SHIP ROUTING OPTIMIZATION AMONG BRICS

Ph.D. Thesis

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CERTIFICATE

This is to certify that thesis entitled **"SHIP ROUTING OPTIMIZATION AMONG BRICS"** being submitted by **Pravendra Kumar Tyagi (2011RME7150)** is a bona-fide research work carried out under my supervision and guidance in fulfillment of the requirement for the award of the degree of **Doctor of Philosophy** in the Department of Mechanical Engineering, Malaviya National Institute of Technology, Jaipur, India. The matter embodied in this thesis is original and has not been submitted to any other University or Institute for the award of any degree.

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DECLARATION

I, **Pravendra Kumar Tyagi**, declare that this thesis titled, **"SHIP ROUTING OPTIMIZATION AMONG BRICS"** and the work presented in it, are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this university.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this university or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotation, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself, jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Date:

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ABSTRACT

In beginning work exposes the impacting key constraints on economic and smooth supply chain execution country wise, specifically Brazil, Russia, India, China and South Africa. Further discusses the approaches to overcome the loose poles in supply chain system by enhancing internationalization and globalization which relates to quantitative and qualitative strengthening in the field of finance and technology. Supply chain integration encompasses the routing and scheduling of inventory maneuver to desired allocation in an economic mode for satisfying the all end-users by prompt connectivity and communication between the links of supply chain. Efforts have been made to explore the series of challenges in BRICS towards supply chain connectivity to achieve the revolution of coined word**,** which is “Broad vision and shared prosperity.”

Moving towards the vision of BRICS summit, it becomes mandatory to have economic linking among above acronym with initial effort to focus the contribution of researchers towards immense area i.e. logistics management and ship routing optimization among BRICS. This thesis is an exploration of the issues and mitigations given by contributors in different relating areas, which are lacking in term of trading enhancement through ship routing optimization between ports of BRICS. Efforts overcome this limp by presenting an approach for effective ship routing with managed loading and unloading inventory at ports according to planned sequence as well as distributing the goods to the desired destinations with least cost between initial pick point to final drop point. The acronym was first coined and prominently used by Goldman Sachs in 2001. Goldman Sachs argued that since they are developing rapidly by 2050, the combined economies of the BRICS could eclipse the combined economies of the current richest countries of the world (First BRICS summit).

The effective and economic approach always supports to execute the planning which further enhances the options to be adopted for solving the problem by taking optimizing logistic planning into consideration for prominence of customer satisfaction. We explore the different possible variants for ship routing problem (SRP) and focusing the suitable variant which can be a best cost reduction tool in the intra shipping route optimization among all defined nodes in desired delivery time and completely utilization of ship capacity**.**

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LIST OF SYMBOLS AND ABBREVIATIONS

B	Brazil
R	Russia
I	India
C	China
S	South Africa
VRP	Vehicle Routing Problem
SRP	Ship Routing Problem
SRPTW	Ship Routing Problem with Time Windows
SRPPDTW	SRP with Pickups-Deliveries and Time Windows
SRPSD	SRP with Stochastic Demand
SDSRP	Site-Dependent or Split-Delivery SRP
FSMSRP	Fleet Size & Mix SRP
SFMP	Ship Fleet Mix Problem
HSRP	Heterogeneous SRP
HSRPTW	Heterogeneous SRPTW
MOO	Multi Objective Optimization
MOEA	Multi Objective Evolutionary Algorithms
GA	Genetic Algorithm
VEGA	Vector Evaluated Genetic Algorithm
MOGA	Multi Objective Genetic Algorithm
MACS	Multiple Ant Colony System
NDSGA	Non Dominated Sorting Genetic Algorithm
SPEA	Strength Pareto Evolutionary Algorithm
SPEA2	Strength Pareto Evolutionary Algorithm version 2
TEU	Twenty Foot Equivalent Units
NM	Nautical Mile
FEU	Forty foot equivalent unit
RORO	Roll-on/roll-off
Dwt	Deadweight tonnage
GDP	Gross domestic product

TERMINOLOGY USED

- **Shipper**: A person who contracts with liner shipping company for the transportation and is the owner of the transported cargo.
- **Cargo**: A cargo is a grouping of containers transported from origin to destination and its volume is given in TEU.
- **Transshipment**: Cargo that is unloaded in a hub and picked up by another vessel.
- **Internal transshipment:** Transshipment within the same route.
- **External transshipment:** Transshipment among different routes.
- **TEU**: It is twenty foot Equivalent Unit, basic measurement for a container size and often used to indicate volume of cargo and capacity of ships.
- **Routing**: Routing is the visiting sequencing of available ships to calling ports in order to ensure adequate cargo capacity and compatibility between the ships and the ports that they visit.
- **Scheduling**: It is associated with time chart for all ships involved to visit calling ports calls, which is published in advance in case of linear shipping.
- **Deployment**: It's a decisions regarding selecting ship from available ships for a specific route with appropriate sailing speed.
- **Fleet management**: It's a deployment of the ships in groups for defined routes regarding sequencing and scheduling perspective.
- **A service:** Providing voyages on a specific route by the collection of ships sailing on the same route.
- **A voyage:** It is single traversal of a route starting at a port which is usually one of the primary loading ports specified by the ship operator.
- **A move:** Activity of loading or unloading the cargo containers to or from a ship.
- **Slow steaming:** It is categorized is a term of slow steaming, extra slows steaming, and super slow steaming when commercial speed of a ship is more than the average speed of a voyage.

CHAPTER I

INTRODUCTION

1.1 Background

Ship routing optimization originated from term management of supply chain which encompass the linking routing and managing time (i.e. scheduling) of cargo movement to required location by cheapest mode for fulfilling users or customer's needs by prompt intra connectivity and communication between the nodes of supply chain. This also includes the activities initiated from the raw material purchasing to manufacturing operations-inventory procurement & control-warehouses management-controlled information network by full cooperation among vendors, manufacturers, distributors, retailers and end-customers. The BRICS (Brazil, Russia, India, China and South Africa) members are developing or newly industrialized countries and are distinguished by their large, fast-growing economies and significant influence on regional and global business. Grouped members representing population strength as 3 billion people and 16.6 trillion $ combined GDP, BRICS Joint Statistical Publication [1]. Initially report contributes the introductory part of above said coined term "BRICS" to unfold the key agendas based on the "broad vision and shared prosperity" or in another sense it is more balanced and includes remaining countries by extending cooperation and sharing knowledge in the area of national security, finance, agriculture, health, trade and education (BRICS Summit, 2009 Russia). According to today's economical surveys, BRICS have already secured a place because of their market opportunities and planned to achieve global stability with security and prosperity. Indeed this is creative endeavor to diffuse resources globally through enormous markets in areas of energy, environment, transport and industrial sector. These countries keep importing and exporting amongst each other to make availability of resources whenever required and satisfy the vision of summit evolving the problem statement about inventory maneuver among BRICS at appreciable total cost, which includes acquiring cost between origin city to origin port, routing cost between origin port to destination point, demurrage and detention cost by optimizing the route between the inventory pick point (left inventory) and inventory drop point (right inventory). This concept arises from the term inventory maneuver management (IMM) shows the capability and effectiveness of supply network to make decision regarding production-inventory-location-transportation-information to make flow of inventory in right direction. In the same concept our endeavors are towards trading enhancement among BRICS by optimizing sea routing to deliver the cargoes in the prescribed time window to attain the customer commitment along with the consideration of input variables, output variables, decision variables and constraints. It is quite difficult for any country to have proficiency to produce all types of required goods because of non-availability of high technology, skilled labor, and appropriate machines. Therefore connecting five countries for containers shipping through optimized route in conjunction with physical location, transportation vehicles and supporting system is mandatory chandrasekaran et al. [2]. Physical location includes supplier ports, warehouses, plants, transportation vehicles or modes are trucks, trains, containerships and supportive system includes ports management system, freight forwarders been held and 9th will hold in.

1.2 BRICS Summit Commencement detail

BRICS summit Commencement has given in table 1.1 in form of date, host country, host leader, location and participants. Total eight summits have China on dated September 3-5, 2017

Table 1.1 BRICS Summit Commencement detail

Summit	**Participant**	**Date**	**Host Country**	**Host leader**	**Location**
1st	BRIC	June 16, 2009	Russia	Medvedev	Yekaterinburg
2nd	BRIC	April 16,2010	Brazil	Lula Da Silva	Brasilia
3rd	BRICS	April 14,2011	China	Hu Jintao	Sanya
4th	BRICS	March 29,2012	India	Manmohan Singh	New Delhi
5th	BRICS	March 26-27,2013	South Africa	Jacob Zuma	Durban
6th	BRICS	July 14-16,2014	Brazil	Dilma Rousseff	Fortaleza
7th	BRICS	July 8-9, 2015	Russia	Putin	Ufa

8th	BRICS	October15-16,2016	India	Narendra Modi	Benaulim, Goa
9th	BRICS	September 3-5, 2017	China	Xi Jinping	Xiamen

1.3 Problem Definition

BRICS takes form in terms of technological, economic, commercial and social network activities expansion among countries and integration of international trade. Availability of products and services in one country and other parts of the world has become promptly accessible or procurable by using advance communication tools and techniques. Coined countries analyzed and realized the positive outcome of international economic integration and fostering this strategy to put in the ground of implementation e.g. - Inauguration of ASEAN economic community in 2015[3]. One of the most impacting force behind international integration of BRICS countries is efficient implication of logistics and distribution system for facilitating the movement of cargo or shipment from supply end to delivery end or point of origin to the point of distribution economically in terms of cost, speed and reliability.

BRICS trading integration also can be made possible through land, air and sea. The most popular land based logistics are buses, trains, trucks not flexible and efficient with respect to distance and amount of cargo they can cover and can carry per round. Long distance transition of the shipment requires remaining modes of transportation, either by air or sea. Air-based logistics are ideal for the transportation of perishable products as they are fast, secure, strictly maintained safety standard, reliable but it has limitations on sizes, weights, and high costs. Third mode of logistics are maritime transportation nearly 90% of the global cargoes are moved by shipping Christiansen et al. [4] with using different types of vessels (different speed and capacity) as per demand among BRICS as ship's capacity available in greater times larger than that of other modes of transportations. Positional view of coined members has been shown on map given below.

Figure 1.1BRICS countries location map

1.4 Research Questions

Considering the background and agendas of BRICS, this research aims to fill the gap in the field of shipping logistics integration. To be more specific, the following research questions will be answered:

1. Realizing that coined acronym (BRICS) results in real-world problem which is inherently multi-objective and carry a scope of integration in the field of liner and industrial shipping. What are the objectives on preference to be optimized that can prove the economic commercial enhancement among partners resulting from the integrative activities?

2. How such integration in (1) should be formulated into a mathematical model followed by an evolutionary algorithm?

3. What will be the key characteristics of the developed mathematical model in (2) with respect to computational complexity and sensitivity to the model parameters?

CHAPTER II

LITERATURE REVIEW

Exhaustive study based literature review is mandatory to cusp and highlight the researchers contributions in the concerned field to initiate the new developments and questing. Efforts are made towards highlighting the key objectives of previous forecasters and contributors in the related area given below.

2.1 Route Optimization

Contributions towards routing network optimization can be quested in many literatures with specific province as minimization of total cost, maximization of benefit and shortest operational time. For instance, Ioannis et al. [5] proposed a solution based approach for shortest path formulation with routing constraints to reduce the gross costs of transportation by implementation of local improvement heuristic and primal-dual algorithm for manipulation of routing constraints and providing upper and lower bounds. Iris et al. [6] classified the decision problem that arises at container terminals which results in more docking time at the port but in order to use these ships efficiently, large amount of cargo container's loading-unloading and transshipment in a least time span without using costly equipment.

Amir et al. [7] accommodated environmental variables at each node which arc logistics independent to find the shortest path from upstream to downstream by applying stochastic dynamic programming. Mabel et al. [8] notified a lacking in inter shipping followed by the vessel routing barriers with inventory constraints to minimize the transportation and inventory cost using heuristics and considered two types of routing strategies commonly used in the shipping, one is numbers of ports of demand (direct) other is transshipment (hub and spoke system), first ones can be considered as a travelling repairman and travelling salesman combined problem, other may be as one warehouse- multi retailer system for hub and spoke strategies to model the inventory cost in the system. Sanja Bauk et al. [9] proposed mathematical approach to solve hopfield-tank neural network for determining the optimal shipping route**.**

Patroklos et al. [10] analyzed the ad-hoc routing protocols and classified them in to five categories as symmetric cryptography, asymmetric cryptography, ad-on mechanism, hybrid solutions and the last one is category of reputation based solutions. Dick et al. [11] focused the supply chain management and optimization in forest industry to make wood available from forest to the miles by coordination between loggers and transporters. Further suggested that synchronizing between supplier orientation and customer orientation is mandatory to achieve supply chain optimization with integral transparency between tactical and strategic planning to execute the short term and long term forecasting. Emad et al. [12] introduced stochastic search methods (evolutionary algorithms) to achieve optimum solution based on social behavior of species and the natural biological evolution subjected to optimization which is not feasible by conventional mathematical technique and also compared the mathematical formulation and outcome of five latest algorithms: Genetic Algorithm, shuffled frog leaping, ant-colony optimization, memetic Algorithm and Particle Swarm optimization.

Koichi et al. [13] formulated two-stage problem by using Genetic Algorithm with consideration of empty containers repositioning to design liner shipping service networks. A new internet routing architecture design and evaluation has been presented by Xiaowei et al. [14] which addresses efficient route representation against route security and failover, also divided route from one end to other end in form of a source and destination address and routes are switched by switching destination. Gonullu et al. [15] used a shortest path model based on geographic information system and route view Pro software to optimize solid waste collection process to minimized cost and claimed the optimization process success was around 14-65% for time and 4-59% for distance.

Luo Junhai et al. [16] presented the classification of multiclass routing protocols with their properties and design features, which is helpful for mobile ad-hoc network researchers in their work. Lector Vaidotas [17] implemented route optimization in municipal solid waste management to reduce empty miles and total expenditures. Zhongzhen Yang et al. [18] covered a new kind of vessels (ships) network that consists of trunk-feeder lines with bi-level programming concept to minimize the transportation cost by optimizing containers shipping network. C.Chitra et al. [19] explored the use of [NDSGA] non-dominated sorting Genetic algorithm for solving the shortest route problem including service quality parameters like delivery time and cost reduction and further focusing the ability of multicast evolutionary algorithms to obtain multiple pareto

–optimal solution in running ones for solving multiple conflicting objectives with the use of NDSGA approach.

Rakesh Kumar et al. [20] implemented GA to achieve the group of optimal routes to transport traffic from one end to required destination with consideration of static and dynamic routing. If the routes between the nodes are pre-computed based on certain factors is known as static routing and when network sequence changes, dynamic routing is used. P. Calduwel newton et al. [21] identified and classified the route optimization mechanism and selected suitable RO protocol to enhance the quality of internet applications. Ming et al. [22] achieved the objectives such as warning and pre-collision preparation for collision avoidance by using the concept of e-navigation and ACO in the area of artificial intelligence for constructing a collision free model that performs optimization behavior in practical application.

Payman Jula et al. [23] proposed the least cost strategy in supply chain optimization of importers of water borne containers from one end to another that includes costs for material handling, transportation, safety stock and pipeline inventory by using MINLP. Khaled et al. [24] included constraints as time windows imposed by end-users, ship capacities for loading shipment problem and proposed a prominent variant of GA for ship scheduling and routing problem for comparing the exact method with proposed algorithm which combine the use of SPP [set partitioning problem] in manner of computational time and quality of solution.

A system has been introduced by Saluka et al. [25] for planning routes for containers carriers in an optimal manner by using Artificial intelligence which takes initially the starting point and the destination point specified by the users and then find the best suitable track to reach its goal destination avoiding all possible obstacles. P. Oddo et al. [26] used a modified Dijkstra algorithm for recovering shortest path in operational ship routing with time dependent oceanographic field by presenting a prototype for decision support system. J. Szlapczynska [27] outlines the commercial application of weather routing multi criteria evolutionary algorithm and discusses the benefits of utilizing pareto front in case of route finding. Cesar et al. [28] attempts to synthesize a number of contributions that is limited to the level of inter-urban linkage with theoretical and mathematical problems to model the framework and discuss the dynamics of a system of cities followed by a review of how urban and logistical elements have been integrated in more dynamical studies of networks.

Sopnamayee Acharya [29] implemented mathematical model and optimization based algorithm for solving vehicle routing problem and allocation of shipments to vehicle to minimize the total distance as the main objective with time window that imposes the customer availability as a constraint. Maria et al. [30] provided a design of global supply chain system that identifies the optimal production allocation capacity and the optimal port of entry towards sustainability related issues by quantitative strategic decision support methodology. Hyun et al. [31] focused the inter multimodal transport to link one or more adjoining countries for delivering and trading the containers cargos with delivery commitment followed by minimum transit time and costs and considered the economic standard vary from country to country which can affect the routes performance due to poor interconnections and interoperability and legal formalities during delivering cargos. In addition to this, Hyun used Fuzzy-AHP for the systematic analysis to propose a decision-aid tool to execute decision support system.

Srecko et al. [32] developed an algorithm for transport planning on a voyage route with multiple loading and unloading ports and named it minimum cost multi commodity flow problem (MCMCF) and this algorithm is also applicable to find appropriate load planning sequence to ensure minimal loading and unloading transshipment cost with fulfillment of cargo demands to concerned ports on the voyage route. Martins et al. [33] proposed a logistics model for short sea shipping routing problem that reduces costs substantially by increasing flexibility to overcome the challenges as optimal route selection, optimal distribution and stowage plan of cargo using Genetic Algorithm.

Chandrasekaran et al. [34] proposed mathematical model implemented by GA with constraints like inventory balancing, capacity and demand at various links to represent a dynamic of single product being produced out of three components, three suppliers, two processing plants, three distribution centers and six retailers. Hariloos N. et al. [35] exercised on costs incurred during liner shipping and tried to identify key performing variables and their impact on costs which are bunker costs, route distance, speed, port time and ship size.

2.2 Loading Unloading Optimization

Mads K et al. [36] proposed a model that emphasizes on shipping capacity, cost effectiveness and environmentally conscious transport solutions with consideration of vehicle routing problem using dynamic programming. Xueping Wang et al. [37] used algorithm in the mathematical model for solving the decision-making paradigm of unloading and loading line equipment, also provided the scientific and technical platform for the multistage decision towards equipments selection. Liu Aizhen et al. [38] built the mathematical model with bi-objective of cost and loading time based on Genetic Algorithm to get the optimal balance between loading time and cost of missiles.

Rao Pino et al. [39] implemented GA to increase the cargo shipment capacity with loading restrictions to achieve a reduction in costs. D.Aprile et al. [40] developed methodology for vessel routing problem with unloading and loading constraints using Simulated Annealing. Richa et al. [41] presented integrated mathematical model with MILP for solving ship routing and scheduling problem with two or more service route, weekly frequency, transshipment of cargo as service constraints.

2.3 Supply Chain Integration

Marcos Fava et al. [42] discussed the supply chain transaction mainly between fruit growers and processing industry with consideration of cost economic approach. Rodney et al. [43] served an integrated business process model for optimizing global supply chain network efficiency which highlights the importance of communication between processes and partners in the supply chain for gaining competitive advantage. Markham et al. [44] provided customer integration strategies towards performance improvement by characterizing each as an arc of integration with customers and suppliers.

Togar et al. [45] established a comprehensive taxonomy of coordination modes which are logistics synchronization, information sharing, collective learning and incentive alignment to have positive impacts on supply chain performance. Chong Liu et al. [46] optimized the size and spatial distribution of city logistics terminals with location model by using Genetic Algorithm to minimize the total freight transportation cost in the city. A. Gunasekaran et al. [47] explored the importance and objectives of build-to-order supply chain management strategy in improving the competitiveness of an organization and meeting individual customer requirements by leveraging the advantage of outsourcing and information technology. Luiz et al. [48] analyzed the literature concerning reference models that operate different information system for the effective supply chain decision (the vertical axis) and supply chain business processes (the horizontal axis).

Peter Trkman et al. [49] combined the utilization of information technology and business process modeling for improving supply chain performance followed by simulation methodology. Taco Van et al. [50] explored the supply chain integration with buyer–supplier relationship and examined the impact of this relationship on supply chain performance. Kevin et al. [51] investigated the relationship between supply chain maturity and performance by presenting the main empirical contributions through the use of the business process maturity model and supply chain operation reference model. Jonas et al. [52] illustrated the relationship and mutual influence of logistics and supply chain management towards industrial structural changes like product design, deal and setup of new productive chain, lean manufacturing adoption. Hussain et al. [53] enhanced supply chain management performance by combining supply chain integration challenges in one source and in the same year Mohammad Othman Nassar et al. [54] further contributed delivering and classification of supply chain integration challenges in an organized manner.

James A et al. [55] applied porter's Diamond framework to assess the strength and weaknesses of the processed citrus industry in each country to confront the combined challenge of effectively combating the effects with maintaining market competitiveness. Rana Basu et al [56] prioritized the risk factors in context to supply chain management in Indian manufacturing organization to mitigate the risk issues for smooth operation of supply chain. Haresh et al. [57] investigated strategies for dealing the types and management of risks faced within the supply chain and resulted from rapid development in science and technology, organizational changes, raw material shortage and short product life.

Chaman Singh et al. [58] introduced expression for the average inventory cost in crisp and fuzzy sense. Waldermiro et al [59] exposed the two bottlenecks in the Brazilian industrial sector one is emphasis on coordination rather than integration in supply chain management and other is insufficient channel of communication between private and public sectors. Jawahar Babu [60] integrated the entire supply chain and managed it as a single entity inbound logistics and identified key challenge involved in supply chain and made effort to reduce operating cost, lead time and inventory cost to grab the growth in the world. Natalia Volgina [61] provided an overview of the major trends taking place in Russian industries with a special emphasis towards localization of foreign manufacturers and vertical specialization of Russian original equipment supplier.

2.4 Logistic Management

Markus et al. [62] considered the logistics as a core component of transport geography to overview of the freight distribution of an integrated demand in connection to traditional perspective**.** Khalid Bichou et al. [63] suggested a relevant framework of conceptualizing ports performance through logistics and supply chain management approach. Hajnal et al. [64] implemented discrete event simulation software to carry optimization in a food distribution centre by introducing variables, equations, and network of process. Michelle et al. [65] proposed one tactic to get best logistics performance to establish consolidation hubs that collect shipments from several vendors and further distribute to manufacturing plants with the help of network design concept and integer linear optimization model.

Patrik et al. [66] Conducted data based analysis in Nordic countries to report and reflect the characteristics of academic discipline concerned with logistics and supply chain management. Nathalie Fabbe [67] analyzed the fundamental platform for logistics and supply chain management by providing link between supply chain integration and performance. Khalid et al. [68] used Ant colony algorithm in optimizing fleet routing of an actual international courier business willing to enhance quality of service delivered and to reduce its cost. Eric Wibisono [69] proposed multi-objective ship routing problem in maritime logistics by considering fixed cost, variable cost and implementing Meta-heuristic approach towards distribution of profit to both ocean carriers. Hui Li et al. [70] implemented Genetic Algorithm in optimization of logistics strategy with two business models, firstly traditional disintegrated and secondly load logistics partner integrated. Sayedyaser Bozorgirad et al. [71] proposed route based Genetic Algorithms to minimize cost of multi product-multi source flexible logistics networks.

Sahidah Zakariah et al. [72] focused challenges of logistics management based on content analysis (at macro level) and survey analysis (at micro level). Okan et al. [73]

presented extensive review based on current state and future of shipping logistics and explored major topics as maritime policies, transport networks, ship management and logistics research. Sae-Yeon et al. [74] considered application of multi-criteria location problem for making humanitarian relief organization with integration of national stability, cost, logistics and location by pre-positioning of warehouses. Harsh et al. [75] optimized warehousing and transportation requirement of integrated logistics management which does not guarantee low cost but assures overall reduction in per unit cost. Paulo et al. [76] considered the cargo distribution and delivery deadlines to improve short sea shipping flexibility by logistics mathematical model that determines the port visiting sequence, containers to stow and embark on board.

2.5 Supply Chain Optimization

Ruth Banomyong [77] discussed the issue of containers security initiative in supply chains and its impact in financing implications. Fashima et al. [78] integrated the previous production- distribution model with aggregate production and distribution plan and solved by mixed integer linear programming. E.Silarbi et al. [79] formulated a mathematical model to minimize cost and time in executing and delivering the customer's orders with considerations of constraints such as suppliers and manufacturers capacity along the whole supply chain process.

Zhen et al. [80] focused on mathematical model based on particle swarm optimization for reverse and forward logistical strategies in multi stage system. Joseph et al.[81] implemented optimization technique in route selection within the given supply nodes to facilitate the third party logistics provider to minimize the total cost of transportations and inventory along with customer requirement fulfillment. Rajeshwar [82] implemented particle swarm optimization to optimize four stages supply chain structure, which includes vendors, manufacturing plants, warehouses and distribution centers with the help of a tactical level model that considers an integrated, multi component, multistage, single product and procurement–production-distribution system design problem.

2.6 Vehicle routing problem

Marielle et al. [83] proposed robust schedule to minimize ship staying idle time in ports at the end of week also suggesting a penalty for ships arriving at close to weekends. Lief et al. [84] used integer Programming with branch and bound method (BBM) to solve vessel scheduling task by branching essential fractional variables and bounds are obtained by using decomposition algorithm. Dusan et al. [85] implemented Fuzzy logics system in solving traffic and transportation problem and analyzed the result achieved. David et al. [86] compiled the contribution made by researchers in last decade in area of ship scheduling and routing problems. Harilaos et al. [87] developed a vehicle routing and scheduling problem based algorithm with time window as constraints.

Si-Hwa et al. [88] considered ship routing and scheduling problem optimization solved by decision support system. Katarina et al. [89] developed feasibility dispatch decision support system to determine the work stress for the dispatcher and improving the quality prompt decision. Fagerholt et al. [90] presented an approach considering of two phase ship scheduling and allocation problem to minimize the transportation cost by using set portioning approach. Leif et al. [91] described algorithm for solving ship scheduling problem by using linear programming and network flow problems by dynamic programming. Marielle et al. [92] presented an optimization based solution for combined multi-inventory model with MVPDP with time window. Dano Bausch et al. [93] spread sheet interface followed by optimization based decision support system along with an integer linear set portioning model to complete loading and deliveries at minimum cost.

Louis et al. [94] presented pruning and propagation technique based on constraint programming to allow an efficient search of problem to avoid local minima in VRP. Zbigniew j.et al. [95] solved vehicle routing problem by using parallel SA algorithm with objective of the best route finding in minimum time. Shih- Wei et al. [96] considered the simulated annealing as a heuristic to solve the VRP with time window and belongs to class of NP- hard problems also concluded that SA produces high quality solutions with minimum time. Petrica et al. [97] implemented integer programming in vehicle routing problem to provide node and flow formulation to produce a stronger lower bound and total routing time.

R. Nallusamy et al. [98] converted MVRP in to VRP by using clustering algorithm and Genetic algorithm to obtain most optimal value and concluded that GA is best heuristic due to constructive nature and extensive search. A. Bachem et al. [99]

presented simulated trading approach with additional constraints to solve vehicle routing problem. Marcin et al. [100] solved routing problem with very high quality solutions by using simulated annealing algorithm with conclusion that SA can be applied to bi-criterion optimization problems. Jean Berger et al. [101] introduces systematic diversification for routing problem where objective is to design least cost routes for a vehicle from one loading node to another unloading node.

Wujun Cao et al. [102] also conducted analysis and surveying for constraints based classification of the vehicle routing problem. Abbassi Abderrahman et al. [103] implemented Ant colony optimization in vehicle routing problem to minimize cost of transportation with penalties reduction.

Jin Qin et al. [104] minimized the cost of transportation and penalties in vehicle routing problem by implementing Genetic Algorithm. Suresh Nanda et al. [105] focused Genetic Algorithm in vehicle routing problem to minimize cost of transportation by reducing travel time and distance. Baldacci et al. [106] accommodated exact algorithm to explore the impact of same on vehicle routing problem.

2.7 Literature Review based on objective and solution method: Objectives, problem type and solution methods implemented by researchers have been tabulated below, which supports in selecting the segment carried out further for work being done.

Table 2.1 Researcher’s objective and solution method

Researchers Name	Year	Problem Type	Objective	Solution Method
Ioannis, Warren	1992	Shortest Path Formulation	Transportation cost minimization	Local improvement heuristic + primal-dual algorithm
A. Bachem, M. Malich, W. Hochstattler	1992	Vehicle routing problem	Minimization of routing cost	Simulated Trading
David Ronen	1993	Ship scheduling problem	Economic routing	Literature survey
Harilaos N, Thomas L, Marius M	1996	Single vehicle routing problem	Minimization of completion time	Dynamic programming
Katarina Vukadinovi,	1997	Loading and	Minimization of	Decision support

Duan Teodorovi		unloading problem	loading and unloading	system
Si-Hwa Kim, Kyung Keun Lee	1997	Ship scheduling	Minimization of empty running of ship	Decision support system
Marielle Christiansen, Kjetil Fagerholt	1998	Ship scheduling problem	Minimization of routing cost	Mathematical programming
Paul Shaw	1998	Vehicle routing problem	Minimization of routing cost	Large neighborhood search
Dan O. Bausch, Gerald G. Brown	1998	Loading and distribution problem	Cost minimization	Set portioning approach
Mark R. McCord, Young Kyun	1999	Ship Routing problem	Reduction in fuel cost	Dynamic programming
Dusan Teodrovic	1999	Transportation problem	Minimization of time	Fuzzy logics
Patrick Prosser, Philip Kilby	2000	Vehicle routing problem	Minimization of routing cost	Tabu search
K Fagerholt, M. Christiansen	2000	Ship scheduling	Cost minimization	Set portioning approach
Rodney McAdam, Daniel McCormack	2001	Supply chain integration	Business process and supply chain integration	Conceptual framework
K.C.Tan, L.H. Lee	2001	Vehicle routing problem	Minimization of routing cost	Simulated annealing
Markham. T. Frohlich, Roy Westbrook	2001	Supply chain integration	Improved customers and suppliers relations	Global based survey of manufacturers
Ruey-Min Wang, Chlin-Hao Chen	2001	Air Freight network problem	Transportation cost minimization	Mathematical programming
Zbigniew J. Czech, Piotr Czarnas	2001	Vehicle routing problem	Minimization of time	Simulated annealing algorithm
Togar M. Simatupang, Alan C. Wright	2002	Coordination modes integration in supply chain	Improved supply chain integration	Conceptual framework
Olli Braysy	2002	Vehicle routing problem	Minimization of routing cost	Tabu search
Marielle Christiansen, Kjetil Fagerholt	2002	Ship scheduling problem	Minimization of idle time at port	Set partitioning approach

Sin C. Ho, Dag Haugland	2002	Vehicle routing problem	Minimization of routing cost	Tabu search
Hua-An Lu	2002	Ship's routing problem	Cost minimization	A mixed integer programming
Serdo kos, Zdenka zenzerovic	2003	Cargo shipment problem	Maximizing profit	Linear programming
Hoong Chuin Lau, Melvyn Sim, Kwong Meng Teo	2003	Vehicle routing problem	Minimization of routing cost	Tabu search
Iris F.A. Vis, Rene de Koster	2003	Containers Transshipment	Minimization of docking time	Automatic guided vehicle
ValentinaCarbone, Marcella Martino	2003	Supply chain and port integration	Improved supply chain and port management	Survey based analysis
Amir Azaron, Farhad Kianfar	2003	Shortest Path Formulation	Transportation Cost Minimization	Stochastic dynamic programming
Mabel Chou, MiaoSong, Chung Piaw	2003	Shipping Routing Problem	Transportation Cost minimization	Heuristics
Haibing Li, Andrew Lim	2003	Vehicle routing problem	Cost minimization	Simulated annealing
Russell Bent, Pascal Van Hentenryck	2004	Vehicle routing problem	Minimize No. of vehicle and cost	Simulated annealing
Sanja Bauk, Natasa Kova	2004	Shipping Routing Problem	Transportation Cost minimization	Mathematical approach
Markus Hesse , Jean-Paul Rodrigue	2004	Logistics and distribution	Transportation Cost minimization	Survey based analysis
Khalid Bichou, Richard Gray	2004	Supply chain and Logistics problem	Supply chain performance improvement	Survey based analysis
Ruth Banomyong	2005	Trade security and port's impact of on SCM	Screening of ports sending containers	Survey based analysis
Chong Liu, Zhongzhen Yang	2005	Cargo Distribution problem	Transportation cost	Genetic algorithm
David Mestera, Olli Braysy	2005	Vehicle routing problems	Cost minimization	Evolution strategies + Guided local search

David Pisinger, Stefan Ropke	2005	Vehicle routing problems	Solving five different variants of VRP	Adaptive large neighborhood search
Peter Trkman, Mojca Indihar Stemberger	2007	Supply chain integration	Supply chain performance improvement	Simulation-based methodology
Koichi Shintai	2007	Liner shipping service networks	Transportation cost minimization	Genetic algorithm
O. Apaydin, M. T. Gonullu	2007	Shortest Path problem	Cost minimization	Route view Pro software
Jean Yves Potvin	2007	Survey of vehicle routing algorithm	Comparison of GA, PSO	Literature survey
Jean-Yves Potvin, Samy Bengio	2007	Vehicle routing problem	Cost Minimization	Genetic algorithm
E. Hajnal,G. Almasy, K. Kollar Hunek	2007	Food distribution planning	Minimization of time	Discrete event simulation software
Michellel L.F. Cheong, Rohit Bhatnagar	2007	Shipments acquiring and Distribution problem	Minimization of time	Network design concept and integer linear optimization
Teodor Grabiel Crainic	2007	Vehicle routing problem	Cost minimization	Branch and bound
D. Aprile, J. Egeblad, A.C. Garavelli	2007	Vehicle routing problem	Cost minimization	Simulated annealing
L. Guerra, T. Murino	2007	Facility location and Vehicle routing problem	Cost minimization	Heuristics algorithm
B. Fahimnia, L. Luong	2008	Two stage supply chain network	Cost minimization	Mixed integer linear programming
Taco vander Vaart, Dirk Pieter	2008	Integrated supply chain	Supply chain performance improvement	Survey based analysis
John Johansen, Patrik Jonsson	2008	Supply chain and Logistics problem	Supply chain performance improvement	Questionnaire based survey
Marianne Jahre, Nathalie Fabbe	2008	Integrated supply chain	Supply chain performance improvement	Survey based analysis

Hisafumi Kokubugata	2008	Vehicle routing problem	Cost minimization	Simulated annealing
Khalid Moussaid, Mohamed Azouazi	2009	Fleet routing problem	Cost minimization	Ant colony algorithm
R. Nallusamy, K. Duraiswamy	2009	Multiple Vehicle routing Problem	Cost minimization	Genetic Algorithm
R. Nallusamy, K. Duraiswamy	2009	Vehicle routing problem	Cost minimization	Genetic Algorithm
Marcin Woch, Piotr Lebkowski	2009	Vehicle routing problem	Cost minimization	Simulated annealing
J.Brito, J.A Moreno	2009	Vehicle routing problem	Cost minimization	Fuzzy logics
Mohammad Othman, Hussain A.H Awad	2010	Supply chain integration	Integrate challenges to one source	Conceptual approach
Mohammad Othman, Hussain A.H Awad	2010	Integrated supply chain	New approach of Integration challenges	Conceptual approach
C. Chitra, P. Subbaraj	2010	Shortest route problem	Cost minimization	Genetic algorithms
Rakesh Kumar, Mahesh Kumar	2010	Static and dynamic routing	Cost minimization	Genetic algorithms
P. Calduwel Newton, L. Arockiam	2010	Mobile network Routing optimization	Quality of service	Linear programming
Zhongzhen Yang	2010	Shipping network	Cost minimization	Genetic algorithm
Qinghai Bai	2010	Analysis of a Heuristics	Improved version of PSO	Research based analysis
Shaohan Cai, Minjoon Jun , Zhilin Yang	2010	Supply chain integration among buyers and suppliers	Improved buyers and suppliers integration	Research based Analysis
Ming-Cheng Tsou, Chao-Kuang Hsueh	2010	Path planning for collision avoidance	Collision minimization	Ant colony algorithm
Radha Gupta, Bijendra Singh	2010	Vehicle routing problem	Transportation costs	Fuzzy logics + Genetic algorithm
Masaya Yoshikawa, Kazuo Otani	2010	Vehicle routing problem	Cost minimization	Ant Colony algorithm+ Tabu Search

H. Nazif, L.S. Lee	2010	Vehicle routing problem	Cost minimization	Genetic algorithm
Payman Jula , Robert C. Leachman	2011	Containerized goods routing	Transportation and handling cost	Mixed integer non-linear programming
Mingwang Dong, Lei Wu, Xueping Wang	2011	Loading and unloading	Optimal unloading and loading	Fuzzy dynamic programming Algorithm
Mads K Jepsen, Berit Loftstedt, Christian E.M. Plum	2011	Vehicle routing problem	Cost minimization	Dynamic programming
Dian Palupi Rini, Siti Mariyam Shamsuddin	2011	Detailed review of PSO	Improved version of PSO	Research based analysis
Chaman Singh, S.R. Singh	2011	Supply chain network	Cost minimization	Fuzzy logics
Mu Mu Han, Lin Guolong, Yang Bin	2011	Short sea Shipping problem	Cost minimization	Linear programming
Farzaneh Amiri Fard, Mostafa Setak	2011	Vehicle routing problem	Minimum distribution time	Tabu Search, Simulated Annealing
Bozorgirad, Mohammed Ishak Desa	2012	Logistics networks problem	Cost Minimization	Genetic Algorithm
Zhen-Hua Che, Tzu A Chiang	2012	Logistics networks problem	Cost minimization	Particle swarm optimization
Khaled Al-Hamad, Mohamed Al-Ibrahim	2012	Ship routing and scheduling problem	Cost minimization	Genetic algorithms + Set partitioning approach
Saluka Kodithuwakku	2012	Ship route planning	Cost minimization	Artificial intelligence
Hui Li, Zhaofang Mao	2012	Logistic between supplier and manufacturers	Transportation cost	Genetic algorithm
E. Ait silarbi, A.Bekrard	2012	Supply chain network	Time and cost minimization	Mathematical approach
Claudine Jordao de Carvalho	2012	Logistics management problem	Improved logistics	Survey based analysis
Petrica C. Pop, Imdat	2012	Vehicle routing	Minimization of time	Integer programming

Kara		problem		
Abhishek Toofani	2012	Vehicle routing problem	Cost minimization	Particle swarm optimization
Elena Simona Nicoara	2012	Population based meta-heuristics	Comparison of Population based meta-heuristics	Comparative analysis
Voratas Kachitvichyanukul	2012	Evolutionary algorithms	Comparison of evolutionary algorithms	Comparative analysis
Anu Chaudhary, Neeraj Kumar	2012	Shortest path problem	Cost minimization	Genetic algorithm
Reza Tavakkoli Moghaddam, Amir Mohmmad	2012	Vehicle routing problem	Cost minimization	Particle swarm optimization
Siva Prasad Darla, C. D. Naiju	2012	Two stage transportation supply chain problem	Cost minimization	Particle swarm optimization+ Genetic algorithm
P. Oddo, N. Pinardi, G. Mannarini	2013	Shortest path planning	Minimization of time	Dijkstra algorithm
J. Szlapczynska	2013	Route Finding	Minimization of time	Multi criteria evolutionary algorithm
Sopnamayee Acharya	2013	Vehicle routing problem	Minimization of distance	Mixed integer non-linear programming
Gonzalo Romero, Guillermo Duran	2013	Ship routing problem	Cost minimization	Greedy randomized adaptive search procedure
Liu Ai-Zhen, Chen Li-Yun, Wang Yin-long	2013	Loading and unloading of Missiles	Minimization of time and cost	Genetic algorithm
Ana Moura, Jorge Oliveira	2013	Ship routing problem	Cost minimization	A mixed integer programming
Raul Pino, Alberto Gomez, Jose Parreno	2013	Loading and unloading of containers	Cost minimization	Genetic algorithm
Junyang Li, Xiaomin Zhu	2013	Logistic management between warehouses & ports	Minimizing operation cost	Genetic Algorithm + Game theory

Rajeshwar. S. Kadadevaramath	2013	Four stages supply chain Problem	Cost minimization	Particle swarm optimization
Sahidah Zakariah, Jaafar Pyeman	2013	Logistics management challenges	Improved logistics performance	Survey based analysis
Sandhya and V.Katiyar	2014	Vehicle routing problem	Transportation costs	Fuzzy and Ant colony algorithm
Suresh Nanda Kumar, Ramasamy	2016	Vehicle routing problem	Minimization of Distance and travel time	Genetic algorithm
Wujun Cao , Wenshui Yang	2016	Vehicle routing problem	Classification of VRP and constraints of VRP	Analysis and surveying
Jin Qin , Yong Ye, Bi-Rong Cheng	2017	Vehicle routing problem	Minimize the costs of transport and penalties	Genetic algorithm
Abbassi Abderrahman	2017	Vehicle routing problem	Minimize the costs of transport and penalties	Ant colony optimization

2.8 Research Gap Identification

Based on literature review, following research gaps have been identified.

(i) Intra- shipping logistics integration and optimization has not been considered.

(ii) Liner and industrial shipping was not considered together.

(iii) Homogenous, heterogeneous combined fleet in ship routing problem with time window (SRPTW) not accounted for.

(iv) Acquisition, routing, distribution, detention and demurrage costs were not included simultaneously.

All the above four points are associated in a way or the other are measured in term of the cost, hence the mathematical model has been framed in term of cost.

2.9 Problem Description

Intra-shipping route optimization among BRICS is a void which initiates the problem title HHSRPTW (homogenous and heterogeneous ship routing problem with time window) is logistics service integration among origin and destination nodes by using combined homogeneous and heterogeneous fleets of ships for pick-up and deliveries at minimum possible cost. In liner shipping frequency is fixed to fix the demand shipped in containers of several sizes as TEUs (Twenty foot equivalent unit) and FEUs (Forty foot equivalent unit) and one FEU is equivalent to two TEUs. The liner shipping logistics companies uses number of moves which is activity of unloading or loading a container to estimate the cost of unloading, loadings and transshipment based on the time spent. Shipping logistics service provider has a proportionate ratio between TEU and FEU, which is used to estimate the time consumption and transshipment cost per TEU. The time consumption per TEU depends on the port ground handling capabilities and the vessel type to accommodate many cranes simultaneously.

Vessels involved are never supposed to be empty in liner shipping and routes are in circular manner and are allocated to single route which it sails continuously. All loaded containers in a port can be unloaded at other port which is on same route and relevant information between ships and ports is required to confirm that port can entertain the ships calling and availability of resources like cranes in ports and cities of BRICS network which includes transportation between origin city and ports, destination city and ports by hinterlands (Trucks and Trains). Port to port is carried out by ships and has been shown in fig.2.1

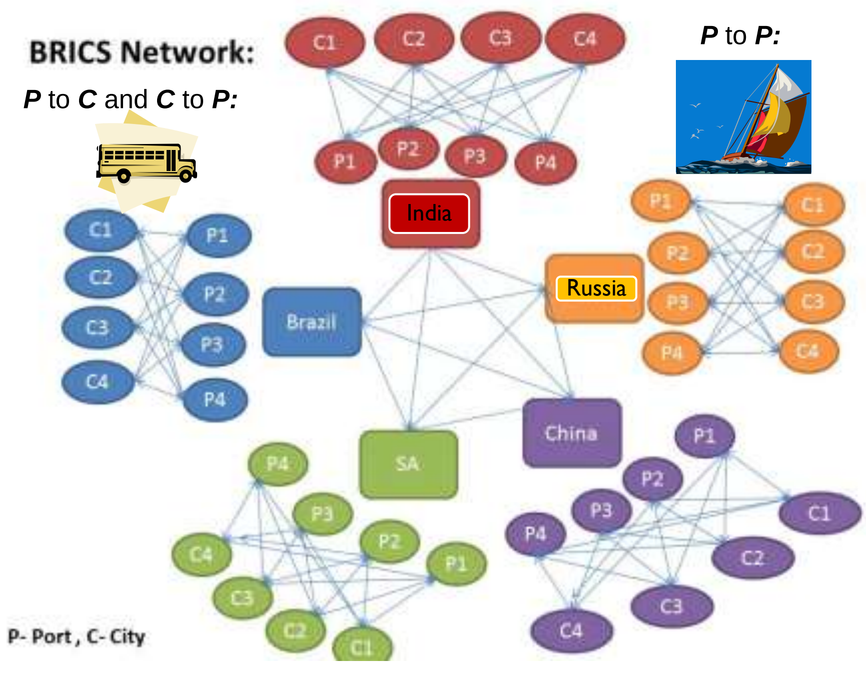

Fig.2.1 BRICS Network

2.9 Research Objectives

Minimization of Transportation cost: The goal of the model formulation is to minimizing the total cost of transportation among BRICS by obtaining the optimal routes followed by three types of costs.

