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Accelerated New Product Development in Credit Card Industry

**A thesis submitted in partial satisfaction
of the requirement for the degree Master of Science
in Management**

by

Ravi Kumar Gupta

2012

ABSTRACT OF THE THESIS

Accelerated New Product Development in Credit Card Industry

by

Ravi Kumar Gupta

Master of Science in Management

University of California, Los Angeles, 2012

Professor Reza Ahmadi, Chair

Credit card industry has seen an unforeseen combinatorial environment of governmental regulations, economic landscape overhauling, significant drop in lending rates, deleveraging and irreversible integration of disruptive technology for credit extension and payment solutions. In this ever changing landscape, card issuers would have to launch new products which reflect these changes. Early capture of market share would be critical from a profitability and long term market share standpoint and the first mover would capture the lions' share. In order to quickly launch the product, firms would need robust product development strategies to meet the market timing while keeping the cost of expedition low. In this paper, we develop models to provide accelerated new product development strategies for credit card issuers which provide expedition of time to market at an optimally low cost. We develop special cases of possible project scenarios and provide solutions for them.

The thesis of Ravi Kumar Gupta is approved.

Rakesh Sarin

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University of California, Los Angeles

2012

DEDICATION

Thanks to

My wife, without whom I wouldn't have accomplished this

My parents and brother, without whom I wouldn't have gotten here

Professor Reza, without whom I wouldn't have finished

Professor Sarin, without whom I wouldn't have re-started

Lydia, who helped me smoothen the long distance
collaboration

friends, who made this time enjoyable

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CHAPTER 1

Introduction

Consumer Finance industry is among the leading industry in the US economy and provides liquidity – convenient and timely access to capital that facilitates day-to-day transactions. Capitalism could exist without it, but only at a much slower pace. The total consumer credit in the U.S as of March 2011 is \$2.43 trillion [1] [2]. We would focus on the revolving credit section of this industry and more specifically on the credit card industry.

Total revolving credit as of March 2011 comprised \$790 billion (33% of total) of which credit card debt re-presents 98%. In a U.S Population of 307 million and 107 million households, as of 2009 consensus report [3], there were 180 million credit card holders who carry 1.4 billion credit cards among them. 78% of the U.S. consumers have at least 1 credit card and 51% have at least 2 credit cards. The average number of credit cards held by a U.S. consumer is 3.5 [1] and average credit card debt per household with credit card debt is \$ 14,743.

On average, today's consumer has a total of 13 credit obligations on record at a credit bureau. These include credit cards (such as department store charge cards, gas cards, and bank cards) and installment loans (auto loans, mortgage loans, student loans, etc.). Of these 13 credit obligations, nine are likely to be credit cards and four are likely to be installment loans [1].

For small businesses as well, credit cards are the most common source for financing and the second most common financial product after checking accounts. As of 2009, 83% of small businesses used credit cards; 64 percent used small business cards, and 41 percent used personal cards [5]. More than 20% of firms applying for a credit card were not able to get a card, and another 5.6% did not accept the card because of unfavorable terms [5]. Typically, there are 20 billion credit card transactions in a year which represent \$1.9 trillion in value. This represents

12.9% of the U.S gross domestic product. The average customer swipes the card 119 times in a year which totals to \$10,500 in value in a year [6]. In the 1980-2000's, there were 4000 card issuers where the top 10 issuers had only 40% of the market share. In contrast, today the top 10 issuers constitute 77% of the market share with Chase and Bank of America leading the pack and enjoying 33% of the market share together. Acquisitions and buy-over has led to such dramatic consolidation of the market players [1] [4] [9]. Since 1950, when the first diner's credit card was introduced, the industry has come a long way. The chart below shows the consistent growth of the credit card national debt from 1968 to 2008 [11] [12].

In Figure 1.1, we can see that consumer credit card debt has increased almost exponentially over the last 40 years and the recent economic debacle in 2008 has led to a significant drop from 2008 to 2010. However, in 2010-11, a plateau of the decline has been reached and the industry experts strongly feel that there would be a dramatic uptick in the curve. This belief is supported by the deluge and uptick of direct mail solicitations in early 2011 [16] [18] [19] [20].

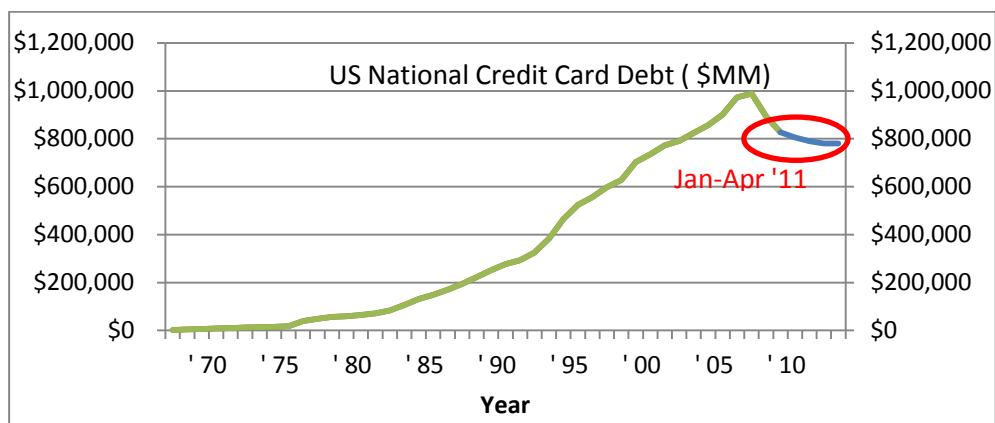


Figure 1.1 US National Credit Card Debt from 1968-2011.

In this cautious but speedy growth environment, card issuers are targeting a huge increase in the direct mail solicitations and companies are working overtime to attract borrowers with good and bad credit. The following specific facts show the most recent phenomenon in the consumer behavior which would require a big overhaul of the new product development of the credit card industry.

- 1) Significant increase in reward seeking behavior: About 60% of consumers have a rewards credit card. [1] [23]
- 2) Oncoming disruptive technology advancement such as contactless cards, Credit Card 2.0, credit extension via cell phones (such as Google Wallet) [1]. About 26% of consumers already have a contactless credit card. [23]
- 3) Low cost of fund environment – One of the key features of a credit card, its APR depends primarily on the prime lending rate and the riskiness of the customer base. The prime lending rate which defines the cost of funding of the loan is at a historic low rate of 3.25% in 2010-11 period [22]. In such a low funding environment any product with high APR would experience dismal response rates due to the APR being uncompetitive. The prime rate fluctuates significantly across years requiring the card companies to update their products to reflect this fluctuation.

These trends would have to be captured in the new products with great speed as the customer loyalty is at an all time low in the card industry. A survey result shows that 67% of consumers are ready to switch to new products which have new features [21]. Additionally, the high adoption pattern in the primary market clubbed with slow switching post adoption in the secondary market [8], leads to huge first movers advantage ; making the time to market the most critical aspect of the new product launch. Even marginal delay in product launch would mean

huge cannibalization of market share to competition. The loss in market share is as huge as 22% when one moves from the being the first mover to going second in order of market launch [49]. The firm that goes 10th in order gets at most 11% of the market share as compared to the first mover

Additionally, given the low mail volume during 2008-10, limited in-market testing has been done to really understand the elasticity curves of the customer base across different dimension of the card offer. Given the elasticity curves are time sensitive, in market test need to be launched as early as possible so that early reads can be used to realize a roll out of the ‘optimal’ product as early as possible.

Due to such time pressure on new product development and launches, Accelerated New Product Development process is increasingly becoming the focus for senior management in the credit card services industry. All of the factors discussed above underscore the need to be able to design, develop, and launch, in a timely fashion, new products that are winners. A strong new product initiative is now considered an essential weapon in both aggressive and conservative initiatives. The quote below from a Director of Marketing at a leading US Credit Card Issuer highlights the same need.

“If we could compress the time between in-market testing and final product roll-out, it would result in significant competitive advantage due to a) pull-forward revenue resulting from early launch b) improved market share from first mover advantage c) better likelihood of attracting more engaged customer before competition snags them and d) better use of marketing dollars spent on a product with higher probability of success” –
Director of Marketing, Leading US Credit Card Issuer, June 2011

In the scenario of a delay in product launch, the firm would suffer a significant loss in the market share due to losing the first mover advantage. Lopez et.al analyzed product history data for financial services industry and established a relationship between the delay in product launch from the first mover and the drop in the market share as a ratio of the first movers' market share. Figure 1.2 shows the relationship. Given this huge loss, it is only prudent to invest in acceleration of new product development. To achieve this, executives are increasingly re-examining their organizations' approach to development and launching of new products to determine if the process can be redesigned for faster reaction time and hence improved success rates and market share.

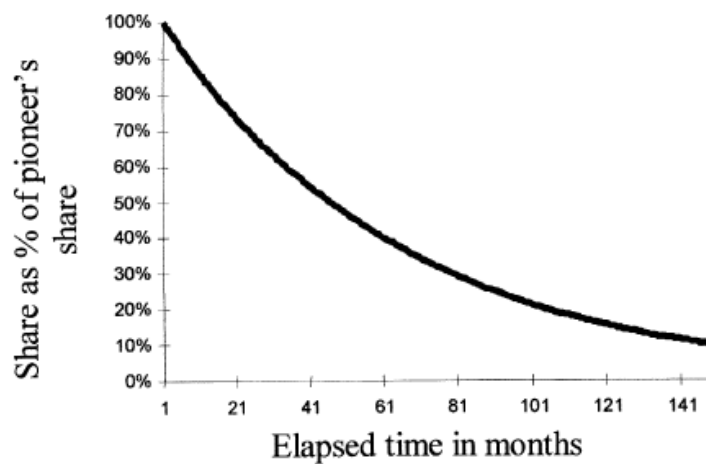


Fig. 5. Results of final model of elapsed time since first entry vs. market share for a prototypical financial services case.

Figure 1.2 Impact of Delay in Product Launch on Firm's Market Share in Financial Services Industry

Currently, most of the firms have almost all of the steps executed in the United States with some steps outsourced to low cost centers in India and China. The expedition of the mail production is done on an ad-hoc basis and due to lack of any organized effort, also leads in delay of mail drop as well as unhappy employees and upper management. In this paper, we attempt to

provide an organized product development model which effectively uses levers such as ‘overlapping’ and outsourcing as levers to a) efficiently and effectively meet the time to market and b) keep the cost of expedition to an optimally low value.

The rest of the paper is structured as follows. In Chapter 2, we review the relevant literature and the current state of the Knowledge Process Outsourcing (KPO) industry. In Chapter 3, we describe the problem in detail, our modeling approach and including the characterization of the rework function which is a result of the overlapping technique, the involved development steps and the product features under development. In Chapter 4, we address the relevant various scenarios which are prevalent in a financial services production environment and provide solutions (and heuristics) for them. In Chapter 5, we provide experimental results based on data generated using industry information and experience of the author in the industry. In section 6, we conclude our paper and provide future research direction.

CHAPTER 2

Literature Review

2.1 New Product Development – Review of Current Research

Our objective in this paper is to develop models and provide strategies via efficient solutions that enable product managers in consumer finance firms to meet the time to market for new card product launch with minimal additional cost. We consider the technique of overlapping ‘core’ activities and outsourcing resulting ‘rework’ activities to meet the time and cost criterion without compromising on quality.

The problem of reducing product development time has been prevalent in the manufacturing industry and hence has generated significant research. The most relevant stream of research looks at how to organize information flows and re-sequence tasks so as to reduce product development times.

In the earlier years of this research stream, overlapping had been established as the ‘core technique for saving development time’ and also the fact that faster product development cycles are most frequently characterized by overlapping product design activities has been established by Imai et al. (1985) [24], Clark and Fujimoto (1989) [25], Smith and Reinertsen (1995) [26] and Takeuch and Nonaka (1986) [27]

Overlapping product design activities differs from the sequential (traditional) approach in that it allows downstream design stages to start before preceding upstream stages have finalized their specifications. As it utilized incomplete information, it requires different ways of communication and co-operations across design stages. The initial years of the research was focused on addressing the information processing, communication and organizational challenge caused due to overlapping. In the later years, however, there has been an interesting body of

research which has introduced different design process models. Carrasosa et al. (1998) [28] is representative of this stream. They estimate the probability of completing a product development project by analyzing the design structure matrix. Smith and Eppinger (1997) [29] present an algorithm for ordering activities to minimize expected completion times. Krishnan et.al. (1997) [30] provide a model-based framework to manage two overlapping coupled activities in which changing the parameters of the first (upstream) activity affects the design of the second (downstream) activity. Loch and Terweisch (1998) [31] present a model for overlapping two activities to minimize completion time. Terweisch and Loch (1999) conduct a statistical analysis on the impact of overlapping activities in different industries. Ahmadi et al. (2001) [32] determine how the activities of a development process should be ordered to minimize the feedback of information from the downstream activities to upstream activities. Roemer et al. (2000) [33] develop models to analyze the time-cost tradeoffs that arise when activities overlap in a project. Roemer and Ahmadi (2004) [34] address the problem of concurrently crashing and overlapping activities. Joglekar et al. (2001) [35] explore overlapping strategies for two coupled activities to maximize overall quality for fixed development time. Joglekar and Ford (2005) [36] use simulation to provide insights into how to allocate resources in a product development process. Roemer et al. (2000) [33] also developed models for scenarios where multiple projects compete for shared resources for projects up to 3 stages. Literature which looks at projects in the financial services industry which have significantly higher number of stages is rather limited. In this paper, we contribute to this field by addressing the problem of how to best schedule multiple projects with multiple stages with the application for and motivation from the financial services industry. We also leverage outsourcing in a successful way to keep the additional cost at a minimal.

