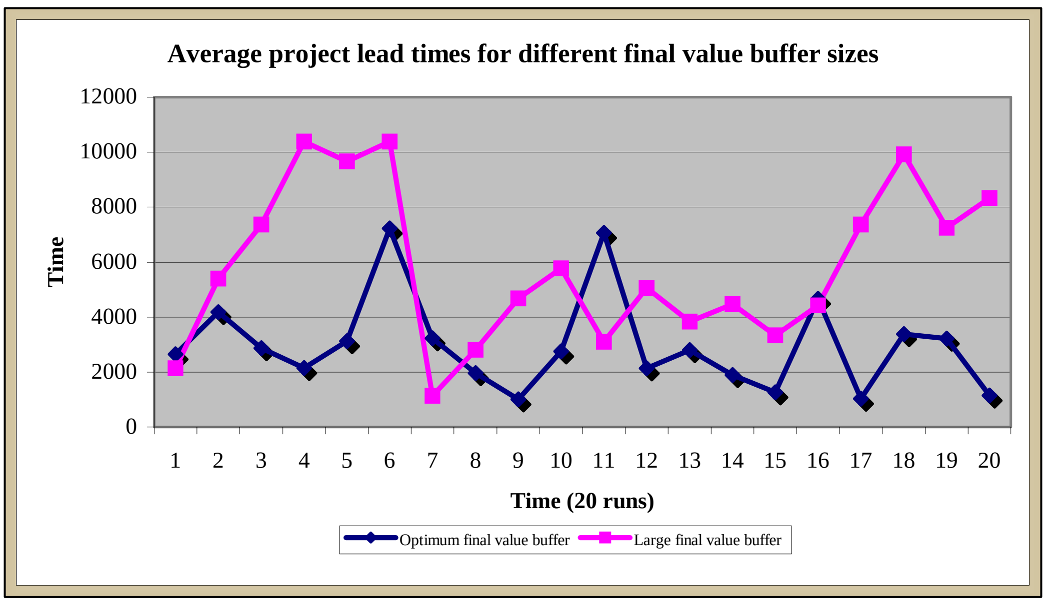

Figure 41: Average project lead times for different final value buffer sizes.

From figure 41 it is evident that the average project lead time decreases dramatically as the final value buffer size decreases. As was discussed in chapter 3, projects will wait in the final value buffer until being "pulled" into the value delivery process by the key resource. In this simulation model the projects waiting in the value buffers are "pulled" from the value buffers on a first-in first-out basis. It therefore explains figure 41, and the fact that as the value buffers get smaller, the shorter the project lead time becomes.

The simulation results for the optimum simulation run with the optimum value buffer size and the simulation run with a larger value buffer is found in Appendix A and B respectively. The status of the optimum value buffer size during a simulation run is shown in figure 42. This value buffer status can be compared to the project lead times for the same simulation run, as shown in figure 43.

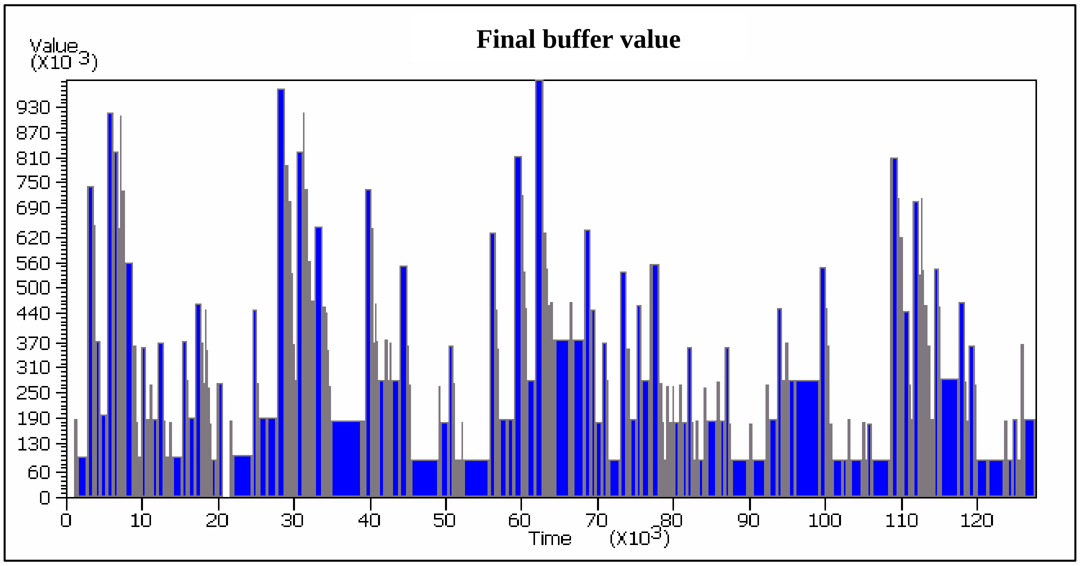

Figure 42: Status of optimum value buffer size during a simulation run.

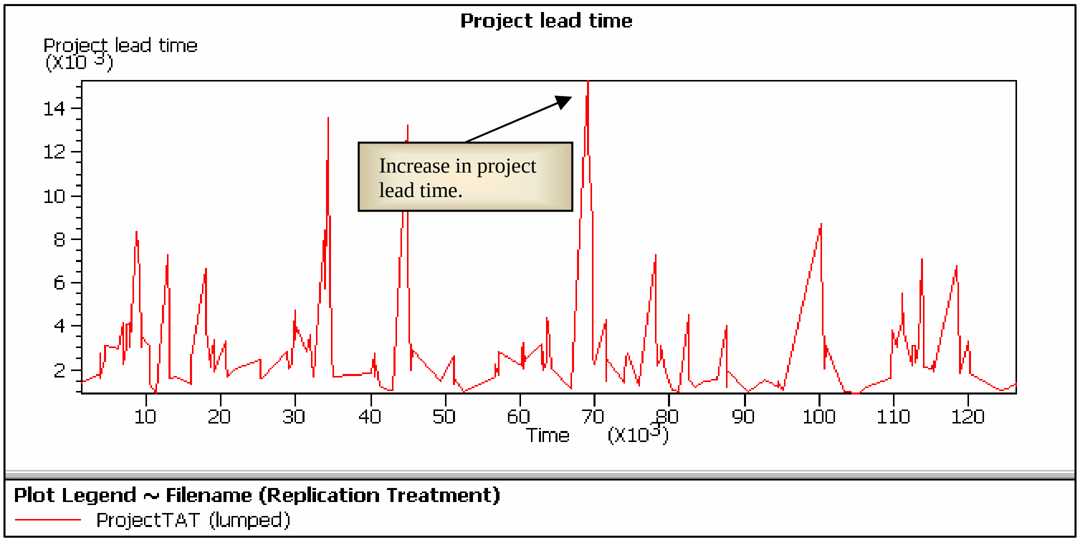

Figure 43: The project lead times during a simulation run for the optimum value buffer size.

The project lead times shown in figure 43 confirm the fact that the project lead time in the project management model is directly related to the value buffer size.

When the value buffer creates a "spike" at approximately 63 000 hours the associated project lead time also increases as shown at approximately 68 000 hours.

5.4 AN OPTIMUM MANAGEMENT SYSTEM

In the previous sections of this chapter, it has been shown that the performance of the proposed management system is sensitive to change in the following parameters:

1. Change in the active key resource participation in the value acquisition and value delivery process.
2. Change in the filter review meeting frequency, which is situated in the value acquisition process.
3. Change in the value buffer size.

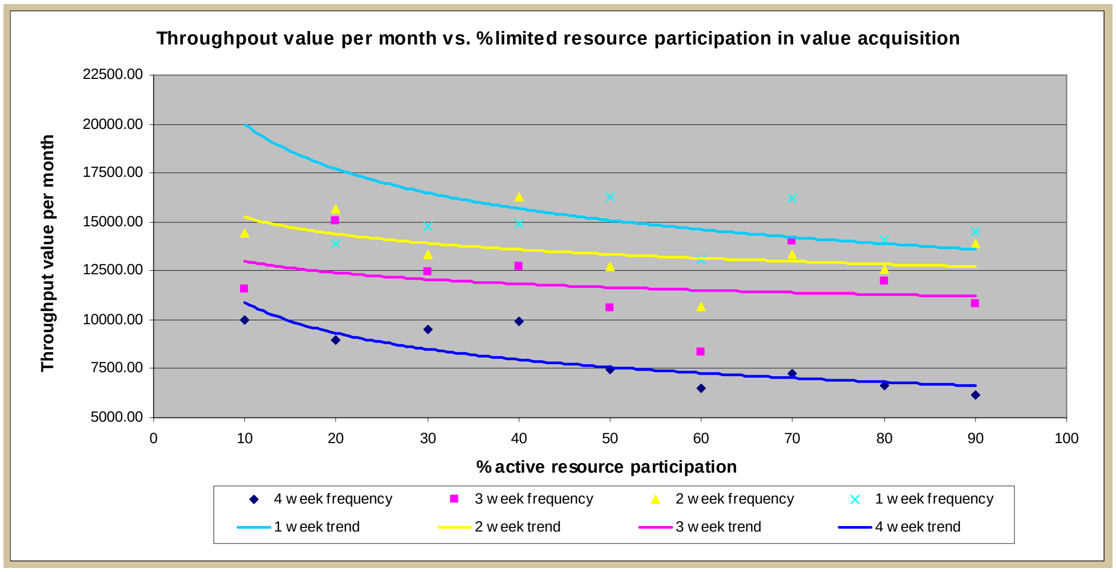

Figure 44: Throughput value rate versus percentage active resource participation.

Figure 44 shows a plot for the percentage active limited resource participation in the value acquisition process versus the throughput value per month for four (four to one week) different filter review meeting frequencies. From figure 44 it is evident that the system parameters need to be as follow for the system to function at its most productive:

1. The key resource should be situated in the last stages of the value chain, in this instance after the final value buffer. This concept was also discussed in chapter 3.
2. The frequency of key events (such as the filter review meetings) upstream of the value buffers should happen as frequently as possible, as events happening upstream of the value buffers play a significant role in the time the value buffer replenishes its lost value.

3. The value buffers are as small as possible. This implies:

- Ensuring that the key resources pulling work from the final value buffer are not starved for work.
- The upper limit of the final buffer has to be of such size that the lead time of projects waiting in the value buffer are kept as short as possible. The sizing of these buffers was discussed in chapter 3.

The optimum system level

Figure 45 shows the utilization of the key resource (development engineer) during an "optimum" run. As can be expected of a drum resource, its utilization is extremely high.

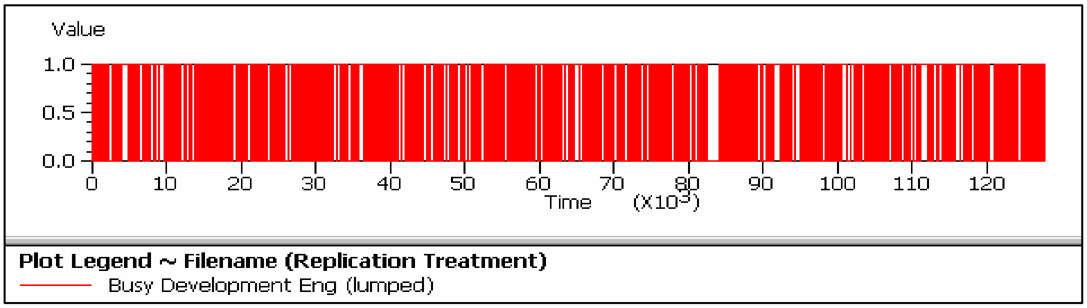

Figure 45: Utilization of the development engineer (drum resource) at an optimum system level.

Figure 46 shows the value in the final value buffer during this simulation run.

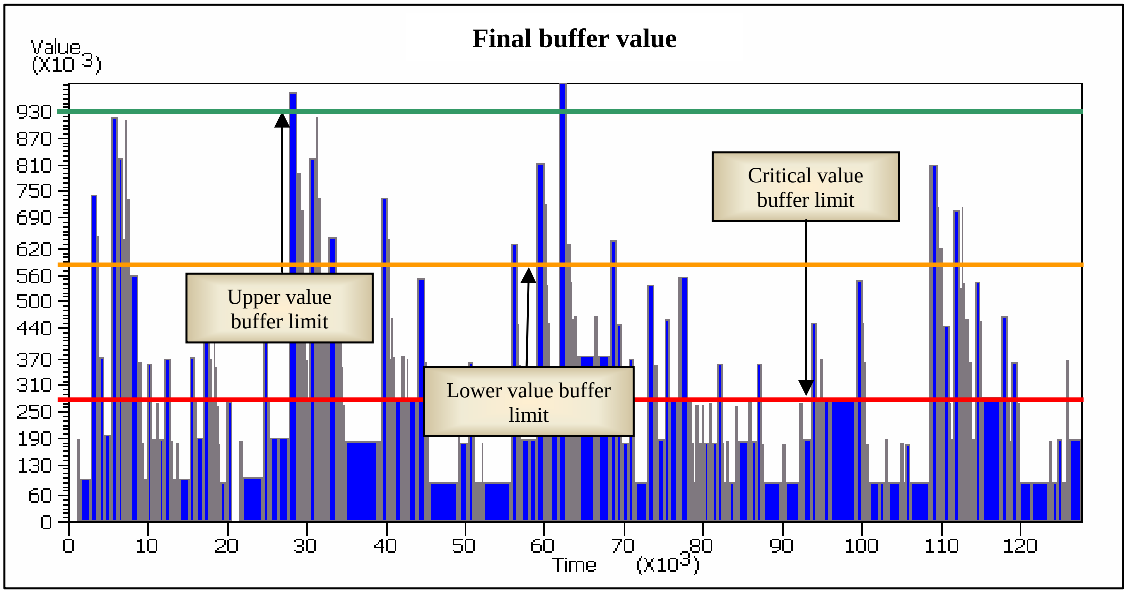

Figure 46: Managing the value in the final buffer in order to achieve optimum system performance.

It is evident that the value in this final value buffer is quite low throughout the simulation run – ensuring project lead times and client response rates are kept as short as possible. The value buffer limits that were used to monitor and manage the value buffer are also indicated.

The results for the optimum simulation run are attached in appendix A.

Now that the results from the simulation have been obtained and analyzed, the EC presented in chapter 1 will be tested. The stated hypothesis will also be scrutinized.

5.5 HYPOTHESIS TESTING

As was highlighted earlier in the study, the proposed management model will be validated if it can be shown that it solves the push problem and could lead to eliminating the negative effects stemming from it and replacing them with the positive effects shown in the FRT presented in chapter 3. In the terminology of the TOC thinking processes, it means that the push don't-push dilemma must be vaporized and that the desired effects must be caused by the proposed project management model.

In chapter 1 the hypothesis was made that it should be possible for project-delivery driven organizations with limited resources to acquire a project management system which will synchronize the flow rate of the value delivery and value acquisition processes in such a way that the organization's value will be maximized in terms of amount and timing.

