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IMPROVMENT OF THE PRODUCTION PROGRAM PLANNING PROCESS IN BUSINESS PRODUCTION SYSTEM

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УНИВЕРЗИТЕТ У БЕОГРАДУ
МАШИНСКИ ФАКУЛТЕТ

Galal Hamed Senussi

Унапређење процеса планирања производног програма у пословно-производним системима

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DEDICATION

Commitment, effort, and dedication were fundamental elements for the completion of my doctoral dissertation, but even more was the support of my family. To my Father, Mother, wife and the two greatest projects of my life: my son Mothafer and Aiham, today I dedicate them this important professional achievement because without their presence, support, and comprehension I would have not achieved my goal.

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Abstract

The aim of doctoral thesis is establishing a new model for production program optimization which is follow the systematization of existing knowledge in field of production program planning and integration method such as activity base calculate, genetic algorithm, and risk management.

This research introduces a contemporary model design for production program planning in business-manufacturing systems.

An integrated model of ABC method and GA technique for cost volume profit (CVP) problems is developed. It applies to check the objective function and constraint function, and to obtain the optimal solution. It uses data provided by ABC systems designed to keep track of variable and fixed costs, and requires the model user to formulate a contribution rule that will allow to compute, for each product, the output required to achieve a given (target) profit. The purpose of the integrated model construction is to invest C-V-P analysis with realism, and to remove a basic deficiency from the traditional C-V-P model.

In this research also, an integrated model of risk management and GA introduces to evaluate the observed results of production program and reduces the risk of operating losses and affects in the efficiency of management in production program planning as well. The integrated model enables the management to choose the best among alternative products and to determine concurrently optimal production levels in the light of a firm's goals and objectives.

In order to verify the presented model, experimental research was conducted into pilot plants. A significant result was reached.

By comparing the obtained results of thesis model (integrated approach) with the traditional model results, it clearly shows that the integrated approach improves the machinery capacity utilization level 58%. This improvement reflects on the determination of right optimal quantities of the products.

The results show also the impact of outer risk sources in the quality of decisions which is directly effect on the Profit margin. This integrated approach improves total revenue and decision quality by eliminated influence of the impact of outer risk sources as much as possible. The improvement of total revenue and decision quality appear clearly in the obtained results. All the results obtained is supporting and confirming the thesis hypothesis.

This model expected to be a significant contribution to the development of industrial engineering as a branch of science that studies the behavior of business-manufacturing systems and methods of manufacturing process management and organization.

Key words: Production Program, Multi-Objective Optimization, (GA) Genetic Algorithm, (ABC) Activity-Based Costing, Risk Management.

Scientific field:

Technical science, Mechanical Engineering.

Narrow scientific field:

Industrial Engineering.

UDC: UDK 658.512:005.3(043.3)

Сажетак

Предмет докторске дисертације је пројектовање новог модела за унапређење процеса планирања производног програма применом пројектованог модела за оптимизацију производног програма у пословно-производним системима.

На основу систематизације постојећих сазнања и њихове анализе, у истраживању се указује да је могуће унапредити процес планирања производног програма кроз избор одговарајућих постојећих метода и њиховом комбинацијом предложеним редоследом чиме се добија адекватније решење за посматрани проблем. Пројектовани модел за унапређење процеса планирања производног програма узима у обзир екстерне и унутрашње утицајне факторе на процес планирања производног програма. Екстерни фактори означени као извори ризика, уврштени су у модел кроз управљање ризиком. Интерни фактори укључени су кроз ограничења у моделу вишекритеријумске оптимизације у којем функције циља представљају нелинеарне функције жељених критеријума за маскимално искоришћење унутрашњих производних ресурса.

У раду је на основу порачуна цене коштања производа према активностима генерисана нелинеарна функција трошкова, а затим је извршена вишекритеријумска оптимизација применом генетских алгоритама за нелинеарне и/или линеарне функције циља чији су излазни резултати представљали улаз за примену методе засноване на оцени ризика како би се оценио сваки алтернативни производни програм у посматраном пословно-производном систему под дејством различитих екстерних утицајних фактора који нису обухваћени у класичној вишекритеријумској анализи која се претежно оријентише на максимално искоришћење унутрашњих ресурса предузећа.

У циљу верификације добијених резултата, спроведено је експериментално истраживање у две пилот фабрике.

Сажетак

Поређењем резултата добијених применом пројектованог модела за унапређење процеса планирања производног програма и традиционалног приступа, утврђено је да је применом унапређеног процеса за планирање производног програма степен коришћења машинских капацитета повећан за 58% и повећање укупног профита чиме је потврђена полазна хипотеза истраживања.

Резултати такође показују утицај извора ризика на квалитет одлуке кроз генерисање матрице ризика за посматрану варијанту производног програма, на основу које је добијена укупна оцена ризика. Менаџмент ризиком омогућава доносиоцу одлуке избор алтернативног производног програма на основу прорачуна укупне оцене ризика за сваку варијанту производног програма и избора оне варијанте чији је укупни ризик најмањи.

Кључне речи: производни програм, вишекритеријумска оптимизација, генетски алгоритми, АБЦ проступ, управљање ризиком.

Научна област:

Техничке науке, Машинство.

Ужа научна област:

Индустријско инжењерство.

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Production Planning Review

1.1 Preface

Today an effective production (or manufacturing) planning and control (PPC) system becomes an important achievable target to any successful company. MPC is a system that concerned with planning and controlling all aspects of manufacturing, including materials, scheduling machines and people, and coordinating suppliers and customers. Therefore, every enterprise or company seeks to have a strong, an effective, and an adaptable PPC system to respond to changes in the competitive arena, customer requirements, strategy, supply chain and other possible problems.

Clements and Northrop [2002] said the development of a set of core assets which include requirements specifications, architecture models, software components, and adopt components is used to develop products of a product line. The communication medium between core asset developers and product developers and how the core assets are used to develop products is production plan. The product line approach is adopted in order by the organizations to achieve a number of goals such as reduced time to market, reduced production costs, and improved quality

To reach these goals which the product line organization wishes, strategic reuse of assets such as Domain and requirements models, the software architecture, test plans and test cases, Reusable software components, budgets, schedules, and work plans should be accomplish by an architecture-centric product development approach [Gary C., John D., 2002].

Clements and Northrop [2002] said the production strategy is the foundation in core assets design which is responsible for products developing.

Core asset developers created general production plan. Then the product developer will be able to create a specific product in product line from the general production plan. In addition, the product developers should be determining product requirements, customizing the product line architecture and components, and specifying the testing assets for the specific product [Gary C., John D.2002].

To maximizing the profit of an organization, some of issues should be taken in consideration during production plan created:

- The most efficient core asset for product building should be determined.
- Chosen the best coordinate way of core-asset creation that support consistent and effective product development in a product line.
- Definition and locating the most helpful information of core asset which support the product development in a product line.
- Chosen the best variation mechanisms that provide core assets.
- The ability of product developers efficiently to utilization the variability mechanisms in the core assets.
- Flexibility of product developers during modifying the core assets of the product line.
- If specific problems arise during integration of assets, what kind of help and where can be found.
- Ability to estimate the cost and schedule if specific product requirements be send.

1.2 Production Plan

The core-asset developer creates the process. Each core asset which includes the requirements, architecture, components, test cases, plans, schedules, and budgets has an attached process and that describes how the core asset is used in product line plan. These steps called production plan which lead to yield a product [Clements, and Northrop 2002].

Complete description of the production plan introduced on concept of Operations [CONOPS or Con Ops] as following: (Cohen, 1999].

- Input requirement to build a product,
- Activities that guide or lead to a completed product,

- Roles and responsibilities of the product developers, and
- Schedule and resources associated needed to build the product.

In product line organizations, CONOPS document is used to describe how the product line organization operates. It is useful document for personnel to understand the roles and responsibilities in the organization. CONOPS describes the characteristics of a proposed system from the viewpoint of an individual who will use that system. Also, it is used to communicate the quantitative and qualitative system characteristics to all stakeholders. In general, the CONOPS progresses and develops from a concept description point to achieve desired objectives or end state point.

Usually concept of operations documents share the same properties such as:

- Statement of the goals and objectives of the system
- Strategies, tactics, policies, and constraints affecting the system
- Organizations, activities, and interactions among participants and stakeholders
- Clear statement of responsibilities and authorities delegated
- Specific operational processes for fielding the system
- Processes for initiating, developing, maintaining, and retiring the system

With a special product line for special products, one plan fits all products. In this case, the product-build process and production schedule are non significant; the only real issue is the production resources. In this type of production lines, the production plan contains all of the information needed by the product developers [Gary C., John D., 2002].

The production plan is designed to contain only the processes and resources required that is relevant to the creation of that special product. Instance, deluxe products have special security features while basic products have not. It means; the product line architecture would have a corresponding variation point that permits different operating systems. In conclude; each product-specific production plan is a brief guide to build one a specific product [Gary C., John D.2002].

1.2.1 Product Line Production Planning Activities

Product line asset engineering and product engineering are the two major engineering processes of Product line. They include several of activates which are identified related to product line production planning [Clements and Northrop, 2002]. Figure 1.1 below shows these activities:

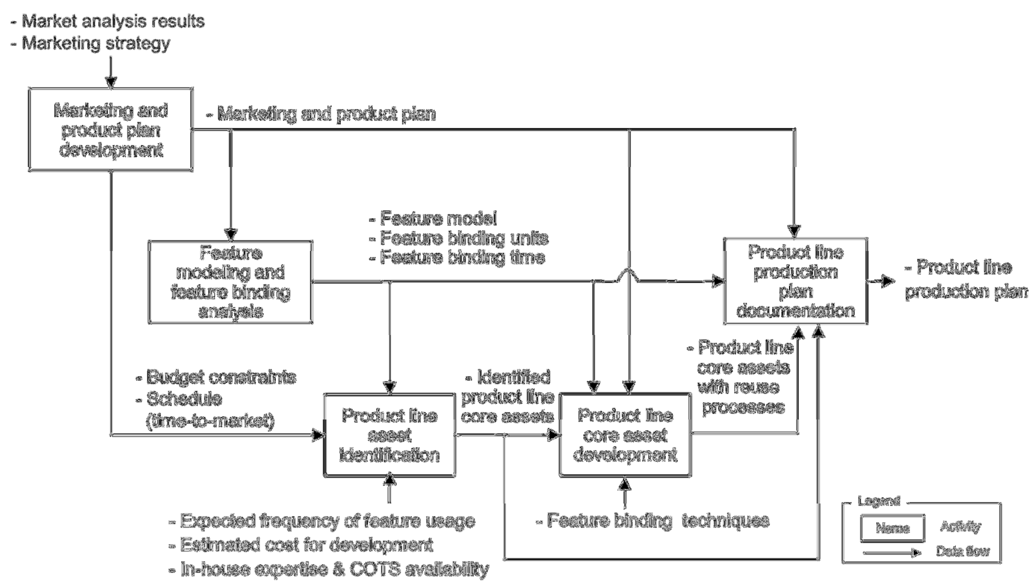

Figure1.1 Product Line Production Planning Activities [Kang and others, 2002]

1.3 Creating the Product Line Production Plan

The production plan for a product line is more complicated and deals with a wide domain of topics reverse than the typical project plan which is used for a single product. It contain the sequence of activities needed to build a product, schedules of activities, bills of materials, and assignments of roles and responsibilities. The production plan for a product line is deferent from one product line organization to another. In spite of, it describes all communication between the core-asset developers and the product developers, as well as a source for resource and schedule estimates in any organizations [Hax and Arnoldo, 1987].

The main responsibility for developing the production plan is the core-asset as explain in figure 1.2 & table 1.1.

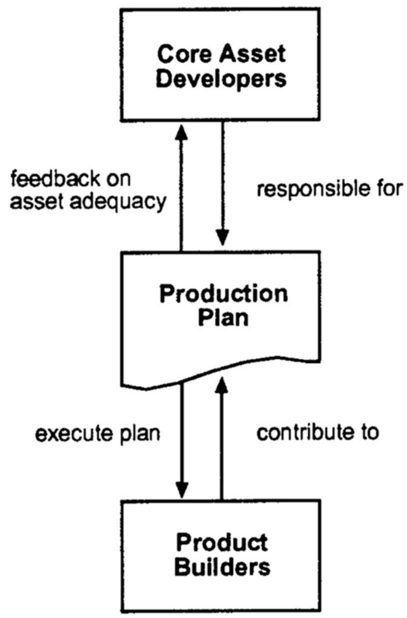

Figure1.2 Relationships between Core-Asset Developers and Product Developers [Gary C., John D.2002]

Table1. 1 Responsibility of core-asset developers & product developers on production plan [Gary C., John D.2002]

Core-asset developers	product developers
• Contribute to the production plan from the perspectives of having analyzed all products within the scope of the product line and having developed the core assets. • Responsible for including sufficient information about each core asset to allow the product developers to understand the assets and make choice. • Provide guidance to the	• Contribute to the production plan from their perspective of actually executing the product-building process. • Provide feedback to the core-asset developers initially as they attempt to understand the product-building process. • Later, provide feedback based on their experience with the product- building process. • Identify process defects,

product developers on how the assets should be used by attaching a process to each core asset. For example, the attached process of the software architecture provides a technique for tailoring the architecture to fit the specific product.	unrealistic constraints, and implicit assumptions in the processes attached to the core assets. • Identify interactions between independent processes that are not properly coordinated and contribute to evolving resources such as Frequently Asked Questions (FAQs).

1.4 Using the Production Plan

The production plan is the guide map of production developers. It determined the path of the product from the beginning to the delivery stage to the customers. All the information needed to track the progress of product provided by production plan. This information helps the product developers as:

1. Provide them alternative choices of variants core-asset to choose the best.
2. This information use as mapping between sets of assets. That helps the product developers to determine which assets are needed to develop the product and the product under construction as well [Gary and McGregor, 2002].

1.5 Relevant Characteristics of Product Lines

Clements and Northrop [2002] introduced product lines in three deferent ways and as shown in figure 1.3:

1. Product line is related to experience of practice area.
2. Product line is related to ripeness or type of product market.
3. Product line related to automation of product ingenuity and innovation.

1.5.1 Practice Area Expertise.

A product line organization improves it's expertise by selecting core assets which related to practices. Organization that has institutionalized will describe all the production process in details. On the other hand, the organization which has not institutionalized could not adopt the product line practices and has only a simple document that may be in the developer's mind [Clements and Northrop, 2002].

1.5.2 Automated Product Creation

Product line of product creation offers fixed set choice from the available set features. That means the information domain is not important for the product developer to know and the actual components being used to implement the product as well. Therefore, a new plan required for each new product. This lead to the product developer needs to expand his components knowledge as well as domain. In the automated product line, all parameters need to build process and the possible values of these parameters are described by the production plan. In contrast, in case of manual creation, the product developers could include requirements analysts, architects, component builders, testers, and so forth. In such type, the production plan provides detailed information about the available components and provides instructions for creating new build scripts [Gary and McGregor, 2002].

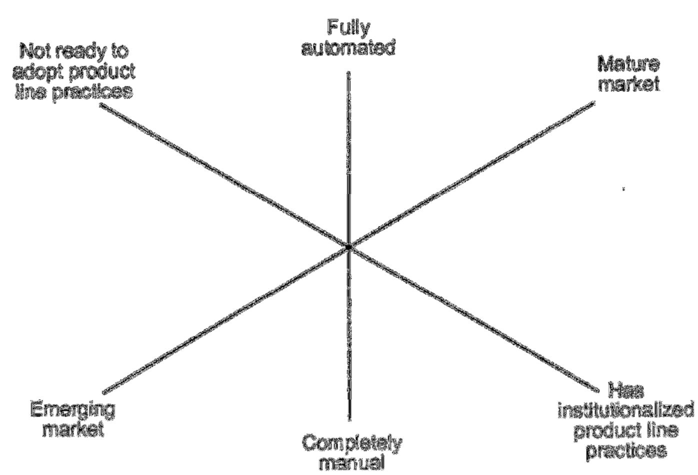

Figure1.3 Classification Dimensions [Gary C., John D.2002]

1.6 Classification of a Product Line

Figure 1.4 shows the directions of product lines movement over the time. The production plan should be changed and flow this movement to match and accommodate the line's new position.

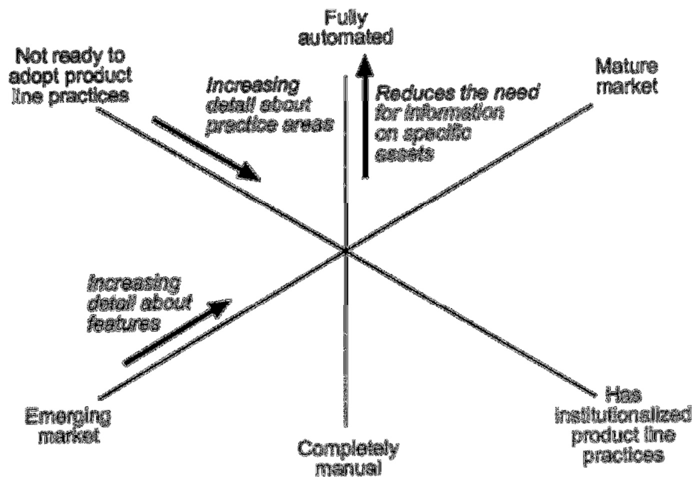

Figure1.4 Product Line Evolutions along the Classification Dimensions [Gary C., John D.2002]

1.7 Issues in Building a Production Plan

Product line's production plan documents could be fully automatic, semi automatic, or completely manual. Every type of product line has a strategy for creating product. This strategy determines the development process that is documented in the production plan.

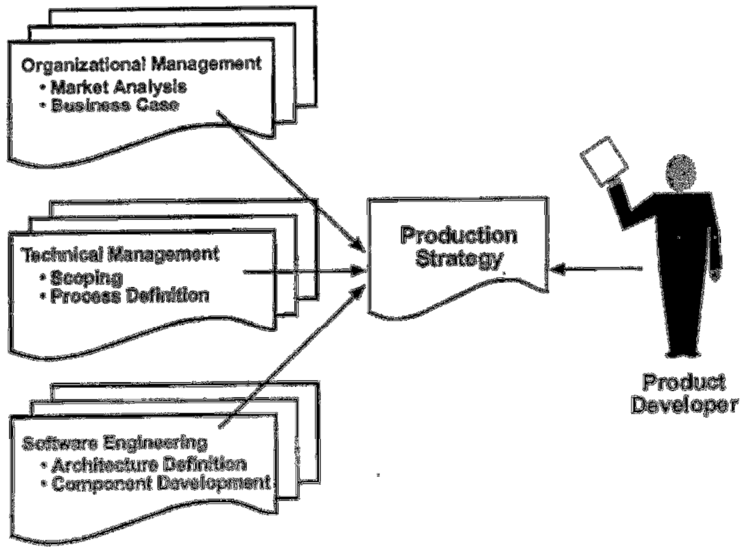

Figure1.5 Production Strategies [Gary C., John D.2002]

As shown in figure 1.5 a number of elements such as market analysis, scoping, technical issues, and the business case are inputs to the production strategy. The production developer is a source of these elements for the production strategy. This strategy is, in turn, the primary input to building the production plan.

This section addresses in some detail about:

- Production strategy description and how it's influence on production plan.
- Describing of product developer's view of a product line.
- Production plan creating.

1.7.1 Production Strategy

The production strategy is built depending on Goals of product. Therefore, Production strategy identifies all conditions and techniques that support those goals for product development. Number of factors are defined by production strategy such product developers skills and how they identify the product, process of product developers, and technical environment needed to build the software product.

1.7.1.1 Qualities of the Production Strategy

Production qualities strategy is defined as the qualities needed to produce a product and not the quality of that product himself. It comes from business case and should be specified before the strategy is defined. Production strategy should have required qualities that achieves to product line goals. Quality of production strategy should be:

- Flexibility. It means the product line has the goal of adopting emerging technologies as quickly as possible.
- Simplicity. Reducing product developers (personal cost).
- Performance. Increase of the product line when entering to a new market.
- Modularity. Ability to maintain of product line goals and standard in an emerging market by replaced or modified some core asset.

1.7.1.2 Influences on the Production Strategy

Market Analysis and Business Case Development are the most significant influence on the production strategy; they called organizational management practice areas.

In case of emerging and flux marketing, unstable product line exists because features of product are changeable rapidly. For mature market, the features are stable and automatic generation products can be applied. In competitive market with high demanding of customers and each with special needs, the organization needs to respond for marketing rapid time to compete successfully.

Business case drives the production strategy in many ways. For example, reducing the long term cost of organization leads to reduce the number of software developers. Also, adopting a product line approach for first time could be face apprehensive and resistance from current staff. So, gradual changeable may be appropriate.

Also, Scoping (domain) and the software engineering practice areas of “Architecture Definition” and “Component Development” are influence on the production strategy as well; they called Technical management practice area.

Product line scoping (domain) drives the production strategy in way if product line includes products that have very tight performance requirements. That needs to determine the types of products and customization at product-build time.

Process definition affects on process model which had chosen as an essential component on production strategy [Gary McGregor, 2002].

Also, architecture definition has significant affect on production strategy. For example, one of the architecture’s quality attributes is build ability. Mechanism needed to achieve that quality attributes which will effect on the strategy for building products [Bass, 1998].

Specifications of component development are determining the production process that is able to do when asset are selected.

1.7.1.3 Interactions between the Production Strategy and Core Assets.

The guide line of core asset developer is the production strategy. It defined the structure information of each component which should be available to the product developer. On other hand, core asset selection can be affected on production strategy. It means production strategy progresses as long as new core assets are starting selected. Other special interaction between production strategy and core assets through development environment constructed such as commercial product line and individual programming tools.

1.7.2 Product Developer’s Perspective.

The person who is deal with the production plan and all its components such as product line’s core assets, attached processes, production process, and production strategy called product developer. The task of product developer is determining the product that should be building and the special core assets are required or needed to build that product. Also, he should make integrated between components which are identified by production strategy.

Production plan has many benefits:

- Efficient. It includes all the activities which are necessary to produce a special product.
- Complete and understandable. Containing all the usable information are needed and without outside assistance.
- Usable. It allows the product developers able to locate needed information quickly and easily.

1.7.3 Building the Production Plan

Two basic elements are needed to build production pan, plan structure and core assets.

1.7.3.1 Plan Structure

Structure of plan consists of:

- Introduction, such as production context, audience, and qualifications.
- Product development strategic view includes assumptions, qualities, possibility product producing from available assets, and production strategy.
- Overview of available core assets, such as basic inputs and dependencies and variations.
- Production processes details.
- Management information like resources of schedule production, bill of materials, details of a specific product, and metrics.

Production plan expands and develops the production strategy and it's concepts and recourses into complete definitions. It integrates the production strategy and core assets required, people and bill of materials. Strategy plan and variation choices identify resources requirements while activities accomplish production plan. Resources distribution and their sequences in order are implemented by the schedule [Gary and McGregor, 2002].

1.7.3.2 Core Assets

Production plan provides all core asset requirements to product developers in appropriate production process place. These core assets are presented depend on variation points and include all information that is relevant to product developers. Variations points are determined by core asset developers depend on where the products are vary [Kang, 1990].

Product developers use the production plan to removal or reduce scattering effect which could face them. This is done by considering only the assets needed in the production plan and organizing the core assets in order of elements list or a sequence such as “product identifier, core asset, variation point, instructions” in the production plan.

1.8 Describing the Product Development Process

Production plan explains the production line process that needs to produce a product. Many criteria are required for this process before building the product. These criteria are defined in CONOPS.

Table 1.2 below contains three different examples describe product line corresponding at specific classification point.

Table1. 2 Examples: Corresponded product line at specific classification [Gary C., John D.2002].

Example	Market	Practices	Process
1	Immature	Not Institutionalized	Manual
2	Mature	Institutionalized	Automated
3	Mature	Institutionalized	Semi- Automated

1.8.1 Example 1

In this case, the product built in an immature market and has minimally automated process. This type is suitable for an organization, whose has not institutionalized practice areas. Allowable paths between practice areas are shown in figure1.6. Experience in product line is needed in all of practice area [Clements and Northrop, 2002]. As competitors add new features as functional of products rapidly changes and improve quality of product to gain market share.

In this type of product line, production plan should be content all critical to avoid any confusing from product developers.

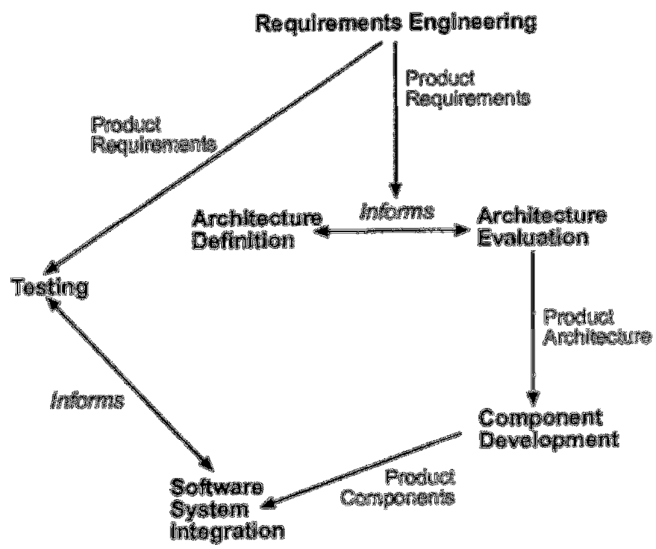

Figure1.6 Dynamic Structure of the Product Builder Pattern [Clements and Northrop, 2002]

1.8.2 Example 2

This case is suite for an organization that has institutionalized practice areas. Also, process of product development is automated and product builds in in a mature market. In view of highly automated development process, no new development is required [Clements and Northrop, 2002]. The product developers collect requirements. After that, they use product line tool to define and assign the requirements to be used. Finally, they test product results.

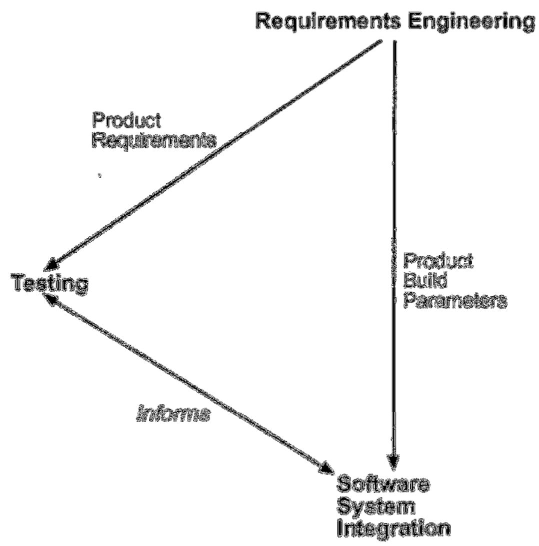

Figure1.7 Dynamic Structure of the Product Generation Variant [Batory, 1997 and Weiss, 1999]

Batory [1997] and Weiss [1999] introduced a simple product development techniques flow for this type as show in figure 1.7.

In this type of product line, requirements process is automated derived by a fixed set of features. After the requirements are selected, the build tool automatically constructs the application. The application of this type of product line basically calls or designates documentation, whose includes definitions and dependencies of all requirements set. On the other hand, the plan should have using instructions of the requirements and testing tools to develop a product. To avoid any incur royalty fees, the bill of materials should include any external components so that the plan provides a unit cost for the product especially in case of produce specific product.

1.8.3 Example 3

In this example, the product build for an evolving market a mature product line organization is suite. Here, the product process is created automatically in the areas of requirements engineering and system integration.

But some activities still accomplish depend on personal experience such as architecture definition and testing.

In this type of product line, production plan include all practice area that could be required to produce specific product as shown in figure 1.7. Also, the production plan is rapidly changing document but the change is well managed. No changeable is possible during the beginning of the product creation unless the changes correct fatal flaws correct in the production plan.

1.9 Specializing Production Plan for a Specific Product

In this type of production line, the plan guides the product developer through an inevitable and unchangeable product-build process. In other words, the product-build process on this type of product line will be fit for all products. Variation of these processes built on the basis of features selection. It means each product has a product-specific production plan. Consequent, each plan has specialized design.

The processes that attached to the production plan direct the product development team in creating the product-specific production plan. These directions are:

- Depending on definition, select and order the process steps that are needed.
- Providing all the assets that use for this specific product will be exist on bill of material of product develop.
- Define build product scheduling time and its estimate time.
- Adapted modified of core asset parts of production plan that must be changed.

1.9.1 Selecting and Ordering Process Steps

Different technologies application, adapting and modifying of assets, and different requirements are responsible of variations between products. The product process becomes more defined and the product takes the exact form as the teams of product make the decisions. After that, the steps of the attached processes of all of the selected assets are integrated into a tight specific production plan.

1.9.2 Developing the Bill of Materials

Bill of materials includes all of the assets that are needed to build the product and it is the basis of cost estimates and schedule predictions in the production line for a special product. Each asset can be assigned one of the following costs:

- Determining royalty fee charged for each royalty fee charged.
- An amortized internal charge that is resulting from developing organization by cut off sum allocated over the projected to be sold.
- Purchase price time form external source for one time.
- No direct charge for the asset.

Scheduling prediction is effected by the bill of material also. Each asset that is includes in the bill of material can be affect on modifies estimate time and data of the schedule. For example:

- Externally mandated components. These components may be core assets or specific component for a particular product. Corporate strategies outside and product line developers are responsible in determining of these components.
- Standard, acquired components. These components are core assets. For example, planning for the product line may lead to select an external vendor who supplies a portion or portions of every final product.
- Local core assets. These are the core assets developed by the product line organization.

1.9.3 Management Estimates

Depend on requirements resources to staff schedule, the initial information of the scheduling and cost estimates will be exist in the production plan. This information will be updated after any specific product definition is completed.

Humphrey [1995] said standard management cost and size estimates is determined by techniques such as Personal Software Process ^{SM} (PSP^{SM}) and Team Software Process ^{SM} (TSP^{SM}). An example of format for such a table for components shown in table 1.3.The time estimates for each phase within each component type are based on measurements collected during previous product development efforts. In other words, as the assets are evolved over time as the bill of materials is updated, consequent, estimates are updated.

Table1. 3 Rate Table [Jacobson and others, 1999]

Component type	Effort required integrate (in hours)
New component, one – time – use	Analysis: Design: Implementation: Test:
New component, new core asset	Analysis: Design: Implementation: Test:
New variant on a core asset	Analysis: Design: Implementation: Test:
Core asset reuse	Analysis: Design: Implementation: Test:

1.9.4 Maintaining the Production Plan

Production plan may change or modified related to some of actions such as:

- Changing in the requirements.
- Emendation or correction of business priorities.
- Creation of a new asset.
- Appearance or issue of a new version of an asset.
- Upgrade of a tool.
- Revision of a process.

Multiple version plans are made before receive to the product line production plan. The current version of the production plan is created and configured when a new product-specific production plans are created. The production plan configuration contains links to the current set of core assets. As these assets are upgraded as a new configuration is created to match and fit the new version. The product line organization draws the policy about how often these new configurations are created as illustrated in figure 1.8.

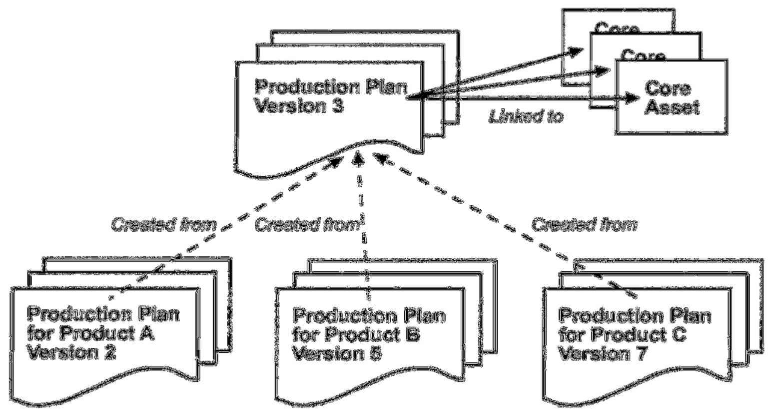

Figure1.8 Configurations of Production Plans [Gary C., John D.2002]

1.10 Using the Production Plan

The production developers use the production plan to guide their day-to-day work and keep communication with each other's. They evaluate the performance and effectiveness of the plan then use that evaluation to correct and improve the production plan.

1.10.1 Interactions

The production plan is used in the context of other synchronous processes. Some of processes such as personnel evaluation process may little or no interaction with the product development process. The most common types of interaction are:

- Processes of software development.
- Processes of product development.

1.10.1.1 Software Development Processes

There are many methods are used by organizations when they begin a product line approach such as the Rational Unified Process (RUP) [Jacobson, 1999]. These types of methods have good features such as a strong support tool and well test approaches. These features are used to build strong software that satisfies a set of requirements.

1.10.1.2 Product Development Processes

The interaction between planning, management, and development portions of the organization is defined by product development processes such as Product and Cycle-Time Excellence (PACE) [McGrath, 1996]. Product development processes may extend to include hardware development, marketing, sales, and maintenance roles. Production plan describes links between the process that create the software and the overall product development process. In some models like PACE model is defined base on projects that are focused on single products. This definition can be in fundamental conflict with the product line approach. For example, in case of an organization which use PACE model to build software, the interaction between the core-asset developers and product developers for each product in the production plan is missing from the PACE model. It means the product developers operate within the structure of the PACE model while the core-asset developers work outside the model as shown in figure 1.9.

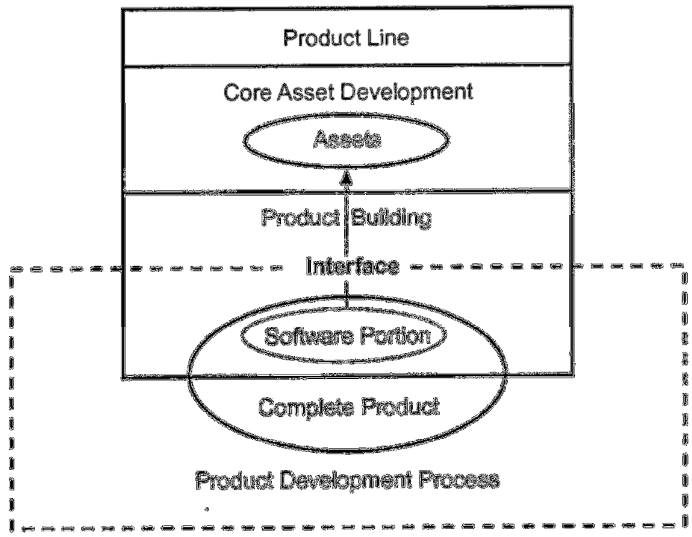

Figure1.9 The integration of the Software and Product Development Processes [McGrath, 1996]

1.10.2 Using the Plan before Product Creation

Construction plan for any product build base on product line's production plan. Product specific production plan is created by processes attached in the production plan. These processes include a lot of information that is useful to determine the practice areas are needed for developing the product. Fore example, PSP technique is one type of that information could be use to estimate the size of the final product [Humphrey, 1995]. Many factors can be used to estimate several product attributes such as number, size, and complexity of each component. An example for such calculation is shown in table 1.4.

Table1. 4 PSP Categories for Size Estimation [Humphrey and Watts, 1995]

Type of Component				LOC
Base Program	Type	Methods	Relative Size	
Base Size (B)	I/S/LC	Integer	Very Large – Very Small	
LOC Deleted (D)				
LOC Modified (M)				
Added LOC				
Base Additions (BA)				
New Objects (NO)				
Reused Program (R)				
Estimated Total LOC	NO + B – D – M + R		=>	

Other techniques such as COCOMO offer only system-level estimates while the PSP technique provides detailed planning information [Boehm, 1981]. The product line will use the technique that best fits its needs.

1.10.3 Using the Plan during Product Development

Production plan includes all the strategy details and roles for the product developers. This plan explains all the roles and responsibilities of the product developers and provides the guide lines for the product developers to do many deferent forms. For example, the plan will be determine variability resolution analysis for product developers, identify parameter values of generators and constructors, and guide conducting reviews, collecting data, and tracking progress for managers.

1.10.4 Using the Plan after Product Development

Production plan should be structured to facilitate any evaluation later. Because the product developers will be evaluate all the operation of the product line process and the effectiveness of the production plan in guiding that process through and after the action. Clarity, completeness, and correctness are some of characteristics that the product developers will be evaluated. Also, each asset listed in the bill of material is also evaluated for goodness of fit with each other and for consistency within the group listed in the bill of materials as well. The product developers will inform the core asset team as quickly as possible by any defects in the assets. On this basis, the core assets developers will make change required in the process depend on report of the product developers.

1.11 Evaluating the Production Plan

The production plan is evaluated periodically. The start of a new product development effort is a particularly useful time at which to review and evaluate the plan. Specifically, reviewing the accuracy of the schedules and cost estimates from previous projects should be done at the start of a new product, before the same calibrations are used to produce new estimates.

The product developers evaluate the plan in terms of the characteristics. The results of that evaluation are provided to the core-asset developers, who evaluate the information in the plan to ensure that it reflects the current version of each core asset. The core-asset developers then update the production plan and any other pieces that need modification.

Jones and Northrop introduced a set of criteria to improve and evaluate the production plan. These criteria are summing up in:

- Appropriateness for purpose,
- Purity and clarity,
- Brevity,
- Sufficient,
- Internal modularity,
- Internal and external coherence and traceability, and
- Usability.

1.11.1 Appropriateness for Purpose

The product developers should collected all the information and put them as contents in production plan. These contents should be clear and appropriate to tie the core assets that are used to build products. The steps that have not affected in product developed should be eliminated.

1.11.2 Clarity

The information which exists in production plan should be clear, readable, and understandable. This is leading the product developers able to locate the appropriate core assets for build a product. So, it is important to determine which parts of the plan are the sources of the most requests for information from the core-asset team.

1.11.3 Brevity

The production plan should include only the necessary and requirement information that needed for the product developers to locate requirement assets to construct the product.

1.11.4 Sufficient Detail

The production plan should contain full and complete details of attached process of each core asset.

1.11.5 Internal Modularity

When a change is made to the product plan, many parts of the plan will be affected. The production plan should be flexible for modular to extent attached processes are included by reference rather than by content. This means it should be able for extend and modify attached processes without modifying the production plan.

1.11.6 Internal and External coherence and Traceability

When a core asset is modified, is it possible to identify where changes should be made in the production plan. Therefore, the production plan should keep external coherence by maintaining the attached processes and keep internal coherence by selecting the process steps from the overall process as illustrated in Figure 1.10.

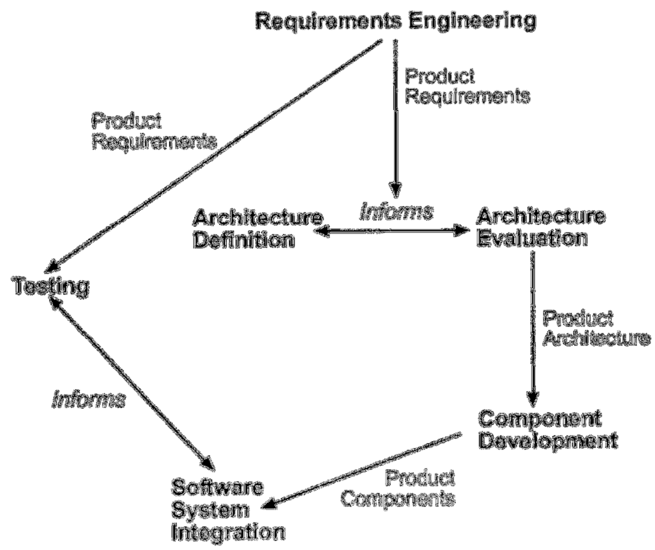

Figure1.10 The Product Builder Pattern [Cohen and Sholom, 1999]

1.11.7 Usability

Usable production plan exists when it is written form the product developer’s perspective. By other word, usable the requested information from the core-asset team and already existed in the product plan.

