

**Business Process Redesign of a Service Cell with
the Synthesis Approach of Heuristic Approach,
Axiomatic Design, Simulation and
Quality Control Tools**

By

Maruli Siregar

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Preface

Bismillaah, Alhamdulillah, Laa hawla wa laa quwwata illaa billah. Wash shalaatu was salaamu `alal asyrafil anbyaa'i wal mursaliin, wa `alaa aalihii wa shahbihii ajma'iin. Amma ba'du.

Praise be to Allah, the Cherisher and Sustainer of the worlds, with His blessing finally this thesis project can be accomplished.

With all best efforts spent, the author realizes that this thesis research is a piece of work with many flaws. There is not much word too say

This work is accomplished with the contribution of so many participants.

The author just wants to express his best gratitude to all of them.

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My dear beloved wife and children

My sister and brother

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ABSTRACT

This thesis project “Business Process Redesign of a Service Cell with Synthesis Approach of Heuristic Approach, Axiomatic Design, Simulation and Quality Control Tools” presents the research activities conducted by the author as a part of the Task Force of Accessories Business Redesign at Standard Aero BV (SABV). The main object of the research is production system of a service company. However, the research is a cross-functional thinking within the context of operations management. It is the author’s belief that research in this field will become more intensified in the next coming decades. In the future, as the economy improving, it is naturally expected to have more service business following trend to become the largest portion of the whole business activities.

This thesis research is conducted within the boundary of accessories cell as part of Accessories Business Redesign Project at SABV. However, the result is more general that can be reflected to *any* business process design of a service cell. Accessories cell of SABV is used as *a model of any* cellular production system in a service company.

This research proposes a new approach for business process redesign (BPR) of a service cell. According to the author’s opinion, a BPR approach is specific based on the nature where the BPR project is conducted. This research proposes synthesis approach that is expected can yield faster and more practical solution.

The proposed approach is a synthesis of *Heuristic Approach, Axiomatic Design, Simulation Method, and Quality Control tools*. Heuristic approach is employed to derive basic elements of BPR which are used to construct BPR framework. From a number of structured design methods, AD is selected as the design method for this research. Because AD is limited on conceptual level, simulation method and quality control tool are combined to fill in the gap between conceptual and shop floor level.

To a certain level, the proposed approach is proven to be an efficient and effective approach for BPR. A simple model of service system architecture is developed herein. However, because of the limited decomposition level, the model is *not* a full representation of service system. Still, to a certain extent, *any* service system will have similarities with this model. Comprehensive architecture will need further decomposition.

The design object and data used in this research are proprietary of SABV. The data is confidential. During the research, the author conducts field observation to gather the required data. In addition, the company's databases are utilized. The data is specific according the nature of SABV. However, the statements, analysis, conclusions expressed in this research are solely of the author who is responsible for any shortcoming and error. This research outcome does not represent the work of SABV.

Chapter 1

INTRODUCTION

1.1 Background

This thesis project "Business Process Redesign of a Service Cell with the Synthesis Approach of Heuristic Approach, Axiomatic Design, Simulation and Quality Control Tools" presents the result of research activities conducted by the author as a part of the Task Force of Accessories Business Redesign at Standard Aero BV. The main object of the research is the production system of a service company. However, the research is a cross-functional thinking within the context of operations management. It is the author's belief that research in this field will become more intensified in the next coming years. The reasons are manifold. Some are discussed in detail as follows.

1.1.1 Service Business: the Growth

The growth of service industry in the past few decades is really something significant. The service businesses grows both in the public and private sectors ranging from transportation, communication, utilities, trade (wholesale and retail); finance, insurance, real estate; government, and miscellaneous services.

This growth is manifested not only in the quantity and the quality of services but also in their types. At present, the services offered to the customers cover a huge variety of activity from the simple one such as a teller service in bank into more complex service such as business consulting. What was not available ten years ago, it does now penetrate all aspects of life. What was considered as free-unorganized service now becomes professional business

Nowadays, in the very competitive environment, many companies compete to win the customers by offering tailor-made services according to the need of customer. Standard Aero (from now on it is abbreviated with SA), the company where this research is conducted, is not excluded. SA serves as an overhaul and repair facility for small gas-turbine engine such as PW100 and PT6. In its website (<http://www.standaero.com>), it is stated the policy of the company to comply with customer needs as follows.

SA has built a reputation with its ability to help customers with cost effective engine management, maintenance, and repair and overhaul solutions. These solutions are designed around mission profiles, operating conditions and unique needs of each one of its customers, and with minimum disruption to their operations.

This significant growth is also reflected from the United States (US) economy. The contribution of service sectors to National Product (GNP) has been rising from 54.7% of the economy in 1947 to 65.5% in 1975. The detail contribution of each sector is summarized in table 1.1 below.