• **Acquisition cost-**From origin city to origin port.

• **Routing cost**-Sailing cost from port to port, this is 60% of the total ship operating costs, (Marie Ameln et.al, 2015)

• **Distribution cost-**From destination port to destination city.

b) **Minimization of penalties:** Include the sum of demurrage (charged by port) and detention (charged by ocean carriers) costs, arising from earliness and tardiness in ship's arrival at ports with respect to the delivery deadlines of customers and also for not picking loaded containers and returning empty containers back.

CHAPTER III

RESEARCH METHODOLOGY

Chapter explores the research methodology includes structural framework to show the way, how the inputs and outputs are combined and linked together in a systematic approach to form an optimal view. Further Research stages to elaborate and detailing the planned approach step-by-step following the parameters schematic for mathematical model to introduce the concept and scope of the research to be conducted i.e. maritime logistics integration.

3.1 Research Framework

In previous chapter, an exhaustive literature survey has been conducted based on a number of segments in the area of shipping logistics, supply chain management, ship route optimization, supply chain integration, loading and unloading optimization and its variants. Initially the supply chain integration initiates the problem that is ship routing problem. Considering further shipping logistics to perform linear, industrial shipping together and problem becomes ship routing problem with time window. Proceeding ahead towards BRICS integration with multi objective optimization, title becomes HHSPRTW and implementing GA to achieve final research outcome.

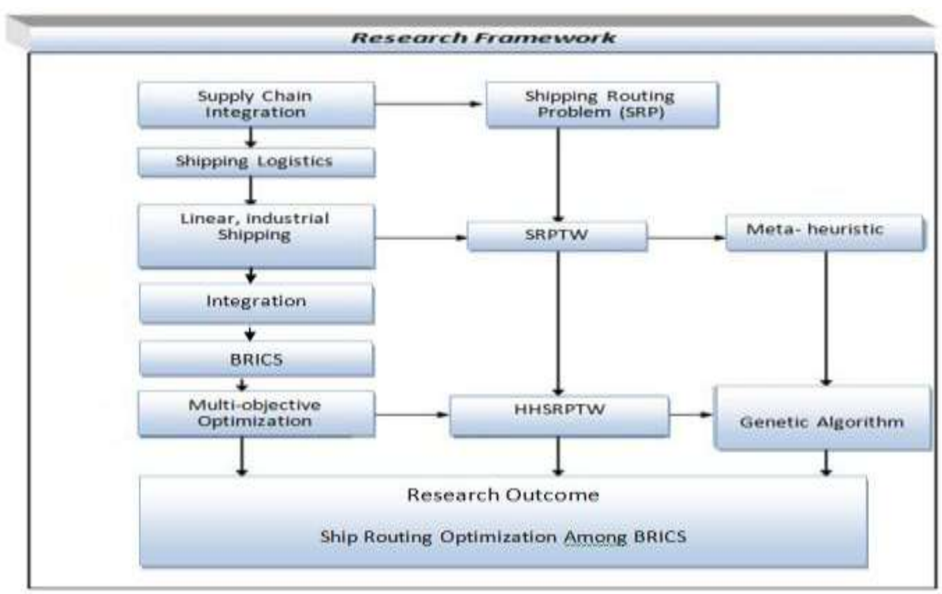

Figure 3.1 Research framework

3.2 Research Stages

These stages are sequence in which problem flows in manner of scope definition which can sustain the research potential and further detailed exhaustive literature review is carried out based on the work done by previous researcher and motivates towards structuring the problem definition, data collection and formulation of mathematical model for homogenous and heterogeneous SRPTW and applying optimization technique (GA) followed by results in MATLAB.

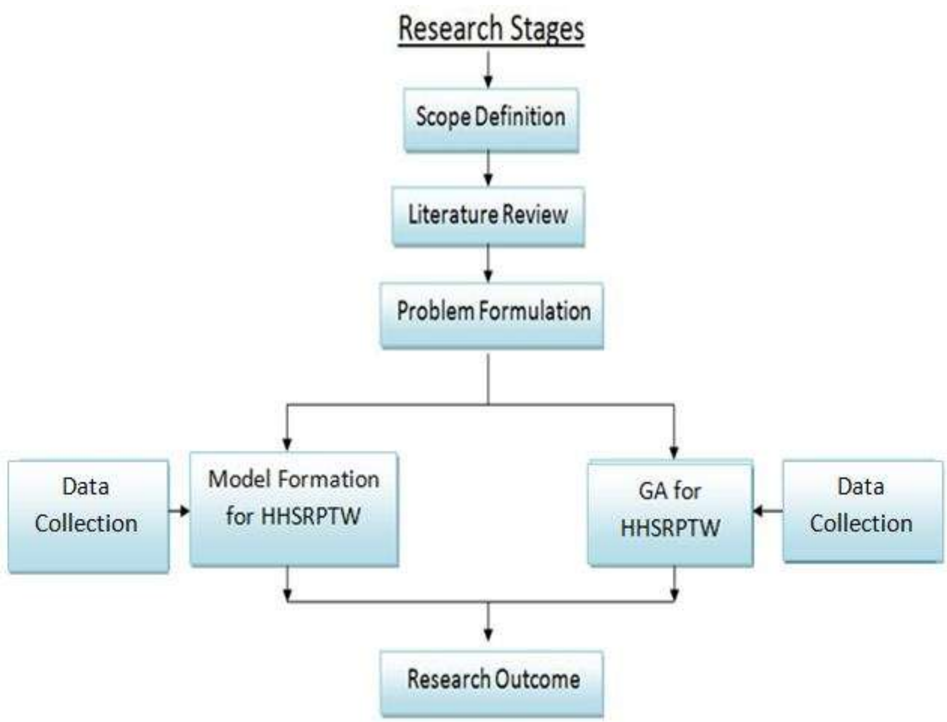

Figure 3.2 Research stages

3.3 Parameters Schematic for model

Model shows the list of operators (ocean carriers) require information regarding vessel speed, BRICS ports, distance data base, vessel capacity, demand and due dates (min & max), further distance data base relates to shipping cost and delivery time which are objective function parameters depends on vessel speed.

Parameters Schematic For Model

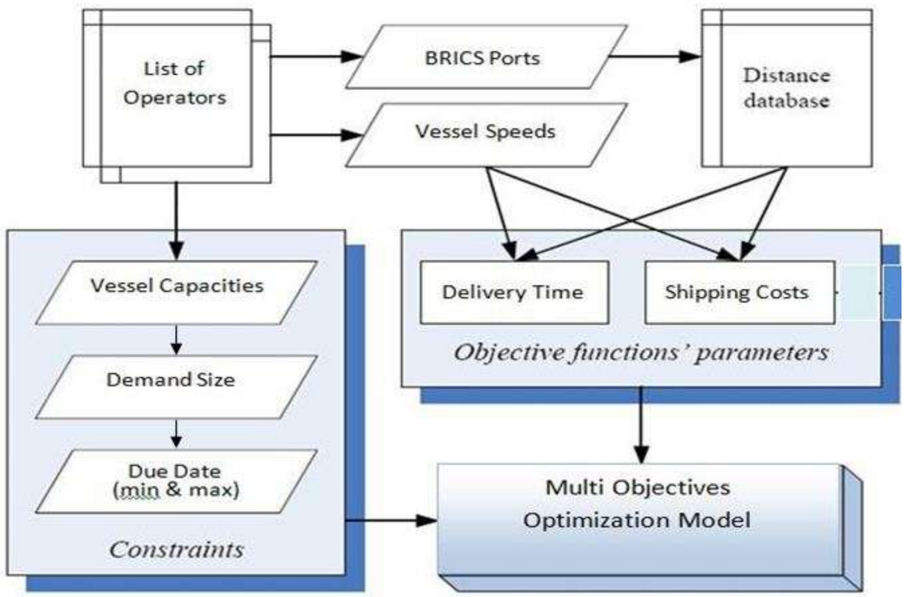

Figure 3.3 Parameters Schematic for model

3.4 Data collection: Tables positioned below provide distance between ports of BRICS and distance among individual country's ports and cities and utilized in executing programmed model.

Table 3.1 Port to Port Distance Between BRICS Countries in KM

DATA COLLECTION (Port to Port Distance Between BRICS Countries in km**)**					
From	To	C1-Zhanjiang	C2-Bahezhen	C3-Port of Xiamen	C4-Port of Tianjin
Belem B1		13674	12792	14226	15509
Fortaleza B2		12934	14559	13497	14780
Paranagua B3		12169	13059	12702	13985
Recife B4		11979	14181	13119	14401
From	To	R1-Kaliningrad	R2-Poronaysk	R3-Azov	R4-Naryan-Mar
Belem B1		6723	16693	7276	8221
Fortaleza B2		6282	15964	6836	7780
Paranagua B3		7957	15179	8510	9455
Recife B4		6319	15565	6871	7815
From	To	S1-Cape town	S2-Port Elizabeth	S3-East London	S4-Richard Bay
Belem B1		5505	5954	6093	6423

Fortaleza B2		4755	5204	5344	5673
Paranagua B3		3970	4419	4559	4888
Recife B4		4377	4826	4965	5295
From	To	I1-Mumbai	I2-Vishakhapatnam	I3-Chennai	I4-Cochin
Belem B1		9915	11110	10690	10101
Fortaleza B2		9475	10861	10250	9661
Paranagua B3		9518	10076	9756	9298
Recife B4		9510	10483	10163	9705
From	To	C1-Zhanjiang	C2-Bahezhen	C3-Port of Xiamen	C4-Port of Tianjin
Kaliningrad R1		11929	13534	12472	13755
Poronaysk R2		3153	2418	2540	2312
Azov R3		8969	10574	9511	10794
Naryan-Mar R4		13421	15026	13963	15247
From	To	S1-Cape town	S2-Port Elizabeth	S3-East London	S4-Richard Bay
Kaliningrad R1		8334	8783	8922	9250
Poronaysk R2		11186	10737	10598	10269
Azov R3		7862	7413	7273	6944
Naryan-Mar R4		9825	10275	10414	10743
From	To	I1-Mumbai	I2-Vishakhapatnam	I3-Chennai	I4-Cochin
Kaliningrad R1		8183	9378	8958	8368
Poronaysk R2		7224	6597	6478	6633
Azov R3		5222	6417	5998	5408
Naryan-Mar R4		9675	10870	10451	9761
From	To	C1-Zhanjiang	C2-Bahezhen	C3-Port of Xiamen	C4-Port of Tianjin
Mumbai I1		4213	5819	4757	6040
Vishakhapatnam I2		3594	5200	4138	5420
Chennai I3		3467	5073	4011	5294
Cochin I4		3623	5229	4167	5450
From	To	S1-Cape town	S2-Port Elizabeth	S3-East London	S4-Richard Bay
Mumbai I1		5546	5097	4958	4628
Vishakhapatnam I2		6066	5617	5478	5149
Chennai I3		5784	5335	5196	4866
Cochin I4		5326	4877	4738	4408
From	To	S1-Cape town	S2-Port Elizabeth	S3-East London	S4-Richard Bay
Zhanjiang C1		8163	8163	7575	7246
Bahezhen C2		9787	9787	9198	8869
Port of Xiamen		8714	8714	8125	7796

C3				
Port of Tianjin C4	10009	10009	9420	9089

Table 3.2 Distance matrix between Major Ports and Major Cities of Brazil in km

From To	B1-Belem	B2-Fortaleza	B3 Paranagua	Recife B4
Sao Paulo	2648	2969	447	2,648
Brasilia	1939	2106	1426	2133
Belo Horizonte	2028	2349	1,034	2,028
Rio de Janeiro	2299	2620	890	2,299

Table 3.3 Distance matrix between Major Ports and Major Cities of China in km

From To	C1-Zhanjiang	C2-Bahezhen	C3-Port of Xiamen	C4-Port of Tianjin
Beijing	2568	1147	2113	140
Shanghai	1898	844	1035	1109
Suzhou	1865	744	1021	1016
Shenzhen	506	1027	609	2164

Table 3.4 Distance matrix between Major Ports and Major Cities of Russia in km

From To	R1-Kaliningrad	R2-Poronaysk	R3-Azov	R4-Naryan-Mar
Samara	2279	8503	1356	2330
Saint Petersburg	877	9918	1821	2576
Moscow	1188	9425	1115	2389
Yekaterinburg	2965	7696	2288	2019

Table 3.5 Distance matrix between Major Ports and Major Cities of South Africa in km

From To	S1-Cape town	S2-Port Elizabeth	S3-East London	S4-Richard Bay
Free state	1111	775	672	711
Eastern cap	919	300	228	871
Durban	1640	911	655	178
Gauteng	1403	1067	964	615

Table 3.6 Distance matrix between Major Ports and Major Cities of India in km

From To	I1-Mumbai	I2-Vishakhapatnam	I3-Chennai	I4-Cochin
Vapi	180	1507	1491	1215
Ankleshwar	337	1544	1647	1848
Chandrapur	914	700	961	1527

Ghaziabad	1442	1683	2154	2667

3.5 Meta-heuristics

3.5.1 GA (Genetic Algorithm)

Genetic algorithms developed by Goldberg and inspired by Darwin's principle (Survival of the fittest) about evolution. Algorithm encompasses main four parameters (initialization, selection, crossover and mutation) and characterized by chromosome (string), gene (element). GA is best applicable for solving problem, when solution space is very high and searching time exhaustively is huge.

Performance of GA mainly depends on following factors.

- Population size (large population mean-100 chromosomes)
- Number of generations
- Crossover rate
- Mutation rate

Algorithm begins with a set of solutions known as population which is represented in term of chromosomes. Solutions obtained by one population are used to generate a new population that will have better fitness value than the previous (old) population. Solution's pair which is chosen to generate new population (offspring) is sorted as per their fitness value, the most suitable more chances to reproduce and is repeated until defined condition is satisfied.

3.5.2 Genetic Algorithm in MATLAB

GA (Genetic algorithm) is a technique for solving optimization of constrained or unconstrained problems by a natural selection process based on biological evolution. The algorithm continuously modifies a population of individual solutions and at each iteration randomly picks individuals from the current population and assigns as parents to produce the offspring for the next successive generations and optimal solution is achieved.

The Algorithm optimizes a problem in two ways:

- At each iteration a population is generated and optimal solution is approached by best point in the population.

- By computation using random number generators to select the next population.
- The above mathematical equations are modelled in MATLAB to find optimized cost.

3.5.3 MATLAB

- Matrix laboratory (MATLAB) is a programming language of fourth-generation and provides multi-paradigm numerical computing environment.
- MATLAB is a programming language developed by Math Works allows matrix manipulations, plotting of functions, data implementation of algorithms, creation of user interfaces and interfacing with programs written in other language including C, C++, Java, Fortran and Python.
- The MATLAB platform is optimized for solving scientific and engineering problems. The matrix-based MATLAB language is the world's most natural way to express computational mathematics built-in graphics, makes it easy to visualize and gain insights from data.
- A large library of pre-built toolboxes provides us in getting started with algorithms essential to our domain and desktop environment invites experimentation, exploration and discovery. These MATLAB tools and capabilities are all rigorously tested and designed to work together.

CHAPTER IV

MATHEMATICAL MODEL FORMULATION

4.1 Proposed Research Model

The model comprises network of ocean carriers between ports and networks of hinterland (road-railway) modes of transportation on ocean ends. The problem is considered as the routes finalization for each required shipment to minimize the costs of transportation. Individual shipment is defined by origin and destination point for picking and delivering at nodes and model searches optimal routing for all O-D (origin – destination) pairs of BRICS intra-network where cities are the points of origin and destination. Maritime is the main and only mode of cargo movement between the ports and between cities of origin and destination countries can be made by hinterland. Proposed model is linear and will be solved by Meta-heuristic technique. Following features have been added in the proposed model.

- Intra BRICS route optimization.
- Acquisition, routing, distribution cost.
- Demurrage and detention penalties.
- Linear and industrial shipping possible together.
- Homogenous and heterogeneous fleets.
- Assigning key responsibilities to Freight Forwarders.
- Variable ship's speed according to delivery time.

4.2 Assumptions of the proposed model

Following assumptions have considered in the model:

1) Only container trading with linear and industrial shipping.
2) Demand is deterministic and can be divided into the no of shipments followed by different path.
3) Time constraint in the form of delivery time as defined by customer.
4) Ship speed is variable to attain the desired delivery time.
5) Heterogeneous and homogeneous fleets are defined by available speed and capacity.

4.3 Consideration towards achieving optimal shipping among BRICS

1. Assign a company or centralized logistics department that may hire ships and containers from different ocean carrier on rent basis.
2. Using four best ocean carrier services having their own ships and containers with different sizes and huge capacity vessels through proper agreement on paper.
3. Option of transshipment hub or port
4. Automation of government governed ports and promotion to private Hi-Tech ports to reduce handling time.
5. Use of high tides concept occurs at different time zone in BRICS coastline to reduce fuel consumption.
6. Assigning more freight forwarders in each country governed by the main company (Logistics department)
7. Allocating cargo collecting zones in all industrial area of each country.
8. Assign following responsibility to freight forwarders.
   a. Pick up of loaded containers from port yard and getting shifted to buyer or customer by road or train depends upon connectivity available.
   b. Collecting empty containers in yard situated in cargo collection zones and shifting them to port yard after completion of cargo loading.
   c. Custom clearance also to be done by FF (freight forwarders) at origin and destination ports.
   d. Online tracking of cargo movement or vessel position.

9. Main focus is given on reducing demurrage and detention cost by suitable ship's speed selection based on delivery time, if it is more than the normal time to reach the destination then slow speed is recommended to avoid the above mentioned charges and if ship arrives too early or too late in both cases cost is charged by port and ocean carrier.

4.4 Parameter & definition

$p \in P$ Set of ports

$c \in C$ Set of cities

$t \in T$ Set of train operators

$r \in R$ Set of road operators

$f \in F$ Set of road-train (combined) operators

$s \in S$ Set of ships

k Є K Set of shipment between origin and destination city

o Є O Set of origin point

d Є D Set of destination point

Q_{p_o} Capacity of origin ports

Q_{p_d} Capacity of destination ports

Q_t Capacity of train operator (train)

Q_r Capacity of road operator (truck)

Q_f Capacity of road-train (combined) operator

Q_s Capacity of ships between port to port

4.5 Input variables

$X_{1c_op_otk}$ Number of TEU transported between origin city and origin port by train

$X_{2c_op_ork}$ Number of TEU transported between origin city and origin port by road

$X_{3c_op_ofk}$ Number of TEU transported between origin city and origin port by road-train (combined)

$\alpha_{1c_op_ot}$ Transportation cost of 1 TEU between origin city and origin port by train

$\alpha_{2c_op_or}$ Transportation cost of 1 TEU between origin city and origin port by road (truck)

$\alpha_{3c_op_of}$ Transportation cost of 1 TEU between origin city and origin port via road-train (combined) operator

$Y_{p_op_dsk}$ Number of TEU transported between origin port and destination port by shipping line

$\beta_{p_op_ds}$ Transportation cost of 1 TEU between origin port to destination port by shipping line

$Z_{1p_dc_dtk}$ Number of TEU transported between destination port and destination city by train

$Z_{2p_dc_drk}$ Number of TEU transported between destination port and destination city by road (truck)

$Z_{3p_dc_dfk}$ Number of TEU transported between destination port and destination city by road-train (combined)

$\gamma_{1p_dc_dt}$ Transportation cost between destination port and destination city by train operator

$\gamma_{2p_dc_dr}$ Transportation cost between destination port and destination city by road operator

$\gamma_{3p_dc_df}$ Transportation cost between destination port and destination city by road-train (combined) operator

W_{dp_ok} Total demand at origin port

W_{dp_dk} Total demand at destination port

W_{dc_dk} Total demand at destination city

μ_o Detention Charges of 1 TEU

N Number of days after expiry of free days for Detention Charge

μ_d Demurrage Charges of 1 TEU

M Number of days after expiry of free days for Demurrage Charge

4.6 Output variables

$U_{c_op_ofk}$ Total cost of TEU transported from origin city to origin port

$U_{p_dc_dfk}$ Total cost of TEU transported from destination port to destination city

$U_{p_op_dsk}$ Total cost of TEU transported between origin port and destination port by shipping line

4.7 Decision variable

$t_{n,}, t_a$ Normal Time, Actual Time

t_w Time window

S Ship Speed

4.8 Objective Function

$$Min \;\; Z = \underbrace{\sum_{c\in C}\sum_{p\in P}\sum_{t\in T}\sum_{k\in K} \alpha_{1c_op_ot} * X_{1c_op_otk}}_{\text{Acquiring cost}} + \underbrace{\sum_{c\in C}\sum_{p\in P}\sum_{r\in R}\sum_{k\in K} \alpha_{2c_op_or} * X_{2c_op_ork}}_{\text{Acquiring cost}}$$

$$+ \underbrace{\sum_{c\in C}\sum_{p\in P}\sum_{f\in F}\sum_{k\in K} \alpha_{3c_op_of} * X_{3c_op_ofk}}_{\text{Acquiring cost}} + \underbrace{\sum_{p\in P}\sum_{s\in S}\sum_{k\in K} \beta_{pps} * Y_{ppsk}}_{\text{Routing cost}}$$

$$+ \underbrace{\sum_{p\in P}\sum_{c\in C}\sum_{t\in T}\sum_{k\in K} \gamma_{1p_dc_dt} * Z_{1p_dc_dtk}}_{\text{Distribution cost}} + \underbrace{\sum_{p\in P}\sum_{c\in C}\sum_{r\in R}\sum_{k\in K} \gamma_{2p_dc_dr} * Z_{2p_dc_drk}}_{\text{Distribution cost}}$$

$$+ \underbrace{\sum_{p\in P}\sum_{c\in C}\sum_{f\in F}\sum_{k\in K} \gamma_{3p_dc_df} * Z_{3p_dc_dfk}}_{\text{Distribution cost}} + \underbrace{\sum_{p\in P}\sum_{k\in K} N * \mu_o}_{\text{Detention cost}} + \underbrace{\sum_{p\in P}\sum_{k\in K} M * \mu_d}_{\text{Demurrage cost}}$$

4.9 Constraints: The constraints of the objective function are as follow.

1. **Demands**

$$\sum_{p \in P}\sum_{t \in T} X_{1c_op_otk} + \sum_{p \in P}\sum_{t \in T} X_{2c_op_ork} + \sum_{p \in P}\sum_{t \in T} X_{3c_op_ofk} = W_{dp_ok} \qquad \forall k \in K$$

$$\sum_{p \in P}\sum_{s \in S} Y_{ppsk} = W_{dp_dk} \qquad \forall k \in K$$

$$\sum_{p \in P}\sum_{t \in T} Z_{1p_dc_dtk} + \sum_{p \in P}\sum_{t \in T} Z_{2p_dc_drk} + \sum_{p \in P}\sum_{t \in T} Z_{3p_dc_dfk} = W_{dc_dk} \qquad \forall k \in K$$

2. **Total no. of transported TEU**

$$\sum_{t \in T} X_{1c_op_otk} + \sum_{r \in R} X_{2c_op_ork} + \sum_{f \in F} X_{3c_op_ofk} = U_{p_op_dsk} \qquad \forall o \in O, \forall k \in K$$

$$\sum_{t \in T} Z_{1p_dc_dtk} + \sum_{r \in R} Z_{2p_dc_drk} + \sum_{f \in F} Z_{3p_dc_dfk} = U_{p_dp_osk} \qquad \forall d \in D, \forall k \in K$$

3. **Capacity**

$$\sum_{d \in D}\sum_{s \in S}\sum_{k \in K} U_{p_op_dsk} \le Q_{p_o} \qquad \forall o \in O$$

$$\sum_{o \in O}\sum_{s \in S}\sum_{k \in K} U_{p_op_dsk} \le Q_{p_d} \qquad \forall d \in D$$

$$\sum_{k \in K} X_{1c_op_otk} \le Q_t \qquad \forall o \in O, \forall t \in T$$

$$\sum_{k \in K} X_{2c_op_ork} \le Q_r \qquad \forall o \in O, \forall r \in R$$

$$\sum_{k \in K} X_{3c_op_ofk} \le Q_f \qquad \forall o \in O, \forall f \in F$$

$$\sum_{k \in K} Y_{ppsk} \le Q_s \qquad \forall s \in S$$

$$\sum_{k \in K} Z_{1p_dc_dtk} \le Q_t \qquad \forall d \in D, \forall t \in T$$

$$\sum_{k \in K} Z_{2p_dc_drk} \le Q_r \qquad \forall d \in D, \forall r \in R$$

$$\sum_{k \in K} Z_{3p_d c_d f k} \leq Q_f \qquad \forall d \in D, \forall f \in F$$

4. **Time Window**

Time window t_w defined as below:

$t_w \geq t_n + 2$

$t_w > t_a$.

CHAPTER V

OCEAN SHIPPING VARIANTS AND TRANSACTION FOR CONTAINERIZED GOODS

5.1 Introduction

Optimal commercial trading among BRICS is major key challenge, approximate 80% of universe trading based on volume and 70% as per value is done by ocean, UNCTAD [107]. There are three classes of shipping services liner, industrial and tramp. Liner shipping and bus mode are very similar as both services have planned ports of demand (bus stops) and cargo containers (passengers) from different supply and delivery end. Liner shipping have some intermediate ports between origin and destination ports, mainly relates to the transportation of cargo containers of furniture, auto parts, toys, appliances, garments, and electronics normally having less price per unit than cargoes, like bananas and sea food require refrigerated containers which need specific equipment driven by electricity generated by vessel's engine to maintain a sufficient temperature, resulting cost of a refrigerated cargo container is much high in compare to dry container of the similar size. In industrial shipping vessel moves from origin port to destination port without intermediate ports and in another sense ship is to be loaded at one end and unloaded at other end following optimal route with minimum cost. Tramp shipping service can accommodate a sudden demand at any node of BRICS and possible by assigning a separate ship for the containers. The principal components, scheme option consideration and planning phases in maritime transportation are shown in table 5.1, 5.2, 5.3 respectively.

Table 5.1 Principal Components of Maritime Transportation

Categories	**Components**
Cargo	Types of cargo
	Quantity of each
	Loading ports for each type cargo
	Delivery ports for each type cargo
	Loading and delivery time-window constraints

Ports	Number of ports
	Water depth which is navigable
	Port to port distance
	Loading/discharging duration for each cargo type
	Storage capacity for each cargo type
	Facilities needs to load or unload for specific Cargo
Ships	Capacity
	Compartments
	Number of ships
	Types (heterogeneous or homogeneous)
	Limitation on ports
	Maximum speed
	Location during start of scheduling chart
	Time of availability
Costs	Spot charter rates
	Port and canal dues
	Idle ship and demurrage charges
	Ship's operating costs in fleet - Port and crew charges - Bunker fuel - Flushing between loads - Repair and maintenance

Table 5.2 Scheme option consideration in maritime transportation

S. No.	Classification	Possible options
1	Points of intersection	Nil One Multiple
2	Operation type	Delivery Pick-up Combined pick-up and delivery

3	Demand type	Deterministic Stochastic Dependent on service
4	Scheduling constraints considered at the port	Fixed time of service in advance Time windows Restrictions free
5	Ships in number	Fixed Changeable
6	Ships in fleet	Heterogeneous Homogeneous
7	Cruising speed	Yes No
8	Demand splitting	Allowed Not allowed
9	Partial satisfaction of demand	Allowed Not allowed
10	Number of commodities	One Multiple
11	Cargo transshipment	Allowed Not allowed
12	Number of routes	One Multiple
13	Planning horizon	Defined-ships must or need not finish routes Undefined
14	Ship empty requirements	Yes No
15	Port precedence process	Exist None
16	Compatibility of ship port	Exist None
17	Types of cost	Fixed costs - Operation - Lay-up Variable costs - Costs of steaming - Entry charges at port - Ship staying time in port - Transshipment - Cargo operation
18	Objective	Minimize costs

		Maximize profits Minimizing environmental impact

5.2 Mechanism for service procurement

The key players in container shipping services are shippers or service buyers such as retailers and manufacturers who need their cargo containers to move from origin to destination and carriers or service sellers such as shipping lines companies which serves shipments transportation. Because of high global expansion in commercialization, we need to link supply chain integration globally through transportation service procurement which results in increasing huge demand by shippers for services from ocean carriers to deliver their cargo in form of finished products as well as raw materials. Figure 5.1 shows the mechanism for transportation service procurement.

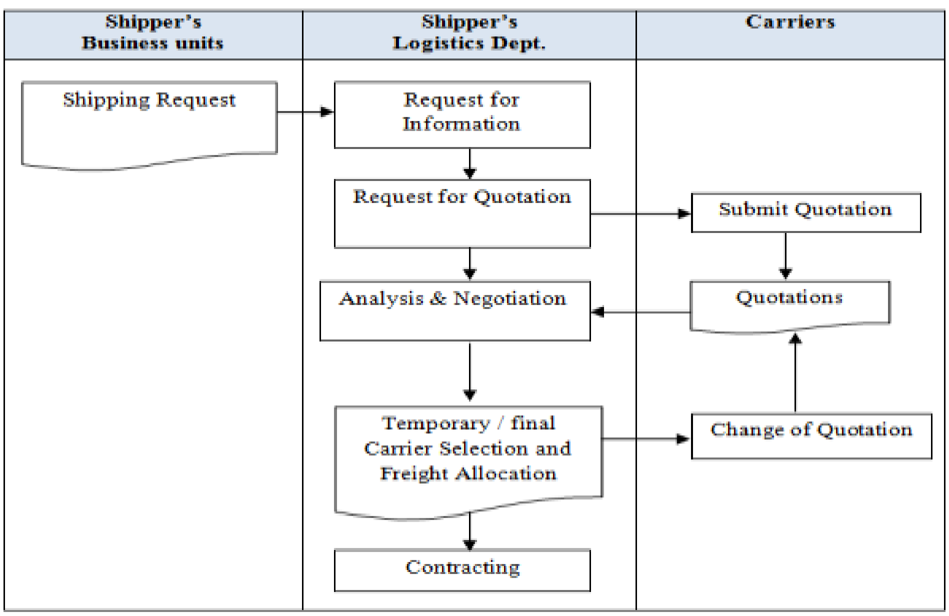

Figure 5.1 Service Procurement Mechanisms

Shippers avail the transportation services managed by own logistics departments that consist of the following four phases which are as follows:

- **Phase 1 Information collection:** Department of logistics gathers enquires in form of shipping request from different manufacturing units of the organization and declares cargo demands for the next coming period.

- **Phase 2 Request for raising quotation:** Logistics cell invites shipping companies to prepare quotations showing charges for different services between various origin and destination points in terms of time taken and different cargo volumes.
- **Phase 3 Study of quotations to negotiate:** This phase of service procurement analyzes the quotations received from the service providers (carriers) and calculates the total shipping cost under different situations also interacts with the carriers to bargain over the conditions and quoted shipping cost.
- **Phase 4 Contract agreement**: Last action includes the decisions towards selection of carrier's service and cargo volumes allocation to the shortlisted carriers and finally select the cost, service conditions and then sign contracts with the carriers

5.3 Planning phases in maritime transportation: Strategic, tactical and operational are the three phases in maritime transportation and they are distinguished by their sub category as given in table below.

Table 5.3 Planning phases in Maritime Transportation

Strategic	Tactical	Operational
1. Selection of market and trade 2. Design of ship 3. Design of transportation and network system 4. Fleet sizing 5. Harbor location, design and size	1. Ship scheduling and routing 2. Scheduling of berth 3. Scheduling of crane 4. Managing container yard 5. Planning of container stowage 6. Ship management 7. Empty containers distribution	1. Cruising speed selection 2. Ship loading 3. Environmental routing

5.4 Phases of operations and related problems: The detailed description of Phases of operations and related problems occurs at ports are shown in Figure 5. 2

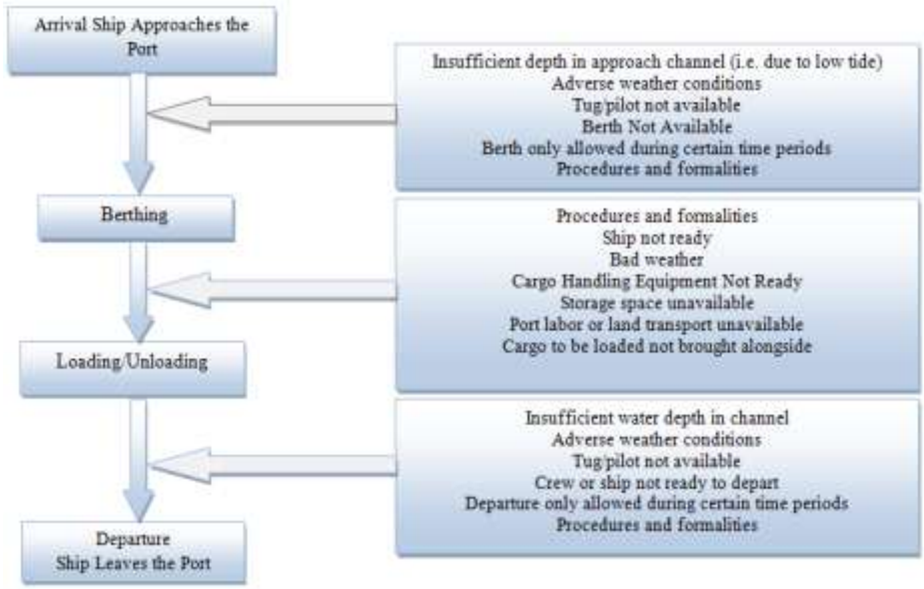

Figure 5.2 Phases of operations and related problems

5.5 Possible classes of shipping operation

5.5.1 Liner shipping

Mostly Containers are transported by the class of liner shipping with planned sequences of ports to be visited at a regular routine frequency which are displayed earlier to attract cargoes volume of shippers by shipping companies. Freight forwarders have freedom to deliver and pick up their shipments at any port covered by the operation of liner services. A single cargo supplier normally has less cargo than a full ship capacity of cargo whereas vessel have to depart according to their prior schedule dates even when a full cargo volume is not available but in our case of linear shipping full capacity of ship is utilized. We can motivate the liner shipping performance by relating them to bus operation. Bus services visit decided bus stops routes sequences. Liner vessel services also visit prior fixed routes sequences of ports. Buses carry passengers and vessels also transport containers from many origins to required destination. We can differentiate liner vessels services and bus services. First, liner vessels services are usually weekly or monthly and schedule of arrival at ports of demand is displayed on company website to support road transportation, on the other end bus services have a 5–15 min frequency interval and buses are subjected to the uncertain traffic and visit many stops hence the uncertain arrival time may be little larger than the nominal waiting time because of the regular service frequency. Second in bus service Passengers are free to choose routes by themselves from origin to destination, on the other end cargo containers are transported optimally. Third, costs do not incur during the alighting, boarding and transfer of passengers in bus services but discharging, transshipment, loading and unloading of containers are expensive and are the main source of revenue for port handling supervisors. Fourth, usually buses run in the day time and cargo ships sail in day-night and throughout the week. Fifth, bus service needs drivers work scheduling and the employees in ship work round the day and night with a shift changing provision.

5.5.2 Tramp Shipping

Tramp shipping is comparable to a taxi service. Mainly spot cargo or project cargo is loaded as a full ship at a specific harbor and delivered to the cargo's destination harbor. Spot cargo is cargo that is picked up on a short term basis and transported as demand is stochastic by hiring a ship on urgent basis. Cargo of extraordinary size like machines and larger vehicles is referred to as project cargo. After delivery of the cargo, the tramp ship might have to travel empty to another harbor before loading the next cargo according to the next order.

5.5.3 Industrial shipping

Industrial shipping (sometimes is addressed as specialized shipping) transport containers in the large volume where ocean carrier is also a cargo owner and transport performance can be raised by accommodating special features in cargo handling equipments, ships design, terminals and specifically utilized for transportation of trucks, earth moving equipment, Chemicals, refrigerated cargo, motor vehicles and forest products.

5.6 Stages to be followed during shipping transaction for containerized goods

This includes the concentration towards the linking among the ocean carrier and buyer or seller. Ocean shipping transaction is just contracting of the shipping lines during maritime transportation which is the main transaction for cargo containers supported by some sub important elements in the transaction are:

- **Pre-carriage**: In this element ocean carriers are supposed to pick the containerized goods at hinterland location and transport to port yard for loading, if ocean carrier is working as freight forwarder.

- **Documentation formalities**: The ocean carrier has to fulfill all legal information required to transport the goods into a country.
- **On-carriage**: When ships arrive to the port then requirements to deliver the container near to hinterland destination can be asked from ocean carrier.
- Using the containers as a system for loading the cargo.
- Releasing of the containers from the unloading port yard when end carriage is arranged by the customer.

5.6.1 Pre-Carriage

The responsibility of maritime carriers is to move ships between port of origin and port of destination which requires the loaded containers ready in the port of loading but according to the deal, the ocean carrier also involves in the process. Empty container has to be handed over to the shippers since the ocean carrier is responsible for supplying the containers and it is important part to be discussed during hiring shipping service. Seller or shipper needs a location to take the cargo free containers from or may request the carrier to arrange the same to its nearest location for cargo loading. The later one needs hiring a local road transport to take the empty container and handover it to the seller for goods loading and takes it again for dropping to the port. Generally shipper can manage local road transport because the vessels of the maritime carrier move in a fixed time chart and it's mandatory to display a deadline (cut-off date) to the shippers before which the all loaded containers must arrive at the port in time**.** Containers are not allowed to be loaded on the main ship that arrive after that deadline and further vessels are required to be booked again or loaded to the next vessel. On other end even a container reaches the port terminal in defined time, still possibility to miss the ship because containers are inspected physically by exports customs before loading the cargo on ship which may take several days resulting in blocking of containers and missing of cut-off date.

5.6.2 Documentation processing in the country of arrival

Maximum countries in the global provide cargo containers in a country's customs controlled zone for documents inspection. A prior intimation to proper authority is required by shipping services about the goods they are bringing into the port to fulfill the demand in a particular country. Customs declaration is also required to transport the goods to other customs controlled zone. The customs documentation filling requirements are done by the maritime carrier before starting of container loading on the ship based on the information provided by either the shipper or freight forwarder, also vessel reaching a port has to provide a list of members on board, technical certificates of all commercial and non-commercial goods on board. The certification of cargo to be loaded or unloaded in or from the containers are scanned and physically inspected by custom when vessel arrives the port.

5.6.3 On-Carriage

This is end carrier haulage where customer may get solved their tasks of shifting the cargoes from the port yard to the destination of end user which is managed by the maritime carriers under the legal framework of notified transport conditions and carrier haulage arrangement. Ocean carriers also retain control of road transport movement of a port to optimize the scheduling of ocean transport and flow of containers (receive empty container very promptly) and minimizing the on-carriage contracting time.

5.6.4 The Container as a Loading Unit

Now days we have a container size new 40 FEU and the maritime carriers may have considerable quantities of cargo containers to maximize the profit of this valuable asset by making prompt effort in returning empty containers to loading yards, otherwise a penalty will be charged by ocean carriers on their customers for delaying in picking up the containers upon arrival and also not bringing back the empty container in time. A daily penalty is charged if a fully loaded cargo container is taken up late by customer and is known as, “demurrage”. If buyer returns back an empty container late daily penalty has to pay by the customer (buyer) known as “detention”. As a courtesy based on relation between large customer and ocean carrier some days as relaxation are permissible before demurrage and detention period start, also lower penalties are applied compared to the average client. The shipping services have to keep follow up of the containers and time they have been stayed at the port of country and decide who will pick-up the container and when empty container to be returned back to empty yard depot. For ease of accessibility for customers to take up the container from the port, ocean carrier issues a complete communication address as pick up location in port, pin-code for resulting transport to occur in very small time window between detention and demurrage limit otherwise the buyer incurs a penalty on violation of deadlines.

5.6.5 Releasing of the Containers at Port

There are some legal guidelines without fulfilling these containers cannot leave a port and at initial level customs assess the risks before releasing the container. Ocean carrier confirms with terminal operator whether road transport operator is the reliable person and aware where the empty container needs to be returned back. Terminal operator verifies their identification and correct pin codes for the cargo containers to be moved out after verifying the right status followed by automating identification process of identity cards and digital documentation and for any lacking vessel's driver will solve the problem before commencement of container's loading at the terminal.

5.7 SRP Variants

5.7.1 Ship routing problem with time window (SRPTW)

The SRPTW most common problem frequently occurs in shipping routing. In this all ports require the same type of service and we consider a central depot from where each ship's route must start and end, also each port must be visited exactly once. This type of variant encompasses two constraints.

- Capacity Constrains:-Ship capacity should not be exceeded any time
- Time window:-Each port must have specified time window interval for visiting, otherwise ship has to wait if reaches before time window begins.

5.7.2 Ship routing problem with time deadline

This is the different variant of SRPTW where no lower limit is considered only upper limit replace the time window.

5.7.3 Ship routing problem, time dependent

This problem takes travel time into an account that depends on both, distance between ports and the delivery time.

5.7.4 Periodic ship routing problem

In this variant of SRP, horizon is divided in a number of periods and in each period ship route is planned or constructed and port is visited in specified period by the customer

5.7.5 SRP with heterogeneous fleet

Ship characteristics are not same or ships do not share the similar parameters.

5.7.6 SRP with multiple depots (SRPMD)

This variant contains multiple depots, where each ship has a choice its route to start and end from any depot.

5.7.7 SRP with backhauls

Ship immediate returns empty back to its pickup assignment after delivery, resulting in increased cost.

5.7.8 Capacitated ship routing problem (CSRP)

This variant defines the utilization of fleet of same capacity to deliver the shipment to required customer from the selected port.

5.7.9 Distance constraint ship routing problem (DCSRP)

In this category of variant, capacity constraint is replaced by time constraint, which is maximum length of routing time from one destination to other and it can be further classified as follows.

a) Pick-Up and delivery ship routing problem (PDSRP)

This variant consist of pick-up from the other port before the port where delivery is done but pick-up shipment may less or more than the ship capacity left. This results use of more ship, also increased of travel distance and cost, therefore shipment pickup and delivery must be between pre defined ports and another option we can have by taking two ships in parallel to accommodate the pick-up and deliver it back to the required port.

b) Split delivery ship routing problem (SDSRP)

Depend on the shipments order we can split the quantity and assign the ships based on the size of the order to be delivered**.**

c) Stochastic ship routing problem

Variant accommodate some random parameters as shipment quantity, number of ports, delivery time and routing time (port to port).