1.12 Some questions might be confused or not clear enough in some organization

The core-asset developers create the production plan for the product developers. In some organizations, the two groups may have very different levels of domain and development expertise. In other organizations, there is no clear separation between the core-asset developers and product developers. Work is needed to determine exactly how the core-asset developers can understand the product developers' perspective and produce a document that is written from that perspective.

Review of Previous Investigations on Production Program Planning

2.1 Review of Literature

Kakumanu [1998] developed a multiproduct cost-volume-profit model. In this model, he integrated sales or product capacity limits for each product on profit levels as determined by the government and located over-cost to a group of products. An algorithm was constructed to solve the model. The algorithm was able to determine the required volume for each product that reached the best rate of return on sales revenue. He also calculated the breakeven volumes and the profits before taxes as a special case. Some assumptions were made to develop this model. The first assumption was divided the cost and expenses into fixed and variable components. The second one, the fixed cost is significant and located to a group of products. Finally, unit selling price, product limits and product mix of each product, and variable cost are unchangeable. Depend on the model algorithm and the database management system, he designed and developed an interactive support system which was helpfully for the manager to conduct a sensitivity analysis and introduce repots to aid decision making. This management repot was divided to seven parts related to numerical results. The first part deal with three parameters that are fixed cost, required rate of return after tax, and tax rate. This part helps the manager to know if any changeable happen on these parameters how it will be affect in the final solution for given input data. The second part includes all the information about total number of product, number of iterations needed to achieve the final solution, product code, price, cost, limits, and product mix. It contains also the final required volume and final product mix which are getting from the model and algorithm developed. The key indicator variables for a given input data are getting from part three. Part four allows the manager to compare solutions obtained based on the algorithm developed and establish the upper bound on the revenue for the solution. In part fifth, the manager able to compare alternative solutions obtained by selecting value of parameters such as fixed cost, rate of return on sale revenue, and tax rate. Part sixth contains the upper (optimistic) and the lower (pessimistic) limits which are computed for cumulative contribution and revenue. This aids the decision maker to monitor the total contribution margin and total sales revenue obtained during the planning period. The last part deals with analysis of the actual product mix during the planning period based on Klipper's [1978] methodology.

The multiproduct CVP model is developed to obtain the target volumes to satisfy the given limits for each product. In case of there is no solutions exist, the algorithm generates the best possible volume and unachieved required profit. The following steps show the way how the Kakumanu built and developed the model and the algorithm.

He use given product mix to calculate weighted sales price and unit cost by the following equations:

A: targeted profit

FC: fixed cost

t: tax rate

r: required profit margin on sale

k: number of products

p_i: unit price of i^{th} product

$c_{i:}$ unit variable cost of i^{th} product

m_i: product mix of i^{th} product

$l_{i:}$ capacity or demand limit for i^{th} product

Weighted sales price equation,

$$W_p = \sum m_i p_i \quad \text{………………………………………………} (2.1)$$

Weighted unit cost equation,

$$Wc = \sum m_i c_i \quad \text{………………………………………………} (2.2)$$

The composite volume requirement (Q) to obtain the required profit margin on sales after the taxes is:

$$Q = [(1- t) * FC] / [(1 - t - r)\ wp - (1 - t)\ wc] \quad \text{.................} \quad (2.3)$$

If wc ≥ [(1- r)/ (1- t)]wp then, the required profit margin can't be achieved

For all products, the required volume is:

$$q_i = m_i Q \quad \text{...} \quad (2.4)$$

And total revenue (TR) is calculated by:

$$TR = \sum q_i\, p_i \quad \text{...} \quad (2.5)$$

If $q_i \le l_i$ for all I, then, ($q1$, q_2, ……….,q_k) represents the required volume of each product to achieve the required profit on sale. And solution of CVP problem is given by equation (2.4) and (2.5).

If qi ≥ li for all I, then, no possible to achieve the required profit on sale. And the best solution is getting by setting the required volume to the given limits:

$$q_i = l_i \text{ for all }_i \quad \text{...} \quad (2.6)$$

And total revenue given by equation (2.5).

In case of finite number of iteration, the algorithm can be adapted to the desired profit model by using equation (2.7) instead to equation (2.3).

$$Q = (1 - t)\ FC + A / [(1 - t)\ (wp - wc)] \quad \text{.........................} \quad (2.7)$$

Chi-Ming Lin (2007) studied multi objective portfolio optimization problem. This problem was deal with the portfolio process of the highest expected return among the various financial commodities of the capital market to meet the expected return objectives. Markowitz (1987) introduced a mean variance approach which was to deal with the portfolio selection problem. The mean variance approach was formulated as:

$$min\ \sum_{i=0}^{n} \sum_{j=1}^{n} \sigma ij\ \dot{x}i\ xj \quad \text{...} \quad (2.8)$$

S.t.

$$\sum_{i=0}^{n} \mu i x i \; \geq E, \;\; \sum_{i=0}^{n} x i = 1, \;\; x i \; \geq 1 \; and \; i = (1, 2, \dots \dots \dots, n) \dots.. (2.9)$$

Where:

σ_{ij}: is the covariance between the return of ith security and jth security.

μ_i: is the expected return rate of the ith security.

E: is the acceptable least rate of the expected return.

x_i: is the investment portion in the ith securities.

Markowitz's approach has capability to derive the minimum investment risk by minimizing the variance, or has capability to derive the maximum returned by the expected returns of portfolio for a given risk level which the investor can tolerate. Expected returns and variance of expected returns of the securities were the main input data of Markowitz mean variance model [M.Ehrgott, and others]. Markowitz's theory uses only mean and variance to describe the characteristics of return. After awhile, Markowitz's theory became a cornerstone of modern portfolio theory about the structures of portfolio.

Due to the huge numbers of financial securities and the acceptable least rate of the expected return is difficult to estimate, Markowitz's model is not practical for applying. Therefore, Chi Ming Lin [2007] expanded Markowitz mean variance approach. Chi Ming's model has two phases. First phase is select short list of the securities according to past performance evaluation. Then, he applied genetic algorithm to decide the investment weight of each securities.

Chi Ming's mathematical model is:

$$\text{Max} \sum_{i=0}^{n} \mu i \; w i \; \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.... (2.10)$$

$$\text{Min} \sum_{i=0}^{n} \sum_{j=1}^{n} \sigma i j \; w i w j \; \dots\dots\dots\dots\dots\dots\dots\dots..\dots\dots (2.11)$$

Where:

i, and j: index of security, i, and j = 1, 2, ……., n.

μi: is the expected of security, i, and j = 1, 2, …………, n.

σij: the covariance between the return of security i and security j, for

i, and j = 1, 2, …………, n.

w_i: is the investment weight of security i.

S.t

$$\sum_{i=0}^{n} wi = 1, \ \ wi \ \geq 0 \ and \ i = (1, \ \ 2, \dots \dots, n) \ \dots\dots\dots\dots. (2.12)$$

He applied the following equation to generate the investment weight of security.

$$wi = \frac{vi}{\sum_{i=0}^{n} vi} \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.13)$$

The objective function of equation (2.9) and (2.10) is to maximizing the total expected return and minimizing the total risk of the portfolio respectively. Chi Ming's mathematical model tracked these two objective functions at same time. Then he generated a set of Pareto front solutions after applying multistage decision based genetic algorithm approach. The experiment result shows that the Chi Ming's model is valid for the portfolio optimization problem and has capability to sole multi-objective functions at same time by applying genetic algorithm approach which can't efficiently solved by traditional optimization methods.

Daniel, and others [2008] developed and analysis of Cost Volume Profit model for a multiproduct situation with variable production structure. The model was redeveloped taking into account the possibilities to identify the cost components in a real world business. So, they segregated indirect costs (fixed cost and variable cost) and direct costs (fixed cost and variable cost). The model provided a relatively simple and tangible framework which illustrates the use of real cost determination for the purposes of cost – volume – profit analysis. They concluded that the specificity of every business situation makes impossible the development of an indirect variable cost universal model, but based on regression a detailed model from case to case can be identified. They developed a useful and potential model which is using in the area of real-world business decision-making.

Gonzah [2001] developed an alternative model for multiproduct cost-volume-profit (CVP) based on linear, non-stochastic, and restricted to one product. He formulated a contribution rule for each product using data provided by ABC systems designed. That allows keeping track of variable and fixed costs. For a given (target) profit, the developed model was proved its ability to compute the output required to achieve that (target) profit. He built his model at some assumption such as the fixed cost for each manufacturing center and costs related to each marketing channel in the short term. Appling linear programming and under deferent constrains and situations of production issues, the algorithm gave the best possible and the worst possible mix.

Shih [1979] introduced a general decision model for cost-volume-profit (C-V-P) analysis which improves the determination of actual sales and profit results by dealing with critical elements of random demand and level of production. The model has applied on real case and treated defects which are in the traditional C-V-P model. This drove to development and improvement in the profit behavior. The stochastic was using to propose probability distributions of profit and the calculations of their means and standard deviations in attempts to identify the best choice available among alternative products. The model takes into account all deficiencies that the traditional model failed to recognize them such as the differences between and the relationships among, sales, demand, and production. The model construction was designed based on separated sales from production and demand and which properly places each one of them in their respective roles. This construction was presenting a more realistic C-V-P relationship. He widely used the normal distribution to illustrate the general results. Out put result of the model provided very useful information and was useful as a valuable tool to aid management in making decisions. The model was applying in two cases. The first case applied on a single production decision problem where the break-even point, mean, and standard deviation of profit were calculated, among others. The second case was concerned with the selection of the most desirable product for marketing among several mutually exclusive products. In both cases, several decision situations were concluded. He introduced capable model for the C-V-P analysis and usefulness in management decision making under uncertainty.

Ishikura [1994] proposed three methods of production planning for the apparel industry with explanation the advantages and disadvantages of each method. The first method is a seasonally changeable production model according to inventory requirements. The second one is a seasonally changeable production model according to actual demands. The last method is preserving and running the same model inventory for several seasons. Every method was built based on some assumptions. For example, every season the design of products are changed, selling prices is divided to a list price and a bargain price, demand at a bargain price is commensurate with demand at the list price, quantities of products is determined based on the profit, and the demand on products flow normal distribution were presuppositions methods for method I. for method II the same assumptions was taken into account except The production quantity is defined according to marketing information. For method III, he assumed that the same products design is used over several season, the sales price and the list price is the same, the demand on products and the quantities of product are kept as in method I assumption. The profit was determined by each method. He concludes that the model I gives the maximum profit for all that method II is generally considered appropriate for the apparel industry. In case of popular product with consumers, the model III is suitable for the firm to obtain higher profit more than by other models. To improve the profit, the relation between the quantities of products should be investigated in production planning.

Liu and Papageorgiou [2013] studied Multi objective optimization of production problem. Total cost, total flow time and total lost sales are taking into account as a key to developed an approach of a multi objective mixed-integer linear programming (MILP). They used two methods as solution approach for multi-objective problem, the ε-constraint method; which is introduced by Haimesetal [1971] And Chankong [1983]; and lexicographic minim ax method. One assumption was considered that the original Capacities of formulation plants will not satisfy the requirement of rapidly increased demand. Which means the capacity planning is also taking into account. They used two strategies for capacity expansion. The first one called the proportional capacity expansion (PCE), the maximum capacity increment of each formulation plant is proportional to its capacity before expansion. This means the capacities before expansion have more ability for expansion. The second strategy called cumulative capacity expansion (CCE). It means for all formulation plants the increment of cumulative capacity is limited regarding to cumulative capacity before expansion. This means the capacity before and after expansion is independent. The ε-constraint method used to solve mixed-integer linear programming models and obtained asset of solutions for each scenario, which are proven to be Pareto-optimal by solving problems. After that, lexicographic minim ax approach was used to determine which Pareto-optimal solution to be implemented in order to get a fair trade-off between cost and responsiveness. They compared a set of solutions with minimum total cost and minimum flow time. The results showed that cumulative capacity expansion generates a better solution.

Kim and Sooyoung [2001] extended linear programming model for a similar hybrid approach which was proposed by Byrne and Bakir. Byrne and Bakir [1999] said the capacity constraints in such a model may not correctly represent the actual situations of the shop floor. Consequently, they applied simulation and a linear programming model iteratively, to find the capacity-feasible production plan. The new hybrid production planning approach that was developed by Bokang and Sooyoung determined the actual workload of the jobs and the resources used at each simulation run. This information was entered to the linear programming model as input data to calculate the optimal production plan with minimum total costs. Adjusted capacities and workload that derived from the simulation model results were the proposed of the new approach. As a hybrid approach, a simulation model was used to support the LP planning model. This means if the model failed to find feasible solution of the optimal production plan, new adjusted capacities and workload should make for the LP capacity constraints based on the simulation results. The results shows the new model gives better feasible optimal production plan solution with less number of iterations compared to the approach by Byrne and Bakir.

Wanga and Liang [2005] introduced a new possibilistic linear programming (PLP) approach for solving the multiproduct aggregate production planning (APP) problem with inaccurate forecast demand, concerned operating costs, and capacity. The approach succeeded to minimize total costs with an indication to inventory levels, labor levels, overtime, subcontracting and backordering levels, machine and warehouse capacity. The minimizing value of imprecise total costs and risk of obtaining higher total costs was used as a strategy. They applied the model to real aggregate production planning (APP) decision problems. The PLP approach gives a satisfying solution for aggregate production planning (APP) problem. Obtaining results shows that the optimal value for APP problem improved when applying PLP approach rather than LP model. These results denote that the PLP solutions are compromise solution and functional compared to the optimal goal value obtained by the LP model. Also, it introduced an acceptable degree of decision maker (DM) in a fuzzy environment that is satisfying with determined goal values.

In the real industrial area, there is always a conflict between the producer and the purchaser profit. The producer's profit needs to consider the problem of sales revenue and manufacturing cost. The purchaser's profit needs to consider the problem of order quantity and used cost of customer. Therefore, the tradeoff between them becomes an important issue. Chen and Liu [2007] introduced a model that deal with this problem but did not consider the used cost of customer. This model was based on the standard news-vendor model without spot markets. Chen and Liu [2011] modified their model which introduced in 2007 for determining the optimum product and process parameters. In their new model, they take into account quantity, product price, used cost of customer, and process quality level. The result shows that the sales price per unit and the mean of the demand of customer have a major effect on the supplier's and the buyer's expected profits. The model was able to determine maximum expected profit of between the producer and the purchaser. This is achieved by determining the optimum purchaser's order quantity, the producer's product price, and the process quality level. It means the modified Chen and Lius [2007] succeeds to determine the optimum process quality level, the wholesale price, and the optimal order quantity simultaneously.

Multi-Criteria Optimization, Genetic Algorithm, and Risk Management

3.1. Optimization of production program

3.1.1 Introduction

Optimization is one of the most important and challenging parts of any en-gingering design. In the real-world design, a multi-objective optimization with constraints has to be considered. Therefore, the optimal solution in this case is not unique because the objectives can contradict each other. Therefore, a set of optimal solutions, which forms the Pareto frontier, should be considered. There are many algorithms to generate a Pareto set like genetic algorithm (GA) as an example. However, only a few of them are potentially capable of providing an evenly distributed set of solutions. This property is especially important in the real-life design because a Decision maker is usually able to analyze only a very limited quantity of solutions.

Optimization is the methodologies for improving the quality and desirability of a product or product concept. It is the process of finding function extreme to solve problems and finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones. The goods are produced the right quantities with maximum profit and higher utility while minimizing costs as well as satisfying customer requirements. Most real life optimization and scheduling problems are too complex to be solved completely.

Glover, Kelly, and Laguna [1999] states that the most real life optimization and scheduling problems are too complex to be solved completely and that the complexity of real life problems often exceeds the ability of classic methods.

Miettinen [1999] considered that a key challenge in the real-life design is to simultaneously optimize different objectives through taking into account different criteria low cost, utility, machinability, manufacturability, long life and good performance, which cannot be satisfied at the same time. Miettinen [1999] stated that the task becomes even more complicated because of additional constraints which always exist in practice. In fact, it is only possible to consider a trade-off among all (or almost all) criteria. The task becomes even more complicated because of additional constraints, which always exist in practice.

Profit maximization is the main objective of business enterprises and as such the subject of numerous investigations. Profit is defined as the difference between the total revenue generated by selling products on the market and the overall costs. In real life, the functions of dependence of production quantity and the total revenue and the total costs are nonlinear. Profit maximization problem is reduced to multi-objective maximization, where we do not know the proportion of the weight of criteria (revenue functions and cost functions) in the total goal. We must take into account the constraint of the model found in real constraints in the observed enterprise that have the greatest impact on production quantity.

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$$P = TR - TC \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

Where:

P – Total profit

S_p – Total revenue

T_c – Total cost

When analyzing the possibilities of profit maximization, it is important to consider the fluctuation of the TR and the TC. The TR depends on supply and market demands for particular types of goods, while the TC depends on different constraints faced by the company, such as the mechanical facilities, number and structure of employees, possibility of providing necessary specific materials for the manufacturing process implementation, delivery etc. For the company, to be competitive on the market means to produce a product at an appropriate price and quantity with the use of capital and labor in the appropriate volume and costs. Therefore, profit maximization refers to the optimization of variable parameters in the observed model, with given production constraints.

$$\text{Max P} = \sum_{i=1}^{n} Q(W_{pi} - W_{vi}) - F_c \text{ ………………………………..…… (3.2)}$$

Where:

P – Profit

Q – Quantity of product

W_{pi} – Selling price of the i^{th} product

W_{vi} – Variable cost of the i^{th} product

F_c – Constant cost

In real life, the functions of dependence of production quantity and the S_p and the T_c are nonlinear. The maximum profit is the maximum difference between the total profit curve and the total cost curve, as represented in the figure 3.1.

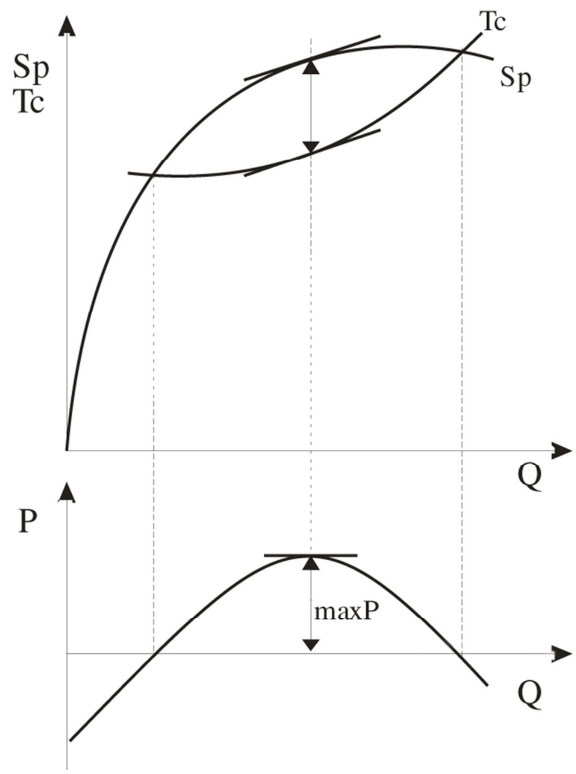


Figure3.1 Graphic representation of profit maximization

In real enterprise's operating conditions the functions of the S_p and the T_c are nonlinear and to determine them two different approaches must be applied.

The T_C function consists of the sum of variable and fixed costs, therefore, the sum of linear function of fixed costs and nonlinear function of variable costs. It is possible to determine the nonlinear function of fixed costs in a mathematical form by applying the Lagrange interpolation polynomial based on the values of variable costs from the previous period. The Lagrange interpolation polynomial is, in our case, a function of production quantity P (Q) with ≤ (n-1) level if we have n data points on the value of costs from the previous period.

$$P(Q) = \sum_{j=1}^{n} P_j(Q) \qquad (3.3)$$

Where:

$$P_j(Q) = y_j \prod_{\substack{k=1 \\ k \neq j}}^{n} \frac{Q - Q_k}{Q_j - Q_k} \quad \text{...(3.4)}$$

**The formula was first published by Waring in 1779, rediscovered by Euler in 1783, and published by Lagrange in 1795 (H.Jeffreys and B.Jeffreys, 1988).

To develop the TR nonlinear function from history data, we cannot rely on the past sales volume information because these data do not represent properly the behavior of the TR curve. The behavior of this function is determined by the adopted pricing policy in the enterprise. Different prices, when ordering a certain quantity of products, are the key points in determining the function also by the Lagrange interpolation polynomial.

After the definition of nonlinear mathematical function of the TR and the TC, in our case the profit maximization problem is reduced to multi-objective maximization, where we do not know the proportion of the weight of criteria (revenue functions and cost functions) in the total goal. We must take into account the constraint of the model found in real constraints in the observed enterprise that have the greatest impact on production quantity.

3.1.2 Multi-objective nonlinear Pareto-optimization

Practical optimization problems mostly have a multi-objective nature much more frequently than a single objective especially the engineering optimization problems. These objectives usually have conflict and versus target, cost and profit functions as example.

In practice, it is rare to face a problem with single objective in real-world decision making problems. In the past, the only way to solve a problem with multi-objective was converting it to a single objective problem before applying an optimization algorithm. Pareto [1986] made one of the most important findings in the field of multi-objective optimization by finding optimal solutions for a multi-objective problem, defined by applying Pareto's idea, are currently called as Pareto-optimal solutions.

Deb [2001] considered that in general, the optimization methods can be split into two principle categories: classical (preference-based) methods and evolutionary algorithms. He states that the classical methods usually use deterministic approaches, whereas evolutionary ones are based on stochastic algorithms. Deb [2005] highlighted that the evolutionary algorithms have a number of clear advantages over the classical approaches. For example, they are not sensitive to non smoothness of objective functions and are efficient in finding a global extremer. On the other hand, in evolutionary methods, there is no guarantee for capturing an optimum solution, but a huge number of solutions are to be considered to generate an even set of optimal solutions.

Two approaches for appropriate definition of multi-objective optimization problem can be draw in case of conflicting objectives:

1. Weighted Sum of Objective Functions: Converting the multi-objective problem to a single objective one by using weighted sum of objective functions as a representative objective function, and then solve the problem as a single objective one.

2. Pareto Optimization: Solving the multi-objective problem by applying Pareto-optimization approach. Decision-maker selects the solution from the resulting Pareto-optimal set.

3.1.3 Pareto Optimization

The concept of Pareto-optimum was introduced by the engineer/economist Pareto V. [1986]. Palli N., and others [1998] said if there is an exist solution which there is no way of improving any objective, then Pareto-optimization approaches for multi-objective optimization can be called as the optimize. Multiple objectives have a set of Pareto-optimal solutions, not a unique optimal solution. These set of Pareto-optimal solutions can be described by Pareto-front – a hyper-surface in the objective function space.

Lampinen [2000] states that the Pareto's relatively simple idea of optimality in case of multiple objectives can be verbally described as a solution is Pareto-optimal if it is dominated by no other feasible solution, which means that there exists no other solution, that is superior at least in case of one objective function value, and equal or superior with respect to the other objective functions values. Lampinen [2000] states that in case of conflicting objectives, the Pareto-optimal solutions are rather a class of solutions, forming a surface in objective function's space, than a single solution. This surface is commonly called as a Pareto-front.

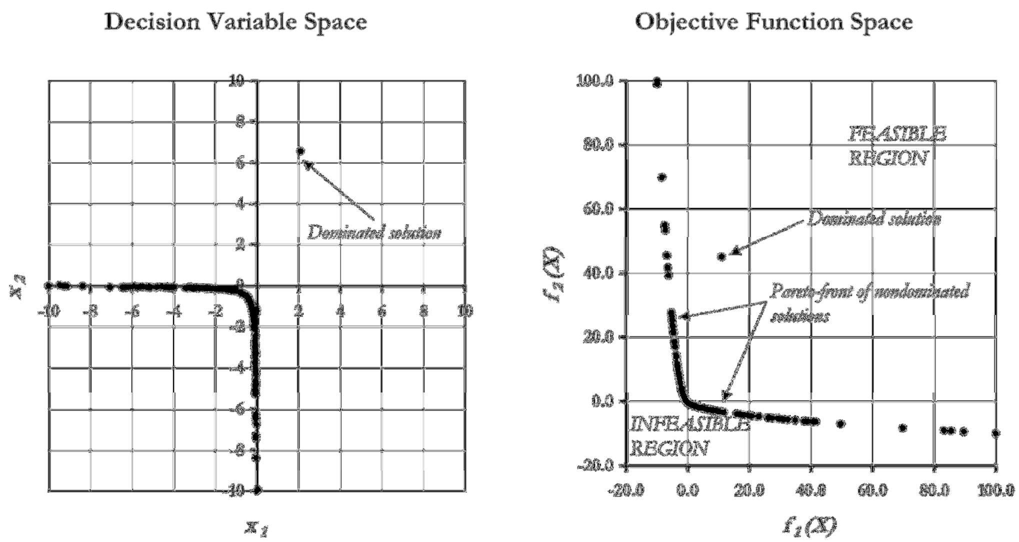


Figure3.2 Set of different Pareto-optimal solutions for bi-objective example problem. [Lampien, 2000]

The Figure 3.2 also clarifies the key concept of Pareto-optimization, namely dominance [Lampinen, 2000]. The points that have formed the Pareto-front do not dominate each other. None of them is better than another, with respect of all objectives (here: both objectives).

Lampinen [2000] also claim that the principle for solving Pareto-optimization problems with population based algorithms is straightforward, where algorithm may maintain a set of non-dominated solutions, meaning a set of solutions, which do not dominate each other. Also, Lampinen [2000] highlights that the non-dominance can be defined with respect the other population members. It is in principle at least possibly to use it as selection criteria which introduce a selection pressure towards the Pareto-front.

Figure 3.3, Lampinen [2000] illustrated a set of 100 different Pareto-optimal solutions for the bi-objective. The objectives are to minimize simultaneously the distance from a circle with radius 6 and from another circle with radius 8, both circles having their center at (0, 0). Any point between the circles is Pareto-optimal, but no other point.

The dominance concept represents the key of Pareto-optimization concept. This dominance classified into dominated solutions and non-dominated solutions. If the solution is not dominated by any other feasible solution, then it is a Pareto-optimal solution. Sometimes, the solution is not dominated by another candidate solution of the current set (or individual) but still is not being Pareto-optimal.

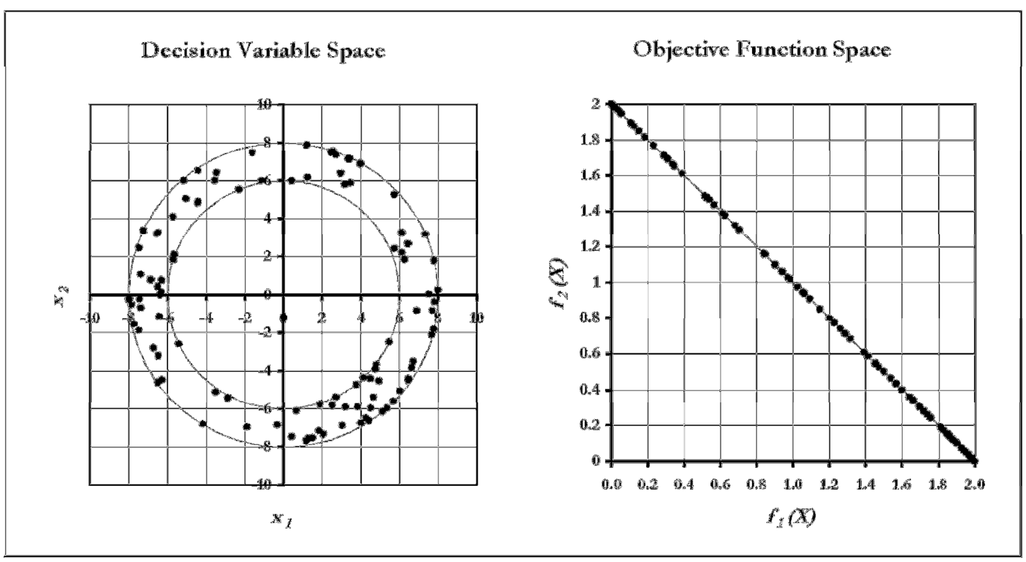


Figure3.3 Set of 100 different Pareto-optimal solutions for the bi-objective example problem. [Lampinen, 2000]

3.1.4 Goal of research

Main goal of our investigation is to develop model for optimization of production program (types and quantity of different product) using nonlinear functions and real life constrains. Non-traditional technique like Genetic Algorithm (GA) are tool which could help us in developing a new multi-objective nonlinear production program optimization and this framework offers a number of advantages like it is a multiple point search technique that examines a set of solutions and not just one solution. So, the main hypothesis of our research is that GA and Pareto front could help as in building new model for nonlinear of multiple objectives and criteria that are generally known as multiple criteria optimization or multiple criteria decision-making (MCDM) problems about production program optimization.

Genetic algorithms were employed to determine the dynamic weights and through the Pareto front the optimum solution is determined. Such approach to solving the profit optimization problem eliminates the shortcomings that arise from the approximation of influential functions with linear functions and subjective assessments when generating weights for some criteria in a multi-criteria model development.

3.2 Genetic Algorithm Approach

3.2.1 History and Introduction

Genetic Algorithm was developed initially by Holland [1975] form the 1960s. By the 1975, the publication of the book Adaptation in Natural and Artificial Systems was starting by Holland and his students and colleagues. Early to mid-1980s, genetic algorithms were being applied to a broad range of subjects. The usual form of GA was described by Goldberg [1989]. GA is stochastic search technique based on the mechanism of natural selection and natural genetics. The central theme of research on GA is to keep a balance between exploitation and exploration in its search to the optimal solution for survival in many different environments. Typically, Goldberg gave an interesting survey of some of the practical work carried out in this era and made clear of the general structure of GA. In 1992 John Koza has used genetic algorithm to evolve programs to perform certain tasks. He called his method "genetic programming" (GP). Michalewicz [1996] did not restrict to the binary string encoding in Holland's GA and applied the GA to all possible encoding strategies to solve the practical optimization problems. GA has been theoretically and empirically proved to provide a robust search in complex search spaces. Many research papers and dissertations have established the validity of GA approach in function optimization problems and application problems.

Genetic Algorithm, differing from conventional search techniques, starts with an initial set of random solutions, population. Each individual in the population is called a chromosome which representing a solution to the problem. The chromosomes evolve through successive iterations, called generations. During each generation, the chromosomes are evaluated by taking some measures of fitness. To create the next generation with new chromosomes, called offspring. The offspring are formed by merging two chromosomes from current generation using the crossover operator and or modifying a chromosome using the mutation operator. A new generation is selected according to the fitness values of the parents and offspring, and then weeds out poor chromosomes so as to keep the population size constant. The algorithms converge to the best chromosome, which hopefully represents the optimum or suboptimal solution to the problem [Gen, M., Cheng, R, 2000].

"Genetic Algorithms are good at taking large, potentially huge search spaces and navigating them, looking for optimal combinations of things, solutions you might not otherwise find in a lifetime." Salvatore Mangano Computer Design, May 1995.

3.2.2 Classes of Search Techniques

Figure 3.4 illustrates search techniques.

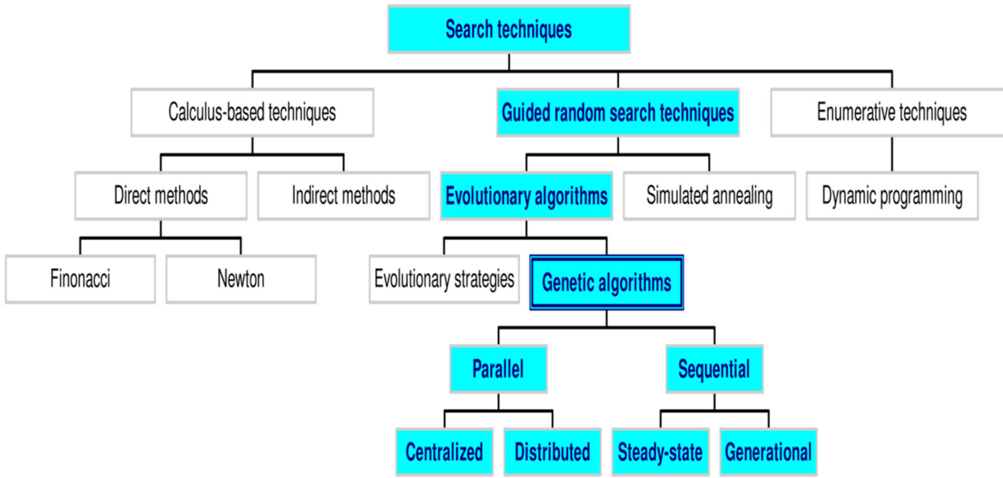


Figure3.4 Classes of Search Techniques [Salvatore Mangano, 1995]

3.2.3 Definition of GA

Genetic algorithm could be defined in many ways, such as:

- A genetic algorithm (or GA) is a search technique used in computing to find true or approximate solutions to optimization and search problems.
- (GA)s are categorized as global search heuristics.
- (GA)s are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination).
- The evolution usually starts from a population of randomly generated individuals and happens in generations.
- In each generation, the fitness of every individual in the population is evaluated, multiple individuals are selected from the current population (based on their fitness), and modified to form a new population.
- The evolution usually starts from a population of randomly generated individuals and happens in generations.

- In each generation, the fitness of every individual in the population is evaluated, multiple individuals are selected from the current population (based on their fitness), and modified to form a new population.

3.2.4 Basic Genetic Algorithm

The basic of GA is:

- Start with a large "population" of randomly generated "attempted solutions" to a problem
- Repeatedly do the following:
  - Evaluate each of the attempted solutions
  - Keep a subset of these solutions (the "best" ones)
  - Use these solutions to generate a new population
- Quit when you have a satisfactory solution (or you run out of time)

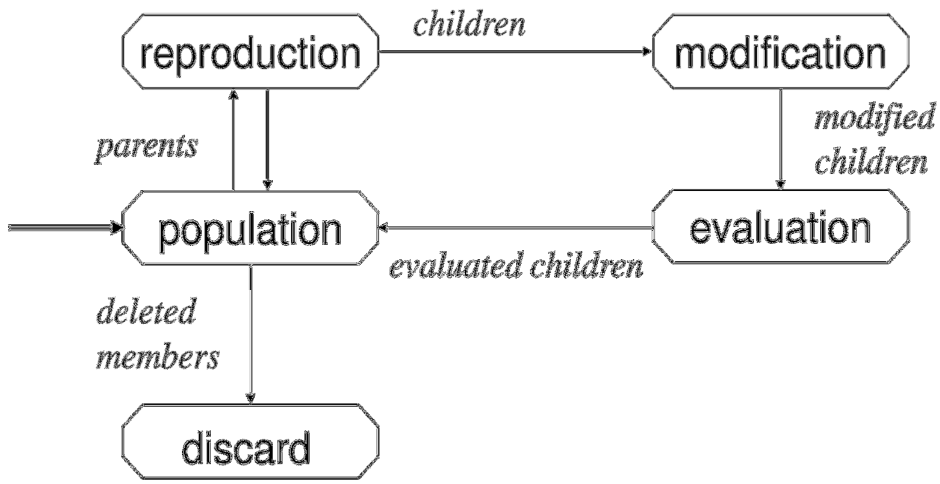


Figure3.5 The GA Cycle of Reproduction [Salvatore Mangano, 1995]

3.2.5 Weight Generating

In the encoding procedure, the value of the gene in the chromosome is generated randomly. When we are generating the weight vector, we have to rescale the weight to satisfy $\sum w_i = 1$. As the result, we convert

$$Wi = \frac{Vi}{\sum_{i=1}^{N} Vi} \quad \text{......................................} (3.5)$$

An example of weight generating is shown in table below. The determination of these weights indicates the relative importance of the various objectives.

Table3. 1 The chromosome consists of vector of weight.

Security ID								
Chromosome V_i	.52	.35	.44	.68	.56	.23	.11	.19
Weighting generating	.17	.11	.14	.22	.18	.07	.04	.06

3.2.6 Random Keys-base Encoding

The random keys-based encoding method is a direct approach, which encodes some information for constructing a set of weights in a chromosome. As we know, a gene in a chromosome is characterized by two factors: locus, (i.e., the position of the gene located within the structure of chromosome), and allele, (i.e., the value the gene takes). In this encoding method, the position of the gene is used to represent the ID number of the security and its value is used to represent the weight for constructing a portfolio. As proposed random keys-based encoding method, randomly generates the initial chromosome first. This encoding method is easily verified that any permutation of the encoding corresponds to the compositions of the portfolio, so that most existing genetic operators can easily be applied to the encoding. The pseudo code for order based encoding as following. More so than differs from other optimization techniques, GA provides a framework of using only objective function information for analyzing many problem types. Within this framework of optimization techniques can be employed to solve the non-smooth, non-continuous and non-differentiable functions which are actually existed in a practical optimization problem [Gen, M., Cheng, R, 2000].

3.2.7 GA Operators

Genetic algorithm operators consist of:

- Methods of representation
- Methods of selection
- Methods of Reproduction

3.2.7.1 Methods of Representation

Chromosomes could be:

- Encode solutions as binary (Bit) strings: sequences of 1's and 0's, where the digit at each position represents the value of some aspect of the solution (0101 ... 1100).
- Second approach is encoding solutions as arrays of integers or decimal numbers (43.2 -33.1 ... 0.0 89.2)
- A third approach is to represent individuals in a GA as strings of letters, where each letter again stands for a specific aspect of the solution.

3.2.7.2 Methods of Selection

Roulette-wheel selection, Elitist selection, Fitness-proportionate selection, Scaling selection, Rank selection, Generational selection, and Hierarchical selection are different techniques and methods which a genetic algorithm can use to select the individuals to be copied over into the next generation.

3.2.7.2.1 Roulette-wheel selection

In this method, the fitter is the solution with the most chances to be chosen. Conceptually, this can be represented as a game of roulette - each individual gets a slice of the wheel, but more fit ones get larger slices than less fit ones. Table 3.1 and Figure 3.6 represent an example of roulette wheel selection.

Table3. 2 An example of roulette wheel selection [Flmban, 2009]

No.	String	Fitness	% Of Total
1	01101	169	14.4
2	11000	576	49.2
3	01000	64	5.5
4	10011	361	30.9
Total		1170	100.0

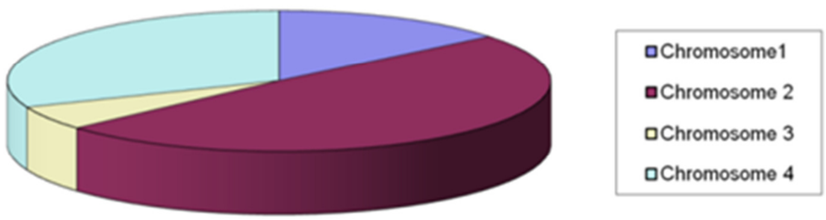


Figure3.6 Diagram of roulette wheel selection [Mutaz F., 2009]

3.2.7.2.2 Elitist selection.

The most fit members of each generation are guaranteed to be selected.

3.2.7.2.3 Rank selection.

Each individual in the population is assigned a numerical rank based on fitness, and selection is based on this ranking.

3.2.7.3 Methods of Reproduction

Once selection has chosen fit individuals, they must be randomly altered in hopes of improving their fitness for the next generation. There are two basic strategies to accomplish this:

- Crossover (recombination).
- Mutation.