Table 1.1 Proportion of US GNP in service sectors

Sector	Proportion of USA GNP (%)	
	1947	1975
Transportation	5.8	3.7
Communication	1.3	2.5
Utilities	1.6	2.4
Wholesale trade	6.7	7.9
Retail trade	12.2	10.0
Finance, insurance, real estate	10.0	13.8
Miscellaneous services	8.7	12.0
Government	8.4	13.0
Total	54.7	65.5

This quite remarkable share is also shown in some other countries outside the American continent such as Europe and Asia. The contribution of service business to Gross Domestic Product in these countries is close or more than half

portion of total GDP i.e. between 49% and 72%. The following table 1.2 on the next page (summarized from Ma, 1999) presents some figure in 1993 and 1995.

Table 1.2 Contribution Service Industry to Total GDP

Country	Contribution to GDP (%)	Year
USA	72	1995
France	71	1995
Japan	60	1995
Poland	55	1993
Colombia	54	1995
Korea	49.5	1993
Brazil	49	1995

1.1.2 Service Business: the Trend

In the previous section, it has been explained, the significant contribution of GDP and GNP. However, to be concerned only with GDP or GNP contribution will give false interpretation about the growth. It is necessary to know the trend of the growth.

Another important parameter required to interpret the service business growth wisely is number of employment. The reason is that growth in share of national economy is not always automatically followed by growth in employment. Some cases especially in a developing country such as Indonesia show that the prices i.e. profit margin of service-producing are much more than of the good-producing. Therefore, the number of employment is very useful and essential to provide information about the direction of the growth. This is what is meant by the trend.

As its contribution to economy, the growth of employment in the field service also shows substantial increase. Again, the United States is a good example. In the early 1900s, only three in every ten workers were employed in services (Fitzsimmons, 1982). It means that 30% of employment was shared in

services. The remaining workers were active in agriculture and manufacturing. This portion became 49.1% in 1947 in, 61.4% in 1968, and 68.3% in 1980 as can be seen in table 1.3.

Table 1.3 Number of Employment in US (thousand workers)

Type of Production	Year	1947	1968	1980
Goods-Producing		26370	28975	31600
Service-Producing		25400	51800	67980
Total		51770	80775	99580

In 1997, within less than a century, the portion increased significantly reaching 80%. It is well above 60% in UK, Canada, France, and Japan (Krajewski, 1999). Looking the table 1.3 at a glance, it is easily seen that those figures shows growth of employment for both goods and service industry. However, careful attention shows that service had remarkable growth of 104% only within 21 years of 1947 until 1968. Although for the period 1968-1980 this growth became 31%, it is still much bigger than 9 % of the goods. The percentage growth is summarized below.

Table 1.4 Percentage of Employment in US (thousand workers)

Period of Growth	Percentage Growth	
	Goods	Service
1947 – 1968	9.9	9
1968 – 1980	104	31

Thus, the two tables 1.3 and 1.4 show the growth of service business in quantity as well as in the percentage. Daniel Bell, a professor of sociology at Harvard University, identified this phenomenon as one of the five dimensions of Postindustrial Society: the creation of service economy (Bell, 1973). Increased

productivity in the manufacturing and agriculture sectors has created a higher level of disposable income in the population, which has led into increased purchases of services. As labor-saving devices are introduced into the production processes, more workers are engaged in non-manufacturing activities, such as maintenance and repair.

Some other literature also cites this trend as follows.

- The more developed the economy, the greater the service's sector share is (Ma, 1999). In table 1.2, USA, Japan, and France are listed as top three countries with the biggest contribution of service industry to total GNP. Since these countries are well known leaders in economy, therefore there is strong indication that the development of service industry depends on the level of economic development.
- As nations become industrialized, there is an inevitable shift of employment from one sector of the economy to another (Clark, 1957).
- During the past 80 years we have witnessed a complete reversal in the work activity of the population (Fitzsimmons, 1982).

In summary, those data and arguments support this following conclusion:

The trend that is progressing globally right now is the transformation of culture from industrial society to postindustrial society. In the future, as the economy improving, it is naturally expected to have more service business following trend to become the largest portion of the whole business activities.

1.1.3 Service Business: The Behavior of Market

According to the author's opinion at least there are three factors that mostly characterize the current market behavior:

- Competitiveness
- Volatile market
- Diversified market

Nowadays, the competition among producers becomes harsh as customers have easier and faster access to the offered products. Information technology is

the primary enabler that makes products more transparent. Customers have diversified choices and can easily turn to the most satisfying one. Process innovation or redesign should be to maintain leadership in a competitive market.

Professor Cochran of the Massachusetts Institute of Technology cites the need to cope with the behavior of market:

In today's competitive environment companies are increasingly forced to respond to diverse market demands with the alignment of their organizational structure and their competitive strategies. The firm's need to respond to change with stable and long-term, yet flexible and responsive, process capabilities is greater than ever before. (Cochran, 2000)

Furthermore, Business Process Engineering – another term used to dub Business Process Design -- is mentioned specifically as new paradigm to respond the behavior market.

Recently emerged paradigms of Lean Management and Business Process Reengineering call for adaptation of production system's organizational structure to be more reactive to a volatile and diversified market behavior (Cochran, 2000).

Company that fails to feel this sense at the early moment will be too late to anticipate the competition and will loose its market and. Company that feels this sense will commit to continuous process innovation required to win the market. The Wal-Mart case is a good example (Chase, 2002). The case is summarized as follows.