2.2 Operations in Credit Card Industry – Review of Current Research

Operations literature has historically focused on manufacturing industry. However, in the last two decades, there has been moderate focus on the services industry with majority of this initiative focused on the transportation, health care, entertainment and hospitality industries. The focus on financial services however has been very limited. The operations techniques developed for manufacturing has only limited applicability in the financial services industry as there are key differences in the characteristics of the business operations such as how fungible is the product, frequency of service encounters and use of technology [37] . Hence, techniques which are applicable to financial services industry should be developed independently.

Additionally, the current literature focuses mainly on topics such as systems design, forecasting, inventory and cash management, operational risk management and pricing and revenue management. Hatzakis et. al. (2010) [37] provides a comprehensive view of the literature for each of these research streams in details and highlights that existing literature in financial services operations have a narrow focus. He also mentions that new research should be encouraged in neglected and/or emerging areas such as new product development. One key factor which would make service operations very successful in the field of financial services is the convergence of operations, finance, marketing and technology [37]. The use of statistics, technology and optimization for service research and design for optimization can really increase the efficiency and effectiveness of financial services.

Moreover, financial services executives view product innovation as the most important and expect a growing role for business model innovation. A McKinsey survey [38-] in 2007 of 312 executives around the globe, of which 33% were C-level, showed that innovation will be a major competitive battleground in the financial-services industry. Respondents, who represent

public and private firms in retail banking, asset management, investment banking, insurance, and other financial services, consider product innovation to be very important and view business model innovation as growing in importance.

However, it was also pointed out that innovation was more challenging in financial-services institutions than for companies in other sectors. Though there have been pockets of successful innovation, but the efforts are not developed and sustained throughout the company. Given the fact that firms have significant room to improve performance on a number of common best practices for fostering innovation, such as using consumer insights to drive new products and dedicating organizational structures and funds to innovation, what is required is a structured framework which can enable this phenomenon in successful manner. Hence, academic and industrial research in this direction is very crucial. This paper is an attempt to add to this upcoming initiative in the industry.

It has also been shown that new innovative products and speed-to-market of the innovation would hold the key in the success of these initiatives [39]. As mentioned in the introduction, the rationale for such criticality is innovation in information technology, changes in industry regulation and fast-moving consumer demands. There has been some literature [39] [40] [41] which emphasizes its importance and provides a conceptual framework around it but does not provide an operational solution to the problem. This paper has attempted to provide the same.

Drew (1995) emphasizes that new products and speed-to-market are the key to growth of financial services and it requires full top management commitment, employee motivation and proactive use of technology and outsourcing [39]. Naude et.al. (1998) [40] use a case study to summarize the benefits, challenges and managerial implications of real time new product development where the products are basically web-based solutions which incorporate real-time

feedback from a select group of customers. They conclude that the use of web for communication between customers and providers would rapidly increase and blur the line between market research and new product development as well as raise the customer expectation levels as well as the pressure on innovation. Edgett and Jones (1991) [41] identify the factors for success for new product development via a case study for a financial institution in UK. They conclude that the most important factor would be the high level of detail, thoroughness and good organization of the development process. Other factors such as adequate financial resources, well identified target market were also important. Thwaites (1992) [42] identifies the key organizational factors which decide the chances of success of new product development in a given firm. The top two things which, he concludes, make the biggest difference are a) the link of mission-people-communication and b) lead time for organization to change the culture to incorporate an 'innovation' atmosphere. In a similar vein, Beard and Dougan (2004) [43] have published a Business Insights Report where they examine the reasons why many in the financial sector have difficulties in implementing innovative projects and offers step-by-step guidelines on how each step of the NPD process can be integrated into organizational culture. Storey et.al (1993) [45] also emphasize the importance of NPD in the success of financial institutions in the UK market, specially the speed of development and its integration with the organization. Hence, we observe that there is abundant literature which concludes that innovation is critical for growth of a financial institution and provides various organizational characteristics which should be conducive to such innovation. However, there is very scarce literature which develops operational models for such new product development in the finance industry. This paper attempts at providing a solution to this issue.

2.3 Outsourcing – Industry Practice and Current Research Overview

Outsourcing in financial services industry has come of ages. Since the 1970's, when it was used by financial institutions for clerical activities such as printing customer financial statements, storing records and mostly back-office business processes, it has come a long way to a stage where the outsourcing company plays a strategic partnership with the client due to a) outsourcing enabling innovation in the information technology industry, b) low cost and stable communication links due to telecom deregulation and increase in bandwidth, c) potential supply of workers to meet changing needs due to availability of talented, well-educated human resources in countries such as India, Russia, and China and d) high quality of the supporting tools and application software [35].

Integration applications and business process management software have become more scalable and sophisticated due to huge improvements in the computing effectiveness due to ground breaking innovation in information technology. Differences in the costs of resources between countries such as India, China and Russia and those in the west still yields an almost immediate cost arbitrage opportunity of at least 30%-50%. The definition and wide acceptance of quality standards such as ISO, SEI CMM and Six-sigma have ensured the quality of business processes moved offshore can be enhanced through a focus on productivity improvement.

The range of business processes being off-shored is continually increasing. Many companies have taken the "core competency" approach to selecting processes to move offshore such as finance, accounting, and human resource management. Companies are also tapping into more highly skilled resources, such as lawyers, accountants, engineers, and investment, consumer, business researchers, to perform more value-added processes such as product design, pharmaceutical research, tax processing, and investment research. This practice of outsourcing

skilled work which requires domain knowledge is called “Knowledge Process Outsourcing (KPO)”.

KPO industry boasts of growing client interest due to unparalleled focus on cost competitiveness and time to market of products and services. Globalization of business has matured and companies are now incorporating off shoring as part of their forward-looking strategies rather employing it as a knee-jerk reaction to cost pressures only. Encouraged by the early success of off shoring in the Information Technology Outsourcing (ITO) and Business Process Outsourcing (BPO) sectors, companies are increasingly exploring the value of sending high-end processes offshore, including ones that directly affect their revenue generation capabilities. This has given rise to much talk about KPO.

TPI, an Information Services Group company, founder and innovator of the sourcing advisory industry, observes growing client interest in KPO services. They deem the industry viable, vibrant and likely to experience steady growth due to significant client interest and attention. Current market estimates indicate that the industry will grow at or higher than the BPO growth rates to reach US\$10–15 billion by 2010-11 based on a CAGR of 50-70% [52]. There has been debate about the estimated being optimistic, but there is consensus around the significant exponential growth of the KPO industry. Compared to the growth of BP and IT outsourcing, which has experienced a growth of 34% in the last 5 years and is forecasted a growth of 24% in the next 5 years, KPO is being forecasted to grow significantly faster compared to BP and IT sectors. A research study was done in India, which represents ~75% of the service providers and revenue generators, for sizing the current status of the KPO industry. It was found that 64 BPO service providers (88% of all) and 23 company owned off-shore teams (captive units) (51% of all) were providing KPO services with the help of 18,000 resources. 65% of these units were

serving the financial services verticals and 26% were serving the business & market intelligence verticals. Rest comprised of pharmaceutical, legal and engineering research.

There is a clear cost benefit which is provided by the KPO industry. A comparative study by TPI shows that in the financial services [53], an investment research analyst costs a firm in New York a total of ~ US\$225,000 in contrast to a total cost of ~US\$60,000 in India. The quality of work and the service delivery is similar given the evolved level of quality control, high-quality resource availability and telecommunication. Hence, there is significant cost benefit to be achieved with a mere change of work location using the KPO services. We use this lever as a significant cost level in our model for new product development.

Given the high emphasis on information security and increase in complexity of analysis, firms are also increasing their inclination towards captive units as opposed to outsourcing. Given the amount of sensitive intellectual property, in-house data and analytical techniques, which form the core competency of some of these firms, which are shared with the off-shore team, firms prefer to use their own subsidiary (captive units) as opposed to third party outsourcers. Also, the clients of KPO services are typically the huge firms, for example, the Fortune 2000 firms as they have the scale to consume such services. Most of these firms already have captive units which are used for more and more sophisticated analytical work. Our interaction with a leading US credit card issuer revealed that they have a significant size captive unit in India, which assists them in market research and credit risk analysis.

We believe that the already in-production captive units can be very 'optimally' utilized for the rework section of the new product development given it already has the structure required for the development process and hence cost effectiveness could be the focus. We would elaborate further on this in the coming section.

In our research, we share with the authors, the focus on short design lead times and minimization of the incurred cost in the process. We combine the benefits of outsourcing and overlapping to meet the time to market with significantly low additional cost. In spite of the fact that this work is motivated by a problem in the credit card industry, it is very applicable to other asset classes in this industry such as mortgage, life and auto insurance. Also, it is equally applicable in any services industry such as software services and retailing. It is also applicable for telecommunication industry where the product shelf life is short such as cell phones and other consumer electronics.

CHAPTER 3

Problem Description and Model Formulation

3.1 NPD for a Credit Card and the Need for Overlapping

After the strategic decision to launch a new product is taken, a series of design and development steps are followed to take the product from a concept to an actual offer in the mail. These product development steps are as follows:

a. Proof of Concept - Test Results or New Market Trend

The proof of concept, which explains why the new product would be the next market winner, is developed in this stage. This is done in two ways: 1) If the firm had the foresight and had done in- markets testing prior, the test results are used as a proof. 2) Market research data which shows the trend leaning towards the new product in contention.

b. Product Features Development

Comprehensive features of the product are developed in this step such as credit line, APR, nature of the promotional period offer, fee structure, terms and conditions. These features are developed in response to the particular market landscape for which the product is a response.

c. Profitability and Risk Analysis

This step typically involves significant quantitative analysis where the business analyst(s) estimate the profitability and inherent credit risk which the firm would incur with the launch of the new product. The results of this step play a crucial role in the decision making of the product launch.

d. P&L Forecasting

Finance team develops the loan amount estimate which the new product would attract and ensures sufficient capital and secured funding is present for smooth operations.

e. Prospect Pool Determination

Prospect Screening team develops the screening criteria to ensure ‘Do-Not-Solicit’ list and similar lists have been eliminated from the potential customer pool.

f. Systemic Implementation

Once the previous steps have been completed, the following steps are the final steps which actually prints and sends out the offers. i) Compile Names ii) Verify Credit and Address iii) Data Merge iv) transfer to Vendors v) Print and Mail

Step b) & c) have a feedback look from step d) due to the fact that if a particular product feature does not prove to have enough ROI, enough NPV or too high of a risk, the product features are re-designed to reach the required target values. Fig. 3.1 shows the systemic steps in a flow chart.

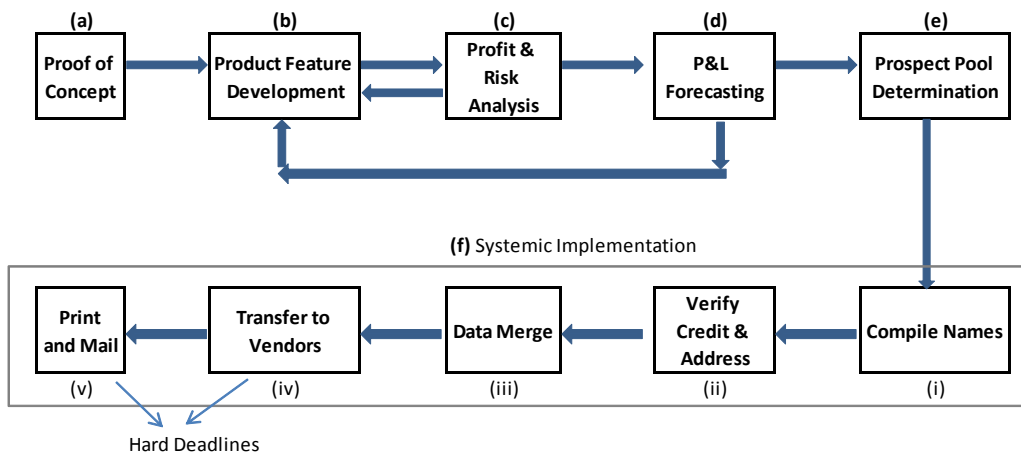


Figure 3.1 Operational Flow of Card Offer Production

The key features of a credit card which are modeled in these above mentioned development stages are:

- 1) Annual Percentage Rate (APR – Interest Rate)
- 2) Credit Line
- 3) Rewards

- 4) Introductory Rate for Balance Transfers
- 5) Introductory Period for Balance Transfers
- 6) Introductory Rate for Purchases
- 7) Introductory Period for Purchases
- 8) Balance Transfer Fee at Originations
- 9) Annual Membership Fees
- 10) Credit Extension Criteria

The various development steps described above essentially design the various features of the card as laid out above and develop the a) risk b) response c) profitability and d) balance build behavior of the customers. This is done via mathematical modeling with the use of the existing behavior history and product feature details. The modeling is done by deploying various statistical analytical tools such as Regression Analysis, CHAID Analysis via various software applications such as Microsoft Excel, SAS, and MATLAB. There is typically feedback across the design stages but in this model we assume that all the feedback incorporation for the upstream processes are incorporated in the estimated processing time as the processing time estimation is done such that it allows and allocated a time window and work load to process feedback from the downstream stages.