3.2.7.3.1 Crossover

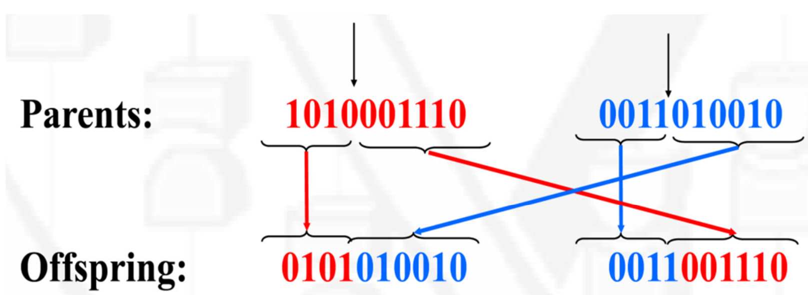
Crossover is the main genetic operator. It operates on two parents (chromosomes) at a time and generates offspring by combining both chromosomes' features. In weight selection problem, crossover plays the role of exchanging weights of the securities of two chosen parents in such a manner that the offspring produced by the crossover represents. Several crossover operators have been proposed for permutation representation, such as Partial-mapped crossover (PMX), Order crossover (OX), Position-based crossover (PX), heuristic crossover, and so on.[Sanchis J., et al, 2008].

Steps below show how offspring generated:

- Two parents produce two offspring
- There is a chance that the chromosomes of the two parents are copied unmodified as offspring
- There is a chance that the chromosomes of the two parents are randomly recombined (crossover) to form offspring
- Generating offspring from two selected parents: single or multi point crossover:

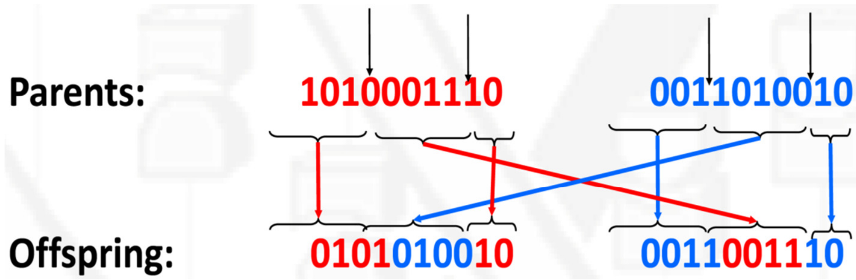
1. Single point crossover

- Randomly one position in the chromosomes is chosen
- Child 1 is head of chromosome of parent 1 with tail of chromosome of parent 2
- Child 2 is head of 2 with tail of 1



2. Two point crossover (Multi point crossover)

- Randomly two positions in the chromosomes are chosen
- Avoids that genes at the head and genes at the tail of a chromosome are always split when recombined



3. Uniform crossover

- A random mask is generated
- The mask determines which bits are copied from one parent and which from the other parent
- Bit density in mask determines how much material is taken from the other parent (takeover parameter)

Mask:	0110011000	(Randomly generated)
Parents:	1010001110	0011010010
Offspring:	0011001010	1010010110

3.2.7.3.2 Mutation

Mutation is a background operator which produces spontaneous random changes in various chromosomes. A simple way to achieve mutation would be to alter one or more genes. In GA, mutation serves the crucial role of either replacing the genes lost from the population during the selection process, so they can be tried in a new context or providing the genes that were not present in the initial population. In this paper, it is relatively easy to produce some mutation operators for permutation representation. Several mutation operators have been proposed for permutation representation, such as Swap mutation, Inversion mutation, Insertion mutation, and so on [Gen M. and Cheng R., 2000].

- Generating new offspring from single parent:

Step 1: select a position in parent at random.

Step 2: insert selected value in randomly selected position of parent.

(5 8 7 2 1 6 3 4) Before

(5 8 6 2 1 7 3 4) After

3.2.8 Evaluation

The evaluation function interprets the chromosome in terms of physical representation and evaluates its fitness based on traits of being desired in the solution. Evaluation function used for the GA is based on the total expected return and the risk of the portfolio. For the portfolio selection problem, we consider the total expected return and the risk. Therefore, the fitness function that involves computational efficiency and accuracy (of the fitness measurement) is defined as follows:

$$\text{eval}\ (v_k) = \frac{f\ (returen)}{f\ (risk)} = \frac{\sum_{i=1}^{n} \mu_i\, w_i}{\sum_{i=1}^{n}\sum_{j=1}^{n} \sigma_{ij} w_i w_j} \quad \ldots\ldots\ldots\ldots\ldots\ldots.. (3.6)$$

Where, eval (v_k) represents the fitness value of the k^{th} chromosome.

3.2.9 Benefits of Genetic Algorithms

- Concept is easy to understand
- Modular, separate from application
- Supports multi-objective optimization
- Always an answer; answer gets better with time.
- Easy to exploit previous or alternate solutions
- Flexible building blocks for hybrid applications

3.2.10 Applications of Genetic Algorithms

A genetic algorithm applies in many applications fields. Table 3.3 shows some of these applications.

Table3. 3 Some application of GA [Flmban, 2009]

Domain	Application type
Control	Gas pipeline, missile evasion
Design	Aircraft design, keyboard configuration, communication networks
Game Playing	Poker, checkers
Security	Encryption and decryption
Robotics	Trajectory planning

3.3 Risk Management

Risk management is a part of the every business production or service enterprise. The process of managing risk has to be an ongoing and not difficult or complex. It needs and requires time and commitment from top management and all employees of the organization.

3.3.1 Definition of Risk management

Risk management is a process with three phases: (a) risk identification and assessment, (b) risk response strategies, or what to do about the risks, and (c) management to reduce the frequency and severity of the risks through an operational plan.

The risk assessment phase identifies and categorizes the hazards associated. All activities that represent a possibility (risk) of harm to persons or property are called hazard activities

There is no specific method for risk identification. Deferent methods are used, depending on the nature and extent of the operation.

Risk response strategies (Phase two) cover various activity risks and control risk financing techniques. Risk control deals with avoidance, reduction, and transfer, whilst risk financing techniques deal with retention in the provider's budget and transfer to a third party, such as indemnification or insurance.

In Phase three, the management phase, includes organization's policies and procedures details. The manager formulates the Operational plan manually to implement and monitor the approaches selected [Ronald Kaiser, 2013].

3.3.2 Types of Risk Management

In business of enterprises, there are several categories of risk: risk of equipment failure (estimated in relation to human safety, to evironment, to business losses, ect.), risk management as a security measure, finacial risk assessment in cases of loan approval, quality management risk, ect.

Generally, Enterprise Risk Management is relatively new concept. Fraser and B.J Simskins [2010] distinguish following risk categories: Shareholder value risk, Financial reporting risk, Governance risk, Customer and market risk, Operations risk, Innovation risk, Brand risk, Partnering risk, and Communications risk.

Risk management consisit of strategic risk, operational risk, financial risk and risk acceptance. Strategic risk deal with competition, market position and economic conditions. Operational risk Concerned with the daily operations, precisely, to the consequences of daily decisions made in the company. The financial risks are related to relations with banks and stockholders, etc.

Table 3.4 shows the types of risk and process steps introduced by Risk Management Committee 2003.

Table3. 4 Enterprise risk Management [Casualty Actuarial Socity (CAC), 2003]

ERM Framework				
	Types of Risk			
Process Steps	Hazard	Financial	Operational	Strategic
Establish Context				
Identify Risks				
Analyze/Quantify Risks				
Integrate Risks				
Assess/Prioritize Risks				
Treat/Exploit Risks				
Monitor & Review				

The risk is defined as product of probability and consequence of certain events, which can be expressed in formula:

$$R = P.\ Q \text{ .... } (3.7)$$

Where:

P - Probability a particular event.

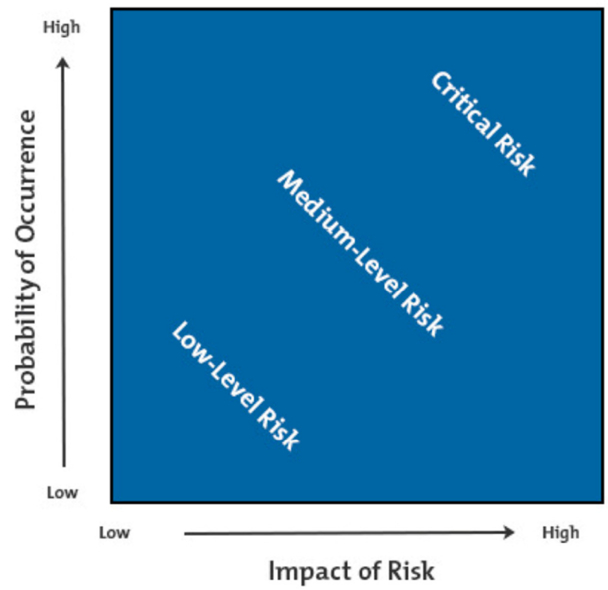
Q – Consequences of particular event.

For any enterprises, there are external and internal of n-sources of risk. The total risk will represented by high-risk, medium-risk and low-risk sources of operating losses.

$$R_i = \{R_{high}, R_{medium}, R_{low}\} \quad (i = 1,2,....n) \text{.......... ....} (3.8)$$

The based approach of applying risk are risk identification - what can affect the implementation of production program, risk analysis - defining the probability of occurrence of that, and risk assessment - determining the consequences, expressed in the form of operating losses.

The most low-risk sources of operating losses refer to good quality decision. Figure 2.7 shows the map for identifying Business risks.



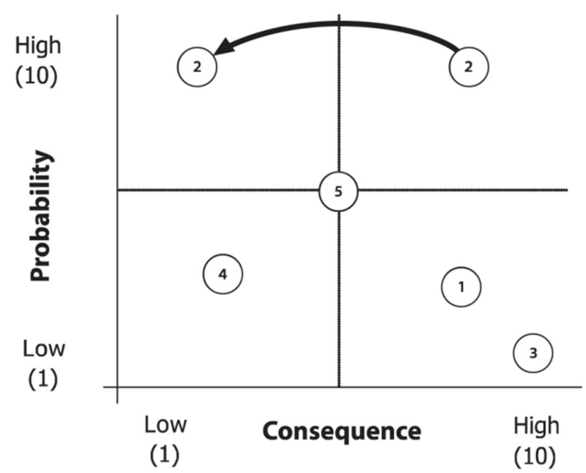


Figure3.7 Risk Impact/Probability Chart, Risk Management Matrix [Marshall & Alexan]

Research Methodology and New Model Development

4.1 Research Methodology

The analysis of the production program of enterprises is an important and complex segment of managing the enterprise, considering the fact that it influences all elements, such as planning of the material, human resources, machinery resources, research and development, marketing etc.

A new model for production programming planning is built to be closed to the real world; the costs are assigned according to the activities that connected to a certain product by using activity-based system (ABC) instead to traditional methods. Also, external factors and real behavior of objective functions are taken in account.

A set of sequential steps was developed to represent the methodology of investigation. In the literature available investigations related to multi-criteria production program optimization, when we have nonlinear functions, lead to the application of genetic algorithms as an appropriate tool for solving the problem set up [1, 2, 3, and 4].

Figure 3.1 illustrates our thesis contribution. It consists of two parts. Part (A) represents a new developing model for production programming planning while part (B) represents traditional technique for solving production programming planning.

The first, second, and third steps are same in both parts A&B with some different considerations.

The first step is problem definition and criteria identification. In accordance with problem definition, there follows generation of criteria whose maximum and minimum values we want to accomplish and realize. In production program optimization the criteria can involve profit maximization, minimization of production costs, maximization of machine capacity utilization and the like [Clements P. and Northrop, 2002].

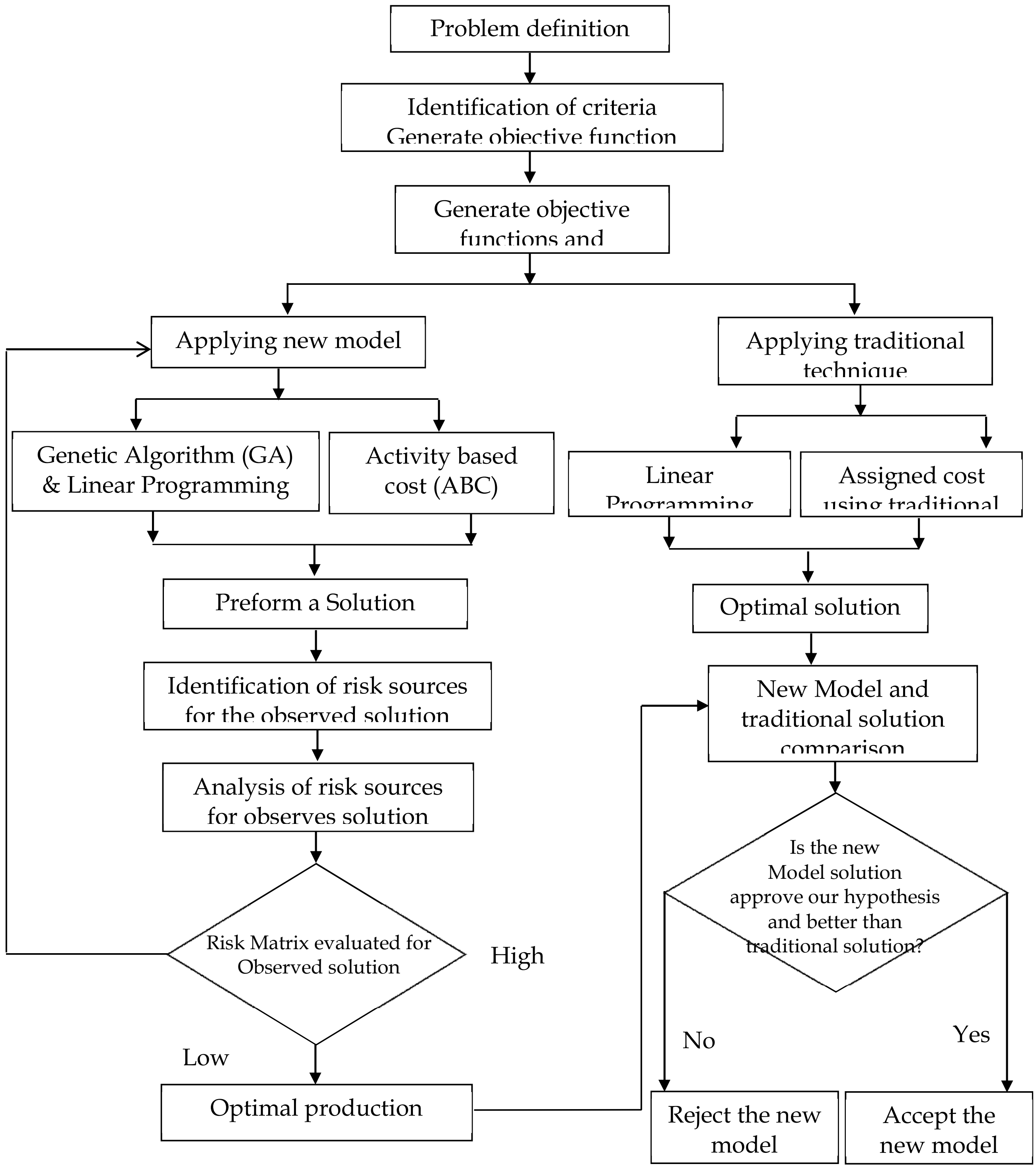


Figure4.1 Research Methodology

After the criteria are defined, it is possible to set up objective functions in a linear or nonlinear form, depending on how they represent in a real situation which is not take into account in part B.

The following step is constraints definition. In Part A, the constrains are defining within the framework of a set up model refers to real production constraints that can derive from production potentials, i.e. machinery capacity, human resources, material resources (Internal factors) and also from the demands for the observed product on the market (External factors) while constrains in part B are setting by using traditional method which is not reflected real case

Next step in part B is applying traditional technique to find optimal solution. Traditional method is using to assign unit cost product and traditional programming such as linear programming (LP) is applying to solve the problem and find optimal solution, while a new model is applying in part B to perform a solution. In this, active based cost is using to assign product cost per unit. Also, genetic algorithm (GA) or linear programming (LP) depends on type and number of objective functions is applying to perform a solution.

The following step in part A is investigated the perform solution and to what extent the external factors could effect in it. This evaluation accomplish by applying risk management. So, risk sources for the observed solution should be specifying. After that, the analysis of risk resources is coming. Then, the risk matrix is applied to evaluate the observed solution. The perform solution calls optimal solution when it pass the risk matrix evaluation with low risk otherwise return to first step in part B.

The next step is comparison. In this block, the optimal solution what is created by traditional technique will compare with the optimal solution what performed by the new model.

The final step is the decision. The new model is acceptable if the new model solution approves our hypothesis and is better than traditional technique solution. Otherwise, reject the new model.

4.2 Thesis contribution

Figure --- represents a new model that used to approve the thesis contribution. In model design phase, many factors were taken into account to give the model more ability and capability to deal with real huge problems. Some of these factors are internal factors such as profit, cost, manpower, machinery, and so on. Other some is external factors like marketing, competition, police, and …etc. also, representation of goal function and cost distribution per unit product was determined as existing in the real problem.

Chosen the experimental enterprise is the first step as the model shown. This model has ability to deal with production and service enterprise. So, type of enterprise should be identifying. The second step is problem definition and criteria identification. According to problem definition, the criteria (Maximizing, Minimizing, or both) that we want to accomplish and realize will be determined and generated. In production program optimization the criteria can involve profit maximization, minimization of production costs, maximization of machine capacity utilization and the like.

The following step is determining the type of targets or objective functions. In this step, the type of objective functions should be determined. For example, objective functions is one linear criterion such as manpower, material utilization, and maximum machine capacity or multi linear, multi non linear, and/or mixed criteria such as maximum profit, minimum cost, and … so on. After determination the type of objective functions, we generate the objective function depend on the criterion. Thereafter, we generate internal constrains and determine cost product per unit by using activity based cost (ABC). By reaching this stage, our model is ready to perform optimal solution under internal constrain conditions. Linear programming is applied to perform an optimal solution in case of one linear criterion and genetic algorithm was used to perform an optimal solution in case of multi criterion. This solution is examined and evaluated by using risk management. This step shows how much the external factors affect in the performed solution. So, we identify and analysis of risk resources for the observed solution. That resource called external factors such as marketing, police, and …etc. The final step is evaluating the observed solution by using risk matrix. If the evaluation of observed solution comes with low risk, then it is optimal production program solution, otherwise turn back to objective function generation step.

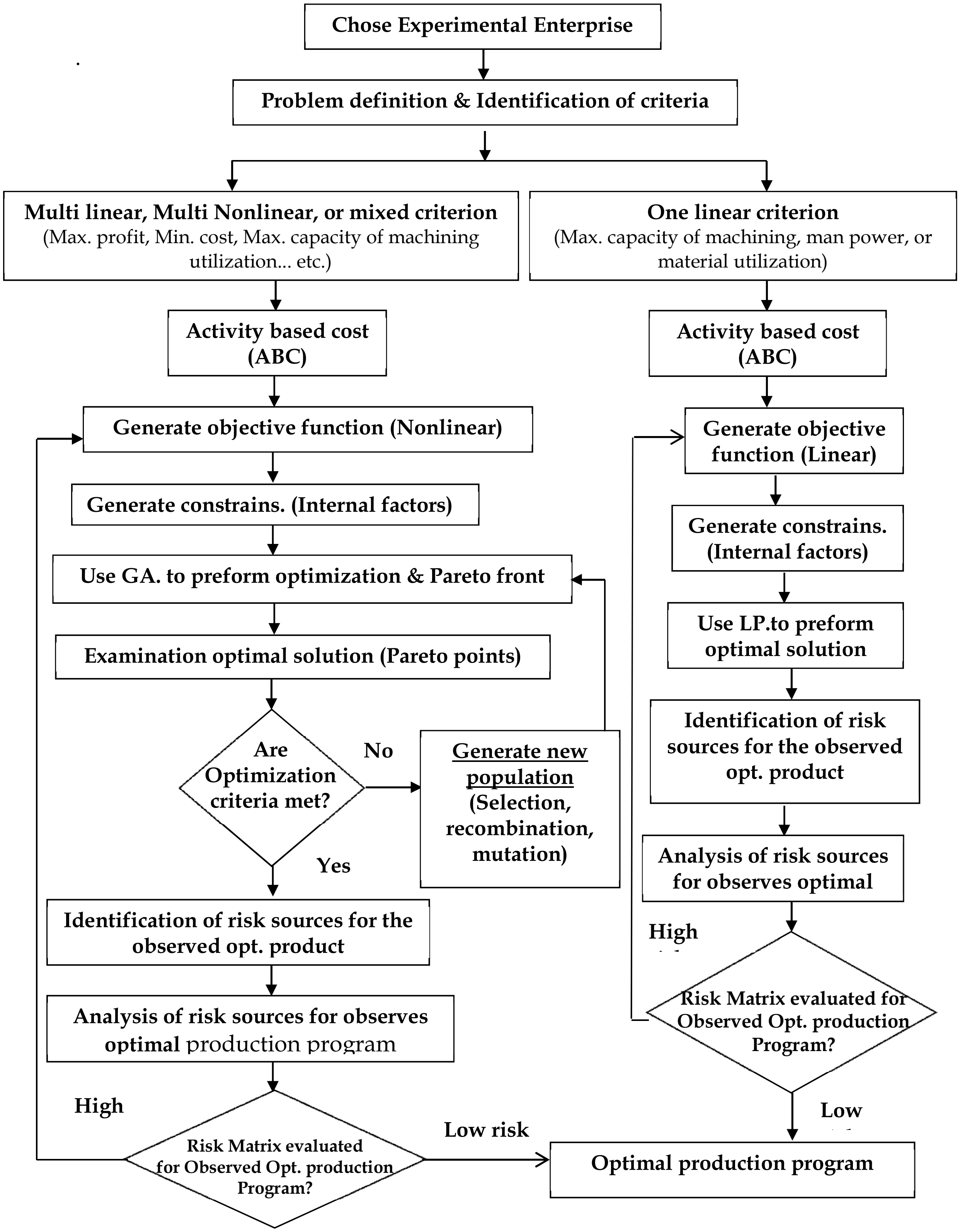


Figure4.2 The new model development

Experimental Work; Data Collection, Analysis, and Discussion

5.1 Problem definition

Problem of production program definition is very important because all other processes in manufacturing are connected and depending from this basic plan – plan of production program. Definition of the problem includes the segregation of products, machinery capacities, human and other production resources whose optimization we want to perform.

The production program of enterprises is an important and complex segment of managing the enterprise, considering the fact that it influences all elements, such as planning of the material, human resources, machinery resources, research and development, marketing etc.

5.2 Criteria and constrains

In accordance with the definition of the problem there follows the generation of the criteria, whose maximum or minimum value we want to accomplish. The criteria in the production program optimization can be: profit maximization, minimum production costs, maximum utilization of production capacities and the like. After the criteria are defined, it is possible to set up the functions of the objective in linear or nonlinear form, depending on how much they represent the real model in the best possible way.

Defining of constraints within the framework of a set up model refers to real production constraints that can derive from production potentials, i.e. machinery capacity, human resources, material resources but also from the demands for the observed product on the market.

In defining criteria and constrains we use equations from Misita [2002]. Author introduced all possibility of general forms of constrains and objective functions. Suppose that a company has:

n – Different products which can be produced ($j=1, 2 \ldots.. n$),

m – Various machines ($i=1, 2\ldots.. m$), h – Different categories of workers (l=1, 2 …..h), and

g – Different types of raw materials (ν=1, 2 …..g)

She introduced the following tags:

x_j – amount of j[th] product that enters the production program

y_j – amount of j[th] product that can be sold on the market

$s_{\nu j}$ – amount of the ν- raw materials needed for production j- unit of product

$s_{\nu o}$ – amount of the ν- raw materials, materials in stock

b_{lj} – the time it takes worker of that l-category (profession, specialty, qualifications) to produce the j-th unit of product

b_{lo} – available fund of working time worker of that l-category

a_{ij} – time needed for producing j- unit of product on i-machine

a_{io} – capacity of i-machine, (time unit)

w_{ckj} – cost per unit for j- unit of product

w_{cpj} – selling price per unit for j- unit of product

d_j – profit per unit for j- unit of product

$T_{nr\,ij}$– Normal time for the r-operation on i- machine for the j[th] product ($T_{nri}=T_{pzri}+T_{kri}$)where T_{pzri}-preliminary-final time for the r-operation on i- machine for the j-th product; T_{kri} - the time per piece for the r- operation on i-machine for the j-th product

T_{mj} – the time required for assembly of the product j

T_{pj} – the time required for packaging of the product j

T_{tj}– time required for transport jth product to the customer (external transport or distribution)

d_{oj}- Delivery

f_j financial investment in the production unit jth product

f_{jo} total available funds for investment in manufacturing

Author generated certain limitations for general model of business-production systems [Misita, 2002]:

1) Limit the needs of the market can be expressed

$$0 \le x_j \le y_j, \qquad (j = 1,2,..., n) ....(5.1)$$

2) Limitation of material resources can be expressed

$$\sum_{j=1}^{n} s_{v\,j} x_j \le s_{v\,o}\,, \quad (v = 1,2,..., g) .... (5.2)`$$

3) Limitation of human resources can be expressed

$$\sum_{j=1}^{n} b_{lj} x_j \le b_{lo}\,, \quad (l = 1,2,..., h) ....(5,3)$$

4) Limit funds for the work can be expressed

$$\sum_{j=1}^{n} a_{ij} x_j \le a_{io}\,, \quad (i = 1,2,...,m) ....(5.4)$$

5) Limitation of delivery means the time required to produce that j -product (T_n=T_{pz}+T_k), for, packaging and distribution should be less than the agreed delivery date:

$$(\sum_{i=1}^{n}\sum_{r=1}^{g} T_{nrij} + T_{mj} + T_{pj} + T_{tj}) \cdot k \le d_{oj}\,, \qquad (j = 1,2,..., n) ....(5.5)$$

k- Correcting factor that takes into account the overlapping of these time requirements.

6) In the metal processing industry is dominated by electricity as an energy source and this restriction can be expressed as:

$$\sum_{j=1}^{n} e_{el.energy\_j} x_j \le e_{el.energy} \quad \text{...} \quad (5.6)$$

Electricity consumption per unit of output should be less than the amount of electricity as a limiting factor.

The general mathematical model for any business-production system will have one or more of the following criteria function and constraints:

I. Revenue

Criterion function follows [Misita, 2002]:

$$Z_1(X) = \sum_{j=1}^{n} d_j x_j \text{..}(5.7)$$

To find a maximum, Limiting conditions can be expressed by the following inequalities:

$$0 \le x_j \le y_j, \qquad (j = 1,2,\ldots, n) \text{.......... ....} (5.8)$$

$$\sum_{j=1}^{n} s_{vj} x_j \le s_{vo}, \quad (v = 1,2,\ldots,g) \text{.......................................}(5.9)$$

$$\sum_{j=1}^{n} b_{lj} x_j \le b_{lo}, \quad (l = 1,2,\ldots, h) \text{.......... ....}(5.10)$$

$$\sum_{j=1}^{n} a_{ij} x_j \le a_{io}, \quad (i = 1,2,\ldots, m) \text{.......... ....}(5.11)$$

$$\left(\sum_{i=1}^{n}\sum_{r=1}^{g} T_{nrij} + T_{mj} + T_{pj} + T_{tj}\right) \cdot k \le d_{oj}, \quad (j = 1,2,\ldots,n) \ldots(5.12)$$

$$\sum_{j=1}^{n} f_j x_j \le f_{io}, \quad (j = 1,2,\ldots, n) \text{.......... ....}(5.13)$$

$$\sum_{j=1}^{n} e_{el.energy\_j}\, x_j \le e_{el.energy} \quad (j = 1,2,...,n) ....(5.14)$$

$$x_j \ge 0, \qquad (j = 1,2,..., n) .... (5.15)$$

II. Maximal capacity utility

Objective function has the following form [Misita, 2002]:

$$Z_2(X) = \sum_{i}^{m} \sum_{j=1}^{n} \frac{1}{a_{io}} a_{ij} x_j \,, \; (i = 1,2,...,m) ....(5.16)$$

Limiting conditions can be expressed by the following inequalities:

$$0 \le x_j \le y_{j,} \qquad (j = 1,2,..., n) .... (5.17)$$

$$\sum_{j=1}^{n} s_{\nu j} x_j \le s_{\nu o} \,, \quad (\nu = 1,2,..., g) ....(5.18)$$

$$\sum_{j=1}^{n} b_{lj} x_j \le b_{lo} \,, \quad (l = 1,2,..., h) ....(5.19)$$

$$\sum_{j=1}^{n} a_{ij} x_j \le a_{io} \,, \quad (i = 1,2,..., m) ....(5.20)$$

$$\left(\sum_{i=1}^{n} \sum_{r=1}^{g} T_{nrij} + T_{mj} + T_{pj} + T_{tj}\right) \cdot k \le d_{oj} \;, \; (j = 1,2,...,n) ....(5.21)$$

$$\sum_{j=1}^{n} f_j x_j \le f_{io} \,, \quad (j = 1,2,..., n) .... (5.22)$$

$$\sum_{j=1}^{n} e_{el.energy\_j}\, x_j \le e_{el.energy} \quad (j = 1,2,...,n) ....(5.23)$$

$$x_j \ge 0, \qquad (j = 1,2,..., n) .... (5.24)$$

III. Min. costs

Objective function has the following form [Misita, 2002]:

$$Z_3(X)=\sum_{j=1}^{n} w_{ckj}x_j \qquad (j=1,2,...,n)\text{..........................}(5.25)$$

Limiting conditions can be expressed by the following inequalities:

$$0\le x_j \le y_j, \qquad (j=1,2,...,n)\text{..........................}(5.26)$$

$$\sum_{j=1}^{n} s_{\nu j}x_j \le s_{\nu o}, \quad (\nu=1,2,...,g)\text{..........................}(5.27)$$

$$\sum_{j=1}^{n} b_{lj}x_j \le b_{lo}, \quad (l=1,2,...,h)\text{..........................}(5.28)$$

$$\sum_{j=1}^{n} a_{ij}x_j \le a_{io}, \quad (i=1,2,...,m)\text{..........................}(5.29)$$

$$(\sum_{i=1}^{n}\sum_{r=1}^{g} T_{nrij}+T_{mj}+T_{pj}+T_{tj})\cdot k \le d_{oj}\ , (j=1,2,...,n)\text{...........}(5.30)$$

$$\sum_{j=1}^{n} f_j x_j \le f_{io}, \quad (j=1,2,...,n)\text{..........................}(5.31)$$

$$\sum_{j=1}^{n} e_{el.energy\_j}x_j \le e_{el.energy}, x_j\ge 0, \ (j=1,2,...,n)\text{..........................}(5.32)$$

5.3 Choosing factory

In the experimental work, thesis methodology and the new model was applied at two case studies. INSA production factory and MetalikaVolf factory was chosen as case studies. More details about these two factories exist on the appendix.

First step of the experimental work following methodology of the thesis is problem definition. In this step, we have chosen two deferent problems for our two case studies. Maximizing utility of machine work and determine optimal numbers of product producing was the problem that chosen for MetalikaVolf factory. While, maximizing of total profit and minimizing of total cost of product was selected problem for INSA production factory. After determination the problem, Identification of criteria and objective function is located. A long time was taken to collect all the data which is useful in our investigation. These data was used to create objective functions and constrains. Only the significant data was selected and neglect insignificant. The following tables show all the data that is selected for the INSA factory.

Number of employees was 620 in 2007.According to the last information; this factory has great market demand. 750 Vagon cars are ordering for export. It received award for the best exporter in the country in 2009. Number of employees was 620 in 2007. Tables 5.1, 5.2, 5.3, 1nd 5.4 show all the data that was collected from INSA factory.

Table5.1 Cost unit details for clock product

(in thousands of dinars, on monthly level)	Min value	Max Value
1. Operating Expenses		
1.1. Procurement cost of intermediate products	52	74
1.2. Materials costs	382	425
1.3. Costs of salaries and fringe benefits	65	78
1.4. Depreciation and provisions	1	1.3
1.5. Other operating expenses	0.6	0.9
2. Financial expenses	0.2	0.5
3. Other expenditures	0	1

Table5.2 Cost unit details for water meter product

(in thousands of dinars, on monthly level)	Min value	Max value
1. Operating Expenses		
1.1. Procurement cost of intermediate products	386	428
1.2. Materials costs	1900	2100
1.3. Costs of salaries and fringe benefits	352	464
1.4. Depreciation and provisions	1.2	1.5
1.5. Other operating expenses	0.6	0.9
2. Financial expenses	0.5	1
3. Other expenditures	0	1

Table5.3 Cost unit details for gas meter product

(in thousands of dinars, on monthly level)	Min value	Max value
1. Operating Expenses		
1.1. Procurement cost of intermediate products	85	93
1.2. Materials costs	365	450
1.3. Costs of salaries and fringe benefits	130	155
1.4. Depreciation and provisions	0.4	1
1.5. Other operating expenses	0.6	0.8
2. Financial expenses	0.2	0.5
3. Other expenditures	0	1

Table5.4 Unit cost and unit price selling for each product in deferent years

		The unit cost (€)				**The unit selling price (€)**			
		2004	2006	2008	2010	2004	2006	2008	2010
WATER MEASURE	per unit	1.267	1.579	1.579	1.980	2.280	2.867	2.867	3.796
	Q	35.303	34.571	43.059	34.848	35.303	34.571	43.059	34.848
GAS MEASURE	per unit	3.467	3.814	3.720	4.4550	4.680	5.525	5.135	6.305
	Q	-	153	7.564	599	-	153	7.564	599
CLOCKS MEASURE	per unit	369	420	420	509	500	540	540	664
	Q	13.267	1.920	2.138	3.453	13.267	1.920	2.138	3.453

Time needed to produce one product unit is 34 min for clock, 29.5 min for water meter, and 8.4 min for gas meter.

Determination of production line capacity is little complicating because different products are producing on different set of machines.

The factory works in one shift, but if there is lot of job to finish, they work in two shifts.

Production cycle time consist of total production time from first operation to last one. Production line in the factory is series. Therefore, there are different production times for each series (they never start production of one clock...). So in case for working in one shift, production time needed to produce 1000 unit is 5 days for clock, 9 days for water meter, and 20 days for gas meter.

After selected the significant data from all these huge data and construct objective functions for each case and building and locating the significant constrains, we applied traditional technique and new model at each case problem to get an optimal solution for comparison. In the traditional technique, cost was assigned using traditional method. Then linear programming method was applied to get optimal solution.

On other hand, cost was assigned using activity based cost (ABC) and genetic algorithm was applied to perform an optimal solution in case of multi criterion or linear programming (L.P) in case of one criterion.

Optimal solution that performed from the new model was investigated by risk management to show how much the external factors (environment) could be affect on the performed solution. Risk matrix method was applied to investigate the performed solution. But before applying risk matrix method, we have identified and analysis risk sources for the observed solution. These risk sources shown in table 5.5.

Table5.5 Risk sources identification and analysis

Risk Source	Trend	Risk rating 1st Q. 2010	Risk 2nd Q. 2010	Risk rating 3rd Q. 2010
Operation cost.	↗	Low	Medium	Medium
Labor cost	→	Low	Medium	Medium
Lubricant cost	↘	Low	Low	Low
Raw martial cost	↗	Medium	High	High
Fixed cost	→	Medium	Medium	Medium
capital availability	→	Medium	Medium	Medium
business operations – supply chain management	→	Medium	Medium	Medium
information technology	↗	Medium	High	High
Planning	↗	Medium	Medium	High
Reporting	↗	Low	Medium	Medium

If the solution performed passes the risk matrix with a low risk, it is then called the optimal solution, otherwise we turn back to the third step (applying new model).

On the right-side of this step, one optimal solution was generated from traditional technique and the other one was generated from the new model. The final step is comparison between the two solutions. In case of the new model solution our hypothesis is proved and if the solution is better than the traditional one, then the new model is accepted, otherwise it is rejected.

Two factories were chosen as case study. Metalika Volf factory was case study A and INSA factory was case study B. In our tow cases, we tried to be more close form the real situation case problems of production program. Where, we take into account all the internal and external factors might be effect in our case studies. But in same time and through all the huge factors were collected, only the significant factors were chosen as constrains and limitations, otherwise it will be impracticable and useless.

5.3.1 Case study A

Total business operating costs consist of the sum of fixed and variable costs. Fixed costs are independent of the volume of production and include the expenses of annuity, depreciation, employees' pays etc. Variable costs depend on the volume of production, and involve costs of material procurement, packing, overtime pay for employees etc. Consequently, total business operating costs are determined by fixed costs, variable costs and volume of production [Cohen and Sholom, 1999].

In theory or practice there is no methodology to precisely determine unit cost of a certain product, but this is reduced to assessment based on reallocation of expenses most commonly performed as follows:

1. Total fixed costs are determined as the sum of all costs created for manufacturing the product.

2. Calculation of total variable costs created for manufacturing the product.

3. Total fixed costs are determined as the sum of total fixed costs and total variable costs.

4. Product unit costs are determined when dividing the obtained total business operating costs by the volume of production.

Such manner of determining the product unit cost has become quite common in today's business operations. The problem arises when the enterprise has more than one product in its production program. Fixed and variable production costs are most often calculated per month, or more precisely, annually, quarterly and monthly. However, to determine the product unit cost, the calculation of costs at a monthly level is the most accurate determination for the acquired detailing level. Namely, in the analysis of production costs, fixed costs include monthly accounts (energy sources, pays, taxes and dues), so that the time period mentioned has become established as the most adequate for approximate determination of the product unit cost [Kang K, and others, 2002] and [Jaejoon Lee, and others,2010]. However, the situation is quite different in variable costs. Variable costs of production depend primarily on the type of production, i. e. whether it is mass, serial or individual. Therefore, each case requires analysis.

Variable costs, as above mentioned, depend on the volume of production, but if a product range includes several products (as is the case very often), variable costs should be grouped according to various products [Hax and Arnoldo, 1987].

$$T_c = F_c + V_c \qquad (5.33)$$

Where:

T_c – Total costs

F_c – fixed costs

V_c – Variable costs

Let n products be manufactured in the enterprise (i=1, 2… n), unit cost for each product would be:

$$W_{ci} = \frac{F_{ci}}{Q_i} + \frac{V_{ci}}{Q_i} \quad \text{..(5.34)}$$

Where:

W_{ci} - Unit cost price of the i[th] product,

Q_i - Volume of production of the i[th] product,

V_{ci} - Variable costs for the i[th] product, and

F_{ci} - Fixed costs the i[th] product.

The product selling price is most commonly determined according to marketing researches of a concrete enterprise and is based on the supply-and-demand ratio, product quality and the like. Profit, being a difference between the selling price and total costs, is often used in the analysis of business operations as a basic function for optimization of business operations [Cohen and Sholom, 1999] and [Jaejoon Lee, and others, 2010]. In profit equation the selling price is data accurately determined, while total costs are often based on the assessment, i.e. approximate variable costs per product unit. Profit is mainly calculated using the formula:

$$P = S_p - T_c = S_p - (F_c + V_c) \quad \text{..............................(5.35)}$$

Where:

P – Profit

S_p - Selling price

The function of profit should contain more detailed information because in real conditions the production program consists of several products. Hence, profit for the i[th] product should be calculated using the formula:

$$P_i = S_{pi} - (F_{ci} + V_{ci}) \quad (i = 1,2,\dots n) \dots\dots\dots\dots \dots\dots\dots\dots \quad (5.36)$$

Where:

P_i – Profit for the i[th] product

S_{pi} - Selling price for the i[th] product and total profit of the enterprise would be:

$$P = \sum_{i=1}^{n} S_{pi} - \sum_{i=1}^{n} (F_{ci} + V_{ci}) = \sum_{i=1}^{n} S_{pi} - F_c - \sum_{i=1}^{n} V_{ci} \dots\dots\dots\dots \quad (5.37)$$

$$F(P)_{\max} = \sum_{i=1}^{n} S_{pi} - \sum_{i=1}^{n} (F_{ci} + V_{ci}) = \sum_{i=1}^{n} S_{pi} - F_c - \sum_{i=1}^{n} V_{ci} \dots\dots\dots \quad (5.38)$$

One of the goals in this investigation is to set up a function for profit maximization to represent as realistic picture of business operations as possible, i.e. to set up the functions of fixed and variable costs as realistic as possible but not to represent approximations.