Wal-Mart, a major retailer business in the US, became a public corporation with only 30 operating stores in 1972. Constantly expanded and renovated its business process, by 1987 Wal-Mart had almost 1200 stores, just over half of Kmart's -- the major leader in retail business at the time. Kmart did react to this threat but with an ineffective strategy by building a more upscale image. Finally, in 1993, Wal-Mart took over the lead from the major market leader Kmart. The Kmart did realize the importance of process business innovation by introducing new computerized procurement and inventory system. However, the human resources were not ready causing hiccup in the new system.

In conclusion, *it is proven that business process redesign should become continuous process required to maintain competitiveness in global market.*

1.1.4 Personal Motivation

The author's first involvement in redesign research activities was "Redesign Assembly Plant using Simulation". It was a final project required to achieve BSc. degree of Industrial Engineering at the University of Indonesia. The project is a part of continuous improvement program at assembly engine plant of Astra-Daihatsu Motor Company – an Indonesian-Japanese joint venture company. It was the author's supervisor, Dr. Ir. Pamungkas, who proposed simulation as methodology to be used in the research.

Currently, accomplishing thesis project required to achieve MSc degree of Engineering Product Design at Hogeschool van Utrecht, the author is involved in Accessories Business Redesign Task Force at Standard Aero BV. Once again simulation is employed in the redesign process. What makes the difference is the moment that Ir. Huijgevoort, the author's lecturer, gave the text book Axiomatic Design (Suh, 2001). It reminded the author's interest to the text book of Principles of Design (Suh, 1990) learned in Product Design course during the bachelor schooling. Furthermore, quality Control tools have become basic and classical knowledge of the author as an Industrial Engineer.

Motivated by the situation and condition above the author decides to work on this research. *It is the author's intention to have new expertise and experience in the design field by combining the existing knowledge and the state-of-the-art design methodology.*

1.2 Research Scope

1.2.1 Research Issues and Related Work

This thesis research "Business Process Redesign of a Service Cell with the Synthesis Approach of Axiomatic Design and Quality Control Tools" is done within the context of Accessories Business Redesign project at SABV. However, the

research is independent in the sense of the methodology that is used. There are four key issues that constitute this research:

- Business Process Redesign,
- service business,
- cellular production system, and
- synthesis approach of design

The field of Operations Management and Design Methodology covers very wide research area. As result of screening this general scope with the preference of the author’s expertise, experience, and personal motivation, four substances are selected. The process is to define the thesis scope is depicted in the schematic diagram below.

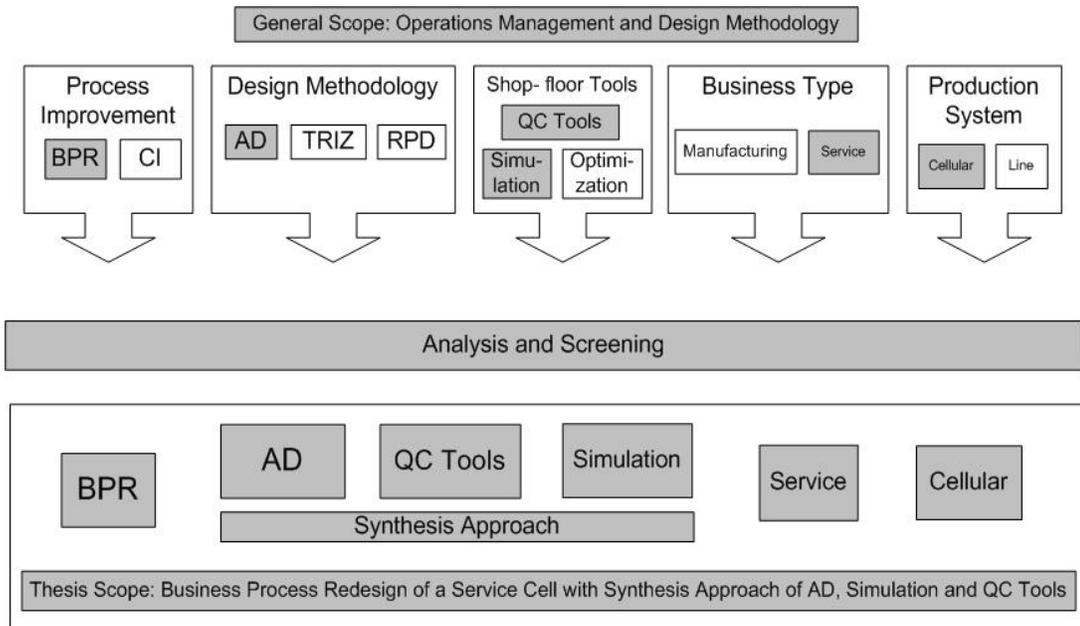


Figure 1.1 Thesis Scope

Note of abbreviation:

BPR = Business Process Redesign

CI = Continuous Improvement

AD = Axiomatic Design

TRIZ = Russian acronym for Theory of Inventive Problem Solving

RPD = Robust Product design also known as Taguchi’s or Design of Experiment

QC = Quality Control

Those issues will be elaborated more detail in the following *chapter 2 Conceptual Framework of Business Process Redesign of a Service Cell: the Existing Approaches*. Nevertheless, to give a complete picture of this research, some general ideas are presented in this section.