The new goals of faster reaction time can be achieved if the New Product development process can be re-structured in order to delivers the required product “on time” at an acceptable cost. The faster reaction time objective basically means that the projects would have to be completed in less than the standard time taken these projects which has historically been a sum of the estimated processing time of all the involved steps which are a subset of the steps explained previously. Currently, firms use an ad-hoc crashing process where ‘heroic’ crunch

work of a few employees is used to meet deadlines towards the end of a project. Also, when such crunch work is infeasible, the firm decides to push out the deadline by a month leading to a market share loss which is not quantified. A more structured approach to lead time management is our proposal here.

As the estimated processing time per step cannot be reduced, expedition of product development or reduction of product development time can be achieved by either a) Crashing or b) overlapping.

We choose overlapping over crashing as a methodology for the following reasons:

- 1) Similar to engineering sector, credit card analytics workload need domain knowledge and given the fact that firm specific analytical approach requires all analysts to spend time understanding the business model and the process before they can be used for productive work. Hence, 'crashing' a project with additional resources might lead to lead-time increase in place of reduction.
- 2) Business analysts become assets for a company and a firm would impose a risk of sensitive intellectual property loss when a contract worker leaves the company post project completion and then is hired by a competitor.
- 3) The new products in the card industry are typically an improvement on the features of the card from the firms' existing best in class products. Hence, overlapping would be more effective as the analysts would have the background and experience of the previous product development as opposed to crashing as the new resources would not have the same background as the existing analysts.

Hence, we would be employing overlapping as our technique to start and finish all but the first design step and finish earlier or on the project deadline. The key is that the development lead

time $L_{overlap}$ is shorter than the lead time for sequential product development required time $L_{sequential}$ and this reduction in lead time is the benefit of overlapping. Figure 3.2 shows the impact of overlapping on the development time.

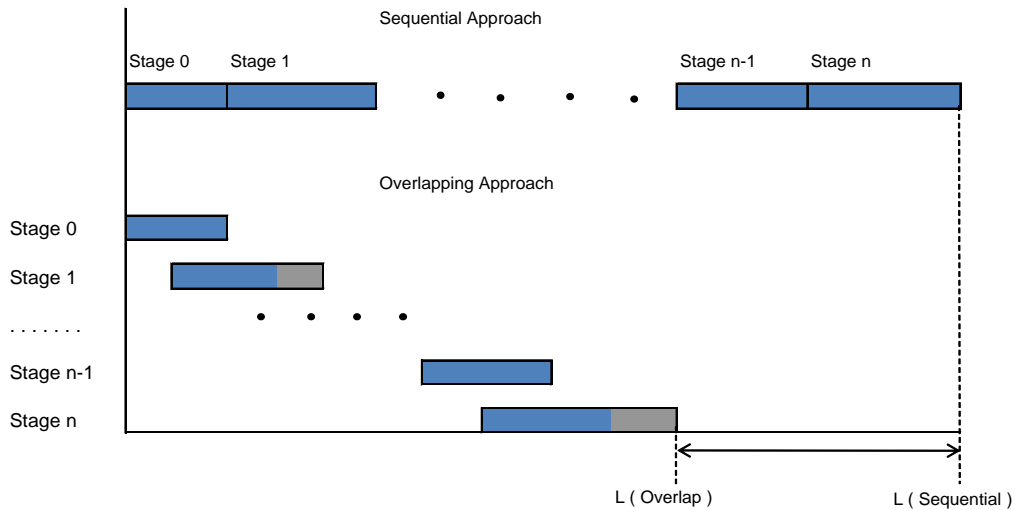


Figure 3.2 Sequential vs Overlapped Design

3.2 Overlapping Technique for New Product Development

The overlapping process requires that subsequent design stages start their work without complete upstream information leading to inevitable rework which accommodates unforeseen upstream developments. For instance, if the assumed APR for the profitability analysis is 12% annual and the final offering turns out to be 9%, the model would have to be updated accordingly.

The total time and work of each design phase, and with it the costs, therefore increase in overlapped processes. Here we propose to treat the initial design work (including the overlap) and the rework as a result of updated information differently. The initial design work (steps (a) to step (f) as described in Chapter 1) requires considerable amount of industry domain knowledge as well of functional expertise. The rework requires the same skill sets. However, in the rework,

the bulk of the work is to update the models and analysis with the new set of product assumptions and hence has more structure around it. It still requires the personnel to have the industry knowledge and the domain skill sets but the work does not have the level of ambiguity as present in the initial design phase. Hence, we proposed to pass on the re-work piece to the off shore team. There are two key benefits of this approach: a) Given the increased work load would translate into additional cost, this cost can be reduced by leveraging the cost arbitrage of the off shore team and b) The on-shore resources can ‘jump’ on to the next project.

In spite of the lower cost structure, the cost of rework would amount to sizable amount given the focus on new product development. Hence, the key is to focus on the efficiency of the overlapping process and find the ‘optimal’ overlapping strategy which minimizes the cost of overlapping for a given time-to market. In the following sections and chapters, we would first characterize the rework cost function and based on the cost structure, develop algorithms and heuristics that determine the minimum cost for a given time to market. In the next section, we first present the general model where we introduce the variables and notations.

3.3 Cost Minimization Problem Formulation

In the general model below, we assume that m projects are given, each consisting of $n+1$ stages. The normal completion time with sequential completion of each of the stages is SD_j . SD_j is the sum of the processing time of each of the stages. In order to launch the product in time to the market, the product however had to be developed by timeline D_j . Given that sequential project completion is not feasible, the stages would have to be overlapped in order to

meet the D_j timeline and the rework outsourced in order to keep the cost of rework at a minimal.

The Gantt chart below shows the problem pictorially.

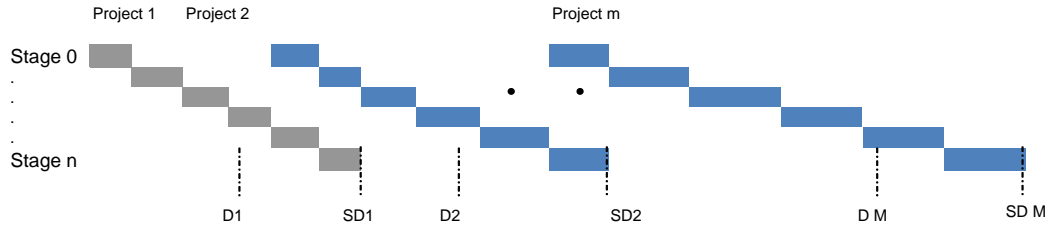


Figure 3.3 Gantt chart for the generic problem

The optimal overlapping strategy is therefore a feasible strategy where all projects finish in time with minimal overlapping costs. To formulate the problem of Scheduling Development Projects SDP, we introduce the following notation and assumptions:

- j : Index for projects , $j = 1, 2, \dots, m$
- i : Index for stages , $i = 0, 1, 2, \dots, n$
- $T_{i,j}$: Time required to complete design stage i, j without overlapping
- $y_{i,j}$: Overlapping between stages $i-1, j$ and i, j ; $y_{0,j} = 0$
- $h_{i,j}(y_{i,j})$: Expected rework at stage i, j
- $c_{i,j}(y_{i,j})$: Cost of expected of rework at stage i, j
- $s_{i,j}$: Starting time of stage i, j
- $d_{i,j}$: Completion time of stage i, j
- S : Earliest starting time for stage 0,1
- D_j : Deadline for project j

SD_j : Sequential Project Deadline for project j ($SD_j = \sum_j T_j$)

OD_j : Overlapped Deadline for project j ($OD_j = D_j < SD_j$)

L_j : Time Benefit for project j

With these notations the problem is formulated as an optimization problem where we solve for minimum cost for overlapping subject to a deadline.

3.3.1 Scheduling Development Projects with M Projects, N stages ($SDP / n/ m$):

$$\begin{aligned}
 (1) \quad & \text{Min}_{y_i} \sum_{j=1}^m \sum_{i=0}^n c_{ij}(y_{ij}) \\
 & \text{s.t.} \\
 & y_{i,j} = d_{i-1,j} - s_{i,j} \forall j, i \in \{2, \dots, n\} \\
 (2) \quad & T_{i,j} + h_{i,j}(y_{i,j}) = d_{i,j} - s_{i,j} \forall i, j \\
 (3) \quad & d_{n,j} < D_j \forall j \\
 (4) \quad & s_{0,1} \geq S \\
 (5) \quad & y_{i,j} \leq \min \{ d_{i-1,j} + h_{i-1,j}(y_{i-1,j}), T_{i,j} + h_{i,j}(y_{i,j}) \} \\
 (6) \quad & d_{i,1} < s_{i,2} \forall i \\
 (7) \quad & D_j < SD_j = s_{0,j} + \sum_{i=0}^n T_{i,j} \\
 (8) \quad &
 \end{aligned}$$

The objective function (1) minimizes the total cost of rework. Constraint (2) defines the overlap between stage $i-1/j$ and i/j as the difference between their completion and starting time respectively. Constraint (3) defines the stage durations and constraint (4) ensures that each project finishes before the due date. Constraint (5) enforces that the first project cannot commence before a given starting time and Constraint (6) ensures that no stage can commence before its predecessor within the same project, nor end after its successor in the same project.

Constraint (7) ensures that no stage can commence before the corresponding stage of the preceding project has terminated. Constraint (8) maintains non-triviality of the problem by ensuring that the due date of each of the project is less than the sum of the processing time of the stages in the project. Another assumption is that $h_{i,j} < y_{i,j}$ as in the scenario $h_{i,j} = y_{i,j}$, there is no benefit of overlap.

The projects must be processed in order of and completed by their due dates D_j . Corresponding stages between projects compete for the same resources so that stage i/j cannot be processed before stage $i/j-1$ has terminated. In contrast, stages within a project may be processed in parallel, by overlapping them. Since the principal flow of information is assumed to be unidirectional, that is from stage $i-1/j$ to stage i/j , overlapping requires to work with incomplete information. Therefore, additional work may occur at stage i/j , increasing the stage's duration from $T_{i,j}$ to $T_{i,j} + h_{i,j}$.

In the next section, we would characterize the objective function in order to understand its driving factors.

3.4 Cost of Rework Function Characterization

As per section 2.3, we propose that the rework function be performed by the low cost structured captive unit. The captive unit consists of a team of analysts who perform the rework by updating the models with the new parameters, auditing the models and conduction validation exercises. The cost of rework $c_{i,j}(y_{i,j})$ for a given stage $[i, j]$ is basically the wage of the analyst doing the rework. For a given daily wage $c_{i,j}$, and given amount of rework given by $h_{i,j}(y_{i,j})$, the cost of rework $c_{i,j}(y_{i,j})$ is given by $c_{i,j}(y_{i,j}) = c_{i,j} * h_{i,j}(y_{i,j})$. Now, as all the analysts have

the same wages, the unit cost of rework is same across projects and stages i.e. $c_{i,j}=c$ for all $[i,$

$j]$. Hence, the cost of rework can be given by $\sum_{j=1}^m \sum_{i=0}^n c_{ij}(y_{ij}) = c * \sum_{j=1}^m \sum_{i=0}^n h_{ij}(y_{ij})$. The outsourced

captive unit's unit cost structure

Leveraging the cost structure generated by the TPI report based on the industry survey [53], the use of outsourcing helps in reduction of the unit cost 'c' significantly. As per the study, in the financial services industry [53], an investment research analyst costs a firm in New York a total of ~ US\$225,000 in contrast to a total cost of ~US\$60,000 in India.