New VRP constraint has been incorporated in the problem by considering above constraints, which is HHSRPTW

CHAPTER VI

SIMULATION AND RESULTS

6.1Basic Steps in GA (Genetic Algorithm)

1. [Start] Random population of *n* chromosomes is generated (Desired solutions for the given problem).
2. [Fitness] In the population, fitness *f(x)* of each chromosome *x* is Evaluated.
3. [New population] Following steps are repeated to create a new population until the new population is complete

1. [Selection] According to chromosomes fitness value in a given population, two parents are selected (Better fitness value, the more chances are to be selected)
2. [Crossover] Cross over the parents with a crossover probability to form a new offspring (children).
3. [Mutation] Mutate new offspring at each locus (position in chromosome) with a mutation probability.
    - [Accepting] Position new offspring to form a new population.
    - [Replace] Run the algorithm with new generated population
    - [Test] Stops, if the end condition is satisfied and returns the best solution in current population
    - [Loop] Go to step 2

6.2 Flow Chart for the Algorithm

Based on sequential entries in MATLAB program, flow chart has been prepared in **Figure 6.1** with entries of origin country, origin city, destination country, destination city, port to port distances, number of days for demurrage, detention penalties and ship's speed in knots (10 knots to 30 knots)

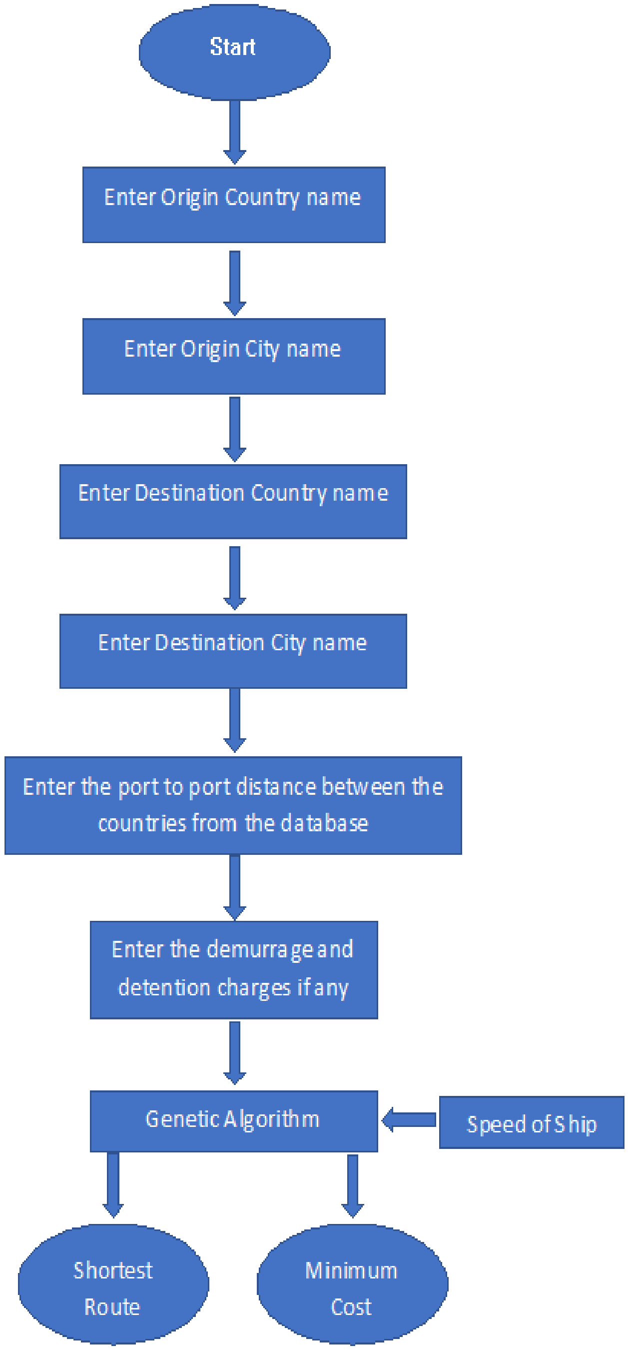

Figure 6.1 Flow chart for the algorithm

6.3 Result Analysis

Illustration 6.3.1 Brazil to china

Let shipment to be transported between Brazil as origin country and china as destination country with Brasilia and Shanghai as the origin and destination city respectively**.** Let us consider B that is Distance in kms between Major Ports and Major Cities of Brazil.

B=

From	To	B1-Belem	B2-Fortaleza	B3-Paranagua	B4-Recife
Brasília		1939	2106	1426	2133
Sao Paulo		2648	2969	447	2,648
Rio de Janeiro		2299	2620	890	2,299
Belo Horizonte		2028	2349	1,034	2,028

Let us consider C that is Distance in kms between Major Ports and Major Cities of China

C=

From	To	C1-Zhanjiang	C2-Bahezhen	C3-Port of Xiamen	C4-Port of Tianjin
Shanghai		1898	844	1035	1109
Beijing		2568	1147	2113	140
Shenzhen		506	1027	609	2164
Suzhou		1865	744	1021	1016
Guangzhou		420	1018	706	2155

Let us consider BC as port to port distance between these two Countries, BC=

From	To	C1-Zhanjiang	C2-Bahezhen	C3-Port of Xiamen	C4-Port of Tianjin
B1-Belem B1		13674	12792	14226	15509
B2-Fortaleza		12934	14559	13497	14780
B3-Paranagua		12169	13059	12702	13985
B4-Recife		11979	14181	13119	14401

Genetic Algorithm is being implemented to find shortest path from all the possible paths.

The results below show the optimized cost to ship 1 TEU.

The Statistics shown below consist four groups, all four groups represent the Rows of matrix BC and sub-elements of each group represent Column and we take one example of each pair of BRICS by taking origin and destination city of each group and see the optimized path, first we take Brazil to china with origin and destination city Brasilia-Shanghai. Cost analysis between each origin port of Brazil to all destination port of China is shown in figure 6.2 to figure 6.7 and optimized path is Brasilia- Paranagua- Bahezhen-Shanghai

a) Brasilia-Shanghai

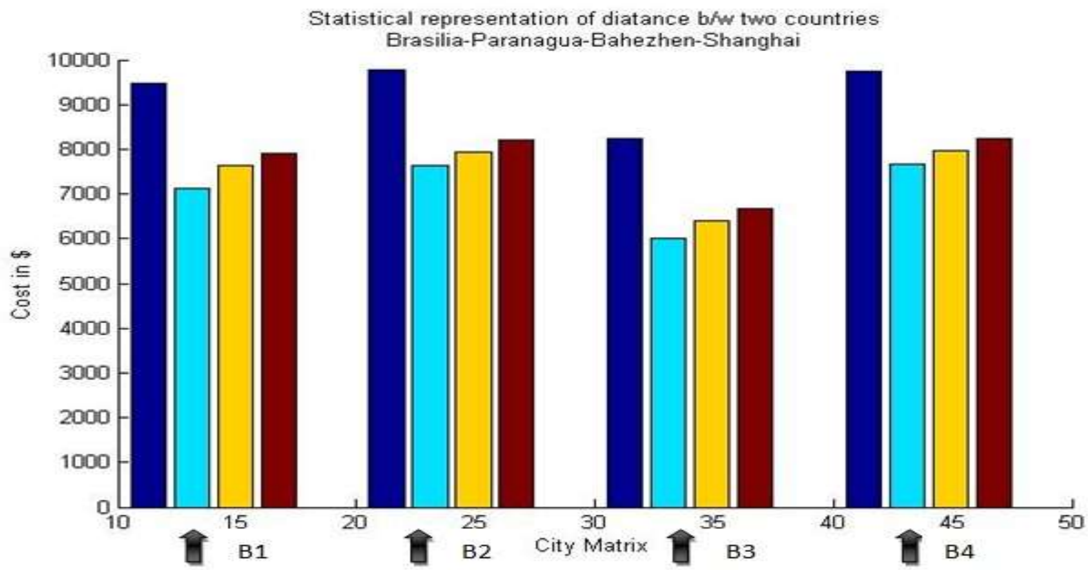

Figure 6.2 Cost analysis Brasilia-Shanghai

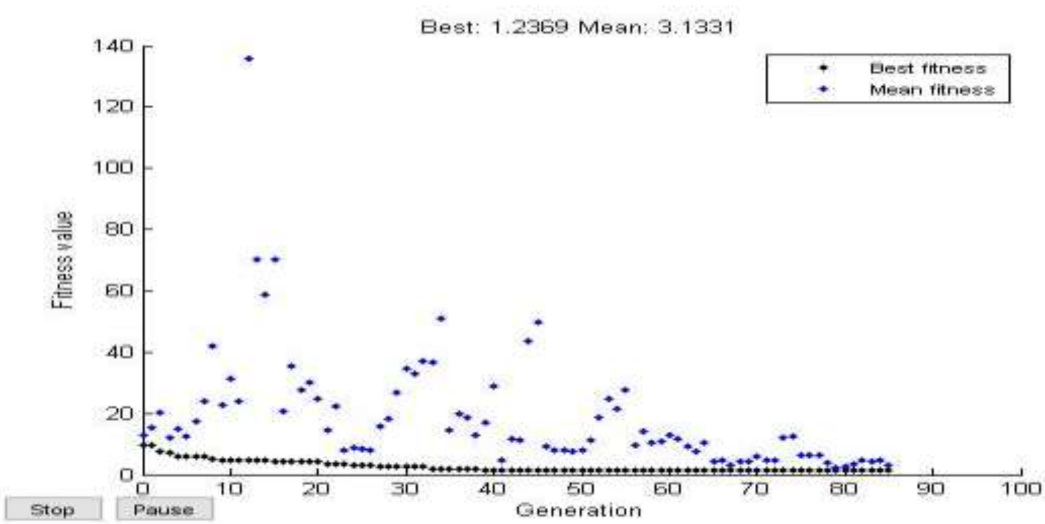

Figure 6.3 GA analyses Brasilia-Shanghai

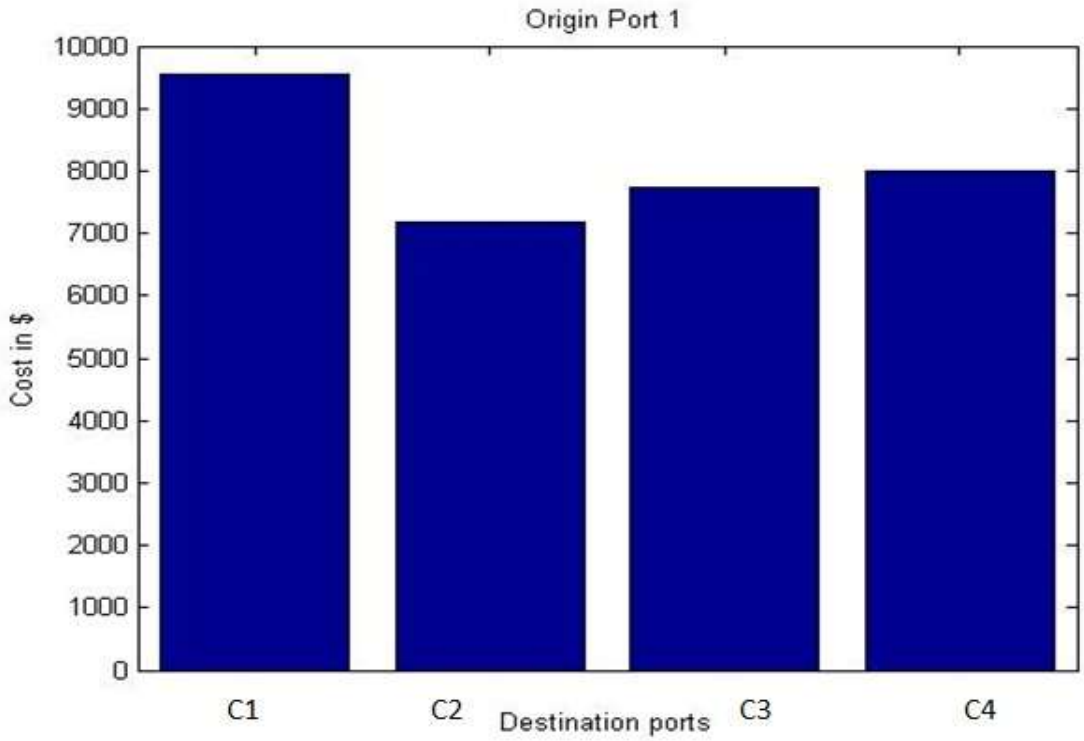

Figure 6.4 Cost analysis, Belem (B1) - destination ports (C)

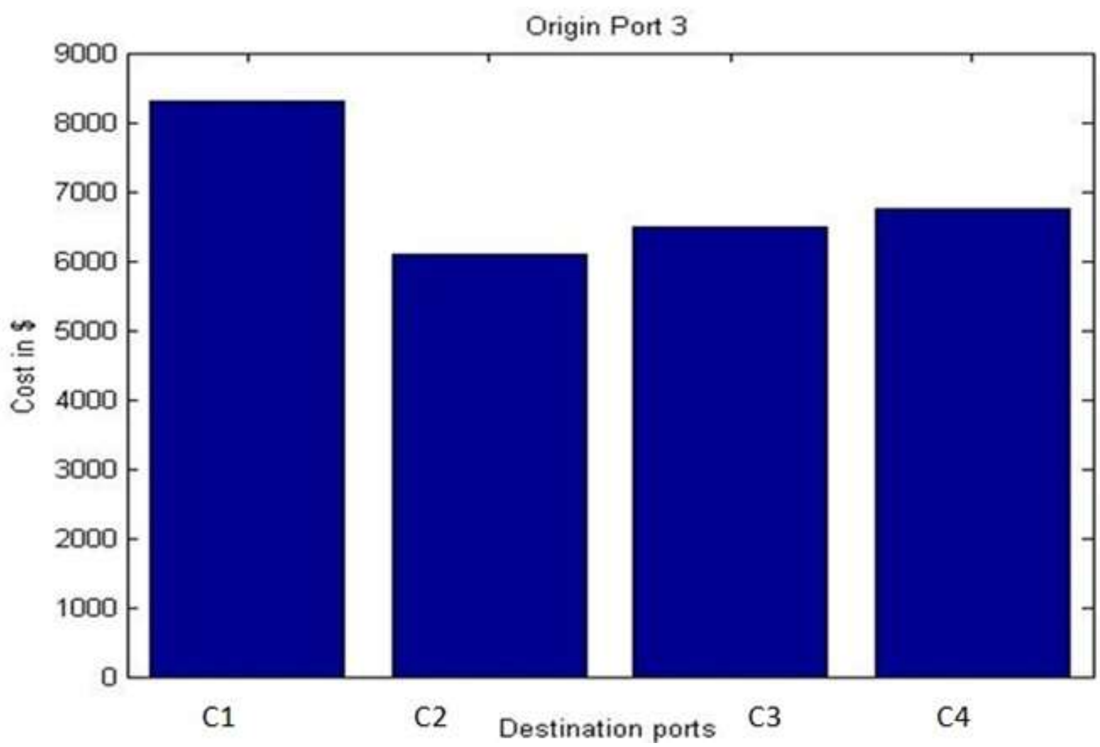

Figure 6.5 Cost analysis, Fortaleza (B2) - destination ports (C)

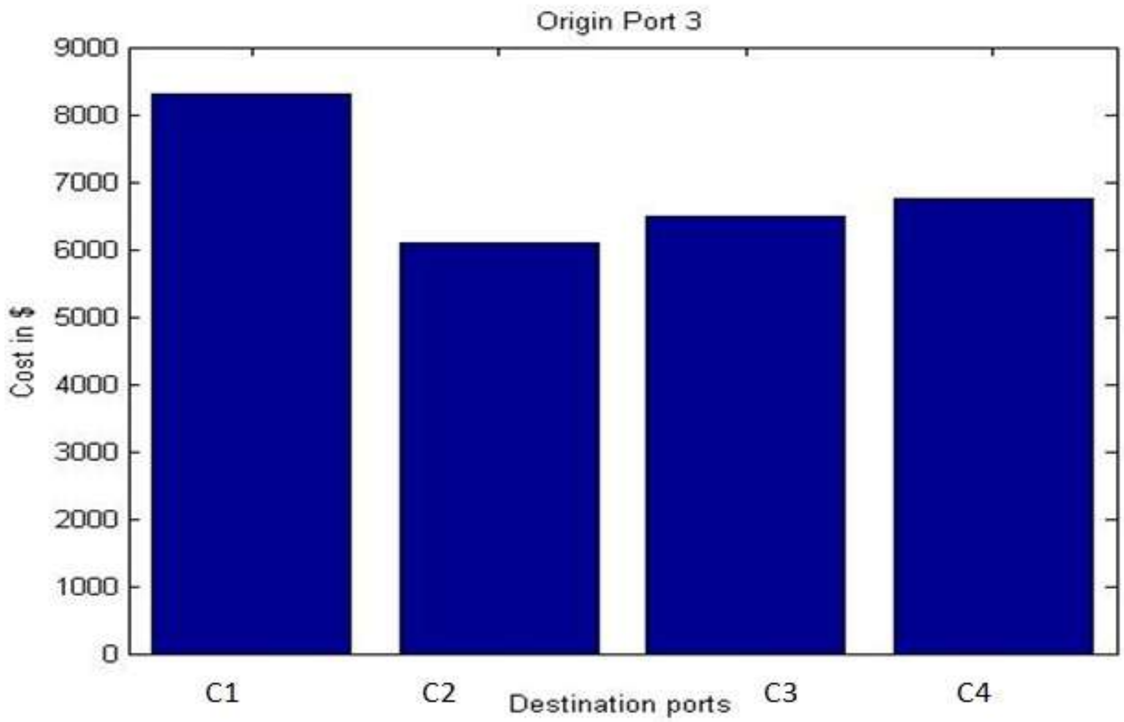

Figure 6.6 Cost analysis, Paranagua (B3) - destination ports (C)

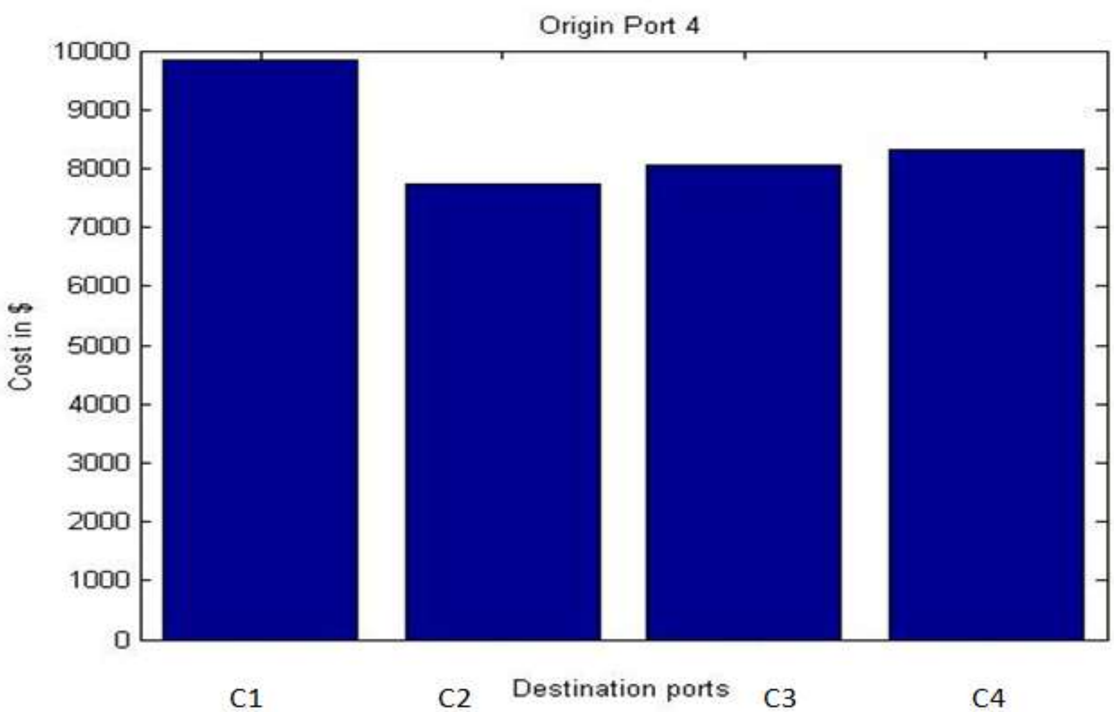

Figure 6.7 Cost analysis, Recife (B4) - destination ports (C)

Optimized path: Brasilia- Paranagua- Bahezhen- Shanghai

Illustration 6.3.2 Russia to India

Cost analysis between each origin port of Russia to all destination port of India is shown in figure 6.8 to figure 6.13 and optimized path is Moscow- Naryan-Mar – Mumbai – Ankleshwar

a) Moscow-Ankleshwar

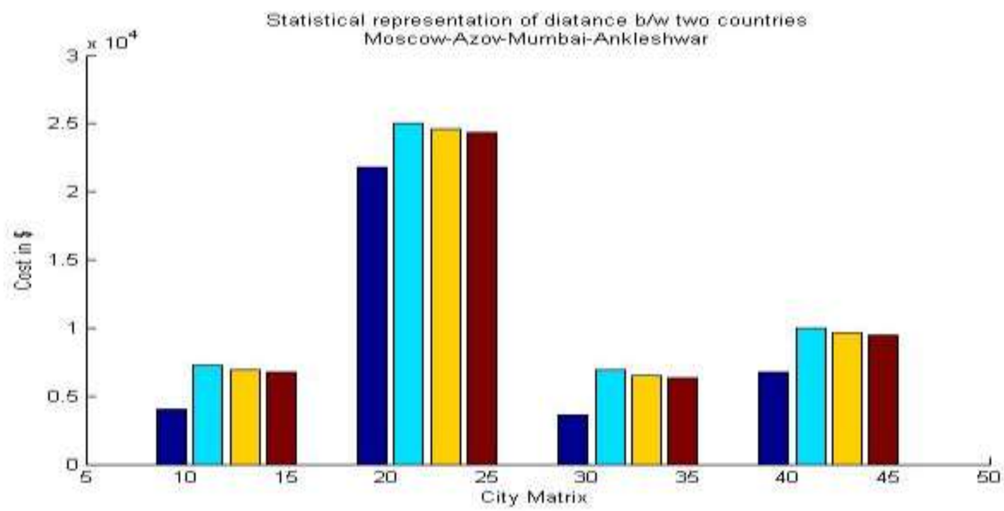

Figure 6.8 Cost analysis, Moscow-Ankleshwar

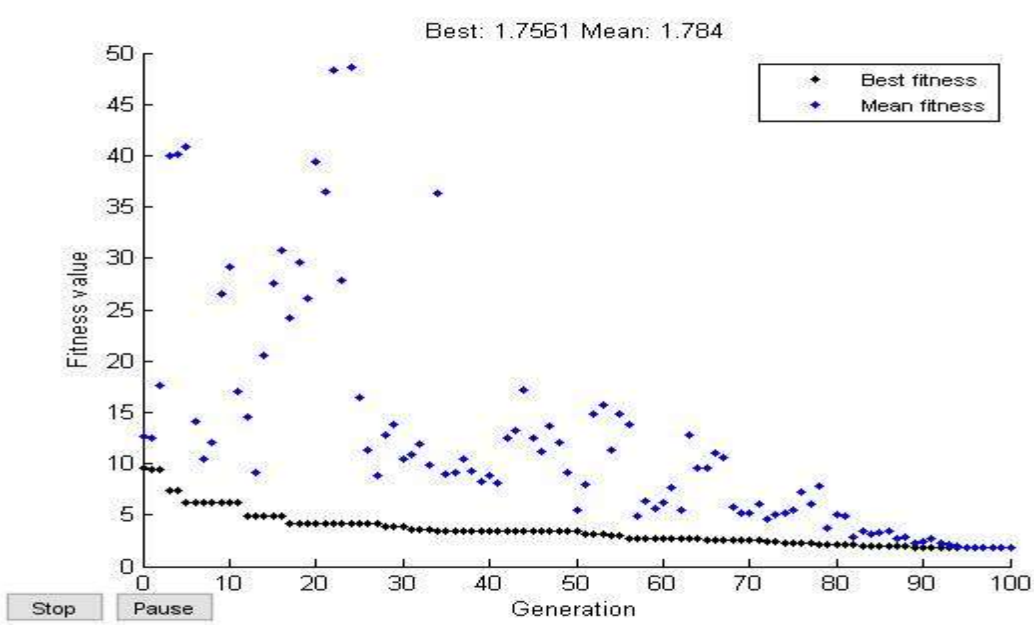

Figure 6.9 GA analyses Moscow-Ankleshwar

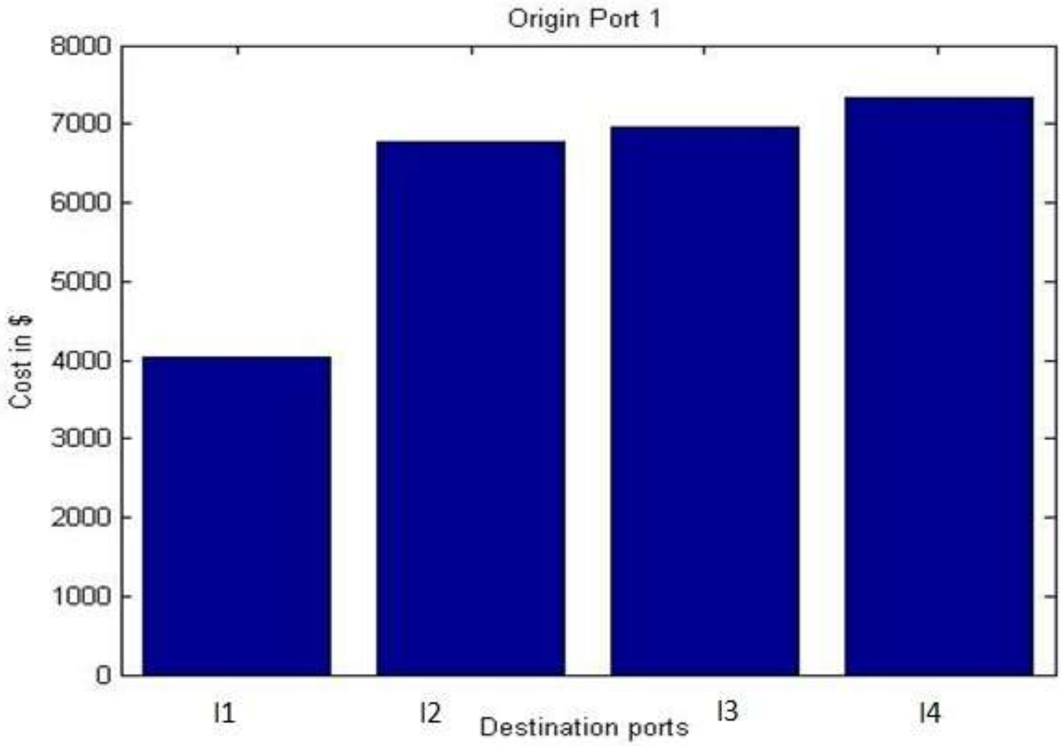

Figure 6.10 Cost analysis, Kaliningrad (R1) - destination ports (I)

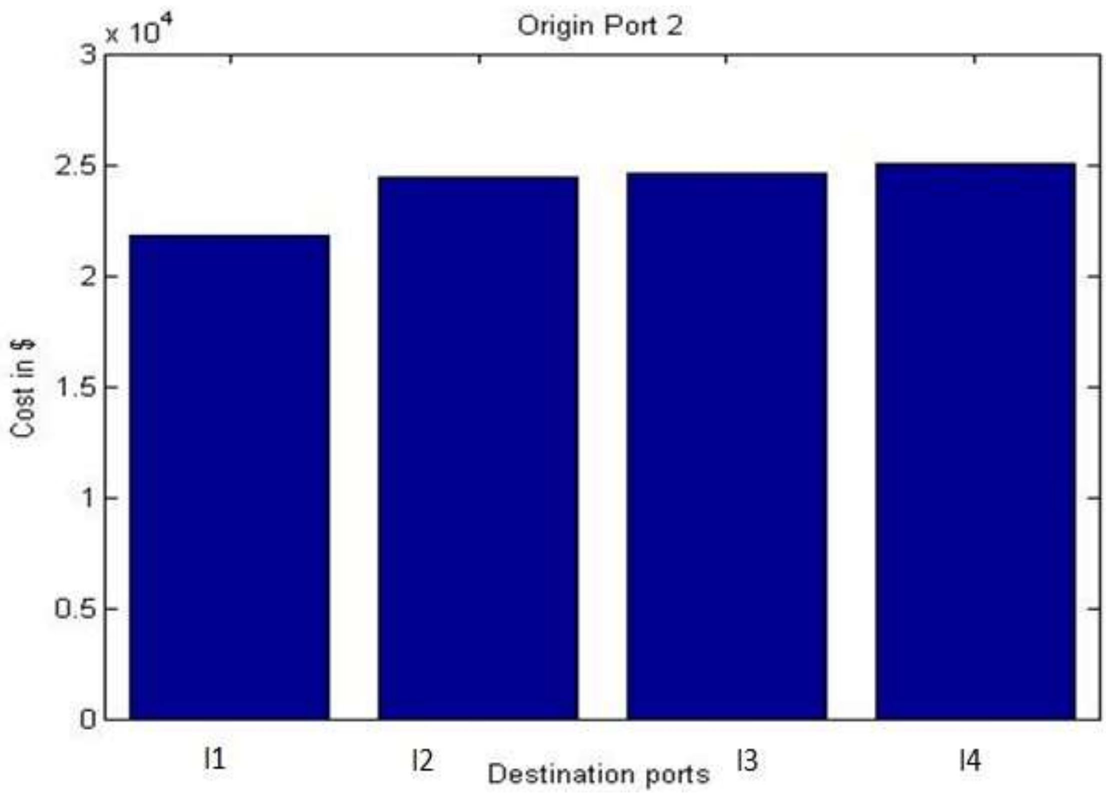

Figure 6.11 Cost analysis, Poronaysk (R2) - destination ports (I)

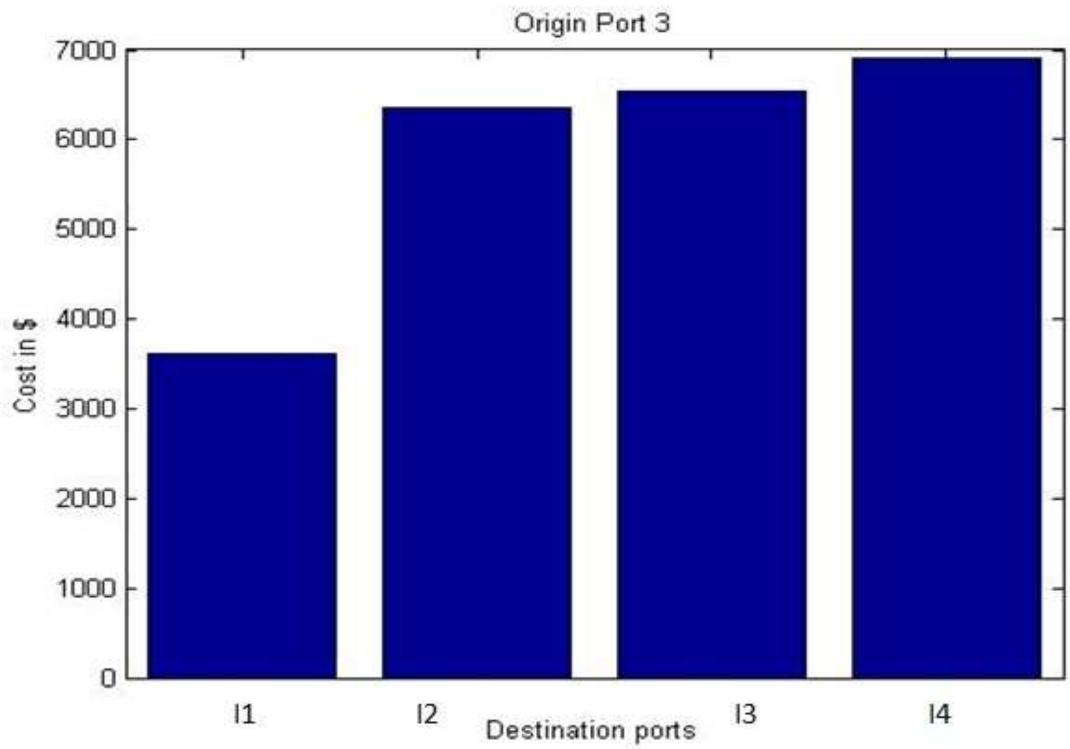

Figure 6.12 Cost analysis, Azov (R3) - destination ports (I)

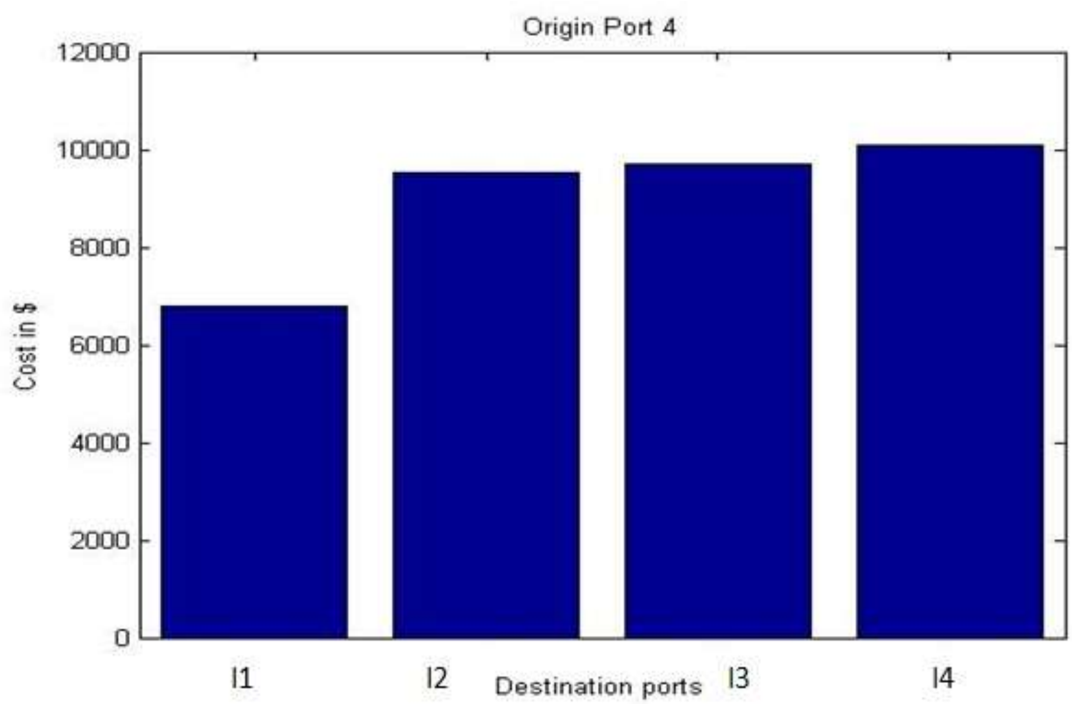

Figure 6.13 Cost analysis, Naryan-Mar (R4) - destination ports (I)

Optimized path: Moscow- Naryan-Mar – Mumbai –Ankleshwar

Illustration 6.3.3 India to South Africa

Cost analysis between each origin port of India to all destination port of South Africa is shown in figure 6.14 to figure 6.19 and optimized path is Ankleshwar-Mumbai–Richard Bay –Durban

a) Ankleshwar-Durban

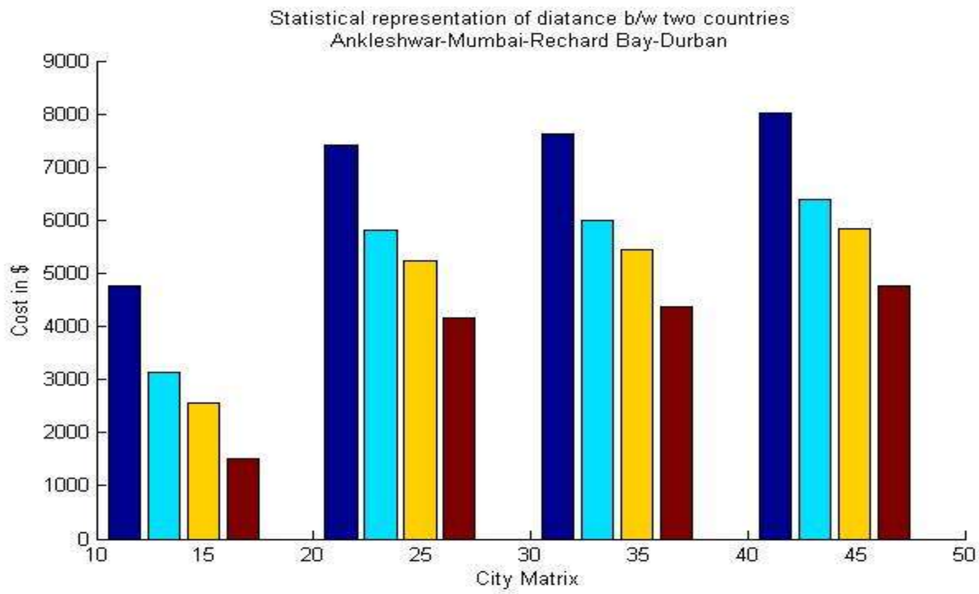

Figure 6.14 Cost analysis, Ankleshwar-Durban

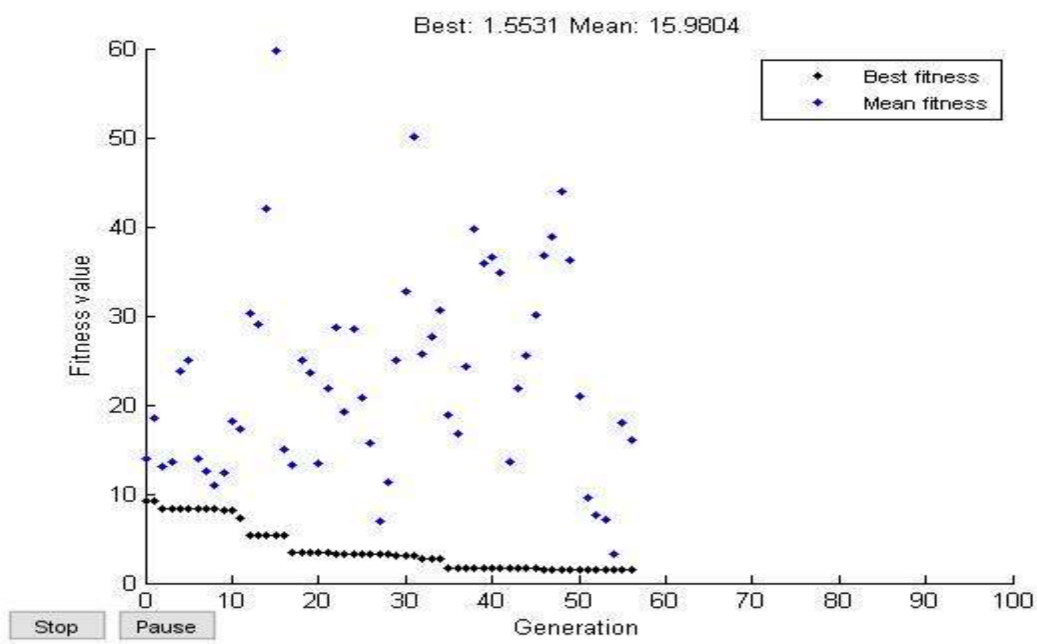

Figure 6.15 GA analyses Ankleshwar-Durban

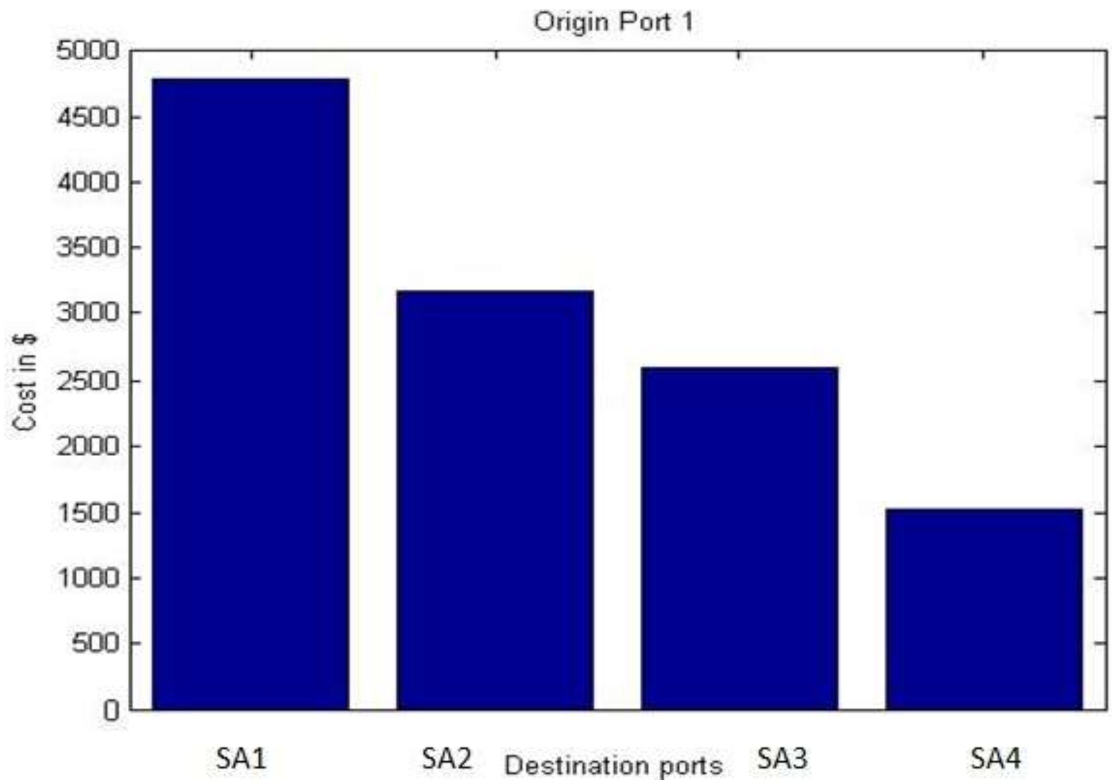

Figure 6.16 Cost analysis, Mumbai (I1) - destination ports (SA)

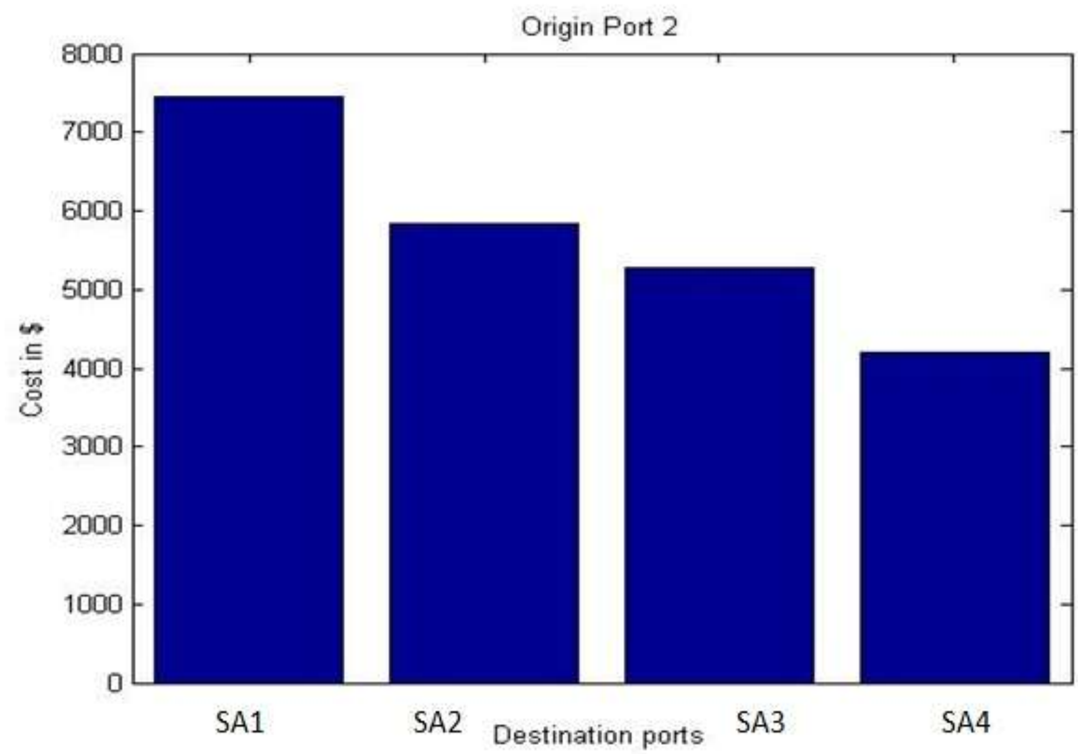

Figure 6.17 Cost analysis, Vishakhapatnam (I2) - destination ports (SA)