Business Process Redesign

Business Process Redesign, also dubbed as Business Process Reengineering or just Reengineering, is an effort to achieve break through in process improvement. It is similar with continuous improvement in sense of the outcome.

Service Process

A service process is a set of sequenced activities performed by the service provider to satisfy the customer needs. Service is different with manufacturing system in the sense of intangible product, inventory, degree of customer involvement, inseparability of customer and service provider.

Cellular Production System

Basically cells are group of machines (or processors) which are dedicated to the processing or assembly of specific groups (families) of parts or products (Moodie, 1995). Similar entities that can be in form of parts, assemblies, processes, tools, instructions, etc. are grouped together. Cellular production system is different with line production system in the sense of degree of flexibility or customization and output rate. In contrast with line production system, cellular production system is applicable for highly customized product with lower rate output.

SABV adopts cellular concept in their production system. Cellular production system has the advantages of greater efficiency and faster cycle time. SABV has configured the shop area into a unique system of cells.

Synthesis Approach of Design

What is meant by synthesis approach in this research is the combination of conceptual design methodology and shop floor tools. Specifically, as shown in

the figure 1 above, it is combination between Axiomatic Design, simulation, and Quality Control Tools. In the next section research methodology, this approach will be explained in general.

1.2.2 Boundary and Limitation

This thesis research is conducted within the boundary of accessories cell as part of Accessories Business Redesign Project at SABV. However, the result is more general that can be reflected to any business process design of a service cell. Accessories cell of SABV is used as a model of any cellular production system in a service company.

The design object and data used in this research are proprietary of SABV. The data is confidential. During the research, the author conducts field observation to gather the required data. In addition, the company's databases are utilized. The data is specific according the nature of SABV. However, the statements, analysis, conclusions expressed in this research are solely of the author who is responsible for any shortcoming and error. This research outcome does not represent the work of SABV.

1.3 Research Approach

According to the author's opinion, a BPR approach is specific based on the nature where the BPR project is conducted. Therefore it is required to develop a BPR approach. In this thesis the author proposes and develops an approach for conducting BPR of a service cell. The development process can be explained as follows:

- First, to provide the theoretical foundation some representatives of BPR approach are discussed in *Chapter2 Conceptual Framework of Business Process Redesign of a Service Cell: The Existing Approaches*.
- Then the developed approach is elaborated in *chapter 3 Conceptual Framework of Business Process Redesign of a Service Cell: the Developed Approach*.

The discussion herein is the summary which serves as the general description of the main ideas.

From the point of view of size a service cell is a relatively not large system. The area of Accessories Cell of SABV is 380 m² (19 m x 20 m). Due to produce customized service according to the customer requirements, this cell has high flexibility use of its resources. As a result, this cell is a very complex system characterized by the interaction among its resources. Therefore, to yield efficient design process, a structured approach is required.

From a number of structured design methods, AD is selected as the design method for this research. However, the author found that applying this method solely to achieve the required design is not sufficient. AD, developed by Nam P. Suh, a Professor of Mechanical Engineering at the Massachusetts Institute of Technology, is limited on conceptual level. This method does not offer practical solution on the shop-floor.

The system to be redesigned is so complex that it is very difficult to yield optimum solution. Therefore, instead of using optimization method, simulation is applied to model and simplify the real system. In addition, quality control tool is combined to fill in the gap between conceptual and shop floor level.

In conclusion, this research proposes synthesis approach that is expected can yield faster and more practical solution. The development of this research approach is divided into chapters: *chapter 2* and *chapter 3*. The algorithm for developing the research approach is summarized in two figures as follow:

- The algorithm for developing research approach that is elaborated in chapter 2
- The algorithm for developing research approach that is elaborated in chapter 3