It was assumed that it would only be possible provided that D–D' or D-B, that are supported by the set of assumptions as shown in the EC, can be invalidated by showing that the proposed injections presented in chapter 3 are indeed invalidating at least one of the assumptions.

5.5.1 VAPOURIZING THE EC BY INDICATING THAT THE PREDICTED EFFECTS AS INIDICATED IN THE FRT ARE INDEED VALID

As a result of the introduction of the injections (discussed throughout this study), three assumptions that supported the necessary conditions and requirement D-D' and D-B in the EC are proven to be invalid, thus vaporizing the EC. The assumptions which are now invalidated are:

1. Push is different to pull – in other words the value acquisition rate is different to the value delivery rate.
2. The work load demanded by the projects is more than the finite capacity can effectively accommodate.
3. Project priorities are set in isolation.

Both the necessary conditions of the EC – to satisfy the demand of the clients and to have a productive system – are still being satisfied as work is pulled through the system from the value buffers that maintain work availability according to the work schedule of the key resources.

The stated hypothesis is therefore true. The management system with the proposed injections therefore provides a valid way to enable the delivery of projects that increase the value of the organization.

Firstly, the assumptions listed above are invalidated, as an organization is now able to leverage its key resources for more value per period of time through using the integrated value acquisition and value delivery system with its strategically placed value buffers. The newly introduced value buffer concept protects the system against variability that may occur and therefore ensures that the key resource always has future work to pull from the final value buffer, consequently increasing the reliability in production. The effect of the foregoing will be that the productivity of the system increases.

Secondly, the value buffers are sized to ensure key resources, which are responsible for work flow in the system, have just enough available project work, taking into account the estimated value buffer consumption and the time for the value buffer to replenish its lost value. The review filters situated before the value buffers enable management to select and prioritize projects before they move into a value buffer, taking into account what is already in the value buffer - ensuring that the correct and right amount of projects are chosen.

As highlighted throughout the study, the management system is based on CC multiple-project scheduling techniques and subordinates the tasks of the other resources around the schedule of the key resource. This implies that the key resource in the organization is selected to serve as a “gate” for project work release from the final value buffer. In other words, the projects will be pulled from the final value buffer into the value delivery process by the key resource. Any new project work will be scheduled to begin in an interval of time where its need for the key resource can be accommodated. CCPM principles and the introduction of the value buffers and the management there-of ensure that projects being added to the portfolio are not seen in isolation but consider the schedules and capacity of the entire organization. As a result, multi-tasking of key resources is reduced to a minimum and project lead times will thus be significantly shorter. Consequently the result will be a higher perception of value from the client, therefore more sales and a higher throughput value for the project.

The introduction of the value buffers will also ensure that project priorities are set and adjusted, before being released from the value buffers – resulting in very few changes when work is conducted.

As a result, project schedules and therefore resource schedules remain valid within the flexibility that is provided by the feeding, project and capacity buffers (which is an integral part of CCMPM). The protection of the project schedules improves the ability to achieve the promised due dates.

The value buffer system proposed, allows for an inimitable way to do global capacity management that has in the past only been done through some kind of aggregate planning in previous management models similar to those presented by Wheelwright and Clark [52] and Cooper [10]. The value buffers protect the system against variability and enable management to estimate the future necessary value opportunity arrival rate. This will provide management with sufficient information to plan the future resource schedules over the two macro processes, ensuring work will be always available in the final value buffer to ensure the key resources, which are responsible for flow in the system, are not starved for work.

5.6 CONCLUSION

In this chapter, simulation runs for different management scenarios have been made; results have been obtained, presented and discussed. The vision for the future and its proposed "injections" to vaporize the Evaporating Cloud (EC), as was presented in the FRT in chapter 3, was simulated to test whether it presents a valid way for organizations with limited resources to synchronize the value acquisition flow rate and the value delivery flow in such a way that value is maximized in terms of amount and timing.

The results obtained showed that three assumptions supporting D-D' and D-B in the EC are invalidated by the proposed injections. The negative effects that stemmed from the push problem are now replaced by the predicted positive effects as was shown in the FRT. The proposed project management model is therefore valid, and consequently provides a positive answer to the third and main research question: *"Is the proposed solution presented in the FRT indeed a valid approach to improve current project management models?"*

In the next chapter only a brief summary of the study with some additional conclusions will be given.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 BACKGROUND

In this chapter final conclusions and recommendations will be made from the findings presented in this study. The implementation process and benefits organizations can reap if the proposed management model is applied to everyday project and opportunity management, will also be briefly discussed.

6.2 RESEARCH RESULTS

In chapter 1 the core management problem for the study was identified by making use of one of the TOC thinking process tools – the Evaporating Cloud. The hypothesis for the research was also established.

In chapter 3 a proposed vision for the future with new injections was presented and discussed through another TOC thinking process tool – the Future Reality Tree (FRT). This FRT was based on the literature presented in chapter 2. The aim of this future vision with the injections, was to invalidate the assumptions supporting the necessary conditions D-D' and also D-B in the EC, and thus vaporizing the EC.

The main goal of the study was to answer the question of whether the proposed vision for the future with its injections is a valid way to vaporize the EC presented in chapter 1.

In chapter 4 and 5, the vision for the future was simulated in Arena 3 and the results were presented and discussed.

The results obtained from the simulation, confirmed that the proposed vision for the future with its proposed injections (as presented and discussed in chapter 3) is indeed a valid way to synchronise the value acquisition rate with the value delivery rate, in such a way that an organizations' value is maximised in terms of amount and timing. The EC was therefore vaporised and the negative effects stemming from it are now replaced by the positive effects as indicated in the FRT.

The hypothesis stated in chapter 1 is therefore true.

6.3 IMPLEMENTATION OF THE PROPOSED MANAGEMENT MODEL

There are two things to be considered with regard to any scheme. In the first place, "Is it good in itself?" In the second, "Can it be easily put into practise?" - Jean-Jacques Rousseau (1712–78), Swiss-born French philosopher.

The implementation of the injection (the stage-gate-buffer management model) will in all likely-hood be a long and costly process.

The implementation could consist of the following set of events or activities:

- Inform employees about the new project management model
- Seek and establish buy-in and commitment from the organization.
- Train employees in the use of the new project management model.
- Bring projects – both new and existing – into the new model.

The implementation phase could be initiated at a meeting where an overview of the process is presented and discussed. At this meeting, management could indicate their commitment to the new management model.

To establish buy-in and commitment from other resources, management could provide internal training sessions and informal discussions around the management model. During these sessions, management should ensure that the management model and the importance of it to the organization, is discussed in detail. Enough reading material regarding the management system should also be freely available within the organization.

Successful implementation of the management model will be dependent on the commitment of the team to the new project management model and their knowledge of the new model.

6.4 THE CONTRIBUTION TO THE PRACTICE

It was shown in chapter 5, that the proposed project management model provides a valid approach to synchronize the value acquisition and value delivery process in such a way that value of an organization will be maximised in terms of amount and timing.

In previous sections of this chapter, it was briefly discussed how organizations could possibly implement the management system.

6.4.1 MAJOR BENEFITS TO ORGANIZATIONS

The major benefits to organizations for implementing and managing the new management system with its unique value buffer concept were highlighted in chapter 5. The core benefits can again be listed as:

1) Increasing the probability of choosing the right amount of projects to be added to the organizations project portfolio taking into account WiP and limited resource availability.
2) Ensuring key resources in the organization always have work for the near future.
3) Providing an imitable way to plan the future scheduling of the key resources over the value acquisition and value delivery process.
4) Organizations can deliver faster on their commitments, therefore increase the throughput value of their projects.

6.6 FUTURE RESEARCH

The research study concludes by proposing a number of research possibilities that became apparent during the development of the management model.

1. In the management model presented in this study, organizations will formally commit themselves to an opportunity after it has been given the "Go" decision at the third filter meeting. This approved project then waits in the final value buffer, until it is pulled into the value delivery process by the key resource. The projects are pulled from the value buffers on a first-in first-out basis. In reality, a first-in first-out basis for projects won't be at the order of the day. This will not happen, as some opportunities carries more "weight" and are more critical to complete than other opportunities. Also, opportunities in the value buffers will need to be prioritized according to their own individual project buffer status. Therefore the need exist to explore a way to prioritize projects within the proposed value buffers, and managing the system in such way.
2. Is there currently a model similar to the one proposed in this study being used in the project portfolio management process of organizations using Critical Chain multi-project management?

6.7 FINAL THOUGHTS

The newly proposed project management model puts discipline into a process. The process is visible, relatively simple and easy to understand. The requirements are clear: for example, what is to be expected of a project team at each stage is spelled out. The management model provides a structure which will allow only high value opportunities to become formal development projects, while at the same time synchronizing the value acquisition rate around the schedule of a constraining resource which is made possible through the introduction of the new value buffer concept. If managed correctly, the value buffer concept ensures that project work is pulled through the system to the work pace of the system's constraint, therefore ensuring fast project delivery, which ultimately results in high value projects.

A final thought to encourage change in current project management models can be drawn from the words of Albert Einstein: "the significant problems we have cannot be solved at the same level of thinking with which we create them."

APPENDIX A

RESULTS FOR THE OPTIMUM SIMULATION RUN

Results - Optimum value buffer.txt

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Warmup Period

Project: Project delivery | Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet | Model revision date: 10/11/2002

Replication ended at time : 1056.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	--	--	--	--	0

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.00000	(Insuf)	.00000	.00000	.00000
Busy Project Manager	.00000	(Insuf)	.00000	.00000	.00000
Manufacturing Eng	.02384	(Insuf)	.00000	1.0000	.00000
Field Service	.00000	(Insuf)	.00000	.00000	.00000
Business Dev	.00000	(Insuf)	.00000	.00000	.00000
Sales Busy	.00000	(Insuf)	.00000	.00000	.00000
Ideas in Final Bucket	.00526	(Insuf)	.00000	2.0000	2.0000
Test Engineer	.00000	(Insuf)	.00000	.00000	.00000
QA Busy	.00000	(Insuf)	.00000	.00000	.00000
Cost Analyst	.00000	(Insuf)	.00000	.00000	.00000
Ideas in Bucket 3	1.5124	(Insuf)	.00000	2.0000	.00000
Ideas in Bucket 2	.02298	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.03718	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	822.66	(Insuf)	.00000	1.8442E+05	1.8442E+05
Divisional Mngr 5	.00663	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	91849.	(Insuf)	.00000	97915.	97915.
Marketing Busy	.04393	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00647	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00745	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00707	(Insuf)	.00000	1.0000	.00000
Construction Eng	.00000	(Insuf)	.00000	.00000	.00000
Variable AK	15.000	(Insuf)	.00000	15.000	15.000
Project Team	.00000	(Insuf)	.00000	.00000	.00000
Divisional Mngr 1	.00724	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	485.36	(Insuf)	.00000	1.8442E+05	1.8442E+05
Variable AL	25.000	(Insuf)	.00000	25.000	25.000
Variable AM	50.000	(Insuf)	.00000	50.000	50.000
Busy Development Eng	.04196	(Insuf)	.00000	1.0000	.00000
Project Engineer	.00000	(Insuf)	.00000	.00000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	0	Infinite
Review2Meetings	0	Infinite
Review1Count	0	Infinite
PrelimCount	0	Infinite
Review1Meetings	0	Infinite
DesignCount	0	Infinite
ValueExecuted	0	Infinite
Ideas	36	Infinite
ExecutedCount	0	Infinite

Results - Optimum value buffer.txt

PointMeetings	35	Infinite
Point1Fail	34	Infinite
Point2Fail	0	Infinite
Stagger1Count	0	Infinite
Point3Fail	0	Infinite
Point1Pass	2	Infinite
Point2Pass	2	Infinite
Point3Pass	2	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 1 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 7392.0
Statistics were cleared at time: 1056.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	2648.7	(Insuf)	1405.4	4155.2	12

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.14362	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.56435	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.30962	(Insuf)	.00000	1.0000	.00000
Field Service	.14362	(Insuf)	.00000	1.0000	.00000
Business Dev	.13258	(Insuf)	.00000	1.0000	.00000
Sales Busy	.14362	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	9.6925	(Insuf)	2.0000	20.000	20.000
Test Engineer	.27620	(Insuf)	.00000	1.0000	.00000
QA Busy	.14362	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.14362	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	4.1270	(Insuf)	.00000	8.0000	.00000
Ideas in Bucket 2	.08698	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.06656	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	5.5850E+05	(Insuf)	1.8442E+05	7.3793E+05	2.6827E+05
Divisional Mngr 5	.00988	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	90689.	(Insuf)	83355.	1.8621E+05	92201.
Marketing Busy	.34131	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00952	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00998	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.01092	(Insuf)	.00000	1.0000	.00000
Construction Eng	.14362	(Insuf)	.00000	1.0000	.00000
Variable AK	15.281	(Insuf)	12.860	18.626	18.626
Project Team	.12981	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00969	(Insuf)	.00000	1.0000	1.0000
Value Final Bucket	4.8750E+05	(Insuf)	97915.	9.1608E+05	7.2994E+05
Variable AL	25.469	(Insuf)	21.434	31.043	31.043
Variable AM	50.939	(Insuf)	42.868	62.086	62.086
Busy Development Eng	.47184	(Insuf)	.00000	1.0000	.00000
Project Engineer	.14362	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit

Stagger2Counter	12	Infinite
Review2Meetings	204	Infinite
Review1Count	19	Infinite
PrelimCount	14	Infinite
Review1Meetings	212	Infinite
DesignCount	14	Infinite
ValueExecuted	1086017	Infinite
Ideas	209	Infinite
ExecutedCount	12	Infinite
PointMeetings	217	Infinite
Point1Fail	179	Infinite
Point2Fail	11	Infinite
Stagger1Count	14	Infinite
Point3Fail	1	Infinite
Point1Pass	30	Infinite
Point2Pass	19	Infinite
Point3Pass	18	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 2 of 20

Project: Project delivery Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet Model revision date: 10/11/2002

Replication ended at time : 13728.0
Statistics were cleared at time: 7392.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	4184.1	(Insuf)	934.72	8308.9	13

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.11916	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.60501	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.24660	(Insuf)	.00000	1.0000	.00000
Field Service	.11916	(Insuf)	.00000	1.0000	.00000
Business Dev	.11048	(Insuf)	.00000	1.0000	.00000
Sales Busy	.11916	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	22.809	(Insuf)	20.000	27.000	27.000
Test Engineer	.22964	(Insuf)	.00000	1.0000	.00000
QA Busy	.11916	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.11916	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	1.4819	(Insuf)	.00000	4.0000	1.0000
Ideas in Bucket 2	.04026	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.02977	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.3040E+05	(Insuf)	82639.	3.5620E+05	1.7452E+05
Divisional Mngr 5	.00555	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	87232.	(Insuf)	82639.	95288.	89878.
Marketing Busy	.26493	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00631	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00618	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00589	(Insuf)	.00000	1.0000	.00000
Construction Eng	.11916	(Insuf)	.00000	1.0000	.00000
Variable AK	23.379	(Insuf)	18.626	27.597	24.906