Converting the rates to a daily basis with as assumption of 00 working days per year, every additional day of rework cost reduces from \$1125 for an on-site rework fulfillment team to \$300 for an outsourced captive unit. Hence, the use of outsourcing for our purposes reduces the cost of rework to ~27%. Given the unit cost of rework being a constant, the focus of the rest of the paper would be to reduce the rework amount itself by finding the optimal overlapping strategies which lead to minimal rework amount. The objective function of the problem gets redefined from

$Min_{y_i} \sum_{j=1}^m \sum_{i=0}^n c_{ij}(y_{ij})$ to $c * Min_{y_i} \sum_{j=1}^m \sum_{i=0}^n h_{ij}(y_{ij})$ and therefore the new objective function is

$Min_{y_i} \sum_{j=1}^m \sum_{i=0}^n h_{ij}(y_{ij})$, where the focus is to minimize the total rework amount across projects and

product stages.

3.5 Rework Function Characterization

In order for us to find optimal overlapping strategies, we would next find the factors which drive and characterize the rework function $h_{i,j}(y_{i,j})$. Based on the interaction with the credit card issuer we have been working with, we learnt that the rework amount is a function of:

- a) Degree of overlap: $y_{i,j}$
- b) The sets of product features in the project where overlap is being done
- c) The two stages in the project across which overlapping is done
- d) Ratio of rework to the actual work for the given stage.

These four factors are mutually exclusive and cumulatively exhaustive. Next, we explain the dependence of the rework amount on these factors and develop the rework amount as a function of these variables.

- a) Degree of Overlap

The degree of overlap has a direct impact on the rework amount. As the degree of overlap increases, the probability of the error on the assumption increases and hence the estimate of the rework amount increases.

Let the probability that the assumption was incorrect for a given products feature assumption for stage i and project j at an overlap level of $y_{i,j}$ be $p_{i,j}(y_{i,j})$.

The probability of assumptive error $p_{i,j}(y_{i,j})$ is a non-decreasing function of the overlap $y_{i,j}$. This can be easily seen by the fact that for a given design stage the further the design stage of the previous stage has progressed, there is more clarity about the product feature under consideration. Hence the probability of the ‘guesstimate’ being wrong increases as the overlap increases. That said, at any point in time, we would assume that the product development team

would come up with their ‘best guesstimate’ of the product feature under consideration based on empirical analysis of the historical product changes leading to a low value of $p_{i,j}(y_{i,j})$ and $p_{i,j}(y_{i,j}) < 1$. However, given the fact that there are multiple potential outcomes for stage i , there is always a non-zero probability of misprediction..Hence, $p_{i,j}(y_{i,j}) < 1$ leading to $0 < p_{i,j}(y_{i,j}) < 1$ for all $y_{i,j} > 0$.

The total amount of expected rework $h_{i,j}(y_{i,j})$ would be an integral of the rework across the overlap: $t \in \{0, y_{ij}\}$. At t , the probability of error is given by $p_{i,j}(t)$. In the case of an error, all the models developed for the product would have to be redone and t would represent the rework amount. However in the scenario where the assumption turns out to be correct, the rework is zero. Hence, the estimated amount of rework created in $[t, t+dt]$ is $p_{i,j}(t) * dt + (1 - p_{i,j}(t)) * 0 = p_{i,j}(t) * dt$. Hence, at every dt , $p_{i,j}(t) * dt$ is the amount of rework, which, when integrated over the extent of overlap y_{ij} leads to the value $h_{ij}(y_{ij})$ as shown below.

$$h_{ij}(y_{ij}) = \int_0^{y_{ij}} p_{ij}(y) dy$$

In the scenario where $t = 0$, the possibility of an error would be 0 as the product features would be readily available for use. Hence $p_{i,j}(0) = 0$ which directly gives $h_{i,j}(0) = 0$. Now for $y_{i,j} > 0$, the fact that $h'_{ij}(y_{ij}) = p_{ij}(y_{ij}) > 0$, $h''_{ij}(y_{ij}) = p'_{ij}(y_{ij})$ and $p'_{ij}(y_{ij}) \geq 0$ (as $p_{i,j}(y_{i,j})$ is a non-decreasing function of the overlap $y_{i,j}$) **proves that $h_{ij}(y_{ij})$ is convex function in $y_{i,j}$.**

As overlap variable $y_{i,j}$ starts at value 0, and at $n y_{i,j} = 0$, $p_{i,j}(0) = 0$, and as $y_{i,j}$ increases, $p_{i,j}(y_{i,j})$ increases in a convex manner. Hence, the function $h_{i,j}(y_{i,j})$ can be characterized as

$h_{i,j}(y_{i,j}) = a * b_1 * y_{i,j}^{(1+b_2)}$ where $a, b_1, b_2 > 0$. Now, for a given overlap value $y_{i,j}$, the coefficients a, b_1, b_2 are defined by the other characteristic of the overlap function:

The variable [a], sensitivity of the rework function depends on:

- b) The rework to actual work ratio for the set of product features for which overlapping is being done - a_{1i} ; depends on the sensitivity of product features, stage independent
- c) The rework to actual work ratio for the stage being overlapped - a_{2j} ; depends on the sensitivity of stage, product independent

The variable [b], evolution of the rework function depends on:

- d) Rate of Information flow from previous stage to the stage being overlapped - b_{1j}, b_{2j} ; depends on the evolution of stage, product independent

These factors [$a_{1i}, a_{1j}, b_{1j}, b_{2j}$] determine the convexity of the rework function.

The sensitivity [a_{1i}] can be understood as follows. For each of these product features, the rework is only a fraction of the actual work; in the case rework becomes a reality. This is due to the fact that the initial analytical framework which was build on a different value of the product feature can be leveraged for the rework framework. However, due to the fact that the degree of leveraging and usage depends on the product feature being developed, the sensitivity variable [a_{1i}] depends on the product under consideration. For example, two different products such as a) APR and b) Credit Line have different level of rework done as for a) APR, the only analytical framework which has to be updated would be the P&L statement. However, for b) Credit Line, the P&L, loss forecast and the balance sheet would have to be reworked. Also, when there are multiple product features being developed the one which has the highest sensitivity becomes the bottleneck and hence is the sensitivity value of the rework ratio.

Similarly, The sensitivity $[a_{2j}]$ can be understood as follows. For each stage of the development, the rework ratio is different due to the fact that each stage needs different level of framework update, audit and model validation. Hence, a stage such as "P&L Forecasting" needs less audit checks than stage such as "Prospect Pool Determination". Hence, the stage determines the sensitivity $[a_{2j}]$.

The evolution variables $[b_{1j}, b_{2j}]$ depends on rate of information flow from previous stage to the stage being overlapped. In the case of a low evolution stage ratio, the previous stage evolves slowly over the time of the stage and hence even for a small overlap, there is considerable rework. However, in the case of high evolution stage ratio, the previous stage evolves quickly and hence at a small overlap, there is only limited information left to be passed on the overlapped stage and hence the rework is minimal. However, if the overlap increases, the rework increases significantly as the information from the previous stage is very limited and hence the rework increases significantly. The convexity of a high evolution rework function is hence significantly higher than that of a low evolution rework function. Figure 3.3 shows four extreme scenarios of evolution and sensitivity. The rework function can be formulated as:

$$\text{Rework: } h_{i,j}(y_{i,j}) = f(y_{i,j}, a_{1i}, a_{2j}, b_{1j}, b_{2j}) = a_{1i} * a_{2j} * b_{1j} * y_{i,j}^{b_{2j}}$$

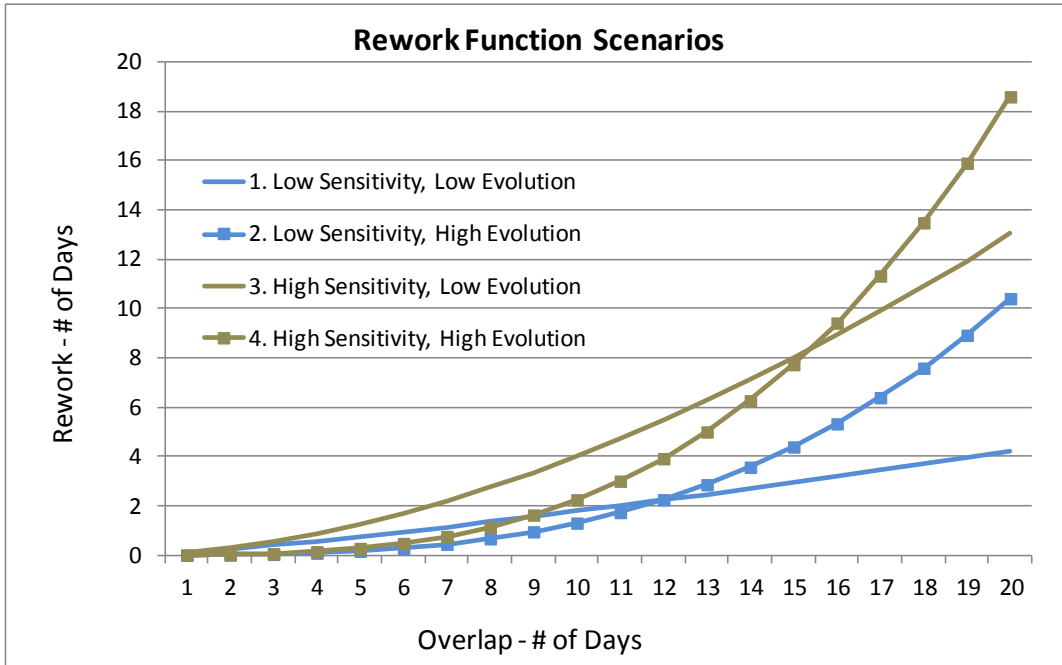


Figure 3.4 Example of convexity of rework function in various scenarios

Scenario 1 and 2 show the low sensitivity curves with 2 showing the higher curvature and lower initial rework due to high evolution. Scenario 3 and 4 show same relationship but due to higher sensitivity, they rework function is higher than 1 & 2. In Chapter 5, we simulate cases based on our industry knowledge to show that our heuristics provide optimal solution by leveraging the convexity of the rework function which is the primary part of the objective function.

CHAPTER 4

Solution to Overlapping Problem

4.1 Project Description

In a credit card firm, typically the direct mail offers go out every month and on a monthly basis, the in-market test results are analyzed and used for incremental improvements of the product. These product changes are peripheral such as different reward structures or fee structures and hence typically consist of very few steps such as P&L forecasting, Balance Forecasting and systemic implementation. However, in the current environment, when the industry is changing rapidly, firms are required to replace incrementally different products with radically new products which would require development via all the steps as discussed in the previous chapter. This leads to having the team of analysts working on 1-2 products at a time for a short release date. In this paper, we would focus on building the model and providing overlapping strategies for developing 1 & 2 new products which would require the NPD team to go through all the 12 stages of product development.

The solution for the single project provided in this category is leveraged from Roemer et.al. [32], because the developed solution was applicable in our scenario due to the fact that the problem definition in [32], was exactly same to our current problem at hand. The solution for the two project solution is then developed in this paper, which takes the optimal solution of 1-project problem as a starting point and develops a high performing heuristic as a solution for the 2-project problem.

4.2 Single Project, Multiple Stages - Optimal Solution

We present the algorithm from Roemer et.al [32], which was developed for a manufacturing problem. Given that the characteristics of the rework function for the financial services are exactly the same as the cost of rework function in [32], we leverage the problem formulation with the objective function replaced with rework function in our application in contrast to cost of rework function in Roemer et.al.

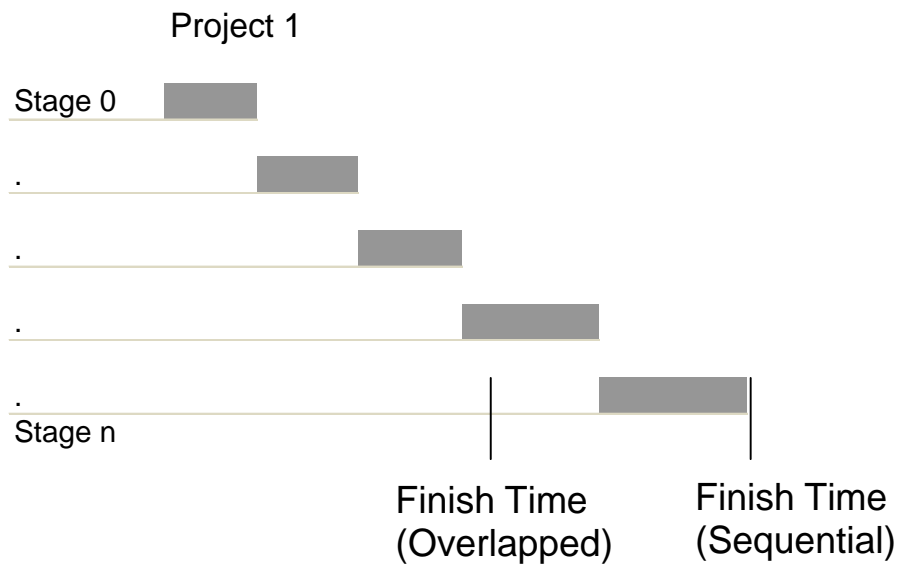


Figure 4.1 Scheduling Problem for 1 project with multiple stages

Figure 4.3 is a 1 project version of Figure 3.3. Model 3.3.1 can be further simplified for the 1-project problem:

$$\begin{aligned}
 (1) \quad & \text{Min}_{y_i} \sum_{i=1}^n h_i(y_i) \\
 & \text{s.t.} \\
 (2) \quad & \sum l_i(y_i) = L_1 \\
 (3) \quad & 0 \leq y_i < U_i
 \end{aligned}$$

Where the following definitions are a part of the model:

$$\begin{aligned}
 (2 \text{ a}) \quad & y_i = d_{i-1} - s_i \\
 (3 \text{ a}) \quad & T_i + h_i(y_i) = d_i - s_i \\
 (4 \text{ a}) \quad & L_1 = SD_1 - OD_1(D_1) \\
 (5 \text{ a}) \quad & s_0 < S \\
 (6 \text{ a}) \quad & U_i = \min [R_{i-1} + h_{i-1}(y_{i-1}), T_i + h_i(y_i)] \\
 (7 \text{ a}) \quad & D_1 = OD_1 < SD_1 = s_{0,1} + \sum_{i=0}^n T_i
 \end{aligned}$$

Constraint (2) basically ensures that the overall reduction in development time is enough to meet the new due date of OD_1 . Constraint 3 ensures that the overlap remains in the feasibility range.