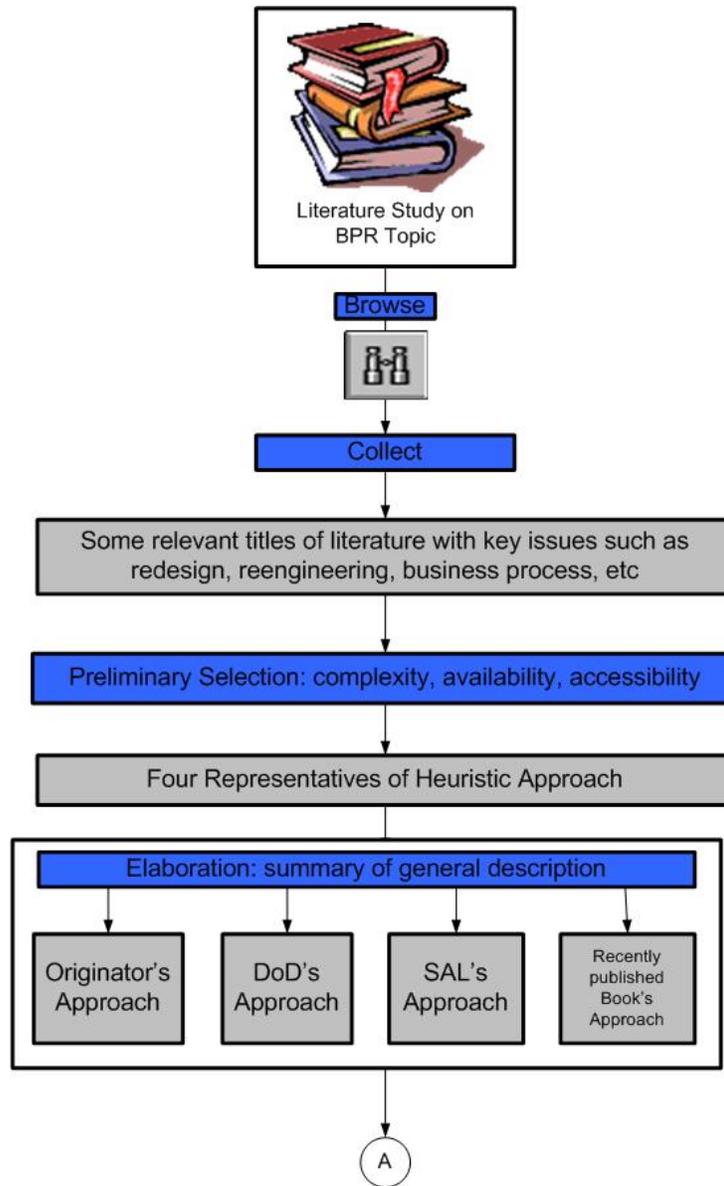


Figure 1.2 The algorithm for developing research approach elaborated in chapter 2

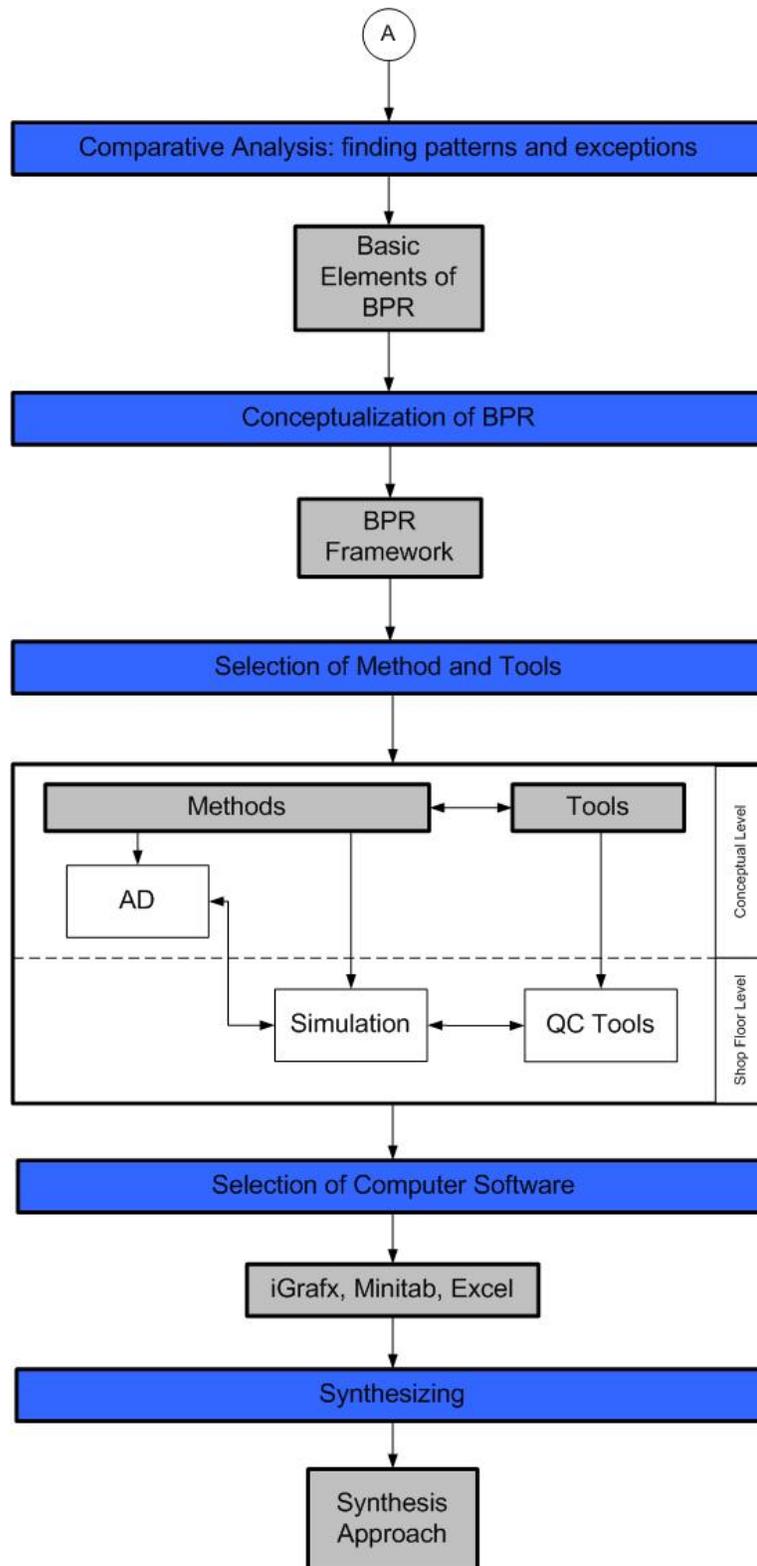


Figure 1.3 The algorithm for developing research approach elaborated in chapter 3