So, let's start from the basic equation for unit costs per unit of the observed product:

$$W_{ci} = \frac{F_{ci}}{Q_i} + \frac{V_{ci}}{Q_i} \dots\dots\dots\dots \dots\dots\dots\dots \dots\dots\dots\dots \dots (5.39)$$

In the traditional approach, unit variable costs are separated for each product (e.g. raw material costs, material costs, variable costs etc.) and there are fixed overhead costs for the entire enterprise. In this approach the allocation of fixed overhead costs is performed proportionally against material costs or labor costs or machine time per product. Hundal [1997] reports that such approach can lead to higher costs being allocated to low-volume products than to those produced in mass quantities.

$$C_{MANF} = (A\%)\cdot C_{MATL} + (B\%)\cdot C_{LABD} \quad .... \quad .... \quad ..... \quad (5.40)$$

Where:

C_{LABD}- Direct labor costs

C_{MATH}- Total materials costs

C_{MANF}-Manufacturing costs

Where coefficients A and B are vary within the range of 100-150% and 200-500% respectively.

Hundal [1997] also reports that traditional costing method derives from the time of mass production when products were simple and few. Today, a larger portion of costs is related to direct labor costs, while fixed costs make up only 10 – 20% of total costs, figure 5.1

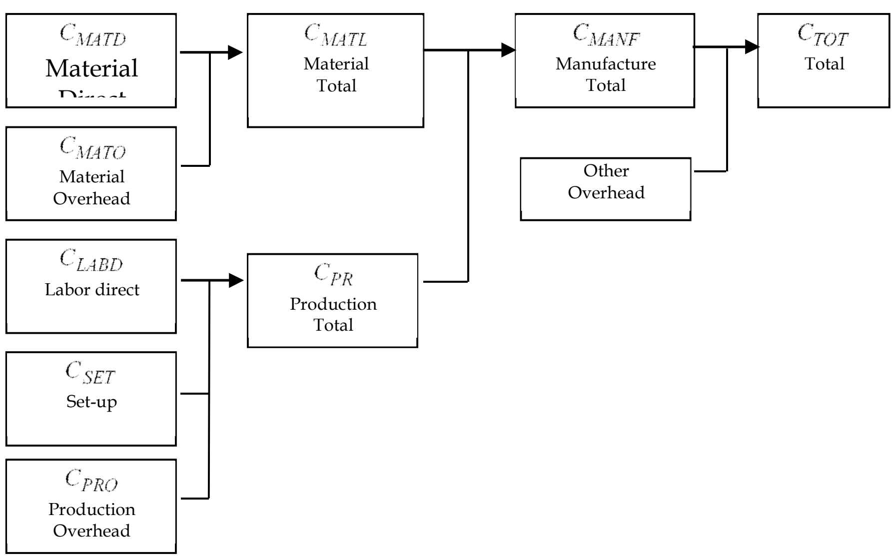


Figure5.1 Detailed breakdown of production costs [M.S. Hundal, 1997]

In the activity-based system the allocation of costs is performed according to the activities connected to the production of a certain product, figure 5.2.

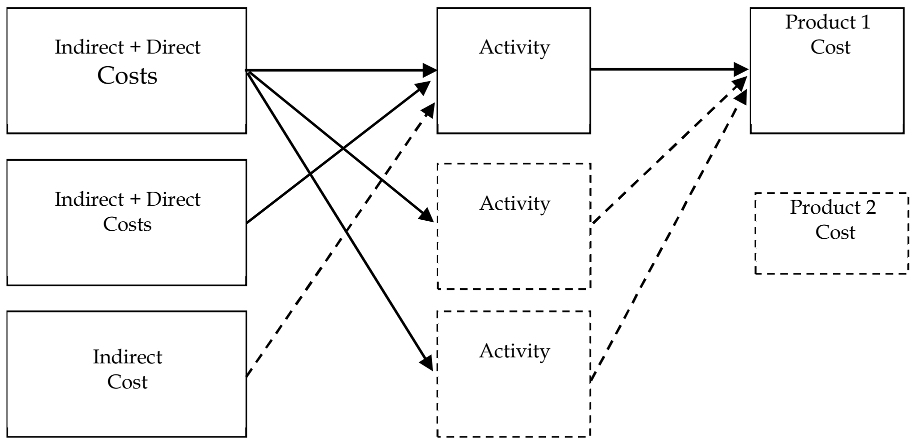


Figure5.2 Activity based costing approach in determination of product costs

$$Max \;\; P = Z_1(X) = \sum_{i=1}^{n} Q_i (W_{pi} - W_{vi}) - T_c \text{ .... } (5.41)$$

Where:

P - Profit

Q_i – quantity of the i^th product

W_{pi} – unit selling cost of the i^th product

W_{vi} – unit variable costs of the i^th product

T_c – constant costs

In real conditions the functions of dependence of production volume and total revenue and total costs are nonlinear. Maximum profit in the graph below represents maximum difference between the total profit curve and total costs, figure 5.3.

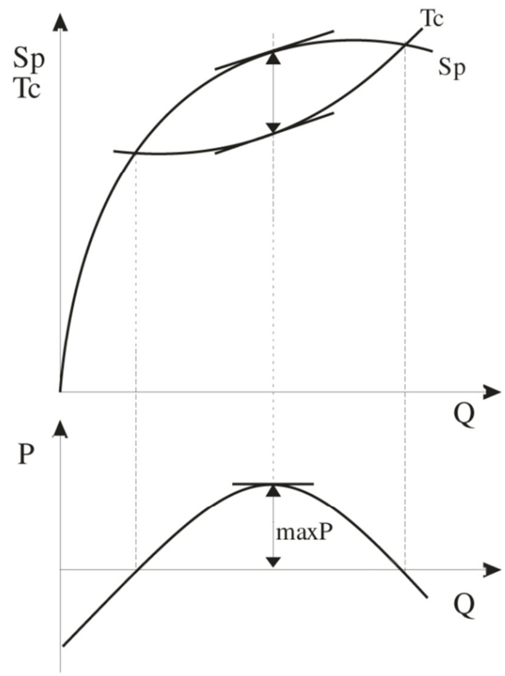


Figure5.3 Graphic representation of profit maximization [E. Waring, 1979]

In the enterprise's real business operating conditions the functions of total revenue and total costs are nonlinear. The function of total revenue consists of the sum of variable costs and fixed costs, i.e. the sum of linear function of fixed costs and nonlinear function of variable costs. Mathematically, it is possible to determine the nonlinear function of variable costs by applying the Lagrange interpolation polynomial based on the values of variable costs from the previous period using: [Hax, 1987 and Bass, 1998]

$$P(Q) = \sum_{j=1}^{n} P_j(Q) \qquad (5.42)$$

Where:

$$P_j(Q) = y_j \prod_{\substack{k=1 \\ k \neq j}}^{n} \frac{Q - Q_k}{Q_j - Q_k} \qquad (5.43)$$

Maximization of the capacity utilization level can be determined via the function:

$$Z_2(X) = \sum_{i}^{m} \sum_{j=1}^{n} \frac{1}{a_{io}} a_{ij} Q_j \,,\ (i = 1,2,...,\ m) \text{.......... ....} \quad (5.44)$$

Where:

- Q_j- Quantity of the jth product included in the production program,
- a_{ij}- needed to produce unit of the jth product on ith machine,
- a_{i0}- The ith machine capacity expressed in time units,
- n – Miscellaneous products that can be produced (j = 1, 2 …n), and
- m – Miscellaneous tools for work (i = 1, 2… m).

The application of ABC (Activity Based Costing) method to calculate product unit cost price requires the classification of fixed and variable costs per product as well as the classification of material, work hours and machine engagement hours per operation for each type of product for the observed business-manufacturing system.

The application of Breakeven Point method (BPM is the analysis of critical point with nonlinear functions of cost price and sales price) is used for the generation of the quadratic function to describe dependency for each product: the volume of production-cost price and the volume of production-revenue. The generation of above mentioned functions was done after data collection on achieved financial results after sales and production of different volumes of production (lots) for each type of product.

5.3.1.1 Case A1:

Objective functions. The first objective function is generated via traditional approach

$$Z_1^{\prime}(X)\min = \sum_{i=1}^{n} W_i \cdot Q_i \text{.......... ....} \ (5.45)$$

$$Z_2(X)_{\max} = \sum_{i}^{m} \sum_{j=1}^{n} \frac{1}{a_{io}} a_{ij} Q_j \,,\ (i = 1,2,..., m) \text{.......... ....} \ (5.46)$$

5.3.1.2 Case A2:

Objective functions. The first objective function is generated via activity-based costing (ABC) approach

$$Z_1''(X)\min = \sum_{i=1}^{n} W_i \cdot Q_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.47)$$

$$Z_2(X)_{\max} = \sum_{i}^{m}\sum_{j=1}^{n}\frac{1}{a_{io}}a_{ij}Q_j\,,\ (i=1,2,\ldots,m)\ldots\ldots\ldots\ldots (5.48)$$

Constraints:

1. Market demand constraint can be expressed by:

$$0 \le Q_j \le y_j \quad (j = 1, 2\ldots n) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.49)$$

2. Maximum available capacity utilization level

$$\sum_{j=1}^{n} a_{ij}x_j \le a_{io}\,, \quad (i=1,2,\ldots,m)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.50)$$

Where:

y_j - Quantity of the jth product that can be sold on the market

After the objective functions are formed and constraints are defined using GA, the Pareto front is generated and optimal solutions are examined. Using a real example, the application of the developed model for production program optimization is presented below.

Investigation to follow refers to the application of described methodology using a concrete example of the enterprise. The selected enterprise is engaged in manufacturing welded pipes, of various profiles, so that the differences in product unit cost price are not high. The basic hypothesis was to investigate whether any difference occurs in production program optimization using genetic algorithms when calculating unit cost price by applying different approaches, i.e. traditional or ABC approach. Therefore, applying the designed methodology in the enterprise where there are no significant differences in the manufacturing process of a certain type of product, the results are expected to differ. However, differences are more pronounced in the enterprise that has a more diverse production program. We have monitored the production process in a factory engaged in the production of welded and seamless pipes. Production is carried out on two lines of similar capacity, and welded pipes of rectangular, circular and square profiles are manufactured.

Figure 5.4 shows data recorded in one month, and delays and interruptions of work during weekend or holiday are included.

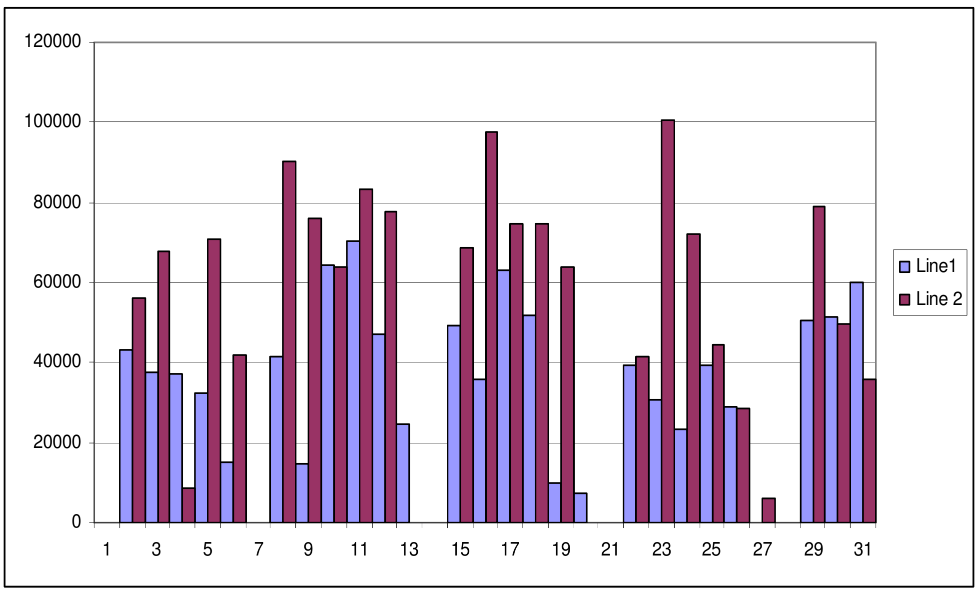


Figure5.4 One-month daily productions on two lines

Figure 5.5 shows data recorded during 211 work days (without holidays, delays, time anticipated for overhauling etc.). Larger oscillations in the volume of production are noticeable in line 2.

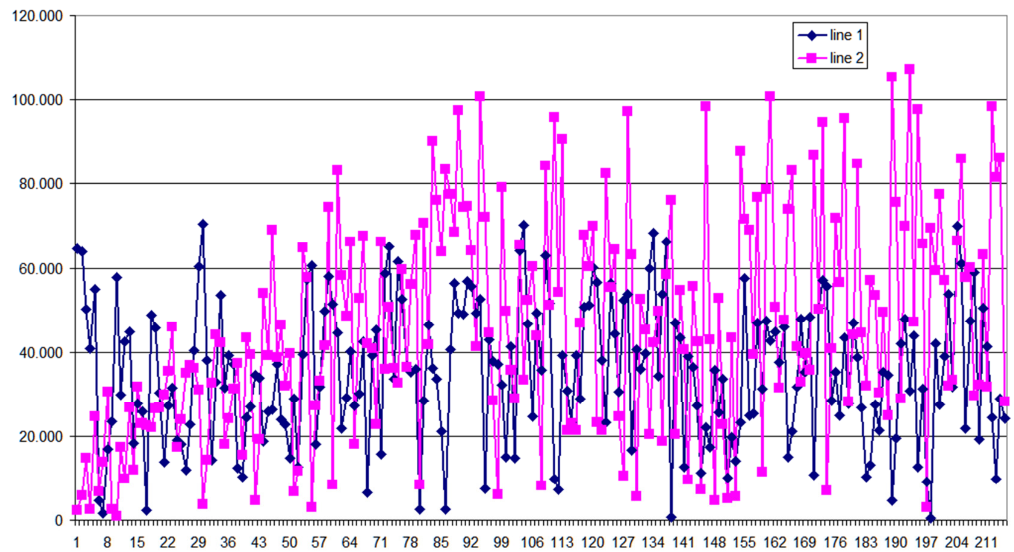


Figure5.5 Production on two lines

For the observed time period, the analysis included direct and overhead costs, market demands, machinery capacities, human resources and constraints that may occur due to shortage of material, tools, etc.

Table5.6 Planned and realized product quantities from the production program in the observed time period

Variable	Product	Planned quantity (t)	Realized quantity (t)	%
X1	Hot-rolling rolls	12,500	11,855	94.84
X2	Hot-rolled sheets 7–15 mm	1,750	1,720	98.29
X3	Hot-rolledsheets16-100mm	1,000	970	97.00
X4	Hot-rolled sheets Č 0563	625	378	60.48
X5	Cold-rolling rolls	2,500	2,430	97.20
X6	Galvanized rolls	1,125	808	71.82
X7	Galvanized strips	75	77	102.60
X8	Welded pipes – square	3,750	2,377	63.39

X9	Welded pipes – rectangular	2,500	1,500	60.00
X10	Welded pipes – circular	3,000	1,600	53.33
X11	Seamless pipes	625	514	82.24
X12	Galvanized pipes	190	189	99.47
X13	INP/UNP carriers	1,125	1,100	97.78
X14	Euro carriers	185	133	71.89
X15	L profiles	875	845	96.57
X16	ZP profiles	175	113	64.57
X17	Solid steels (rolled and drawn light)	325	297	91.38
X18	Firiket	150	140	93.33
X19	Flah	350	310	88.57
X20	Ribbed reinforcement	100	59	59.00
X21	Electrodes	12,5	10,5	84.00
X22	Al rolls	75	41	54.67
X23	Al pipes	12,5	10,5	84.00
X24	Al profiles	37,5	30	80.00

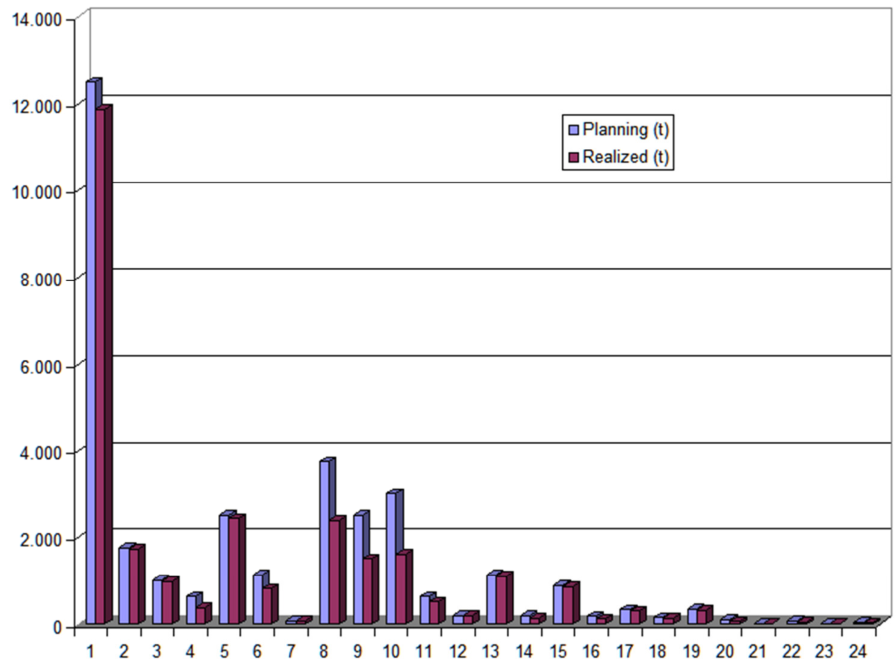


Figure5.6 Planned and realized production for the observed three-month period.

It is easy to find out using the ABC analysis that the production of X1, X5, X8, X2, X10 and X9 products accounts for 80% of the total production. In the analysis below products X1 and X5 are observed as well as variables X1 and X2 respectively.

Capacity utilization:

$$Z(X_1, X_2)_{max} = 43.09\,X_1 + 8.83X_2 \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; (5.51)$$

The demand is larger than capacity resources; the capacity of two production lines is a constraint (max. capacity is 250 t per shift and per line).

Product unit prices:

Product X1

Traditional:

$$Z_1(X_1)_{min} = 536.11\,X_1^2 + 689.59\,X_2 + 5346.1 \;\ldots\ldots\ldots\ldots\ldots\; (5.52)$$

Activity-based approach:

$$Z_1\,(X_1)_{\,min} = 553.17\,X_1^2 + 624.3\,X_2 + 5458.4 \;\ldots\ldots\ldots\ldots\ldots\ldots\; (5.53)$$

Product X2

Traditional:

$$Z_1\,(X_2)_{\,min} = -\,2255\,X_2^2 + 8751.4\,X_2 - 396 \;\ldots\ldots\ldots\ldots\ldots\ldots\; (5.54)$$

Activity base approach:

$$Z_1\,(X_2)_{\,min} = -\,2368.4\,X_2^2 + 9246.6\,X_2 - 455.83 \ldots\ldots\ldots\ldots\ldots\; (5.55)$$

So, the objective functions are:

1. Case A1

$$Z_1'\,(X_1, X_2)_{\,min} = 536.11\,X_1^2 - 689.91\,X_1 - 2255\,X_2^2$$

$$+\,8751.4\,X_2 + 4950.1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; (5.56)$$

$$Z_2'\,(X_1, X_2)_{\,max} = 43.09\,X_1 + 8.83\,X_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; (5.57)$$

2. Case A2

$$Z_1''\,(X_1, X_2)_{\,min} = 553.17\,X_1^2 - 624.3\,X_1 - 2368.4\,X_2^2$$

$$+\,9246.6\,X_2 + 5503 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; (5.58)$$

$$Z_1''\,(X_1, X_2)_{\,max} = 43.09\,X_1 - 8.83\,X_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; (5.59)$$

RESULTS

Using a Mat lab software package, options for multi-objective optimization via genetic algorithms for the defined objective and constraint functions, produces the results as presented in Figures 5.7, 5.8, 5.9, and 5.10.

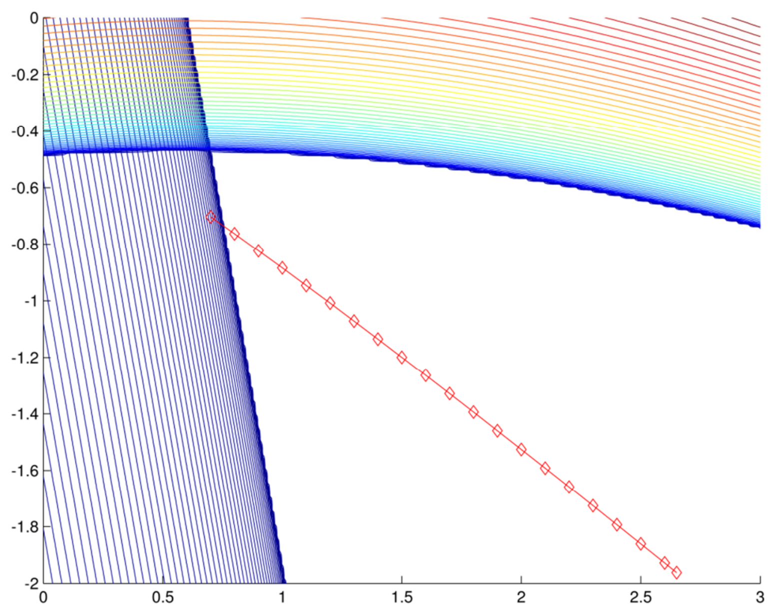


Figure5.7 Contours of objective functions for case A1

Table 5.7 and Figures 5.19 display contours of the objective functions, nonlinear function of product cost, depending on the volume of production and linear function of machinery capacity utilization, for the observed two cases.

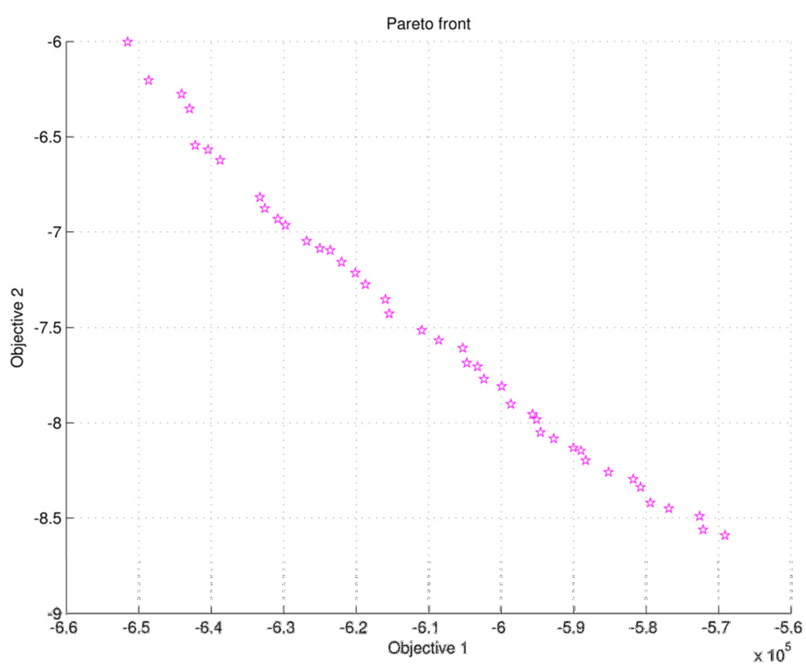


Figure5.8 Pareto front for case A1

Figure 5.8 and 5.10 shows a set of points representing optimal solution for the observed functions for the two observed cases each.

Optimal solution is readable from Figures 5.8 and 5.10 respectively, where the point of minimum is sought, i.e. the point closest to the coordinate-system origin and represents the minimum for the two opposing criteria (maximum is sought for one criterion and is multiplied by -1 to obtain the reverse case and then minimum is sought, which is necessary to generate the Pareto front).

In tables 5.7 and 5.8 only singled out points are given, representing the middle part of a set of points (the analysis involves over 50 points), i.e. a set of points closest to the coordinate-system origin. Point No 6 represents optimal solution for case 1, while point No 37 is optimal solution for case 2.

Table5.7 Points singled out from Pareto front for case A1

Node no.	X1 (t)	X2 (t)	Z1(cost)	Z2(profit)
27	11.9	19.7	-6.3	6.9
30	12.0	19.7	-6.3	6.9
9	12.1	19.7	-6.3	7.0
29	12.3	19.7	-6.3	7.0
35	12.4	19.7	-6.2	7.1
31	12.4	19.7	-6.2	7.1
7	12.6	19.7	-6.2	7.2
3	12.7	19.7	-6.2	7.2
4	12.8	19.7	-6.2	7.3
28	13.0	19.7	-6.2	7.4

42	13.2	19.7	-6.2	7.4
22	13.4	19.7	-6.1	7.5
6	**13.5**	**19.7**	**-6.1**	**7.6**
12	13.6	19.7	-6.1	7.6
19	13.8	19.7	-6.0	7.7
34	13.9	19.7	-6.0	7.7
10	14.0	19.7	-6.0	7.8
11	14.1	19.7	-6.0	7.8
38	14.3	19.7	-6.0	7.9
33	14.4	19.7	-6.0	8.0
39	14.5	19.7	-6.0	8.0
20	14.6	19.7	-5.9	8.0
21	14.7	19.7	-5.9	8.1
32	14.8	19.7	-5.9	8.1
23	14.9	19.7	-5.9	8.1
16	15.0	19.7	-5.9	8.2
27	11.9	19.7	-6.3	6.9
30	12.0	19.7	-6.3	6.9
9	12.1	19.7	-6.3	7.0

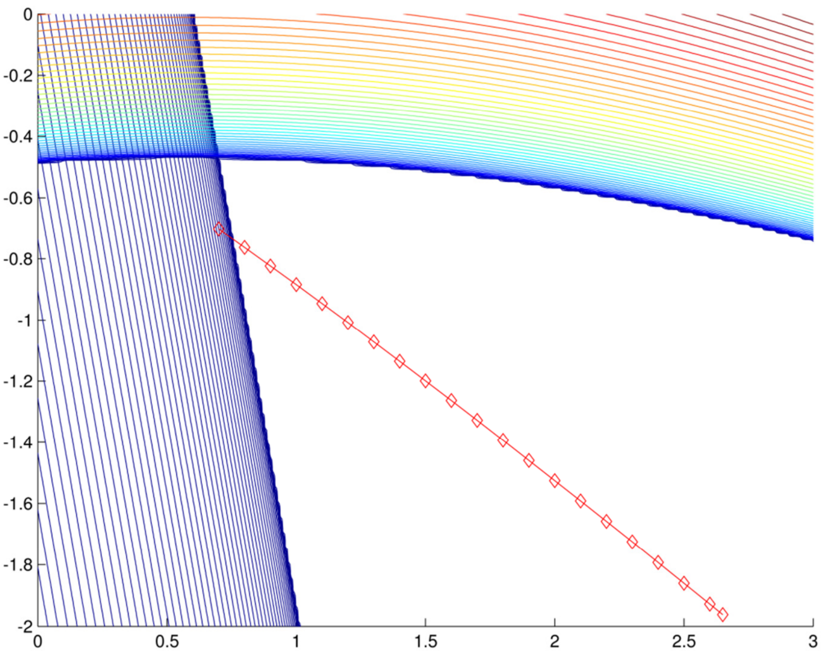


Figure5.9 Contours of objective functions for case A2

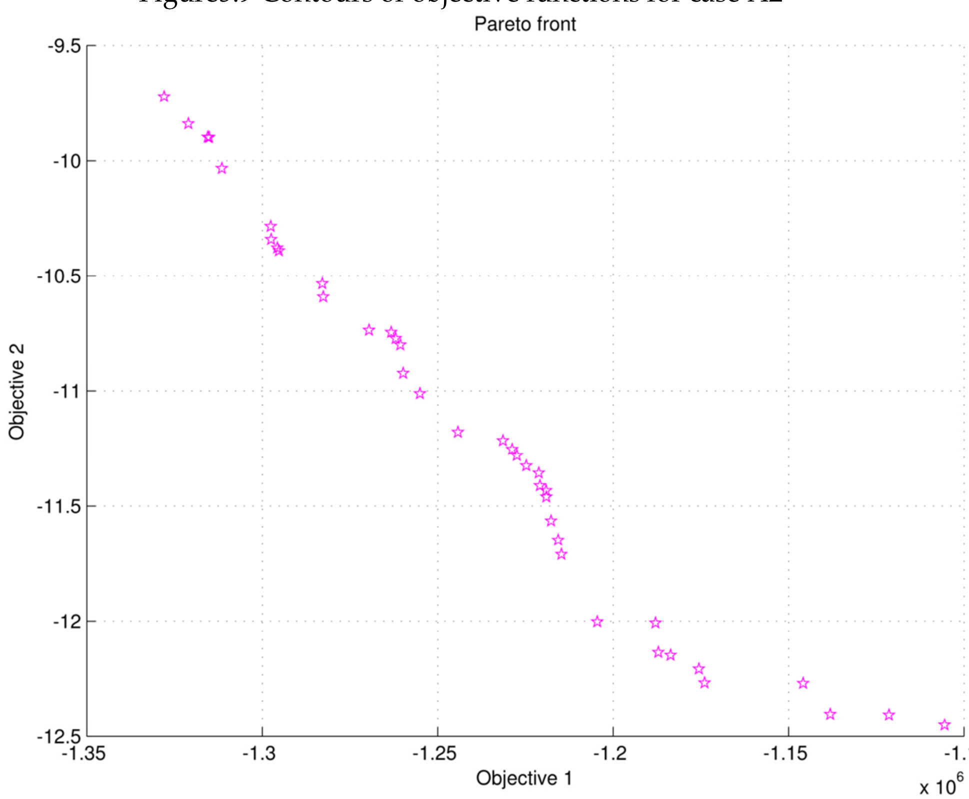


Figure5.10 Pareto front for case A2

Table5.8 Points singled out from Pareto front for case A2

Node no.	X1	X2	Z1(profit)	Z2(cost)
3	22.37	26.82	11.95	1.14
28	22.33	26.95	11.94	1.14
36	21.66	26.91	12.18	1.12
12	21.52	26.89	11.88	1.16
6	21.33	26.87	13.06	0.97
35	21.10	26.83	12.59	1.05
15	21.04	26.82	11.92	1.14
10	20.99	26.83	12.72	1.04
9	20.86	26.80	10.76	1.25
37	**20.79**	**26.82**	**10.92**	**1.24**
39	20.68	26.82	12.38	1.07
8	20.62	26.82	12.29	1.10
2	20.53	26.83	11.45	1.23
11	20.43	26.92	12.35	1.09
20	20.04	26.94	11.08	1.24
22	19.83	26.94	12.58	1.06
5	19.55	26.90	12.74	1.03
38	19.49	26.90	11.47	1.22
19	19.42	26.90	12.99	0.98
29	19.39	26.95	11.76	1.20
24	19.05	27.00	12.45	1.07

14	18.92	26.98	12.71	1.04
30	18.58	27.02	12.93	0.99
16	18.55	27.02	12.74	1.03
32	18.46	27.02	12.93	0.99
25	18.34	27.00	11.17	1.23

The results for production program optimization indicate that there are significant differences in the obtained optimal quantities of the observed products when the product cost price is calculated via traditional or ABC approach.

In calculating the cost price via the two mentioned approaches the nonlinear functions of cost price were used, depending on the volume of production. Although those calculations of the cost price via two approaches indicated at first sight very similar dependences of production volume on cost price, it turned out later that there are significant differences in optimal production volume of the observed products as it appears in figures 5.11, 5.12, 5.13, 5.14 and Table 5.9.

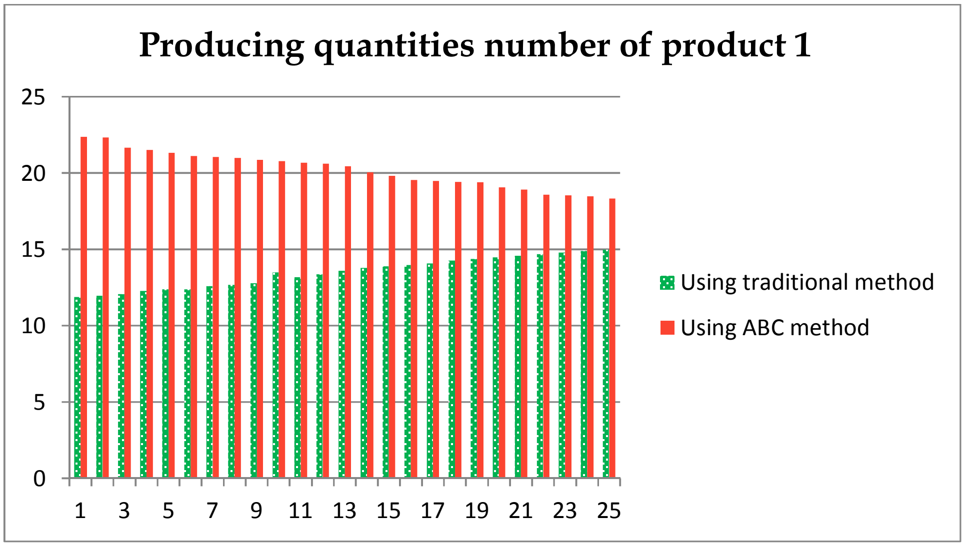


Figure5.11 Traditional methods vs. ABC method in calculating of optimal production number of product 1.

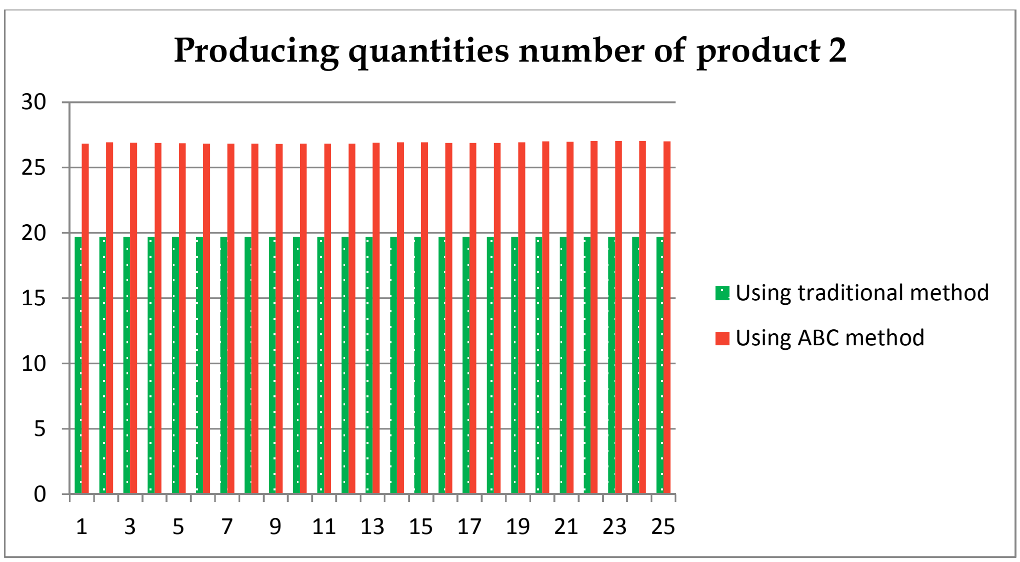


Figure5.12 Traditional methods vs. ABC method in calculating of optimal production number of product 2.

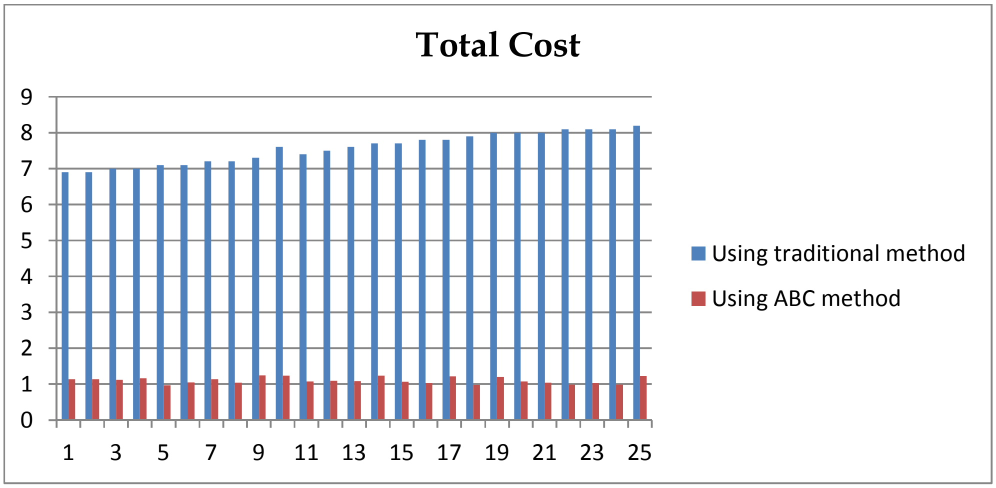


Figure5.13 Traditional methods vs. ABC method in calculating of total production cost

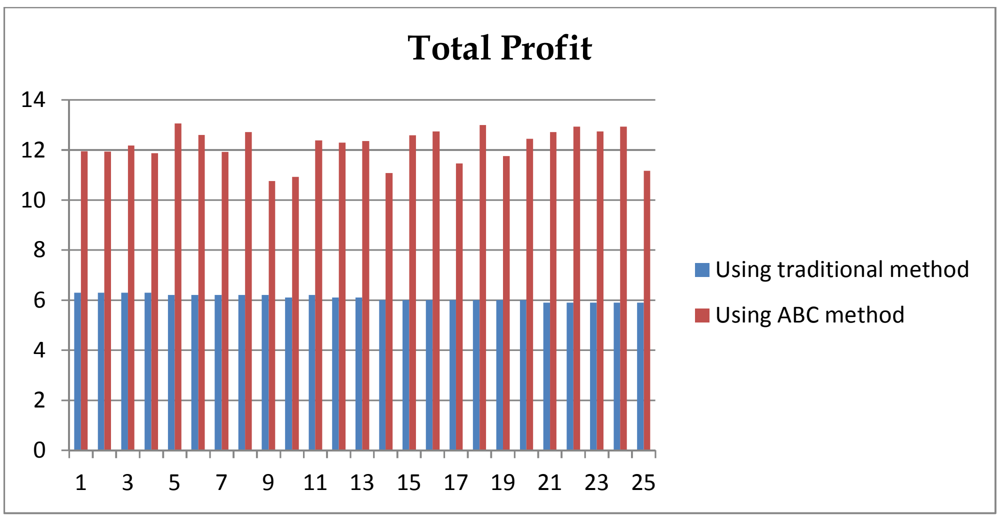


Figure5.14 Traditional methods vs. ABC method in calculating of total production profit

Table5.9 Optimum quantity, total revenue, and total cost calculated by traditional and ABC approach incase A2

	Optimal quantity of product 1(X1)	Optimal quantity of product 1 (X1)	Total Revenue	Total cost	Net profit	% of Improvement
Traditional Method	13.5	19.7	7.6	6.1	1.5	86.5
ABC Method	20.1	26.82	10.92	1.24	9,68	

In conclude of case A Metalika Volf factory, ABC approach and genetic algorithm was applied to improve machinery capacity utilization level and determine the optimal quantities simultaneously. In this case, the target functions were mixed. The cost target was nonlinear function while the utility function was linear.

This investigation presents the analysis of production program with respect to impact criteria: cost price and machinery capacity utilization level. Cost price depending on the volume of production is represented by nonlinear function for the case when the calculation of product cost price is performed by the ABC approach. Optimal product quantity with respect to the two set up criteria is determined by forming the Pareto front in the optimization model using genetic algorithms. The results indicate significant differences in the optimal production program, which depends on the type of approach applied in determining the product cost price. Determination of optimal production program is more adequate when the ABC approach is used, because it describes a real model more approximately.