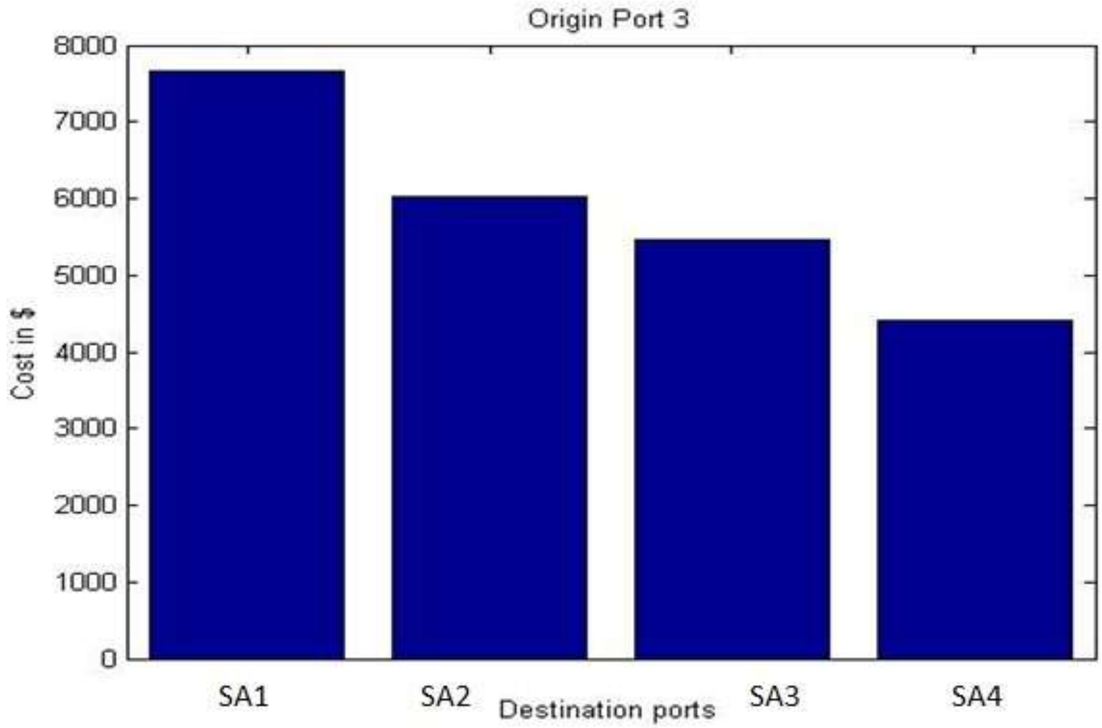

Figure 6.18 Cost analysis, Chennai (I3) - destination ports (SA)

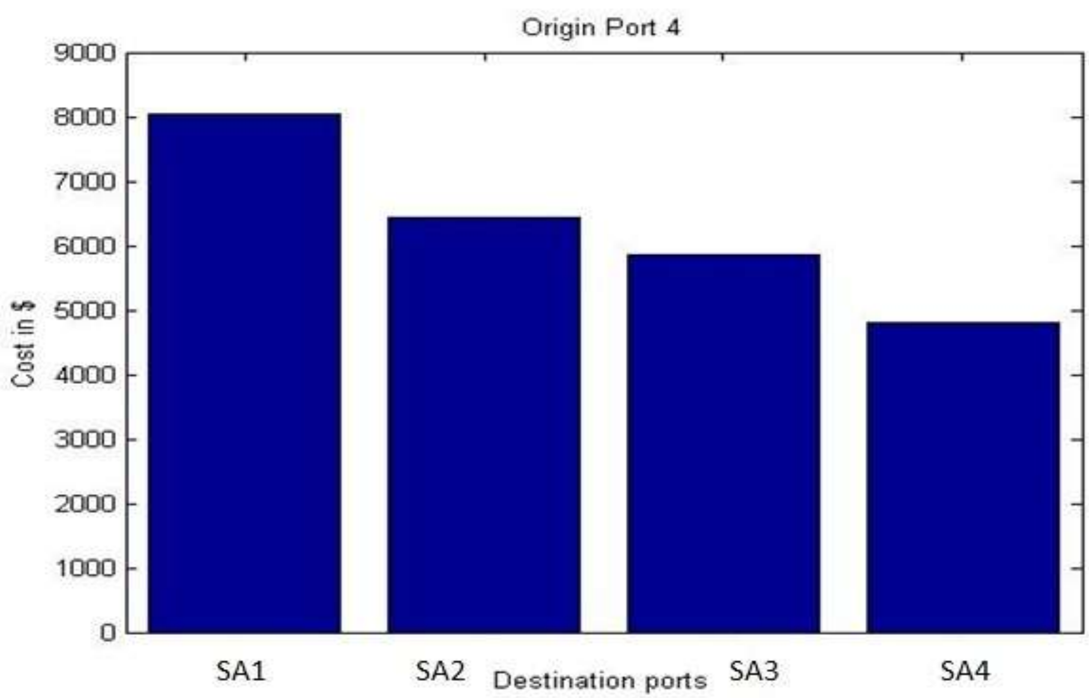

Figure 6.19 Cost analysis, Cochin (I4) - destination ports (SA)

Optimized path: Ankleshwar-Mumbai–Richard Bay –Durban

Illustration 6.3.4. Russia to South Africa

Cost analysis between each origin port of Russia to all destination port of South Africa is shown in figure 6.20 to figure 6.25 and optimized path is Moscow –Kaliningrad- Richard Bay –Durban

a) Moscow-Durban

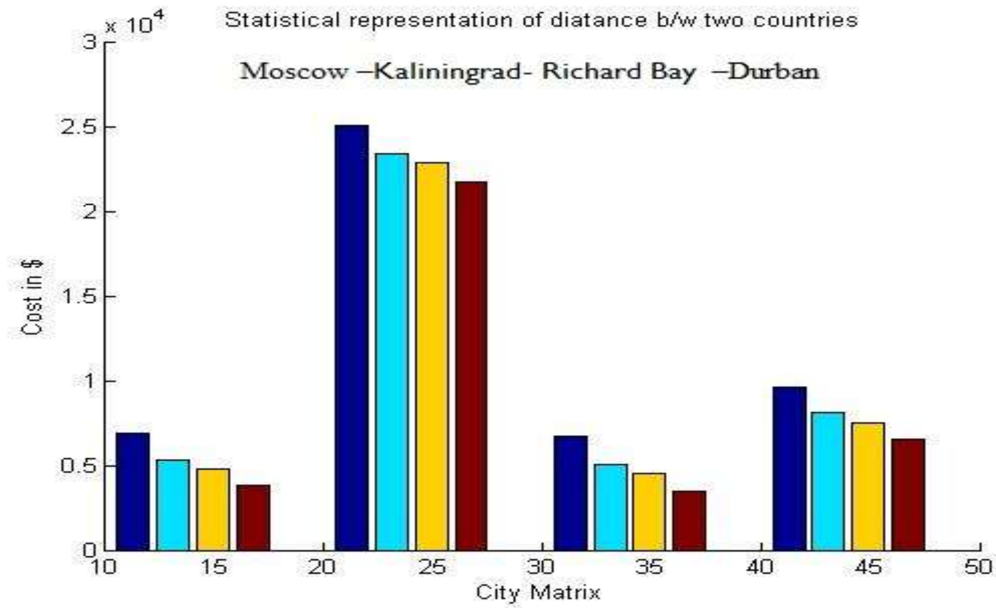

Figure 6.20 Cost analysis, Moscow-Durban

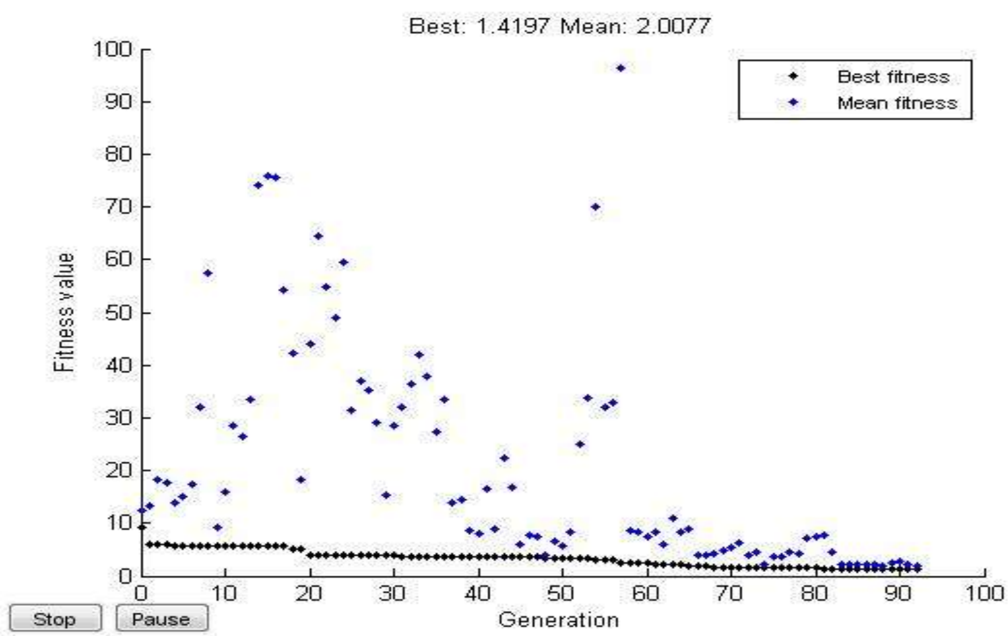

Figure .6.21 GA analysis, Moscow-Durban

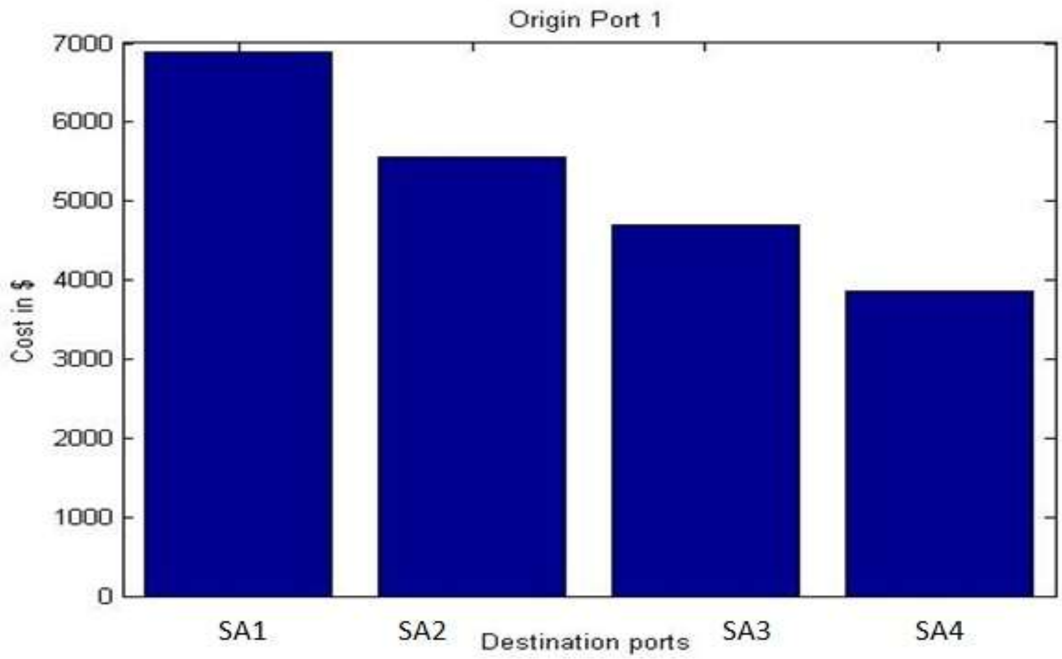

Figure 6.22 Cost analysis, Kaliningrad (R1) - destination ports (SA)

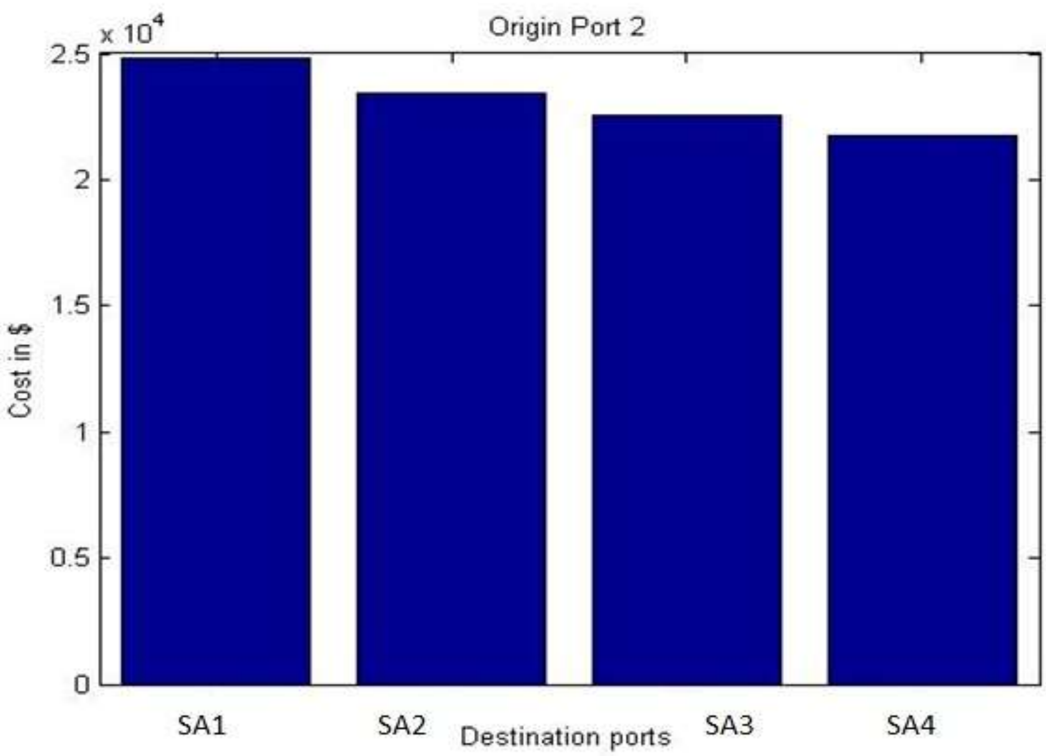

Figure 6.23 Cost analysis, Poronaysk (R2) - destination ports (SA)

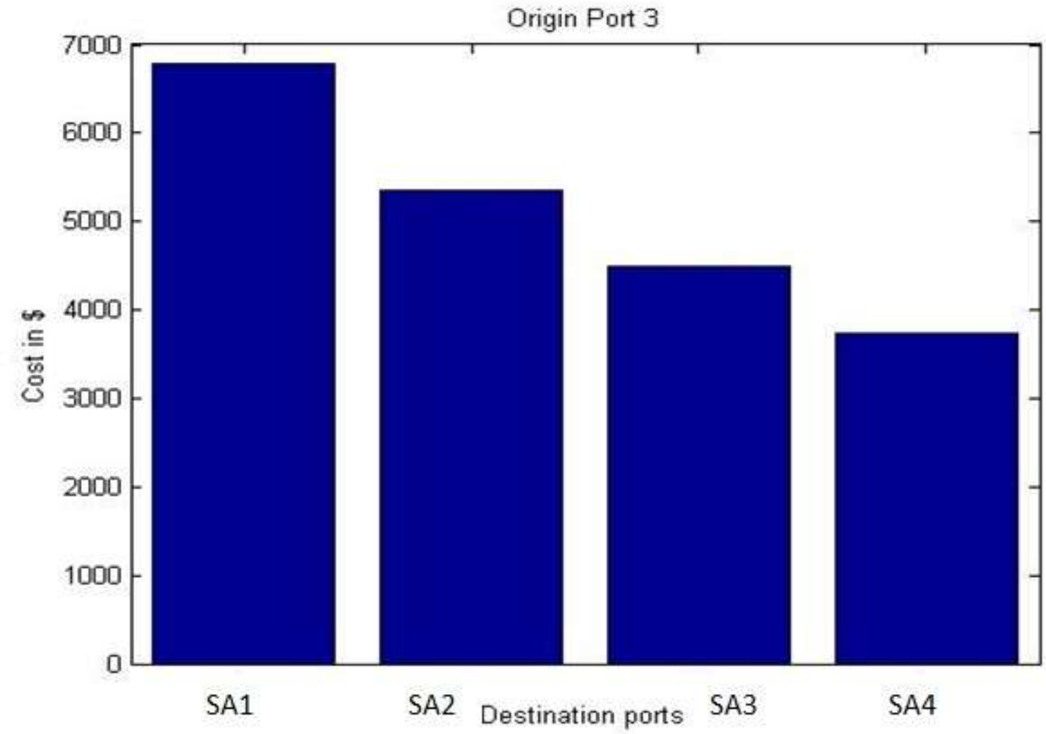

Figure 6.24 Cost analysis, Azov (R3) - destination ports (SA)

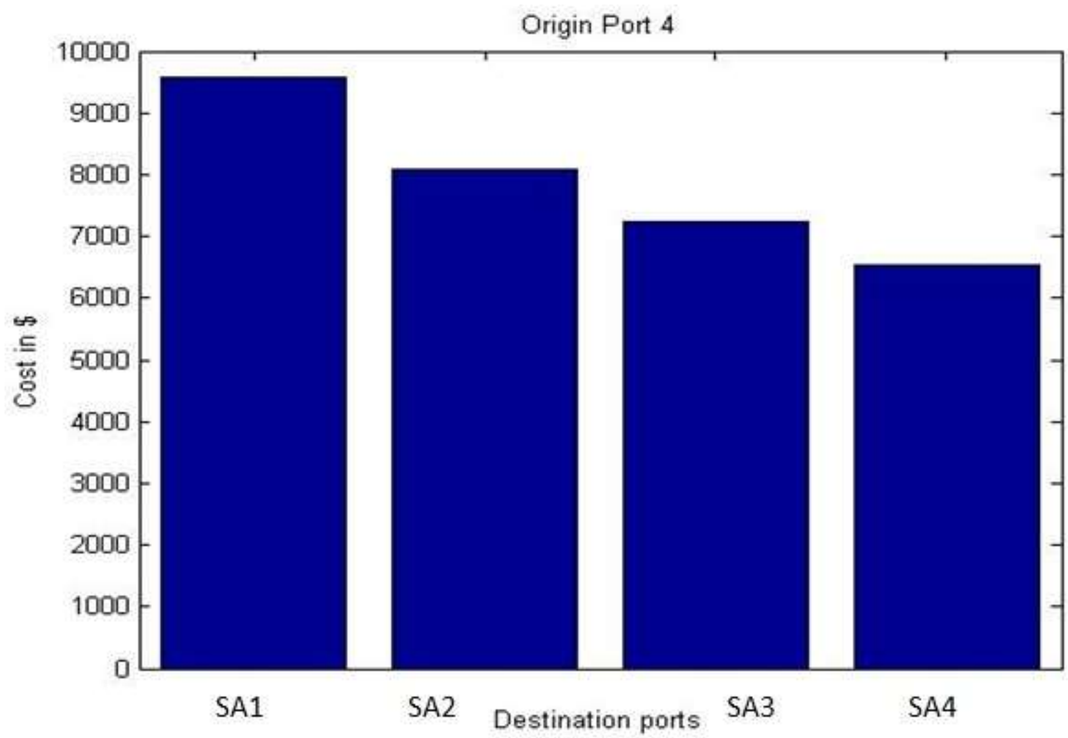

Figure 6.25 Cost analysis, Naryan-Mar (R4) - destination ports (SA)

Optimized path: Moscow –Kaliningrad- Richard Bay –Durban

Illustration 6.3.5. Russia to China

Cost analysis between each origin port of Russia to all destination port of China is shown in figure 6.26 to figure 6.31 and optimized path is Moscow-Azov -– Bahezhen –Shanghai

a) Moscow-Shanghai

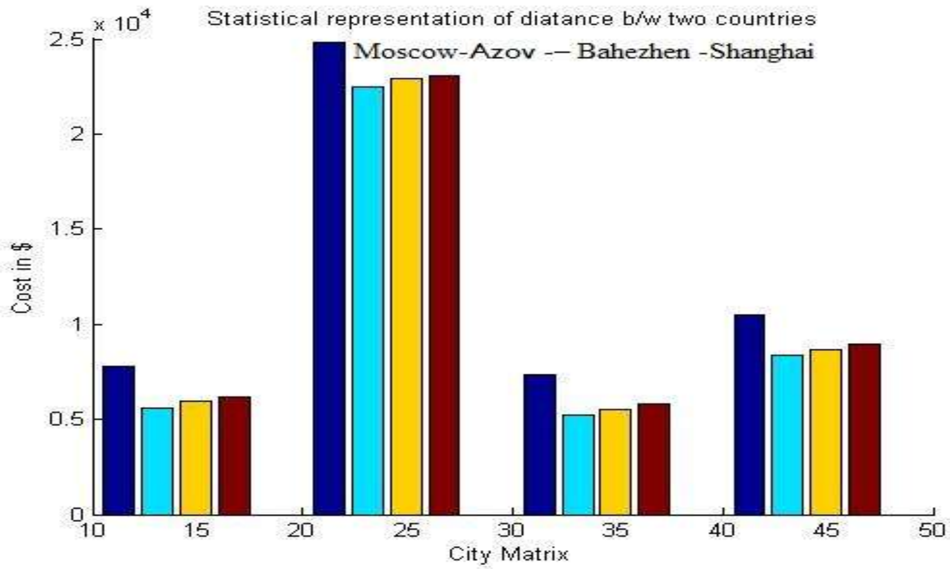

Figure 6.26 Cost analysis, Moscow-Shanghai

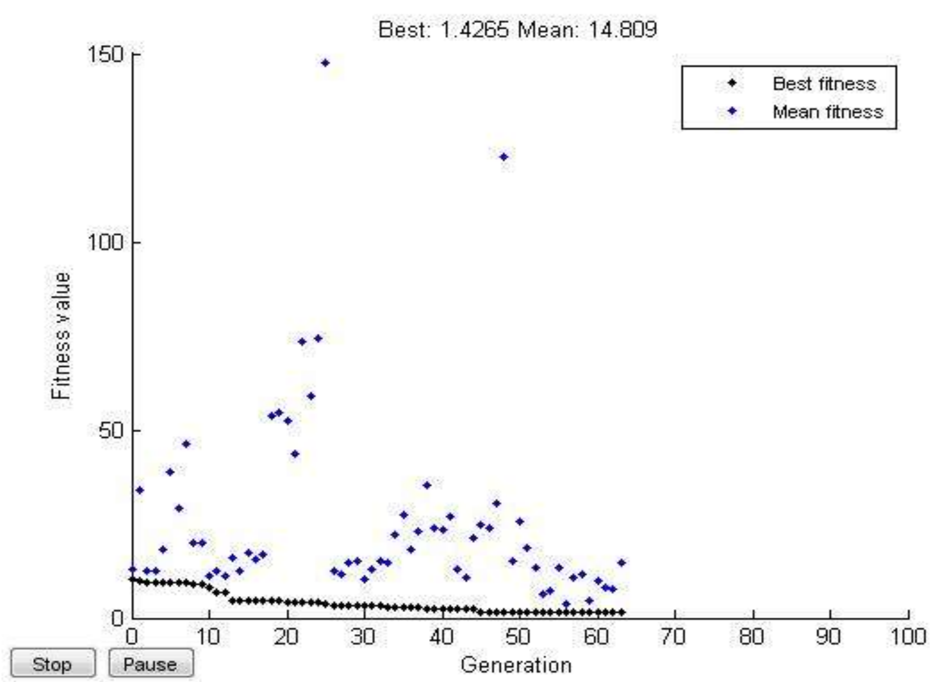

Figure 6.27 GA analysis, Moscow-Shanghai

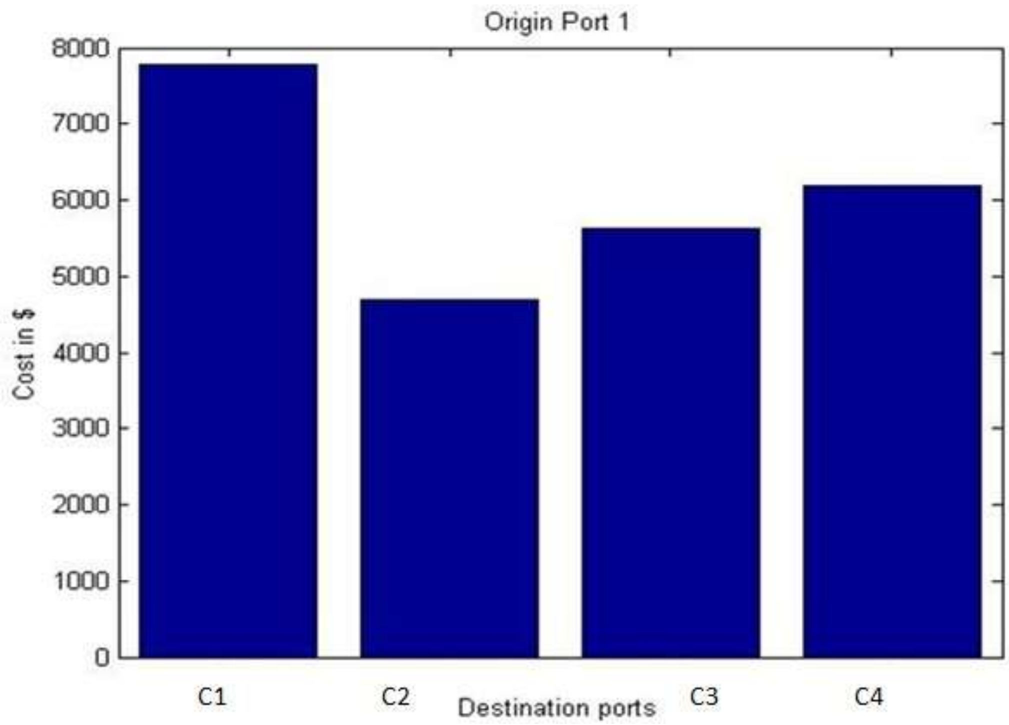

Figure 6.28 Cost analysis, Kaliningrad (R1) - destination ports (C)

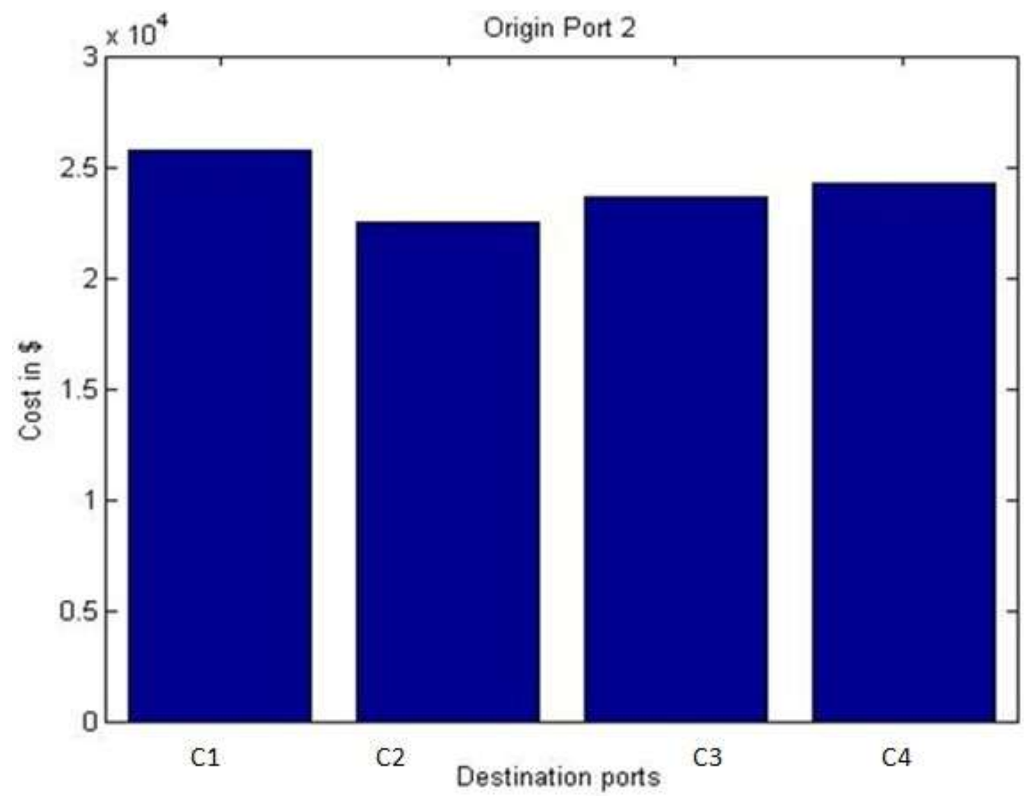

Figure 6.29 Cost analysis, Poronaysk (R2) - destination ports (C)

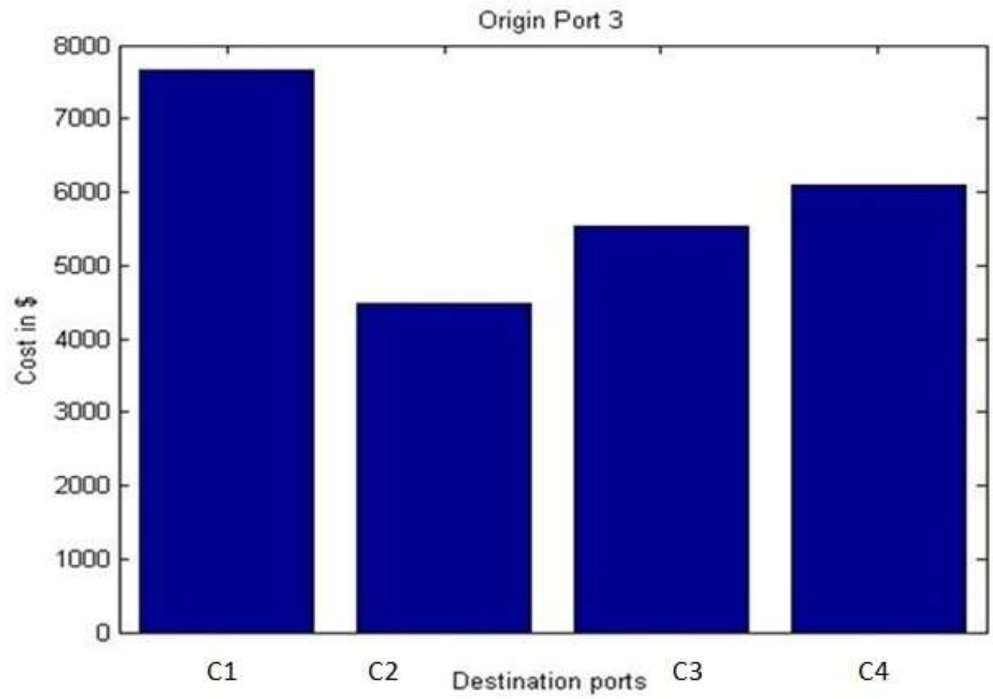

Figure 6.30 Cost analysis, Azov (R3) - destination ports (C)

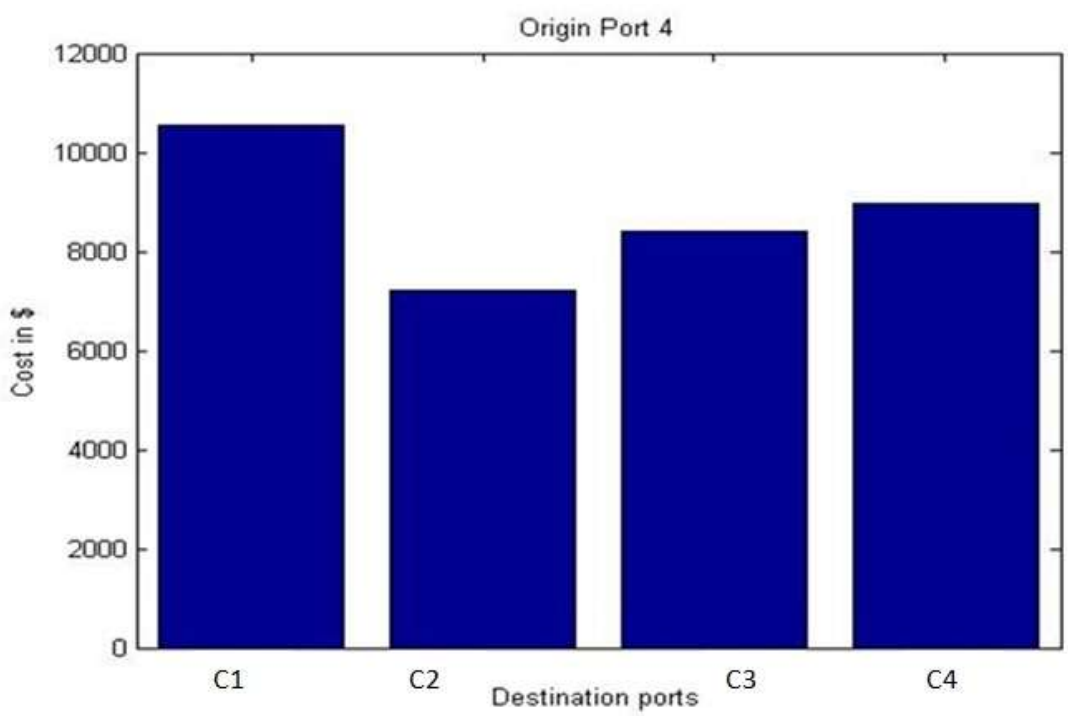

Figure 6.31 Cost analysis, Naryan-Mar (R4) - destination ports (C)

Optimized path: Moscow-Azov -– Bahezhen –Shanghai

Illustration 6.3.6. Brazil to Russia

Cost analysis between each origin port of Brazil to all destination port of Russia is shown in figure 6.32 to figure 6.37 and optimized path is Brasilia - Recife –Azov- Moscow

a) Brasilia-Moscow

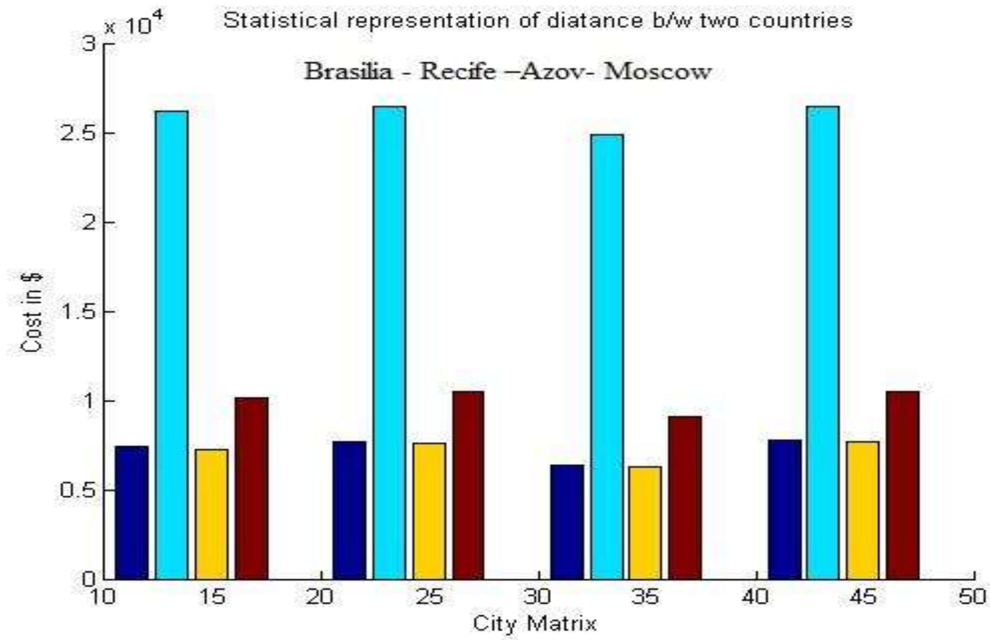

Figure 6.32 Cost analysis, Brasilia-Moscow

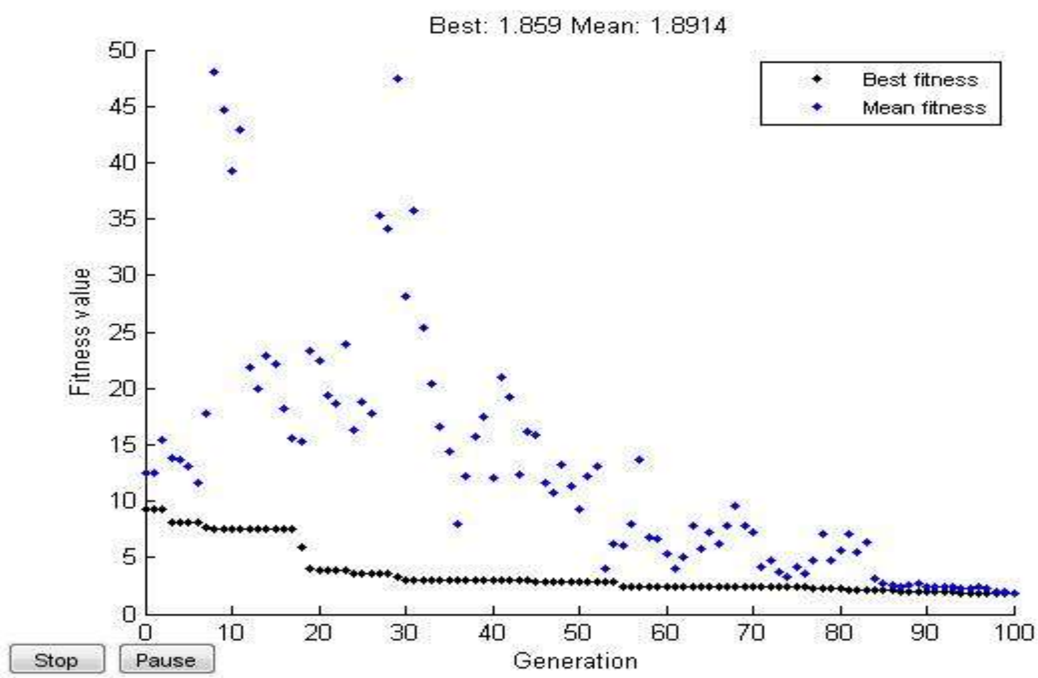

Figure 6.33 GA analysis, Brasilia-Moscow

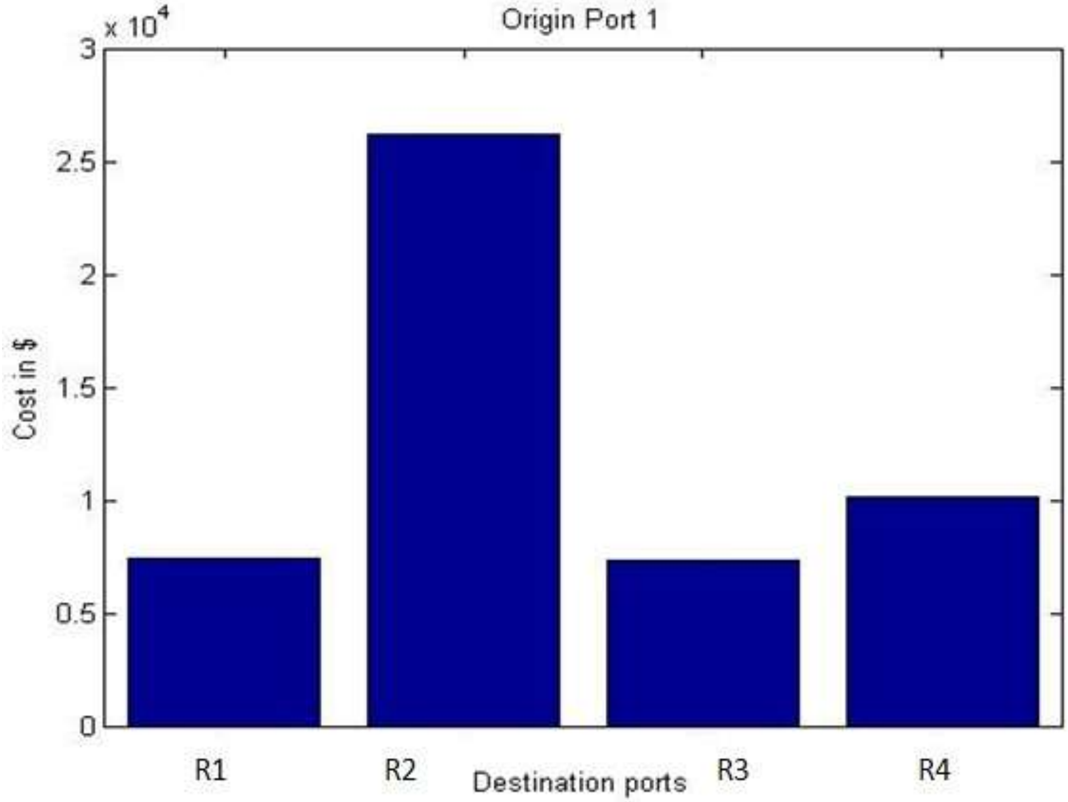

Figure 6.34 Cost analysis, Belem (B1) - destination ports (R)

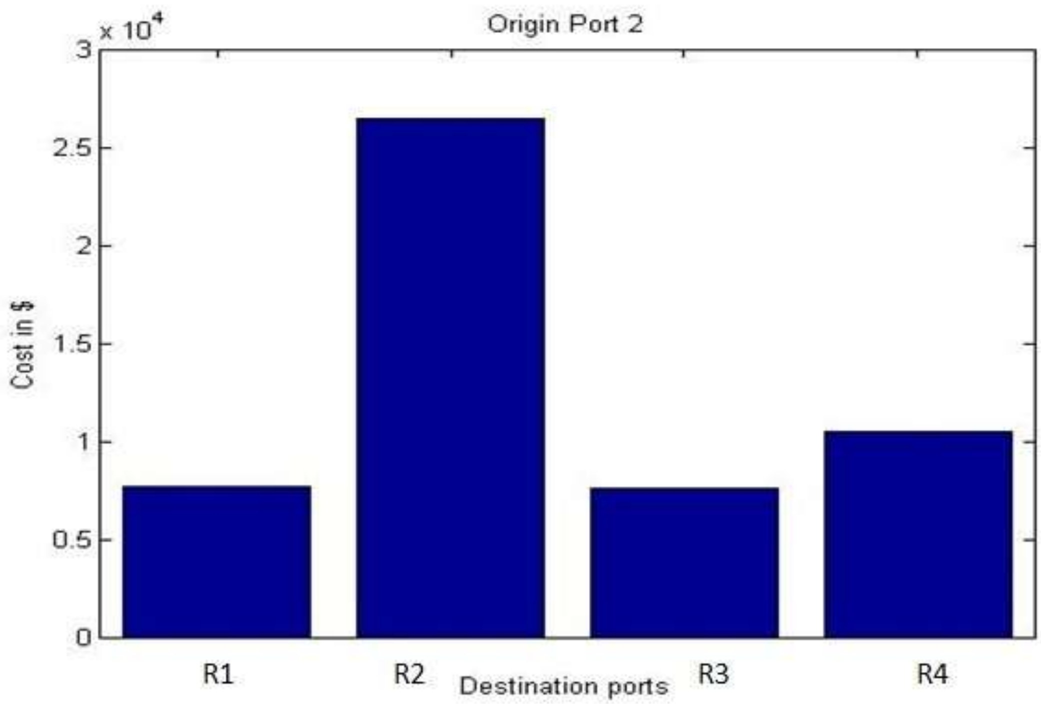

Figure 6.35 Cost analysis, Fortaleza (B2) - destination ports (R)