1.4 Research Framework

This research is conducted within a framework of BPR. This framework is meant to be used as general guidance and outline to conduct the research. This framework will be elaborated in the chapters of thesis report. To create this framework, the author analyzes some existing approaches and finds the basic elements of BPR. As will be elaborated in chapter 3 section “3.2 Heuristic Approach to Construct BPR Framework”, basically there are found some common elements:

- New Design Requirements.
- Current system description.
- Redesign Process that uses a Synthesis Approach.
- New Design which is characterized by Breakthrough in Process Improvement.
- Implementation.

Based on these elements, the BPR framework is constructed as depicted in the following figure.

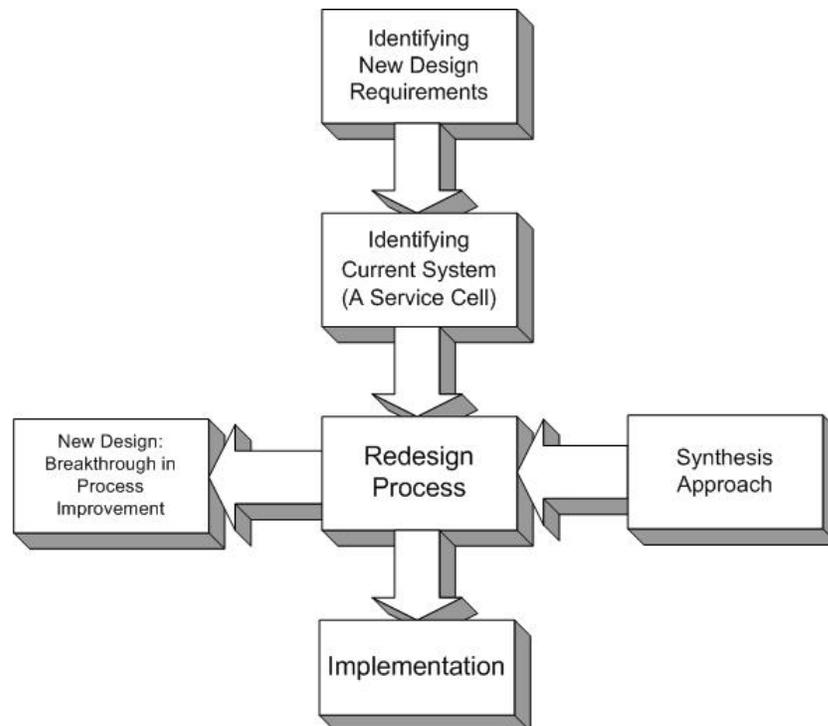


Figure 1.4 BPR Framework

1.5 The Objectives of Research

This research proposes a new approach for business process redesign of a service cell. It is expected that this proposed approach will fulfill the purposes as listed in the table on the following page:

Table 1.5 Objectives of Research

1. Develop business process design methodology for a service cell.
 2. Develop an efficient business process redesign methodology in the sense of giving faster solution
 3. Develop an effective business process redesign methodology in the sense of filling in the gap between conceptual design and shop floor solution.
- The effectiveness and the efficiency of this methodology is demonstrated by a case study of Accessories Business Redesign Project at Standard Aero BV

1.6 Project Goals

Within the frame of research objectives, referring to Term of Reference (TOR) SABV Accessories Business Redesign Project, the following project goals are identified:

1. To anticipate future growth of average 14% until 2008, starting from year 2004. The growth will be:
 - 2 years annual growth of 20%
 - 3 years annual growth of 10%All growths above are for loose accessories. For the engine related accessories, the demand is assumed to be constant.
2. To design processes and control systems need exceed a monthly average of a "first test pass rate" of maximum 1.2.
3. To reduce cycle time (turn around time) of various loose accessories services
The target of turn around time is tabulated in the table on the following page:

Table 1.6 Targeted Turn Around Time (TAT)

Type of Component	2003 TAT (days)	Target (days)
Fuel Nozzles	15	5
Flow Dividers	13.7	15
HP Fuel Control	33	15
LP Fuel Control	33	15
Fuel Pumps	21	15

- PW100 MFCU's & HMU's (Mechanical Fuel Control Units & Hydro-Mechanical Fuel control Units) - 15 calendar days max.
 - Fuel Pumps – 15 calendar days max.
 - Fuel Nozzles – 5 calendar days max.
4. To achieve a Due Date Compliance of 100% three months after the implementation phase.
 5. To set additional performance objectives and control systems.