Results - Optimum value buffer.txt

Project Team	.10696	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 1	.00663	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	3.2722E+05	(Insuf)	95188.	7.2994E+05	1.8002E+05
Variable AL	38.966	(Insuf)	31.043	45.996	41.511
Variable AM	77.932	(Insuf)	62.086	91.992	83.023
Busy Development Eng	.50663	(Insuf)	.00000	1.0000	.00000
Project Engineer	.11916	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	13	Infinite
Review2Meetings	214	Infinite
Review1Count	8	Infinite
PrelimCount	12	Infinite
Review1Meetings	212	Infinite
DesignCount	12	Infinite
ValueExecuted	1162833	Infinite
Ideas	139	Infinite
ExecutedCount	13	Infinite
PointMeetings	208	Infinite
Point1Fail	124	Infinite
Point2Fail	5	Infinite
Stagger1Count	12	Infinite
Point3Fail	2	Infinite
Point1Pass	15	Infinite
Point2Pass	10	Infinite
Point3Pass	7	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 3 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 20064.0
Statistics were cleared at time: 13728.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	2865.3	(Insuf)	1340.4	6622.6	9

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.08770	(Insuf)	.00000	1.0000	1.0000
Busy Project Manager	.46153	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.20639	(Insuf)	.00000	1.0000	1.0000
Field Service	.08770	(Insuf)	.00000	1.0000	1.0000
Business Dev	.10101	(Insuf)	.00000	1.0000	.00000
Sales Busy	.08770	(Insuf)	.00000	1.0000	1.0000
Ideas in Final Bucket	31.306	(Insuf)	27.000	37.000	37.000
Test Engineer	.18871	(Insuf)	.00000	1.0000	1.0000
QA Busy	.08770	(Insuf)	.00000	1.0000	1.0000
Cost Analyst	.08770	(Insuf)	.00000	1.0000	1.0000
Ideas in Bucket 3	1.6159	(Insuf)	.00000	3.0000	1.0000
Ideas in Bucket 2	.04167	(Insuf)	.00000	2.0000	.00000

Results - Optimum value buffer.txt

# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.03490	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.2463E+05	(Insuf)	1.7452E+05	2.7573E+05	1.8197E+05
Divisional Mngr 5	.00591	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	99562.	(Insuf)	82291.	1.7162E+05	82291.
Marketing Busy	.22229	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.00726	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00792	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00667	(Insuf)	.00000	1.0000	.00000
Construction Eng	.08770	(Insuf)	.00000	1.0000	1.0000
Variable AK	22.126	(Insuf)	19.272	25.287	22.222
Project Team	.07922	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00689	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	2.4582E+05	(Insuf)	90884.	4.6316E+05	2.7285E+05
Variable AL	36.876	(Insuf)	32.120	42.145	37.037
Variable AM	73.753	(Insuf)	64.241	84.290	74.075
Busy Development Eng	.39896	(Insuf)	.00000	1.0000	.00000
Project Engineer	.08770	(Insuf)	.00000	1.0000	1.0000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	9	Infinite
Review2Meetings	213	Infinite
Review1Count	10	Infinite
PrelimCount	11	Infinite
Review1Meetings	208	Infinite
DesignCount	8	Infinite
ValueExecuted	813837	Infinite
Ideas	149	Infinite
ExecutedCount	9	Infinite
PointMeetings	210	Infinite
Point1Fail	129	Infinite
Point2Fail	10	Infinite
Stagger1Count	11	Infinite
Point3Fail	0	Infinite
Point1Pass	20	Infinite
Point2Pass	10	Infinite
Point3Pass	10	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 4 of 20

Project: Project delivery   Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet   Model revision date: 10/11/2002

Replication ended at time : 26400.0
Statistics were cleared at time: 20064.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	2146.9	(Insuf)	1577.2	3315.6	7

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.05829	(Insuf)	.00000	1.0000	.00000

Results - Optimum value buffer.txt

Busy Project Manager	.28202	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.11704	(Insuf)	.00000	1.0000	.00000
Field Service	.05829	(Insuf)	.00000	1.0000	.00000
Business Dev	.03472	(Insuf)	.00000	1.0000	.00000
Sales Busy	.05829	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	39.707	(Insuf)	37.000	43.000	43.000
Test Engineer	.09302	(Insuf)	.00000	1.0000	.00000
QA Busy	.05829	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.05829	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	1.9836	(Insuf)	.00000	6.0000	6.0000
Ideas in Bucket 2	.08507	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.04503	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	3.0156E+05	(Insuf)	1.8197E+05	4.3895E+05	4.3895E+05
Divisional Mngr 5	.01035	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	89717.	(Insuf)	82291.	99111.	84470.
Marketing Busy	.13192	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.00879	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00966	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.01068	(Insuf)	.00000	1.0000	.00000
Construction Eng	.05829	(Insuf)	.00000	1.0000	.00000
Variable AK	16.715	(Insuf)	11.670	23.931	12.882
Project Team	.06383	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.01068	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	1.6825E+05	(Insuf)	5.2387E-10	4.4616E+05	1.8796E+05
Variable AL	27.859	(Insuf)	19.451	39.885	21.470
Variable AM	55.719	(Insuf)	38.902	79.771	42.940
Busy Development Eng	.25171	(Insuf)	.00000	1.0000	.00000
Project Engineer	.05829	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	7	Infinite
Review2Meetings	212	Infinite
Review1Count	6	Infinite
PrelimCount	4	Infinite
Review1Meetings	209	Infinite
DesignCount	7	Infinite
ValueExecuted	613341	Infinite
Ideas	198	Infinite
ExecutedCount	7	Infinite
PointMeetings	212	Infinite
Point1Fail	168	Infinite
Point2Fail	17	Infinite
Stagger1Count	4	Infinite
Point3Fail	2	Infinite
Point1Pass	30	Infinite
Point2Pass	13	Infinite
Point3Pass	6	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 5 of 20

Project: Project delivery　　Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet　　Model revision date: 10/11/2002

Replication ended at time : 32736.0
Statistics were cleared at time: 26400.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Results - Optimum value buffer.txt

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	3128.5	(Insuf)	1687.9	4730.3	13

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.13968	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.61513	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.29435	(Insuf)	.00000	1.0000	.00000
Field Service	.13968	(Insuf)	.00000	1.0000	.00000
Business Dev	.12942	(Insuf)	.00000	1.0000	.00000
Sales Busy	.13968	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	52.542	(Insuf)	43.000	59.000	59.000
Test Engineer	.26910	(Insuf)	.00000	1.0000	.00000
QA Busy	.13968	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.13968	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	3.7885	(Insuf)	.00000	9.0000	3.0000
Ideas in Bucket 2	.05415	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.05451	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	5.1663E+05	(Insuf)	94950.	7.8468E+05	94950.
Divisional Mngr 5	.00854	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	89112.	(Insuf)	80247.	98083.	80247.
Marketing Busy	.32403	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00865	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00890	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00765	(Insuf)	.00000	1.0000	.00000
Construction Eng	.13968	(Insuf)	.00000	1.0000	.00000
Variable AK	16.030	(Insuf)	12.882	21.636	21.636
Project Team	.13337	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00820	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	6.1883E+05	(Insuf)	1.8796E+05	9.7264E+05	4.6769E+05
Variable AL	26.717	(Insuf)	21.470	36.061	36.061
Variable AM	53.435	(Insuf)	42.940	72.122	72.122
Busy Development Eng	.50723	(Insuf)	.00000	1.0000	.00000
Project Engineer	.13968	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	13	Infinite
Review2Meetings	212	Infinite
Review1Count	16	Infinite
PrelimCount	14	Infinite
Review1Meetings	210	Infinite
DesignCount	14	Infinite
ValueExecuted	1141106	Infinite
Ideas	201	Infinite
ExecutedCount	13	Infinite
PointMeetings	210	Infinite
Point1Fail	179	Infinite
Point2Fail	9	Infinite
Stagger1Count	14	Infinite
Point3Fail	0	Infinite
Point1Pass	22	Infinite
Point2Pass	13	Infinite
Point3Pass	16	Infinite

Results - Optimum value buffer.txt
Summary for Replication 6 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 39072.0
Statistics were cleared at time: 32736.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	7220.4	(Insuf)	1713.0	13610.	6

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.04972	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.32139	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.11177	(Insuf)	.00000	1.0000	.00000
Field Service	.04972	(Insuf)	.00000	1.0000	.00000
Business Dev	.04735	(Insuf)	.00000	1.0000	.00000
Sales Busy	.04972	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	61.757	(Insuf)	59.000	62.000	62.000
Test Engineer	.09706	(Insuf)	.00000	1.0000	.00000
QA Busy	.04972	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.04972	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	.97620	(Insuf)	.00000	6.0000	6.0000
Ideas in Bucket 2	.04920	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.02362	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	1.2648E+05	(Insuf)	84321.	2.5780E+05	89963.
Divisional Mngr 5	.00653	(Insuf)	.00000	1.0000	1.0000
Value Bucket 2	90050.	(Insuf)	80247.	98709.	85883.
Marketing Busy	.12332	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00577	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 3	.00576	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 2	.00698	(Insuf)	.00000	1.0000	1.0000
Construction Eng	.04972	(Insuf)	.00000	1.0000	.00000
Variable AK	26.048	(Insuf)	21.636	27.021	27.021
Project Team	.05932	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00528	(Insuf)	.00000	1.0000	1.0000
Value Final Bucket	3.0167E+05	(Insuf)	1.8173E+05	6.4524E+05	1.8173E+05
Variable AL	43.414	(Insuf)	36.061	45.035	45.035
Variable AM	86.829	(Insuf)	72.122	90.071	90.071
Busy Development Eng	.27771	(Insuf)	.00000	1.0000	.00000
Project Engineer	.04972	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	6	Infinite
Review2Meetings	213	Infinite
Review1Count	3	Infinite
PrelimCount	6	Infinite
Review1Meetings	209	Infinite
DesignCount	6	Infinite
ValueExecuted	547831	Infinite
Ideas	122	Infinite
ExecutedCount	6	Infinite
PointMeetings	215	Infinite
Point1Fail	104	Infinite

Results - Optimum value buffer.txt

Point2Fail	9	Infinite
Stagger1Count	6	Infinite
Point3Fail	2	Infinite
Point1Pass	18	Infinite
Point2Pass	8	Infinite
Point3Pass	3	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 7 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 45408.0
Statistics were cleared at time: 39072.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	3231.4	(Insuf)	1012.5	13270.	12

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.12153	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.53199	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.24550	(Insuf)	.00000	1.0000	.00000
Field Service	.12153	(Insuf)	.00000	1.0000	.00000
Business Dev	.11364	(Insuf)	.00000	1.0000	.00000
Sales Busy	.12153	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	70.020	(Insuf)	62.000	74.000	74.000
Test Engineer	.23516	(Insuf)	.00000	1.0000	.00000
QA Busy	.12153	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.12153	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	1.1356	(Insuf)	.00000	6.0000	.00000
Ideas in Bucket 2	.04623	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.02425	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.1611E+05	(Insuf)	88201.	5.5193E+05	2.7098E+05
Divisional Mngr 5	.00569	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	91878.	(Insuf)	85883.	97389.	90998.
Marketing Busy	.26057	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00515	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00594	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00586	(Insuf)	.00000	1.0000	.00000
Construction Eng	.12153	(Insuf)	.00000	1.0000	.00000
Variable AK	36.566	(Insuf)	27.021	50.096	50.096
Project Team	.12814	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00553	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	4.1183E+05	(Insuf)	1.7812E+05	7.3366E+05	1.7812E+05
Variable AL	60.943	(Insuf)	45.035	83.493	83.493
Variable AM	121.88	(Insuf)	90.071	166.98	166.98
Busy Development Eng	.40005	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.12153	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit

Results - Optimum value buffer.txt

Stagger2Counter	13	Infinite
Review2Meetings	210	Infinite
Review1Count	12	Infinite
PrelimCount	13	Infinite
Review1Meetings	208	Infinite
DesignCount	13	Infinite
ValueExecuted	1105932	Infinite
Ideas	89	Infinite
ExecutedCount	12	Infinite
PointMeetings	209	Infinite
Point1Fail	73	Infinite
Point2Fail	11	Infinite
Stagger1Count	13	Infinite
Point3Fail	0	Infinite
Point1Pass	16	Infinite
Point2Pass	6	Infinite
Point3Pass	12	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 8 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 51744.0
Statistics were cleared at time: 45408.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	1967.0	(Insuf)	1296.5	2895.1	5

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.04104	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.14289	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.09131	(Insuf)	.00000	1.0000	.00000
Field Service	.04104	(Insuf)	.00000	1.0000	.00000
Business Dev	.03788	(Insuf)	.00000	1.0000	.00000
Sales Busy	.04104	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	75.226	(Insuf)	74.000	78.000	78.000
Test Engineer	.07891	(Insuf)	.00000	1.0000	.00000
QA Busy	.04104	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.04104	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	.63529	(Insuf)	.00000	2.0000	1.0000
Ideas in Bucket 2	.04010	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.01921	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	1.4425E+05	(Insuf)	88303.	2.7098E+05	1.8201E+05
Divisional Mngr 5	.00469	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	89674.	(Insuf)	82823.	95720.	92751.
Marketing Busy	.09879	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00551	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00589	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00523	(Insuf)	.00000	1.0000	.00000
Construction Eng	.04104	(Insuf)	.00000	1.0000	.00000
Variable AK	30.567	(Insuf)	23.120	50.096	23.120
Project Team	.03165	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00520	(Insuf)	.00000	1.0000	.00000

Results - Optimum value buffer.txt

Value Final Bucket	1.4466E+05	(Insuf)	89747.	3.6101E+05	89747.
Variable AL	50.946	(Insuf)	38.534	83.493	38.534
Variable AM	101.89	(Insuf)	77.069	166.98	77.069
Busy Development Eng	.12441	(Insuf)	.00000	1.0000	.00000
Project Engineer	.04104	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	4	Infinite
Review2Meetings	212	Infinite
Review1Count	4	Infinite
PrelimCount	4	Infinite
Review1Meetings	213	Infinite
DesignCount	4	Infinite
ValueExecuted	445178	Infinite
Ideas	107	Infinite
ExecutedCount	5	Infinite
PointMeetings	214	Infinite
Point1Fail	90	Infinite
Point2Fail	11	Infinite
Stagger1Count	4	Infinite
Point3Fail	1	Infinite
Point1Pass	17	Infinite
Point2Pass	6	Infinite
Point3Pass	4	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 9 of 20

Project: Project delivery Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet Model revision date: 10/11/2002

Replication ended at time : 58080.0
Statistics were cleared at time: 51744.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	1910.1	(Insuf)	1005.0	2830.8	6