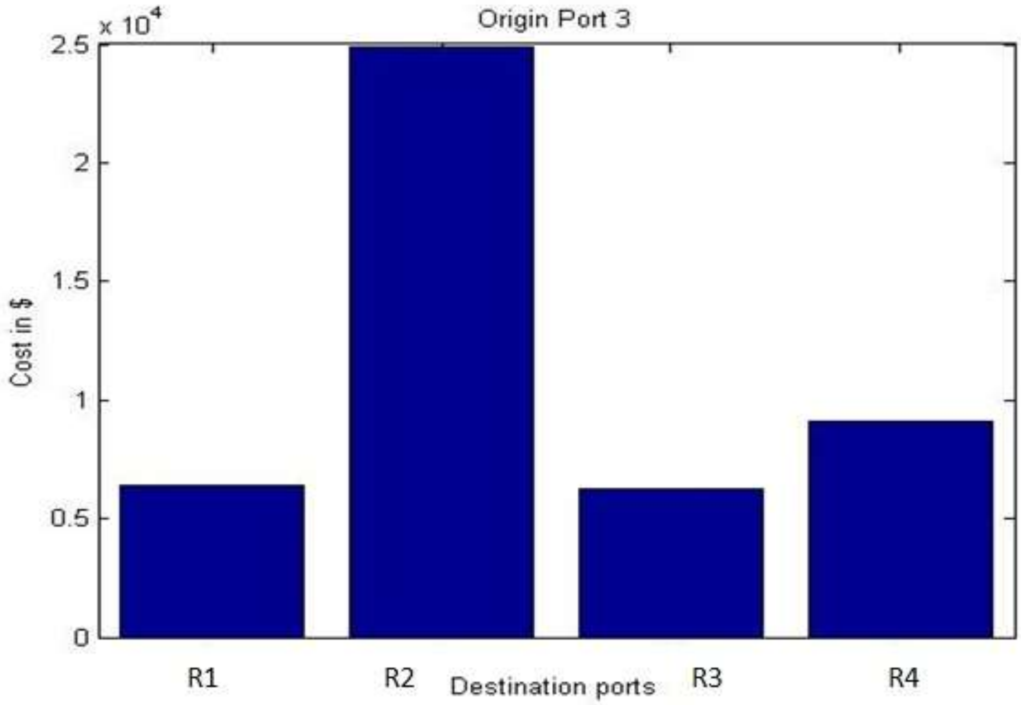

Figure 6.36 Cost analysis, Paranagua (B3) - destination ports (R)

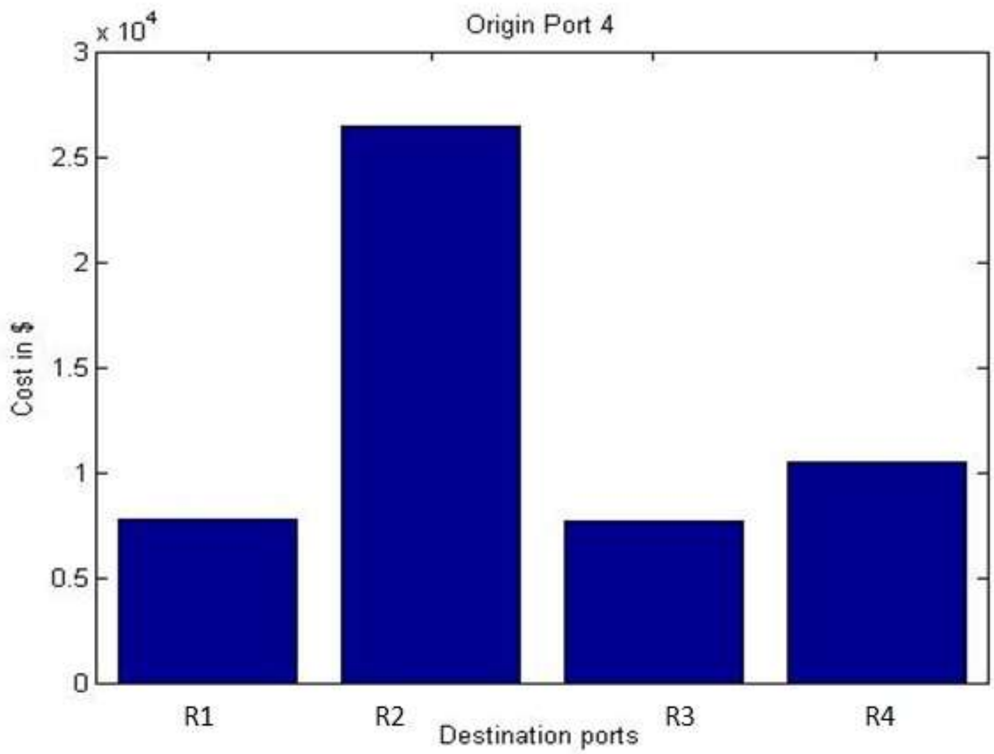

Figure 6.37 Cost analysis, Recife (B4) - destination ports (R)

Optimized path: Brasilia - Recife –Azov- Moscow

Illustration 6.3.7. Brazil to South Africa

Cost analysis between each origin port of Brazil to all destination port of South Africa is shown in figure 6.38 to figure 6.43 and optimized path is Brasilia-Paranagua –Richard Bay –Durban

a) Brasilia- Durban

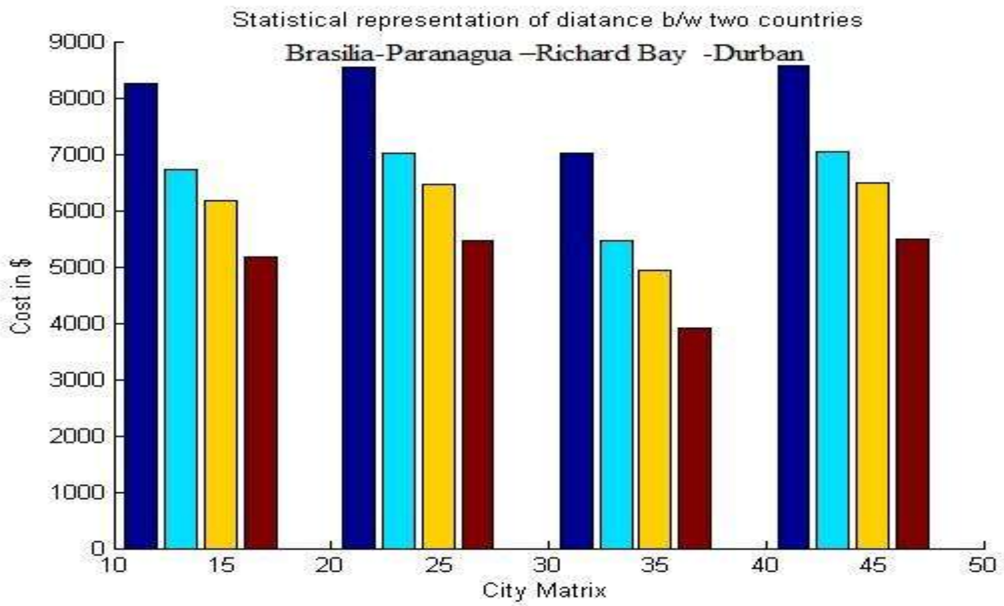

Figure 6.38 Cost analysis, Brasilia- Durban

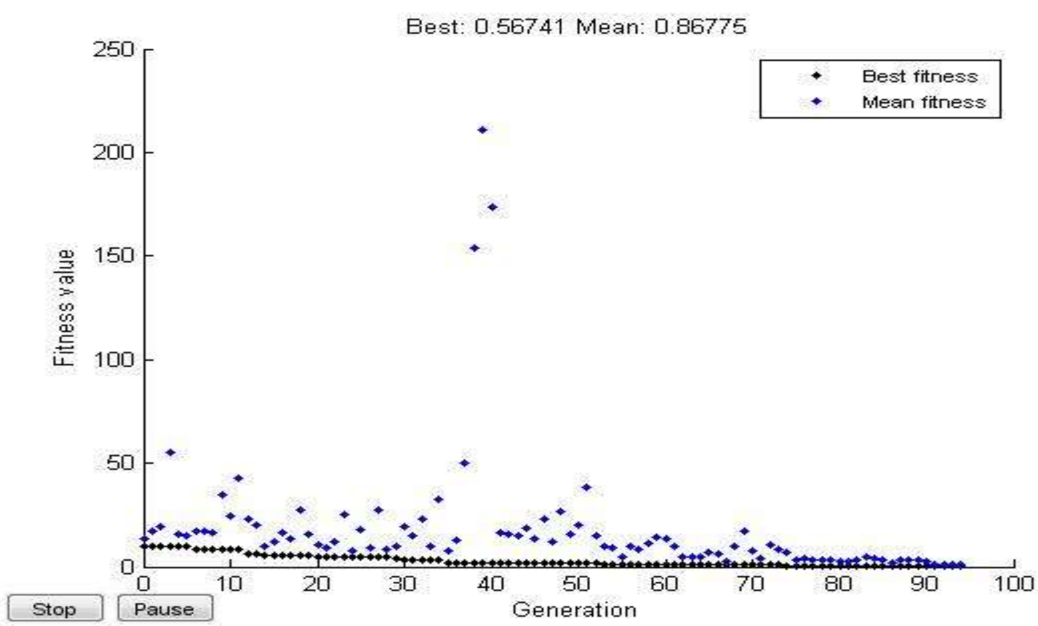

Figure 6.39 GA analysis, Brasilia- Durban

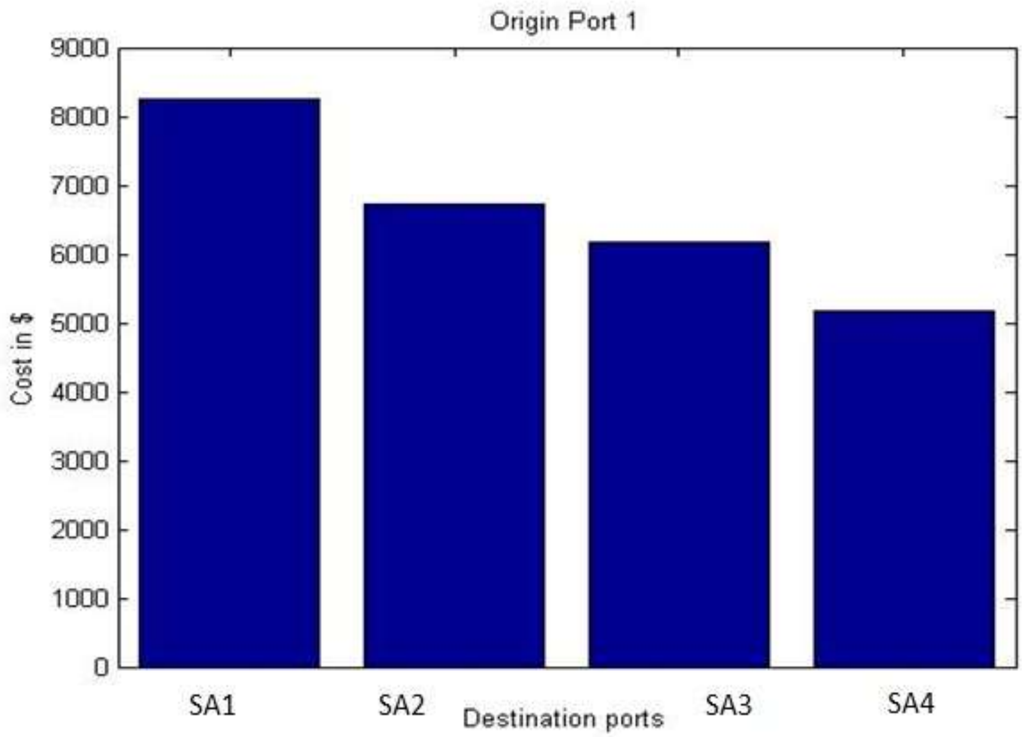

Figure 6.40 Cost analysis, Belem (B1) - destination ports (SA)

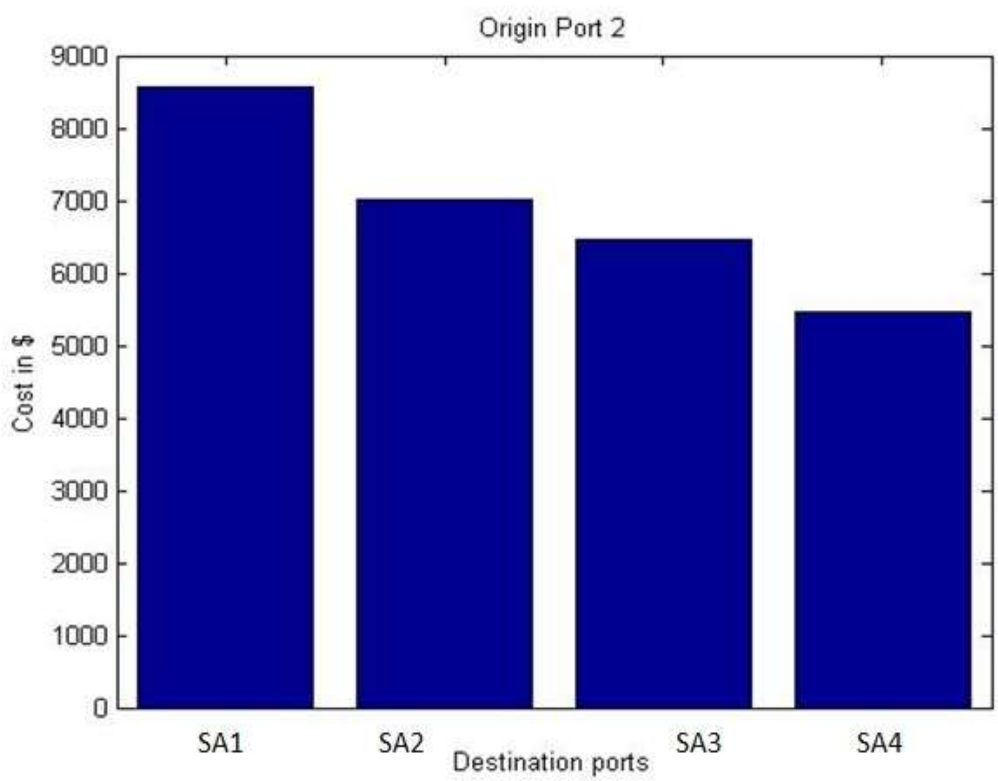

Figure 6.41 Cost analysis, Fortaleza (B2) - destination ports (SA)

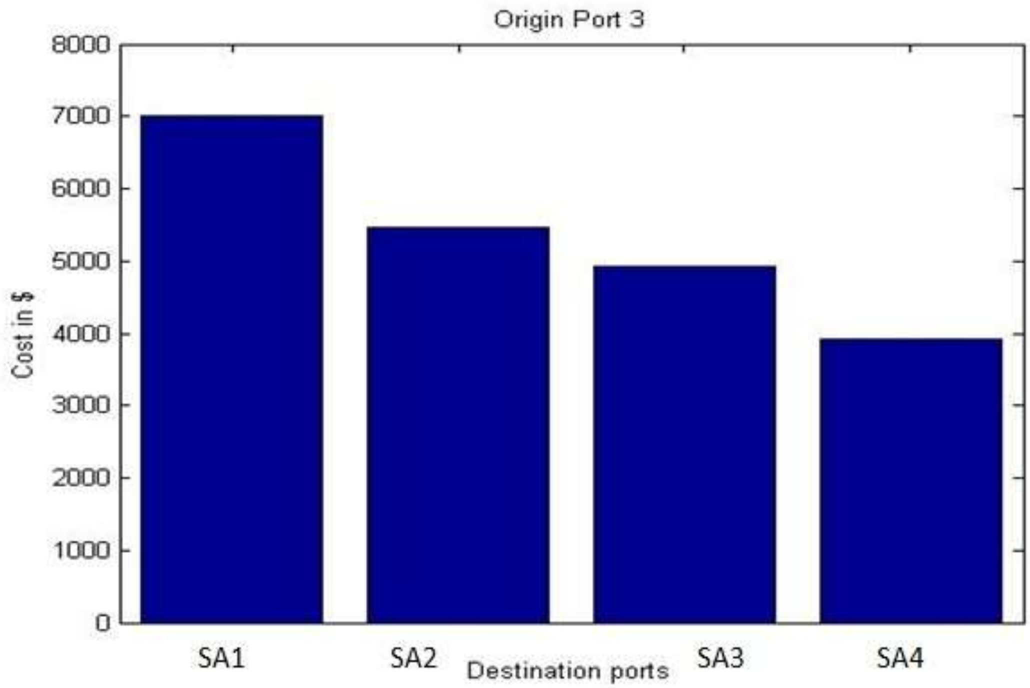

Figure 6.42 Cost analysis, Paranagua (B3) - destination ports (SA)

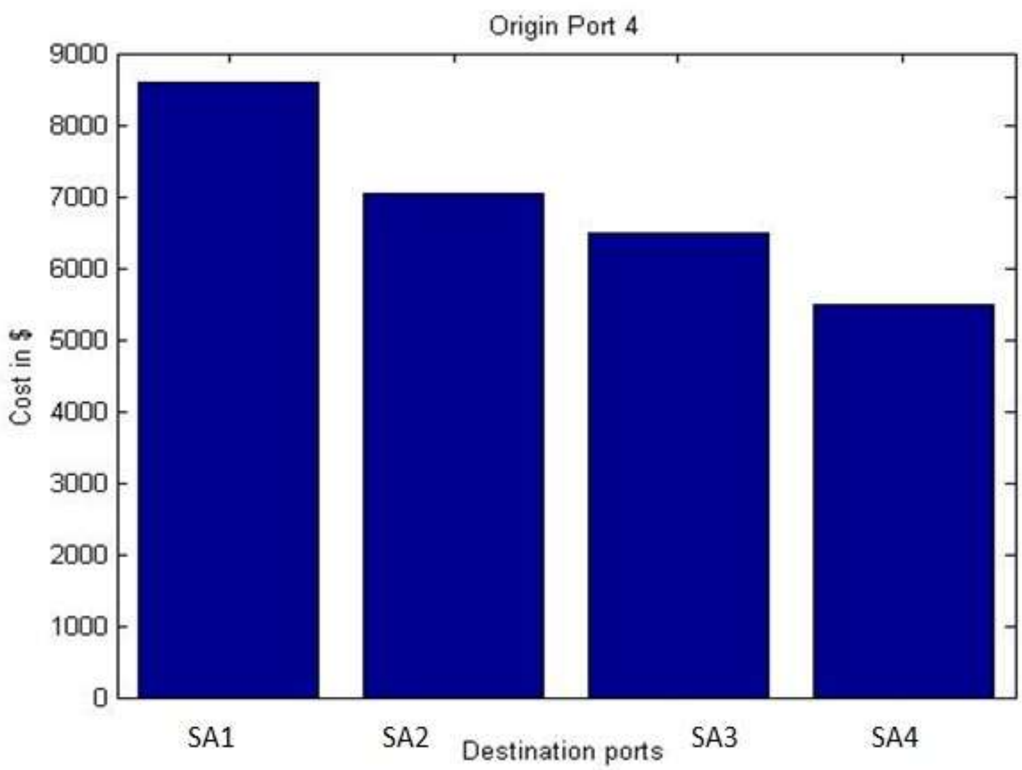

Figure 6.43 Cost analysis, Recife (B4) - destination ports (SA)

Optimized path: Brasilia-Paranagua –Richard Bay –Durban

Illustration 6.3.8. Brazil to India

Cost analysis between each origin port of Brazil to all destination port of India is shown in figure 6.44 to figure 6.49 and optimized path is Brasilia-Paranagua Mumbai -Ankleshwar

a) Brasilia-Ankleshwar

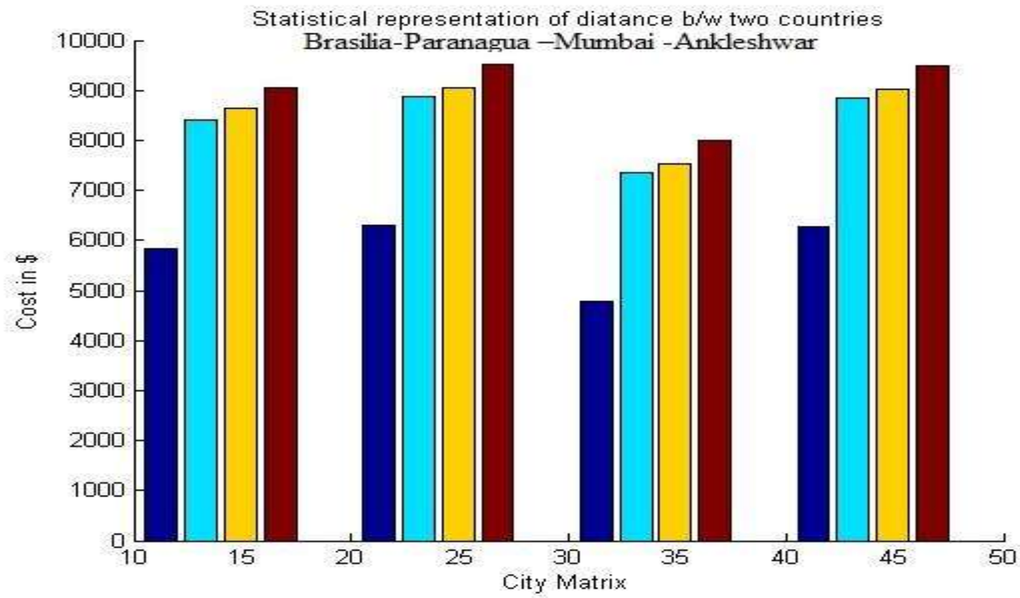

Figure 6.44 Cost analysis, Brasilia-Ankleshwar

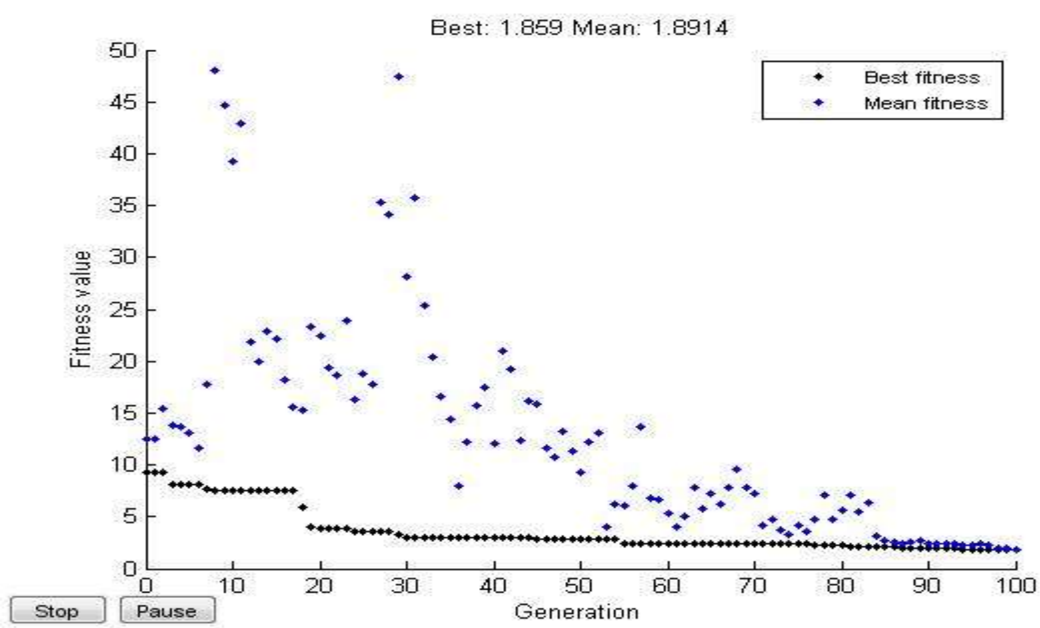

Figure 6.45 GA analyses, Brasilia-Ankleshwar

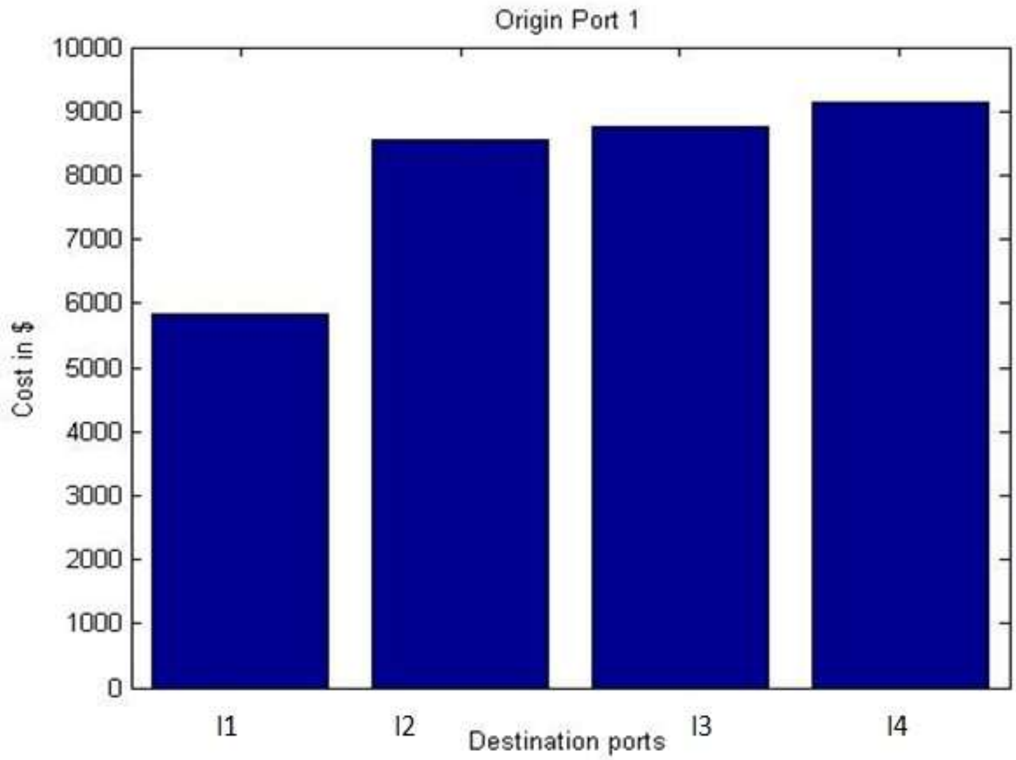

Figure 6.46 Cost analysis, Belem (B1) - destination ports (I)

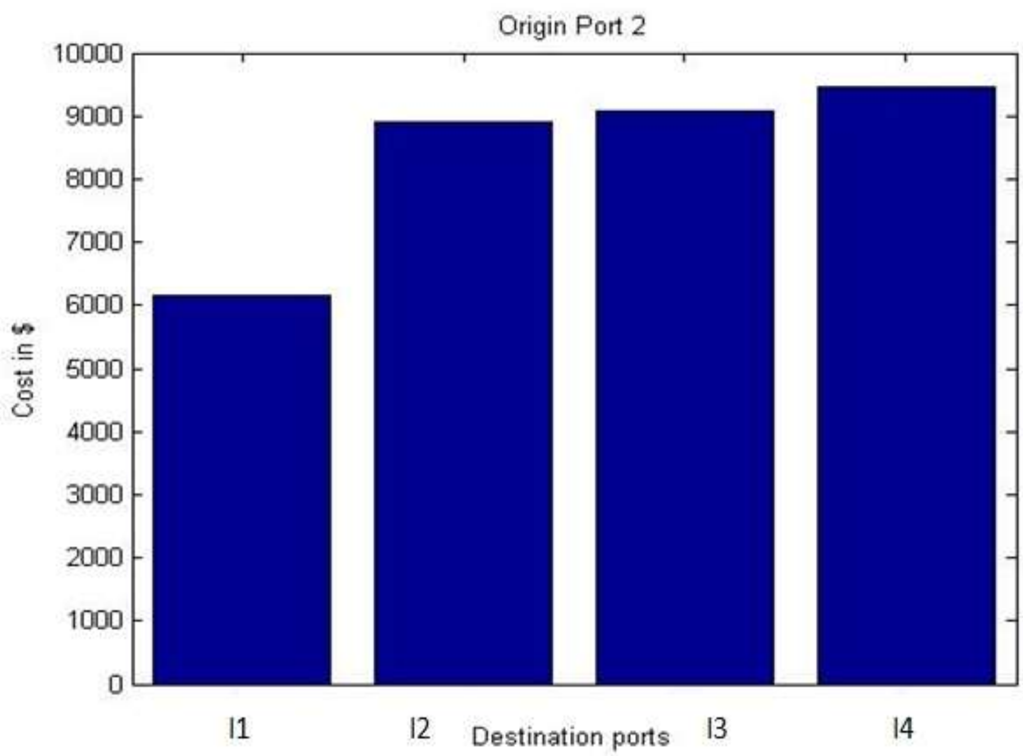

Figure 6.47 Cost analysis, Fortaleza (B2) - destination ports (I)

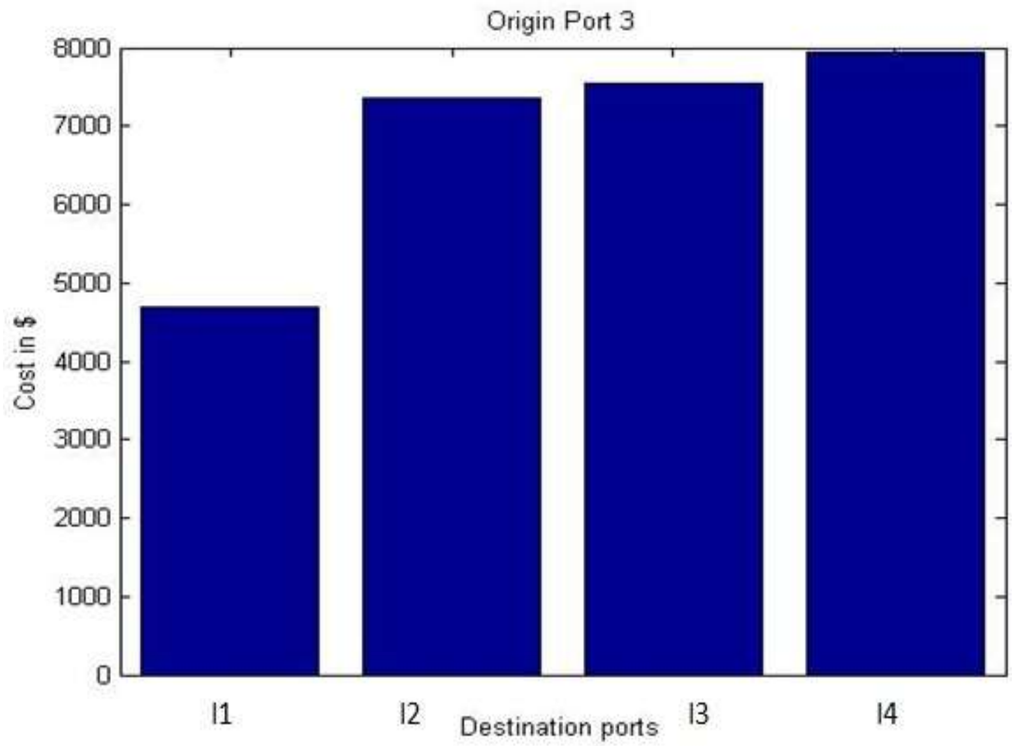

Figure 6.48 Cost analysis, Paranagua (B3) - destination ports (I)

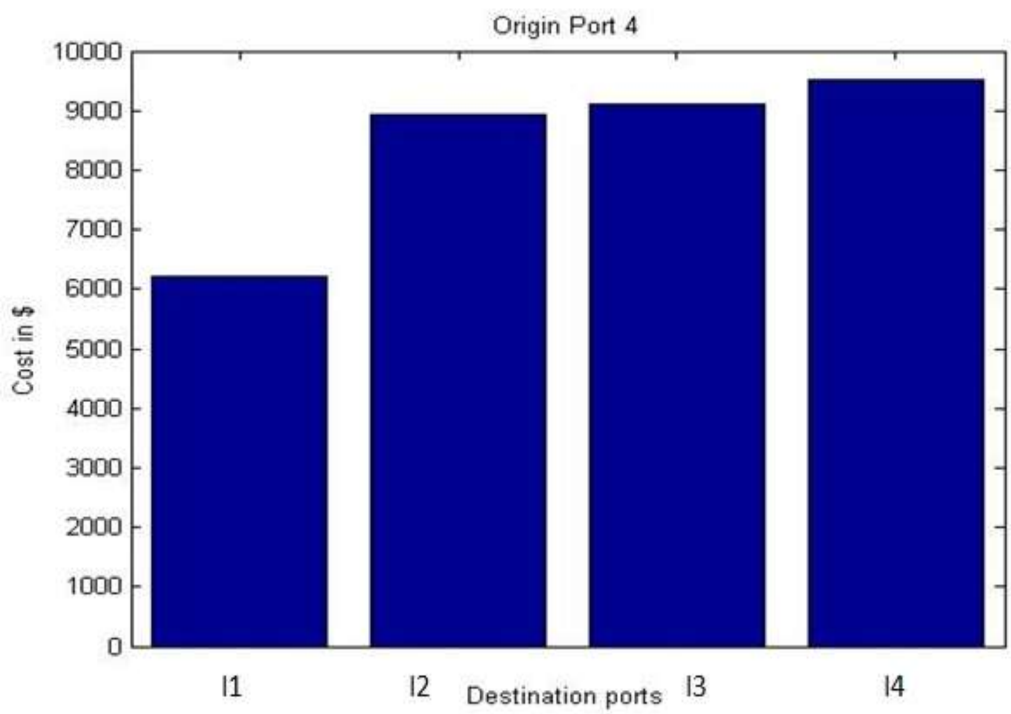

Figure 6.49 Cost analysis, Recife (B4) - destination ports (I)

Optimized path: Brasilia-Paranagua –Mumbai -Ankleshwar

Illustration 6.3.9. China to South Africa

Cost analysis between each origin port of China to all destination port of South Africa is shown in figure 6.50 to figure 6.55 and optimized path is Shanghai- Bahezhen –Richard Bay –Durban

a) Shanghai- Durban

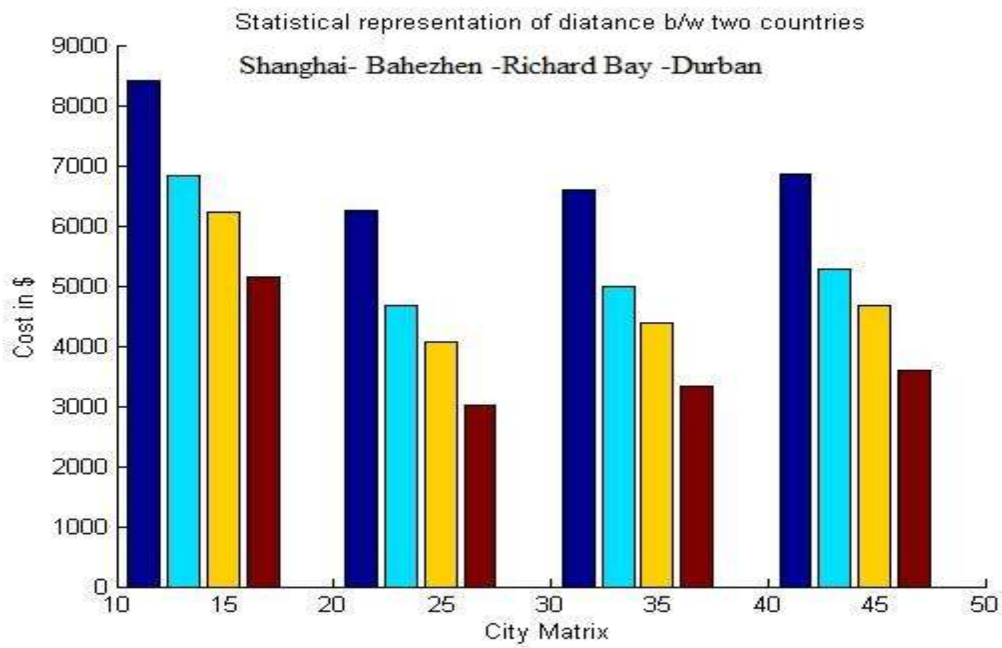

Figure 6.50 Cost analysis, Shanghai- Durban

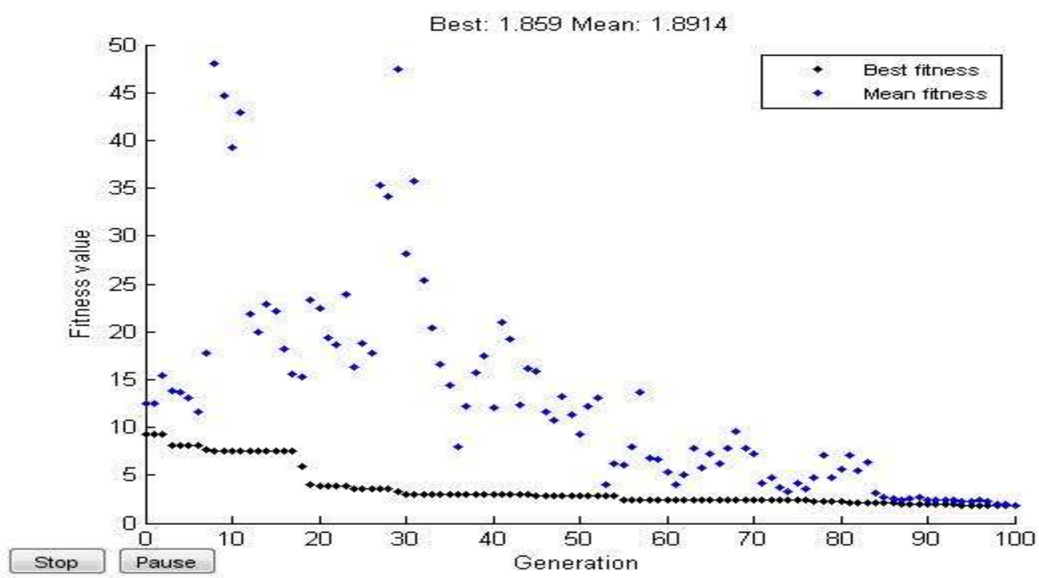

Figure 6.51 GA analyses, Shanghai- Durban

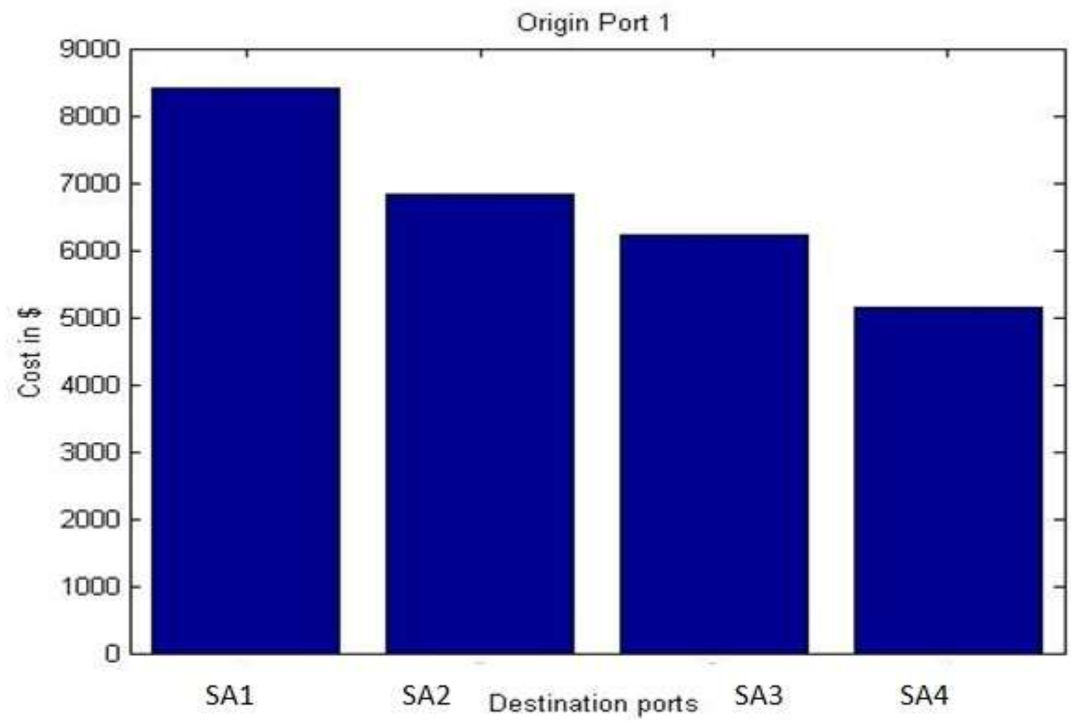

Figure 6.52 Cost analysis, Zhanjiang (C1) – destination ports (SA)

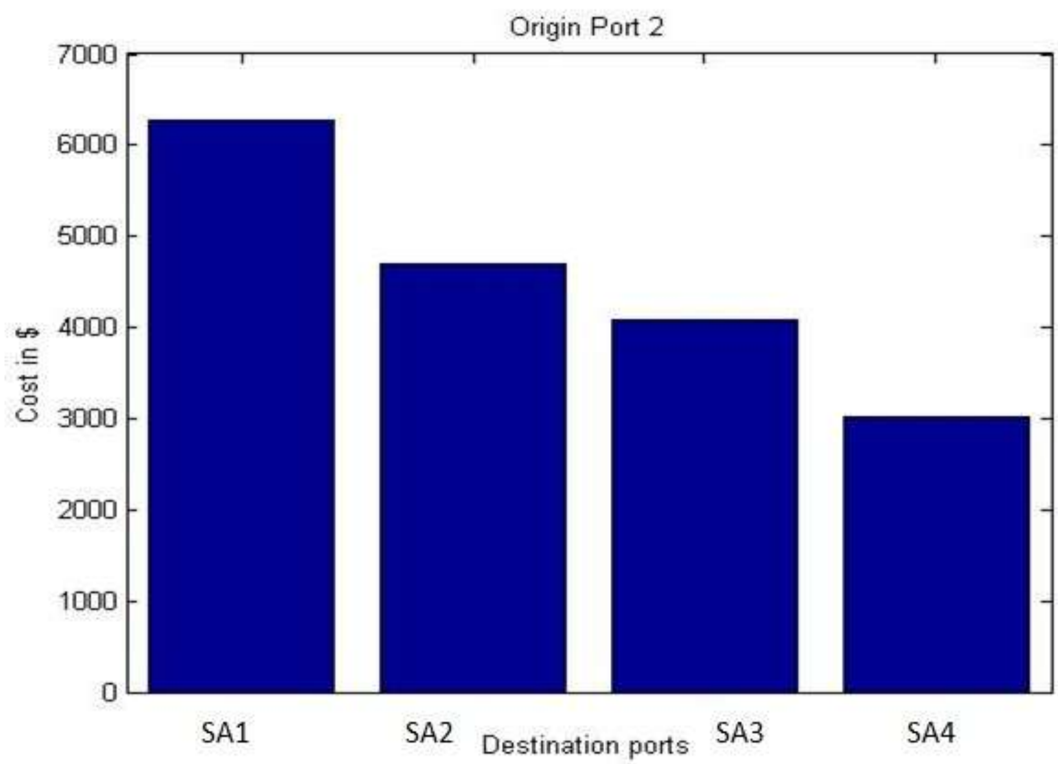

Figure 6.53 Cost analysis, Bahezhen (C2) – destination ports (SA)

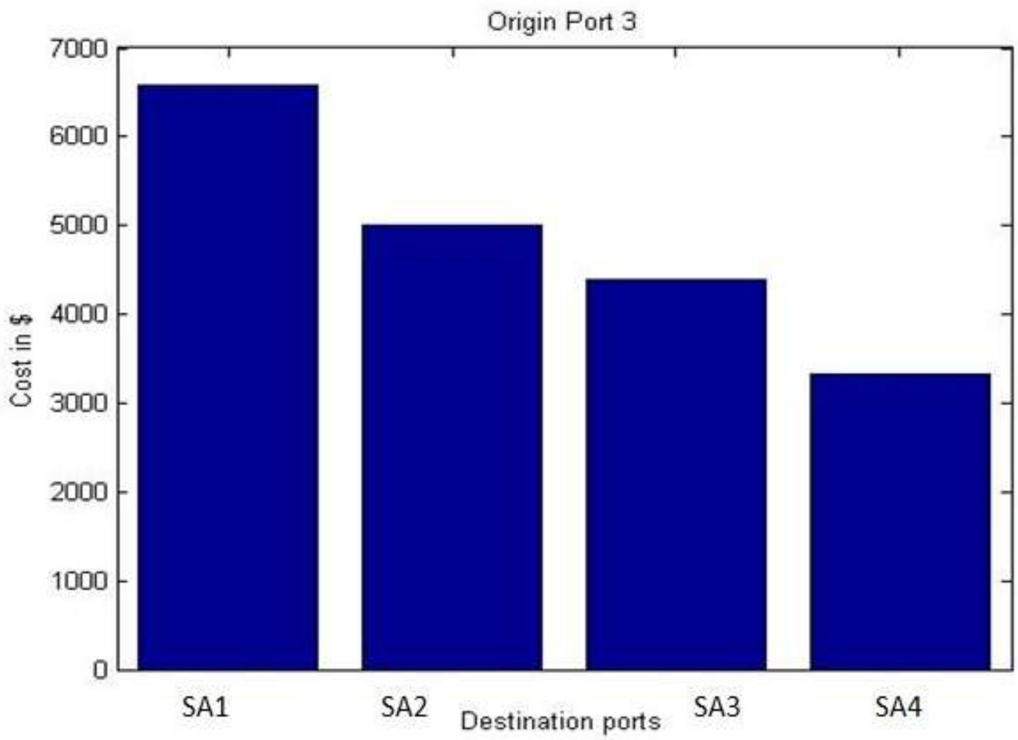

Figure 6.54 Cost analysis, Port of Xiamen (C3) – destination ports (SA)

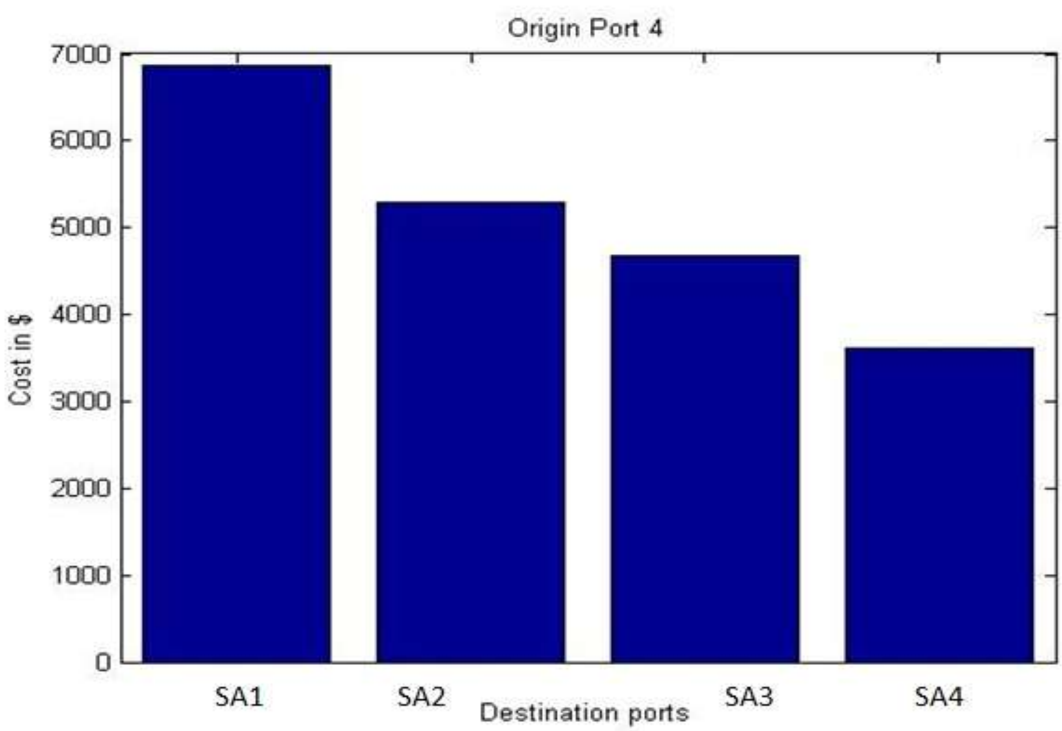

Figure 6.55 Cost analysis, Port of Tianjin (C4) – destination ports (SA)

Optimized path: Shanghai- Bahezhen –Richard Bay –Durban

Similarly remaining pair of origin and destination city of same group (Brazil-China, Russia –India, India-South Africa, Russia- South Africa, Russia- China, Brazil-Russia, Brazil- South Africa, Brazil- India and China- South Africa) have been taken and cost analysis and optimized path is shown in figure 113-figure193

CHAPTER VII

SUMMARY AND CONCLUSIONS

7.1 Summary

Research work achieves the optimal intra- route with minimum distance and required delivery time among BRICS for each O-D pair to minimize the total cost [Acquisition, Routing, Distribution, Demurrage and Detention costs] by keeping variation in ship's speed depends upon delivery time assigned by customer and assigning responsibility to freight forwarders for positioning loaded containers to end customers and repositioning empty containers to desired Yard.