1.7 The Structure of Thesis

This thesis document summarizes the result of research activities as part of Accessories Business Redesign Project at SABV. This thesis is organized into eight chapters as depicted in the figure on the following page.

- The first chapter *Introduction* presents the motivation of this research. Then, the scope, methodology, framework, and objective of the research are addressed. Finally, the references are listed based on the topic and some important literatures are given special note.
- The second chapter *Conceptual Framework of Business Process Redesign of a Service Cell: the Existing Approaches* elaborates some representatives of BPR approach. It is theoretical foundation that shall be used to develop an approach specifically for the problem in this thesis that shall be elaborated later on in chapter 3.

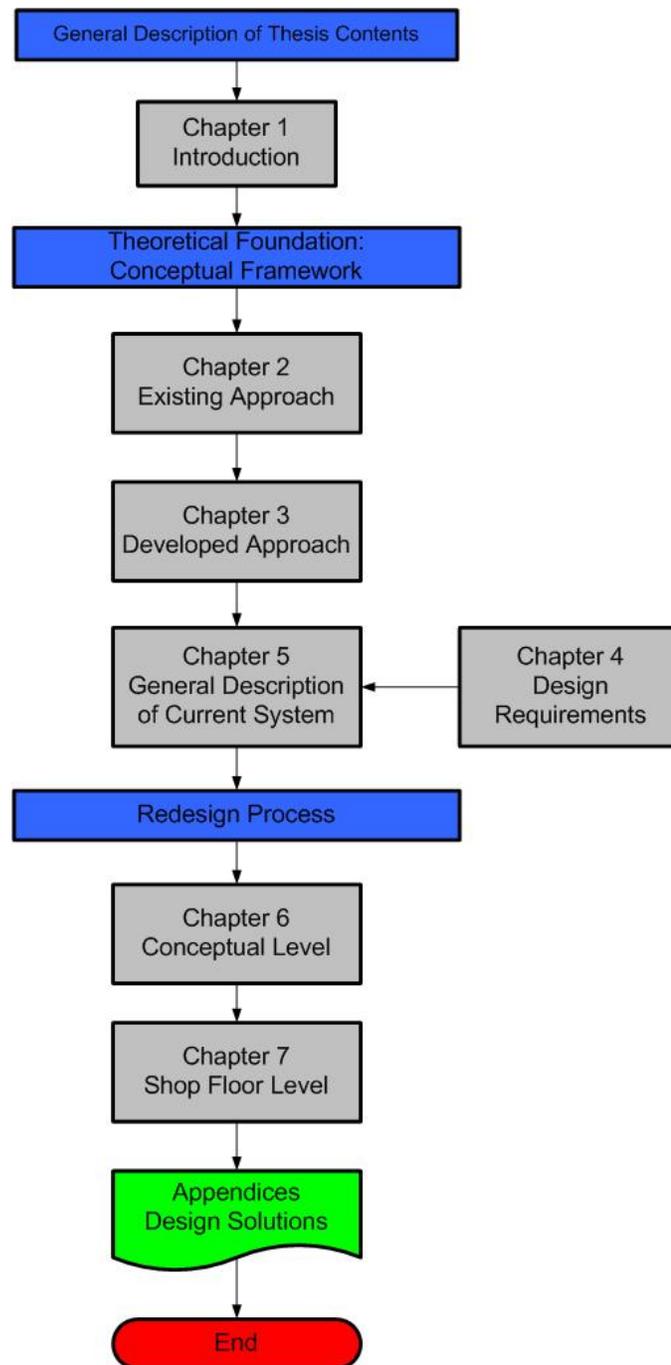


Figure 1.5 Structure of Thesis

- The third chapter *Conceptual Framework of Business Process Redesign of a Service Cell: the Developed Approach* presents an approach to a BPR effort. It is general guidance that shall be used *the Redesign Process* discussed in chapter 6 and chapter 7.

- The fourth chapter *Design Requirements* specifies the functional requirements needed to fulfill in the new design. Some of the design requirements refer to the Term of Reference of Accessories Business Redesign Project of SABV.
- The fifth chapter *Current System Description* covers detail description of the operating system. Two descriptions are elaborated: the design context and the design object. The design context is the outer system of design object such as general profile of Dunlop Standard Aerospace (DSA) group and Standard Aero Division. The design object is Accessories Cell which is one of the existing of Standard Aero BV, which is one of strategic business units (SBU) of Standard Aero Limited.
- The sixth chapter *Redesign Process of Conceptual Level by Using AD* describes the detail of redesign process through the proposed synthesis approach at conceptual level. First, some theoretical foundation is presented. Then, the theory is applied according the case in this thesis project.
- The seventh chapter *Redesign Process of Shop floor Level by Using Simulation Combined with QC Tools* describes the detail of redesign process through the proposed synthesis approach at shop floor level. First, some theoretical foundation is presented. Then, the theory is applied according the case in this thesis project.
- Finally, the eighth chapter *Conclusion* and *Recommendation* close the thesis. Conclusions are drawn regarding the proposed approach and the design object. Recommendations are made based on the conclusions. Some further researches are pointed out.