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.04972	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.21096	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.12335	(Insuf)	.00000	1.0000	1.0000
Field Service	.04972	(Insuf)	.00000	1.0000	.00000
Business Dev	.04735	(Insuf)	.00000	1.0000	.00000
Sales Busy	.04972	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	81.063	(Insuf)	78.000	85.000	85.000
Test Engineer	.09706	(Insuf)	.00000	1.0000	.00000
QA Busy	.04972	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.04972	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	2.7755	(Insuf)	.00000	8.0000	8.0000
Ideas in Bucket 2	.05116	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.04821	(Insuf)	.00000	1.0000	.00000

Results - Optimum value buffer.txt

Value Bucket 3	2.8408E+05	(Insuf)	89108.	6.2880E+05	6.2880E+05
Divisional Mngr 5	.00992	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	1.0354E+05	(Insuf)	80689.	1.8722E+05	93228.
Marketing Busy	.14862	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.01025	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00944	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00993	(Insuf)	.00000	1.0000	.00000
Construction Eng	.04972	(Insuf)	.00000	1.0000	.00000
Variable AK	14.969	(Insuf)	10.711	23.120	12.119
Project Team	.05061	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00899	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	2.0198E+05	(Insuf)	89747.	6.3162E+05	1.8500E+05
Variable AL	24.948	(Insuf)	17.852	38.534	20.198
Variable AM	49.897	(Insuf)	35.705	77.069	40.397
Busy Development Eng	.19803	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.04972	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	6	Infinite
Review2Meetings	210	Infinite
Review1Count	7	Infinite
PrelimCount	6	Infinite
Review1Meetings	211	Infinite
DesignCount	6	Infinite
ValueExecuted	535724	Infinite
Ideas	226	Infinite
ExecutedCount	6	Infinite
PointMeetings	214	Infinite
Point1Fail	203	Infinite
Point2Fail	8	Infinite
Stagger1Count	6	Infinite
Point3Fail	1	Infinite
Point1Pass	23	Infinite
Point2Pass	15	Infinite
Point3Pass	7	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 10 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 64416.0
Statistics were cleared at time: 58080.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	2750.9	(Insuf)	1985.1	4410.0	14

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.12390	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.60552	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.26677	(Insuf)	.00000	1.0000	.00000

Results - Optimum value buffer.txt

Field Service	.12390	(Insuf)	.00000	1.0000	.00000
Business Dev	.11679	(Insuf)	.00000	1.0000	.00000
Sales Busy	.12390	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	94.441	(Insuf)	85.000	101.00	101.00
Test Engineer	.24069	(Insuf)	.00000	1.0000	.00000
QA Busy	.12390	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.12390	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	3.7136	(Insuf)	.00000	12.000	1.0000
Ideas in Bucket 2	.06062	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.05802	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	7.9606E+05	(Insuf)	90963.	1.0907E+06	90963.
Divisional Mngr 5	.01012	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	98076.	(Insuf)	83148.	1.8123E+05	90677.
Marketing Busy	.29574	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.00941	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.01018	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.01032	(Insuf)	.00000	1.0000	.00000
Construction Eng	.12390	(Insuf)	.00000	1.0000	.00000
Variable AK	15.739	(Insuf)	12.119	21.385	21.385
Project Team	.13340	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.01058	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	5.7629E+05	(Insuf)	1.8500E+05	9.9489E+05	3.7465E+05
Variable AL	26.233	(Insuf)	20.198	35.642	35.642
Variable AM	52.466	(Insuf)	40.397	71.285	71.285
Busy Development Eng	.49794	(Insuf)	.00000	1.0000	.00000
Project Engineer	.12390	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	14	Infinite
Review2Meetings	213	Infinite
Review1Count	16	Infinite
PrelimCount	14	Infinite
Review1Meetings	212	Infinite
DesignCount	14	Infinite
ValueExecuted	1243614	Infinite
Ideas	210	Infinite
ExecutedCount	14	Infinite
PointMeetings	210	Infinite
Point1Fail	184	Infinite
Point2Fail	12	Infinite
Stagger1Count	14	Infinite
Point3Fail	5	Infinite
Point1Pass	26	Infinite
Point2Pass	14	Infinite
Point3Pass	16	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 11 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 70752.0
Statistics were cleared at time: 64416.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations

ProjectTAT	7062.9	(Insuf)	1109.1	15290.	6

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.05366	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.31206	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.13477	(Insuf)	.00000	1.0000	1.0000
Field Service	.05366	(Insuf)	.00000	1.0000	.00000
Business Dev	.06634	(Insuf)	.00000	1.0000	1.0000
Sales Busy	.05366	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	102.92	(Insuf)	101.00	107.00	107.00
Test Engineer	.12000	(Insuf)	.00000	1.0000	1.0000
QA Busy	.05366	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.05366	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	1.3070	(Insuf)	.00000	3.0000	.00000
Ideas in Bucket 2	.05366	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.02930	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	1.5974E+05	(Insuf)	90677.	2.8391E+05	2.8391E+05
Divisional Mngr 5	.00571	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	88335.	(Insuf)	83090.	99452.	85412.
Marketing Busy	.15044	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.00605	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00618	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00547	(Insuf)	.00000	1.0000	.00000
Construction Eng	.05366	(Insuf)	.00000	1.0000	.00000
Variable AK	29.880	(Insuf)	21.385	37.737	37.737
Project Team	.05593	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00670	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	3.9864E+05	(Insuf)	1.7909E+05	6.3682E+05	3.6998E+05
Variable AL	49.801	(Insuf)	35.642	62.895	62.895
Variable AM	99.602	(Insuf)	71.285	125.79	125.79
Busy Development Eng	.27323	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.05366	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	6	Infinite
Review2Meetings	213	Infinite
Review1Count	6	Infinite
PrelimCount	7	Infinite
Review1Meetings	210	Infinite
DesignCount	6	Infinite
ValueExecuted	548618	Infinite
Ideas	109	Infinite
ExecutedCount	6	Infinite
PointMeetings	209	Infinite
Point1Fail	90	Infinite
Point2Fail	11	Infinite
Stagger1Count	9	Infinite
Point3Fail	3	Infinite
Point1Pass	19	Infinite
Point2Pass	8	Infinite
Point3Pass	6	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 12 of 20

Results - Optimum value buffer.txt

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 77088.0
Statistics were cleared at time: 70752.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	2141.2	(Insuf)	1271.1	4329.9	9

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.08838	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.42181	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.20382	(Insuf)	.00000	1.0000	1.0000
Field Service	.08838	(Insuf)	.00000	1.0000	.00000
Business Dev	.09516	(Insuf)	.00000	1.0000	1.0000
Sales Busy	.08838	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	111.17	(Insuf)	107.00	118.00	118.00
Test Engineer	.18355	(Insuf)	.00000	1.0000	1.0000
QA Busy	.08838	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.08838	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	1.7844	(Insuf)	.00000	5.0000	.00000
Ideas in Bucket 2	.05823	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.03854	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	3.3281E+05	(Insuf)	2.7351E+05	4.4621E+05	2.7511E+05
Divisional Mngr 5	.00660	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	91849.	(Insuf)	83907.	97269.	97269.
Marketing Busy	.22338	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.00619	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00513	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00510	(Insuf)	.00000	1.0000	.00000
Construction Eng	.08838	(Insuf)	.00000	1.0000	.00000
Variable AK	35.513	(Insuf)	29.873	41.181	41.181
Project Team	.09085	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00583	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	2.9342E+05	(Insuf)	89747.	5.5520E+05	5.5520E+05
Variable AL	59.188	(Insuf)	49.789	68.635	68.635
Variable AM	118.37	(Insuf)	99.578	137.27	137.27
Busy Development Eng	.35270	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.08838	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	9	Infinite
Review2Meetings	211	Infinite
Review1Count	11	Infinite
PrelimCount	10	Infinite
Review1Meetings	210	Infinite
DesignCount	9	Infinite
ValueExecuted	809610	Infinite
Ideas	89	Infinite
ExecutedCount	9	Infinite
PointMeetings	212	Infinite
Point1Fail	70	Infinite
Point2Fail	8	Infinite
Stagger1Count	10	Infinite

Results - Optimum value buffer.txt

Point3Fail	0	Infinite
Point1Pass	19	Infinite
Point2Pass	11	Infinite
Point3Pass	11	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 13 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 83424.0
Statistics were cleared at time: 77088.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	2796.1	(Insuf)	982.22	7285.4	11

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.11521	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.54328	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.20678	(Insuf)	.00000	1.0000	.00000
Field Service	.11521	(Insuf)	.00000	1.0000	.00000
Business Dev	.07840	(Insuf)	.00000	1.0000	.00000
Sales Busy	.11521	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	120.90	(Insuf)	118.00	125.00	125.00
Test Engineer	.19361	(Insuf)	.00000	1.0000	.00000
QA Busy	.11521	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.11521	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	.96317	(Insuf)	.00000	2.0000	1.0000
Ideas in Bucket 2	.01545	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.02902	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	1.7348E+05	(Insuf)	88245.	2.7511E+05	92684.
Divisional Mngr 5	.00337	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	89286.	(Insuf)	80599.	97269.	80599.
Marketing Busy	.22076	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00306	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00359	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00403	(Insuf)	.00000	1.0000	.00000
Construction Eng	.11521	(Insuf)	.00000	1.0000	.00000
Variable AK	50.349	(Insuf)	41.181	58.076	55.172
Project Team	.12603	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00337	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	2.8389E+05	(Insuf)	89747.	5.5520E+05	1.8243E+05
Variable AL	83.915	(Insuf)	68.635	96.794	91.954
Variable AM	167.83	(Insuf)	137.27	193.58	183.90
Busy Development Eng	.42530	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.11521	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	12	Infinite
Review2Meetings	210	Infinite

Results - Optimum value buffer.txt

Review1Count	7	Infinite
PrelimCount	10	Infinite
Review1Meetings	210	Infinite
DesignCount	12	Infinite
ValueExecuted	998337	Infinite
Ideas	66	Infinite
ExecutedCount	11	Infinite
PointMeetings	214	Infinite
Point1Fail	56	Infinite
Point2Fail	2	Infinite
Stagger1Count	8	Infinite
Point3Fail	0	Infinite
Point1Pass	10	Infinite
Point2Pass	8	Infinite
Point3Pass	7	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 14 of 20

Project: Project delivery　　Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet　　Model revision date: 10/11/2002

Replication ended at time : 89760.0
Statistics were cleared at time: 83424.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	1898.1	(Insuf)	1184.8	4034.4	6

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.03946	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.20217	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.08784	(Insuf)	.00000	1.0000	.00000
Field Service	.03946	(Insuf)	.00000	1.0000	.00000
Business Dev	.03788	(Insuf)	.00000	1.0000	.00000
Sales Busy	.03946	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	128.32	(Insuf)	125.00	130.00	130.00
Test Engineer	.07734	(Insuf)	.00000	1.0000	.00000
QA Busy	.03946	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.03946	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	.73359	(Insuf)	.00000	2.0000	1.0000
Ideas in Bucket 2	.01531	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.01796	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	1.6754E+05	(Insuf)	92684.	1.8130E+05	1.7601E+05
Divisional Mngr 5	.00376	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	90952.	(Insuf)	80599.	95872.	85824.
Marketing Busy	.09745	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00252	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00320	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00221	(Insuf)	.00000	1.0000	.00000
Construction Eng	.03946	(Insuf)	.00000	1.0000	.00000
Variable AK	48.946	(Insuf)	36.393	55.172	36.393
Project Team	.04784	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00295	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	1.7251E+05	(Insuf)	89747.	3.5695E+05	89747.
Variable AL	81.577	(Insuf)	60.656	91.954	60.656

Results - Optimum value buffer.txt

Variable AM	163.15	(Insuf)	121.31	183.90	121.31
Busy Development Eng	.16440	(Insuf)	.00000	1.0000	.00000
Project Engineer	.03946	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	5	Infinite
Review2Meetings	215	Infinite
Review1Count	5	Infinite
PrelimCount	5	Infinite
Review1Meetings	211	Infinite
DesignCount	5	Infinite
ValueExecuted	536120	Infinite
Ideas	68	Infinite
ExecutedCount	6	Infinite
PointMeetings	210	Infinite
Point1Fail	60	Infinite
Point2Fail	2	Infinite
Stagger1Count	5	Infinite
Point3Fail	1	Infinite
Point1Pass	8	Infinite
Point2Pass	6	Infinite
Point3Pass	5	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 15 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 96096.0
Statistics were cleared at time: 89760.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	1262.9	(Insuf)	1005.8	1564.4	5

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.04735	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.23763	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.10277	(Insuf)	.00000	1.0000	.00000
Field Service	.04735	(Insuf)	.00000	1.0000	.00000
Business Dev	.04419	(Insuf)	.00000	1.0000	.00000
Sales Busy	.04735	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	133.47	(Insuf)	130.00	137.00	137.00
Test Engineer	.09154	(Insuf)	.00000	1.0000	.00000
QA Busy	.04735	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.04735	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	.74628	(Insuf)	.00000	3.0000	.00000
Ideas in Bucket 2	.02470	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.02317	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	1.4516E+05	(Insuf)	85824.	2.6516E+05	89545.
Divisional Mngr 5	.00458	(Insuf)	.00000	1.0000	.00000

Results - Optimum value buffer.txt

Value Bucket 2	88813.	(Insuf)	83033.	96546.	89545.
Marketing Busy	.11469	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00422	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00447	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00442	(Insuf)	.00000	1.0000	.00000
Construction Eng	.04735	(Insuf)	.00000	1.0000	.00000
Variable AK	27.409	(Insuf)	22.937	36.393	30.848
Project Team	.04316	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00435	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	2.1871E+05	(Insuf)	89747.	4.5146E+05	2.7821E+05
Variable AL	45.683	(Insuf)	38.228	60.656	51.413
Variable AM	91.366	(Insuf)	76.457	121.31	102.82
Busy Development Eng	.20585	(Insuf)	.00000	1.0000	.00000
Project Engineer	.04735	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	5	Infinite
Review2Meetings	214	Infinite
Review1Count	7	Infinite
PrelimCount	5	Infinite
Review1Meetings	210	Infinite
DesignCount	5	Infinite
ValueExecuted	432158	Infinite
Ideas	116	Infinite
ExecutedCount	5	Infinite
PointMeetings	211	Infinite
Point1Fail	106	Infinite
Point2Fail	4	Infinite
Stagger1Count	5	Infinite
Point3Fail	0	Infinite
Point1Pass	10	Infinite
Point2Pass	6	Infinite
Point3Pass	7	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 16 of 20

Project: Project delivery   Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet   Model revision date: 10/11/2002

Replication ended at time   : 102432.0
Statistics were cleared at time: 96096.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	4673.0	(Insuf)	2021.4	8677.1	5