5.3.2 Case study B

In the company engaged in manufacturing precision measuring instruments, we have analyzed the available data and formed nonlinear functions of the TR and the TC for the three products:

a) Clocks

Revenue function

$$f(x)_{11} = TR(Q) = -0.04Q^2 + 686Q - 1375.3 \qquad (5.60)$$

Cost function

$$f(x)_{21} = TC(Q) = -0.024Q^2 + 410.Q - 4342 \qquad (5.61)$$

b) Water meter

Revenue function

$$f(x)_{12} = TR(Q) = -0.18Q^2 + 4298Q - 343884 \text{ .... } (5.62)$$

Cost function

$$f(x)_{22} = TC(Q) = -0.49Q^2 + 3382.4Q - 463764 \text{ .... } (5.63)$$

c) Gas meter

Revenue function

$$f(x)_{13} = TR(Q) = -0.87Q^2 + 5984.5Q - 5715.1 \text{ .... } (5.64)$$

Cost function

$$f(x)_{23} = TC(Q) = -0.58Q^2 + 3818.2Q - 3643.6 \text{ .... } (5.65)$$

The functions of criteria for profit maximization will have the form:

$$\max f(x) = \sum_{i=1}^{3} f_{1i} = f(x)_{11} + f(x)_{12} + f(x)_{13} \text{ .... } (5.66)$$

$$\min f(x) = \sum_{i=1}^{3} f_{2i} = f(x)_{21} + f(x)_{22} + f(x)_{23} \text{ .... } (5.67)$$

Respectively:

F(1)= -0.04*x(1)^2 + 686*x(1) - 0.18*x(2)^2 + 4298*x(2) - 0.87*x(3)^2 + 5984.5*x(3) - 350975.4; …………………………………………………………..(5.68)

F(2)= -0.024*x(1)^2 +410*x(1) - 0.49*x(2)^2 + 3382.4*x(2) -0.58*x(3)^2 + 3818.2*x(3) - 463066; ………..………………………………………………………(5.69)

Constraints:

If we consider the production capacity as a key constraint in the production quantity of some products, temporarily ignoring the structure of demand for mentioned products on the market, the restrictions are:

$$0 \leq x1 \leq 4400$$

$$0 \leq x2 \leq 2444$$

$$0 \leq x3 \leq 1100$$

***Employees and raw material in the observed company are not of limiting character

Table5.10 Points singled out from Pareto front for case B

No	Quantity of product one(X1)	Quantity of product two(X2)	Quantity of product three(X3)	Total profit (F1)	Total cost (F2)
2	2312.1	2192.8	944.4	14456485.9	8506146.3
13	2312.1	2192.8	944.4	14456485.9	8506146.3
17	2193.0	1804.7	838.9	12539641.9	7623919.3
5	1973.0	1678.2	775.6	11670974.7	7161283.7
15	2087.2	1561.3	624.9	10578074.5	6534024.5
19	1799.6	1408.7	317.1	8261883.3	5142047.1
18	367.9	1168.4	269.1	6219789.9	3953260.5
7	2008.5	1157.9	735.7	9532647.3	6018204.1
9	907.5	1050.0	816.4	8859057.3	5631201.6
6	269.9	1020.1	297.5	5731639.4	3670859.1
4	1926.2	899.0	513.4	7383810.4	4689945.6
3	461.2	671.9	161.3	3706113.7	2373117.9
10	68.2	547.2	24.2	2137830.5	1360931.1
20	124.1	392.5	249.4	2831668.3	1756049.6
12	1395.3	266.3	545.7	4666573.9	2838989.5
8	345.0	225.2	90.2	1372601.8	752203.7
14	9.8	161.3	184.4	1417831.6	757824.9
11	197.1	153.5	23.6	578938.0	214266.9

The Pareto front and values of the functions F1 and F2 are shown in figure 5.15

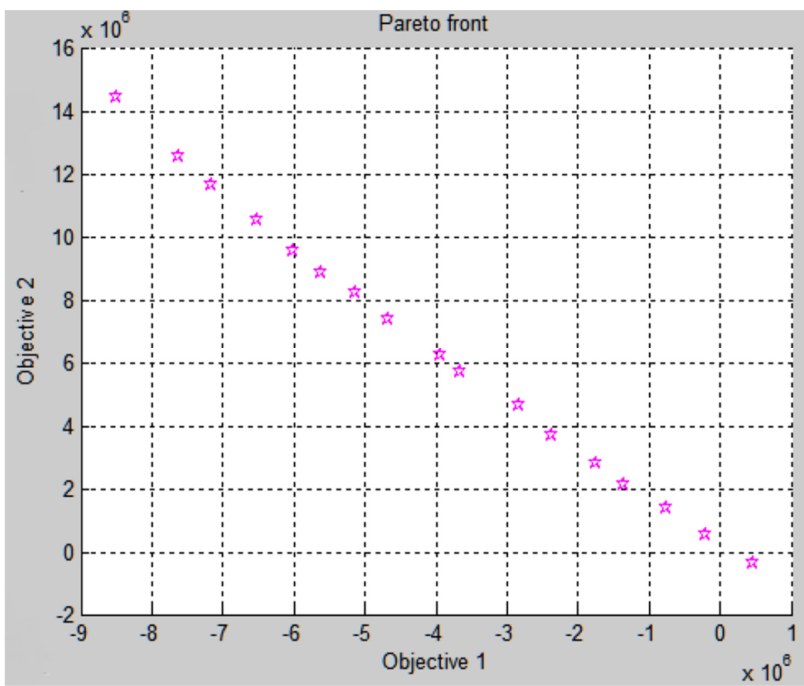


Figure5.15 The Pareto front of optimum solution

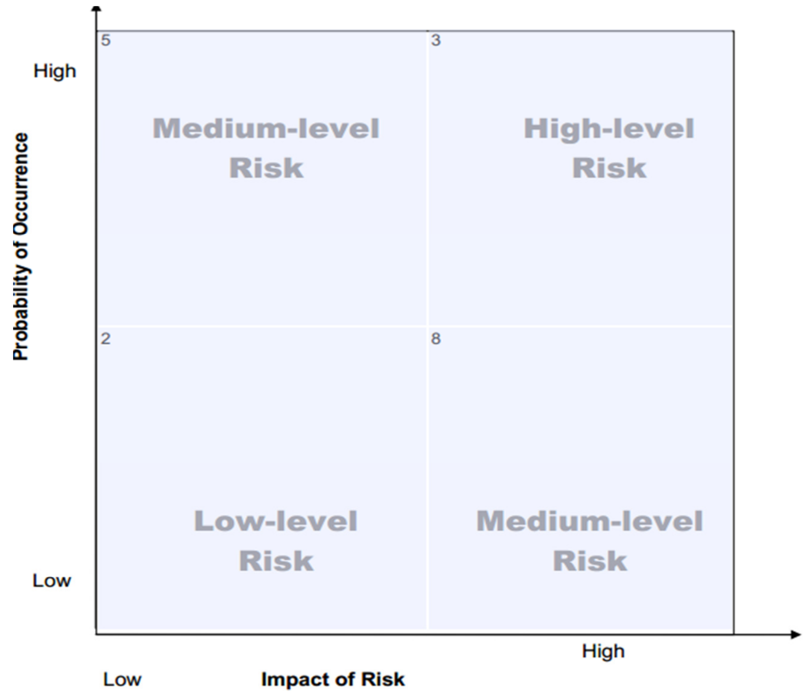
From the Pareto front diagram figure 5.15, it is evident that optimum solution for production quantity and profit maximization under given constraints is a set [2312; 219; 944], where the maximum profit is 5,950,340 RSD calculated as max (F1-F2).

After getting the optimum solution, the second step is Identify and analysis of risk sources for the observed optimum product program. The essence of risk management is not avoiding or eliminating risk but deciding which ones to avoid or hedge.

In our case, we have focused on the internal resources only. Identification, evaluations, and determination of trend are shown in the table below:

Table5.11 Evaluation of internal risk sources and determination of trend

Internal Risk Source	Trend	Risk rating 1st Q. 2010	Risk 2nd Q. 2010	Risk rating 3rd Q. 2010
Operation cost.	↗	Low	Medium	Medium
Labor cost	→	Low	Medium	Medium
Lubricant cost	↘	Low	Low	Low
Raw martial cost	↗	Medium	High	High
Fixed cost	→	Medium	Medium	Medium
capital availability	→	Medium	Medium	Medium
business operations – supply chain management	→	Medium	Medium	Medium
information technology	↗	Medium	High	High
planning	↗	Medium	Medium	High
reporting	↗	Low	Medium	Medium



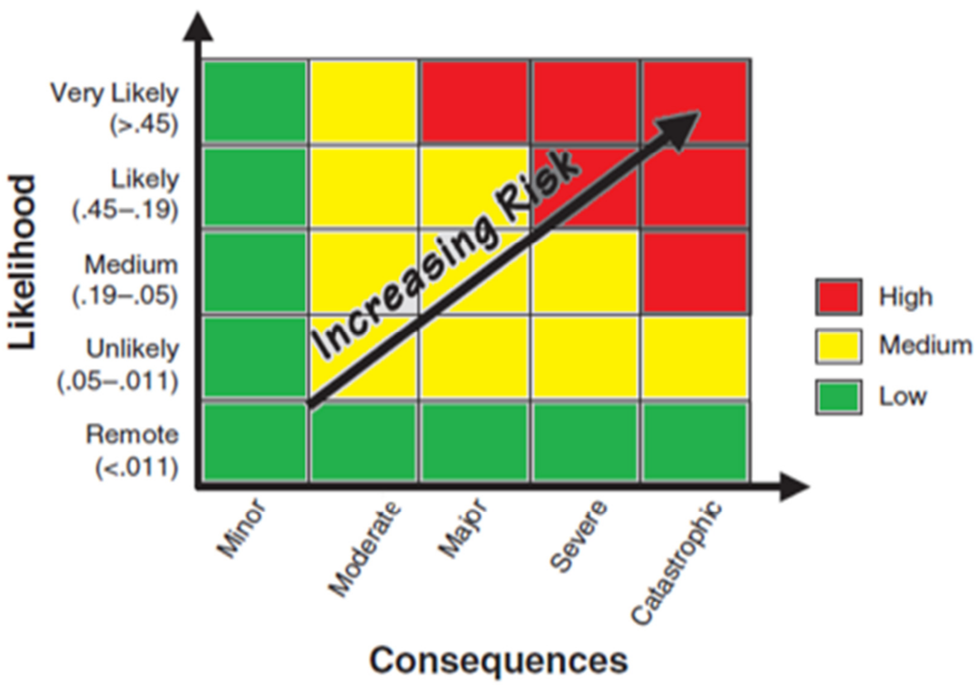


Figure5.16 Two-Dimensional Risk Map for identifying Business risks [J. Fraser, B.J. Simskins, 2010]

This figure 5.16 shows a two-dimension risk map. The vertical axis represents loss likelihood and the horizontal axis represents loss impact. The four quarter panels stand for different combinations of likelihood and impact.

Figure 5.17 represents two dimensional of risk map developed for identified and evaluated internal risk sources. It indicates a small number of high-risky, a small number of low-risk risk sources, but the largest number risk sources with medium probability and consequences for business losses, namely:

$$R_i = \{R_{high}, R_{medium}, R_{low}\} = \{2,15,3\}$$

Over all research results indicate that at these restrict conditions of production, there is comparatively high risk of production losses. Therefore, it is necessary to resolve our problem to find another optimal solution and repeat analysis until achieved an optimal production program.

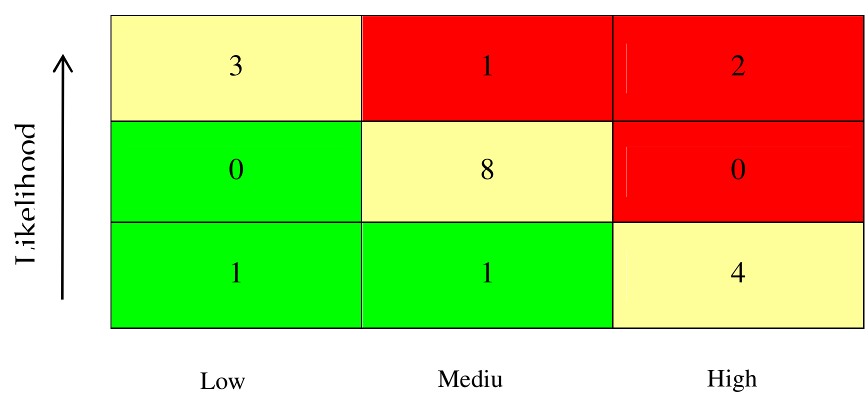


Figure5.17 Two dimensional of risk map was developed for identified and evaluated internal risk sources

In conclude of case B of INSA factory, genatic algorithim combinding with risk mamagement mtrix was applied to improve total profit and reduce total cost with taking into account reducing the impact of outer risk sources in the quality of decision. Both of the functions target, cost and profit were nonlinear fuctions.

A strong and cabable model of genatic algorithim combinding with risk mamagement mtrix is intrduced and developed to get optimal production program and increase the quality of decisions.

Applying genatic algorithm as a technique deals with huge conflect constrains to create one or altrenative optimal solusions. On ther hand, applying risk mamagement mtrix for choice of optimal production program reduces the risk of operating losses and affects on the efficiency of management. Furthermore, qualitative aspects that are defined through risk sources and by its identification and evaluation, more realistic production program evaluation can be taking into account. Integrated both of them, genetic algorithim and risk management matrix guide to optimal production program.

Conclusion

The production program of enterprises is an important and complex segment of managing the enterprise, considering the fact that it influences all elements, such as planning of the material, human resources, machinery resources, research and development, marketing etc.

Previous investigations [Gonzah, 2001 and Shih, 1979] have found a correlation between the method of calculating unit cost price and the results obtained by applying the multi-criteria analysis method in the optimization of production program. Earlier investigations [Kakumanu, 1998 and Chi-Ming Lin, 2007] have also proved that optimal production program exerts direct influence on financial indicators of the business–manufacturing system's business operations.

In this investigation, improved financial results has achieved in operating business of the observed business-manufacturing system by applying the new thesis approach compared to classical approach in production program planning. Introducing the ABC approach into the unit cost price calculations, nonlinear goal functions for costs and sales prices in multi-criteria analysis, applying genetic algorithms for several goal functions to determine the optimal production program, and applying risk-based approaches to evaluate the observed production program was enhancing and supporting the process of production program planning to get better financial results.

Calculation of product unit cost price by ABC (Activity Based Costing) method was helpful and useful to classify the fixed and variable costs per product as well as material, work hours and machine engagement hours per operation for each type of product for the observed business-manufacturing system.

Breakeven Point method (Analysis of critical point with nonlinear functions of cost price and sales price) was Appling to generated quadratic function. This quadratic function has ability to describe dependency for each product: the volume of production-cost price and the volume of production-revenue.

A genetic algorithm in a software package Mat lab was useful and strong method to deal and determine the optimum points of multi-nonlinear function. Also, Risk-based methods were useful to evaluate these various alternative solutions for the optimal production program with regard to real application in the observed business-manufacturing system under the influence of various external impact factors not included in the previous multi-criteria analysis predominantly oriented to the maximum utilization of a company's internal resources.

During the work period of the thesis, we tried to be more close form the real situation case problems of production program. Where, we take into account all the internal and external factors might be effect in our case studies. But in same time and through all the numerous factors were collected, only the significant factors were chosen as constrains and limitations, otherwise it will be impracticable and useless.

The results have approved and shown that applying the integrated approach of the ABC approach and genetic algorithm was useful and significant in the production programming for any enterprise.

The results for production program optimization indicate that there are significant differences in the obtained optimal quantities of the observed products when the product cost price is calculated via traditional or ABC approach.

This improvement is coming by using ABC method to customize and assign unit cost and price for each unit type of product depend on of the necessity and the need. The ABC approach is more adequate for determining the optimal production program because it describes and simulates the reality.

As a capable and strong tool, genetic algorithm was an important tool to solve our two conflict and complex objective functions. Where, the genetic algorithm considers one of the few tools that deal with and solves such as problems like multi nonlinear functions and/or linear functions such as the utility and cost target functions.

Comparing between the two results obtained, we can see clearly that the integrated approach improves the machinery capacity utilization level 58% more than before. This improvement reflects on the determination of right optimal product quantities of X1 and X2. As a result, Production level increases from 13.5 to 20.1 and 19.7 to 26.82 for X1 and X2 respectively, which in turn increase the total revenue from 7.6 to 10.92 and reducing the total cost from 6.1 to 1.24. This means the production level increase for 148% for X1 and 136% for x2 (we can say about 140%). Total revenue rise for 143% and total cost reduce for 76.7%.

In this investigation also, a general realistic model of production program has been evaluated by taking into account the qualitative aspects that are defined through risk sources and by their identification as well.

Results have also approved and shown the impact of outer risk sources in the quality of decisions which is directly effect on the Profit margin. The combinding approach of genatic algorithim with risk mamagement matrix has figure out and slove this problem. Results approved that the approach is strong technique that deals with huge conflect constrains to create one or altrenative optimal solusions and reduces the risk of operating losses and increasing of the management efficiency.

This approach improves total revenue and decision quality by eliminated influence of the impact of outer risk sources as much as possible. The improvement of total revenue and decision quality appear clearly in the obtained results.

From the Pareto front diagram figure 5.11, it is evident that the suggestion optimum solution for production quantity, maximum profit, and minimum cost under given constraints is:

- Suggestion optimum quantity of product 1 (X1) = 2312;
- Suggestion optimum quantity of product 2 (X2) = 219;
- Suggestion optimum quantity of product 3 (X3) = 944],
- Suggestion maximum profit (F1) = 14456485.9, and
- Suggestion minimum cost (F2) = 8506146.3

Where the suggestion net profit is 5,950,340 RSD calculated as deferent between (F1-F2).

This suggestion solution has tested and evaluated by internal sources of risk matrix support our decision.

Risk matrix indicates a small number of high-risky ($R_{high} = 2$), a small number of low-risk risk sources ($R_{low} = 3$), but the largest number risk sources with medium probability and consequences for business losses ($R_{medium} = 15$).

Over all research results indicate that at these restrict conditions of production, there is comparatively high risk of production losses. Research results indicate that at this suggestion solution of production capacity utilization, there is relatively high risk of production losses. Consequently, it is necessary to resolve the problem and repeat the analysis of risk sources as well until achieved an optimal production program.

Integrated model of Multi-criteria analysis of production program with Risk management provides the top manager deferent decision choices of an optimal production program. In same time, it helps him to select the non risky decision. namely not to take into account only quantity indicators such as capacity utilization, production resources, restrict limitations, but to consider qualitative aspects that are defined trough risk sources and by its identification and evaluation as well. It means, more realistic production program evaluation has represented of our problem. As result, integrated model reduces the risk of operating losses and affects in the efficiency of management in production program planning as well.

References

1. Clements, P. and Northrop, "Software Product Lines, Practices and Patterns", Addison Wesley, Upper Saddle River, NJ (2002)

2. Gary Chastek and John D. McGregor, "Guidelines for Developing a Product Line Production Plan", CMU/SEI-2002-TR-006, ESC-TR-2002-006, June 2002.

3. Cohen and Sholom, "Guidelines for Developing a Product Line Concept of Operations", (CMU/SEI-99-TR-008, ADA367714).Pittsburgh, PA, Software Engineering Institute, Carnegie Mellon University, 1999.

4. Kang K., Lee J., and Donohoe P., "Feature-Oriented Product Line Engineering. IEEE Software", 19(4), July/August (2002) 58-65.

5. Jaejoon Lee, Kyo C. Kang, and Sajoong Kim, "a Feature-Based Approach to Product Line Production Planning", Korea Software Institute (KSI), Korea IT Industry Promotion Agency (KIPA), KIPA Bldg., 79-2, Garakbon-dong, Songpagu, Seoul, Republic of Korea, Sep 14, 2010.

6. M.S. Hundal: Product Costing: A Comparasion of Convetional and Activity-based Costing Methods, Journal of Engineering Design, 1997, Vol. 8, No. 1, ISSN: 0954-4828.

7. E. Waring: Problems Concerning Interpolations. Philos. Trans. Roy. Soc. London Ser. A, Vol. 69, 1979. pp. 59- 67, ISSN 0031-8116.

8. Hax and Arnoldo "Aggregate Production Planning." Production Handbook, Fourth Edition. New York, NY: John Wiley & Sons, 1987.

9. Bass, Len, Clements, Paul, Kazman, and Rick, "Software Architecture in Practice", Boston, MA, Addison-Wesley, 1998.

10. Kang, Kyo C., Cohen, Sholom G., Hess James A., Novak, William E., and Peterson, A., "Feature-Oriented Domain Analysis Feasibility Study",

(CMU/SEI-90-TR-21, ADA235785).Pittsburgh, PA, Software Engineering Institute, Carnegie Mellon University, 1990.

11. Batory and Don, "Intelligent Components and Software Generators", (Technical Report 97-06).Austin, TX, Department of Computer Sciences, University of Texas at Austin, 1997.
12. Weiss, David M., Lai, and Chi Tau, "Robert Software Product-Line Engineering Reading", MA, Addison-Wesley, 1999.
13. Humphrey and Watts. A, "Discipline for Software Engineering", the Complete PSP Book. Boston, MA: Addison-Wesley, 1995.
14. Jacobson, Ivar, Booch, Grady, Rumbaugh, and James. "The Unified Software Development Process", Boston, MA: Addison-Wesley, 1999.
15. McGrath and Michael E., "Setting the PACE in Product Development", Woburn, MA, Butterworth-Heinemann, 1996.
16. Boehm and Barry, "Software Engineering Economics", Englewood Cliffs, NJ, Prentice-Hall, 1981.
17. Klipper H. and Breakeven, "analysis with variable product mix", Management Accounting, April 51-54, 1978.
18. Prasad Kakumanu, "multi-product cost-volume-profit model with product limits", Production planning & control, Vol.9, No. 1, pp. 87-95, ISSN: 0953-7287. 1998.
19. Chin Ming Lin, "An Effective Decision-Based Genetic Algorithm Approach to Multi-objective portfolio Optimization problem", applied Mathematical Sciences, Vol. 1, 2007, No. 5, pp. 201 – 210.
20. H. Markowizt, "Mean – Variance Analysis in Portfolio Choice and Capital Market", Basil Blackwell, New York, 1987.

21. M. Ehrgott, K. Klamroth, and C. Schwehm, "An MCDM Approach to Portfolio Optimization, European Journal of Operational Research, 155 (2004), pp. 752 -770.

22. Daniel Stefan, Anamari-B. Stefan, and others, "A cost-Volume-Profit Model for A Multiproduct Situation with Variable Production Structure", International Conference "20th EURO Mini Conference", Continuous Optimization and Knowledge-Based Technologies, ISBN 978-9955-28-283-9, Vilnius, pp. 349–352, 2008.

23. Luis Gonzah lez., "Multiproduct CVP analysis based on contribution rules", Int. J. Production Economics 73 (2001) 273}284, 26 January, 2001.

24. Wei Shih, "A General Decision Model for Cost-Volume-Profit Analysis under Uncertainty", American Accounting Association, Vol. 54, No. 4, pp. 687-706, Oct. 1979.

25. Hiroki Ishikura, "Study on the Production Planning of Apparel Products, Determining Optimal Production Times and Quantities", Computers Ind. Eng., Vol. 27, No. 1-4, pp. 19-22, 1994.

26. Songsong Liu, Lazaros G. Papageorgiou, "Multi-objective optimization of production, distribution and capacity planning of global supply chains in the process industry", Omega 41(2013)369–382, 2013.

27. Haimes YY, Lasdon LS, and Wismer DA. "On a bi-criterion formulation of the problems of integrated system identification and system optimization", IEEE Transactions on Systems, Man, and Cybernetics, 1:296–7, 1971.

28. Chankong V and Haimes YY., "Multi objective Decision Making Theory and Methodology", New York, Elsevier Science, 1983.

29. Bokang Kim and Sooyoung Kim, "Extended model for a hybrid production planning approach", Int. J. Production Economics, PP. 165-173, 2001.

30. Reay-Chen Wanga and Tien-Fu Liang, “Applying possibilistic linear programming to aggregate production planning”, Int. J. Production Economics, PP.328–341, 2005.

31. Chen, S. L. and Liu, C. L., “Procurement strategies in the presence of the spot market-an analytical framework”, Production Planning and Control, PP.297–309, 2007.

32. Chen, S. L. and Liu, C. L., “Optimum profit model based on order quantity, product price, and process quality level”, Expert Systems with Applications, PP. 7886–7893, 2011.

33. Glover F., Kelly J.P., Laguna M., New Advances for Wedding Optimization and Simulation, Proceedings of Winter Simulation Conference, 1999.

34. Kaisa Miettinen, Nonlinear Multiobjective Optimization, Kluwer Academic Publishers, 1999.

35. Jeffreys, H. and Jeffreys, B. S. "Lagrange's Interpolation Formula." §9.011 in Methods of Mathematical Physics, 3rd ed. Cambridge, England: Cambridge University Press, p. 260, 1988

36. Pareto, V., Cours D’Economie Politique, volume I and II. F. Rouge, Lausanne, 1986

37. Deb K., Multi-objective optimization using evolutionary algorithms. Chichester, UK: Wiley; 2001.

38. Deb, K., et al., Scalable test problems for evolutionary multi-objective optimization. Evolutionary Multi-objective Optimization. Theoretical Advances and Applications, 105–145.), 2005.

39. N. Palli, S. Azarm, P. McCluskey, P. Sandarajan, An Interactive - Inequality Constraint Method for Multiple Objectives Decision Making, Transactions of the ASME, Journal of Mechanical Design, 1998, Vol. 120, No.4, pp. 678–686, ISSN 1050-0472.
40. Lampinen, J., Multiobjective Nonlinear Pareto-Optimization, Lappeenranta Univeristy, 2000.
41. Holland, J. H. (1975/1992). Adaptation in Natural and Arti¯cial Systems. Cambridge, MA, MIT Press. Second edition (First edition, 1975).
42. Goldberg, D. E., Genetic Algorithms in Search, Optimization, and Machine Learning, Reading, MA, Addison-Wesley. 1989
43. John R. Koza, James Rice, Automatic Programming of Robots Using Genetic Programming. AAAI 1992: 194-201
44. Michalewicz, Z., Genetic Algorithms + Data Structures = Evolution Programs, Springer, New York, 3rd (extended) edition, 1996.
45. Gen, M., Cheng, R., Genetic Algorithms and Engineering Optimization, John Wiley, New York, 2000, ISSN 0-471-12741-8.
46. Salvatore Mangano, Genetic Algorithms A tutorial, Computer Design, May 1995.
47. Mutaz Flmban, Genetic Algorithms (GAs) Tutorial, Jun 6, 2009
48. Sanchis, J., et al., A new perspective on multi-objective optimization by enhanced normalized normal constraint method. Structural and Multidisciplinary Optimization, 2008, 36 (5), 537–546.
49. Ronald Kaiser, Risk Management, Chapter 16, Ken Robinson Risk Manager, Texas A & M University, 2013.
50. J. Fraser, B.J. Simskins, Enterprise risk management: Today's Leading Research and Best Practices for Tomorrow's Executives, John WIley & Sons, ISBN 978-0-470-49908-5, USA, 2010.

51. The CAS Enterprise Risk Management Committee, Overview of Enterprise Risk, Management,Casualty Actuarial Society Forum, 2003, Pages 99-164, ISSN 1046-6487.

52. Marshall, M. I., & Alexander, C. (2006). Using a contingency plan to combat human resource risk" Journal of Extension [On-line], 44(2) Article 2IAW 1. Available at: http://www.joe.org/joe/2006april/iw1.shtml

53. S. Utyuzhnikov, P. Fantini, M. Guenov: A method for generating a well-distributed Pareto set in nonlinear multi-objective optimization, Journal of Computational and Applied Mathematics, 2009, Vol. 223, No. 2, pp. 820–841, ISSN 0377-0427.

54. P.S. Georgilakis: Genetic algorithm model for profit maximization of generating companies in deregulated electricity markets, Applied Artificial Intelligence, Vol. 26, No.6, pp. 538-552, ISSN 0883-9514.

55. C. Hwang, M. Abu Sayed, Multiple Objective Decision Making – Methods and Applications, Springer Verlag, 1979, ISBN 10 0387091114

56. Misita, M., Optimization of production program, Journal - Industry, Vol 30. No.1-4, pp.33-48.

57. J. Zimmerman: Accounting for Decision Making and Control, 7th ed., McGraw-Hill, ISBN-13 978-0-07-813672-6, New York, 2011.

58. D.E. Akyol. G. Tunecl, G.M. Bayhan: A comparative analysis od activity-based costing and traditional costing, World Academy of Science, Enigneering and Technology, Vol. 3. 2005, pp 44-47, ISSN 2010376X.

59. R. Kaplan, R. Cooper: Cost & Effect: Using Integrated Cost Systems to Drive Profitability and Performance, Harvard Business School Press, ISBN 0-87584-788-9, Boston, 1998.

60. M.S. Hundal: Product Costing: A Comparasion of Convetional and Activity-based Costing Methods, Journal of Engineering Design, 1997, Vol. 8, No. 1, ISSN: 0954-4828.

61. E. Waring: Problems Concerning Interpolations. Philos. Trans. Roy. Soc. London Ser.A, Vol. 69, 1779.pp. 59- 67, ISSN 0031-8116.

62. H. Jeffreys, B. Jeffreys: Methods of Mathematical Physics, 3rd ed. Cambridge University Press, ISBN-10: 0521664020, England: 2000.

Appendix A:

- Generation steps of Multi-Objective Functions

* **CLOCKS**

Q	2000	1190	121
Selling price	1220	762	81
Cost	728	458	54
Net Profit	492	304	27

* **WATER METER**

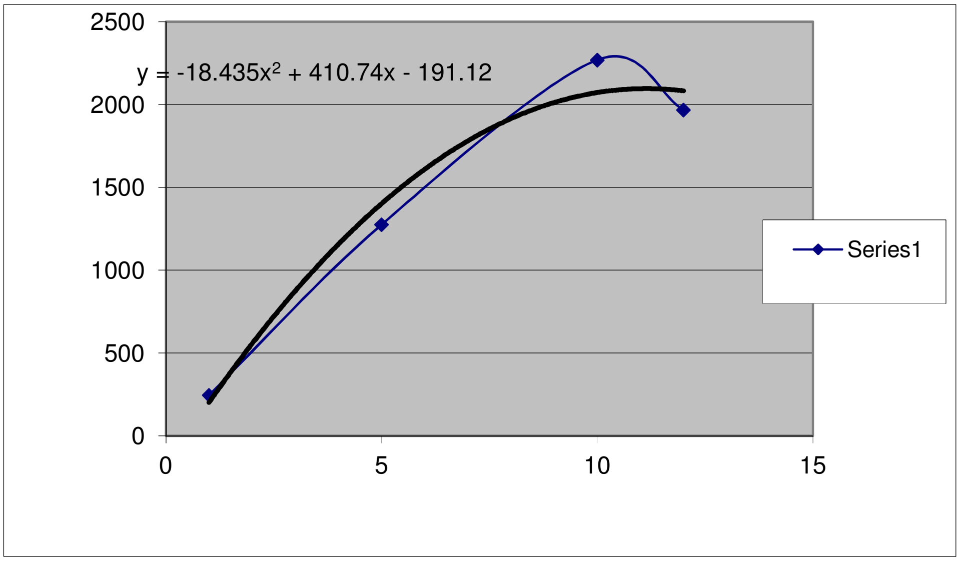
Q	1740	801	410
Selling price	3796	3796	3451
Cost	2191	2470	2191
Net Profit	1605	1326	1260

* **GAS METER**

Q	419	222	22
Selling price	5472	5923	5753
Cost	3482	3770	3661
Net Profit	1990	2153	2092

Appendix A:

Generation steps of Multi-Objective Functions



water meter

quantity	cost	seling
410	898,310.00	1,414,910.00
737	1,614,707.00	2,643,367.00
752	1,867,440.00	2,864,592.00
801	1,978,470.00	3,040,596.00
983	2,163,763.00	3,731,468.00
1018	2,703,362.00	3,864,328.00
1080	2,867,800.00	4,099,680.00
1096	2,401,336.00	4,160,416.00
1485	3,818,650.00	5,581,140.00
1620	4,001,400.00	6,149,520.00
1665	3,648,015.00	6,320,340.00
1740	3,812,340.00	6,605,040.00

GAS meter

quantity	cost	seling
22	80,542.00	126,566.00
48	177,889.00	279,642.00
53	197,160.00	309,809.00
140	520,380.00	812,280.00
222	835,940.00	1,314,908.00
269	989,746.00	1,523,885.00
278	973,000.00	1,529,000.00
375	1,410,750.00	2,217,000.00
419	1,459,959.00	2,292,768.00

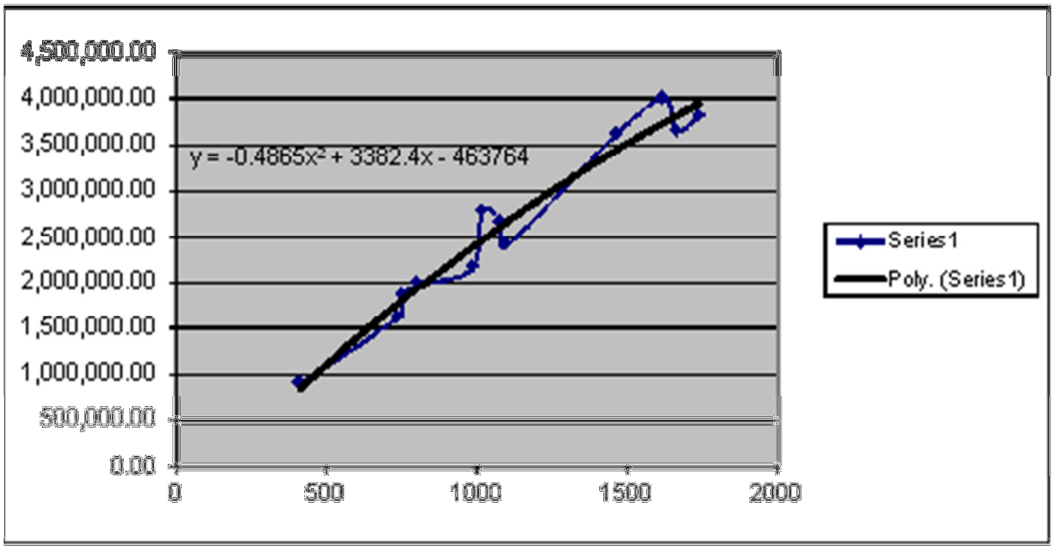
CLOCKS

quantity	cost	seling
121	53,603.00	
1190	458,150.00	
2000	728,000.00	

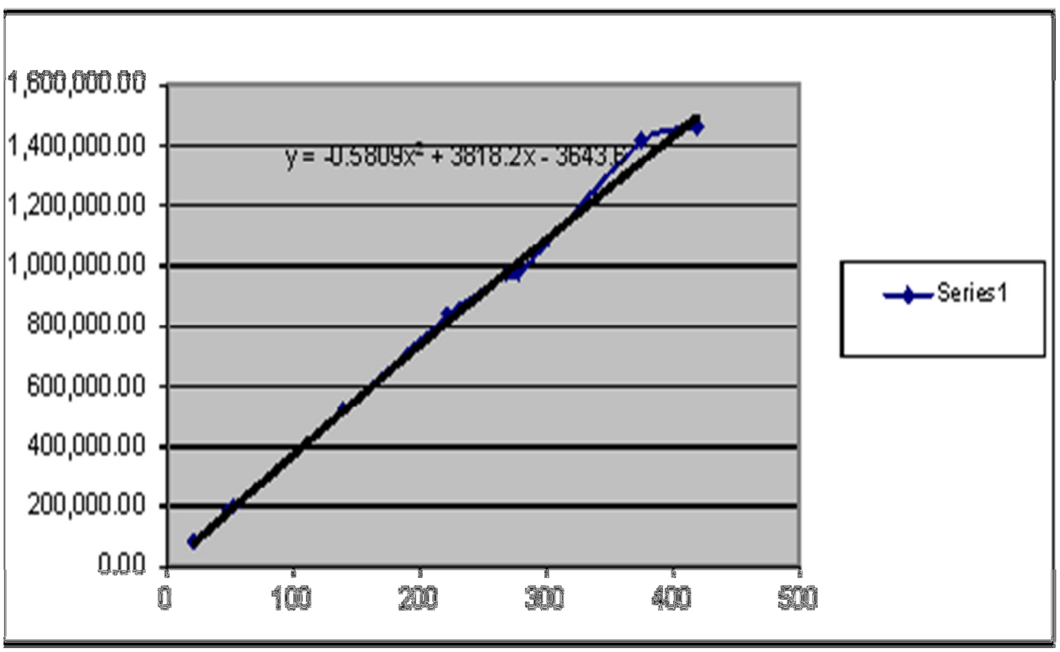
Appendix A:

Generation steps of Multi-Objective Functions

Water Meter Function



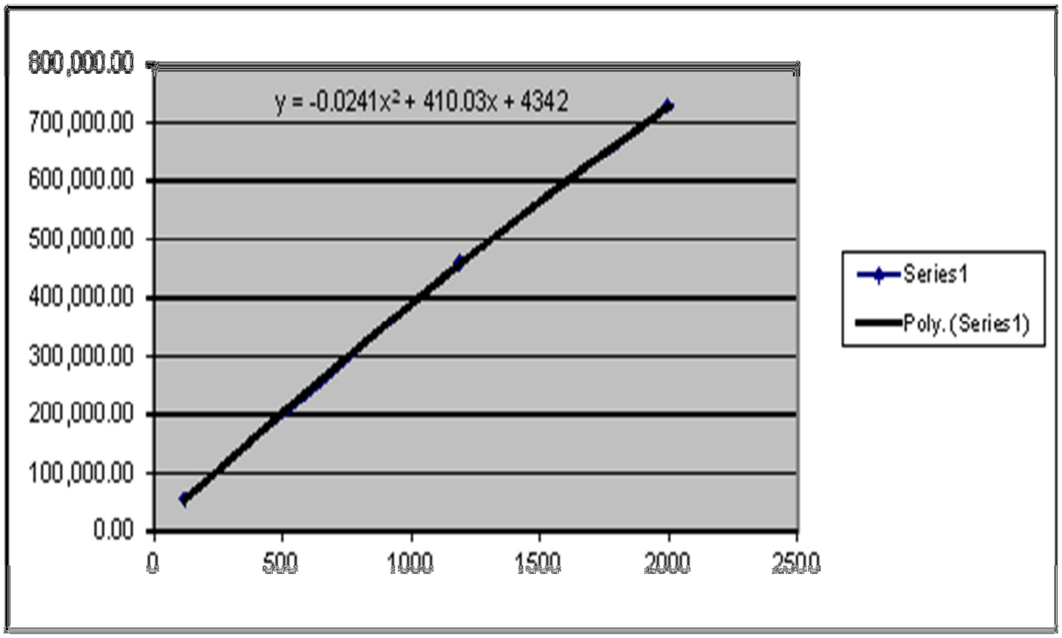
Gas Meter Function



Appendix A:

Generation steps of Multi-Objective Functions

Clocks Function

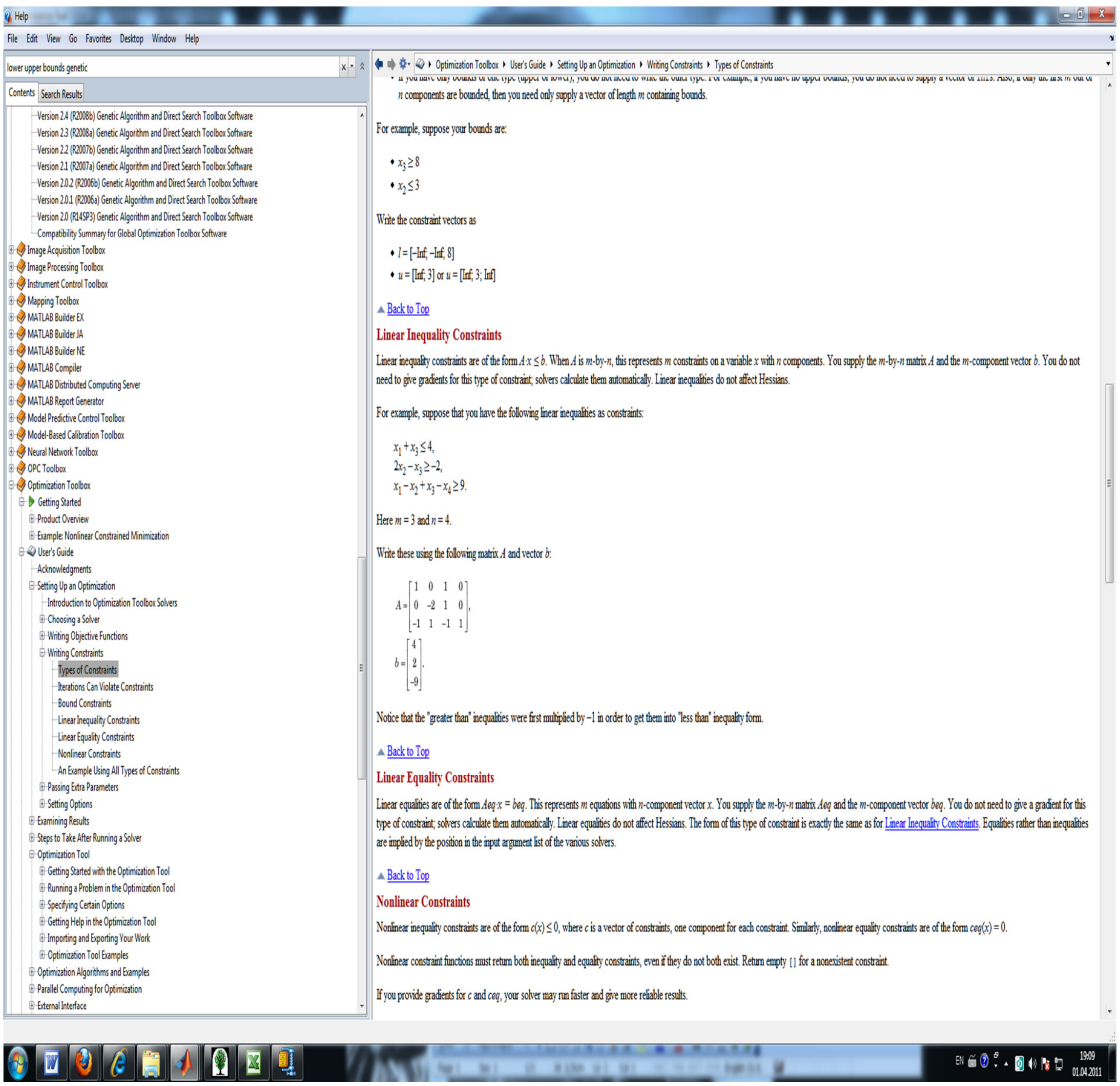


Appendix B:

Set up problem, analysis, and running on Math lab

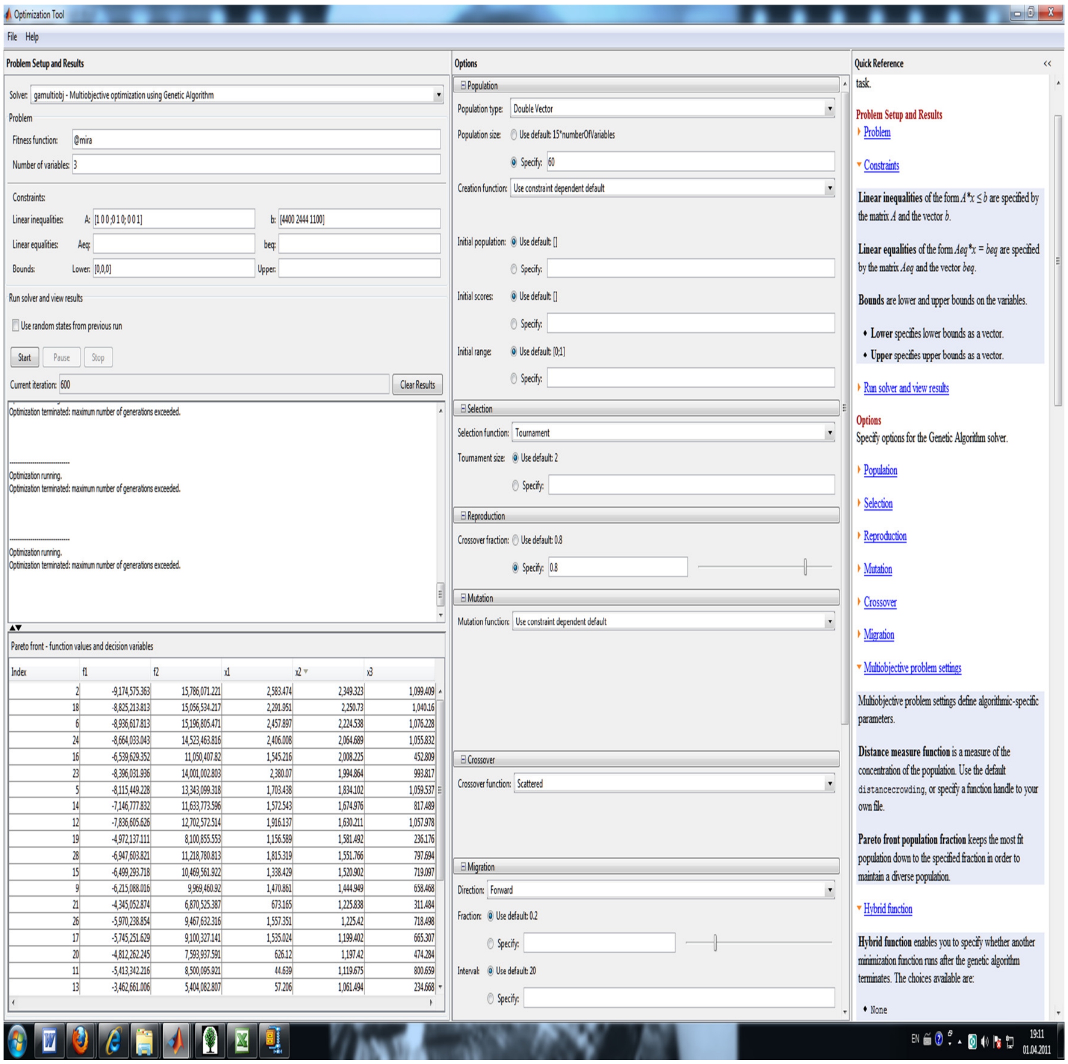
Appendix B:

```
Function f = galal(x)
%
f(1)= +0.024*x(1)^2 - 410*x(1) + 0.49*x(2)^2 - 3382.4*x(2) + 0.58*x(3)^2 -
3818.2*x(3) + 463066;
f(2)= -0.04*x(1)^2 + 686*x(1) - 0.18*x(2)^2 + 4298*x(2) - 0.87*x(3)^2 + 5984.5*x(3)
- 350975.4;
```



Appendix B:

Set up problem, analysis, and running on Math lab

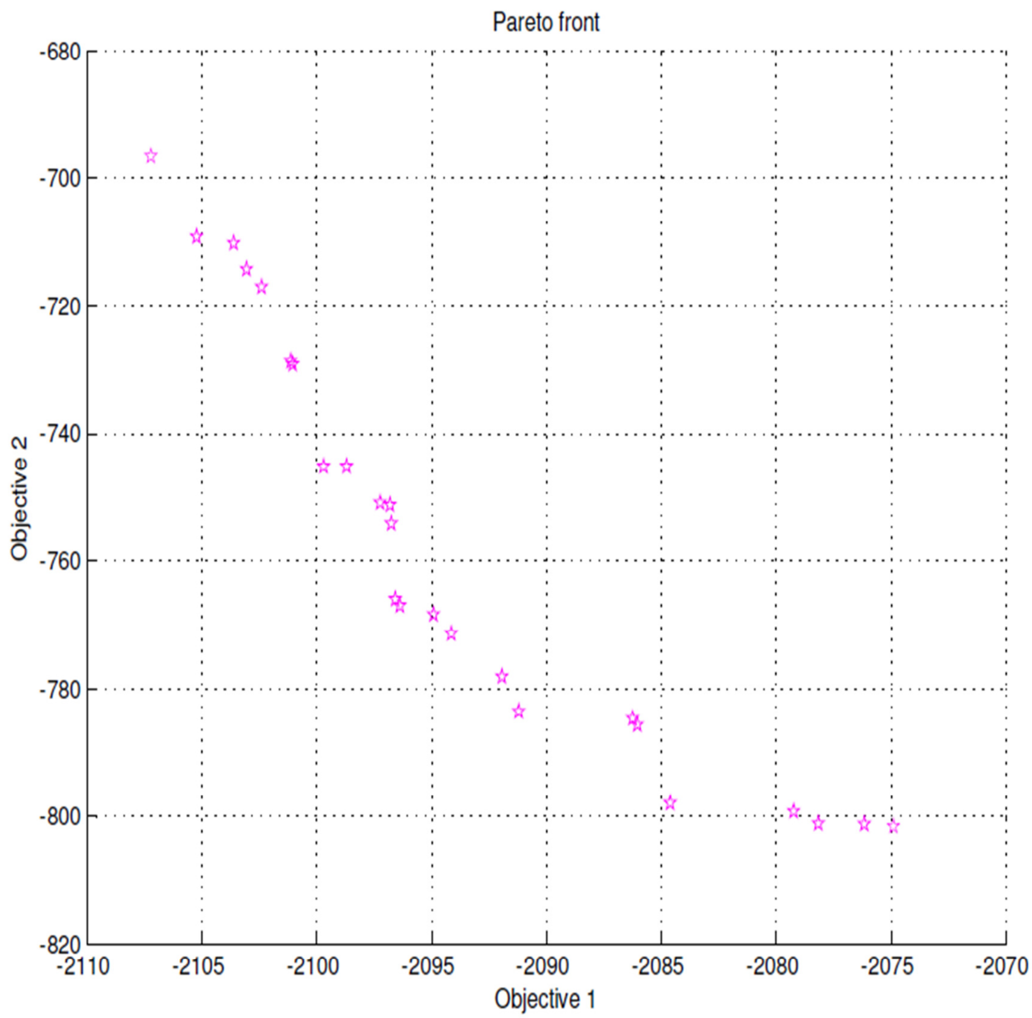


Appendix B:

Set up problem, analysis, and running on Math lab

- Set up problem, analysis, and running on Math lab

- Some of Math lab output solutions with deferent of weights, Population size, Population type, Selection Function, Crossover Function, Mutation Function, and Migration Direction.



Appendix B:

Set up problem, analysis, and running on Math lab

MATLAB Variable Editor: optimresults.x Page 1
Jan 4, 2012 7:15:13 AM

	1	2
1	8.2667	4.6346
2	8.2551	5.3816
3	8.2689	5.0570
4	8.2665	4.2859
5	8.2739	4.5321
6	8.2168	5.4719
7	8.2782	4.8577
8	8.2671	3.7728
9	8.2725	4.9475
10	8.2503	5.1767
11	8.2626	4.0994
12	8.2689	4.6787
13	8.2665	4.2781
14	8.2697	4.5363
15	8.2684	3.9701
16	8.2732	4.9000
17	8.2333	5.4210
18	8.2682	4.6276
19	8.2304	5.4531
20	8.2503	5.1923
21	8.2632	4.0550
22	8.2705	5.1413
23	8.2219	5.4625
24	8.2623	3.9918
25	8.2782	4.8733

Appendix B:

Set up problem, analysis, and running on Math lab

MATLAB Variable Editor: optimresults.fval — Page 1
Jan 4, 2012 — 7:15:51 AM

	1	2
1	-2.0968e+03	-751.1821
2	-2.0846e+03	-797.8930
3	-2.0919e+03	-778.0769
4	-2.1010e+03	-729.0713
5	-2.0997e+03	-745.0880
6	-2.0749e+03	-801.5006
7	-2.0966e+03	-765.9642
8	-2.1072e+03	-696.5767
9	-2.0941e+03	-771.3382
10	-2.0862e+03	-784.6400
11	-2.1024e+03	-717.0271
12	-2.0967e+03	-754.1024
13	-2.1011e+03	-728.5761
14	-2.0987e+03	-745.1185
15	-2.1052e+03	-709.1559
16	-2.0949e+03	-768.3654
17	-2.0792e+03	-799.1820
18	-2.0972e+03	-750.8239
19	-2.0782e+03	-801.0570
20	-2.0860e+03	-785.6304
21	-2.1030e+03	-714.2445
22	-2.0912e+03	-783.5148
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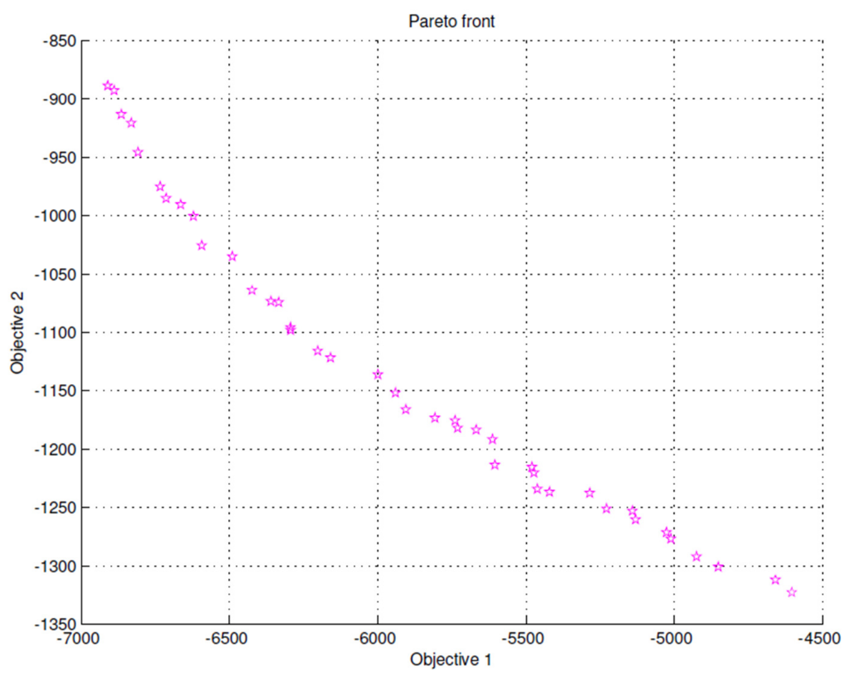
24	-2.1036e+03	-710.1976
25	-2.0964e+03	-766.9547



Appendix B:

Set up problem, analysis, and running on Math lab

MATLAB Variable Editor: optimresults.x | Page 1
Jan 4, 2012 | 7:23:58 AM

	1	2
1	17.1152	2.6636
2	16.9913	3.7148
3	17.0593	2.0474
4	16.9670	3.9881
5	17.0203	-0.4417
6	17.0544	0.4955
7	17.1166	2.3853
8	17.1049	2.3576
9	17.0707	0.6468
10	17.0307	0.7662
11	17.1015	3.4690
12	17.0194	4.3876
13	17.0828	1.8767
14	16.9615	6.0623
15	17.0468	3.6317
16	16.9277	5.9237
17	17.0154	5.6641
18	17.0952	1.2589
19	17.0179	-0.8356
20	17.0873	4.5988
21	17.0198	0.9323
22	17.1012	2.7660
23	17.1041	4.2089
24	16.9961	-0.3073
25	16.9942	4.3362
26	17.0226	3.7857
27	17.0179	-0.8356
28	17.0168	1.4750
29	17.0452	0.0441
30	16.9617	4.7222
31	17.0338	2.0828
32	17.0505	3.2923
33	17.0166	5.5257
34	16.9746	5.0638

MATLAB Variable Editor: optimresults.x | Page 2
Jan 4, 2012 | 7:23:58 AM

	1	2
35	16.9690	3.8575
36	17.0137	3.0673
37	16.9977	-0.7536
38	17.1094	4.5395
39	16.9836	5.3150
40	17.0023	4.8963
41	16.9319	4.9865
42	16.9572	5.2525

Appendix B:

Set up problem, analysis, and running on Math lab

MATLAB Variable Editor: optimresults.fval — Page 1
Jan 4, 2012 — 7:25:23 AM

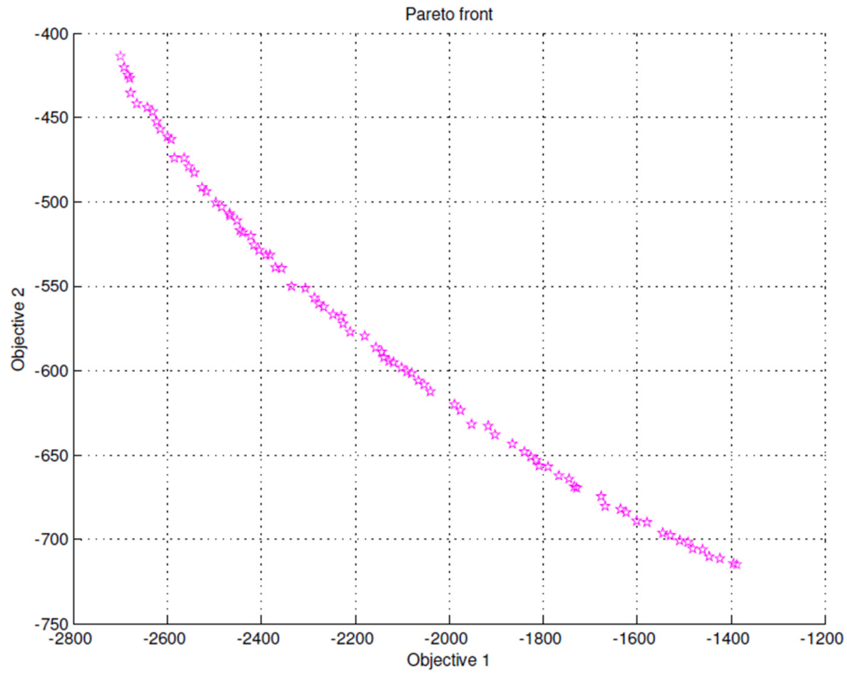
	1	2
1	-6.2021e+03	-1.1158e+03
2	-5.7392e+03	-1.1756e+03
3	-6.3596e+03	-1.0737e+03
4	-5.6123e+03	-1.1916e+03
5	-6.8644e+03	-913.7326
6	-6.7334e+03	-975.0281
7	-6.2930e+03	-1.0983e+03
8	-6.2943e+03	-1.0959e+03
9	-6.7137e+03	-985.5236
10	-6.6640e+03	-990.8775
11	-5.9047e+03	-1.1661e+03
12	-5.4729e+03	-1.2198e+03
13	-6.4235e+03	-1.0642e+03
14	-4.6032e+03	-1.3228e+03
15	-5.8070e+03	-1.1734e+03
16	-4.6580e+03	-1.3121e+03
17	-4.8514e+03	-1.3005e+03
18	-6.5930e+03	-1.0257e+03
19	-6.9100e+03	-888.6269
20	-5.4202e+03	-1.2370e+03
21	-6.6214e+03	-1.0008e+03
22	-6.1589e+03	-1.1215e+03
23	-5.6042e+03	-1.2132e+03
24	-6.8309e+03	-920.9152
25	-5.4798e+03	-1.2152e+03
26	-5.7303e+03	-1.1818e+03
27	-6.9100e+03	-888.6269
28	-6.4901e+03	-1.0350e+03
29	-6.8081e+03	-945.9059
30	-5.2847e+03	-1.2378e+03
31	-6.3333e+03	-1.0745e+03
32	-5.9397e+03	-1.1521e+03
33	-4.9243e+03	-1.2918e+03
34	-5.1301e+03	-1.2602e+03

MATLAB Variable Editor: optimresults.fval — Page 2
Jan 4, 2012 — 7:25:23 AM

	1	2
35	-5.6676e+03	-1.1834e+03
36	-5.9990e+03	-1.1358e+03
37	-6.8885e+03	-892.7135
38	-5.4611e+03	-1.2344e+03
39	-5.0113e+03	-1.2766e+03
40	-5.2281e+03	-1.2511e+03
41	-5.1409e+03	-1.2529e+03
42	-5.0262e+03	-1.2712e+03

Appendix B:

Set up problem, analysis, and running on Math lab



MATLAB Variable Editor: optimresults.x — Page 1
Jan 4, 2012 — 7:32:34 AM

	1	2
1	8.3283	-0.6427
2	8.3106	2.7295
3	8.3261	2.1672
4	8.3305	2.7925
5	8.3265	1.4274
6	8.3162	2.2265
7	8.2956	3.7633
8	8.3239	2.0223
9	8.2533	4.0708
10	8.3181	0.0397
11	8.3485	1.0505
12	8.3124	3.2194
13	8.3123	1.7023
14	8.3266	0.9387
15	8.3278	-0.1324
16	8.3400	1.1009
17	8.3411	1.5588
18	8.3348	1.6645
19	8.3172	3.1010
20	8.3409	3.0719
21	8.2585	4.0579
22	8.3484	1.0019
23	8.3276	0.7291
24	8.3255	1.9803
25	8.2989	3.8829
26	8.3442	0.6130
27	8.3270	0.3432
28	8.3169	-0.2146
29	8.3348	0.6605
30	8.3224	0.7972
31	8.3410	2.0577
32	8.3252	0.0101
33	8.3292	-0.5717
34	8.3313	2.1148

MATLAB Variable Editor: optimresults.x — Page 2

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	1	2
35	8.3263	2.5683
36	8.3094	3.5066
37	8.2708	3.9997
38	8.3381	3.2735
39	8.3214	3.6053
40	8.3283	2.2883
41	8.3250	1.1154
42	8.2976	3.6402
43	8.3183	-0.7369
44	8.3030	3.3935
45	8.3333	1.2335
46	8.3388	2.3813
47	8.2944	3.8120
48	8.2778	3.8406
49	8.3128	1.8834
50	8.3451	0.8890
51	8.3222	3.0345
52	8.3323	1.5105
53	8.3190	2.5204
54	8.3482	0.8667
55	8.3056	3.7318
56	8.3188	2.9609
57	8.3536	1.2057
58	8.3175	2.8874
59	8.3371	1.7477
60	8.3217	3.0033
61	8.3220	0.2125
62	8.3393	2.0933
63	8.3334	0.7427
64	8.3245	2.2040
65	8.3295	0.2844
66	8.3291	2.3277
67	8.3343	-0.0673
68	8.3447	0.5090

Appendix B:

Set up problem, analysis, and running on Math lab

MATLAB Variable Editor: optimresults.fval Page 1
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	1	2
1	-2.6920e+03	-420.0672
2	-1.9168e+03	-632.8519
3	-2.1013e+03	-598.0594
4	-1.9022e+03	-637.9451
5	-2.3061e+03	-551.1892
6	-2.0799e+03	-601.2725
7	-1.5290e+03	-697.5517
8	-2.1434e+03	-588.7527
9	-1.3876e+03	-714.7030
10	-2.5921e+03	-462.7524
11	-2.4043e+03	-528.5150
12	-1.7447e+03	-664.0028
13	-2.2294e+03	-567.8282
14	-2.4220e+03	-520.2176
15	-2.6225e+03	-452.3847
16	-2.3898e+03	-531.2352
17	-2.2773e+03	-560.3296
18	-2.2472e+03	-566.6790
19	-1.7895e+03	-656.7652
20	-1.8080e+03	-656.2284
21	-1.3948e+03	-714.1748
22	-2.4153e+03	-525.4259
23	-2.4674e+03	-506.9829
24	-2.1561e+03	-586.1820
25	-1.4814e+03	-705.3183
26	-2.4967e+03	-500.5460
27	-2.5425e+03	-482.4889
28	-2.6311e+03	-446.5675
29	-2.4839e+03	-503.0340
30	-2.4513e+03	-511.0081
31	-2.1389e+03	-591.9443
32	-2.5993e+03	-461.2681
33	-2.6837e+03	-424.6163
34	-2.1187e+03	-595.0265

MATLAB Variable Editor: optimresults.fval — Page 2
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	1	2
35	-1.9756e+03	-623.4977
36	-1.6352e+03	-682.0404
37	-1.4234e+03	-711.1691
38	-1.7334e+03	-668.8585
39	-1.6007e+03	-688.9641
40	-2.0652e+03	-605.8592
41	-2.3813e+03	-531.3283
42	-1.5789e+03	-689.8571
43	-2.6996e+03	-413.5396
44	-1.6763e+03	-674.5181
45	-2.3563e+03	-539.2741
46	-2.0398e+03	-612.3396
47	-1.5089e+03	-700.5719
48	-1.4916e+03	-701.4640
49	-2.1794e+03	-579.3322
50	-2.4392e+03	-518.0858
51	-1.8150e+03	-652.8289
52	-2.2869e+03	-556.7737
53	-1.9887e+03	-620.0601
54	-2.4452e+03	-516.8447
55	-1.5451e+03	-696.1040
56	-1.8399e+03	-647.9721
57	-2.3698e+03	-538.6334
58	-1.8651e+03	-643.2408
59	-2.2254e+03	-572.0770
60	-1.8259e+03	-650.8212
61	-2.5642e+03	-473.9306
62	-2.1278e+03	-594.1086
63	-2.4665e+03	-508.1668
64	-2.0896e+03	-600.3033
65	-2.5540e+03	-478.8986
66	-2.0532e+03	-608.4012
67	-2.6147e+03	-456.8679
68	-2.5174e+03	-493.9769

Appendix B:

Set up problem, analysis, and running on Math lab

MATLAB Variable Editor: optimresults.fval — Page 3
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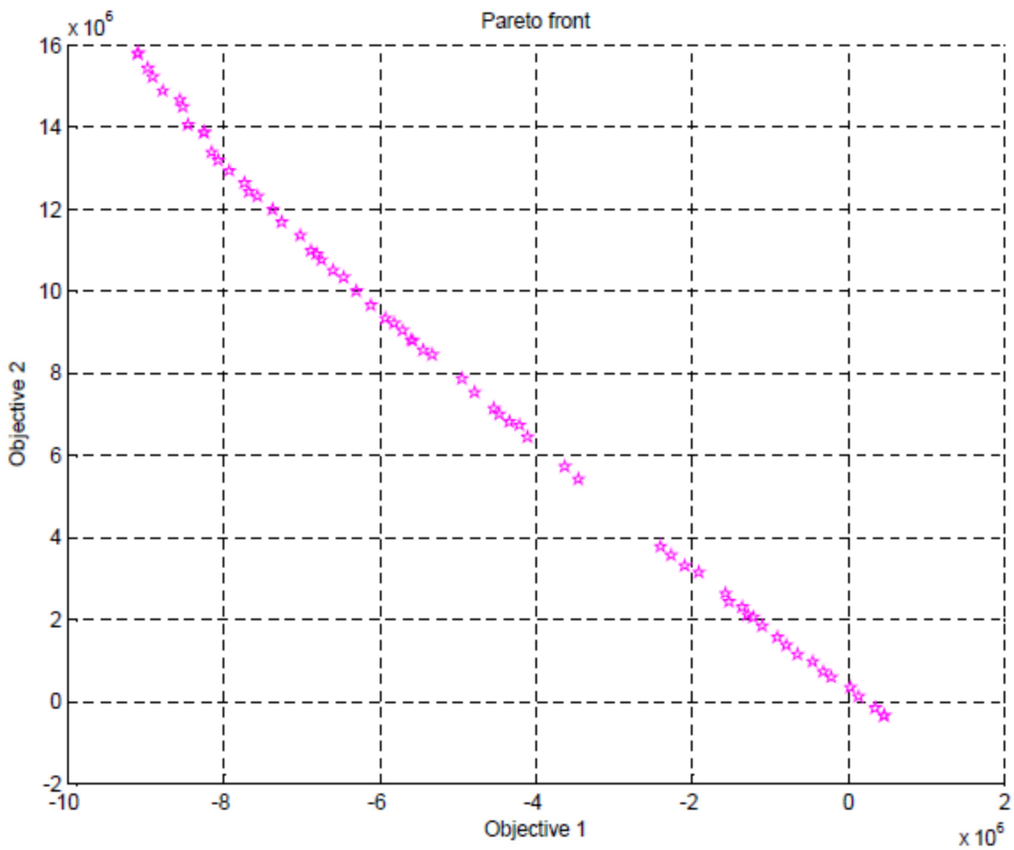
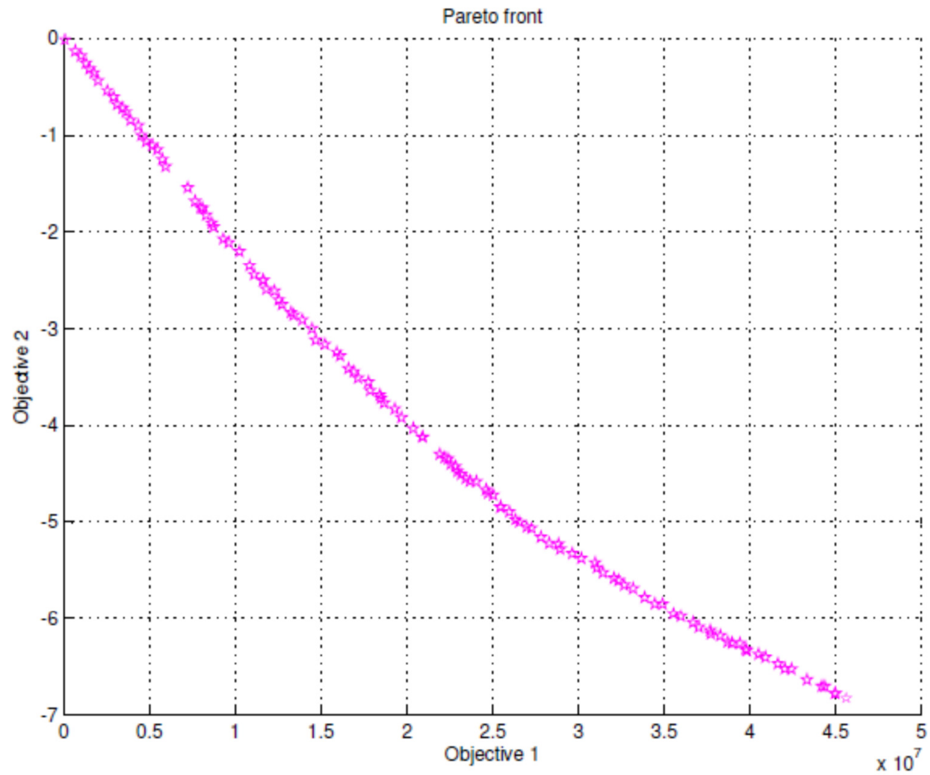
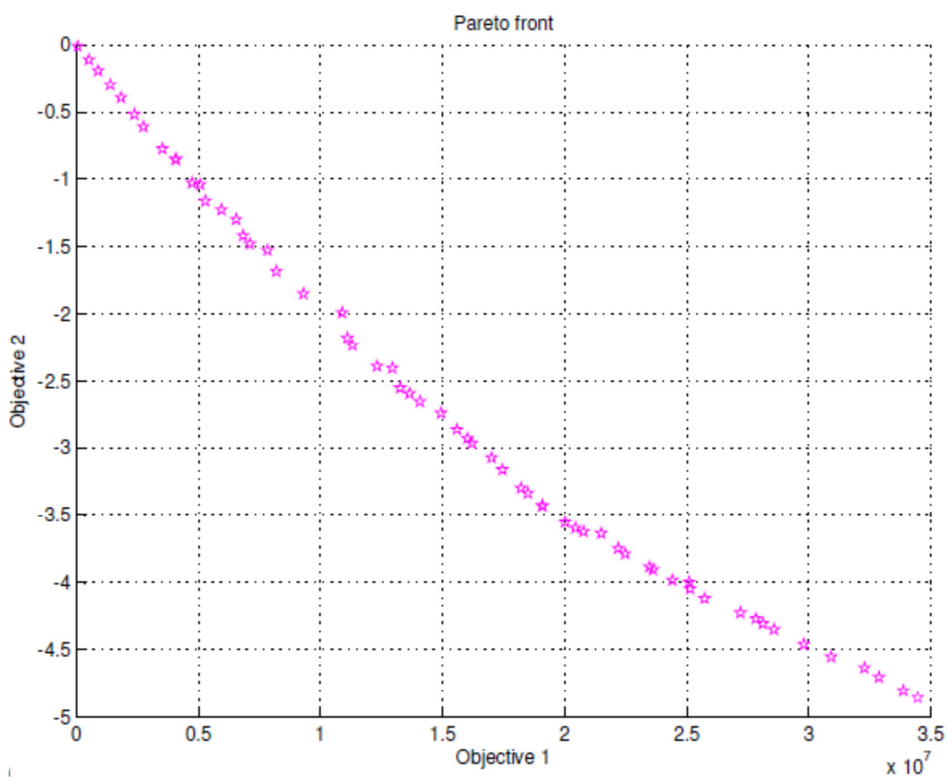
	1	2
69	-2.5256e+03	-491.3963
70	-1.4606e+03	-705.8889
71	-2.2104e+03	-576.9425
72	-1.6230e+03	-684.0214
73	-2.6646e+03	-441.7549
74	-1.4463e+03	-709.9821
75	-1.7283e+03	-669.5201
76	-2.2670e+03	-562.3516
77	-2.6422e+03	-444.1059
78	-1.7664e+03	-662.0428
79	-2.3351e+03	-550.0375
80	-2.6780e+03	-435.5246
81	-1.9521e+03	-631.7382
82	-2.6798e+03	-426.5972
83	-2.5846e+03	-473.7886
84	-1.6676e+03	-680.2949



Appendix B:

Set up problem, analysis, and running on Math lab





Appendix B:

Set up problem, analysis, and running on Math lab

MATLAB Variable Editor: optimresults.fval　　　Page 1
Apr 13, 2011　　　11:29:33 AM

	1	2
1	3.4471e+07	-4.8601
2	6.1692e+04	-0.0092
3	3.2288e+07	-4.6366
4	2.5105e+07	-3.9963
5	2.7833e+07	-4.2712
6	1.3655e+07	-2.5922
7	8.2009e+06	-1.6857
8	2.8575e+07	-4.3515
9	2.0775e+07	-3.6231
10	8.9553e+05	-0.1907
11	2.7501e+06	-0.6071
12	1.0893e+07	-1.9917
13	2.7208e+07	-4.2281
14	1.1107e+07	-2.1785
15	1.9093e+07	-3.4301
16	1.4013e+06	-0.2974
17	5.1962e+05	-0.1087
18	7.1205e+06	-1.4782
19	1.7013e+07	-3.0735
20	2.3847e+06	-0.5178
21	2.4417e+07	-3.9815
22	2.9799e+07	-4.4609
23	6.8321e+06	-1.4166
24	9.3121e+06	-1.8523
25	2.1500e+07	-3.6381
26	1.2318e+07	-2.3897
27	5.9552e+06	-1.2268
28	1.6027e+07	-2.9298
29	7.8297e+06	-1.5262
30	6.5511e+06	-1.2977
31	1.8416e+06	-0.3927
32	1.9093e+07	-3.4301
33	3.5333e+06	-0.7689
34	6.1692e+04	-0.0092
35	1.8220e+07	-3.2977
36	1.7458e+07	-3.1613
37	5.2880e+06	-1.1618

MATLAB Variable Editor: optimresults.fval | Page 2
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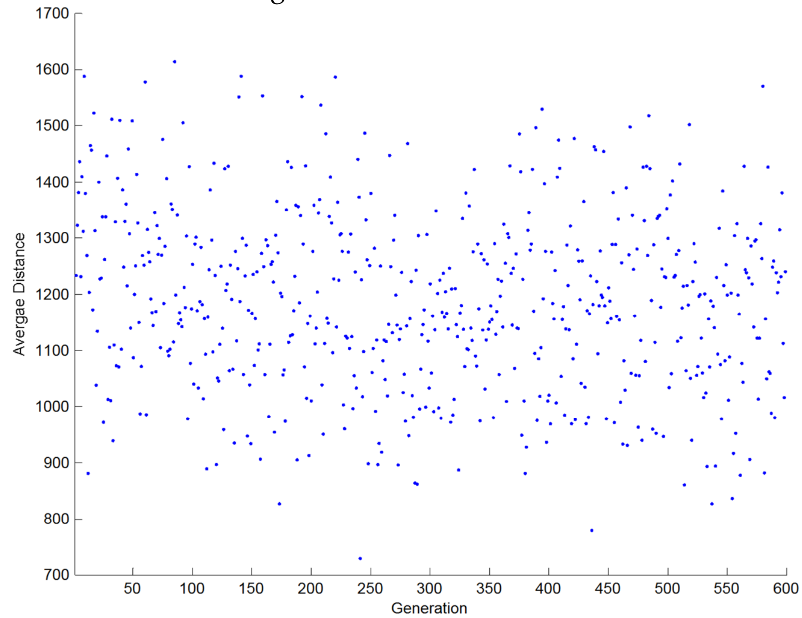
	1	2
38	1.5591e+07	-2.8616
39	4.0779e+06	-0.8482
40	1.3267e+07	-2.5526
41	2.3632e+07	-3.9057
42	4.7446e+06	-1.0262
43	3.0921e+07	-4.5549
44	2.2196e+07	-3.7482
45	1.1313e+07	-2.2339
46	2.2483e+07	-3.7883
47	1.4945e+07	-2.7382
48	2.5141e+07	-4.0445
49	2.0448e+07	-3.5960
50	2.5740e+07	-4.1184
51	3.3875e+07	-4.8067
52	5.0788e+06	-1.0390
53	3.2880e+07	-4.7055
54	2.3479e+07	-3.8847
55	1.8500e+07	-3.3351
56	2.8130e+07	-4.3066
57	1.4078e+07	-2.6522
58	1.2951e+07	-2.4036
59	1.6209e+07	-2.9669
60	2.0024e+07	-3.5544
61	4.0779e+06	-0.8482
62	6.1868e+04	-0.0093
63	3.4471e+07	-4.8601

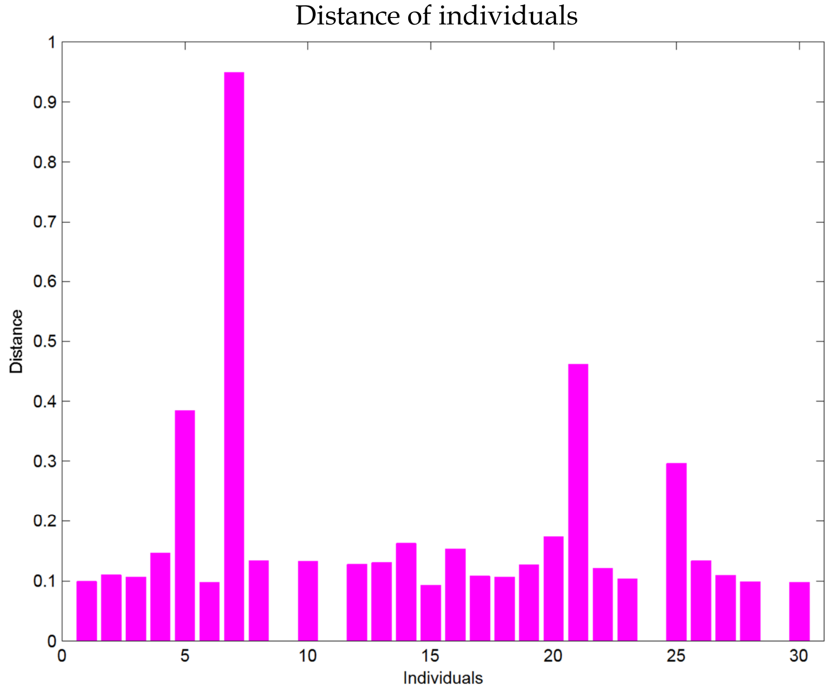
Appendix B:

Set up problem, analysis, and running on Math lab

Average Distance between Individuals

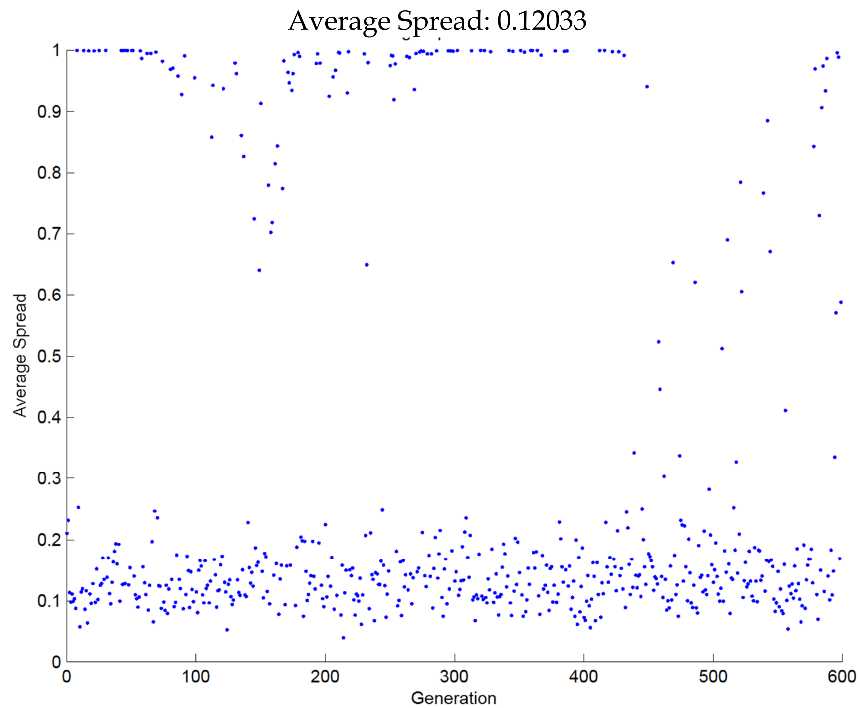


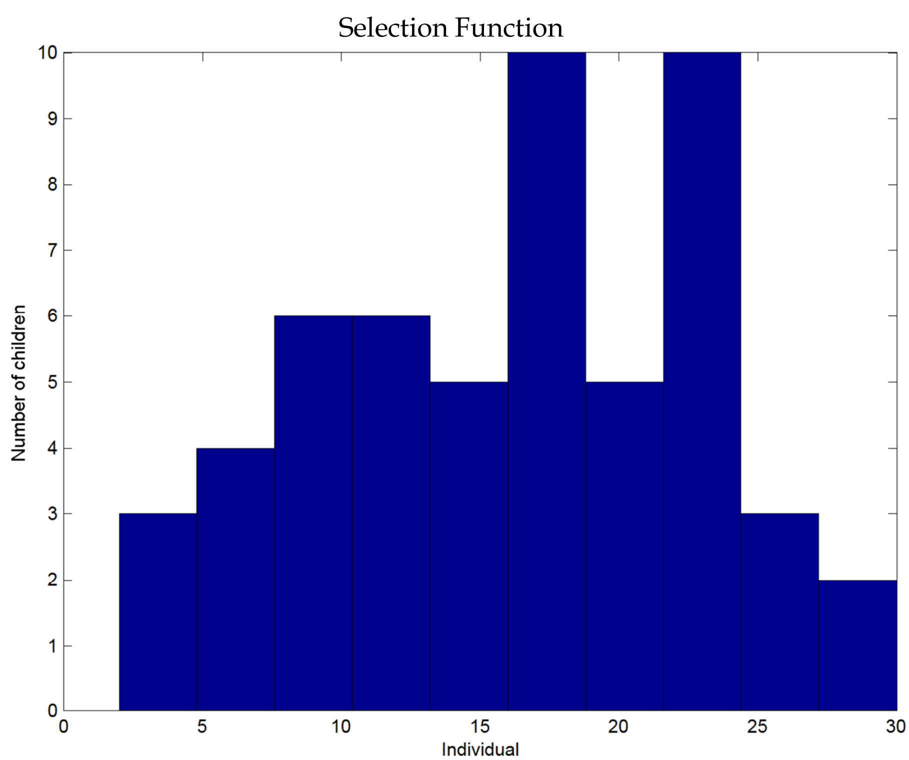
Distance of individuals



Appendix B:

Set up problem, analysis, and running on Math lab

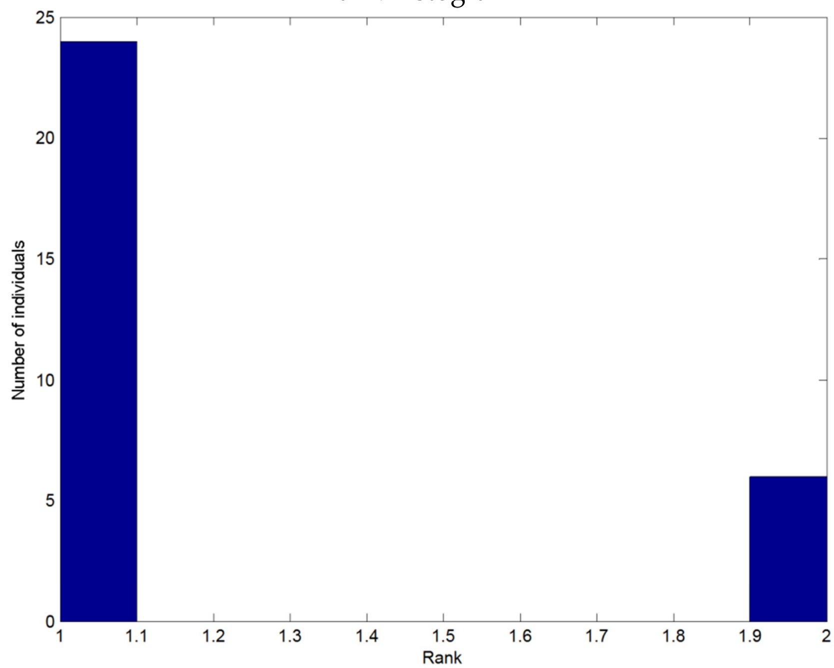




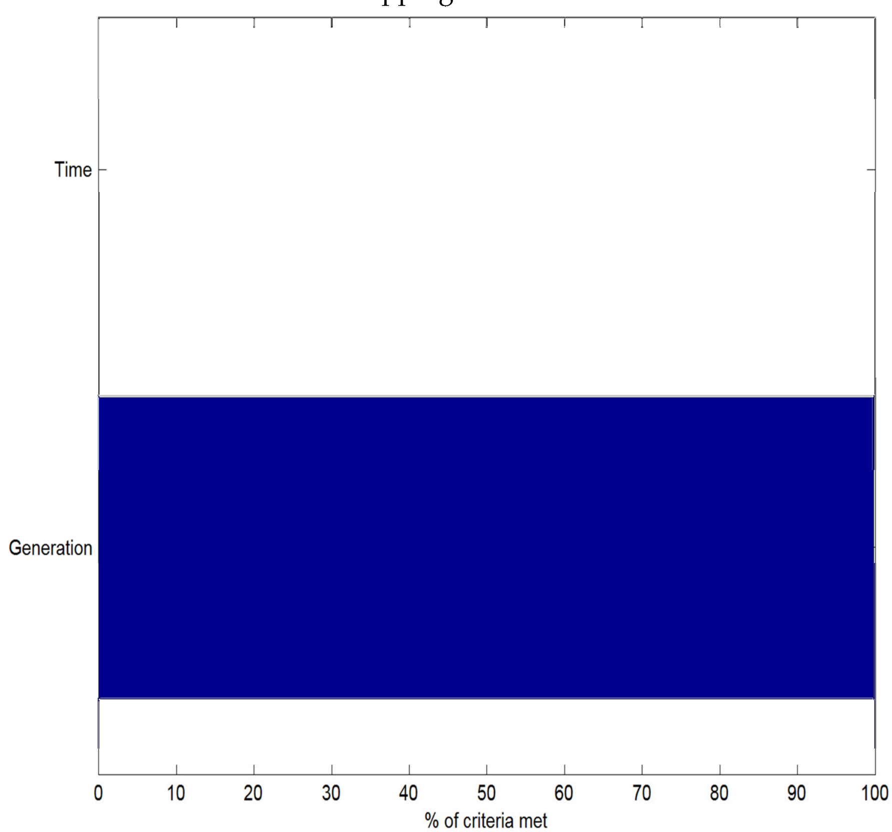
Appendix B:

Set up problem, analysis, and running on Math lab

Rank histogram



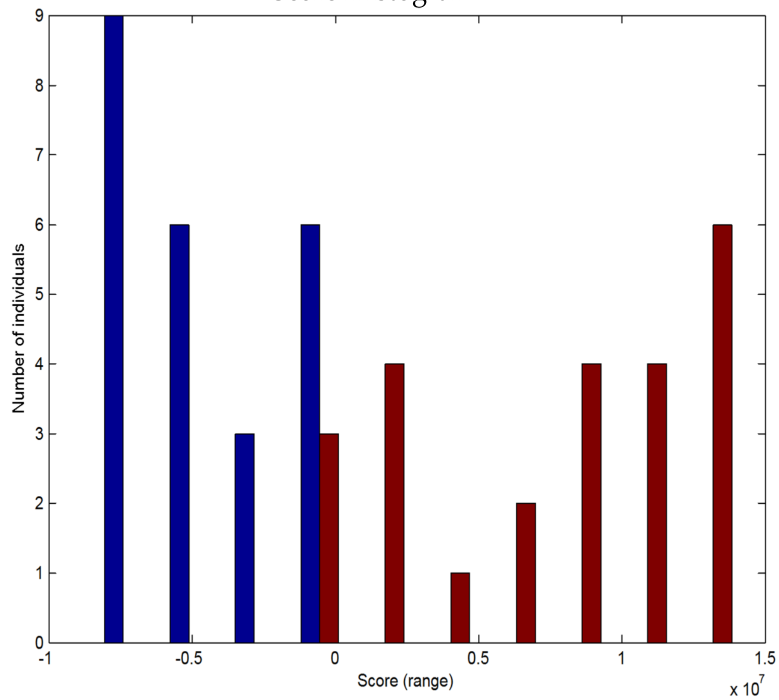
Stopping Criteria



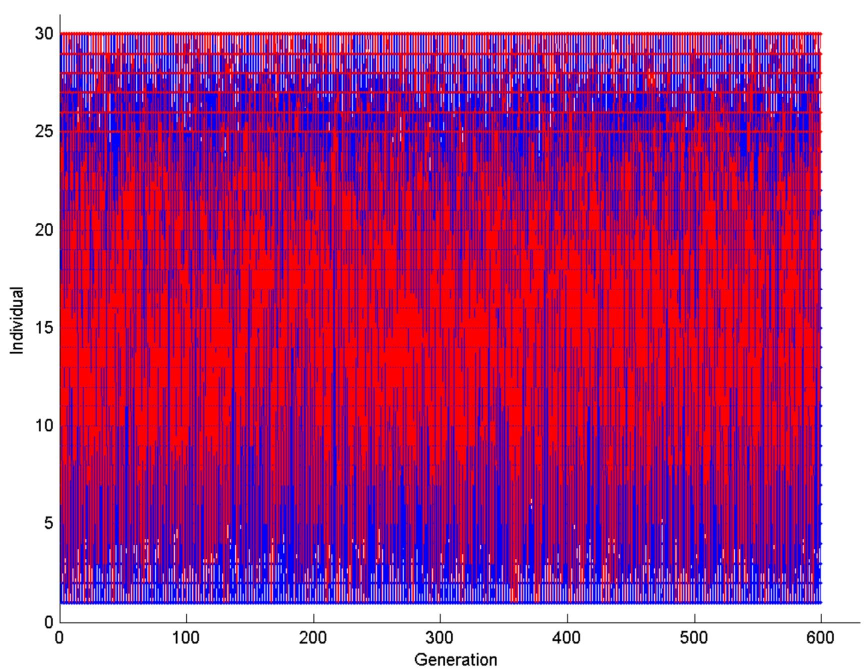
Appendix B:

Set up problem, analysis, and running on Math lab

Score Histogram



Genealogy



Appendix B:

Set up problem, analysis, and running on Math lab

M-Code

6/29/11 10:27 PM C:\Documents and Settings\Jalal\Desktop\Untitled

```
function createlegend(axes1)
%CREATELEGEND(AXES1)
%  AXES1:  legend axes

%  Auto-generated by MATLAB on 29-Jun-2011 22:00:53

% Create legend
legend(axes1,'show');
```

M-File

6/29/11 10:28 PM C:\Documents and Settings\Jalal\Desktop\paper 2011.m 1 of 1

```
function [x,fval,exitflag,output,population,score] = paper 2011(nvars,Aineq,bineq,lb, ↙
PopulationSize_Data)
% This is an auto generated M-file from Optimization Tool.

% Start with the default options
options = gaoptimset;
% Modify options setting
options = gaoptimset(options,'PopulationSize' ,PopulationSize_Data);
options = gaoptimset(options,'Display' ,'iter');
options = gaoptimset(options,'PlotFcns' ,{  @gaplotdistance @gaplotgenealogy↙
@gaplotscorediversity @gaplotselection @gaplotstopping @gaplotparetodistance↙
@gaplotrankhist @gaplotspread });
options = gaoptimset(options,'OutputFcns' ,{ [] });
[x,fval,exitflag,output,population,score] = ...
gamultiobj(@mira1,nvars,Aineq,bineq,[],[],lb,[],options);
```

Appendix B:

Set up problem, analysis, and running on Math lab

MATLAB Command Window

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Generation	f-count	Average Pareto distance	Average Pareto sprea
1	61	0.101374	0.210985
2	91	0.113572	0.232104
3	121	0.058804	0.114176
4	151	0.035767	0.0986907
5	181	0.0365558	0.111719
6	211	0.0313276	0.0998855
7	241	0.0283997	0.103793
8	271	0.023425	0.0885069
9	301	0.0329823	0.999694
10	331	0.0998216	0.253214
11	361	0.0173604	0.0585488
12	391	0.032111	0.115198
13	421	0.0326812	0.120144
14	451	0.0322768	0.999536
15	481	0.0324388	0.0870424
16	511	0.0406513	0.117058
17	541	0.019158	0.06458
18	571	0.027668	0.999304
19	601	0.0308331	0.111138
20	631	0.0278383	0.0963975
21	661	0.0392368	0.128785
22	691	0.0484361	0.999107
23	721	0.0310713	0.0976713
24	751	0.0435248	0.152616
25	781	0.026806	0.102261
26	811	0.0361258	0.999693
27	841	0.0284486	0.125473
28	871	0.0271417	0.128653
29	901	0.0403611	0.170803
30	931	0.0316524	0.135589

Generation	f-count	Average Pareto distance	Average Pareto sprea
31	961	0.0431588	0.999911
32	991	0.0300032	0.138825
33	1021	0.0438522	0.170819
34	1051	0.0277881	0.11192
35	1081	0.0222232	0.0954457
36	1111	0.0320353	0.130444
37	1141	0.0474776	0.164187
38	1171	0.0478776	0.18146
39	1201	0.0506751	0.193939
40	1231	0.0465706	0.160625
41	1261	0.0644956	0.193548
42	1291	0.0369492	0.100062
43	1321	0.0317116	0.999402
44	1351	0.0429435	0.127258
45	1381	0.0325566	0.999816
46	1411	0.0369657	0.128576
47	1441	0.0507646	0.999651
48	1471	0.0721176	0.999581
49	1501	0.0384777	0.126154
50	1531	0.040633	0.154646

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51	1561	0.024128	0.999856
52	1591	0.0289065	0.999535
53	1621	0.038431	0.140755
54	1651	0.0344862	0.110338
55	1681	0.0357291	0.103975
56	1711	0.026636	0.0905829
57	1741	0.0326563	0.106915
58	1771	0.0410947	0.999117
59	1801	0.0297105	0.986878
60	1831	0.056811	0.156066

Generation	f-count	Average Pareto distance	Average Pareto sprea
61	1861	0.0404605	0.129844
62	1891	0.0362531	0.110521
63	1921	0.0445343	0.994737
64	1951	0.0257733	0.0854576
65	1981	0.0395453	0.125477
66	2011	0.0481422	0.995135
67	2041	0.0646013	0.197018
68	2071	0.0202072	0.0667566
69	2101	0.0884923	0.247351
70	2131	0.0857987	0.996815
71	2161	0.0826655	0.236424
72	2191	0.0330412	0.12514
73	2221	0.0391957	0.124218
74	2251	0.0278173	0.088068
75	2281	0.0424652	0.981831
76	2311	0.0284689	0.0987272
77	2341	0.0263896	0.0846861
78	2371	0.0409863	0.126021
79	2401	0.0290184	0.0803174
80	2431	0.0482341	0.11971
81	2461	0.0624762	0.968984
82	2491	0.0443774	0.135349
83	2521	0.0467242	0.971235
84	2551	0.0329337	0.0912586
85	2581	0.0304785	0.097505
86	2611	0.0556165	0.175409
87	2641	0.0239676	0.958014
88	2671	0.0334995	0.135141
89	2701	0.0400358	0.120632
90	2731	0.0304025	0.927901

Generation	f-count	Average Pareto distance	Average Pareto sprea
91	2761	0.0239239	0.0874397
92	2791	0.0286534	0.990894
93	2821	0.0362545	0.110694
94	2851	0.0566962	0.173625
95	2881	0.0518574	0.149436
96	2911	0.0240553	0.0896079
97	2941	0.0476017	0.147524
98	2971	0.0356226	0.11878
99	3001	0.0281526	0.0990187
100	3031	0.0506022	0.955472

Appendix B:

Set up problem, analysis, and running on Math lab

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101	3061	0.0371936	0.114535
102	3091	0.02799	0.0812464
103	3121	0.0465871	0.150079
104	3151	0.0438772	0.16566
105	3181	0.0432402	0.156946
106	3211	0.0290514	0.1101
107	3241	0.025944	0.0968445
108	3271	0.0436704	0.165922
109	3301	0.0331202	0.120073
110	3331	0.027746	0.126099
111	3361	0.0213902	0.0972997
112	3391	0.0327344	0.132697
113	3421	0.0390179	0.858014
114	3451	0.0334361	0.943007
115	3481	0.041077	0.168332
116	3511	0.0318913	0.14268
117	3541	0.0226373	0.0901261
118	3571	0.0311268	0.116657
119	3601	0.0296282	0.118107
120	3631	0.0457561	0.159301

Generation	f-count	Average Pareto distance	Average Pareto sprea
121	3661	0.0528662	0.173802
122	3691	0.0574742	0.937339
123	3721	0.0338657	0.130825
124	3751	0.0283565	0.114967
125	3781	0.0137911	0.0535517
126	3811	0.0397313	0.127329
127	3841	0.0387736	0.134745
128	3871	0.0403639	0.107657
129	3901	0.0323106	0.094477
130	3931	0.0391218	0.101738
131	3961	0.0495452	0.97927
132	3991	0.0326273	0.962207
133	4021	0.0475276	0.13472
134	4051	0.0354834	0.114265
135	4081	0.0267465	0.109092
136	4111	0.0386698	0.860515
137	4141	0.0465947	0.151297
138	4171	0.0444344	0.82652
139	4201	0.0314958	0.11005
140	4231	0.0292806	0.107612
141	4261	0.0707823	0.228964
142	4291	0.0549802	0.154468
143	4321	0.0365234	0.129059
144	4351	0.0413527	0.146585
145	4381	0.033138	0.124722
146	4411	0.055972	0.724403
147	4441	0.0582439	0.186924
148	4471	0.0497057	0.157669
149	4501	0.0540623	0.163591
150	4531	0.0457168	0.641037

Generation	f-count	Average Pareto distance	Average Pareto sprea

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151	4561	0.0374139	0.913733
152	4591	0.0424054	0.148353
153	4621	0.033957	0.105177
154	4651	0.0601238	0.17842
155	4681	0.0539148	0.172891
156	4711	0.0321063	0.115478
157	4741	0.0337895	0.77989
158	4771	0.0284651	0.0956389
159	4801	0.0556738	0.702152
160	4831	0.0528648	0.718177
161	4861	0.0392313	0.141884
162	4891	0.0503523	0.814957
163	4921	0.0561953	0.161329
164	4951	0.0294816	0.843845
165	4981	0.026061	0.0787049
166	5011	0.0432741	0.13576
167	5041	0.053055	0.158719
168	5071	0.0450587	0.774877
169	5101	0.0869386	0.98288
170	5131	0.0320499	0.0944111
171	5161	0.056169	0.157013
172	5191	0.0484525	0.96394
173	5221	0.0383508	0.947419
174	5251	0.0592215	0.158535
175	5281	0.0268483	0.934853
176	5311	0.0324692	0.961942
177	5341	0.0388235	0.99285
178	5371	0.0271923	0.093157
179	5401	0.0572462	0.188484
180	5431	0.0372844	0.996019

Generation	f-count	Average Pareto distance	Average Pareto sprea
181	5461	0.035728	0.990248
182	5491	0.0545234	0.205043
183	5521	0.0538646	0.198957
184	5551	0.0200048	0.0751747
185	5581	0.0513553	0.198161
186	5611	0.0426365	0.148364
187	5641	0.028475	0.101207
188	5671	0.033231	0.110611
189	5701	0.0374525	0.128948
190	5731	0.0427728	0.141716
191	5761	0.0601251	0.198319
192	5791	0.0458265	0.139925
193	5821	0.0382455	0.119322
194	5851	0.0348548	0.978421
195	5881	0.0388886	0.994044
196	5911	0.0557784	0.194961
197	5941	0.0451828	0.979199
198	5971	0.0316811	0.125614
199	6001	0.0372071	0.103751
200	6031	0.0350763	0.0910559
201	6061	0.0855668	0.225039
202	6091	0.0384339	0.106397
203	6121	0.0426308	0.139784

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204	6151	0.0452683	0.92544
205	6181	0.0380698	0.124382
206	6211	0.0507065	0.171227
207	6241	0.0296906	0.956767
208	6271	0.0266827	0.0871546
209	6301	0.0428274	0.967569
210	6331	0.0270759	0.109334

Generation	f-count	Average Pareto distance	Average Pareto spre.
211	6361	0.0336209	0.99617
212	6391	0.026688	0.995786
213	6421	0.026155	0.0772344
214	6451	0.0493109	0.158193
215	6481	0.0108301	0.0406587
216	6511	0.0367635	0.113725
217	6541	0.0536563	0.150603
218	6571	0.0332368	0.931132
219	6601	0.0514214	0.997431
220	6631	0.0461023	0.151234
221	6661	0.0491333	0.141731
222	6691	0.0611667	0.153866
223	6721	0.0377558	0.101686
224	6751	0.0267808	0.0774561
225	6781	0.0368898	0.111134
226	6811	0.0400835	0.10858
227	6841	0.0326999	0.0996819
228	6871	0.0407053	0.137642
229	6901	0.0184395	0.0623679
230	6931	0.030504	0.110397
231	6961	0.0342467	0.994222
232	6991	0.0753258	0.207287
233	7021	0.0518814	0.649974
234	7051	0.0484496	0.97974
235	7081	0.0272877	0.0878674
236	7111	0.074462	0.211518
237	7141	0.0454583	0.142725
238	7171	0.0362004	0.135037
239	7201	0.0170536	0.0684645
240	7231	0.0425079	0.145995

Generation	f-count	Average Pareto distance	Average Pareto spre.
241	7261	0.0442305	0.143942
242	7291	0.0358514	0.12714
243	7321	0.0427853	0.126848
244	7351	0.049307	0.165039
245	7381	0.0665664	0.249419
246	7411	0.0430432	0.158691
247	7441	0.0343972	0.12503
248	7471	0.0202731	0.0739003
249	7501	0.037127	0.111317
250	7531	0.0412255	0.148915
251	7561	0.0262003	0.974847
252	7591	0.0327118	0.991525
253	7621	0.0218738	0.990728

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254	7651	0.0443153	0.920204
255	7681	0.0304722	0.977653
256	7711	0.0564592	0.181773
257	7741	0.0320275	0.0922944
258	7771	0.031901	0.10129
259	7801	0.0498732	0.163745
260	7831	0.0204782	0.0769302
261	7861	0.0443019	0.166242
262	7891	0.0343771	0.123287
263	7921	0.0455906	0.142515
264	7951	0.0196125	0.990394
265	7981	0.0331835	0.118406
266	8011	0.049313	0.987757
267	8041	0.0415198	0.144478
268	8071	0.0323748	0.0957857
269	8101	0.0354244	0.138366
270	8131	0.0348276	0.936544

Generation	f-count	Average Pareto distance	Average Pareto sprea
271	8161	0.0229258	0.994923
272	8191	0.0508434	0.147696
273	8221	0.0442522	0.153582
274	8251	0.0479316	0.996915
275	8281	0.0347349	0.998729
276	8311	0.0532191	0.212222
277	8341	0.0330204	0.998557
278	8371	0.0352896	0.14115
279	8401	0.0308119	0.124004
280	8431	0.0491152	0.994371
281	8461	0.0470871	0.174696
282	8491	0.0394192	0.140365
283	8521	0.025931	0.993985
284	8551	0.0237161	0.0890044
285	8581	0.039035	0.153085
286	8611	0.0658969	0.204216
287	8641	0.0471772	0.998736
288	8671	0.0367457	0.13749
289	8701	0.0505201	0.177389
290	8731	0.0579416	0.215541
291	8761	0.0312695	0.105685
292	8791	0.0223174	0.074987
293	8821	0.0518112	0.152462
294	8851	0.0538889	0.168999
295	8881	0.0262694	0.0960003
296	8911	0.0310273	0.999052
297	8941	0.0285185	0.119336
298	8971	0.0279527	0.999081
299	9001	0.0437491	0.182513
300	9031	0.0545393	0.99834

Generation	f-count	Average Pareto distance	Average Pareto sprea
301	9061	0.0362322	0.132706
302	9091	0.0411497	0.147316
303	9121	0.0242439	0.999514

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304	9151	0.0339297	0.109729
305	9181	0.0361613	0.118617
306	9211	0.0390379	0.133472
307	9241	0.0492393	0.189022
308	9271	0.0363868	0.13371
309	9301	0.0627093	0.213057
310	9331	0.0619928	0.236308
311	9361	0.0515117	0.171326
312	9391	0.0461838	0.138537
313	9421	0.0714059	0.207508
314	9451	0.0460601	0.999093
315	9481	0.0371475	0.101827
316	9511	0.035026	0.106811
317	9541	0.0230788	0.0686216
318	9571	0.038896	0.110344
319	9601	0.031285	0.104099
320	9631	0.0480575	0.176843
321	9661	0.0434064	0.999937
322	9691	0.0306994	0.108343
323	9721	0.0263959	0.102458
324	9751	0.0439831	0.999757
325	9781	0.031913	0.106147
326	9811	0.0282715	0.096953
327	9841	0.0411075	0.136076
328	9871	0.0338659	0.118364
329	9901	0.0627367	0.997494
330	9931	0.0533881	0.18512

Generation	f-count	Average Pareto distance	Average Pareto sprea
331	9961	0.0325025	0.0975158
332	9991	0.0354117	0.113279
333	10021	0.043819	0.144378
334	10051	0.0322848	0.106977
335	10081	0.0225321	0.0776284
336	10111	0.0347418	0.107539
337	10141	0.0295694	0.110757
338	10171	0.0427901	0.154928
339	10201	0.0570907	0.193158
340	10231	0.0480129	0.17784
341	10261	0.033545	0.123369
342	10291	0.046284	0.140618
343	10321	0.030544	0.999847
344	10351	0.0269864	0.0970283
345	10381	0.0239839	0.0763762
346	10411	0.0519987	0.998394
347	10441	0.042529	0.116407
348	10471	0.0575245	0.202963
349	10501	0.0341294	0.127278
350	10531	0.0480856	0.196661
351	10561	0.0451832	0.146011
352	10591	0.0439926	0.999359
353	10621	0.0302849	0.109998
354	10651	0.0224602	0.0755025
355	10681	0.0586995	0.997175
356	10711	0.0247125	0.082616

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357	10741	0.0307479	0.102014
358	10771	0.0479804	0.153813
359	10801	0.0393752	0.127348
360	10831	0.0407144	0.999742

Generation	f-count	Average Pareto distance	Average Pareto spre
361	10861	0.0423338	0.999351
362	10891	0.0524073	0.179534
363	10921	0.0445058	0.153774
364	10951	0.0513454	0.181197
365	10981	0.0588954	0.999468
366	11011	0.0294764	0.108987
367	11041	0.0209567	0.0790333
368	11071	0.0298966	0.992409
369	11101	0.0583737	0.175087
370	11131	0.0331132	0.119354
371	11161	0.0384906	0.125747
372	11191	0.0574746	0.158325
373	11221	0.0331675	0.114214
374	11251	0.0210958	0.08514
375	11281	0.0504548	0.152934
376	11311	0.0446596	0.155682
377	11341	0.0226639	0.0982608
378	11371	0.0361552	0.126078
379	11401	0.0462506	0.999128
380	11431	0.027126	0.0979898
381	11461	0.0270962	0.111331
382	11491	0.0618506	0.229107
383	11521	0.0641962	0.201897
384	11551	0.0452365	0.155903
385	11581	0.0479648	0.130847
386	11611	0.0263646	0.998401
387	11641	0.0532373	0.151115
388	11671	0.0656829	0.998714
389	11701	0.040607	0.124527
390	11731	0.0442486	0.1572

Generation	f-count	Average Pareto distance	Average Pareto spre
391	11761	0.0248162	0.0867437
392	11791	0.0292938	0.105688
393	11821	0.0499322	0.132267
394	11851	0.020621	0.0751315
395	11881	0.0620811	0.20003
396	11911	0.0212093	0.062557
397	11941	0.0493917	0.171134
398	11971	0.0230746	0.0828488
399	12001	0.0321211	0.123833
400	12031	0.0744949	0.186961
401	12061	0.0301813	0.0733529
402	12091	0.0238325	0.0692197
403	12121	0.0302981	0.0999187
404	12151	0.0395067	0.141565
405	12181	0.0268412	0.0923006
406	12211	0.0202695	0.056916

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407	12241	0.0292334	0.103296
408	12271	0.0625248	0.162454
409	12301	0.0432167	0.140116
410	12331	0.0218219	0.0683342
411	12361	0.0576248	0.162658
412	12391	0.0365429	0.110689
413	12421	0.0358011	0.999422
414	12451	0.0221223	0.0742603
415	12481	0.0331249	0.130075
416	12511	0.0313991	0.11226
417	12541	0.0344758	0.999446
418	12571	0.0643014	0.228418
419	12601	0.0455699	0.155432
420	12631	0.0399763	0.130715

Generation	f-count	Average Pareto distance	Average Pareto spre
421	12661	0.0490286	0.171761
422	12691	0.0418726	0.143689
423	12721	0.0352123	0.997949
424	12751	0.0414911	0.168562
425	12781	0.0395758	0.155584
426	12811	0.0296021	0.116692
427	12841	0.0606899	0.214806
428	12871	0.029776	0.997721
429	12901	0.0439725	0.141414
430	12931	0.0485544	0.15286
431	12961	0.0328424	0.119726
432	12991	0.0278444	0.991278
433	13021	0.0258478	0.0898653
434	13051	0.0740926	0.245639
435	13081	0.060239	0.220019
436	13111	0.0498682	0.160079
437	13141	0.0340946	0.110989
438	13171	0.0468259	0.168615
439	13201	0.03348	0.122383
440	13231	0.0411408	0.342533
441	13261	0.0450738	0.142371
442	13291	0.0398241	0.121813
443	13321	0.0502658	0.140752
444	13351	0.0485609	0.142971
445	13381	0.0330194	0.107539
446	13411	0.0716237	0.250231
447	13441	0.0615709	0.200858
448	13471	0.044763	0.156021
449	13501	0.0352805	0.126837
450	13531	0.0493837	0.940776

Generation	f-count	Average Pareto distance	Average Pareto spre
451	13561	0.041334	0.177476
452	13591	0.0430829	0.172548
453	13621	0.0494239	0.165721
454	13651	0.043889	0.156005
455	13681	0.0323133	0.117675
456	13711	0.0385891	0.139451

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457	13741	0.0452224	0.136523
458	13771	0.0360924	0.128143
459	13801	0.0458933	0.524181
460	13831	0.033727	0.445719
461	13861	0.0391925	0.139979
462	13891	0.0297633	0.105894
463	13921	0.0252562	0.303516
464	13951	0.0348683	0.135541
465	13981	0.0272222	0.0858205
466	14011	0.0312843	0.100433
467	14041	0.027024	0.0888197
468	14071	0.0374832	0.157298
469	14101	0.0337378	0.1017
470	14131	0.0323575	0.653299
471	14161	0.0573704	0.17492
472	14191	0.0396424	0.111033
473	14221	0.0456414	0.126414
474	14251	0.0227051	0.0750966
475	14281	0.0598613	0.33792
476	14311	0.0786639	0.231888
477	14341	0.0750433	0.224583
478	14371	0.0511809	0.132496
479	14401	0.0699758	0.223009
480	14431	0.0501154	0.155817

Generation	f-count	Average Pareto distance	Average Pareto spre.
481	14461	0.0267836	0.100628
482	14491	0.05584	0.201632
483	14521	0.0364879	0.146426
484	14551	0.0324358	0.0973634
485	14581	0.0274675	0.0898189
486	14611	0.0392597	0.125554
487	14641	0.0257607	0.621445
488	14671	0.0303593	0.0888933
489	14701	0.0313915	0.0810143
490	14731	0.0535172	0.190974
491	14761	0.0341283	0.13852
492	14791	0.0398011	0.14226
493	14821	0.0324634	0.115038
494	14851	0.052707	0.214151
495	14881	0.0305751	0.118152
496	14911	0.0320926	0.110866
497	14941	0.0409706	0.141648
498	14971	0.0910234	0.282227
499	15001	0.0621559	0.207984
500	15031	0.0487442	0.159377
501	15061	0.042106	0.130608
502	15091	0.0446335	0.150859
503	15121	0.0594373	0.194989
504	15151	0.0423092	0.140284
505	15181	0.0352276	0.111179
506	15211	0.0307115	0.0999902
507	15241	0.0356363	0.12091
508	15271	0.0641685	0.512987
509	15301	0.0305859	0.0998874

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510	15331	0.0634455	0.182481

Generation	f-count	Average Pareto distance	Average Pareto spre.
511	15361	0.0423649	0.146876
512	15391	0.0277223	0.690032
513	15421	0.0483744	0.160198
514	15451	0.0231491	0.0802396
515	15481	0.0406311	0.137232
516	15511	0.0333433	0.135285
517	15541	0.0758163	0.252414
518	15571	0.0586599	0.183399
519	15601	0.0296107	0.32738
520	15631	0.0415136	0.145474
521	15661	0.0715032	0.209937
522	15691	0.119909	0.784992
523	15721	0.0733895	0.606174
524	15751	0.0341981	0.105669
525	15781	0.0477981	0.133332
526	15811	0.0603154	0.163283
527	15841	0.0437852	0.123191
528	15871	0.0351039	0.128002
529	15901	0.0497122	0.181734
530	15931	0.0376324	0.132611
531	15961	0.0267458	0.107711
532	15991	0.0247938	0.100312
533	16021	0.0499108	0.187836
534	16051	0.0353834	0.132361
535	16081	0.028828	0.0993857
536	16111	0.0541389	0.183874
537	16141	0.0504345	0.182645
538	16171	0.0307189	0.133942
539	16201	0.0379212	0.140686
540	16231	0.0234676	0.766991

Generation	f-count	Average Pareto distance	Average Pareto spre.
541	16261	0.0346525	0.116349
542	16291	0.0454797	0.16675
543	16321	0.0190186	0.886131
544	16351	0.0422134	0.164553
545	16381	0.0593556	0.670757
546	16411	0.0464818	0.167306
547	16441	0.0443939	0.156512
548	16471	0.0347873	0.103394
549	16501	0.0275082	0.083464
550	16531	0.0264235	0.0971786
551	16561	0.0408748	0.14836
552	16591	0.0291953	0.0911352
553	16621	0.0412795	0.11934
554	16651	0.0261374	0.0844747
555	16681	0.0222632	0.0799591
556	16711	0.0386153	0.159834
557	16741	0.0405993	0.411655
558	16771	0.0315212	0.101289
559	16801	0.0160567	0.0545878

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560	16831	0.0362938	0.124707
561	16861	0.0361463	0.112254
562	16891	0.0397804	0.128063
563	16921	0.0363056	0.104896
564	16951	0.0474593	0.157262
565	16981	0.0290557	0.116771
566	17011	0.0454805	0.185485
567	17041	0.0350244	0.128395
568	17071	0.0357309	0.103204
569	17101	0.0236435	0.0666299
570	17131	0.0333024	0.0922192

Generation	f-count	Average Pareto distance	Average Pareto spr
571	17161	0.0607464	0.191605
572	17191	0.0248546	0.0881871
573	17221	0.041434	0.134288
574	17251	0.0443769	0.158579
575	17281	0.048286	0.16899
576	17311	0.0430724	0.168384
577	17341	0.0439394	0.185121
578	17371	0.0320845	0.129898
579	17401	0.0309183	0.842788
580	17431	0.0249995	0.969455
581	17461	0.0300912	0.110878
582	17491	0.0249364	0.0705627
583	17521	0.0648933	0.730008
584	17551	0.0407375	0.150589
585	17581	0.0314289	0.90671
586	17611	0.0396262	0.974522
587	17641	0.0327128	0.115854
588	17671	0.0356002	0.933945
589	17701	0.0251713	0.98651
590	17731	0.0349185	0.14093
591	17761	0.0234225	0.101955
592	17791	0.0455984	0.18363
593	17821	0.0309904	0.110177
594	17851	0.0387276	0.149067
595	17881	0.044949	0.335849
596	17911	0.0554334	0.570828
597	17941	0.0329031	0.995696
598	17971	0.0533939	0.98866
599	18001	0.0417164	0.169644
600	18031	0.0220651	0.587733

Appendix B:

Set up problem, analysis, and running on Math lab

MATLAB Workspace

MATLAB Variable Editor: optimproblem — Page 1
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Field	Value	Min	Max
fitnessfcn	@mira1		
nvars	3	3	3
Aineq	[1,0,0;0,1,0;0,0,1]	0	1
bineq	[4400;2444;1100]	1100	4400
Aeq	[ ]		
beq	[ ]		
lb	[0,0,0]	0	0
ub	[ ]		
randstate	[ ]		
randnstate	[ ]		
solver	'gamultiobj'		
options	*<1x1 struct>*		

MATLAB Variable Editor: optimresults.output — Page 1
Jun 29, 2011 — 10:11:03 PM

Field	Value	Min	Max
problemtype	'linearconstraints'		
randstate	*<625x1 uint32>*	90	2147...
randnstate	[4.2860e+09;1274...	1274...	4.28...
generations	600	600	600
funccount	18031	18031	18031
message	'Optimization termi...		
averagedistance	0.0221	0.0221	0.0221
spread	0.5877	0.5877	0.5877

Appendix B:

Set up problem, analysis, and running on Math lab

F1 and F_2 value function results

MATLAB Variable Editor: optimresults.fval	Page 1
Jun 29, 2011	10:10:02 PM

	1	2
1	-6.8677e+06	1.1292e+07
2	-5.7825e+06	9.4135e+06
3	-7.9679e+06	1.3253e+07
4	-1.4724e+05	4.5168e+05
5	-8.5510e+06	1.4332e+07
6	-3.7061e+06	5.8853e+06
7	4.6300e+05	-3.5087e+05
8	-7.6609e+06	1.2890e+07
9	-7.4760e+06	1.2176e+07
10	-1.7064e+06	2.7351e+06
11	-4.3308e+05	1.0468e+06
12	-2.0744e+06	3.3287e+06
13	-5.1204e+06	8.0414e+06
14	-5.9311e+06	9.8037e+06
15	-4.2841e+06	6.7686e+06
16	1.9820e+05	5.7121e+03
17	-5.5692e+06	8.8360e+06
18	-4.9174e+06	7.7293e+06
19	-6.3120e+06	1.0078e+07
20	-1.3257e+06	2.2131e+06
21	-6.6391e+06	1.0678e+07
22	-8.3417e+05	1.6294e+06
23	-8.5510e+06	1.4332e+07
24	-8.1379e+06	1.3624e+07

Population results

MATLAB Variable Editor: optimresults.population	Page 1
Jun 29, 2011	10:12:11 PM

	1	2	3
1	1.2882e+03	1.7845e+03	692.8011
2	525.2875	1.6478e+03	509.1913
3	979.7912	1.9730e+03	1.0181e+03
4	24.5695	171.7388	8.8675
5	1.5285e+03	1.8576e+03	195.8723
6	1.6593e+03	2.0697e+03	1.1000e+03
7	458.3182	363.4189	738.4260
8	953.4353	498.5300	649.6368
9	0.1413	9.9206e-04	0
10	1.0201e+03	2.0667e+03	852.3808
11	1.4571e+03	1.8089e+03	771.1049
12	817.9751	1.7169e+03	1.0071e+03
13	449.9113	453.4513	149.2240
14	438.9219	26.8313	169.4700
15	462.5268	424.5663	274.7544
16	989.2242	808.7403	835.9176
17	245.9783	1.8119e+03	503.2876
18	785.1739	1.2009e+03	297.5852
19	101.0112	65.0714	1.4853
20	941.6109	1.2789e+03	619.6174
21	894.0488	1.5045e+03	258.0517
22	895.5641	724.3898	854.6182
23	1.3397e+03	1.3784e+03	750.0570
24	257.3966	156.7015	316.1783
25	528.1991	1.7507e+03	650.4278
26	116.8934	297.2698	210.7587
27	968.9056	1.5178e+03	813.5762
28	349.8867	73.0733	248.2640
29	1.6593e+03	2.0697e+03	1.1000e+03
30	1.4364e+03	2.0388e+03	986.5299

Appendix B:

Set up problem, analysis, and running on Math lab

Score diversity output.