1.8 Literature Note (see references)

There are two sources of reference: textbook and scientific paper. The textbooks provide fundamental and general understanding of the research scope. The scientific papers with case studies help the author comprehend the current development and application of design methodology. To the author, it is a

shortcut to have quick understanding. The references are categorized based on their topics and sorted based on the published year. They are listed on the following table:

Table 1.7 Category of References

Topics	Text Books	Scientific Paper
Operations Management	<ul style="list-style-type: none"> ▪ Chase et al, 2002. ▪ Harrison, 2002. ▪ Monden, 2000. ▪ Krajewski et al, 1999. ▪ Slack et al, 1998. ▪ Fitzsimmons & Sullivan, 1982. 	<ul style="list-style-type: none"> ▪ Ma, 1999. ▪ Jacobs & Mabert, 1986. ▪ Mabert & Moodie, 1982.
BPR	<ul style="list-style-type: none"> ▪ Davenport, 1993. ▪ Hammer & Champy, 1993. 	<ul style="list-style-type: none"> ▪ Rejniak, 2002. ▪ Yoemans, 1996. ▪ Kutschker, 1994. ▪ Vidgena, 1994. ▪ Hammer, 1990. ▪ Davenport & Short, 1990.
Axiomatic Design	<ul style="list-style-type: none"> ▪ Suh, 2001. ▪ Suh, 1990. 	<ul style="list-style-type: none"> ▪ Cochran et al, 2000. ▪ Engelhardt, 2000. ▪ Reynal et al, 1996. ▪ Flinchbaugh, 1998. ▪ Nordlund et al, 1996. ▪ Cochran et al, 1996.
Design Methods	<ul style="list-style-type: none"> ▪ Mann, 2003. ▪ Roy, 2001. ▪ Terninko, 1998. 	<ul style="list-style-type: none"> ▪ Hu and Yang, 2002. ▪ Mann, 2002. ▪ Cavallucci, 2002. ▪ Yang & Zhang, 2000.
Simulation	<ul style="list-style-type: none"> ▪ Robinson, 2004. ▪ Law and Kelton, 1991. ▪ Banks and Carson, 1984. 	
Optimization	<ul style="list-style-type: none"> ▪ Onwubolu, 2002. ▪ Johnson, 1974. 	
QC Tools	<ul style="list-style-type: none"> ▪ McClave, 2001. ▪ Aczel, 1999. ▪ Ledolter and Burill, 1999. ▪ Mortimer, 1988. ▪ Feigenbaum, 1986. 	<ul style="list-style-type: none"> ▪ Dobyms, 1990. ▪ Roberts, 1990.
Cellular Production System	<ul style="list-style-type: none"> ➤ Moodie et al, 1995. ➤ Irani, 1999. 	<ul style="list-style-type: none"> ▪ Chen, 2003

Some of the cited references provide the author so invaluable understanding and information that are necessary to be given special notes.

BPR is a term which is interpreted differently in the literature. However, for BPR approach issue, the author many times consults with the following references:

- T. H. Davenport: *Process Innovation*, 1993. This book describes some fundamental BPR concepts. It is a very conceptual for high-level ideas but necessary to read to understand basic concepts of BPR.
- Malhotra: "Business Process Redesign: An Overview", 1998. This paper provides "quick" review on BPR concept. A reader who is new to BPR concept and would like to have quick understanding is recommended to consult this paper.

The books especially focus on the AD topic are limited (in fact as far as the author concerns, they are only written by the originator of AD that is Professor Nam P. Suh). As the concept of Axiomatic Design is something new to the author and the available time is very limited, the author does "quick review" and grasps the fundamental concept and application of AD by studying a variety of papers on AD. Some of the major references are:

- Nam P Suh, 1990: *The Principles of Design*; and Nam P Suh, 2001: *Axiomatic Design: Advances and Applications*. As written by the originator concept of AD, these two books provide strong theoretical foundation and some applications of AD. Other literature on AD always cites this book as reference.
- Cochran and Reynal, 1996: "Axiomatic Design of Manufacturing Design". This paper introduces the use of axiomatic design in the design of manufacturing systems. The two primary functional requirements of *any* manufacturing system are developed.
- Houshmand and Jamshidnezhad, 2002: "Conceptual Design of Lean Production Systems". This paper presents a real case study at automotive assembly line in Iran by which the author is inspired to make problem decomposition.

Service operation is one of major issues in operations management. Since it is a long-established knowledge, standard text book on this topic are vastly available and can easily be found. However, the author selects the following literature as the major references:

- Fitzsimmons and Sullivan, 1982: *Service Operations Management*. This old edition book provides good starting point for selecting the thesis topic. Section "1.1 Background" mainly refers to this book.
- Chase et al, 2002: *Operations Management for Competitive Advantage*. It is a very systematic well-written book with a lot of interesting case studies. Although this book covers detail operations management topics which are cross related with other subjects (e.g. quality control, time study, etc.), it can give equivalent understanding compared with the books especially written for the topic.
- Ma, 1999: "An Approach to the Representation of Service Process Design". It is a PhD thesis which aims to develop an approach to the design of service processes. Some ideas about process thinking refer to this reference.