Constraints 2a – 7a define the structure of the problem.

Primal Solution to the simplified problem:

KKT conditions, which are a necessary condition for optimality:

- 1) Primal Constraints : $y_i < U_i \forall i$
- 2) Dual Constraints : $\lambda_i \geq 0$
- 3) Complementary Slackness : $\lambda_i(y_i - U_i) = 0 \rightarrow \lambda_i = 0 \forall i$
- 4) Gradient of LaGrange w.r.t. to y goes to zero :

$$L = -\sum_{i=1}^n h_i(y_i) + \lambda_i(y_i - U_i) + \nu(\sum l_i(y_i) - L)$$

Taking an example with $i = 3$

$$\begin{aligned}
 L &= -h_1(y_1) - h_2(y_2) - h_3(y_3) + \lambda_1(y_1 - U_1) + \lambda_2(y_2 - U_2) + \lambda_3(y_3 - U_3) \\
 &\quad + \nu(l_1(y_1) + l_2(y_2) + l_3(y_3) - L) \\
 &= -h_1(y_1) - h_2(y_2) - h_3(y_3) + \nu(l_1(y_1) + l_2(y_2) + l_3(y_3) - L) \quad \text{as } \lambda_i = 0 \forall i
 \end{aligned}$$

$$\begin{aligned}
\therefore \frac{dL}{dy} &= -\frac{dh_1(y_1)}{y_1} - \frac{dh_2(y_2)}{y_2} - \frac{dh_3(y_3)}{y_3} + \nu \left(\frac{dl_1(y_1)}{y_1} + \frac{dl_2(y_2)}{y_2} + \frac{dl_3(y_3)}{y_3} \right) = 0 \\
&= \left[\frac{dh_1(y_1)}{y_1} - \nu \frac{dl_1(y_1)}{y_1} \right] + \left[\frac{dh_2(y_2)}{y_2} - \nu \frac{dl_2(y_2)}{y_2} \right] + \left[\frac{dh_3(y_3)}{y_3} - \nu \frac{dl_3(y_3)}{y_3} \right] = 0 \\
&= \frac{1}{\nu} = \frac{dh_1(y_1)}{dl_1(y_1)} = \frac{dh_2(y_2)}{dl_2(y_2)} = \frac{dh_3(y_3)}{dl_3(y_3)} = M
\end{aligned}$$

Hence, unless $y_i = 0$; $M_i = \frac{dh_i(y_i)}{dl_i(y_i)} = M$ for all i in any optimal solution.

This requirement of optimality helps provide a structure to the solution problem. Any given due date OD_1 is linked to L_1 . The required time benefit of L_1 is linked to the incurred rework amount $h(y)$ by the marginal price M . So, for any given M , each overlap is increased till its marginal price is M . If the overlap exceeds its relative bound it joins its predecessor group to form a group, and forcing the overlap of the newly form group to increase further collectively to reach the marginal price M . The following algorithm, which was developed by [32], would be used to develop the overlap structure across stages for a given value of M .

4.2.1 Overlapping Policy Algorithm SDP/n/1:

Step 0 : $y_0 := 0$; $i := 1$; $a_j := j$ for $j := 1, 2, \dots, n$; $U := \emptyset$

while $i \leq n$ **do** ;

Step 1 : $G := \{a(i) \leq j \leq i\}$; Determine \hat{y}_G s. t. $M_G(\hat{y}_G) := M$

Step 2 : **If** $\hat{y}_{a(i)} < U_{a(i)}$ and $\hat{y}_j < Y_j \forall j \in G \setminus a(i)$

Then $y_j := \hat{y}_j \forall j \in G$, $i := i + 1$, **Goto** Step 1.

Else $\max y_{a(i)} < U_{a(i)}$ s. t. $y_j = T_{j-1} + h_{j-1}(y_{j-1}) \leq Y_j \forall j \in G \setminus a(i)$

Step 3 : If $y_j < U_j$ and $\hat{y}_j < Y_j \forall j \in G$ and $a(i)-1 \notin U$, then $U := U \cup G$, $i := i+1$

Else $a(j) := a(a(i)-1) \forall j \in G$

End

The next step would be to solve for M. A simple binary search has to be conducted on M until the solution is sufficiently close to the required lead time benefit of L_1 . A lower bound \underline{M} can be established by calculating $\min_i M_i(0)$ and an upper bound \bar{M} can be calculated by solving the trivial case of maximum overlap.

Complexity of the Algorithm

For a given marginal price M, the algorithm above finds the optimal overlap across the stages. Overlap for each stage is found by solving the equation $y_j = T_{j-1} + h_{j-1}(y_{j-1})$. This can be solved in $O(\log M)$. In order to check the feasibility, for an n size problem, the algorithm takes at most 2n iterations. Hence, the complexity of the algorithm is $O(n \log M)$. Including the binary search of the value for M leads to the overall complexity of the problem to $O(n(\log \bar{M})^2)$. This algorithm would be the starting point for the solution for the 2 project multiple stage problem for which we provide a heuristic based solution.

4.3 Two Projects, Multiple Stages - Heuristic based Solution

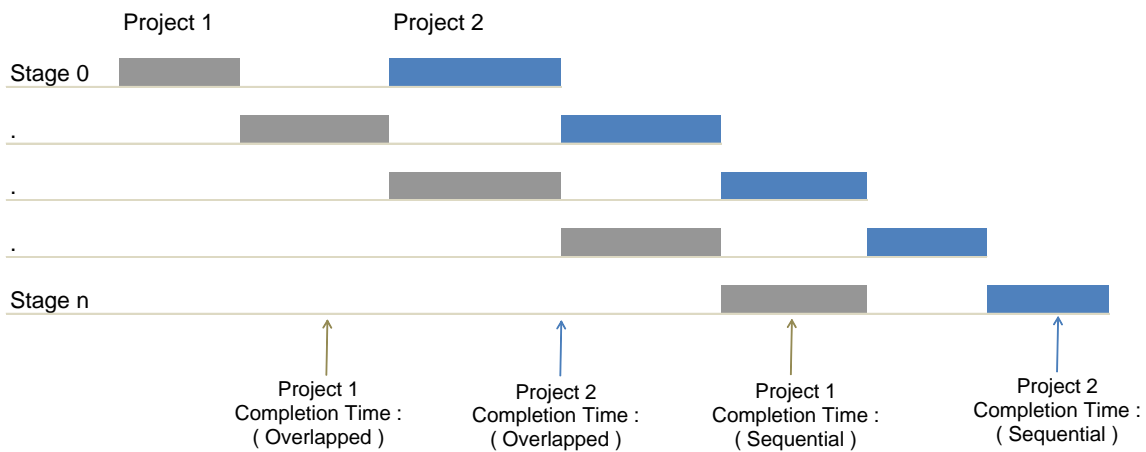


Figure 4.2 Scheduling Problem for Two projects with multiple stages

Fig.4.4 shows the Gantt chart of sequentially scheduled two projects who have a completion due date as SD_1 and SD_2 . Due to overlapping the completion date can be expedited to OD_1 and OD_2 respectively. OD_1 and OD_2 become the new completion due dates, namely D_1 and D_2 for the two projects. The benefit of overlapping is the time benefit: $L_1 = SD_1 - OD_1$ and $L_2 = SD_2 - OD_2$. The following steps formulate and solve the problem:

Problem Definition:

SDP_1^2 : Two project problem on the project index set $j=\{1,2\}$.

SDP_1^1 : Problem on the project index set $j=1$

SDP_2^2 : Problem on the project index set $j=2$

$DSDP_1^2$: SDP_1^2 problem decomposed into two separate problems SDP_1^1 and SDP_2^2 .

4.3.1 Bridge Approach

Approach:

Optimal solution for the $DSDP_1^2$ would have a lower value at optimality as compared to the solution to SDP_1^2 as $DSDP_1^2$ has 1 less constraint ($d_{i,1} < s_{i,2} \forall i$) than SDP_1^2 . Hence, if an optimal solution to $DSDP_1^2$ is feasible for SDP_1^2 , then its optimal as well for SDP_1^2 as the objective value represents a feasible and lower bound solution. Hence, we would first solve SDP_2^2 using 2.3 (Overlapping Policy Algorithm) and then solve SDP_1^1 with $d_{n,1} = \min(D_1, s_{n,2}^*)$ where $s_{n,2}^*$ is the optimal starting point for Stage n in Project 2 at optimality. With this condition, we ensure that the stage 0 and stage n has no slack across projects. Now, if there is no clash of stages across stages 1 to n-1, then the solution to $DSDP_1^2$ is optimal for SDP_1^2 .

However, if there is at least 1 stage which has a clash of timings i.e. $d_{i,1} > s_{i,2}$, a feasible solution for SDP_1^2 is generated by removing the infeasibility at the lower possible cost. An algorithm is presented which summarizes the methodology. In order to do so, we first define the concepts of bridges below.

Definition of 'Bridges':

In order to derive the optimal solution, we introduce the concept of bridges. Bridges are defined at any stage i where $d_{i,1} = s_{i,2}$. The starting point of the bridge $s_{i,1}$ could be flexible depending on the kind of bridge.

We define 'natural' bridges as stages where $d_{i,1} = s_{i,2}$ based on the initial solution to $DSDP_1^2$. 'Forced' bridges are stages where $d_{i,1} > s_{i,2}$ in the initial solution but are further

updated to $s_{i,2} = d_{i,1}$ in order to achieve feasibility. Once the bridges for the solution are defined, optimality is derived by optimizing between two bridges and ensuring that across bridges there is no possible cost minimization potential without impacting feasibility adversely.

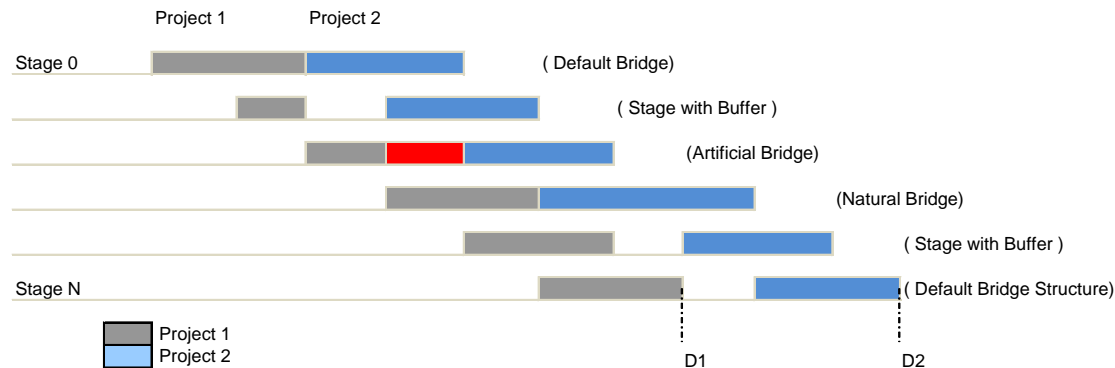


Figure 4.3 Default, Natural and Forced Bridges for a two project optimal solution

4.3.1.1. Properties of the Extreme Stages at Optimality:

Proposition 1: Stage 0 has a ‘natural’ bridge with fixed starting and ending points.

Proof:

Given that $s_{0,1} \geq S_0$ as a constraint, and for any $s_{0,1} > S_0$, reducing the $s_{0,1}$ to S_0 would lead to reduction of cost without any feasibility issue, there is a unique starting point for $s_{0,1} \Rightarrow S_0$. Given that $d_{0,1} = s_{0,2}$, starting point of project 2 is also uniquely determined. Hence proved.

Proposition 2: Stage n has either fixed ending points with a ‘gap’ in the bridge or a natural bridge with fixed ending point.