7.2 Conclusions

Based on the cost analysis followed by optimized path shown in **Table 7.1**, we can conclude that if distance between origin city, origin port, destination port and destination city is less but cost is still high because in this case road distance is more compare to sea distance, also on the contrary part if distance is high and cost is less due to more sea distance than road distance. Optimized paths along with cost for all combination of origin – destination pair are shown as follows.

Table 7.1 Optimized path among origin and destination cities of BRICS

Origin Country	Origin City	Destination Country	Destination City	Demurrage {No. of Days}	Detention {No. of Days}	Ship's Speed {Knots}	Distance {in km}	Cost {in $}
Brazil	Brasilia	China	Shanghai	0	0	20	15329	6049
Optimized path: Brasilia- Paranagua- Bahezhen- Shanghai								
Brazil	Sao Paulo	China	Shanghai	0	0	20	14184	3976
Optimized path: Sao paulo- Paranagua- Bahezhen- Shanghai								
Brazil	Rio de Janeiro	China	Shanghai	0	0	20	14627	4938
Optimized path: Rio de Janeiro-Paranagua- Bahezhen- Shanghai								
Brazil	Belo Horizonte	China	Shanghai	0	0	20	14771	5250
Optimized path:Belo Horizonte-Paranagua- Bahezhen- Shanghai								

Brazil	Sao Paulo	China	Beijing	0	0	20	14572	2532
Optimized path:Sao Paulo-Paranagua- Tianjin –Beijing								
Brazil	Rio de Janeiro	China	Shenzhen	0	0	20	13565	4124
Optimized path:Rio de Janeiro - Paranagua- Zhanjiang- Shenzhen								
Brazil	Belo Horizonte	China	Suzhou	0	0	20	14757	5033
Optimized path:Belo Horizonte - Paranagua- Bahezhen- Suzhou								
Brazil	Brasilia	Russia	Moscow	0	0	20	**9576**	**6279**
Optimized path:Brasilia - Recife –Azov- Moscow								
Brazil	Sao Paulo	Russia	Samara	0	0	20	10313	4678
Optimized path: Sao Paulo- Paranagua –Azov-Samara								
Brazil	Rio de Janeiro	Russia	Yekaterinb urg	0	0	20	10955	4391
Optimized path: Rio de Janeiro- Paranagua –Naryan-Mar –Yekaterinburg								
Brazil	Belo Horizonte	Russia	Saint Petersburg	0	0	20	9224	4863
Optimized path: Belo Horizonte-Paranagua –Kaliningrad -Saint Petersburg								
Brazil	Brasilia	India	Ankleshwar	0	0	20	**10145**	**2217**
Optimized path: Brasilia-Paranagua –Mumbai –Ankleshwar								
Brazil	Sao Paulo	India	Vapi	0	0	20	11281	4682
Optimized path: Sao Paulo-Paranagua –Mumbai –Vapi								
Brazil	Rio de Janeiro	India	Ghaziabad	0	0	20	11850	5917
Optimized path:Rio de Janeiro-Paranagua –Mumbai –Ghaziabad								
Brazil	Belo Horizonte	India	Chandrapur	0	0	20	11466	4669
Optimized path: Belo Horizonte-Paranagua –Vishakhapatnam –Chandrapur								
Brazil	Brasilia	South Africa	Durban	0	0	20	**6492**	**3920**
Optimized path: Brasilia-Paranagua –Richard Bay -Durban								
Brazil	Sao Paulo	South Africa	Free state	0	0	20	**5528**	**2838**
Optimized path: Sao Paulo-Paranagua –East London -Free state								

Brazil	Rio de Janeiro	South Africa	Gauteng	0	0	20	6263	3705
Optimized path: Rio de Janeiro-Paranagua –Richard Bay –Gauteng								
Brazil	Belo Horizonte	South Africa	Eastern cap	0	0	20	5753	3148
Optimized path: Belo Horizonte-Paranagua –East London -Eastern cap								
Russia	Moscow	India	Ankleshwar	0	0	20	**6674**	**3620**
Optimized path: Moscow-Azov – Mumbai –Ankleshwar								
Russia	Samara	India	Vapi	0	0	20	6758	3803
Optimized path: Samara-Azov – Mumbai –Vapi								
Russia	Yekaterinburg	India	Ghaziabad	0	0	20	8952	8381
Optimized path: Yekaterinburg-Naryan-Mar –Mumbai–Ghaziabad								
Russia	Saint Petersburg	India	Chandrapur	0	0	20	7957	4266
Optimized path: Saint Petersburg-Kaliningrad –Vishakhapatnam-Chandrapur								
India	Ankleshwar	China	Shanghai	0	0	20	6129	3086
Optimized path: Ankleshwar-Mumbai –Bahezhen-Shanghai								
India	Vapi	China	Beijing	0	0	20	6360	1238
Optimized path: Vapi-Mumbai-Tianjin-Beijing								
India	Ghaziabad	China	Shenzhen	0	0	20	5783	4606
Optimized path:Ghaziabad –Mumbai- Zhanjiang –Shenzhen								
India	Chandrapur	China	Suzhou	0	**0**	**20**	**5859**	**3601**
Optimized path: Chandrapur-Vishakhapatnam – Bahezhen –Suzhou								
India	Ankleshwar	South Africa	Durban	**0**	**0**	**20**	**5143**	**1534**
Optimized path: Ankleshwar-Mumbai–Richard Bay –Durban								
India	Vapi	South Africa	Free state	**0**	**0**	**20**	**5519**	**2295**
Optimized path: Vapi-Mumbai -East London-Free state								

India	Ghaziabad	South Africa	Gauteng	0	0	20	6685	4880
Optimized path: Ghaziabad-Mumbai –Richard Bay –Gauteng								
India	Chandrapur	South Africa	Eastern cap	0	0	20	6100	**2506**
Optimized path: Chandrapur-Vishakhapatnam-East London-Eastern cap								
Russia	Moscow	South Africa	Durban	0	0	20	**9043**	**3743**
Optimized path: Moscow –Kaliningrad- Richard Bay –Durban								
Russia	Samara	South Africa	Free state	0	0	20	9301	**5055**
Optimized path: Samara-Azov – East London –Free state								
Russia	Yekaterinburg	South Africa	Gauteng	0	0	20	9847	**6682**
Optimized path: Yekaterinburg-Naryan-Mar –Richard Bay –Gauteng								
Russia	Saint Petersburg	South Africa	Eastern cap	0	0	20	9322	**3200**
Optimized path: Saint Petersburg-Kaliningrad -East London-Eastern cap								
Russia	Moscow	China	Shanghai	0	0	20	**11661**	**5202**
Optimized path: Moscow-Azov – Bahezhen –Shanghai								
Russia	Samara	China	Beijing	0	0	20	5043	4503
Optimized path: Samara-Azov – Tianjin –Beijing								
Russia	Yekaterinburg	China	Shenzhen	0	0	20	5358	6674
Optimized path: Yekaterinburg-Naryan-Mar –Zhanjiang –Shenzhen								
Russia	Saint Petersburg	China	Suzhou	0	0	20	4774	3801
Optimized path: Saint Petersburg-Kaliningrad -Bahezhen –Suzhou								
China	Shanghai	South Africa	Durban	0	0	20	**9009**	**3015**
Optimized path: Shanghai- Bahezhen -Richard Bay –Durban								
China	Beijing	South Africa	Free state	0	0	20	9940	2609
Optimized path: Beijing- Tianjin -East London -Free state								

China	Shenzhen	South Africa	Gauteng	0	0	20	8367	3084
Optimized path: Shenzhen- Xiamen -East London –Gauteng								
China	Suzhou	South Africa	Eastern cap	0	0	20	9374	2937
Optimized path: Suzhou- Bahezhen -East London -Eastern cap								

7.3 Result Justification

Result mentioned in above table are justified by manual calculation for possible origin – destination cities of each country with all ports of origin and destination country and found the same value with more iteration compare to GA, shown in table given below.

Table 7.2 Result Justification between Brazil and China

Origin City	Brazil Origin port	China Destination Port	Destination City	Demurrage {No. of Days}	Detention {No. of Days}	Ship, Speed {Knots}	Distance {in kms.}	Cost {in $}
Brasilia and Shanghai are origin and destination city of Brazil and China								
Brasilia	Belem	Zhanjiang	Shanghai	0	0	20	17511	9502
Brasilia	Belem	Xiamen	Shanghai	0	0	20	17200	7677
Brasilia	Belem	Bahezhen	Shanghai	0	0	20	15575	7139
Brasilia	Belem	Tianjin	Shanghai	0	0	20	18557	7947
Brasilia	Fortale-za	Zhanjiang	Shanghai	0	0	20	16938	9801
Brasilia	Fortale-za	Xiamen	Shanghai	0	0	20	16638	7976
Brasilia	Fortale-za	Bahezhen	Shanghai	0	0	20	17509	7653
Brasilia	Fortale-za	Tianjin	Shanghai	0	0	20	17995	8247
Brasilia	Parangua	Zhanjiang	Shanghai	0	0	20	15493	8259
Brasilia	Parangua	Xiamen	Shanghai	0	0	20	15163	6432
Brasilia	**Parangua**	**Bahezhen**	**Shanghai**	**0**	**0**	**20**	**15329**	**6049**
Brasilia	Parangua	Tianjin	Shanghai	0	0	20	16520	6703
Brasilia	Recife	Zhanjiang	Shanghai	0	0	20	16010	9777
Brasilia	Recife	Xiamen	Shanghai	0	0	20	16287	8002
Brasilia	Recife	Bahezhen	Shanghai	0	0	20	17158	7679
Brasilia	Recife	Tianjin	Shanghai	0	0	20	17643	8273

Table 7.3 Result Justification between Brazil and Russia

Origin City	Brazil Origin port	Russia Destination Port	Destination City	Demurrage {No. of Days}	Detention {No. of Days}	Ship, Speed {Knots}	Distance {in kms.}	Cost {in $}
Brasilia and Moscow are origin and destination city of Brazil and Russia								
Brasilia	Belem	Kaliningrad	Moscow	0	0	20	9850	7363
Brasilia	Belem	Poronaysk	Moscow	0	0	20	28057	2609
Brasilia	Belem	Azov	Moscow	0	0	20	10330	7252
Brasilia	Belem	Naryan-	Moscow	0	0	20	12547	1009

		Mar						
Brasilia	Fortale-za	Kaliningrad	Moscow	0	0	20	9570	7675
Brasilia	Fortale-za	Poronaysk	Moscow	0	0	20	27495	2639
Brasilia	Fortale-za	Azov	Moscow	0	0	20	10057	7577
Brasilia	Fortale-za	Naryan-Mar	Moscow	0	0	20	12273	1041
Brasilia	Parangua	Kaliningrad	Moscow	0	0	20	12273	1041
Brasilia	Parangua	Poronaysk	Moscow	0	0	20	26030	2485
Brasilia	Parangua	Azov	Moscow	0	0	20	11051	6245
Brasilia	Parangua	Naryan-Mar	Moscow	0	0	20	13268	9087
Brasilia	Recife	Kaliningrad	Moscow	0	0	20	9640	7750
Brasilia	Recife	Poronaysk	Moscow	0	0	20	27123	2641
Brasilia	**Recife**	**Azov**	**Moscow**	**0**	**0**	**20**	**9576**	**6279**
Brasilia	Recife	Naryan-Mar	Moscow	0	0	20	12335	1048

Table 7.4 Result Justification between Brazil and India

Origin City	Brazil Origin port	India Destination Port	Destination City	Demurrage {No. of Days}	Detention {No. of Days}	Ship, Speed {Knots}	Distance {in kms.}	Cost {in $}
Brasilia and Ankleshwar are origin and destination city of Brazil and India								
Brasilia	Belem	Mumbai	Ankleshwar	0	0	20	12227	5794
Brasilia	Belem	Vishakhapatnam	Ankleshwar	0	0	20	14593	8513
Brasilia	Belem	Chennai	Ankleshwar	0	0	20	14276	8701
Brasilia	Belem	Cochin	Ankleshwar	0	0	20	13888	9086
Brasilia	Fortale-za	Mumbai	Ankleshwar	0	0	20	11918	6116
Brasilia	Fortale-za	Vishakhapatnam	Ankleshwar	0	0	20	14511	8854
Brasilia	Fortale-za	Chennai	Ankleshwar	0	0	20	14003	9025
Brasilia	Fortale-za	Cochin	Ankleshwar	0	0	20	13615	9411
Brasilia	**Parangua**	**Mumbai**	**Ankleshwar**	**0**	**0**	**20**	**10145**	**2217**
Brasilia	Parangua	Vishakhapatnam	Ankleshwar	0	0	20	13046	7311
Brasilia	Parangua	Chennai	Ankleshwar	0	0	20	12829	7507
Brasilia	Parangua	Cochin	Ankleshwar	0	0	20	12572	7904
Brasilia	Recife	Mumbai	Ankleshwar	0	0	20	11980	6177
Brasilia	Recife	Vishakhapatnam	Ankleshwar	0	0	20	14160	8880
Brasilia	Recife	Chennai	Ankleshwar	0	0	20	12572	9076
Brasilia	Recife	Cochin	Ankleshwar	0	0	20	13686	9473

Table 7.5 Result Justification between Brazil and South Africa

Origin City	Brazil Origin port	SA Destination Port	Destination City	Demurrage {No. of Days}	Detention {No. of Days}	Ship, Speed {Knots}	Distance {in kms.}	Cost {in $}
Brasilia and Durban are origin and destination city of Brazil and SA								
Brasilia	Belem	Cape town	Durban	0	0	20	9084	8239
Brasilia	Belem	Port Elizabeth	Durban	0	0	20	8804	6696
Brasilia	Belem	East London	Durban	0	0	20	8687	6153
Brasilia	Belem	Richard Bay	Durban	0	0	20	8540	5146
Brasilia	Fortale-za	Cape town	Durban	0	0	20	8501	8537
Brasilia	Fortale-za	Port Elizabeth	Durban	0	0	20	8221	6944
Brasilia	Fortale-za	East London	Durban	0	0	20	8105	6451
Brasilia	Fortale-za	Richard Bay	Durban	0	0	20	7957	5442
Brasilia	Parangua	Cape town	Durban	0	0	20	7036	6994
Brasilia	Parangua	Port Elizabeth	Durban	0	0	20	6756	5451
Brasilia	Parangua	East London	Durban	0	0	20	6492	3901
Brasilia	**Parangua**	**Richard Bay**	**Durban**	0	0	20	**6492**	**3920**
Brasilia	Recife	Cape town	Durban	0	0	20	8150	8563
Brasilia	Recife	Port Elizabeth	Durban	0	0	20	7870	7020
Brasilia	Recife	East London	Durban	0	0	20	7753	6476
Brasilia	Recife	Richard Bay	Durban	0	0	20	7606	5470

Table 7.6 Result Justification between Russia and South Africa

Origin City	Russia Origin port	SA Destination Port	Destination City	Demurrage {No. of Days}	Detention {No. of Days}	Ship, Speed {Knots}	Distance {in kms.}	Cost {in $}
Moscow and Durban are origin and destination city of Russia and SA								
Moscow	Kaliningr-ad	Cape town	Durban	0	0	20	11162	6853
Moscow	Kaliningr-ad	Port Elizabeth	Durban	0	0	20	10882	5310
Moscow	Kaliningr-ad	East London	Durban	0	0	20	10579	4753
Moscow	**Kaliningr-ad**	**Richard Bay**	**Durban**	**0**	**0**	**20**	**9043**	**3743**
Moscow	Poronaysk	Cape town	Durban	0	0	20	21951	2432
Moscow	Poronaysk	Port Elizabeth	Durban	0	0	20	21073	2335
Moscow	Poronaysk	East London	Durban	0	0	20	20678	2278
Moscow	Poronaysk	Richard Bay	Durban	0	0	20	19872	2172
Moscow	Azov	Cape town	Durban	0	0	20	10617	6654
Moscow	Azov	Port Elizabeth	Durban	0	0	20	9439	5033
Moscow	Azov	East London	Durban	0	0	20	9043	4466
Moscow	Azov	Richard Bay	Durban	0	0	20	8237	3403
Moscow	Naryan-mar	Cape town	Durban	0	0	20	13854	9587
Moscow	Naryan-mar	Port Elizabeth	Durban	0	0	20	13575	8044

Moscow	Naryan-mar	East London	Durban	0	0	20	13458	7501
Moscow	Naryan-mar	Richard Bay	Durban	0	0	20	13310	6494

Table 7.7 Result Justification between Russia and China

Origin City	Russia Origin port	China Destination Port	Destination City	Demurrage {No. of Days}	Detention {No. of Days}	Ship, Speed {Knots}	Distance {in kms.}	Cost {in $}
Moscow and Shanghai are origin and destination city of Russia and China								
Moscow	Kaliningr-ad	Zhanjiang	Shanghai	0	0	20	15015	7722
Moscow	Kaliningr-ad	Bahezhen	Shanghai	0	0	20	15566	5573
Moscow	Kaliningr-ad	Port of Xiamen	Shanghai	0	0	20	14695	5896
Moscow	Kaliningr-ad	Port of Tianjin	Shanghai	0	0	20	16052	6167
Moscow	Poronaysk	Zhanjiang	Shanghai	0	0	20	14476	2484
Moscow	Poronaysk	Bahezhen	Shanghai	0	0	20	12687	2249
Moscow	Poronaysk	Port of Xiamen	Shanghai	0	0	20	13000	2291
Moscow	Poronaysk	Port of Tianjin	Shanghai	0	0	20	12846	2305
Moscow	Azov	Zhanjiang	Shanghai	0	0	20	11982	7309
Moscow	**Azov**	**Bahezhen**	**Shanghai**	**0**	**0**	**20**	**11661**	**5202**
Moscow	Azov	Port of Xiamen	Shanghai	0	0	20	11661	5483
Moscow	Azov	Port of Tianjin	Shanghai	0	0	20	12973	5750
Moscow	Naryan-mar	Zhanjiang	Shanghai	0	0	20	17708	1045
Moscow	Naryan-mar	Bahezhen	Shanghai	0	0	20	18259	8307
Moscow	Naryan-mar	Port of Xiamen	Shanghai	0	0	20	17387	8630
Moscow	Naryan-mar	Port of Tianjin	Shanghai	0	0	20	18745	8901

Table 7.8 Result Justification between Russia and India

Origin City	Russia Origin port	India Destination Port	Destination City	Demurrage {No. of Days}	Detention {No. of Days}	Ship, Speed {Knots}	Distance {in kms.}	Cost {in $}
Moscow and Ankleshwar are origin and destination city of Russia and India								
Moscow	Kaliningr-ad	Mumbai	Ankleshwar	0	0	30	9708	4013
Moscow	Kaliningr-ad	Vishakhapatnam	Ankleshwar	0	0	30	12110	6734
Moscow	Kaliningr-ad	Chennai	Ankleshwar	0	0	30	11793	6922

Moscow	Kaliningr-ad	Cochin	Ankleshwar	0	0	30	11404	7307
Moscow	Poronaysk	Mumbai	Ankleshwar	0	0	30	17006	2180
Moscow	Poronaysk	Vishakhapatnam	Ankleshwar	0	0	30	17566	2437
Moscow	Poronaysk	Chennai	Ankleshwar	0	0	30	17550	2458
Moscow	Poronaysk	Cochin	Ankleshwar	0	0	30	19641	2518
Moscow	**Azov**	**Mumbai**	**Ankleshwar**	**0**	**0**	**30**	**6674**	**3620**
Moscow	Azov	Vishakhapatnam	Ankleshwar	0	0	30	9076	6321
Moscow	Azov	Chennai	Ankleshwar	0	0	30	8760	6509
Moscow	Azov	Cochin	Ankleshwar	0	0	30	8371	6894
Moscow	Naryan-mar	Mumbai	Ankleshwar	0	0	30	12401	6747
Moscow	Naryan-mar	Vishakhapatnam	Ankleshwar	0	0	30	14803	9469
Moscow	Naryan-mar	Chennai	Ankleshwar	0	0	30	14487	9656
Moscow	Naryan-mar	Cochin	Ankleshwar	0	0	30	13998	1003

Table 7.9 Result Justification between China and South Africa

Origin City	China Origin port	SA Destination Port	Destination City	Demurrage {No. of Days}	Detention {No. of Days}	Ship, Speed {Knots}	Distance {in kms.}	Cost {in $}
Shanghai and Durban are origin and destination city of China and SA								
Shanghai	Zhanjiang	Cape town	Durban	0	0	30	11701	8379
Shanghai	Zhanjiang	Port Elizabeth	Durban	0	0	30	10972	6797
Shanghai	Zhanjiang	East London	Durban	0	0	30	10128	6191
Shanghai	Zhanjiang	Richard Bay	Durban	0	0	30	9322	5128
Shanghai	Bahezhen	Cape town	Durban	0	0	30	12279	6249
Shanghai	Bahezhen	Port Elizabeth	Durban	0	0	30	11542	4650
Shanghai	Bahezhen	East London	Durban	0	0	30	10697	4043
Shanghai	**Bahezhen**	**Richard Bay**	**Durban**	**0**	**0**	**30**	**9009**	**3015**
Shanghai	Port of Xiamen	Cape town	Durban	0	0	30	11389	6554
Shanghai	Port of Xiamen	Port Elizabeth	Durban	0	0	30	10660	4972
Shanghai	Port of Xiamen	East London	Durban	0	0	30	9815	4336
Shanghai	Port of Xiamen	Richard Bay	Durban	0	0	30	9009	3302
Shanghai	Port of Tianjin	Cape town	Durban	0	0	30	3758	6052
Shanghai	Port of Tianjin	Port Elizabeth	Durban	0	0	30	3029	4470
Shanghai	Port of Tianjin	East London	Durban	0	0	30	11184	4638
Shanghai	Port of Tianjin	Richard Bay	Durban	0	0	30	10376	3574

Table 7.10 Result Justification between India and South Africa

Origin City	India Origin port	SA Destination Port	Destination City	Demurrage {No. of Days}	Detention {No. of Days}	Ship, Speed {Knots}	Distance {in kms.}	Cost {in $}
Ankleshwar and Durban are origin and destination city of India and SA								
Anklesh-war	Mumbai	Cape town	Durban	0	0	30	7523	4767
Anklesh-war	Mumbai	Port Elizabeth	Durban	0	0	30	6345	3146
Anklesh war	Mumbai	East London	Durban	0	0	30	5950	2579
Anklesh war	**Mumbai**	**Richard Bay**	**Durban**	**0**	**0**	**30**	**5143**	**1534**
Anklesh war	Vishakhap atnam	Cape town	Durban	0	0	30	9250	7431
Anklesh war	Vishakhap atnam	Port Elizabeth	Durban	0	0	30	8072	5810
Anklesh war	Vishakhap atnam	East London	Durban	0	0	30	7677	5242
Anklesh war	Vishakhap atnam	Richard Bay	Durban	0	0	30	6871	4179
Anklesh war	Chennai	Cape town	Durban	0	0	30	9071	7630
Anklesh war	Chennai	Port Elizabeth	Durban	0	0	30	7893	6009
Anklesh war	Chennai	East London	Durban	0	0	30	7498	5442
Anklesh war	Chennai	Richard Bay	Durban	0	0	30	6691	4378
Anklesh war	Cochin	Cape town	Durban	0	0	30	8814	8027
Anklesh war	Cochin	Port Elizabeth	Durban	0	0	30	7636	6406
Anklesh war	Cochin	East London	Durban	0	0	30	7241	5839
Anklesh war	Cochin	Richard Bay	Durban	0	0	30	6434	4775

7.4 Research Contribution

Realistic problem based research has contributed a approach of variable ship's speed selection based on delivery time window to emphasize in reduction of demurrage and detention penalties for intra ships connectivity for linear, industrial shipping separately or together to obtain least total cost of transportation.

7.5 Future Research Directions

Efforts propose bright exposure in future for intra ships connectivity by implementing ship routing optimization approach among 2806 ports of BRICS over 70696 km coastline to attain a great level of reduction in cost.

Following innovative steps are further suggested towards enhancement of overall shipping and hinterland operation from one end to final end customers for attaining cost friendly operation.

(i) Automation of ports to reduce loading and unloading time in case of internal and external transshipment, also in linear shipping.

(ii) Suggesting light weight material for containers designing in context of fuel economy.

(iii) Study of high tides in sea route among BRICS countries to perform fuel saving in shipping.

7.6 Limitation of Research

(i) Risk and reliability is not in the current scope of the work, however can be Considered in the future research work.

(ii) In real life the problem is quite complex, researchers can consider the more real life problem and sensitivity analysis.

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APPENDIX A

GA CODES IN MATLAB

```
GA Coding
clear all;
clc;
% Select Origin Country %
disp(' *          BRICS          *');
disp(' *Origin Country*');
disp(' *Brazil=1');
disp(' *Russia=2');
disp(' *India=3');
disp(' *China=4');
disp(' *South Africa=5');
O_country_name=input('  Please enter the Origin Country =   ');
% City Selection %
disp(' *Origin_city*');
switch (O_country_name)

Case 1
disp(' *Brasília=1');
disp(' *Sao Paulo=2');
disp(' *Rio de Janeiro=3');
disp(' *Belo Horizonte=4');
%Brazil%
   %Brasília% %São Paulo%   %Rio de Janeiro% %Belo Horizonte%
 B = [1939       2648          2299          2028     %Belem B1%
      2106       2969          2620          2349     %Fortaleza B2%
      1426        447          890          1034     %Paranagua  B3%
      2133       2648          2299          2028];   %Recife B4%

 Case 2
disp(' *Moscow=1');
disp(' *Samara=2');
disp(' *Yekaterinburg=3');
disp(' *Saint Petersburg=4');
%Russia%
    %Moscow%    %Samara%   %Yekaterinburg% %Saint Petersburg%
 B = [1188       2279          2965           877     %Kaliningrad R1%
      9425       8503          7696          9918     %Poronaysk R2%
      1115       1356          2288          1821     %Azov R3%
      2389       2330          2019          2576];   %Naryan-Mar R4%

   Case 3
```

```
disp(' *Ankleshwar=1');
disp(' *Vapi=2');
disp(' *Ghaziabad=3');
disp(' *Chandrapur=4');
%India%
   %Ankleshwar%    %Vapi%      %Ghaziabad%     %Chandrapur%
  B = [337        180          1442           914     %Mumbai I1%
       1544       1507          1683           700     %Vishakhapatnam I2%
       1647       1491          2154           961     %Chennai I3%
       1848       1215          2667          1527];   %Cochin I4%

  Case 4
disp(' *Shanghai=1');
disp(' *Beijing=2');
disp(' *Shenzhen=3');
disp(' *Suzhou=4');
   %Shanghai%    %Beijing%   %Shenzhen%   %Suzhou%
B =    [1898       2568        506       1865      %Zhanjiang C1%
        844       1147       1027        744      %Bahezhen C2%
       1035       2113        609       1021      %Port of Xiamen C3%
       1109        140       2164       1016];    %Port of Tianjin C4%

   Case 5
disp(' *Durban=1');
disp(' *Free state=2');
disp(' *Gauteng=3');
disp(' *Eastern cap=4');
%South Africa%
     %Durban%    %Free state%   %Gauteng%      %Eastern cap%
  B = [1640       1111           1403           919     %Cape town S1%
       911        775           1067           300     %Port Elizabeth S22%
       655        672            964           228     %East London S3%
       178        711            615           871];   %Richard Bay S4%

Otherwise
 display ('error in country name give proper country name')
end;

m=input('  Please enter the Origin city =   ');

% Select Destination Country %
disp(' *          BRICS          *');
disp(' *Destination Country*');
disp(' *Brazil=1');
disp(' *Russia=2');
disp(' *India=3');
```

```
disp(' *China=4');
disp(' *South Africa=5');
D_country_name=input('  Please enter the Destination Country =   ');
% City Selection %
disp(' *Destination_city*');
switch (D_country_name)

 Case 1
disp(' *Brasília=1');
disp(' *São Paulo=2');
disp(' *Rio de Janeir=3');
disp(' *Belo Horizonte=4');
%Brazil%
    %Brasília% %São Paulo%   %Rio de Janeiro% %Belo Horizonte%
  C = [1939       2648           2299           2028     %Belem B1%
       2106       2969           2620           2349     %Fortaleza B2%
       1426        447            890           1034     %Paranagua  B3%
       2133       2648           2299           2028];   %Recife B4%

   Case 2
disp(' *Moscow=1');
disp(' *Samara=2');
disp(' *Yekaterinburg=3');
disp(' *Saint Petersburg=4');
%Russia%
     %Moscow%    %Samara%   %Yekaterinburg% %Saint Petersburg%
  C = [1188       2279           2965            877     %Kaliningrad R1%
       9425       8503           7696           9918     %Poronaysk R2%
       1115       1356           2288           1821     %Azov R3%
       2389       2330           2019           2576];   %Naryan-Mar R4%

   Case 3
disp(' *Ankleshwar=1');
disp(' *Vapi=2');
disp(' *Ghaziabad=3');
disp(' *Chandrapur=4');
%India%
   %Ankleshwar%    %Vapi%      %Ghaziabad%      %Chandrapur%
  C = [337        180           1442            914     %Mumbai I1%
        1544       1507          1683            700     %Vishakhapatnam I2%
        1647       1491          2154            961     %Chennai I3%
        1848       1215          2667           1527];   %Cochin I4%

   Case 4
disp(' *Shanghai=1');
disp(' *Beijing=2');
```

```
disp(' *Shenzhen=3');
disp(' *Suzhou=4');
   %Shanghai%    %Beijing%   %Shenzhen%   %Suzhou%
C =    [1898       2568        506        1865      %Zhanjiang C1%
        844       1147       1027        744      %Bahezhen C2%
       1035       2113        609       1021      %Port of Xiamen C3%
       1109        140       2164       1016];    %Port of Tianjin C4%

   Case 5
disp(' *Durban=1');
disp(' *Free state=2');
disp(' *Gauteng=3');
disp(' *Eastern cap=4');
%South Africa%
     %Durban%    %Free state%   %Gauteng%     %Eastern cap%
  C = [1640       1111           1403            919     %Cape town S1%
        911        775           1067            300     %Port Elizabeth S22%
        655        672            964            228     %East London S3%
        178        711            615            871];   %Richard Bay S4%
   otherwise
 display('error in country name give proper D_country_name')
end;

n=input ('  Please enter the Destination city =   ');

%Port to Port distance between countries%
BC=input('  Please enter the Port to Port distance between countries  ');

display ('Generally enter 0 days for Detention charge, if there is any please enter ');
Detention charge=input (‘Please enter the (Detention charge) No. days =   ');

display('Generally enter 0 days for Demurrage charge, if there is any please enter ');
Demurrage charge=input('  Please enter the (Demurrage charge) No. days =   ');

%speed of ship%
disp(' *For 10 knots=1');
disp(' *For 15 knots=2');
disp(' *For 20 knots=3');
disp(' *For 25 knots=4');
disp(' *For 30 knots=5');
S=input('  Please enter the Speed of Ship =   ');
switch (S)
   Case 1
      M=0.084;
   Case 2
      M=0.086;
```

```
  Case 3
     M=0.089;
  Case 4
     M=0.092;
  Case 5
     M=0.095;
end;

  for i=[1:4]
     for l=[1:4]
     H(i,l)=[B(i,m)+BC(i,l)+C(l,n)]
     end;
  end;

  A=min (H);
  Z=min (A);

  for i=[1:4]
     for l=[1:4]
D(i,l)=[2.17*B(i,m)+M*BC(i,l)+2.17*C(l,n)]+3*Detention_charge+7*Demurrage_charge
     end;
  end;
  L=min (D);
  Y=min (L)

figure;
xlabel('City Matrix')
ylabel('Cost in $')
title ('Statistical representation of distance b/w two countries')
hold all
Bar ([ 11 12 13 14; 21 22 23 24; 31 32 33 34; 41 42 43 44],D)

%ga plot%
G(i,l)=[[2.17*B(i,m)+M*BC(i,l)+2.17*C(l,n)]+3*Detention_charge+7*Demurrage_char
ge]/10000;

y = parameterized_fitness(G,i,l);

FitnessFunction = @(G) parameterized_fitness(G,i,l);
numberOfVariables = 2;

options = gaoptimset('plotfcns',@gaplotbestf)

[D,fval,exitFlag,Output] =  ga(FitnessFunction,numberOfVariables,options)
```

```
display ('Shortest distance b/w origin and destination cities') Z

display('Minimum cost to ship 1 TEU b/w origin and destination cities')
```

Codes without GA Implementation

```
clear all;
clc;

A=input (‘Please enter the distance b/w origin city and origin port = ‘);

P=input (‘Please enter the distance b/w origin port and destination port =   ');

N=input (‘Please enter the distance b/w destination port and destination city =   ');

display('Generally enter 0 days for Detention charge, if there is any please enter ');
Detention charge=input('  Please enter the (Detention charge) No. days =   ');

display('Generally enter 0 days for Demurrage charge, if there is any please enter ');
Demurrage charge=input('  Please enter the (Demurrage charge) No. days =   ');

%speed of ship%
disp(' *For 10 knots=1');
disp(' *For 15 knots=2');
disp(' *For 20 knots=3');
disp(' *For 25 knots=4');
disp(' *For 30 knots=5');
S=input (‘Please enter the Speed of Ship =   ');
switch (S)
   case 1
      M=0.083;
   case 2
      M=0.086;
   case 3
      M=0.09;
   case 4
      M=0.094;
   case 5
      M=0.098;
end;

Distance = A+P+N;

Cost_DD = 2.17*A+M*P+2.17*N+3*Detention_charge+7*Demurrage_charge;

Cost = 2.17*A+0.086*P+2.17*N;
```

```
display('distance b/w origin and destination cities')

Distance

display('cost without Demurrage and detention charges of ship for 1 TEU b/w origin and destination cities')

Cost

display('cost with Demurrage and detention charges of ship for 1 TEU b/w origin and destination cities')

Cost_DD
```

APPENDIX B

GRAPHS FOR COST ANALYSIS
Illustration 1. Brazil to China

b) Sao Paulo-Beijing

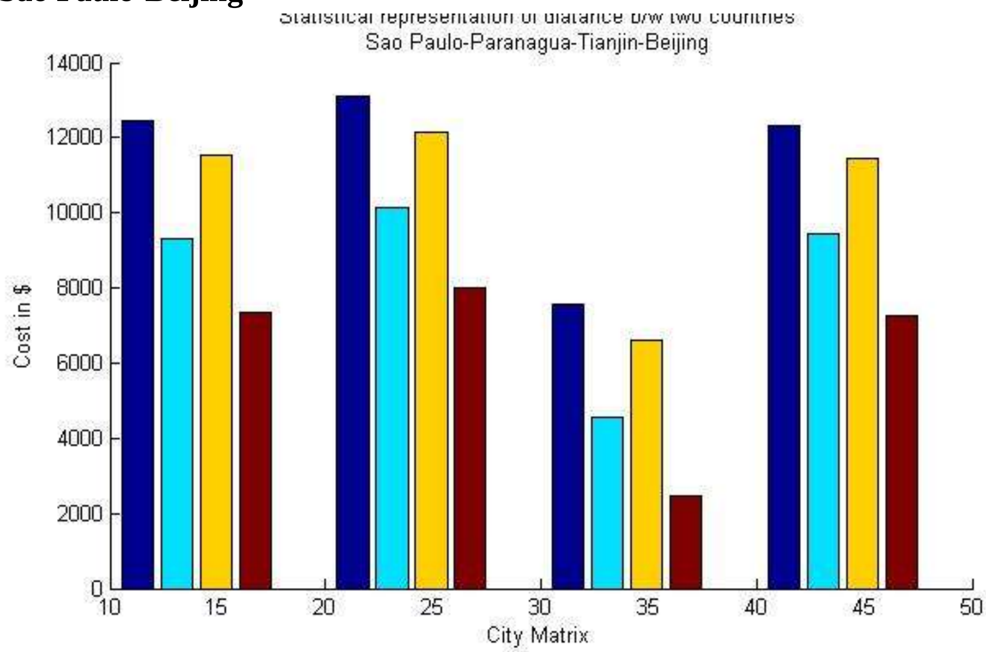


Figure B 1 Cost analysis Sao Paulo-Beijing

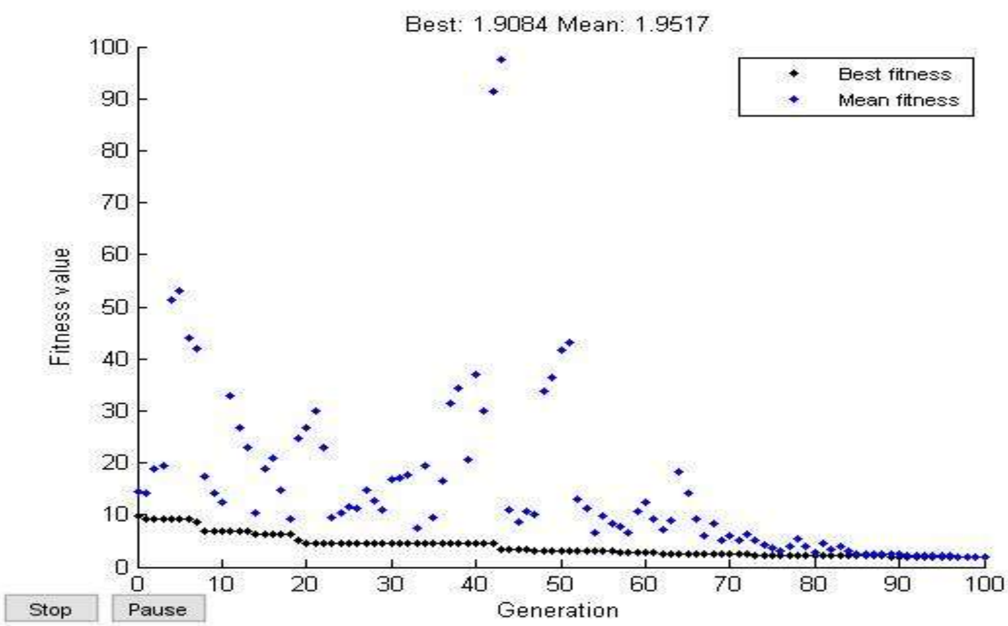


Figure B 2 GA analysis Sao Paulo-Beijing

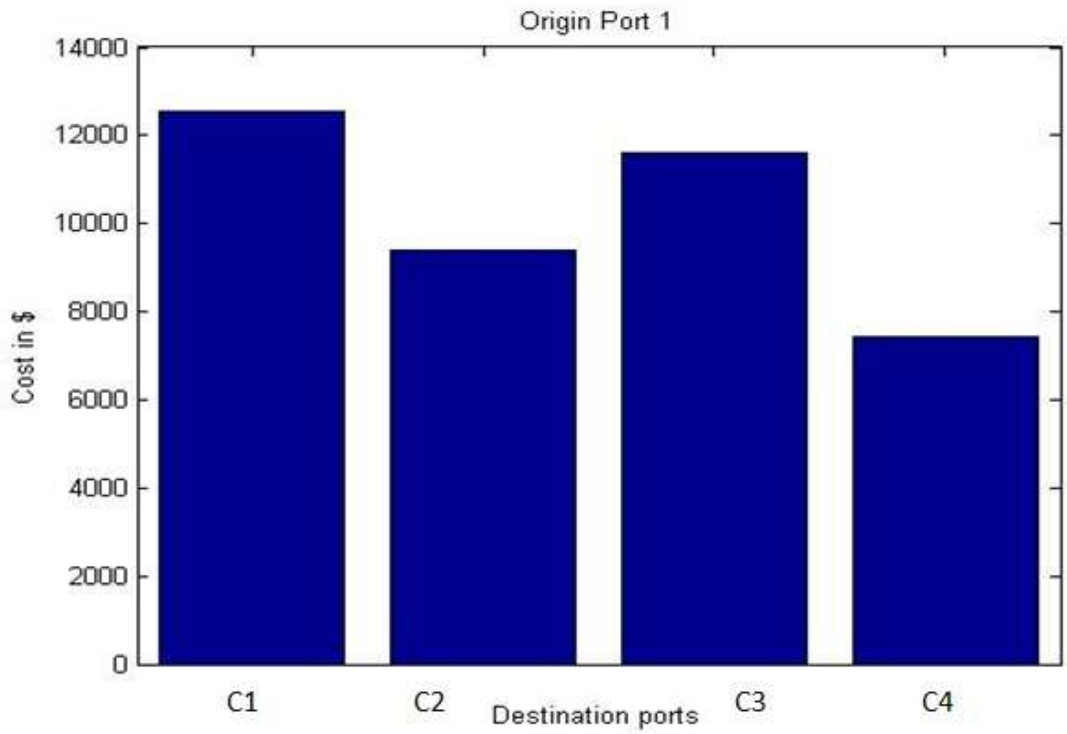


Figure B 3 Cost analysis Belem (B1) – destination ports (C)