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.05524	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.24185	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.11170	(Insuf)	.00000	1.0000	.00000
Field Service	.05524	(Insuf)	.00000	1.0000	.00000
Business Dev	.05051	(Insuf)	.00000	1.0000	.00000

Results - Optimum value buffer.txt

Sales Busy	.05524	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	138.49	(Insuf)	137.00	140.00	140.00
Test Engineer	.10574	(Insuf)	.00000	1.0000	.00000
QA Busy	.05524	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.05524	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	.47182	(Insuf)	.00000	3.0000	1.0000
Ideas in Bucket 2	.01738	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.00955	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	1.7990E+05	(Insuf)	89545.	2.7018E+05	2.7018E+05
Divisional Mngr 5	.00267	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	90673.	(Insuf)	85993.	97946.	95328.
Marketing Busy	.11956	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00371	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00276	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00275	(Insuf)	.00000	1.0000	.00000
Construction Eng	.05524	(Insuf)	.00000	1.0000	.00000
Variable AK	40.375	(Insuf)	30.848	49.315	36.251
Project Team	.04884	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00343	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	2.7669E+05	(Insuf)	89747.	5.4838E+05	89747.
Variable AL	67.293	(Insuf)	51.413	82.192	60.418
Variable AM	134.58	(Insuf)	102.82	164.38	120.83
Busy Development Eng	.19542	(Insuf)	.00000	1.0000	.00000
Project Engineer	.05524	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	5	Infinite
Review2Meetings	207	Infinite
Review1Count	3	Infinite
PrelimCount	5	Infinite
Review1Meetings	210	Infinite
DesignCount	5	Infinite
ValueExecuted	458635	Infinite
Ideas	78	Infinite
ExecutedCount	5	Infinite
PointMeetings	211	Infinite
Point1Fail	70	Infinite
Point2Fail	4	Infinite
Stagger1Count	5	Infinite
Point3Fail	0	Infinite
Point1Pass	8	Infinite
Point2Pass	4	Infinite
Point3Pass	3	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 17 of 20

Project: Project delivery | Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet | Model revision date: 10/11/2002

Replication ended at time : 108768.0
Statistics were cleared at time: 102432.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	1029.2	(Insuf)	901.74	1193.3	3

Results - Optimum value buffer.txt

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.04223	(Insuf)	.00000	1.0000	1.0000
Busy Project Manager	.16546	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.11518	(Insuf)	.00000	1.0000	1.0000
Field Service	.04223	(Insuf)	.00000	1.0000	1.0000
Business Dev	.05366	(Insuf)	.00000	1.0000	.00000
Sales Busy	.04223	(Insuf)	.00000	1.0000	1.0000
Ideas in Final Bucket	142.28	(Insuf)	140.00	151.00	151.00
Test Engineer	.09589	(Insuf)	.00000	1.0000	1.0000
QA Busy	.04223	(Insuf)	.00000	1.0000	1.0000
Cost Analyst	.04223	(Insuf)	.00000	1.0000	1.0000
Ideas in Bucket 3	2.3803	(Insuf)	.00000	8.0000	1.0000
Ideas in Bucket 2	.05657	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.03893	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	1.2606E+05	(Insuf)	85533.	7.1873E+05	7.1873E+05
Divisional Mngr 5	.00770	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	92316.	(Insuf)	81128.	1.8328E+05	83462.
Marketing Busy	.13270	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.00803	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00760	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00728	(Insuf)	.00000	1.0000	.00000
Construction Eng	.04223	(Insuf)	.00000	1.0000	1.0000
Variable AK	21.501	(Insuf)	11.728	36.251	12.021
Project Team	.02964	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00732	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	1.3213E+05	(Insuf)	89747.	8.0847E+05	8.0847E+05
Variable AL	35.836	(Insuf)	19.547	60.418	20.036
Variable AM	71.673	(Insuf)	39.094	120.83	40.072
Busy Development Eng	.16123	(Insuf)	.00000	1.0000	.00000
Project Engineer	.04223	(Insuf)	.00000	1.0000	1.0000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	3	Infinite
Review2Meetings	213	Infinite
Review1Count	11	Infinite
PrelimCount	5	Infinite
Review1Meetings	209	Infinite
DesignCount	3	Infinite
ValueExecuted	270314	Infinite
Ideas	161	Infinite
ExecutedCount	3	Infinite
PointMeetings	210	Infinite
Point1Fail	139	Infinite
Point2Fail	11	Infinite
Stagger1Count	10	Infinite
Point3Fail	0	Infinite
Point1Pass	22	Infinite
Point2Pass	11	Infinite
Point3Pass	11	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 18 of 20

Project: Project delivery　　Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet　　Model revision date: 10/11/2002

Results - Optimum value buffer.txt

Replication ended at time : 115104.0
Statistics were cleared at time: 108768.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	3381.6	(Insuf)	1640.9	7034.0	16

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.17716	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.86502	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.34904	(Insuf)	.00000	1.0000	.00000
Field Service	.17716	(Insuf)	.00000	1.0000	.00000
Business Dev	.14836	(Insuf)	.00000	1.0000	.00000
Sales Busy	.17716	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	155.64	(Insuf)	151.00	163.00	163.00
Test Engineer	.32551	(Insuf)	.00000	1.0000	.00000
QA Busy	.17716	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.17716	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	2.8608	(Insuf)	.00000	7.0000	.00000
Ideas in Bucket 2	.04450	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.04668	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	5.1547E+05	(Insuf)	1.8250E+05	7.1873E+05	3.5882E+05
Divisional Mngr 5	.00622	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	88456.	(Insuf)	82907.	97764.	91044.
Marketing Busy	.37327	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00777	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00814	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00853	(Insuf)	.00000	1.0000	.00000
Construction Eng	.17716	(Insuf)	.00000	1.0000	.00000
Variable AK	16.480	(Insuf)	12.021	21.743	21.743
Project Team	.16560	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00856	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	5.5138E+05	(Insuf)	1.8431E+05	8.0847E+05	4.5537E+05
Variable AL	27.466	(Insuf)	20.036	36.239	36.239
Variable AM	54.933	(Insuf)	40.072	72.479	72.479
Busy Development Eng	.71672	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.17716	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	18	Infinite
Review2Meetings	209	Infinite
Review1Count	12	Infinite
PrelimCount	16	Infinite
Review1Meetings	210	Infinite
DesignCount	18	Infinite
ValueExecuted	1414618	Infinite
Ideas	200	Infinite
ExecutedCount	16	Infinite
PointMeetings	214	Infinite
Point1Fail	180	Infinite
Point2Fail	8	Infinite
Stagger1Count	11	Infinite
Point3Fail	1	Infinite
Point1Pass	20	Infinite

Results - Optimum value buffer.txt

Point2Pass	12	Infinite
Point3Pass	12	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 19 of 20

Project: Project delivery   Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet   Model revision date: 10/11/2002

Replication ended at time   : 121440.0
Statistics were cleared at time: 115104.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	3214.4	(Insuf)	1791.4	6784.2	8

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.06155	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.33819	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.12531	(Insuf)	.00000	1.0000	.00000
Field Service	.06155	(Insuf)	.00000	1.0000	.00000
Business Dev	.05682	(Insuf)	.00000	1.0000	.00000
Sales Busy	.06155	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	164.98	(Insuf)	163.00	167.00	167.00
Test Engineer	.11837	(Insuf)	.00000	1.0000	.00000
QA Busy	.06155	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.06155	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	.56566	(Insuf)	.00000	2.0000	.00000
Ideas in Bucket 2	.02305	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.01533	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.4893E+05	(Insuf)	1.7717E+05	3.5882E+05	1.7717E+05
Divisional Mngr 5	.00404	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	89277.	(Insuf)	82426.	95628.	82426.
Marketing Busy	.13550	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00437	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00405	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00531	(Insuf)	.00000	1.0000	.00000
Construction Eng	.06155	(Insuf)	.00000	1.0000	.00000
Variable AK	28.589	(Insuf)	21.743	34.761	26.897
Project Team	.06507	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00426	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	2.7669E+05	(Insuf)	89747.	4.6623E+05	89747.
Variable AL	47.649	(Insuf)	36.239	57.935	44.829
Variable AM	95.298	(Insuf)	72.479	115.87	89.658
Busy Development Eng	.27839	(Insuf)	.00000	1.0000	.00000
Project Engineer	.06155	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	6	Infinite
Review2Meetings	210	Infinite
Review1Count	4	Infinite
PrelimCount	6	Infinite

Results - Optimum value buffer.txt

Review1Meetings	216	Infinite
DesignCount	6	Infinite
ValueExecuted	726941	Infinite
Ideas	113	Infinite
ExecutedCount	8	Infinite
PointMeetings	207	Infinite
Point1Fail	103	Infinite
Point2Fail	6	Infinite
Stagger1Count	6	Infinite
Point3Fail	0	Infinite
Point1Pass	10	Infinite
Point2Pass	4	Infinite
Point3Pass	4	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 20 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 127776.0
Statistics were cleared at time: 121440.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	1153.5	(Insuf)	1010.1	1363.0	4

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.03709	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.17287	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.09813	(Insuf)	.00000	1.0000	.00000
Field Service	.03709	(Insuf)	.00000	1.0000	.00000
Business Dev	.03472	(Insuf)	.00000	1.0000	.00000
Sales Busy	.03709	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	169.06	(Insuf)	167.00	172.00	172.00
Test Engineer	.07181	(Insuf)	.00000	1.0000	.00000
QA Busy	.03709	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.03709	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	1.9904	(Insuf)	.00000	11.000	11.000
Ideas in Bucket 2	.06207	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.04581	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	1.7916E+05	(Insuf)	92798.	2.7551E+05	2.7551E+05
Divisional Mngr 5	.00953	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	92103.	(Insuf)	80775.	1.8578E+05	88261.
Marketing Busy	.12016	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00977	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00868	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00879	(Insuf)	.00000	1.0000	.00000
Construction Eng	.03709	(Insuf)	.00000	1.0000	.00000
Variable AK	16.379	(Insuf)	12.461	26.897	13.092
Project Team	.04040	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00846	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	1.4783E+05	(Insuf)	89747.	3.6526E+05	1.8520E+05
Variable AL	27.299	(Insuf)	20.768	44.829	21.820
Variable AM	54.599	(Insuf)	41.537	89.658	43.640
Busy Development Eng	.17300	(Insuf)	.00000	1.0000	.00000

Results - Optimum value buffer.txt

Project Engineer	.03709	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	4	Infinite
Review2Meetings	214	Infinite
Review1Count	5	Infinite
PrelimCount	4	Infinite
Review1Meetings	211	Infinite
DesignCount	4	Infinite
ValueExecuted	368479	Infinite
Ideas	197	Infinite
ExecutedCount	4	Infinite
PointMeetings	213	Infinite
Point1Fail	172	Infinite
Point2Fail	9	Infinite
Stagger1Count	4	Infinite
Point3Fail	0	Infinite
Point1Pass	25	Infinite
Point2Pass	16	Infinite
Point3Pass	5	Infinite

Simulation run time: 2.12 minutes.
Simulation run complete.

APPENDIX B

RESULTS FOR A SIMULATION RUN WITH A LARGE VALUE BUFFER

Results - Large value buffer.txt

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Warmup Period

Project: Project delivery
Analyst: Konstant Bruinet

Run execution date : 1/ 1/1998
Model revision date: 10/11/2002

Replication ended at time : 1056.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	--	--	--	--	0

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.06155	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.13267	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.15622	(Insuf)	.00000	1.0000	.00000
Field Service	.06155	(Insuf)	.00000	1.0000	.00000
Business Dev	.05682	(Insuf)	.00000	1.0000	.00000
Sales Busy	.06155	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	.40607	(Insuf)	.00000	1.0000	1.0000
Test Engineer	.11837	(Insuf)	.00000	1.0000	.00000
QA Busy	.06155	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.06155	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	1.3673	(Insuf)	.00000	3.0000	3.0000
Ideas in Bucket 2	.08935	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.04794	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	35249.	(Insuf)	.00000	86506.	86506.
Divisional Mngr 5	.00897	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	87487.	(Insuf)	.00000	97915.	81263.
Marketing Busy	.17765	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00991	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.01024	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.01051	(Insuf)	.00000	1.0000	.00000
Construction Eng	.06155	(Insuf)	.00000	1.0000	.00000
Variable AK	15.000	(Insuf)	.00000	15.000	15.000
Project Team	.06992	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.01045	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	35127.	(Insuf)	.00000	86506.	86506.
Variable AL	25.000	(Insuf)	.00000	25.000	25.000
Variable AM	50.000	(Insuf)	.00000	50.000	50.000
Busy Development Eng	.11345	(Insuf)	.00000	1.0000	.00000
Project Engineer	.06155	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	0	Infinite
Review2Meetings	0	Infinite
Review1Count	1	Infinite
PrelimCount	1	Infinite
Review1Meetings	2	Infinite
DesignCount	1	Infinite
ValueExecuted	0	Infinite
Ideas	37	Infinite
ExecutedCount	0	Infinite

Results - Large value buffer.txt

PointMeetings	22	Infinite
Point1Fail	32	Infinite
Point2Fail	1	Infinite
Stagger1Count	1	Infinite
Point3Fail	0	Infinite
Point1Pass	5	Infinite
Point2Pass	4	Infinite
Point3Pass	1	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 1 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 7392.0
Statistics were cleared at time: 1056.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	2132.1	(Insuf)	1373.2	3508.6	9

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.08207	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.42354	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.19510	(Insuf)	.00000	1.0000	.00000
Field Service	.08207	(Insuf)	.00000	1.0000	.00000
Business Dev	.07576	(Insuf)	.00000	1.0000	.00000
Sales Busy	.08207	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	6.3696	(Insuf)	1.0000	12.000	12.000
Test Engineer	.15783	(Insuf)	.00000	1.0000	.00000
QA Busy	.08207	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.08207	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	3.3171	(Insuf)	.00000	8.0000	8.0000
Ideas in Bucket 2	.17004	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.06053	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	3.8264E+05	(Insuf)	86506.	6.1643E+05	4.3713E+05
Divisional Mngr 5	.01318	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	89689.	(Insuf)	81263.	1.8755E+05	1.8755E+05
Marketing Busy	.22362	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.01306	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.01354	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.01340	(Insuf)	.00000	1.0000	.00000
Construction Eng	.08207	(Insuf)	.00000	1.0000	.00000
Variable AK	11.059	(Insuf)	8.4995	15.000	9.1473
Project Team	.07123	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.01313	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	2.7132E+05	(Insuf)	.00000	5.3213E+05	2.8069E+05
Variable AL	18.432	(Insuf)	14.165	25.000	15.245
Variable AM	36.864	(Insuf)	28.331	50.000	30.491
Busy Development Eng	.39897	(Insuf)	.00000	1.0000	.00000
Project Engineer	.08207	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit

Results - Large value buffer.txt

Stagger2Counter	9	Infinite
Review2Meetings	35	Infinite
Review1Count	11	Infinite
PrelimCount	8	Infinite
Review1Meetings	35	Infinite
DesignCount	8	Infinite
ValueExecuted	770130	Infinite
Ideas	297	Infinite
ExecutedCount	9	Infinite
PointMeetings	134	Infinite
Point1Fail	261	Infinite
Point2Fail	16	Infinite
Stagger1Count	8	Infinite
Point3Fail	4	Infinite
Point1Pass	36	Infinite
Point2Pass	20	Infinite
Point3Pass	11	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 2 of 20

Project: Project delivery　　Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet　　Model revision date: 10/11/2002

Replication ended at time : 13728.0
Statistics were cleared at time: 7392.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	5403.4	(Insuf)	3988.4	6065.5	5

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.14915	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.53650	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.33421	(Insuf)	.00000	1.0000	.00000
Field Service	.14915	(Insuf)	.00000	1.0000	.00000
Business Dev	.14205	(Insuf)	.00000	1.0000	.00000
Sales Busy	.14915	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	20.782	(Insuf)	12.000	27.000	27.000
Test Engineer	.29119	(Insuf)	.00000	1.0000	.00000
QA Busy	.14915	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.14915	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	10.131	(Insuf)	.00000	17.000	16.000
Ideas in Bucket 2	.19972	(Insuf)	.00000	3.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.09307	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	1.1043E+06	(Insuf)	4.3713E+05	1.5709E+06	1.5709E+06
Divisional Mngr 5	.02159	.00399	.00000	1.0000	.00000
Value Bucket 2	1.1059E+05	(Insuf)	81565.	2.7902E+05	89853.
Marketing Busy	.38228	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.01874	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.01830	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.01983	(Insuf)	.00000	1.0000	.00000
Construction Eng	.14915	(Insuf)	.00000	1.0000	.00000
Variable AK	6.5891	(Insuf)	5.2029	9.1473	7.7238

Results - Large value buffer.txt

Project Team	.18625	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.01876	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	1.0390E+06	(Insuf)	2.8069E+05	1.6592E+06	1.1794E+06
Variable AL	10.981	(Insuf)	8.6716	15.245	12.873
Variable AM	21.963	(Insuf)	17.343	30.491	25.746
Busy Development Eng	.41231	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.14915	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	13	Infinite
Review2Meetings	35	Infinite
Review1Count	15	Infinite
PrelimCount	18	Infinite
Review1Meetings	35	Infinite
DesignCount	18	Infinite
ValueExecuted	479748	Infinite
Ideas	480	Infinite
ExecutedCount	5	Infinite
PointMeetings	141	Infinite
Point1Fail	428	Infinite
Point2Fail	27	Infinite
Stagger1Count	18	Infinite
Point3Fail	2	Infinite
Point1Pass	52	Infinite
Point2Pass	25	Infinite
Point3Pass	15	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 3 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 20064.0
Statistics were cleared at time: 13728.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	7362.5	(Insuf)	2715.6	14131.	16

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.09470	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.61303	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.23981	(Insuf)	.00000	1.0000	1.0000
Field Service	.09470	(Insuf)	.00000	1.0000	.00000
Business Dev	.10231	(Insuf)	.00000	1.0000	1.0000
Sales Busy	.09470	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	37.225	(Insuf)	27.000	58.000	58.000
Test Engineer	.19700	(Insuf)	.00000	1.0000	1.0000
QA Busy	.09470	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.09470	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	16.400	(Insuf)	.00000	32.000	9.0000
Ideas in Bucket 2	.18425	(Insuf)	.00000	3.0000	2.0000

Results - Large value buffer.txt

# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.08558	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.0144E+06	(Insuf)	1.5709E+06	2.8852E+06	2.8852E+06
Divisional Mngr 5	.02173	.00412	.00000	1.0000	.00000
Value Bucket 2	1.0871E+05	(Insuf)	80922.	2.6902E+05	89279.
Marketing Busy	.29097	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.01902	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.01970	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.02032	(Insuf)	.00000	1.0000	.00000
Construction Eng	.09470	(Insuf)	.00000	1.0000	.00000
Variable AK	6.7868	(Insuf)	5.1046	8.5257	6.3750
Project Team	.10012	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.01954	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	1.1517E+06	(Insuf)	-2.619e-10	2.7893E+06	2.5008E+06
Variable AL	11.311	(Insuf)	8.5077	14.209	10.625
Variable AM	22.622	(Insuf)	17.015	28.419	21.250
Busy Development Eng	.56015	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.09470	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	8	Infinite
Review2Meetings	35	Infinite
Review1Count	31	Infinite
PrelimCount	11	Infinite
Review1Meetings	35	Infinite
DesignCount	10	Infinite
ValueExecuted	1467891	Infinite
Ideas	480	Infinite
ExecutedCount	16	Infinite
PointMeetings	134	Infinite
Point1Fail	427	Infinite
Point2Fail	26	Infinite
Stagger1Count	29	Infinite
Point3Fail	1	Infinite
Point1Pass	53	Infinite
Point2Pass	25	Infinite
Point3Pass	31	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 4 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 26400.0
Statistics were cleared at time: 20064.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	10385.	(Insuf)	6073.8	15497.	26

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.18150	(Insuf)	.00000	1.0000	.00000

Results - Large value buffer.txt

Busy Project Manager	1.0000	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.42982	(Insuf)	.00000	1.0000	1.0000
Field Service	.18150	(Insuf)	.00000	1.0000	.00000
Business Dev	.20621	(Insuf)	.00000	1.0000	1.0000
Sales Busy	.18150	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	68.287	(Insuf)	58.000	75.000	75.000
Test Engineer	.38771	(Insuf)	.00000	1.0000	1.0000
QA Busy	.18150	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.18150	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	10.841	(Insuf)	.00000	21.000	10.000
Ideas in Bucket 2	.16703	(Insuf)	.00000	3.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.08893	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.2637E+06	(Insuf)	1.8674E+06	2.8852E+06	1.8674E+06
Divisional Mngr 5	.01656	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	1.0101E+05	(Insuf)	82144.	2.6436E+05	83737.
Marketing Busy	.46734	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.01646	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.01558	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.01622	(Insuf)	.00000	1.0000	.00000
Construction Eng	.18150	(Insuf)	.00000	1.0000	.00000
Variable AK	9.0091	(Insuf)	6.3750	12.114	12.114
Project Team	.18816	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.01674	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	2.5718E+06	(Insuf)	1.7075E+06	3.8287E+06	1.7075E+06
Variable AL	15.015	(Insuf)	10.625	20.190	20.190
Variable AM	30.030	(Insuf)	21.250	40.381	40.381
Busy Development Eng	.85526	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.18150	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	26	Infinite
Review2Meetings	35	Infinite
Review1Count	17	Infinite
PrelimCount	24	Infinite
Review1Meetings	34	Infinite
DesignCount	20	Infinite
ValueExecuted	2310003	Infinite
Ideas	365	Infinite
ExecutedCount	26	Infinite
PointMeetings	131	Infinite
Point1Fail	323	Infinite
Point2Fail	22	Infinite
Stagger1Count	14	Infinite
Point3Fail	4	Infinite
Point1Pass	42	Infinite
Point2Pass	22	Infinite
Point3Pass	17	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 5 of 20

Project: Project delivery Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet Model revision date: 10/11/2002

Replication ended at time : 32736.0
Statistics were cleared at time: 26400.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Results - Large value buffer.txt

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	9666.0	(Insuf)	7956.1	12620.	16

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.19371	(Insuf)	.00000	1.0000	1.0000
Busy Project Manager	.85340	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.38350	(Insuf)	.00000	1.0000	1.0000
Field Service	.19371	(Insuf)	.00000	1.0000	1.0000
Business Dev	.16812	(Insuf)	.00000	1.0000	.00000
Sales Busy	.19371	(Insuf)	.00000	1.0000	1.0000
Ideas in Final Bucket	78.361	(Insuf)	75.000	95.000	95.000
Test Engineer	.36184	(Insuf)	.00000	1.0000	1.0000
QA Busy	.19371	(Insuf)	.00000	1.0000	1.0000
Cost Analyst	.19371	(Insuf)	.00000	1.0000	1.0000
Ideas in Bucket 3	13.868	(Insuf)	.00000	20.000	2.0000
Ideas in Bucket 2	.10938	(Insuf)	.00000	3.0000	1.0000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.04181	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	1.8617E+06	(Insuf)	1.8342E+06	1.8674E+06	1.8342E+06
Divisional Mngr 5	.00845	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	1.0374E+05	(Insuf)	83737.	2.7480E+05	83936.
Marketing Busy	.40886	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.00931	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00901	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00800	(Insuf)	.00000	1.0000	.00000
Construction Eng	.19371	(Insuf)	.00000	1.0000	1.0000
Variable AK	16.341	(Insuf)	12.114	19.366	19.280
Project Team	.18833	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00929	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	1.3427E+06	(Insuf)	2.8589E+05	2.1201E+06	2.1201E+06
Variable AL	27.236	(Insuf)	20.190	32.277	32.134
Variable AM	54.472	(Insuf)	40.381	64.555	64.269
Busy Development Eng	.66829	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.19371	(Insuf)	.00000	1.0000	1.0000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	18	Infinite
Review2Meetings	35	Infinite
Review1Count	20	Infinite
PrelimCount	20	Infinite
Review1Meetings	36	Infinite
DesignCount	20	Infinite
ValueExecuted	1421632	Infinite
Ideas	198	Infinite
ExecutedCount	16	Infinite
PointMeetings	137	Infinite
Point1Fail	173	Infinite
Point2Fail	12	Infinite
Stagger1Count	20	Infinite
Point3Fail	0	Infinite
Point1Pass	25	Infinite
Point2Pass	12	Infinite
Point3Pass	20	Infinite

Results - Large value buffer.txt
Summary for Replication 6 of 20

Project: Project delivery
Analyst: Konstant Bruinet

Run execution date : 1/ 1/1998
Model revision date: 10/11/2002

Replication ended at time : 39072.0
Statistics were cleared at time: 32736.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	10381.	(Insuf)	3674.3	27340.	26

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.19376	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.96140	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.34399	(Insuf)	.00000	1.0000	.00000
Field Service	.19376	(Insuf)	.00000	1.0000	.00000
Business Dev	.14520	(Insuf)	.00000	1.0000	.00000
Sales Busy	.19376	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	97.576	(Insuf)	95.000	99.000	99.000
Test Engineer	.33896	(Insuf)	.00000	1.0000	.00000
QA Busy	.19376	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.19376	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	1.1183	(Insuf)	.00000	3.0000	.00000
Ideas in Bucket 2	.04195	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.01350	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	6.1344E+05	(Insuf)	84880.	1.8342E+06	84880.
Divisional Mngr 5	.00448	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	88122.	(Insuf)	82887.	96728.	87120.
Marketing Busy	.35349	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00456	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00475	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00478	(Insuf)	.00000	1.0000	.00000
Construction Eng	.19376	(Insuf)	.00000	1.0000	.00000
Variable AK	27.035	(Insuf)	19.280	35.745	33.958
Project Team	.21883	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00419	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	1.2887E+06	(Insuf)	97915.	2.1940E+06	97915.
Variable AL	45.058	(Insuf)	32.134	59.576	56.597
Variable AM	90.117	(Insuf)	64.269	119.15	113.19
Busy Development Eng	.72258	(Insuf)	.00000	1.0000	.00000
Project Engineer	.19376	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	24	Infinite
Review2Meetings	35	Infinite
Review1Count	4	Infinite
PrelimCount	17	Infinite
Review1Meetings	34	Infinite
DesignCount	22	Infinite
ValueExecuted	2385006	Infinite
Ideas	120	Infinite
ExecutedCount	26	Infinite
PointMeetings	138	Infinite
Point1Fail	111	Infinite

Point2Fail	7	Infinite
Stagger1Count	9	Infinite
Point3Fail	1	Infinite
Point1Pass	9	Infinite
Point2Pass	3	Infinite
Point3Pass	4	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 7 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 45408.0
Statistics were cleared at time: 39072.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	1142.1	(Insuf)	1142.1	1142.1	1

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.05761	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.16366	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.13193	(Insuf)	.00000	1.0000	.00000
Field Service	.05761	(Insuf)	.00000	1.0000	.00000
Business Dev	.05366	(Insuf)	.00000	1.0000	.00000
Sales Busy	.05761	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	101.42	(Insuf)	99.000	107.00	107.00
Test Engineer	.11127	(Insuf)	.00000	1.0000	.00000
QA Busy	.05761	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.05761	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	1.9513	(Insuf)	.00000	7.0000	3.0000
Ideas in Bucket 2	.08177	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.03815	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.2598E+05	(Insuf)	84880.	6.2395E+05	6.2395E+05
Divisional Mngr 5	.00784	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	94021.	(Insuf)	81344.	1.8991E+05	94235.
Marketing Busy	.14849	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00668	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00760	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00762	(Insuf)	.00000	1.0000	.00000
Construction Eng	.05761	(Insuf)	.00000	1.0000	.00000
Variable AK	18.522	(Insuf)	10.437	33.958	11.520
Project Team	.06338	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00715	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	2.5647E+05	(Insuf)	97915.	7.3100E+05	7.3100E+05
Variable AL	30.870	(Insuf)	17.395	56.597	19.201
Variable AM	61.741	(Insuf)	34.791	113.19	38.402
Busy Development Eng	.12871	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.05761	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit

Results - Large value buffer.txt

Stagger2Counter	3	Infinite
Review2Meetings	35	Infinite
Review1Count	8	Infinite
PrelimCount	6	Infinite
Review1Meetings	35	Infinite
DesignCount	6	Infinite
ValueExecuted	90415	Infinite
Ideas	201	Infinite
ExecutedCount	1	Infinite
PointMeetings	133	Infinite
Point1Fail	183	Infinite
Point2Fail	6	Infinite
Stagger1Count	6	Infinite
Point3Fail	1	Infinite
Point1Pass	18	Infinite
Point2Pass	12	Infinite
Point3Pass	8	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 8 of 20

Project: Project delivery   Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet   Model revision date: 10/11/2002

Replication ended at time : 51744.0
Statistics were cleared at time: 45408.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	2812.7	(Insuf)	1944.5	3982.1	15

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.16139	(Insuf)	.00000	1.0000	1.0000
Busy Project Manager	.67917	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.33716	(Insuf)	.00000	1.0000	1.0000
Field Service	.16139	(Insuf)	.00000	1.0000	1.0000
Business Dev	.15152	(Insuf)	.00000	1.0000	.00000
Sales Busy	.16139	(Insuf)	.00000	1.0000	1.0000
Ideas in Final Bucket	115.61	(Insuf)	107.00	123.00	123.00
Test Engineer	.31290	(Insuf)	.00000	1.0000	1.0000
QA Busy	.16139	(Insuf)	.00000	1.0000	1.0000
Cost Analyst	.16139	(Insuf)	.00000	1.0000	1.0000
Ideas in Bucket 3	3.4905	(Insuf)	.00000	9.0000	2.0000
Ideas in Bucket 2	.11200	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.05157	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	5.7068E+05	(Insuf)	3.5121E+05	7.9120E+05	3.5979E+05
Divisional Mngr 5	.01014	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	1.0054E+05	(Insuf)	80525.	1.8321E+05	90053.
Marketing Busy	.37132	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.01060	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.01224	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.01157	(Insuf)	.00000	1.0000	.00000
Construction Eng	.16139	(Insuf)	.00000	1.0000	1.0000
Variable AK	13.572	(Insuf)	11.498	17.464	17.464
Project Team	.13442	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.01153	(Insuf)	.00000	1.0000	.00000