Proof:

Given that $d_{n,1} = \min(D_1, s_{n,2}^*)$ leads to two possible scenarios. In Scenario 1, namely $d_{n,1} = D_1$, $d_{n,1} < s_{n,2}$ and hence there is a gap in the bridge. However, $d_{n,1} = D_1$, $d_{n,2} = D_2$ leading to unique end points of the two projects, i.e. at their due dates.

In Scenario 2, namely, $d_{n,1} = s_{n,2}$, a natural bridge is formed by definition. However, the starting point $s_{n,1}$ would depend on the overlap of the previous step. However, $d_{n,2} = D_2$ leads to a fixed ending point for the bridge. Hence proved.

In both the scenarios, Stage n still acts as a natural bridge as the end points in both the cases are fixed and hence this structure can be exploited for further steps.

Proposition 3: At optimality, any movement of forced bridge overlaps would lead to either a) infeasibility or b) higher costs.

Proof:

Let stage i be a forced bridge. Hence, $d_{i,1} = s_{i,2}$ such that $d_{i,1} \leq d_{i,1}^*$ and $s_{i,2} \geq s_{i,2}^*$ where $d_{i,1}^*$ and $s_{i,2}^*$ are the optimal solution to $DSDP_1^2$ such that $d_{i,1}^* > s_{i,2}^*$. Hence, the marginal cost at $d_{i,1}, s_{i,2}$ are significantly higher compared to other stage overlaps. Given the natural and inflexible bridges at stage 0 and n, any movement in stage i would have to be replaced with opposite movement in other stage which has lower marginal cost given the convexity of the rework function.

Hence, if only the high marginal cost overlap is reduced, it would lead to infeasibility as $d_{i,1} = s_{i,2}$. Alternatively, if the equality is maintained, the higher marginal cost would lead to increase in overall cost in order to maintain feasibility. Hence proved.

4.3.1.2. Development of low cost forced bridges in case of infeasibility:

Solution to $DSDP_1^2$ leads to the following:

For all $i \in I _ \forall 0 < i < n$; K represents the ‘natural bridges’ where $d_{i,1} = s_{i,2}$.

For all $j \in J _ \forall 0 < j < n$; K represents the ‘forced bridges’ where $d_{j,1} > s_{j,2}$.

For all $k \in K _ \forall 0 < k < n$; K represents the ‘slack stages’ where $d_{k,1} < s_{k,2}$.

Every forced bridge is surrounded by slack stages k , natural bridges i and other forced bridges j .

For making the forced bridges feasible, we zero in on the bridges by beginning at stage j_1 where the $d_{j_1,1} - s_{j_1,2}$ is maximum across all forced bridges.

The stages 1 and n are stages which have fixed overlaps. The key concept is to first remove the infeasibility in the bridge which has the maximum clash followed by residual clashes (if any). In order to solve for infeasibility j_1 , the clash $d_{j_1,1} - s_{j_1,2}$ is reduced in steps of dy (critical dimension of heuristic). For every step dy , the lowest cost reduction is found by horseracing the cost of clash removal. Now, the dy can be reduced by either increasing the overlap in project 1 at stage j_1 : $y(j_1,1) = y(j_1,1) + dy$ or decreasing the overlap in project 2 at stage j_1 : $y(j_1,2) = y(j_1,2) - dy$

The heuristic finds the lowest marginal cost of reducing the overlap at stage j_1 via Project 1 in stage $x1a$: $M(x1a,1) = \min(M(i,1))$ for all $1 < i \leq j_1$ and maximum marginal benefit across all available buffer stages in Project 1 be $M(x1b,1)$ where $M(x1b,1) = \max(M(i,1))$ for all $j_1 < i \leq n$.

Now, given the convexity of the rework function, $M(x1a,1) > (M(x1b,1))$ and hence a dy movement would lead to a cost of $C(dy,1) = M(x1a,1) - (M(x1b,1))$

In a similar fashion the cost of movement of dy in Project 2 would be

$$C(dy,2) = -M(x2b,2) + M(x2a,2).$$

If $C(dy,1) < C(dy,2)$ then $y(x1a,1) = y(x1a,1) + dy$ and $y(x1b,1) = y(x1b,1) - dy$.

or

If $C(dy,1) \Rightarrow C(dy,2)$ then $y(x2a,2) = y(x2a,2) - dy$ and $y(x2b,2) = y(x2b,2) + dy$

With these changes, we check if the infeasibility has been resolved. If not, the process is repeated until $d_{j_1,1} - s_{j_1,2}$. This process is iterated until the infeasibility is solved or the project is declared infeasible. The next infeasible stage is attacked in a similar fashion.

Given the convex structure of the overlap, this approach would provide the lowest cost method for removal of infeasibility and creation of forced bridges. The algorithm below shows these steps summarized.

4.3.1.3 Bridge Heuristic for SDP/n/2:

Step 1: Solve SDP_1^1 using OPA

Step 2: Solve SDP_2^2 using OPA

Step 3: If $DSDP_1^2$ is feasible for SDP_1^2 , then solution to $DSDP_1^2$ is optimal; **End.**

Step 4: If infeasible *Then*;

Step 5: $i \in I _ \forall 0 < i \leq n; d_{i,1} = s_{i,2}$ or $i=n$

$j \in J _ \forall 0 < j < n; d_{i,1} > s_{i,2}$

$k \in K _ \forall 0 < k < n; d_{k,1} < s_{k,2}$

$j_1 = j \in J$ s.t. $d_{j_1,1} - s_{j_1,2} > d_{j,1} - s_{j,2}$ for all $j \in J$

Step 6: $f(j_1) = d_{j_1,1} - s_{j_1,2}$

Find $x_{1a}, x_{1b}, x_{2a}, x_{2b}$ s.t.

$$M(x_{1a}, 1) = \min(M(i, 1)) \text{ for all } i \leq j_1;$$

$$M(x_{1b}, 1) = \max(M(i, 1)) \text{ for all } i > j_1;$$

$$M(x_{2a}, 2) = \max(M(i, 2)) \text{ for all } i \leq j_1;$$

$$-M(x_{2b}, 2) = \min(M(i, 2)) \text{ for all } i > j_1;$$

$$C(dy, 1) = M(x_{1a}, 1) - (M(x_{1b}, 1))$$

$$C(dy, 2) = M(x_{2b}, 2) - M(x_{2a}, 2).$$

If $C(dy, 1) < C(dy, 2)$ then $y(x_{1a}, 1) = y(x_{1a}, 1) + dy$ and $y(x_{1b}, 1) = y(x_{1b}, 1) - dy$

If $C(dy, 1) > C(dy, 2)$ then $y(x_{2a}, 2) = y(x_{2a}, 2) - dy$ and $y(x_{2b}, 2) = y(x_{2b}, 2) + dy$

Step 7: If $f(j_1) > 0$ then goto Step 6 else goto Step 8

Step 8: Update J

If $J = 0$; **End**; else; $j_1 = j \in J$ s.t. $d_{j,1} - s_{j,2} > d_{j,1} - s_{j,2}$ for all $j \in J$;

Goto Step 6

There are at most n major iterations in the algorithm, each requiring at most $2n$ binary searches.

With $Y \equiv \max_j [D_j - S_j]$ each binary search is limited to the range $(0, Y)$ and thus the complexity

of the algorithm is $o(n^2 \cdot \log(Y))$ which renders the heuristic polynomial in order.

CHAPTER 5

Experimental Results

5.1 Industry Knowledge Based Simulated Real-Life Scheduling Problem

We simulate a product development project scheduling problem for two products, based on our conversation with the product management team at a credit card issuer, and use the developed heuristic to find a solution and measure their quality in this chapter.

The details of the scheduling project are as follows:

1. The two new products under development - We take examples of product features under development from the production line at the credit card firm.
Product 1: Revolver Centric Product - New BT Intro APR, New BT Intro Period and New BT Fee
Product 2: Transactor Centric Product - New Credit Line and Credit Extension Criteria
2. Deadline for Each Product - D_j

The deadline for each product launch is determined by the marketing managers who determine the timing of the launch based on the competition and the mailing cycle of the firm. Given the starting time is the point of decisioning; the deadline is finally interpreted by the product development manager as a % reduction in development time. The steady stage development time is a sum of the processing time of all stages. The typically achievable compression in processing time, from a viability standpoint, is 30-70%. In this project, we require the following:

First Product - 30% Compression of Processing Time

Second Product - 60% Compression of Processing Time

3. Number of Stages - 12 stages in each product development as both are new products
4. Estimate of Processing Time by Project and Stage - $T_{i,j}$

The processing time for each of the development stages are determined by taking an average which the production managers at the firm have observed. Given these values are estimates; we also develop a typical variance from the average and use a uniform distribution to sample the processing time for each stage. The processing time is dependent on the processing step only and is independent of the product or market scenarios. Based on the sampling of the processing times and using the compression determined based on the deadline, the processing time per stage for both the products are shown below in Table 5.1. The average estimate of the processing time by stage and the average variance by stage is given in Appendix-1.

5. Cost of Unit Rework Function - c

The cost of unit rework - \$300 / day is based on the industry study by TIPI and is also verified by the product managers. The cost being constant, is not a part of the heuristic but helps in estimating the final incurred cost.

6. Rework Amount as a function of Overlap by Product and Stage : $h_{i,j}$

The estimates sensitivity and coefficients factors by product and stage were developed based on the discussion with the product development managers. These estimates are provided in Appendix-2 in a tabular form. Applying these estimates on the products for our scheduling problem, we generate our rework amount as a function of the overlap amount. The rework amount has a unit of days and the overlap is also measured in terms of days.

(Days)	Project	
Stages	1	2
0	18	19
1	13	14
2	13	14
3	18	18
4	13	13
5	13	13
6	7	7
7	7	7
8	10	10
9	10	10
10	10	10
11	10	10
Deadline - Pre Overlap	138	162
Deadline - Post Overlap	97	75

Table 5.1 Example of a 12 Stage 2 Project – Processing Time and Deadline

Stage	Rework Ratio	Evolution Coefficients	Product Based	Product Based	Rework Function	
	Coefficients (a_{2j})	(b_{1j} , b_{2j})	Sensitivity - Max a_{1j} (Product 1)	Sensitivity - Max a_{1j} (Product 2)	(Product 1)	(Product 2)
0	-	-	-	-	-	-
1	0.5	[0.0104, 2.0]	1.00	1.00	$0.0052 * (y^{2.0})$	$0.0052 * (y^{2.0})$
2	0.5	[0.0104, 2.0]	1.00	1.00	$0.0052 * (y^{2.0})$	$0.0052 * (y^{2.0})$
3	0.3	[0.0009, 2.7]	1.00	1.00	$0.0003 * (y^{2.7})$	$0.0003 * (y^{2.7})$
4	0.3	[0.0907, 1.4]	0.44	1.00	$0.0121 * (y^{1.4})$	$0.0272 * (y^{1.4})$
5	0.3	[0.0907, 1.4]	0.44	1.00	$0.0121 * (y^{1.4})$	$0.0272 * (y^{1.4})$
6	0.3	[0.0907, 1.4]	1.00	1.00	$0.0272 * (y^{1.4})$	$0.0272 * (y^{1.4})$
7	0.1	[0.0907, 1.4]	0.44	0.44	$0.0040 * (y^{1.4})$	$0.0040 * (y^{1.4})$
8	0.2	[0.0907, 1.4]	0.44	0.44	$0.0081 * (y^{1.4})$	$0.0081 * (y^{1.4})$
9	0.2	[0.0907, 1.4]	0.44	0.44	$0.0081 * (y^{1.4})$	$0.0081 * (y^{1.4})$
10	0.2	[0.0907, 1.4]	0.44	0.44	$0.0081 * (y^{1.4})$	$0.0081 * (y^{1.4})$
11	0.2	[0.0907, 1.4]	0.44	0.44	$0.0081 * (y^{1.4})$	$0.0081 * (y^{1.4})$

Table 5.2 Rework as a function of Overlap - Two Product Scheduling Problem

5.2 Results of MATLAB Implementation of Heuristic

MATLAB was used as a platform to conduct the implementation of the heuristic. The parameters and values from the 2 product scheduling problem from section 5.1 were initialized. The bridge heuristic developed was coded and also the convex optimization module of MATLAB was

leveraged. The heuristic and convex optimization, both found feasible solution and also concluded at a minimal rework optimal recommendation respectively. The recommendation for overlap for both the approaches is shown in table 5.3 in days. Also, Figure 5.1 shows the Gantt Chart of the non-overlapped schedule in contrast to the heuristic based overlap and the convex optimization based overlap.