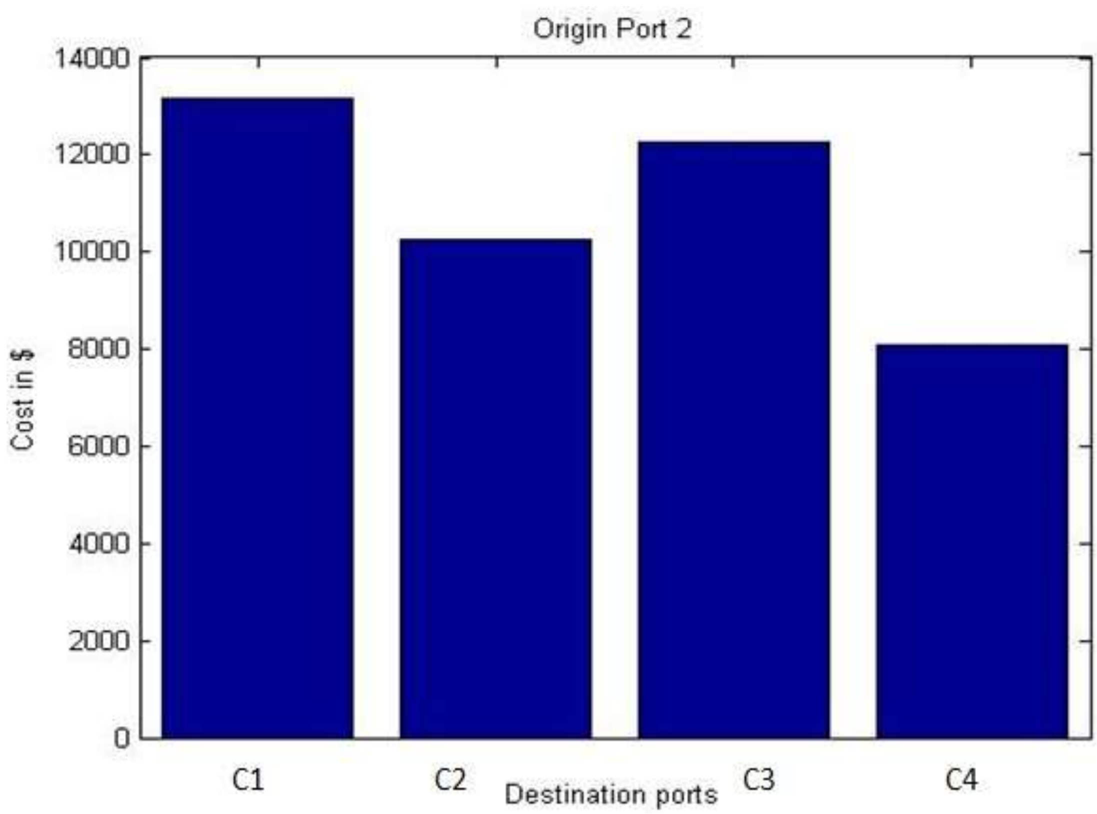


Figure B 4 Cost analysis Fortaleza (B2) – destination ports (C)

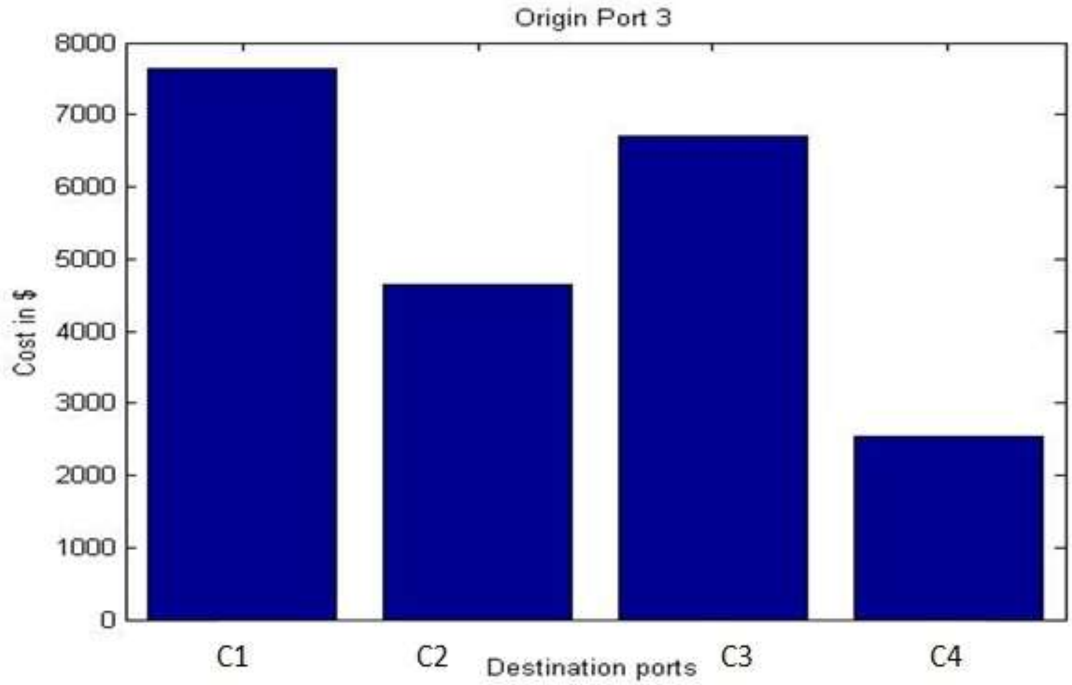


Figure B 5 Cost analysis Paranagua (B3) – destination ports (C)

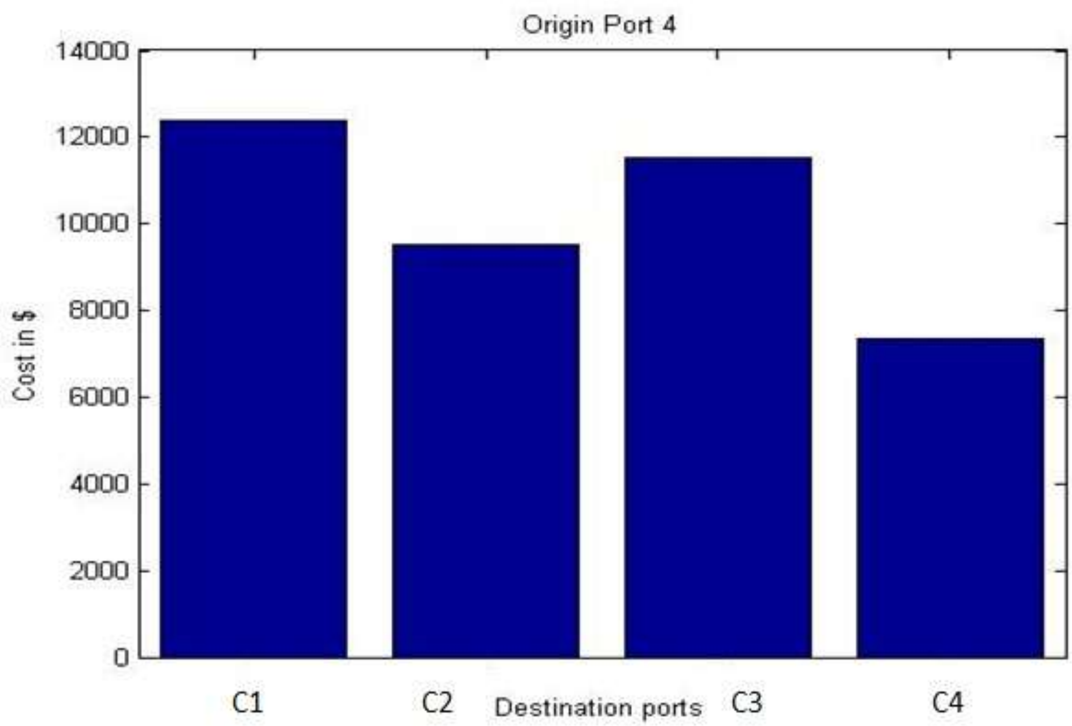


Figure B 6 Cost analysis Recife (B4) – destination ports (C)

Optimized path:Sao Paulo-Paranagua- Tianjin –Beijing

c) Rio de Janeiro-Shenzhen

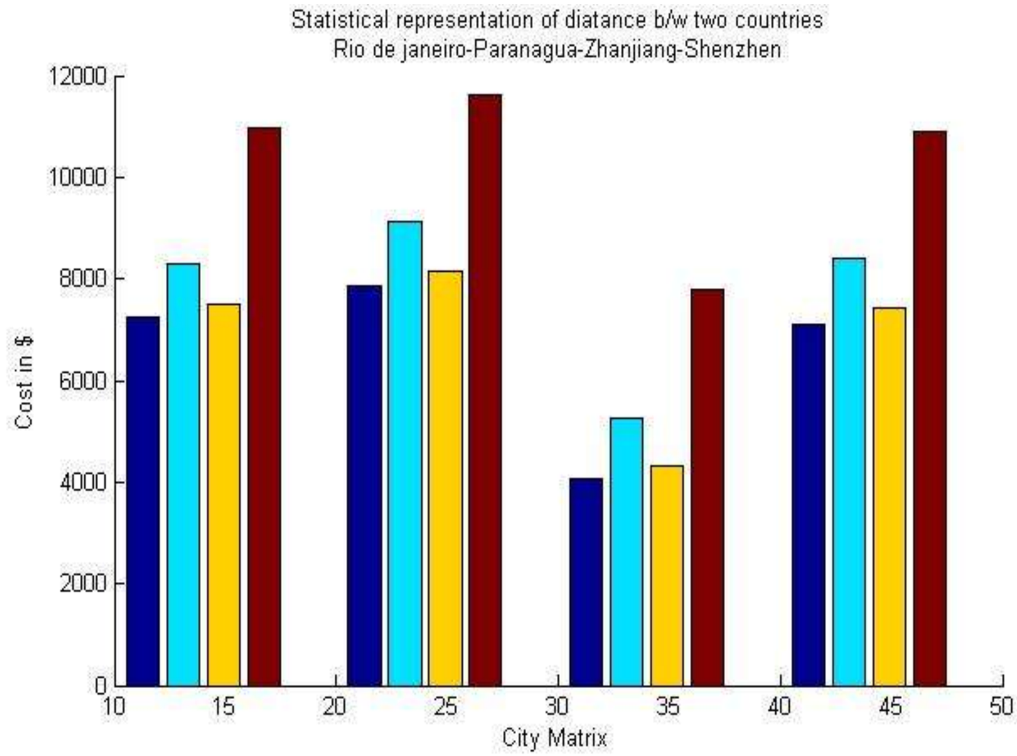


Figure B 7 Cost analysis Rio de Janeiro-Shenzhen

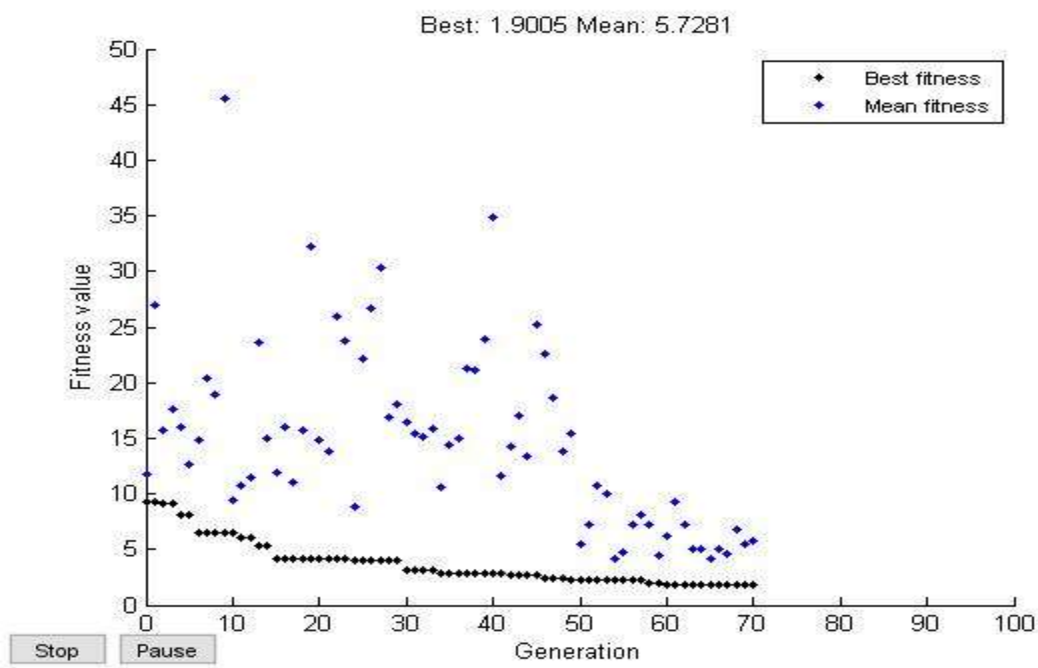


Figure B 8 GA analysis Rio de Janeiro-Shenzhen

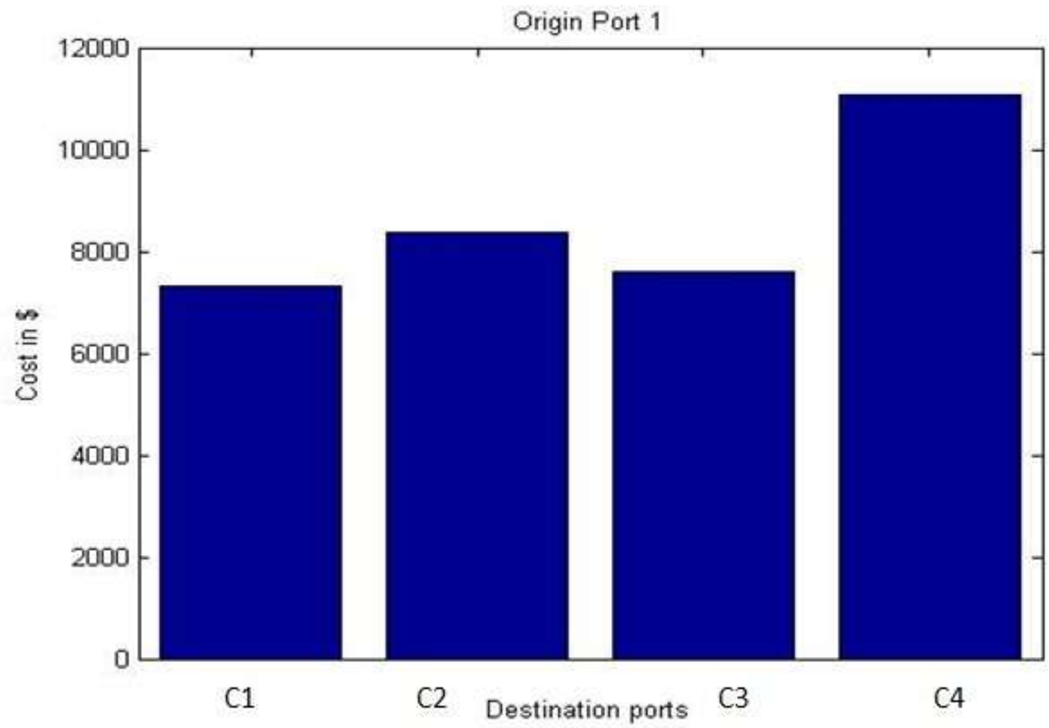


Figure B 9 Cost analysis Belem (B1) – destination ports (C)

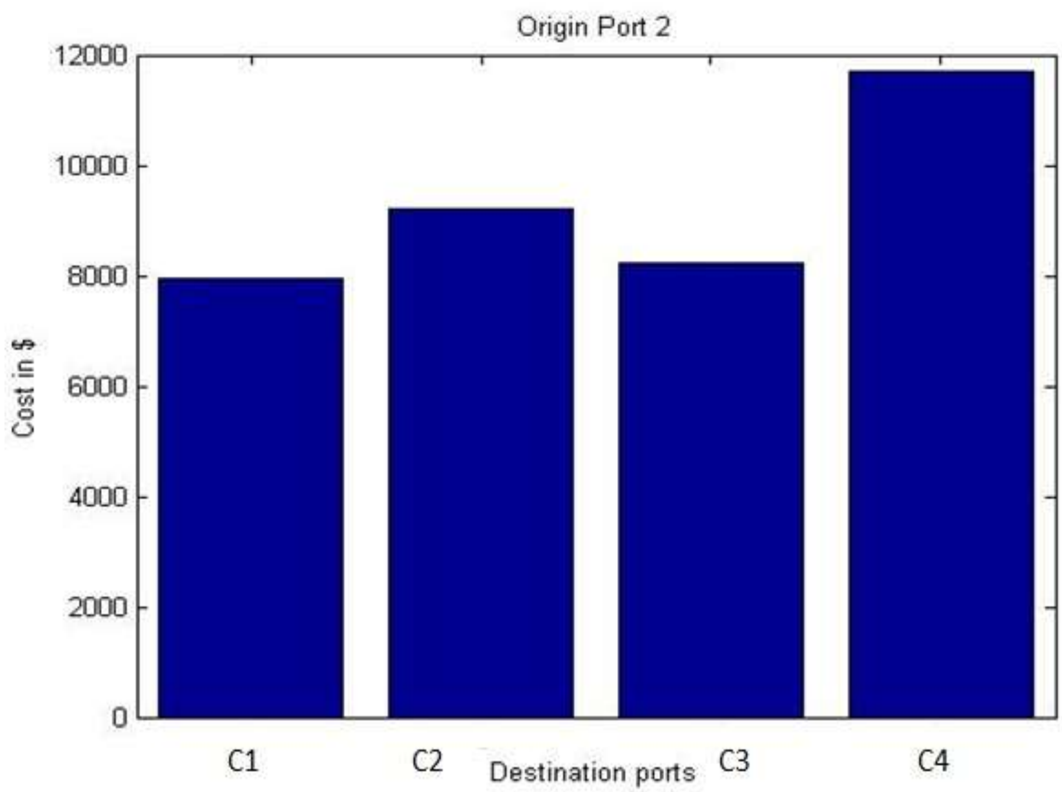


Figure B 10 Cost analysis Fortaleza (B2) – destination ports (C)

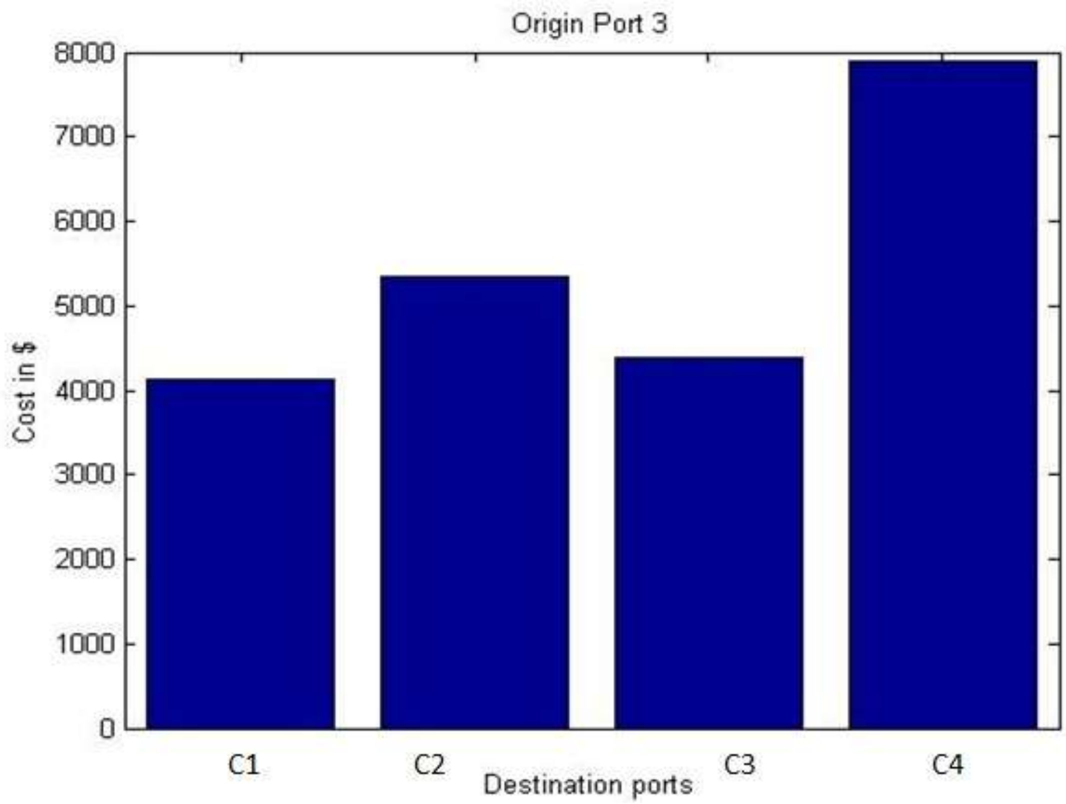


Figure B 11 Cost analysis Paranagua (B3) – destination ports (C)

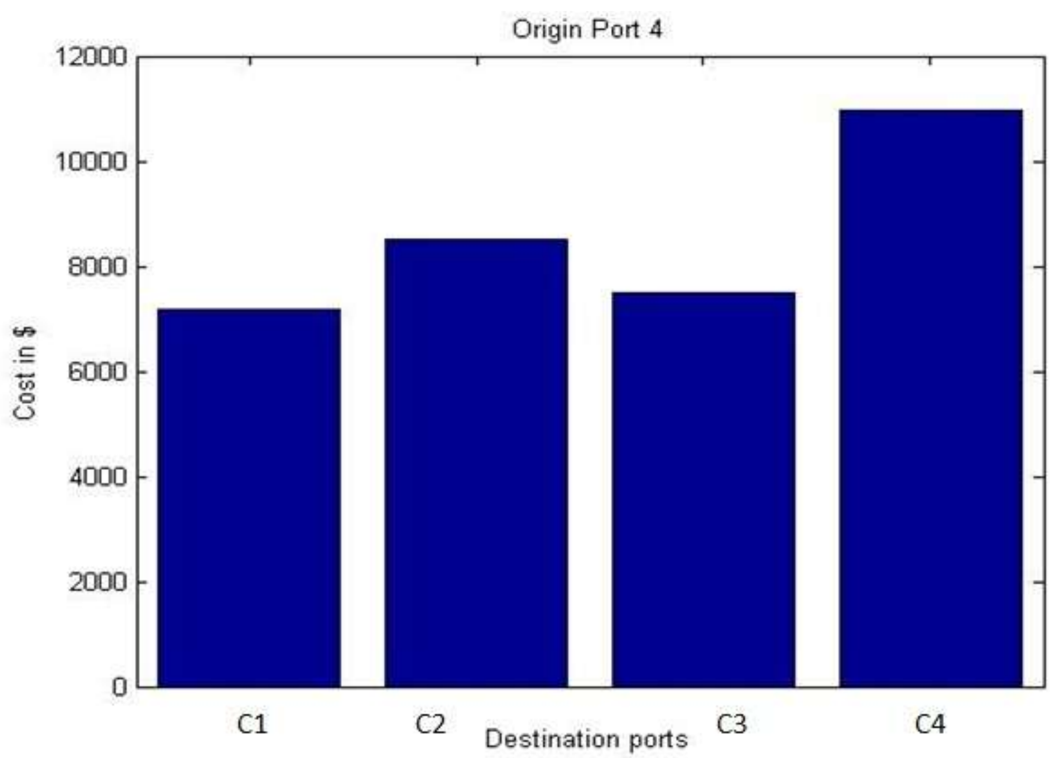


Figure B 12 Cost analysis Recife (B4) – destination ports (C)

Optimized path: Rio de Janeiro - Paranagua- Zhanjiang- Shenzhen

d) Belo Horizonte-Suzhou

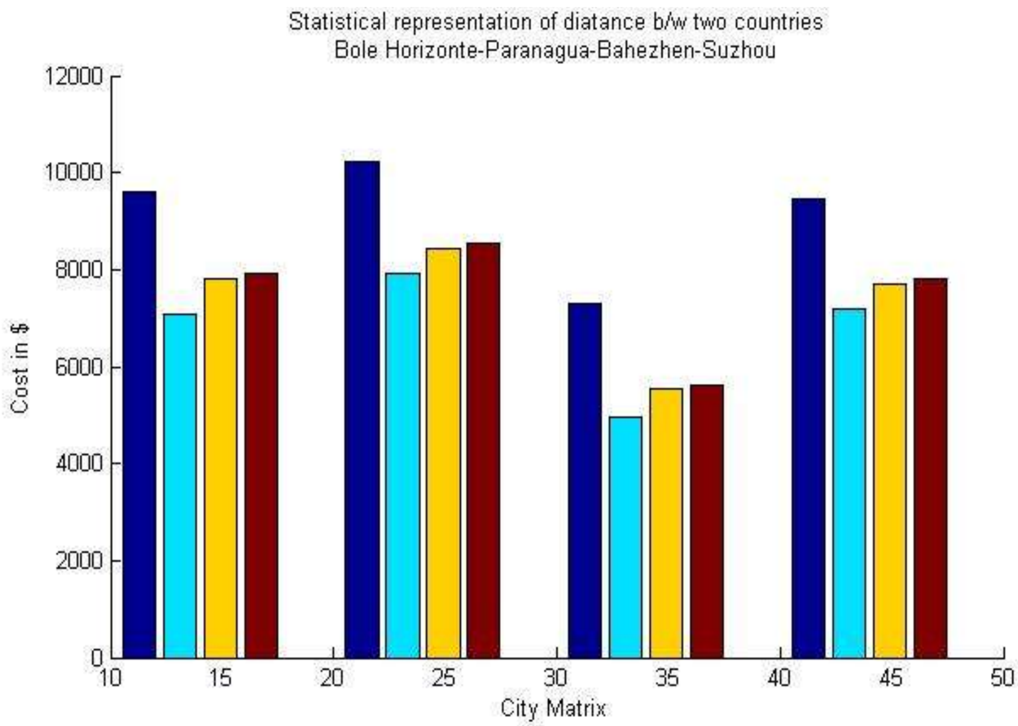


Figure B 13 Cost analysis Belo Horizonte-Suzhou

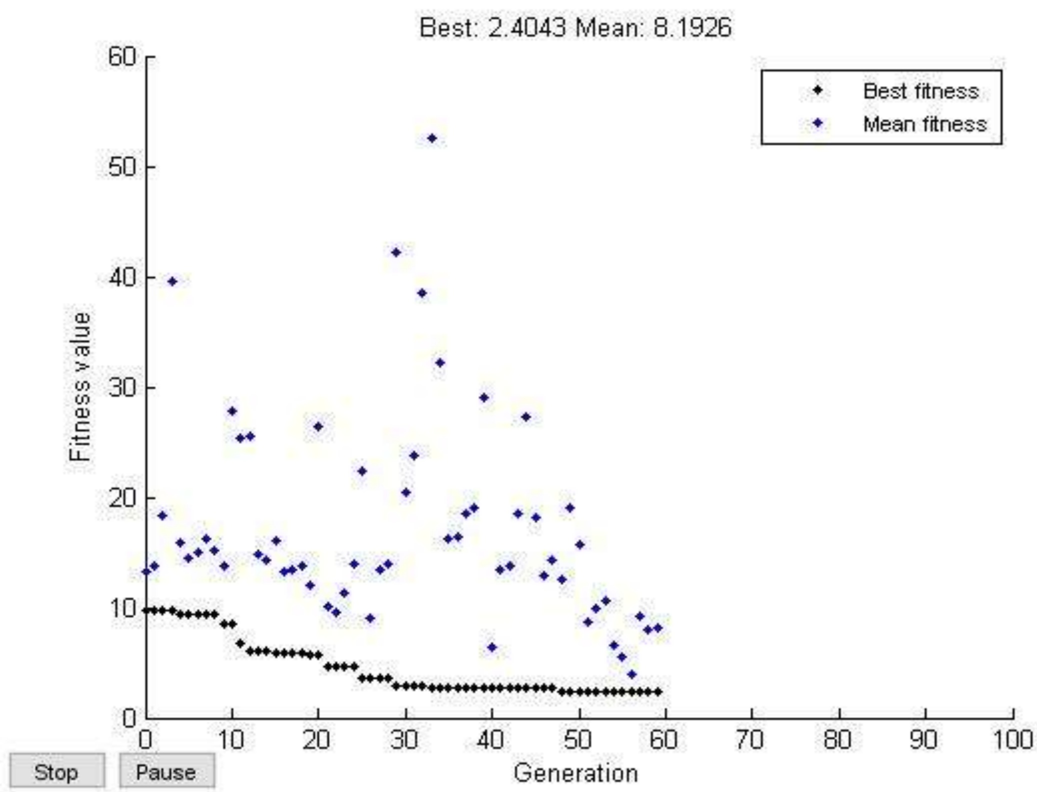


Figure B 14 GA analysis Belo Horizonte-Suzhou

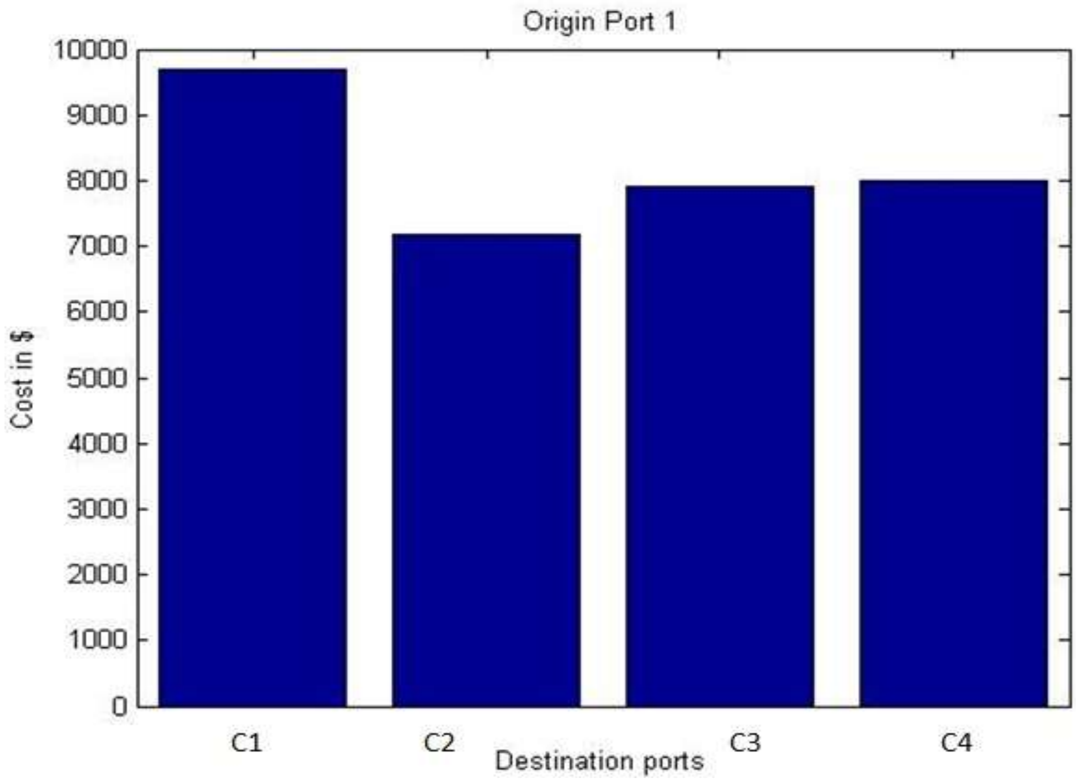


Figure B 15 Cost analysis Belem (B1) – destination ports (C)

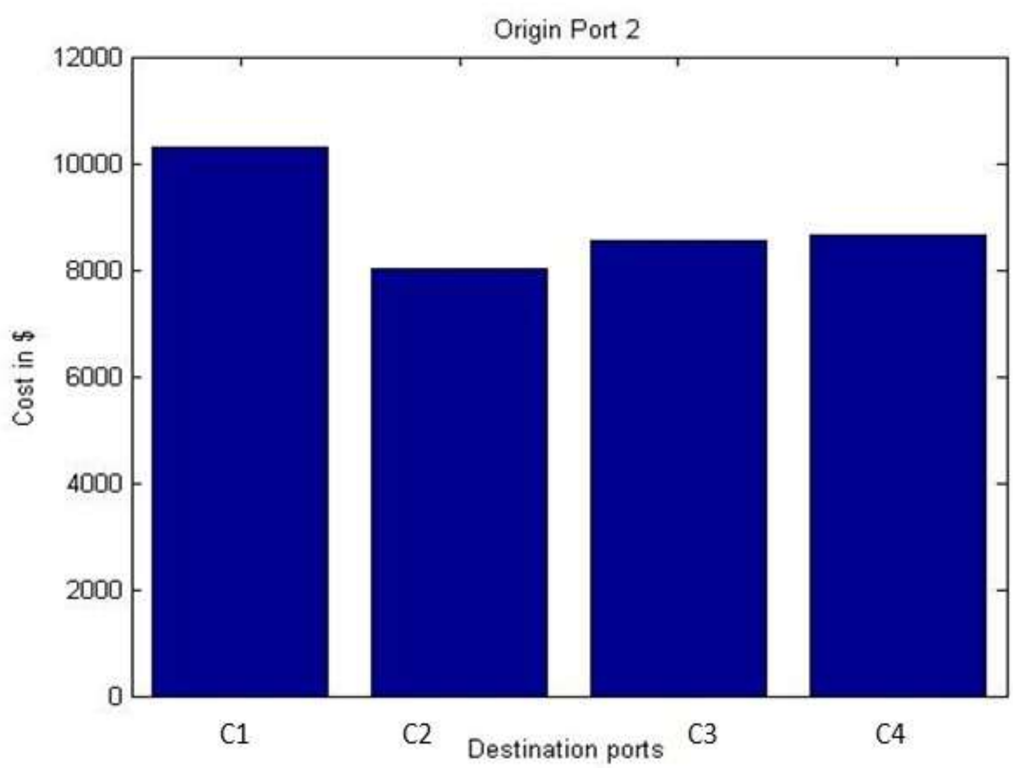


Figure B 16 Cost analysis Fortaleza (B2) – destination ports (C)

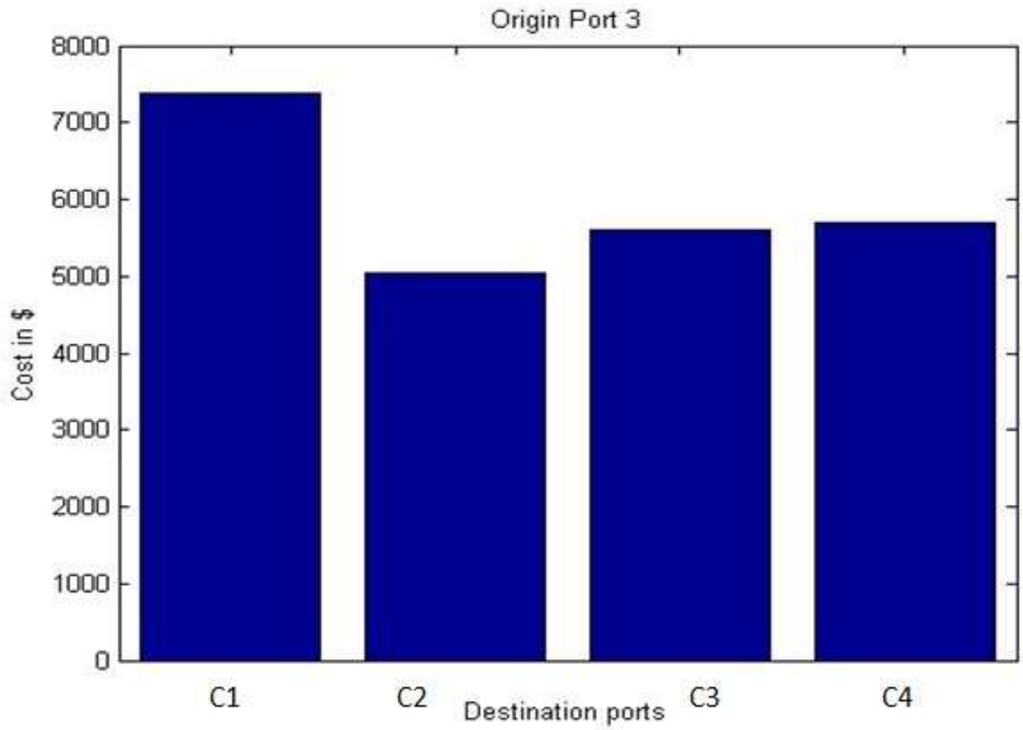


Figure B 17 Cost analysis Paranagua (B3) – destination ports (C)

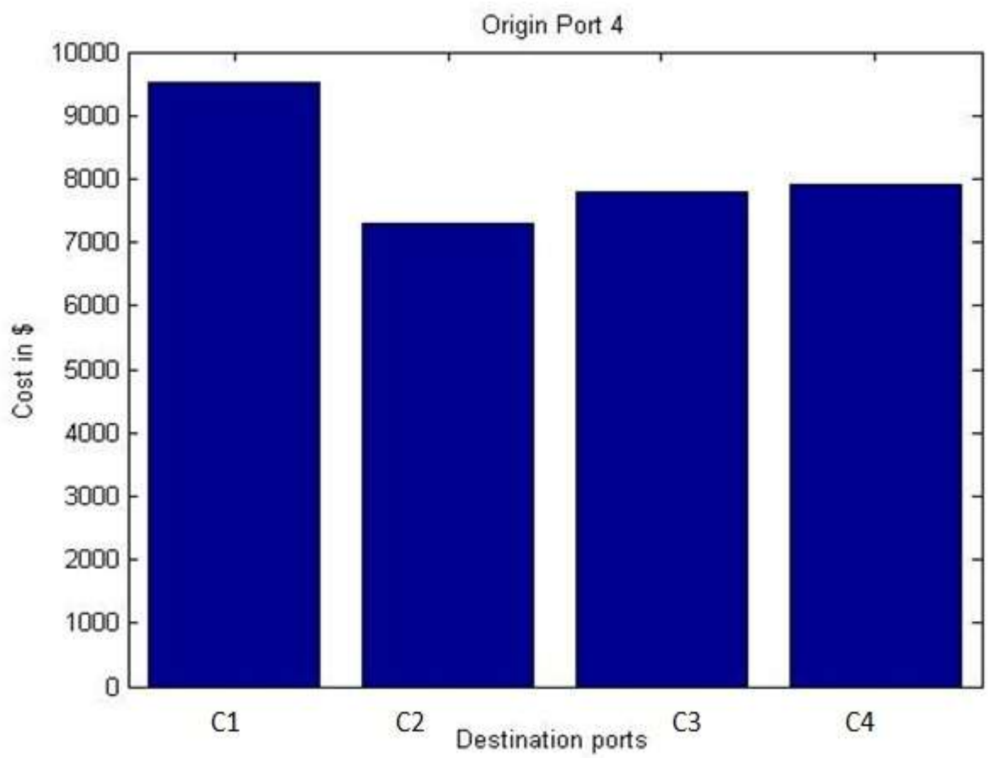


Figure B 18 Cost analysis Recif**e** (B4) – destination ports (C)