Results - Large value buffer.txt

Value Final Bucket	7.2236E+05	(Insuf)	2.8632E+05	1.0828E+06	8.3006E+05
Variable AL	22.621	(Insuf)	19.164	29.106	29.106
Variable AM	45.242	(Insuf)	38.329	58.213	58.213
Busy Development Eng	.56738	(Insuf)	.00000	1.0000	.00000
Project Engineer	.16139	(Insuf)	.00000	1.0000	1.0000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	13	Infinite
Review2Meetings	34	Infinite
Review1Count	16	Infinite
PrelimCount	16	Infinite
Review1Meetings	35	Infinite
DesignCount	15	Infinite
ValueExecuted	1318973	Infinite
Ideas	232	Infinite
ExecutedCount	15	Infinite
PointMeetings	141	Infinite
Point1Fail	200	Infinite
Point2Fail	16	Infinite
Stagger1Count	17	Infinite
Point3Fail	1	Infinite
Point1Pass	32	Infinite
Point2Pass	16	Infinite
Point3Pass	16	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 9 of 20

Project: Project delivery | Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet | Model revision date: 10/11/2002

Replication ended at time : 58080.0
Statistics were cleared at time: 51744.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	4685.1	(Insuf)	1522.4	12868.	14

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.07693	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.52858	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.16948	(Insuf)	.00000	1.0000	.00000
Field Service	.07693	(Insuf)	.00000	1.0000	.00000
Business Dev	.06944	(Insuf)	.00000	1.0000	.00000
Sales Busy	.07693	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	126.97	(Insuf)	123.00	132.00	132.00
Test Engineer	.14638	(Insuf)	.00000	1.0000	.00000
QA Busy	.07693	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.07693	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	2.4151	(Insuf)	.00000	7.0000	2.0000
Ideas in Bucket 2	.08884	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.04786	(Insuf)	.00000	1.0000	.00000

Results - Large value buffer.txt

Value Bucket 3	4.2587E+05	(Insuf)	3.5979E+05	6.2435E+05	6.2435E+05
Divisional Mngr 5	.00746	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	90960.	(Insuf)	83532.	1.7723E+05	93060.
Marketing Busy	.18788	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00836	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00803	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00934	(Insuf)	.00000	1.0000	.00000
Construction Eng	.07693	(Insuf)	.00000	1.0000	.00000
Variable AK	16.725	(Insuf)	13.067	19.759	15.154
Project Team	.06710	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00891	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	4.9252E+05	(Insuf)	1.9466E+05	8.3006E+05	3.8188E+05
Variable AL	27.876	(Insuf)	21.778	32.931	25.256
Variable AM	55.752	(Insuf)	43.557	65.863	50.513
Busy Development Eng	.48691	(Insuf)	.00000	1.0000	.00000
Project Engineer	.07693	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	14	Infinite
Review2Meetings	35	Infinite
Review1Count	9	Infinite
PrelimCount	8	Infinite
Review1Meetings	34	Infinite
DesignCount	9	Infinite
ValueExecuted	1258169	Infinite
Ideas	188	Infinite
ExecutedCount	14	Infinite
PointMeetings	137	Infinite
Point1Fail	165	Infinite
Point2Fail	12	Infinite
Stagger1Count	7	Infinite
Point3Fail	2	Infinite
Point1Pass	23	Infinite
Point2Pass	11	Infinite
Point3Pass	9	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 10 of 20

Project: Project delivery   Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet   Model revision date: 10/11/2002

Replication ended at time : 64416.0
Statistics were cleared at time: 58080.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	5771.8	(Insuf)	1167.0	13105.	7

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.07576	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.37564	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.15930	(Insuf)	.00000	1.0000	.00000

Results - Large value buffer.txt

Field Service	.07576	(Insuf)	.00000	1.0000	.00000
Business Dev	.06944	(Insuf)	.00000	1.0000	.00000
Sales Busy	.07576	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	135.33	(Insuf)	132.00	137.00	137.00
Test Engineer	.14520	(Insuf)	.00000	1.0000	.00000
QA Busy	.07576	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.07576	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	1.3090	(Insuf)	.00000	4.0000	4.0000
Ideas in Bucket 2	.06300	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.02828	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.3459E+05	(Insuf)	90134.	6.2435E+05	3.4636E+05
Divisional Mngr 5	.00715	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	90766.	(Insuf)	83033.	1.7390E+05	1.7390E+05
Marketing Busy	.17759	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00620	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00728	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00778	(Insuf)	.00000	1.0000	.00000
Construction Eng	.07576	(Insuf)	.00000	1.0000	.00000
Variable AK	16.575	(Insuf)	13.920	18.925	13.920
Project Team	.07258	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00753	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	4.1247E+05	(Insuf)	1.8860E+05	6.3894E+05	1.8860E+05
Variable AL	27.625	(Insuf)	23.201	31.542	23.201
Variable AM	55.251	(Insuf)	46.403	63.084	46.403
Busy Development Eng	.31867	(Insuf)	.00000	1.0000	.00000
Project Engineer	.07576	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	7	Infinite
Review2Meetings	34	Infinite
Review1Count	5	Infinite
PrelimCount	7	Infinite
Review1Meetings	35	Infinite
DesignCount	7	Infinite
ValueExecuted	630797	Infinite
Ideas	194	Infinite
ExecutedCount	7	Infinite
PointMeetings	137	Infinite
Point1Fail	177	Infinite
Point2Fail	8	Infinite
Stagger1Count	7	Infinite
Point3Fail	2	Infinite
Point1Pass	17	Infinite
Point2Pass	9	Infinite
Point3Pass	5	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 11 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 70752.0
Statistics were cleared at time: 64416.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations

ProjectTAT	3099.6	(Insuf)	1928.1	5041.0	6

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.18466	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.52364	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.38595	(Insuf)	.00000	1.0000	.00000
Field Service	.18466	(Insuf)	.00000	1.0000	.00000
Business Dev	.17045	(Insuf)	.00000	1.0000	.00000
Sales Busy	.18466	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	145.96	(Insuf)	137.00	154.00	154.00
Test Engineer	.35511	(Insuf)	.00000	1.0000	.00000
QA Busy	.18466	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.18466	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	4.9476	(Insuf)	.00000	12.000	4.0000
Ideas in Bucket 2	.12820	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.05883	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	6.8570E+05	(Insuf)	3.4636E+05	1.0910E+06	1.0910E+06
Divisional Mngr 5	.01338	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	97191.	(Insuf)	81128.	1.8564E+05	89607.
Marketing Busy	.41661	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.01396	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.01193	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.01253	(Insuf)	.00000	1.0000	.00000
Construction Eng	.18466	(Insuf)	.00000	1.0000	.00000
Variable AK	11.262	(Insuf)	8.9587	13.920	11.467
Project Team	.18086	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.01329	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	7.4374E+05	(Insuf)	1.8860E+05	1.3758E+06	1.1898E+06
Variable AL	18.771	(Insuf)	14.931	23.201	19.113
Variable AM	37.542	(Insuf)	29.862	46.403	38.226
Busy Development Eng	.37632	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.18466	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	8	Infinite
Review2Meetings	35	Infinite
Review1Count	17	Infinite
PrelimCount	18	Infinite
Review1Meetings	34	Infinite
DesignCount	18	Infinite
ValueExecuted	545481	Infinite
Ideas	285	Infinite
ExecutedCount	6	Infinite
PointMeetings	136	Infinite
Point1Fail	251	Infinite
Point2Fail	17	Infinite
Stagger1Count	18	Infinite
Point3Fail	0	Infinite
Point1Pass	34	Infinite
Point2Pass	17	Infinite
Point3Pass	17	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 12 of 20

Results - Large value buffer.txt

Project: Project delivery   Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet   Model revision date: 10/11/2002

Replication ended at time   : 77088.0
Statistics were cleared at time: 70752.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	5060.5	(Insuf)	1710.9	11810.	20

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.08681	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.72955	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.18570	(Insuf)	.00000	1.0000	.00000
Field Service	.08681	(Insuf)	.00000	1.0000	.00000
Business Dev	.08207	(Insuf)	.00000	1.0000	.00000
Sales Busy	.08681	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	159.94	(Insuf)	154.00	166.00	166.00
Test Engineer	.16888	(Insuf)	.00000	1.0000	.00000
QA Busy	.08681	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.08681	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	3.1246	(Insuf)	.00000	7.0000	3.0000
Ideas in Bucket 2	.08245	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.03757	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	5.1424E+05	(Insuf)	91753.	1.0910E+06	4.3435E+05
Divisional Mngr 5	.00857	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	90954.	(Insuf)	83896.	1.8475E+05	1.8475E+05
Marketing Busy	.20779	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.01017	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.01018	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.01054	(Insuf)	.00000	1.0000	.00000
Construction Eng	.08681	(Insuf)	.00000	1.0000	.00000
Variable AK	14.077	(Insuf)	11.467	16.609	14.177
Project Team	.09070	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00876	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	5.7036E+05	(Insuf)	97915.	1.1898E+06	4.4959E+05
Variable AL	23.462	(Insuf)	19.113	27.681	23.628
Variable AM	46.924	(Insuf)	38.226	55.363	47.256
Busy Development Eng	.64549	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.08681	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	19	Infinite
Review2Meetings	35	Infinite
Review1Count	12	Infinite
PrelimCount	10	Infinite
Review1Meetings	35	Infinite
DesignCount	10	Infinite
ValueExecuted	1789591	Infinite
Ideas	224	Infinite
ExecutedCount	20	Infinite
PointMeetings	136	Infinite
Point1Fail	196	Infinite
Point2Fail	16	Infinite
Stagger1Count	10	Infinite

Point3Fail	1	Infinite
Point1Pass	28	Infinite
Point2Pass	12	Infinite
Point3Pass	12	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 13 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 83424.0
Statistics were cleared at time: 77088.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	3835.9	(Insuf)	1857.4	11949.	10

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.07418	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.48571	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.17575	(Insuf)	.00000	1.0000	1.0000
Field Service	.07418	(Insuf)	.00000	1.0000	.00000
Business Dev	.07388	(Insuf)	.00000	1.0000	1.0000
Sales Busy	.07418	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	171.15	(Insuf)	166.00	181.00	181.00
Test Engineer	.14806	(Insuf)	.00000	1.0000	1.0000
QA Busy	.07418	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.07418	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	3.2736	(Insuf)	.00000	9.0000	2.0000
Ideas in Bucket 2	.10394	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.05441	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.6985E+05	(Insuf)	1.8310E+05	8.1317E+05	8.1317E+05
Divisional Mngr 5	.01140	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	98910.	(Insuf)	82383.	1.8475E+05	91485.
Marketing Busy	.19866	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.00985	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00983	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00953	(Insuf)	.00000	1.0000	.00000
Construction Eng	.07418	(Insuf)	.00000	1.0000	.00000
Variable AK	14.165	(Insuf)	10.309	17.218	10.567
Project Team	.07235	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00998	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	3.7055E+05	(Insuf)	97915.	9.1108E+05	9.1108E+05
Variable AL	23.609	(Insuf)	17.182	28.698	17.612
Variable AM	47.218	(Insuf)	34.365	57.396	35.224
Busy Development Eng	.44578	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.07418	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	9	Infinite
Review2Meetings	35	Infinite

Results - Large value buffer.txt

Review1Count	15	Infinite
PrelimCount	8	Infinite
Review1Meetings	35	Infinite
DesignCount	8	Infinite
ValueExecuted	892529	Infinite
Ideas	232	Infinite
ExecutedCount	10	Infinite
PointMeetings	137	Infinite
Point1Fail	204	Infinite
Point2Fail	14	Infinite
Stagger1Count	12	Infinite
Point3Fail	0	Infinite
Point1Pass	28	Infinite
Point2Pass	14	Infinite
Point3Pass	15	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 14 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 89760.0
Statistics were cleared at time: 83424.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	4478.1	(Insuf)	1834.5	6319.1	16

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.15862	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.88860	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.32435	(Insuf)	.00000	1.0000	.00000
Field Service	.15862	(Insuf)	.00000	1.0000	.00000
Business Dev	.14393	(Insuf)	.00000	1.0000	.00000
Sales Busy	.15862	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	185.62	(Insuf)	181.00	191.00	191.00
Test Engineer	.30254	(Insuf)	.00000	1.0000	.00000
QA Busy	.15862	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.15862	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	3.9113	(Insuf)	.00000	11.000	2.0000
Ideas in Bucket 2	.09503	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.04104	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	5.8732E+05	(Insuf)	96754.	9.8510E+05	96754.
Divisional Mngr 5	.00887	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	94297.	(Insuf)	82586.	1.8333E+05	97781.
Marketing Busy	.34688	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00949	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00863	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00958	(Insuf)	.00000	1.0000	.00000
Construction Eng	.15862	(Insuf)	.00000	1.0000	.00000
Variable AK	13.686	(Insuf)	10.567	17.249	17.249
Project Team	.16683	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00926	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	7.6203E+05	(Insuf)	1.9291E+05	1.0936E+06	3.7049E+05
Variable AL	22.810	(Insuf)	17.612	28.749	28.749

Results - Large value buffer.txt

Variable AM	45.621	(Insuf)	35.224	57.499	57.499
Busy Development Eng	.73123	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.15862	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	17	Infinite
Review2Meetings	34	Infinite
Review1Count	10	Infinite
PrelimCount	17	Infinite
Review1Meetings	34	Infinite
DesignCount	17	Infinite
ValueExecuted	1441237	Infinite
Ideas	239	Infinite
ExecutedCount	16	Infinite
PointMeetings	137	Infinite
Point1Fail	214	Infinite
Point2Fail	13	Infinite
Stagger1Count	13	Infinite
Point3Fail	2	Infinite
Point1Pass	25	Infinite
Point2Pass	12	Infinite
Point3Pass	10	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 15 of 20

Project: Project delivery　　　　Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet　　　　Model revision date: 10/11/2002

Replication ended at time : 96096.0
Statistics were cleared at time: 89760.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	3329.5	(Insuf)	1215.3	8492.3	10