Overlap (Days)	Convex		Bridge Heuristic		Bridge Heuristic - Rounded Down to Days	
1	0.00	0.00	0.00	0.00	0.00	0.00
2	4.72	6.06	4.69	5.83	4.00	5.00
3	4.72	6.06	4.69	5.83	4.00	5.00
4	11.89	13.63	11.85	13.97	11.00	13.00
5	4.39	6.45	4.42	6.49	4.00	6.00
6	4.39	6.45	4.43	6.49	4.00	6.00
7	0.61	6.45	0.62	6.50	0.00	6.00
8	6.51	6.86	6.52	6.86	6.00	6.00
9	6.56	6.86	6.56	6.86	6.00	6.00
10	10.11	10.12	10.11	10.12	10.00	10.00
11	10.21	10.21	10.21	10.21	10.00	10.00
12	10.21	10.21	10.21	10.21	10.00	10.00

Table 5.3 Overlap recommendations for 2/12 Project - Heuristic vs. Optimal Solution

As shown in the Table 5.3, Table 5.4 and Gantt Chart 5.1, the heuristic and the convex optimization provide similar overlap recommendations, while the heuristic has polynomial degree of complexity as compared to the convex optimization which has exponential degree of complexity. The optimal overlap via heuristic leads to a 0.03% higher cost structure compared to convex optimization. Also, in a realistic scenario, where the overlap recommendations are rounded down to the nearest days, the cost is 12.1% lower as shown in Table 5.4. The lower cost is due to the rounding down of the overlap, leading to an overall reduction of rework amount. Given the constraints of the overlapping process, it would be a prudent practice to always round down the overlap amount in contrast to round up or round off.

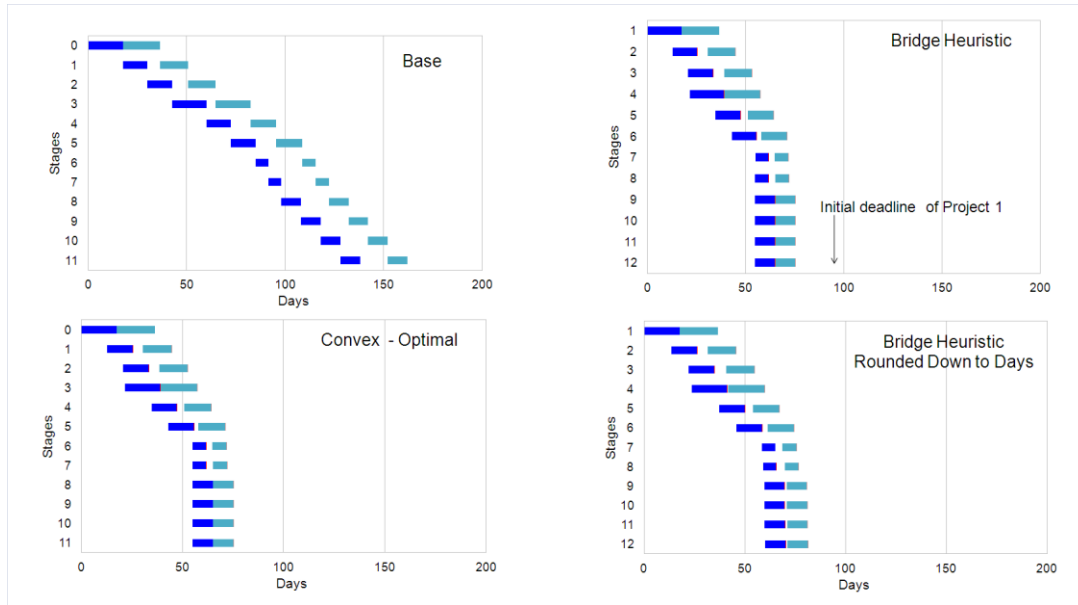


Figure 5.1 Gantt Chart for 2/12 Project - Baseline and Overlap Recommendations

	Convex - Optimal		Bridge Heuristic		Bridge Heuristic - Rounded Down	
	Project 1	Project 2	Project 1	Project 2	Project 1	Project 2
Process Time (Days)	138.0	162.1	138.0	162.1	138.0	162.1
Deadline (Days)	96.6	75.3	96.6	75.3	96.6	75.3
Finish Time (Days)	65.1	75.3	65.1	75.3	70.3	81.4
Meet Deadlines?	Yes	Yes	Yes	Yes	Yes	No
Mismatch in Projects?	No		No		No	
Expedition (Days)	72.9	86.8	72.9	86.8	67.7	80.7
Total Rework (Days)	1.44	2.61	1.44	2.61	1.27	2.29
Cost of Rework (\$)	\$432.94	\$782.04	\$432.45	\$782.92	\$379.80	\$688.15
Total Cost of Rework (\$)	\$1,214.98		\$1,215.37		\$1,067.95	
Cost of Bridge Heuristic (As a % of Convex)			100.03%		87.90%	

Table 5.4 Performance Comparison for 2/12 Project - Convex vs Heuristic Performance

The next step would be to establish the quality and robustness of the heuristic using multiple scenario simulations. Once the assessment proves that the heuristic is robust enough to be used in a production environment, we would outline the benefit in market share which can be achieved using the heuristic based acceleration via overlapping.

5.3 Quality and Consistency Assessment of Heuristic

The heuristic provides very close to optimal solution for the simulated problem under review. In order to assess the quality and consistency of the heuristic, we also performed multiple scenario simulations. Given the simulated problem is a combination of processing time sampling, deadline sampling and product choice, we ran simulations with 10 scenarios of 1) Different Processing Time Scenarios 2) Different Due Date Ratio Scenarios and 3) Different Product combination scenarios. We compare the cost of expedition based on the convex optimization vs. the bridge heuristic. The details of the first simulation: Different Processing Time is shown in Table 5.27. The due date for the a) 1st project is 77% of the sum of the processing time and for the b) 2nd project is 56% of the sum of the processing time. The product feature under development for the two projects is also shown in the Table 5.5.

Project		
	1	2
Scenario - Different Processing Time		
Due Date Ratio	77%	56%
Products	APR	Credit Line Assignment
	Purchase Intro - Period	Balance Transfer Intro - Period
Processing Time	Sampling from Uniform Distribution (10 Samples)	Sampling from Uniform Distribution (10 Samples)

Table 5.5 Simulation Scenario Details for 2/12 Project - Different Processing Time

Table 5.6 shows the results for the first scenario. The Bridge Heuristic performs at par with the convex optimization algorithm.

Different Processing Times			
Scenario	Bridge	Convex	Bridge / Convex Cost Ratio
1	\$524.62	\$524.56	100.01%
2	\$542.03	\$541.90	100.02%
3	\$515.45	\$515.42	100.01%
4	\$581.28	\$580.65	100.11%
5	\$594.94	\$594.87	100.01%
6	\$530.12	\$530.04	100.02%
7	\$519.48	\$519.34	100.03%
8	\$531.53	\$546.65	97.24%
9	\$550.45	\$553.15	99.51%
10	\$477.98	\$477.98	100.00%

Table 5.6 Simulation Results for 2/12 Project - Different Processing Time

The next scenario is different Due Dates. We take different due dates and the scenario chosen are shown in Table 5.29.

Project		
	1	2
Scenario - Different Due Dates		
Due Date Ratio		
Scenarios	1	2
	77%	56%
	60%	57%
	69%	71%
	71%	57%
	40%	61%
	54%	79%
	77%	78%
	65%	76%
	45%	49%
	80%	71%
Products	APR	Credit Line Assignment
	Purchase Intro - Period	Balance Transfer Intro - Period
Processing Time	Sampling from Uniform Distribution (1 Sample)	Sampling from Uniform Distribution (1 Sample)

Table 5.7 Simulation Scenario Details for 2/12 Project - Different Due Dates

The results in Table 5.8 for the Different Due Dates simulation also show that the heuristic performs very close to the Convex Optimization.

Different Due Date Ratios			
Scenario	Bridge	Convex	Bridge / Convex Cost Ratio
1	\$524.62	\$524.56	100.01%
2	\$552.64	\$552.60	100.01%
3	\$312.62	\$312.59	100.01%
4	\$503.29	\$503.21	100.02%
5	\$784.58	\$784.55	100.00%
6	\$405.68	\$405.64	100.01%
7	\$196.89	\$196.88	100.01%
8	\$313.39	\$313.37	100.01%
9	\$852.10	\$852.06	100.00%
10	\$236.55	\$236.53	100.01%

Table 5.8 Simulation Results for 2/12 Project Different Due Dates

The next and final scenario is different Products. We assume different products and the scenario chosen are shown in Table 5.9.

Project		
	1	2
Scenario - Different Products		
Due Date Ratio	77%	56%
Products		
Scenarios	1 APR , Purchase Intro - Period	Credit Line , BT Intro - Period
	2 AMF , BT Intro - Rate	Credit Line , Purchase Intro - Rate
	3 BT Intro - Period , Purchase Intro - Rate	Purchase Intro - Rate , Purchase Intro - Rate
	4 Purchase Intro - Rate , Purchase Intro - Period	APR , Credit Criteria
	5 AMF , Credit Line	AMF , Credit Line
	6 BT Fee , Credit Line	Credit Line , BT Fee
	7 AMF , Purchase Intro - Rate	Purchase Intro - Period , AMF
	8 APR , BT Intro - Period	AMF , Credit Line
	9 BT Fee , BT Fee	Credit Line , Purchase Intro - Period
	10 BT Intro - Rate , Purchase Intro - Period	BT Fee , Purchase Intro - Period
Processing Time	Sampling from Uniform Distribution (1 Sample)	Sampling from Uniform Distribution (1 Sample)

Table 5.9 Simulation Scenario Details for 2/12 Project Different Products

The results in Table 5.10 for the Different Products simulation also show that the heuristic performs very close to the Convex Optimization.

Different Product Combinations			
Scenario	Bridge	Convex	Bridge / Convex Cost Ratio
1	\$524.62	\$524.56	100.01%
2	\$524.62	\$524.56	100.01%
3	\$524.62	\$524.56	100.01%
4	\$543.15	\$542.97	100.03%
5	\$524.62	\$524.56	100.01%
6	\$524.62	\$524.56	100.01%
7	\$524.62	\$524.56	100.01%
8	\$524.62	\$524.56	100.01%
9	\$483.68	\$483.58	100.02%
10	\$524.62	\$524.56	100.01%

Table 5.10 Simulation Results for 2/12 Project Different Products

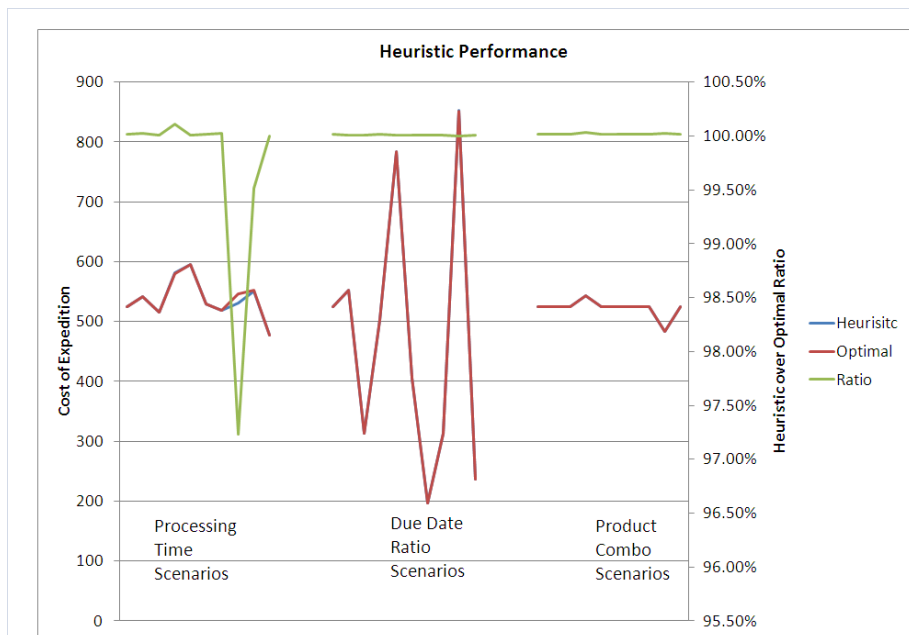


Figure 5.2 Pictorial view of the Heuristic Performance for 2/12 Project Scheduling

This simulation shows that the heuristics presented in this paper is robust and performs at optimal level with polynomial order of processing time increase with scale of the problem. In business scenarios where the number of stages is higher, the heuristic would provide quicker results due to lower processing times. Figure 5.2 shows all the three simulation scenarios ran

together in a graph which shows that for all the scenarios the heuristic performs at par with the convex optimization.

Another observation from the simulation is the fact that cost of expedition is not very sensitive to different processing times as well as different product combinations as long as the due date ratios (which decide the amount of overlap) are constant. However, the due date ratios have a significant impact on the cost of expedition as the overlap degree is heavily dependent on it.

5.4 Impact of Development Acceleration on Market Share

As shown in section 5.3, the bridge heuristic is very robust and can be used to accelerate product development using overlapping recommendation. In the section below, we first establish the current industry trends of balance growth and then use it to establish the impact the simulated acceleration would have on the firm's market share of balances.