MATLAB Variable Editor: optimresults.score Jun 29, 2011	Page 1 10:12:50 PM

	1	2
1	-6.8677e+06	1.1292e+07
2	-5.7825e+06	9.4135e+06
3	-7.9679e+06	1.3253e+07
4	-1.4724e+05	4.5168e+05
5	-5.4255e+06	9.1058e+06
6	-8.5510e+06	1.4332e+07
7	-3.3875e+06	5.4380e+06
8	-3.7061e+06	5.8853e+06
9	4.6300e+05	-3.5087e+05
10	-7.6609e+06	1.2890e+07
11	-7.1978e+06	1.1847e+07
12	-7.4760e+06	1.2176e+07
13	-1.7064e+06	2.7351e+06
14	-4.3308e+05	1.0468e+06
15	-2.0744e+06	3.3287e+06
16	-5.1204e+06	8.0414e+06
17	-5.9311e+06	9.8037e+06
18	-4.2841e+06	6.7686e+06
19	1.9820e+05	5.7121e+03
20	-5.5692e+06	8.8360e+06
21	-4.8107e+06	7.7756e+06
22	-4.9174e+06	7.7293e+06
23	-6.3120e+06	1.0078e+07
24	-1.3081e+06	2.2972e+06
25	-6.4047e+06	1.0498e+07
26	-1.3257e+06	2.2131e+06
27	-6.6391e+06	1.0678e+07
28	-8.3417e+05	1.6294e+06
29	-8.5510e+06	1.4332e+07
30	-8.1379e+06	1.3624e+07

- Program Parameters

- Population type: Double Vector
- Population Size: Double Vector
- Selection Function: Tournament
- Crossover Function: Intermediate
- Mutation Function: Use constrain dependent default
- Migration Direction: Forward

Appendix B:

Set up problem, analysis, and running on Math lab

- Final running of case1 problem (Satisfied Solution).

MATLAB Variable Editor: optimresults.output   Page 1
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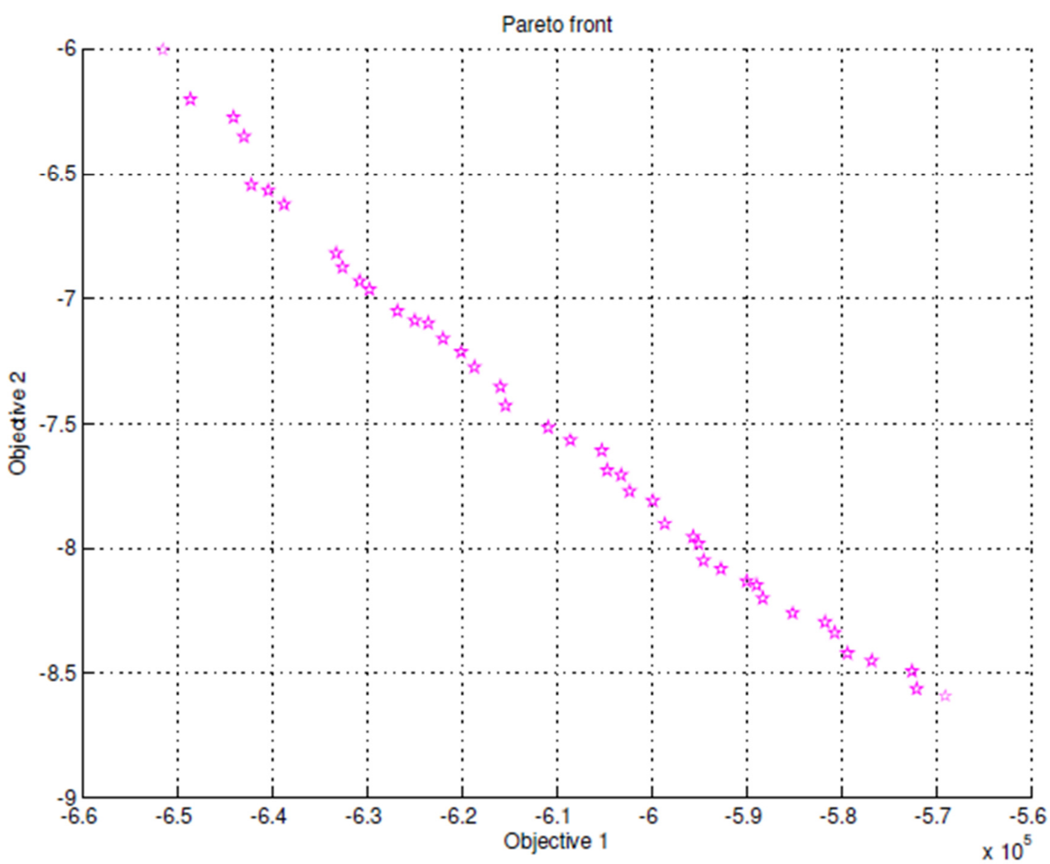
Field	Value	Min	Max
problemtype	'boundconstraints'		
randstate	<625x1 uint32>	244	2147...
randnstate	[614963577;1.2339...	6149...	1.23...
generations	146	146	146
funccount	17641	17641	17641
message	'Optimization termi...		
averagedistance	0.0062	0.0062	0.0062
spread	0.2179	0.2179	0.2179



Appendix B:

Set up problem, analysis, and running on Math lab

F1 and F2 Values of Objective Functions

MATLAB Variable Editor: optimresults.fval
јан 10, 2012
Page 1
11:39:45 AM

	1	2
1	-5.7258e+05	-8.4910
2	-6.3876e+05	-6.6236
3	-6.2010e+05	-7.2157
4	-6.1870e+05	-7.2751
5	-6.4218e+05	-6.5459
6	-6.0858e+05	-7.5678
7	-6.2201e+05	-7.1587
8	-5.7684e+05	-8.4502
9	-6.2975e+05	-6.9636
10	-6.0236e+05	-7.7710
11	-5.9990e+05	-7.8088
12	-6.0528e+05	-7.6099
13	-5.8175e+05	-8.2974
14	-5.8517e+05	-8.2600
15	-6.5153e+05	-6.0030
16	-5.8833e+05	-8.1990
17	-6.4407e+05	-6.2744
18	-5.6911e+05	-8.5918
19	-6.0473e+05	-7.6873
20	-5.9456e+05	-8.0497
21	-5.9272e+05	-8.0826
22	-6.1092e+05	-7.5147
23	-5.8896e+05	-8.1467
24	-6.4860e+05	-6.2031
25	-5.7211e+05	-8.5622
26	-6.4041e+05	-6.5682
27	-6.3259e+05	-6.8760
28	-6.1595e+05	-7.3535
29	-6.2682e+05	-7.0495
30	-6.3079e+05	-6.9308
31	-6.2357e+05	-7.0973
32	-5.9003e+05	-8.1318
33	-5.9567e+05	-7.9558
34	-6.0324e+05	-7.7076
35	-6.2499e+05	-7.0877
36	-6.4298e+05	-6.3508
37	-5.7938e+05	-8.4212

MATLAB Variable Editor: optimresults.fval
јан 10, 2012
Page 2
11:39:45 AM

	1	2
38	-5.9865e+05	-7.9025
39	-5.9510e+05	-7.9817
40	-5.8075e+05	-8.3390
41	-6.3328e+05	-6.8174
42	-6.1541e+05	-7.4277

Appendix B:

Set up problem, analysis, and running on Math lab

X1 and X2 Numbers of Products

MATLAB Variable Editor: optimresults.x jaн 10, 2012	Page 1 11:39:23 AM

	1	2
1	15.6792	19.6472
2	11.3297	19.7247
3	12.7084	19.7017
4	12.8453	19.7064
5	11.1459	19.7412
6	13.5271	19.6945
7	12.5755	19.7041
8	15.5777	19.6801
9	12.1178	19.7290
10	13.9975	19.6995
11	14.0883	19.6850
12	13.6294	19.6709
13	15.2249	19.6716
14	15.1329	19.6964
15	9.8960	19.6927
16	14.9889	19.7082
17	10.5283	19.6806
18	15.9123	19.6511
19	13.8043	19.6948
20	14.6402	19.7197
21	14.7181	19.7114
22	13.4021	19.7023
23	14.8706	19.6934
24	10.3559	19.7146
25	15.8391	19.6737
26	11.2006	19.7268
27	11.9135	19.7333
28	13.0281	19.7021
29	12.3181	19.7235
30	12.0413	19.7303
31	12.4337	19.7010
32	14.8348	19.6999
33	14.4274	19.6940
34	13.8533	19.6848
35	12.4086	19.7148
36	10.7035	19.6904
37	15.5068	19.6977

MATLAB Variable Editor: optimresults.x jaн 10, 2012	Page 2 11:39:23 AM

	1	2
38	14.3011	19.7081
39	14.4869	19.6979
40	15.3202	19.6778
41	11.7800	19.7220
42	13.1959	19.7234

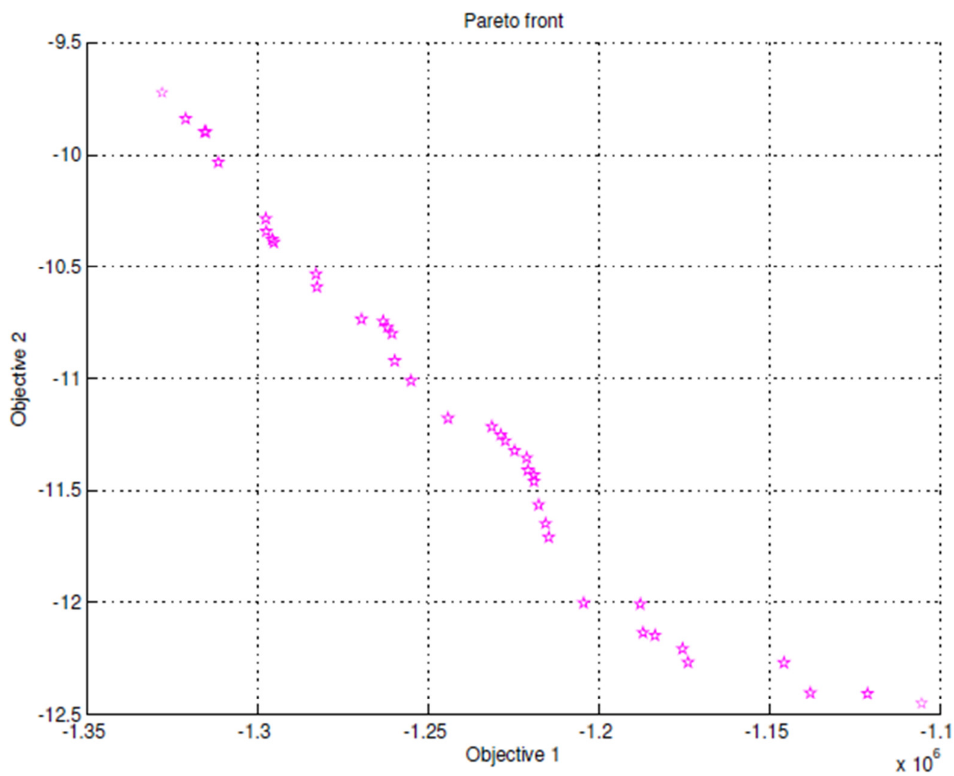
Appendix B:

Set up problem, analysis, and running on Math lab

- Final running of case2 problem (Satisfied Solution).

MATLAB Variable Editor: optimresults.output — Page 1
Jan 10, 2012 — 11:48:07 AM

Field	Value	Min	Max
problemtype	'boundconstraints'		
randstate	*<625x1 uint32>*	344	2147...
randnstate	[3.2918e+09;3.810...	3.29...	3.81...
generations	139	139	139
funccount	16801	16801	16801
message	'Optimization termi...		
averagedistance	0.0107	0.0107	0.0107
spread	0.2781	0.2781	0.2781



Appendix B:

Set up problem, analysis, and running on Math lab

MATLAB Variable Editor: optimresults.fval | Page 1
jaн 10, 2012 | 11:47:47 AM

	1	2
1	-1.1870e+06	-12.1361
2	-1.2313e+06	-11.2156
3	-1.1879e+06	-12.0081
4	-1.3115e+06	-10.0335
5	-1.2606e+06	-10.7989
6	-1.2176e+06	-11.5651
7	-1.1836e+06	-12.1490
8	-1.2287e+06	-11.2529
9	-1.2211e+06	-11.3561
10	-1.2208e+06	-11.4118
11	-1.2442e+06	-11.1785
12	-1.2156e+06	-11.6486
13	-1.3280e+06	-9.7219
14	-1.2828e+06	-10.5341
15	-1.2190e+06	-11.4326
16	-1.2956e+06	-10.3791
17	-1.1055e+06	-12.4516
18	-1.1213e+06	-12.4074
19	-1.2632e+06	-10.7450
20	-1.2550e+06	-11.0122
21	-1.1739e+06	-12.2682
22	-1.2598e+06	-10.9241
23	-1.1380e+06	-12.4040
24	-1.2826e+06	-10.5916
25	-1.2975e+06	-10.2854
26	-1.1755e+06	-12.2081
27	-1.3210e+06	-9.8402
28	-1.2045e+06	-12.0030
29	-1.2695e+06	-10.7354
30	-1.2952e+06	-10.3912
31	-1.3151e+06	-9.8989
32	-1.2974e+06	-10.3423
33	-1.3155e+06	-9.8979
34	-1.1458e+06	-12.2702
35	-1.2190e+06	-11.4605
36	-1.2147e+06	-11.7108
37	-1.2247e+06	-11.3249

MATLAB Variable Editor: optimresults.fval | Page 2
jaн 10, 2012 | 11:47:47 AM

	1	2
38	-1.2619e+06	-10.7720
39	-1.2274e+06	-11.2798

Appendix B:

Set up problem, analysis, and running on Math lab

MATLAB Variable Editor: optimresults.x — Page 1
jaн 10, 2012 — 11:47:25 AM

	1	2
1	22.6576	26.8730
2	20.5305	26.8288
3	22.3714	26.8213
4	17.7474	27.0229
5	19.5494	26.8978
6	21.3340	26.8662
7	22.6922	26.8509
8	20.6181	26.8234
9	20.8615	26.8049
10	20.9863	26.8263
11	20.4260	26.9183
12	21.5237	26.8863
13	17.0193	27.0476
14	18.9189	26.9755
15	21.0358	26.8206
16	18.5499	27.0211
17	23.4963	26.3537
18	23.3713	26.4630
19	19.4244	26.8978
20	20.0362	26.9379
21	22.9735	26.8277
22	19.8311	26.9415
23	23.3357	26.5990
24	19.0481	26.9956
25	18.3364	27.0016
26	22.8371	26.8127
27	17.2970	27.0323
28	22.3322	26.9539
29	19.3921	26.9457
30	18.5779	27.0218
31	17.4389	27.0043
32	18.4643	27.0217
33	17.4359	27.0073
34	23.0251	26.5988
35	21.0983	26.8323
36	21.6639	26.9060
37	20.7858	26.8206

MATLAB Variable Editor: optimresults.x — Page 2
jaн 10, 2012 — 11:47:25 AM

	1	2
38	19.4869	26.8978
39	20.6806	26.8234

Appendix C:

INSA in A brief

Appendix C

- INSA production factory

INSA was founded in the year 1950 as a clock producing factory, which since then has become a major producer of clocks and watch mechanisms, as well as a producer of water meters and many other products in the field of measurement technology and mechanics.

Our research studying was applied on there types of it’s products. These types are clocks, water meters, and gas meters.

1. Clocks product

INSA's alarm clock mechanisms are designed according to classical technical solutions and all mechanical parts are made of copper and brass.

In this field, they produce two types of clocks with two deferent types of material plastic and wooden. The figure1 below shows these types of products.

 Chess Plastic	 Chess Wooden

Appendix C:

INSA in A brief

Figure C1. Chess Clocks types

		
Wooden	Contemporary quartz Wall clock	Traditional Pendulum

2. Water meter clocks

INSA factory produces three deferent groups of these types. These groups are residential water meters, industrial water meters, and apartment water meters.

All three types include dry and wet mechanisms. Both mechanisms are compliant to standard ISO 4064 Class B and appropriate with hot and cold water.

Figure C2. VVS3 Multi yet water meter with dry mechanism (residential water meter clocks)

Appendix C:

INSA in A brief

 WPI Woltman horizontal	 VWV - S3 Combined Water

Figure C3. Combined and cold water (Industrial water meter clocks)

Figure C4. RF1 G4 Residential diaphragm gas meter (Gas meter clock)

TRADITIONAL PENDULUM WALL CLOCK

Traditional pendulum wall clock

This traditional pendulum wall clock is encased in solid oak wood and is operated by a quartz movement, with an accuracy of +/- 0.3 seconds per day.
The movement is operated by two AA batteries.
Manufacturers warranty on all defective parts and labour is valid for two years from date of purchase.

The clock measures:
Height 55 cm (21,6") / Width 24,2 cm (0.7") / Depth 9,5 cm (1.9").

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info@insa.rs

RF1 G4 RESIDENTIAL DIAPHRAGM GAS METER

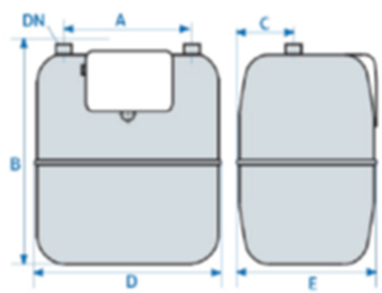
The RF1 is a compact residential gas meter designed to measure accurately volumes of natural gas, LPG and all non-corrosive gases.

OPERATING PRINCIPLE

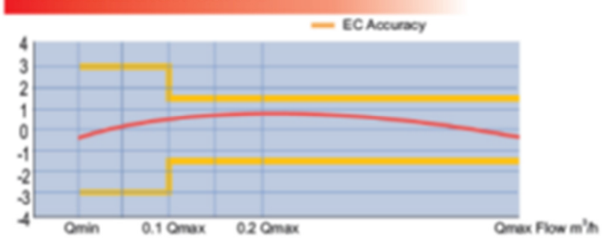
The RF1 is a positive displacement diaphragm gas meter with a stand-alone twin chamber measuring unit. The twin chambers are each fitted with a flexible and gas-tight diaphragm which is moved by the differential between the inlet and outlet pressure.
The gas enters one side of the diaphragm pan while on the other side it comes out through a separate port on the valve. When one side is full, the sliding valve moves on to the next position, allowing the gas to fill the empty side.
A transmission gear and a magnetic coupling or stuffing box transfer the reciprocating motion to the mechanical or electrical index. The measuring unit is housed in a robust gas-tight casing.

DIMENSIONS AND WEIGHT

Connection	DN	20	25	25*	25*	25
A	mm	220 250	210 250	250	152	Cav
B	mm	269	263	276	320	274
C	mm	71	71	77	80	71
D	mm	325	325	316	297	233
E	mm	177	177	211	198	177
Weight	kg	2.7	2.7	4.2	4	2.5



TYPICAL ERROR CURVE



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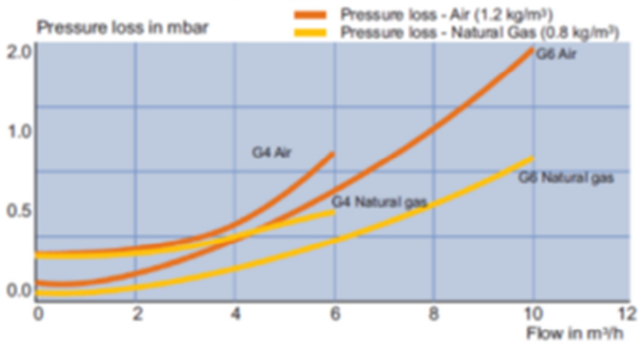
Appendix C:

INSA in A brief

TYPICAL PRESSURE LOSS CURVE



TECHNICAL CHARACTERISTICS

Gas Type	Natural gas, air, propane, butane, nitrogen and all non-corrosive gases
Cyclic Volume	2dm³
Temperature Range	-10° C to +50° C (optional -20° C to +50° C)
Temperature Range - Storage	-40° C to + 70° C
Maximum Operating Pressure	0.5 bar for steel version, 1.5 bar for aluminium version (HP)
Measuring Range	G4 Qmin 0.04 m³/h Qmax 6 m³/h G 1.6 Qmin 0.016 m³/h Qmax 2.5 m³/h G2.5 Qmin 0.025 m³/h Qmax 4 m³/h G6 Qmin 0.06 m³/h Qmax 10 m³/h
Pulse Generator	Standard 0.1 m³ / pulse, Optional 0.01 m³ / pulse
Pulse transmitter	Retrofittable LF-system, 24 Vdc max - 50 mA max. Standard 0.1 m³ / pulse
Casing Material	Steel or aluminium
Connections Threads	G 1" A ; G 1" 1/4 A ; G 1" 3/4 A ; GM 1" ; GM 3/4" ; Others on request
Colour	RAL 7035 for steel, RAL 9010 for aluminium

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Appendix C:

INSA in A brief

Insa

VVS3
Multi jet water meter
with dry mechanism

Compliant accordig to standard: EN 4064 Class B and C

This class of meter is used to measure the volume of clean water, with temperatures up to 40°C and pressure up to 16 bars.

DESCRIPTION AND PURPOSE

Insa's Multi Jet, dry propeller, water meter is produced in according to international standards - EN 4064. Accuracy classes are available in B and C.

A primary characteristic of these meters are the dry dial mechanism, which are isolated from the water. Meters of this type are designed to measure the volume of consumed pure water, with temperatures up to 40°C and pressure up to 16 bars.

Our VVS - 3 type gauge is generaly called: multi jet - propeller water meter with dry mechanism.

The propeller rotation is transmitted through the magnetic coupling of the dial mechanism. This isolated the mechanism from the influence of water and moisture.

The smallest dial the "liter wheel" contains a small metal plate that is used to generate pulses in the electronic device for remote readout. This device can be mounted on the water meter without the need for dismantling or disassembly.)

This type of water meter is suitable for remote sensing based on the need for AMR technology, whereby the pulse generator is mounted on the "liter wheel".The dial gauge contains a security hologram with serial number.

MECHANISM CHARACTERISTICS

- The mechanism is compatible with currently produced water meters.
- The mechanism housing has a square shaped intake and exit opening. This type of opening provides for much better water flow and causes a more favorable error curve.
- By changing the design and materials used in production of the propeller and mechanism, sensitivity and life of the gauge are significantly increased.
- The dial includes a fifth red hand which enables precise readout of deciliters.
- This water meter with this type of mechanism is approved by the Federal Bureau for Measures and Precious Metals, (Document dated 19.01.2009. with an official label Z-14-24), in Serbia.

INSTRUCTIONS FOR INSTALLATION AND USE

- Before installation of the meter, the water supply network should be flushed with water, to remove any debris.
- The filter should be installed at the entrance of the water meter.
- The direction of the arrow on the meter should follow the as direction of the water flow through the supply network.
- Water meter should be placed horizontally with the dial facing up.
- Be sure to protect the water mater from freezing. Any use of open flame for warming the water meter is prohibited.

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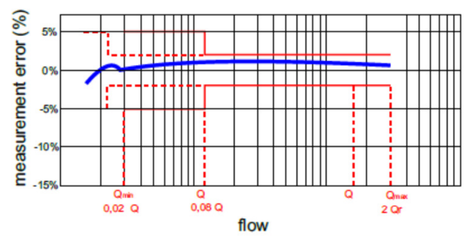
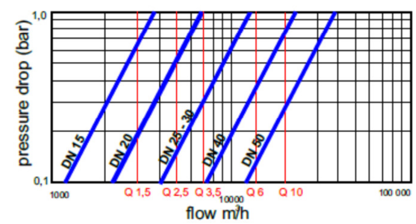
TYPICAL ERROR CURVE



TYPICAL PRESSURE DROP CURVE

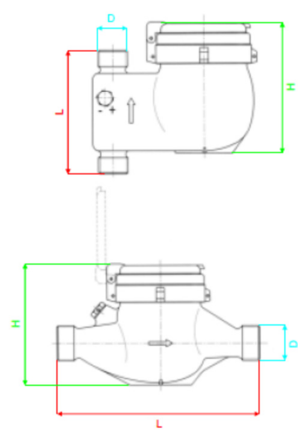


METEOROLOGYCAL CHARACTERISTICS

Diameter DN	mm	15	20	25	30	40	50
Class		B	B	B	B	B	B
Qmax	m³/h	3	5	10	10	20	30
Qn	m³/h	1,5	2,5	5	5	10	15
Qt	l/h	120	200	400	400	800	1200
Qmin	l/h	15	25	100	100	200	300
Initial flow	l/h	<10	<15	<20	<20	<20	<20
Max reading	m³	99.999	99.999	99.999	99.999	999.999	999.999
Min reading	litar	0,05	0,05	0,05	0,05	0,5	0,5
PN	bar	16	16	16	16	16	16
Pressure drop at Qmax	bar	<1	<1	<1	<1	<1	<1

DIMENSIONS

Water meter		Unit	Horizontal					Vertical
Diameter		mm/ inch	13 ½"	20 3/4"	25 1"	30 5/4"	40 6/4"	13 ½"
Lenght	L	mm	165	190	260	260	300	105
Height	H	mm	115	120	130	130	160	121
Thread diameter	D	inch	3/4"	1"	5/4"	6/4"	2"	3/4"
Weight		kg	1,75	2,00	2,70	2,70	6,20	1,80



REMOTE READOUT SYSTEM

ADO OPTIONS

The VVS3 series of water meters are ready to be upgraded for remote readout. Upgrade consists of replacement of the "deciliter" hand with an by replacing the old glass with a new one. The new glass contains two fixing points for ADO devices.

** compatibile devices are ADO-RF24/RF868 and ADO M-Bus*

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VWV - S3 Combined Water meter

This class of meters is used for measuring the total amount of cold water that flows through the pipelines of industrial enterprises and mining plants. This type of water meter (called “mother - child” water meter) contains large industrial - Waltman water meter class „B“, small - multi jet water meter in class „C“ and toggle valve.

- New design, easy maintenance.
- Large dial for easy readout.
- Minimal initial flow.
- Especially suitable for systems with variable flow rate.
- VWV S3 - has easy changeable mechanism sealed in special liquid capsule.

BASIC TECHNICAL DATA

ERROR DISPLAY

In a small area ± 5% of the minimum flow rate (Qmin) to the edge of the transitional flow (Qt).

In a small area ± 2% of the transitional flow (Qt) to overload flow (QS).

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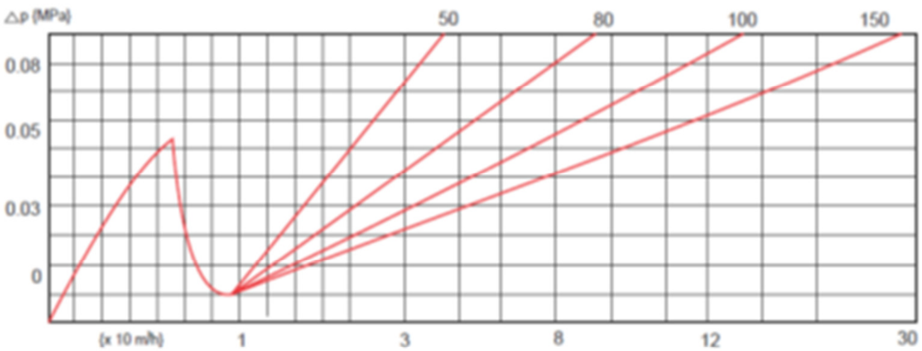
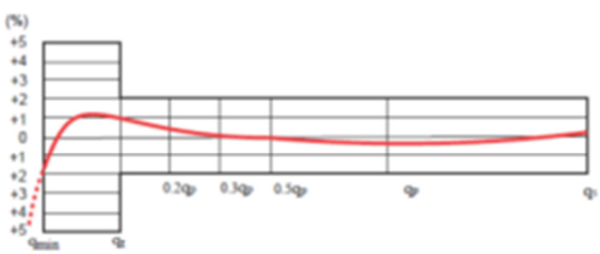
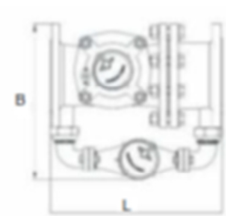
TYPICAL PRESSURE LOSS CURVE



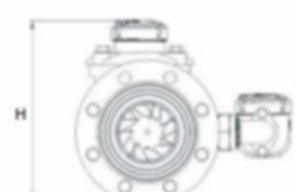
TYPICAL ERROR CURVE





DIMENSIOS AND WEIGHT

Diameter DN (mm)	L Lenght	B Width	H Height	Flange			Weight kg
	mm			mm	Bolt circle (screw) - diameter mm	Screw diameter and quantity pcs.	
50	270	268	250	165	125	4 x M 16	20
80	300/370	310	265	200	160	8 x M 16	27.5
100	360/370	320	275	220	180	8 x M 16	31
150	500	445	285	285	240	8 x M 20	82



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WPI Woltman horizontal water meter

Compliant according to standard: ISO 4064 Class B

This class of meter is used for measuring the total flow of cold water entering industrial size compounds and other large plants.

MAIN CHARACTERISTIC

- Dry mechanism with magnetic transmission.
- Vacumed dial eliminates fogging, wich makes reading much easier.
- For pemanent and reliable operation,high quality materials are used in production.
- The accuracy of measurement is in compliance with ISO 4064 standard, Class B.
- Minimal registry loss on minimum flow.
- The Universal register can be removed without removing the meter from the pipeline, which enables very easy maintance and replacement.

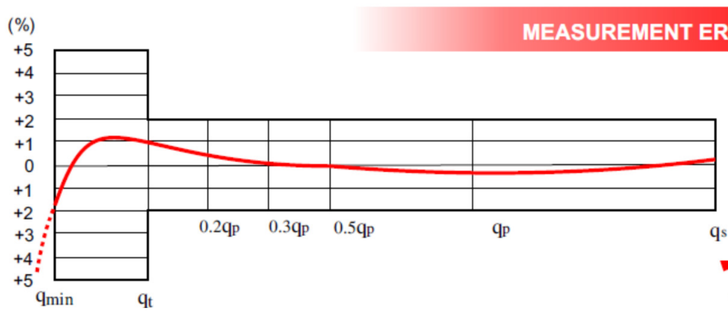
PERFORMANCE CHARACTERISTICS

Work conditions

Water temperature	⩽	40º C
Min. work pressure	⩽	1.0 MPa
Max. work pressure	⩽	1.6 MPa

Diameter DN (mm)	Class	Qs Max. flow	Qp Nominal flow	Qt Tranzition flow	Qmin Minimal flow	Initial flow	Min. digits readout	Max. digits readout
		m^3/h				L/h	m^3	
50	B	30	15	3	0.45	150	0.01	9999999
65	B	50	25	5	0.75	170	0.01	9999999
80	B	80	40	8	1.2	280	0.01	9999999
100	B	120	60	12	1.8	400	0.01	9999999
125	B	200	100	20	3	800	0.01	9999999
150	B	300	150	30	4.5	1200	0.01	9999999
200	B	500	250	50	7.5	1500	0.01	9999999

MEASUREMENT ERROR CURVE



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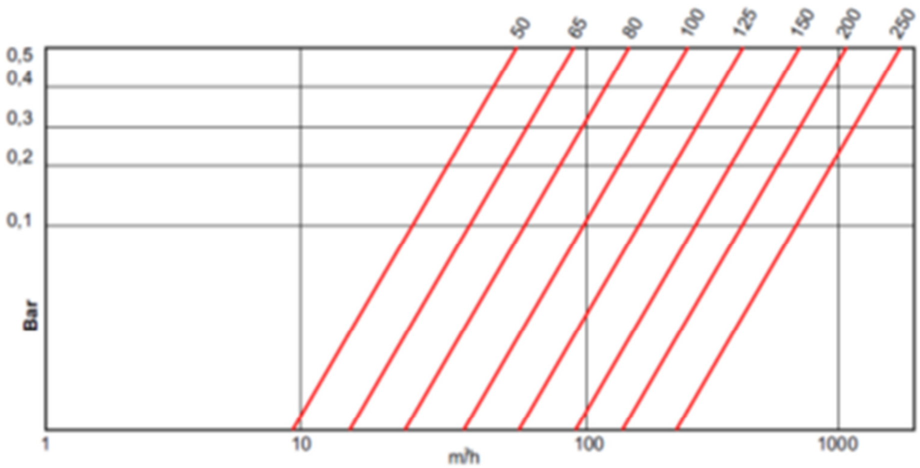
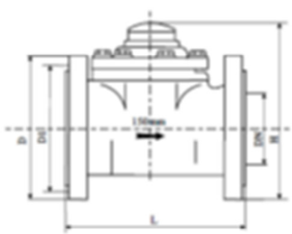
MINIMUM FLOW LOSS



DIMENSIONS AND WEIGHT



Diameter DN (mm)	L Lenght	B Width	H Height	Flange			Weight kg
	mm			D mm	D1 mm	Screw dimensions and quantity	
50	200	175	257	165	125	4 x M 16	12
65	200	185	267	185	145	4 x M 16	13
80	225	200	277	200	160	8 x M 16	15
100	250	220	287	220	180	8 x M 16	19
125	250	245	297	245	210	8 x M 16	22
150	300	285	375	285	240	8 x M 20	47
200	350	345	400	340	295	8 x M 20	48

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CHESS CLOCKS

WOODEN CASE

Housed in a beautiful solid wooden case, it runs extremely quiet for an analog clock and its extra large size along with the white and black artwork makes for easy viewing during play. The large buttons on top are easy to find and are much quieter than brass buttons on similar clocks. Insa's unique five minute flag has 15 second increments in the final minute for blitz games. The Clock will run 24 hours on a single winding. Measures 18.7cm x 10cm x 5.5cm (6.7" x 4.3" x 2.2").

PLASTIC CASE

Housed in a beautiful plastic case, available in several colours, it runs extremely quiet for an analog clock and its extra large size along with the white and black artwork makes for easy viewing during play. The large buttons on top are easy to find and are much quieter than brass buttons on similar clocks. Insa's unique five minute flag has 15 second increments in the final minute for blitz games. The Clock will run 24 hours on a single winding. Measures 18.7cm x 10cm x 5.5cm (6.7" x 4.3" x 2.2").

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WOODEN WALL CLOCK

Wooden wall clock

This pendulum clock has a solid oak wood frame and features a quartz movement, which is accurate to +/- 0.3 seconds per day. The movement is operated by two AA batteries.
Manufacturers warranty on all defective parts and labour is valid for two years from date of purchase.

The clock measures:
Height 53,5 cm (21"), Width 31,5 cm (12.4"), Depth 7,5 cm (2.95").

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CONTEMPORARY QUARTZ WALL CLOCK

Contemporary quartz wall clock

The clock features a white plastic frame, with rectangular minute and hour hands. It features a quartz movement, accurate to +/- 0,3 seconds per day, and is operated by a single AA battery.
Especially suitable for professional environments, like offices and retail outlets.
Manufacturers warranty on all defective parts and labour is valid for two years from date of purchase.

The clock measures:
Ø 32 cm (12.5”), Depth 6 cm (2.36”).

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Прилог 1.

Изјава о ауторству

Потписани-а Galal Hamed Senussi

број уписа D 48/10

Изјављујем

да је докторска дисертација под насловом

IMPROVMENT OF THE PRODUCTION PROGRAM PLANNING PROCESS IN BUSINESS PRODUCTION SYSTEM.

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- да нисам кршио/ла ауторска права и користио интелектуалну својину других лица.

Потпис докторандаУ

Београду, / /2013

Прилог 2.

Изјава о истоветности штампане и електронске верзије докторског рада

Име и презиме аутора: **Galal Hamed Senussi**

Број уписа: D 48/10

Студијски програм: Doktorske studije

Наслов рада :

IMPROVMENT OF THE PRODUCTION PROGRAM PLANNING PROCESS IN BUSINESS PRODUCTION SYSTEM.

Ментор : Dr.Mirjana Misita**,** associate Professor

Потписани : Galal Hamed Senussi

изјављујем да је штампана верзија мог докторског рада истоветна електронској верзији коју сам предао/ла за објављивање на порталу **Дигиталног репозиторијума Универзитета у Београду.**

Дозвољавам да се објаве моји лични подаци везани за добијање академског звања доктора наука, као што су име и презиме, година и место рођења и датум одбране рада.

Ови лични подаци могу се објавити на мрежним страницама дигиталне библиотеке, у електронском каталогу и у публикацијама Универзитета у Београду.

Потпис докторанда

У Београду, / /2013

Прилог 3.

Изјава о коришћењу

Овлашћујем Универзитетску библиотеку „Светозар Марковић“ да у Дигитални репозиторијум Универзитета у Београду унесе моју докторску дисертацију под насловом:

IMPROVMENT OF THE PRODUCTION PROGRAM PLANNING PROCESS IN BUSINESS PRODUCTION SYSTEM.

која је моје ауторско дело.

Дисертацију са свим прилозима предао/ла сам у електронском формату погодном за трајно архивирање.

Моју докторску дисертацију похрањену у Дигитални репозиторијум Универзитета у Београду могу да користе сви који поштују одредбе садржане у одабраном типу лиценце Креативне заједнице (Creative Commons) за коју сам се одлучио/ла.

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