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.09312	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.38692	(Insuf)	.00000	1.0000	.00000
Manufacturing Eng	.20883	(Insuf)	.00000	1.0000	.00000
Field Service	.09312	(Insuf)	.00000	1.0000	.00000
Business Dev	.08838	(Insuf)	.00000	1.0000	.00000
Sales Busy	.09312	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	195.91	(Insuf)	191.00	202.00	202.00
Test Engineer	.18150	(Insuf)	.00000	1.0000	.00000
QA Busy	.09312	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.09312	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	2.0158	(Insuf)	.00000	6.0000	4.0000
Ideas in Bucket 2	.10509	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.05384	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.2892E+05	(Insuf)	96754.	5.2233E+05	5.2233E+05
Divisional Mngr 5	.01170	(Insuf)	.00000	1.0000	.00000

Results - Large value buffer.txt

Value Bucket 2	93221.	(Insuf)	81872.	1.7086E+05	91967.
Marketing Busy	.22857	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.01036	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.01117	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00940	(Insuf)	.00000	1.0000	.00000
Construction Eng	.09312	(Insuf)	.00000	1.0000	.00000
Variable AK	12.093	(Insuf)	7.9819	17.249	8.8106
Project Team	.11474	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.01268	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	3.3277E+05	(Insuf)	97915.	6.1853E+05	4.4439E+05
Variable AL	20.155	(Insuf)	13.303	28.749	14.684
Variable AM	40.311	(Insuf)	26.606	57.499	29.368
Busy Development Eng	.30736	(Insuf)	.00000	1.0000	.00000
Project Engineer	.09312	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	9	Infinite
Review2Meetings	35	Infinite
Review1Count	11	Infinite
PrelimCount	11	Infinite
Review1Meetings	35	Infinite
DesignCount	11	Infinite
ValueExecuted	889043	Infinite
Ideas	277	Infinite
ExecutedCount	10	Infinite
PointMeetings	138	Infinite
Point1Fail	251	Infinite
Point2Fail	12	Infinite
Stagger1Count	11	Infinite
Point3Fail	1	Infinite
Point1Pass	26	Infinite
Point2Pass	14	Infinite
Point3Pass	11	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 16 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 102432.0
Statistics were cleared at time: 96096.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	4428.9	(Insuf)	2260.3	6065.3	7

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.13573	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.61332	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.30917	(Insuf)	.00000	1.0000	.00000
Field Service	.13573	(Insuf)	.00000	1.0000	.00000
Business Dev	.12626	(Insuf)	.00000	1.0000	.00000

Sales Busy	.13573	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	209.31	(Insuf)	202.00	215.00	215.00
Test Engineer	.26199	(Insuf)	.00000	1.0000	.00000
QA Busy	.13573	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.13573	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	10.546	(Insuf)	.00000	19.000	19.000
Ideas in Bucket 2	.22116	(Insuf)	.00000	3.0000	1.0000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.10291	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	9.9435E+05	(Insuf)	5.2233E+05	1.3543E+06	1.3543E+06
Divisional Mngr 5	.01919	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	1.0889E+05	(Insuf)	81626.	2.7155E+05	95138.
Marketing Busy	.37090	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.01919	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.02024	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.02049	(Insuf)	.00000	1.0000	.00000
Construction Eng	.13573	(Insuf)	.00000	1.0000	.00000
Variable AK	7.1793	(Insuf)	5.6990	8.8106	8.2538
Project Team	.12636	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.02011	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	8.8759E+05	(Insuf)	2.7683E+05	1.4588E+06	9.8844E+05
Variable AL	11.965	(Insuf)	9.4983	14.684	13.756
Variable AM	23.931	(Insuf)	18.996	29.368	27.512
Busy Development Eng	.55994	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.13573	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	12	Infinite
Review2Meetings	35	Infinite
Review1Count	13	Infinite
PrelimCount	14	Infinite
Review1Meetings	34	Infinite
DesignCount	14	Infinite
ValueExecuted	637907	Infinite
Ideas	457	Infinite
ExecutedCount	7	Infinite
PointMeetings	138	Infinite
Point1Fail	402	Infinite
Point2Fail	24	Infinite
Stagger1Count	14	Infinite
Point3Fail	2	Infinite
Point1Pass	55	Infinite
Point2Pass	30	Infinite
Point3Pass	13	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 17 of 20

Project: Project delivery Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet Model revision date: 10/11/2002

Replication ended at time : 108768.0
Statistics were cleared at time: 102432.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	7364.0	(Insuf)	4929.9	10037.	9

Results - Large value buffer.txt

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.11191	(Insuf)	.00000	1.0000	1.0000
Busy Project Manager	.57659	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.35096	(Insuf)	.00000	1.0000	1.0000
Field Service	.11191	(Insuf)	.00000	1.0000	1.0000
Business Dev	.19255	(Insuf)	.00000	1.0000	.00000
Sales Busy	.11191	(Insuf)	.00000	1.0000	1.0000
Ideas in Final Bucket	226.38	(Insuf)	215.00	247.00	247.00
Test Engineer	.30446	(Insuf)	.00000	1.0000	1.0000
QA Busy	.11191	(Insuf)	.00000	1.0000	1.0000
Cost Analyst	.11191	(Insuf)	.00000	1.0000	1.0000
Ideas in Bucket 3	19.631	(Insuf)	.00000	36.000	12.000
Ideas in Bucket 2	.25526	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.09287	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.0323E+06	(Insuf)	1.3543E+06	3.2193E+06	3.2193E+06
Divisional Mngr 5	.02182	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	97753.	(Insuf)	81303.	1.8380E+05	90248.
Marketing Busy	.38843	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.02252	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.02396	.00515	.00000	1.0000	.00000
Divisional Mngr 2	.02264	(Insuf)	.00000	1.0000	.00000
Construction Eng	.11191	(Insuf)	.00000	1.0000	1.0000
Variable AK	7.3722	(Insuf)	5.5878	9.5719	7.1528
Project Team	.09439	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 1	.02220	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	1.3094E+06	(Insuf)	1.8572E+05	3.0465E+06	3.0465E+06
Variable AL	12.287	(Insuf)	9.3130	15.953	11.921
Variable AM	24.574	(Insuf)	18.626	31.906	23.842
Busy Development Eng	.54036	(Insuf)	.00000	1.0000	.00000
Project Engineer	.11191	(Insuf)	.00000	1.0000	1.0000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	6	Infinite
Review2Meetings	34	Infinite
Review1Count	32	Infinite
PrelimCount	22	Infinite
Review1Meetings	35	Infinite
DesignCount	12	Infinite
ValueExecuted	802717	Infinite
Ideas	443	Infinite
ExecutedCount	9	Infinite
PointMeetings	137	Infinite
Point1Fail	379	Infinite
Point2Fail	36	Infinite
Stagger1Count	30	Infinite
Point3Fail	4	Infinite
Point1Pass	64	Infinite
Point2Pass	29	Infinite
Point3Pass	32	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 18 of 20

Project: Project delivery　　Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet　　Model revision date: 10/11/2002

Results - Large value buffer.txt

Replication ended at time   : 115104.0
Statistics were cleared at time: 108768.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	9923.2	(Insuf)	6327.0	15135.	25

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.16824	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	.98913	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.28495	(Insuf)	.00000	1.0000	.00000
Field Service	.16824	(Insuf)	.00000	1.0000	.00000
Business Dev	.06944	(Insuf)	.00000	1.0000	.00000
Sales Busy	.16824	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	258.57	(Insuf)	247.00	266.00	266.00
Test Engineer	.23768	(Insuf)	.00000	1.0000	.00000
QA Busy	.16824	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.16824	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	10.773	(Insuf)	.00000	21.000	14.000
Ideas in Bucket 2	.15323	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.08261	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.3984E+06	(Insuf)	1.8853E+06	3.2193E+06	1.8853E+06
Divisional Mngr 5	.01482	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	1.0104E+05	(Insuf)	81627.	1.9181E+05	91011.
Marketing Busy	.32472	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.01440	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.01422	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.01702	(Insuf)	.00000	1.0000	.00000
Construction Eng	.16824	(Insuf)	.00000	1.0000	.00000
Variable AK	10.010	(Insuf)	7.1528	13.592	13.592
Project Team	.19244	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.01537	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	3.1356E+06	(Insuf)	2.4970E+06	4.2805E+06	2.4970E+06
Variable AL	16.684	(Insuf)	11.921	22.654	22.654
Variable AM	33.369	(Insuf)	23.842	45.308	45.308
Busy Development Eng	.83507	(Insuf)	.00000	1.0000	1.0000
Project Engineer	.16824	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	28	Infinite
Review2Meetings	35	Infinite
Review1Count	19	Infinite
PrelimCount	8	Infinite
Review1Meetings	35	Infinite
DesignCount	18	Infinite
ValueExecuted	2253747	Infinite
Ideas	326	Infinite
ExecutedCount	25	Infinite
PointMeetings	141	Infinite
Point1Fail	283	Infinite
Point2Fail	20	Infinite
Stagger1Count	10	Infinite
Point3Fail	2	Infinite
Point1Pass	43	Infinite

Results - Large value buffer.txt

Point2Pass	23	Infinite
Point3Pass	19	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 19 of 20

Project: Project delivery
Analyst: Konstant Bruinet
Run execution date : 1/ 1/1998
Model revision date: 10/11/2002

Replication ended at time : 121440.0
Statistics were cleared at time: 115104.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	11817.	(Insuf)	7140.4	16465.	17

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.25695	(Insuf)	.00000	1.0000	1.0000
Busy Project Manager	.98970	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.56646	(Insuf)	.00000	1.0000	1.0000
Field Service	.25695	(Insuf)	.00000	1.0000	1.0000
Business Dev	.28725	(Insuf)	.00000	1.0000	.00000
Sales Busy	.25695	(Insuf)	.00000	1.0000	1.0000
Ideas in Final Bucket	273.85	(Insuf)	266.00	285.00	285.00
Test Engineer	.54420	(Insuf)	.00000	1.0000	1.0000
QA Busy	.25695	(Insuf)	.00000	1.0000	1.0000
Cost Analyst	.25695	(Insuf)	.00000	1.0000	1.0000
Ideas in Bucket 3	10.465	(Insuf)	.00000	21.000	2.0000
Ideas in Bucket 2	.08979	(Insuf)	.00000	2.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.06010	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	1.7432E+06	(Insuf)	2.6122E+05	1.9004E+06	2.6122E+05
Divisional Mngr 5	.00780	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	93204.	(Insuf)	82858.	1.8220E+05	88067.
Marketing Busy	.59971	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 4	.00789	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00817	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00762	(Insuf)	.00000	1.0000	.00000
Construction Eng	.25695	(Insuf)	.00000	1.0000	1.0000
Variable AK	19.208	(Insuf)	13.592	25.829	25.829
Project Team	.25871	(Insuf)	.00000	1.0000	1.0000
Divisional Mngr 1	.00848	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	2.4365E+06	(Insuf)	1.8847E+06	3.3270E+06	2.6790E+06
Variable AL	32.014	(Insuf)	22.654	43.049	43.049
Variable AM	64.029	(Insuf)	45.308	86.099	86.099
Busy Development Eng	.74893	(Insuf)	.00000	1.0000	.00000
Project Engineer	.25695	(Insuf)	.00000	1.0000	1.0000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	14	Infinite
Review2Meetings	35	Infinite
Review1Count	19	Infinite
PrelimCount	33	Infinite

Results - Large value buffer.txt

Review1Meetings	34	Infinite
DesignCount	27	Infinite
ValueExecuted	1521637	Infinite
Ideas	166	Infinite
ExecutedCount	17	Infinite
PointMeetings	129	Infinite
Point1Fail	144	Infinite
Point2Fail	10	Infinite
Stagger1Count	23	Infinite
Point3Fail	5	Infinite
Point1Pass	22	Infinite
Point2Pass	12	Infinite
Point3Pass	19	Infinite

ARENA Simulation Results
K.Bruinette - License #9400000

Summary for Replication 20 of 20

Project: Project delivery — Run execution date : 1/ 1/1998
Analyst: Konstant Bruinet — Model revision date: 10/11/2002

Replication ended at time : 127776.0
Statistics were cleared at time: 121440.0
Statistics accumulated for time: 6336.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
ProjectTAT	12329.	(Insuf)	6833.9	29530.	24

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Process Engineer	.15104	(Insuf)	.00000	1.0000	.00000
Busy Project Manager	1.0000	(Insuf)	.00000	1.0000	1.0000
Manufacturing Eng	.25616	(Insuf)	.00000	1.0000	.00000
Field Service	.15104	(Insuf)	.00000	1.0000	.00000
Business Dev	.09470	(Insuf)	.00000	1.0000	.00000
Sales Busy	.15104	(Insuf)	.00000	1.0000	.00000
Ideas in Final Bucket	287.31	(Insuf)	285.00	290.00	290.00
Test Engineer	.24573	(Insuf)	.00000	1.0000	.00000
QA Busy	.15104	(Insuf)	.00000	1.0000	.00000
Cost Analyst	.15104	(Insuf)	.00000	1.0000	.00000
Ideas in Bucket 3	1.6832	(Insuf)	.00000	4.0000	1.0000
Ideas in Bucket 2	.03671	(Insuf)	.00000	1.0000	.00000
# in Marketing_Q	.00000	(Insuf)	.00000	.00000	.00000
Research Eng	.02099	(Insuf)	.00000	1.0000	.00000
Value Bucket 3	2.4638E+05	(Insuf)	92841.	3.6008E+05	92841.
Divisional Mngr 5	.00332	(Insuf)	.00000	1.0000	.00000
Value Bucket 2	92696.	(Insuf)	80972.	97986.	90697.
Marketing Busy	.26617	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 4	.00449	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 3	.00322	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 2	.00286	(Insuf)	.00000	1.0000	.00000
Construction Eng	.15104	(Insuf)	.00000	1.0000	.00000
Variable AK	36.873	(Insuf)	25.829	50.311	50.311
Project Team	.16116	(Insuf)	.00000	1.0000	.00000
Divisional Mngr 1	.00342	(Insuf)	.00000	1.0000	.00000
Value Final Bucket	1.9783E+06	(Insuf)	1.0110E+06	2.6790E+06	1.0110E+06
Variable AL	61.455	(Insuf)	43.049	83.852	83.852
Variable AM	122.91	(Insuf)	86.099	167.70	167.70
Busy Development Eng	.82653	(Insuf)	.00000	1.0000	1.0000

Project Engineer	.15104	(Insuf)	.00000	1.0000	.00000

COUNTERS

Identifier	Count	Limit
Stagger2Counter	24	Infinite
Review2Meetings	35	Infinite
Review1Count	5	Infinite
PrelimCount	11	Infinite
Review1Meetings	35	Infinite
DesignCount	17	Infinite
ValueExecuted	2120900	Infinite
Ideas	90	Infinite
ExecutedCount	24	Infinite
PointMeetings	135	Infinite
Point1Fail	81	Infinite
Point2Fail	5	Infinite
Stagger1Count	11	Infinite
Point3Fail	0	Infinite
Point1Pass	9	Infinite
Point2Pass	4	Infinite
Point3Pass	5	Infinite

Simulation run time: 2.47 minutes.
Simulation run complete.