5.4.1. Monthly Growth of Credit Card Balances - Market Share Growth

The average monthly growth of credit card balances from Jan'68 to Jan' 07 is \$1.86 Billion per month [2]. After the sharp rise in 2007, fall during 2008-2010, flattening in 2011, the industry saw an uptick in the balances in Q4'2011 at the same rate of ~\$2 B / month. We assume that in the future years a similar growth would continue and every month \$2B would be the increase in balances. The first movers would get the lion share [49] and based on the ratio of first mover to followers; we develop the benefit of expedition in this paper. As shown in Fig. 1.2, every additional month expedition leads to an additional 1% increase in the market share w.r.t. to the leader's market share. Every additional day leads to an additional 0.04% ratio over the pioneer's

market share. With the monthly balance growth of \$2B, even a miniscule % leads to a significant increase in balance and hence profitability and long term market share. Table 5.11 shows the market leader in purchases and the market leader in outstanding balances in 2010, which is from the Nelson Report for 2010 trends in credit card industry [55]. The market leader in credit card purchase activity, American Express had 25% of the market share in 2010, while the leader in outstanding balance in 2010, Chase had 19% of the market share. The reason for American Express having only 11% of the market share in outstanding balance in spite of being the leader in purchases is due to the fact that American Express purchases have a significant % of purchases done by transactors who pay the balance at the end of the cycle, hence reducing the outstanding balances. However, for Chase purchases, there is significantly higher % of customers who revolve the balance. Hence, the nature of the products defines the selection of customers. In this paper, we focus on increasing the market share by purchases for a given profile of products. The market share for balance would depend on the nature of the purchases. We would use the 25% as the estimate of the leader's market share in our analysis. The profitability of credit card firms on any additional balances is positive and significant and hence any additional balances lead to additional profitability. The key drivers are profitability are the risk adjusted net interest margin (APR charged on a credit card net of the average loss due to customer defaults) and the fee (late, over limit etc.) income. In this paper, we would show the correlation of potential additional balance increase as a result of expedited New Product Development. With these simulated values for all the variables, we now present the heuristic solution

Top 15 U.S. Credit Card Issuers in 2010 : Purchase Volume (in Billions)					Top 15 U.S. Credit Card Issuers in 2010 : Outstanding Balance (in Billions)				
Rank	Issuer	Purchase Volume	% of Market	Cum Market Share	Rank	Issuer	Outstanding Balances	Market Share	Cum Market Share
1	American Express	\$461	25%	24.6%	1	Chase	\$133	19%	18.6%
2	Chase	\$333	18%	42.4%	2	Bank of America	\$122	17%	35.8%
3	Bank of America	\$238	13%	55.1%	3	Citi	\$95	13%	49.2%
4	Citibank	\$192	10%	65.4%	4	American Express	\$80	11%	60.4%
5	Capital One	\$98	5%	70.6%	5	Capital One	\$53	7%	67.9%
6	Discover	\$92	5%	75.6%	6	Discover	\$45	6%	74.2%
7	U.S. Bancorp	\$74	4%	79.5%	7	Wells Fargo	\$33	5%	78.8%
8	Wells Fargo	\$49	3%	82.1%	8	US Bank	\$22	3%	82.0%
9	HSBC	\$31	2%	83.8%	9	HSBC	\$19	3%	84.7%
10	Barclays	\$30	2%	85.3%	10	USAA	\$15	2%	86.7%
11	USAA	\$28	2%	86.9%	11	Barclays	\$10	1%	88.2%
12	GE Money	\$21	1%	88.0%	12	GE Money	\$8	1%	89.2%
13	PNC	\$14	1%	88.7%	13	Target	\$6	1%	90.1%
14	Cabela's WFB	\$12	1%	89.4%	14	Navy FCU	\$5	1%	90.8%
15	Target	\$9	0.5%	89.8%	15	PNC Bank	\$4	0.6%	91.4%
	Industry Volume	\$1,872				Industry Debt	\$711		

Table 5.11 Market Share of Top Credit Card Issuers in 2010 as per Nilson Report, 2010

5.4.2. Benefit of Acceleration on Market Share

The benefit of acceleration via heuristic recommendation, as shown in Table 5.12, is an incremental market share of 1.75% which translates into incremental \$35.01 MM in balances at a rework cost of \$1,215.4.

	Convex - Optimal		Bridge Heuristic		Bridge Heuristic - Rounded Down	
	Project 1	Project 2	Project 1	Project 2	Project 1	Project 2
Expedition (Days)	72.9	86.8	72.9	86.8	67.7	80.7
Total Cost of Rework (\$)	\$1,215.0		\$1,215.4		\$1,067.9	
Additional Market Share (%)	0.80%	0.95%	0.80%	0.95%	0.74%	0.88%
Additional Market Share (\$ MM)	\$15.98	\$19.03	\$15.98	\$19.03	\$14.85	\$17.70
Total Additional (\$ MM)	\$35.01		\$35.01		\$32.55	

Table 5.12 Benefit of Acceleration in terms of Additional Market Share of Balances

The profitability of the balances would depend on the risk and stickiness profile of the customer base which depends heavily on the attributes of the product. As per the finance managers of the credit card firm, it is safe to say that all credit card balances are profitable if the product attributes lead to a positive select. Therefore, with that assumptions, we observe and conclude that a very minimal rework cost can lead to a significant increase in the profitable market share

growth of credit card balances with the use of product development acceleration using the heuristic developed in the paper.

CHAPTER 6

Conclusion, Managerial Insights and Future Research

6.1 Conclusion

This research is the first in consumer finance operations literature which provides a solution to the prevalent time to market problem for the new product development in the credit card industry using overlapping design technique and outsourcing to reduce the time-to market in a cost effective manner. It also provides an estimate of the cost of overlapping and the benefit achieved from the expedited time to market. We leverage applicable algorithms from the design overlapping literature focusing on the manufacturing industry and also develop an efficient and highly performing heuristic that determines the overlapping strategy which provides the desired time to market at minimal rework cost. We also apply these algorithms and the heuristic to industry scenarios developed using the author's experience and knowledge of the industry. The results show that the algorithms which are polynomial in processing time provide significant benefit in the profitability due to reduced time to market and the rework cost as a result of the overlap is very miniscule compared to the attained benefits. The results also show that the heuristic which is polynomial in order performs at par with the computer generated (exponential order) solution. Hence, these algorithms would provide quick and easy to use solutions for meeting the required time to market to maximize the profitability or minimize the loss in market share from any delay in the new product launch.

Given the high time pressure in financial services firm, these algorithms which are quick and simple to implement would prove very useful. As most of these firms have significant investment in information technology, the implementation of such algorithms and heuristics would be relatively easy. We also provide the details around the connection of cost of rework

and outsourcing and why it is sensible to outsource the rework generated via overlapping to offshore captive units. Hence, the management can very easily parallel set up the offshore unit to get the re-work done along with overlapping.

In this paper, we show that the benefits of new product development are significantly high in the case of financial services. Given the current status of competition, where the timing to market of new products are very critical, accelerated NPD can be used as an effective tool to enter the market quickly at a low additional cost with the use of effective outsourcing. We develop algorithms and Matlab solution for various scenarios which managers come across in financial services industry.

6.2 Managerial Insights and Implications

In today's highly dynamic financial services market, where time to market has a huge impact on the short term profitability and long term market share of a firm, management should consider overlapping of product development stages as a tool for meeting their product launch timelines. Our learning from our discussion with a credit card issuer indicates that firms are unable to effectively manage their new product development efforts currently. It typically leads to last minute crunching and depends on a few high performers in the team working overtime; hence risking the quality of the project and the timely completion of the project itself. The technique developed in this paper provides an alternative which is organized and significantly lower risk and cost. It also provides management better control over the process and hence would lead to significantly higher quality of output. The significant advancement in technology has made the use of offshore resources risk-free and presents a cost arbitrage which leads to significant low cost requirement for the deployment of this technique. Hence, we believe that the

technique provided in this paper should be considered by the financial services firms in their operational models.

6.3 Future Research

The heuristic developed and the algorithms stated in this paper are developed for credit card industry where typically the cost of rework function is always increasing and mostly convex in nature. However, other asset classes in consumer finance such as mortgages, auto loans, commercial & personal loans and small business loans have similar cost structure given the similarity of the product development process. These sectors of the industry can hence benefit from similar structured operational techniques to meet their time pressure for new product launches.

Another extension of this paper would be the inclusion of a feedback loop in the overlap. A very interesting phenomenon of feedback is that it leads to decrease in both product development time and cost in certain scenarios. Given the fact that, in new product development in financial services, the various steps are quasi-serial in nature, decrease in cost occurs because of early warnings from downstream stages about infeasibilities or costly designs caused upstream.

Furthermore, the various project scenarios we have considered are based on our discussion with the credit card issuer. Hence, the scenarios could be extended to multiple scenarios for various other business situations where multiple projects with multiple stages (3 and higher) are prevalent. The heuristic provided in this paper can be extended to 3 stages or higher using the same logic as developed in this paper.

CHAPTER 7

Appendix

These coefficient estimates were developed based on discussion with product managers on the production line as well as the industry knowledge of the authors.

Appendix- I

Processing Time Mean and Variance Estimates:

Stage	Stage Description	Avg Processing	Avg Processing (Value)	Processing Variance	Processing Variance (Time)
0	Proof of Concept	Med	10	High	15
1	Product Features- Front End	Low	5	High	15
2	Product Features- Back End	Low	5	High	15
3	Revenue Analysis & Forecast	High	20	Low	5
4	Risk Analysis & Forecast	Med	10	Low	5
5	Response Analysis & Forecast	Med	10	Low	5
6	P&L Forecasting	Low	5	Low	3
7	Loan and Capital Forecasting	Low	5	Low	3
8	Prospect Pool Determination	Med	10	Low	0
9	Systemic Implementation – Compile Names	Med	10	Low	0
10	Systemic Implementation – Verify Credit and Address	Med	10	Low	0
11	Systemic Implementation – Data Merge	Med	10	Low	0

Appendix- II

Product Dependent Sensitivity Estimates Matrix (a_{li}) :

		Product Index			
		1	2	3	4
		APR	Credit Line	Rewards	BT - Intro APR
		(Evolution - Constant)			
Stages	Sensitivity				
0	Proof of Concept	-	-	-	-
1	Product Features- Front End	High	High	Low	High
2	Product Features- Back End	High	High	Low	High
3	Revenue Analysis & Forecast	High	High	Low	High
4	Risk Analysis & Forecast	Low	Low	Low	Low
5	Response Analysis & Forecast	Low	Low	Low	Low
6	P&L Forecasting	High	High	Low	High
7	Loan and Capital Forecasting	Low	Low	Low	Low
8	Prospect Pool Determination	Low	Low	Low	Low
9	Systemic Implementation – Compile Names	Low	Low	Low	Low
10	Systemic Implementation – Verify Credit and Address	Low	Low	Low	Low
11	Systemic Implementation – Data Merge	Low	Low	Low	Low

5	6	7	8	9	10
BT - Intro Period	Retail - Intro APR	Retail - Intro Period	BT Fee	AMF	Credit Extension Criteria
-	-	-	-	-	-
High	High	High	Low	Low	High
High	High	High	Low	Low	High
High	High	High	Low	Low	High
Low	Low	Low	Low	Low	High
Low	Low	Low	Low	Low	High
High	High	High	Low	Low	High
Low	Low	Low	Low	Low	Low
Low	Low	Low	Low	Low	Low
Low	Low	Low	Low	Low	Low
Low	Low	Low	Low	Low	Low
Low	Low	Low	Low	Low	Low

Where; High =1, Medium = 0.66, Low = 0.44.

Stage Dependent Sensitivity & Evolution Coefficient Estimates Matrix (a_{2j}, b_{1j}, b_{2j}) :

Stage	Stage Description	Rework Ratio Coefficients (a _{2j})	Evolution	Evolution Coefficients (b _{1j} , b _{2j})
0	Proof of Concept	-	-	-
1	Product Features- Front End	0.5	Med	[0.0104, 2.0]
2	Product Features- Back End	0.5	Med	[0.0104, 2.0]
3	Revenue Analysis & Forecast	0.3	High	[0.0009, 2.7]
4	Risk Analysis & Forecast	0.3	Low	[0.0907, 1.4]
5	Response Analysis & Forecast	0.3	Low	[0.0907, 1.4]
6	P&L Forecasting	0.3	Low	[0.0907, 1.4]
7	Loan and Capital Forecasting	0.1	Low	[0.0907, 1.4]
8	Prospect Pool Determination	0.2	Low	[0.0907, 1.4]
9	Systemic – Compile Names	0.2	Low	[0.0907, 1.4]
10	Systemic – Verify Credit and Address	0.2	Low	[0.0907, 1.4]
11	Systemic – Data Merge	0.2	Low	[0.0907, 1.4]

CHAPTER 8

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