Optimized path: Belo Horizonte - Paranagua- Bahezhen- Suzhou

Illustration 2. Russia to India

b) Samara-Vapi

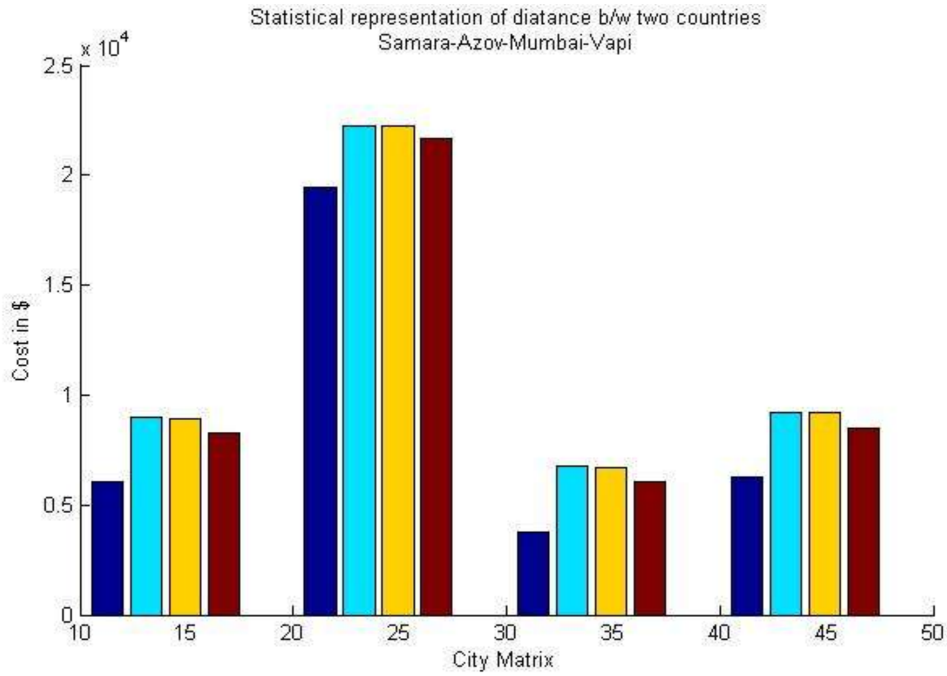


Figure B 19 Cost analysis Samara-Vapi

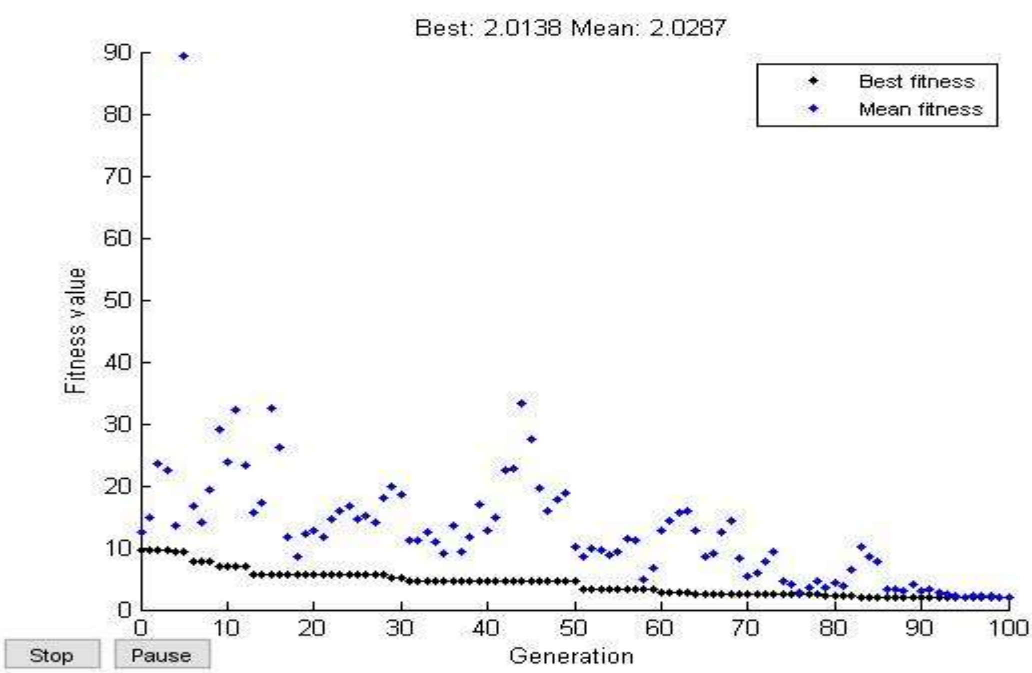


Figure B 20 GA analysis Samara-Vapi

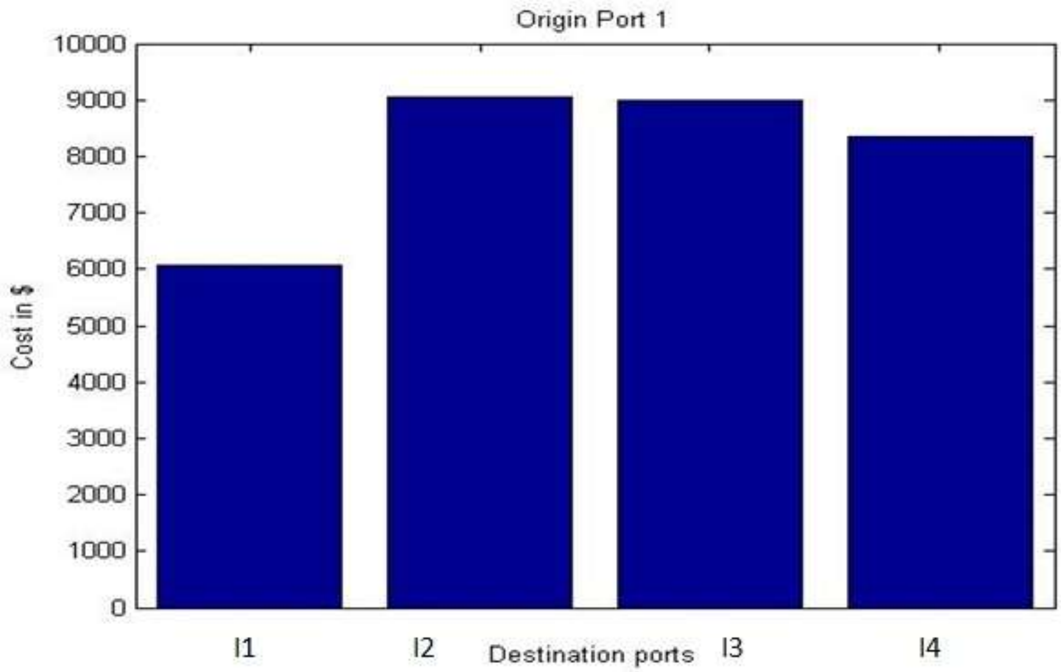


Figure B 20 Cost analysis Kaliningrad (R) – destination ports (I)

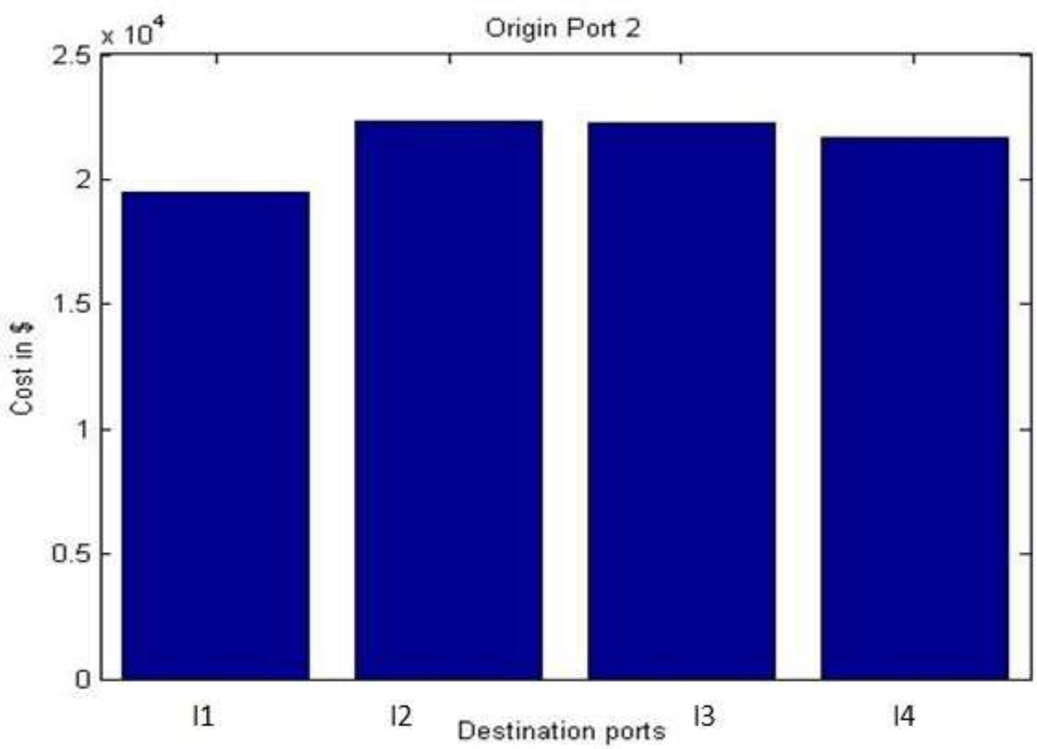


Figure B 21 Cost analysis Poronaysk (R) – destination ports (I)

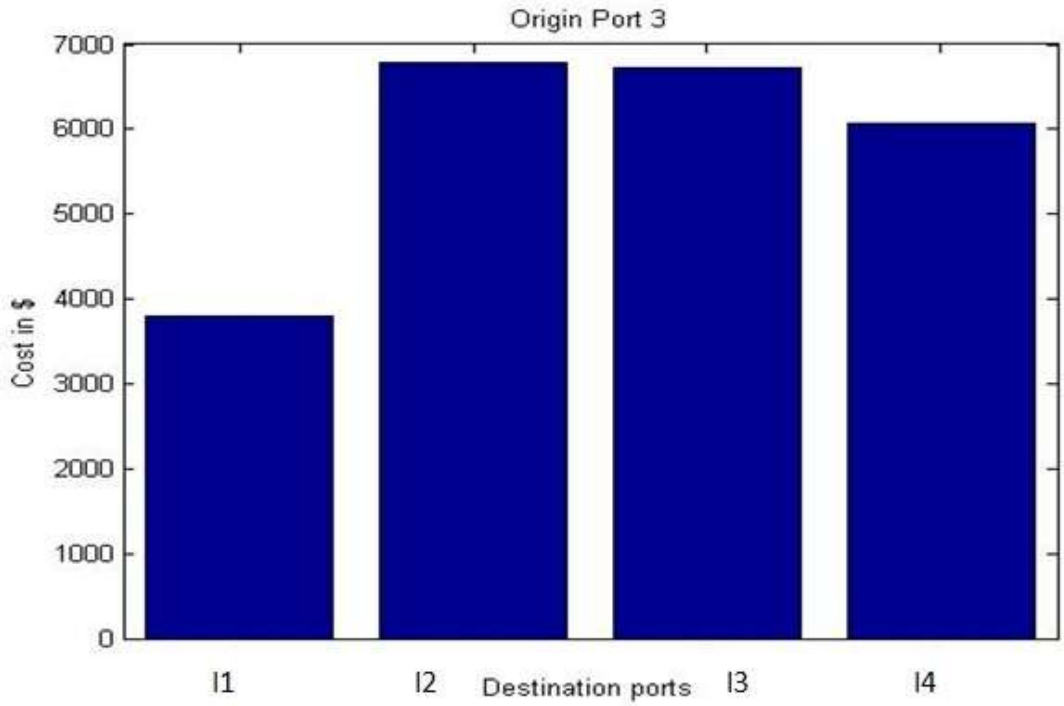


Figure B 22 Cost analysis Azov (R) – destination ports (I)

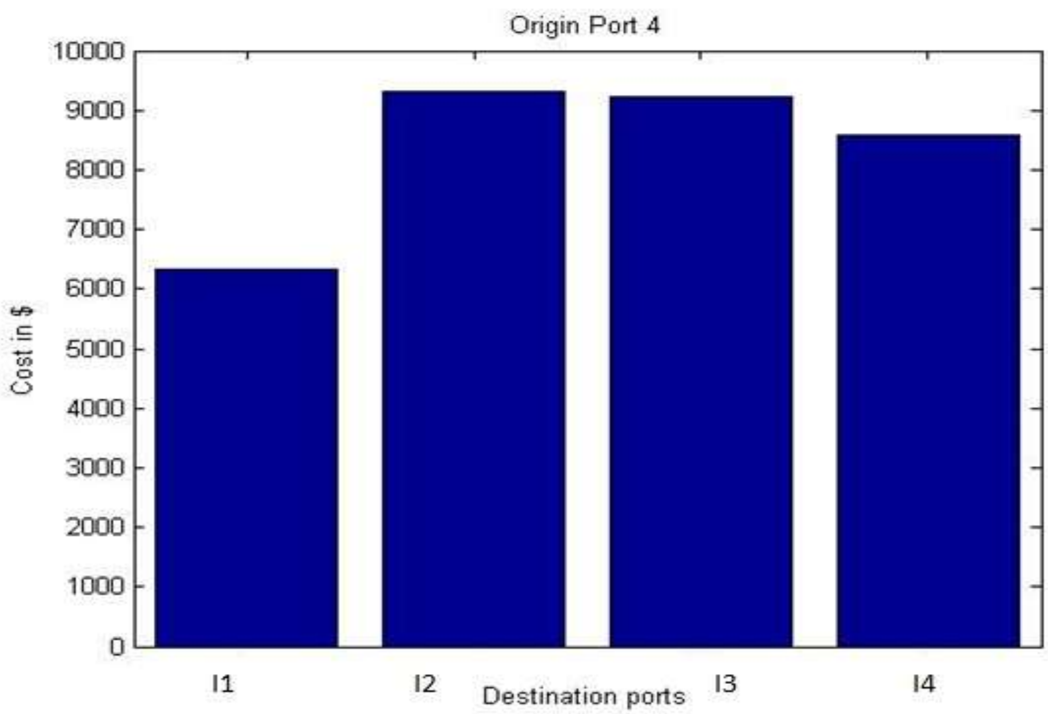


Figure B 23 Cost analysis Naryan-Mar (R) – destination ports (I)

Optimized path: Samara-Azov – Mumbai -Vapi

c) Yekaterinburg-Ghaziabad

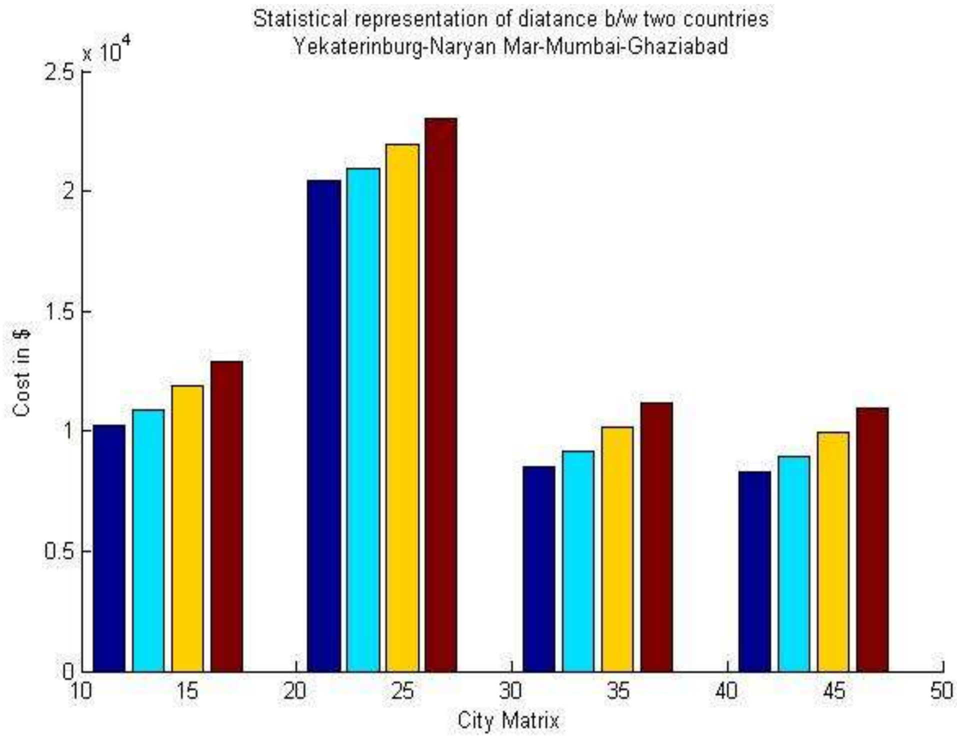


Figure B 24 Cost analysis Yekaterinburg-Ghaziabad

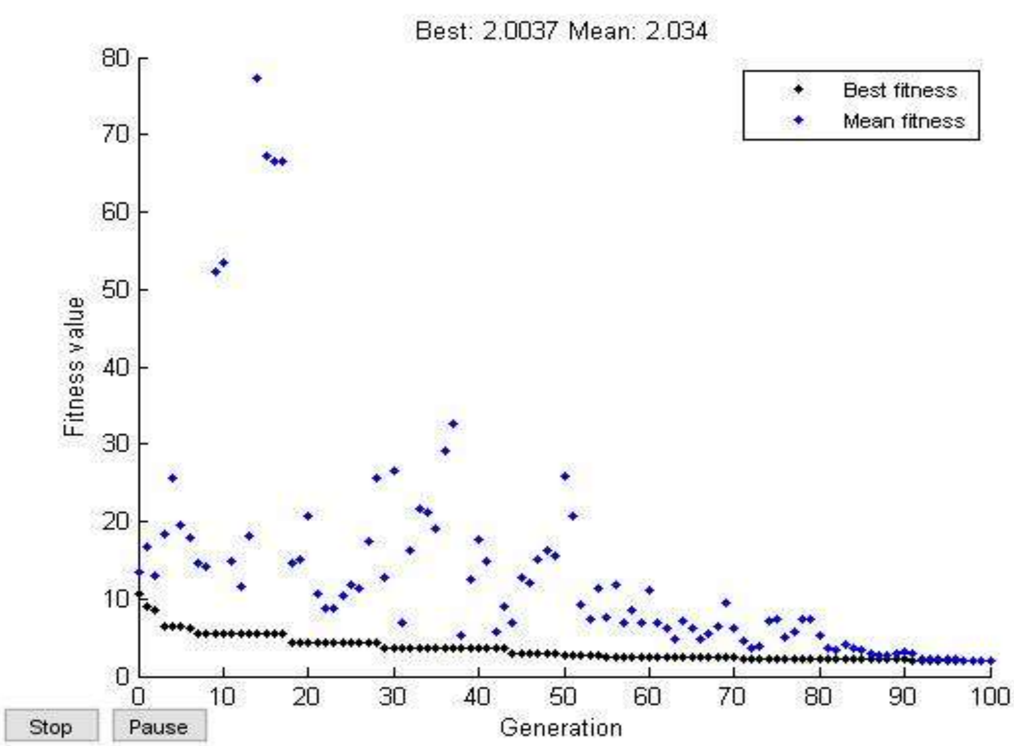


Figure B 25 GA analysis Yekaterinburg-Ghaziabad

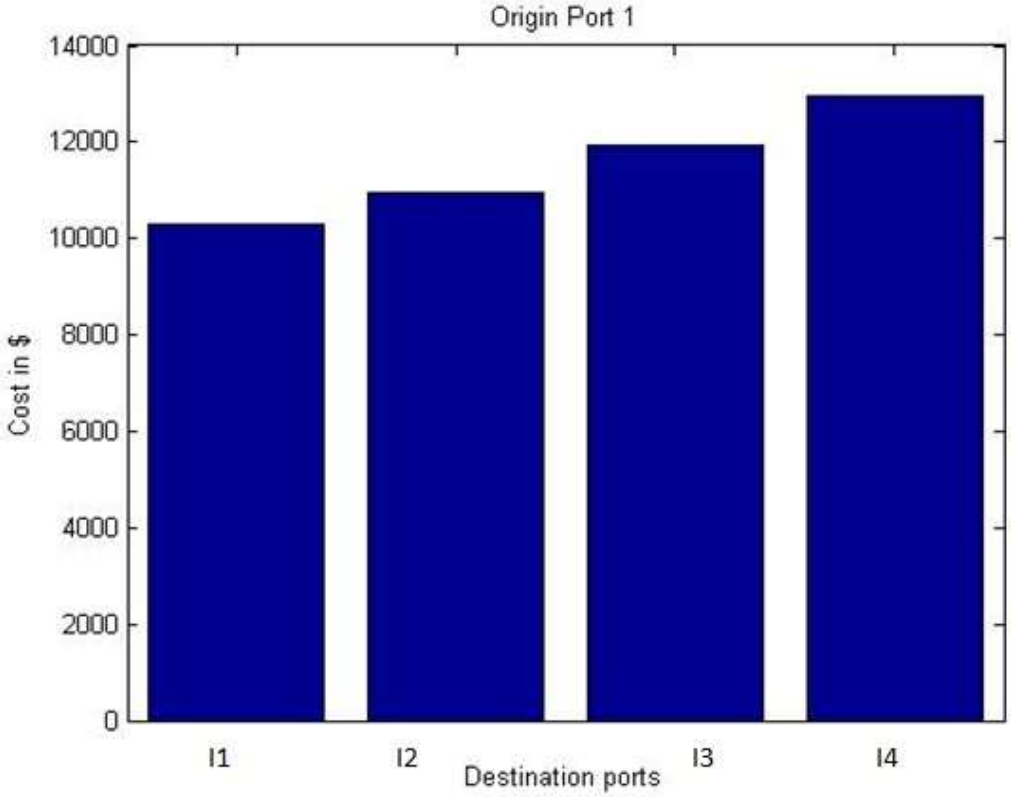
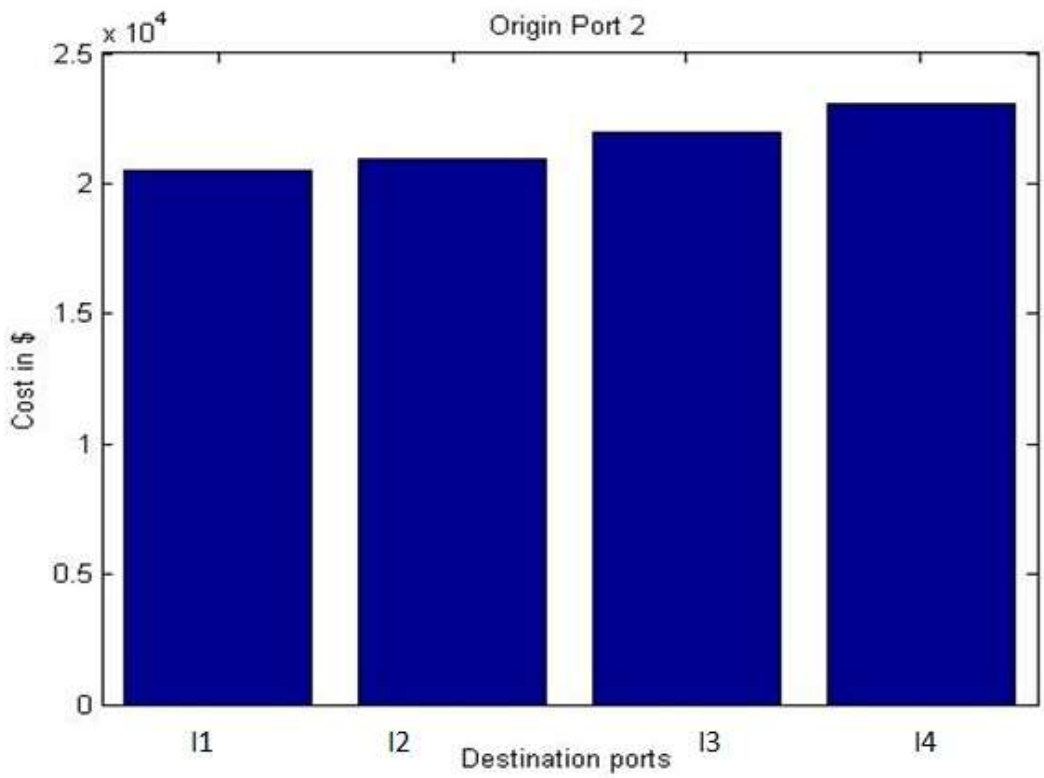


Figure B 26 Cost analysis Kaliningrad (R) – destination ports (I)



Azov **Figure B 27** Cost analysis Poronaysk (R) – destination ports (I)

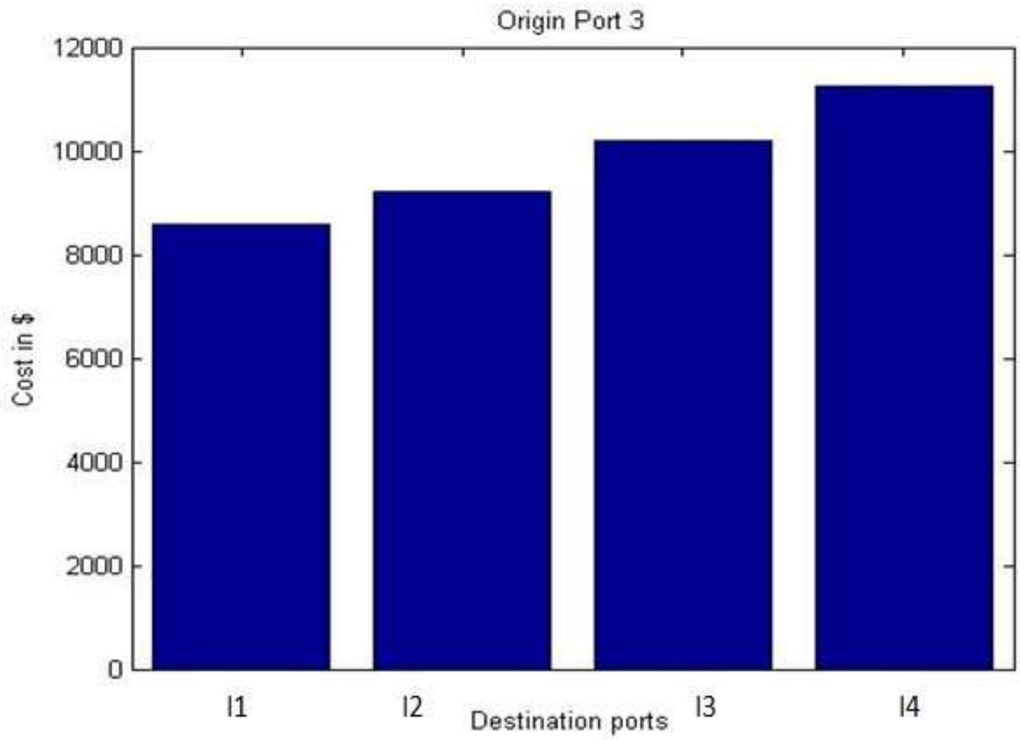


Figure B 28 Cost analysis Azov (R) – destination ports (I)

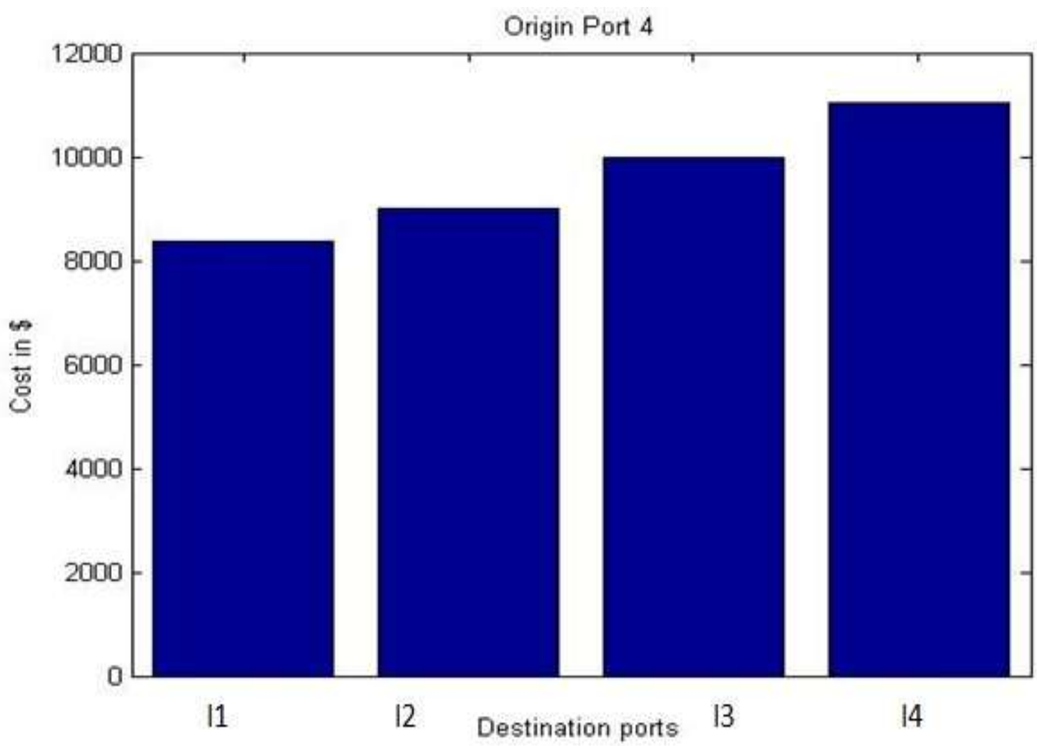


Figure B 29 Cost analysis Naryan-Mar (R) – destination ports (I)

Optimized path: Yekaterinburg-Naryan-Mar –Mumbai–Ghaziabad

d) Saint Petersburg-Chandrapur

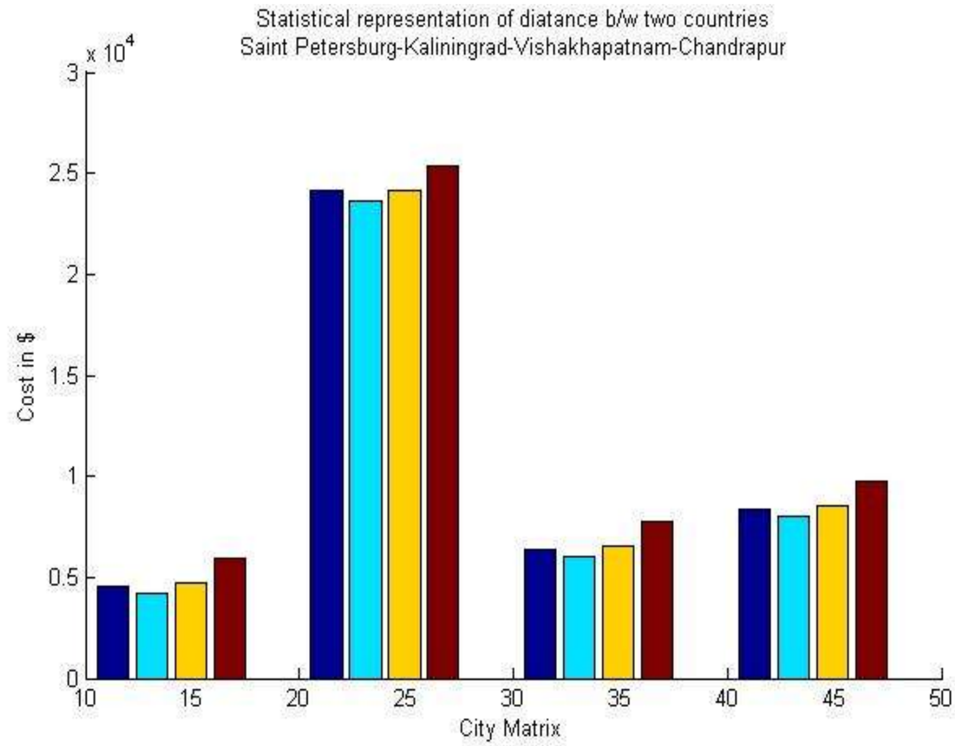


Figure B 30 Cost analysis Saint Petersburg-Chandrapur

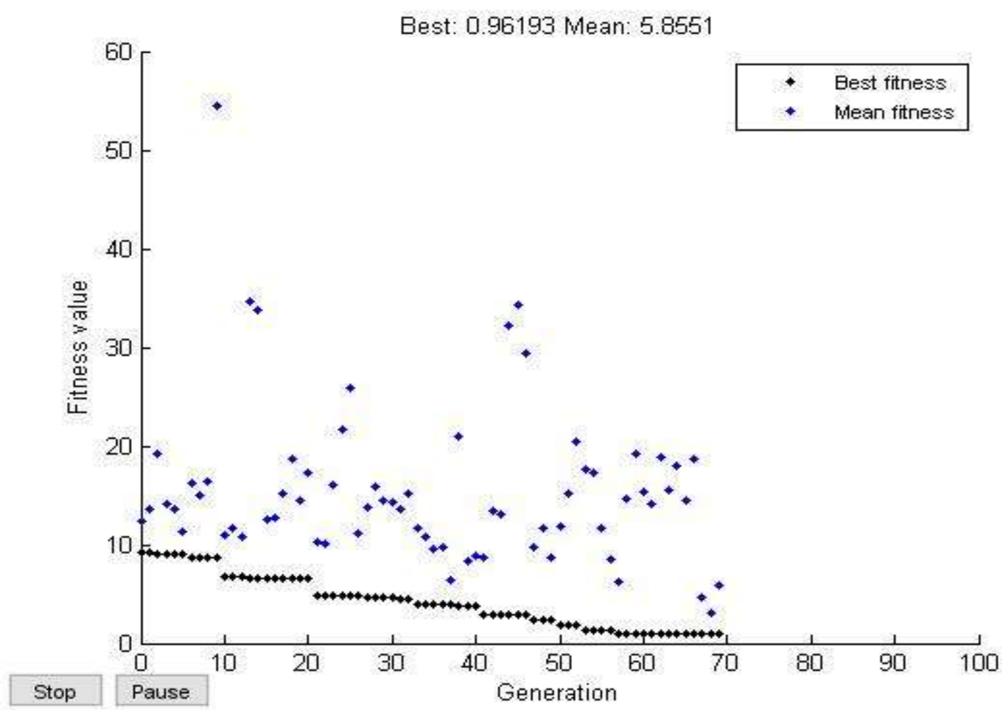


Figure B 31 GA analysis Saint Petersburg-Chandrapur

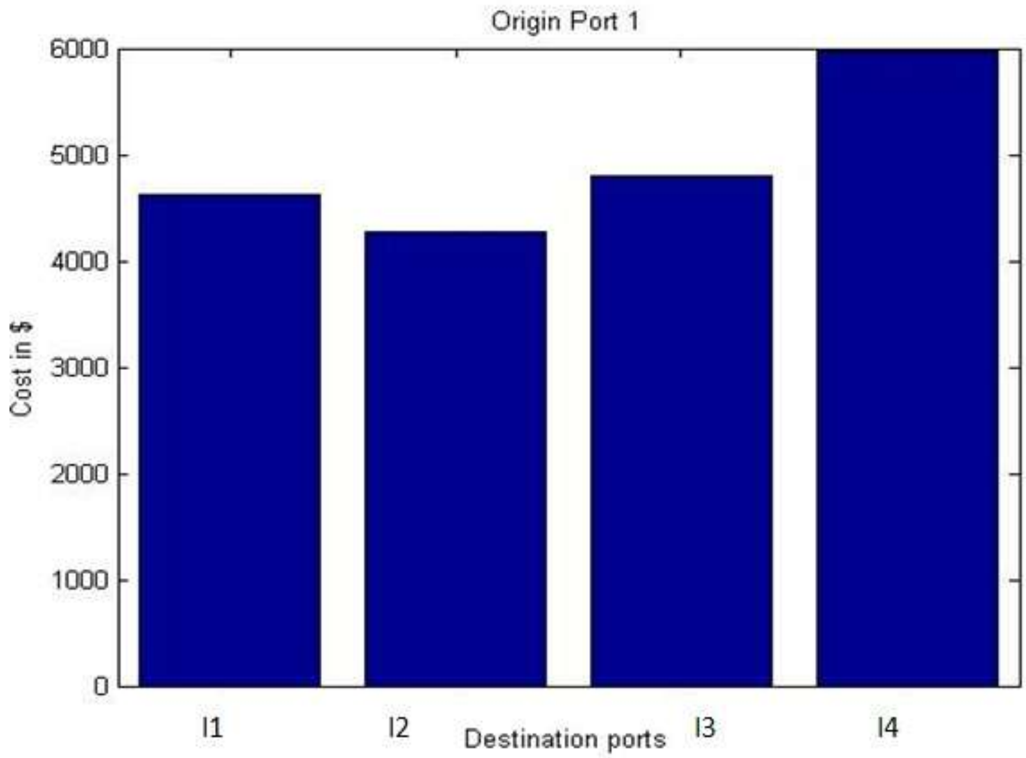


Figure B 32 Cost analysis Kaliningrad (R) – destination ports (I)

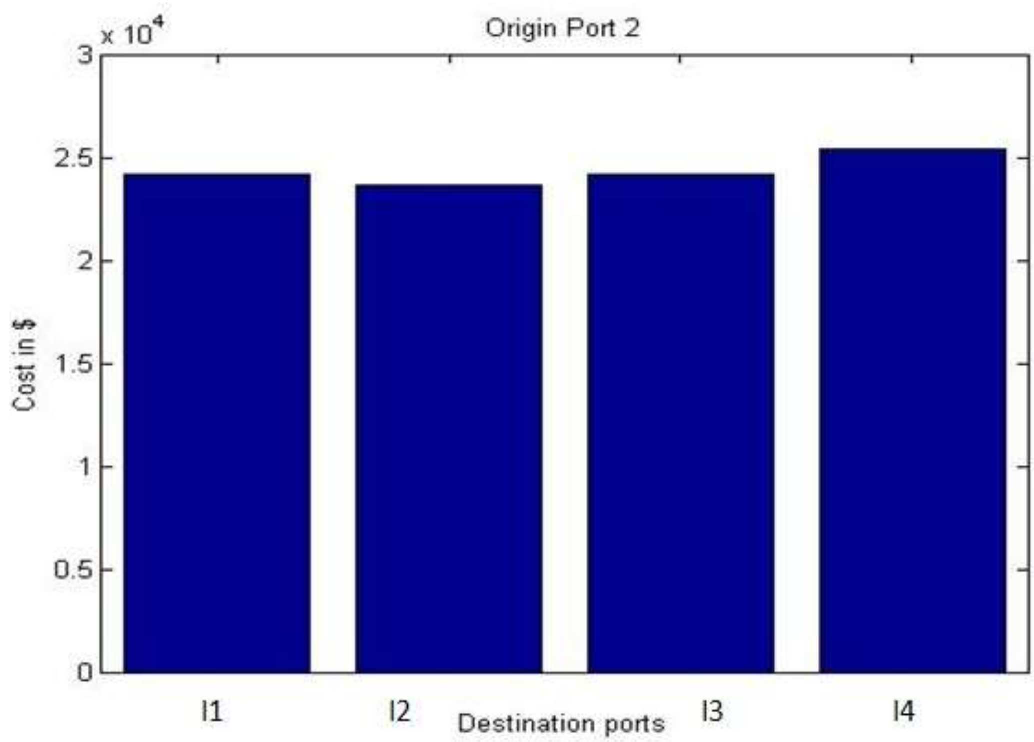


Figure B 33 Cost analysis Poronaysk (R) – destination ports (I)

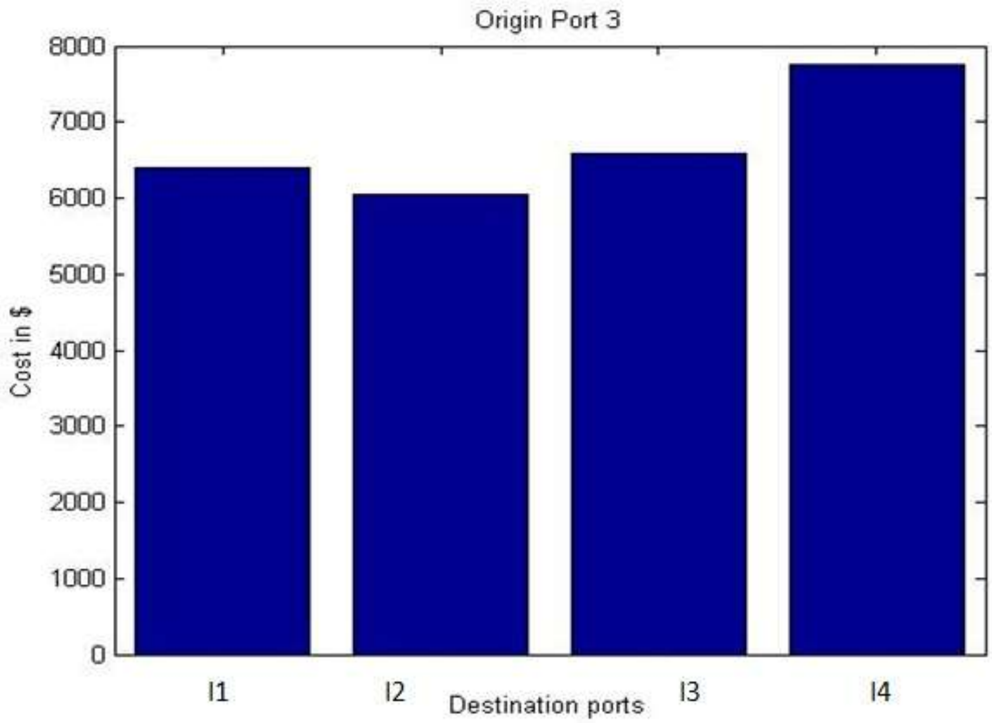


Figure B 34 Cost analysis Azov (R) – destination ports (I)

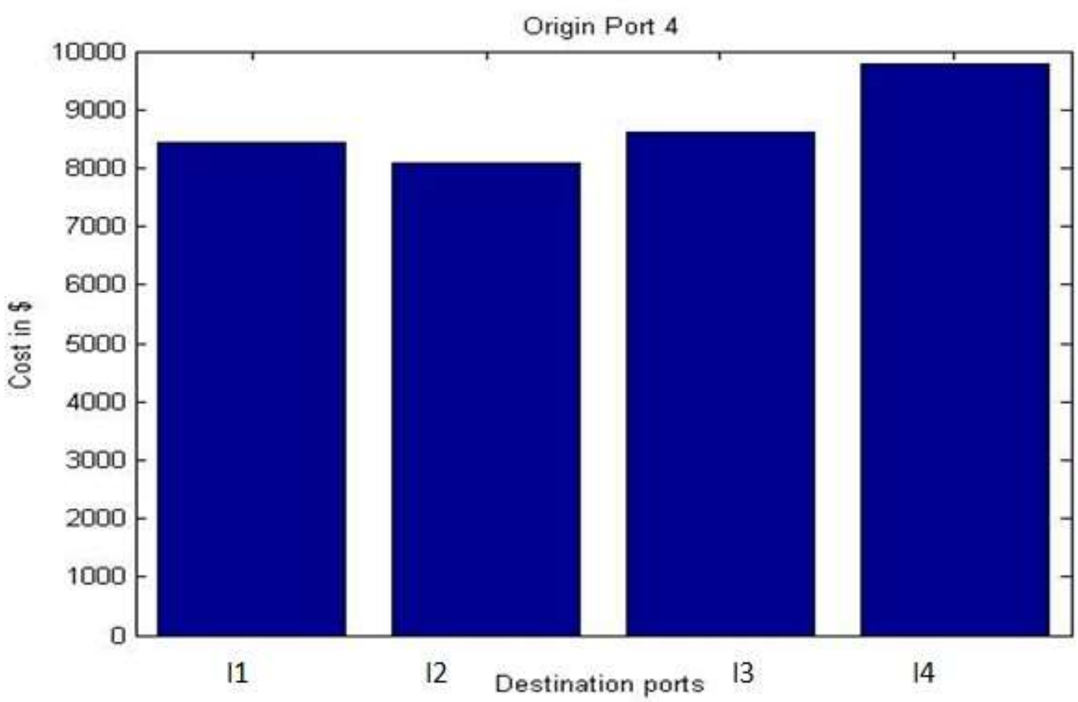


Figure B 35 Cost analysis Naryan-Mar (R) – destination ports (I)

Optimized path: Saint Petersburg-Kaliningrad –Vishakhapatnam-Chandrapur

Illustration 3. India to South Africa

b) Vapi-Free State

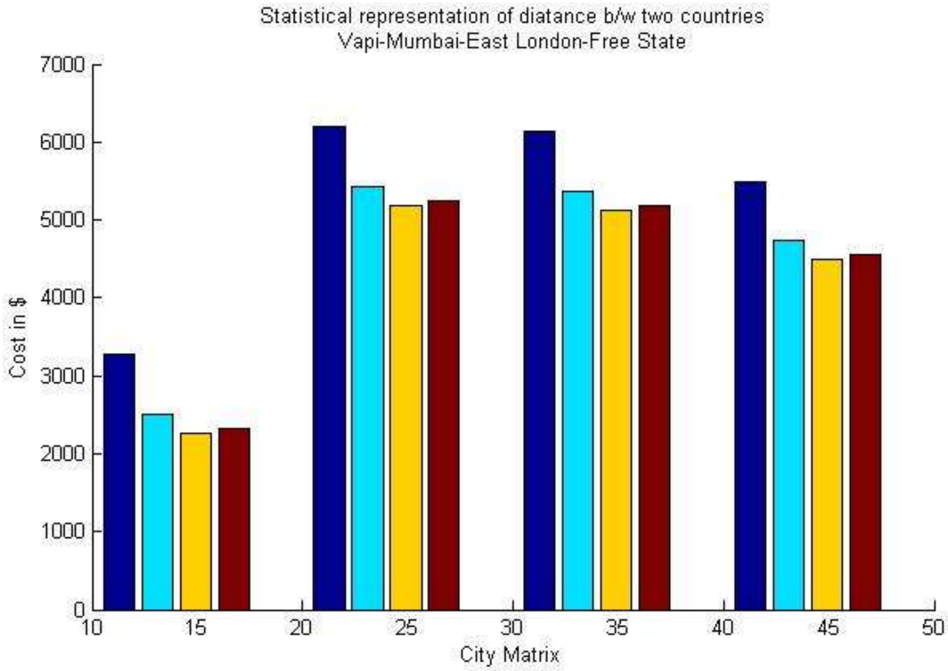


Figure B 36 Cost analysis Vapi-Free State

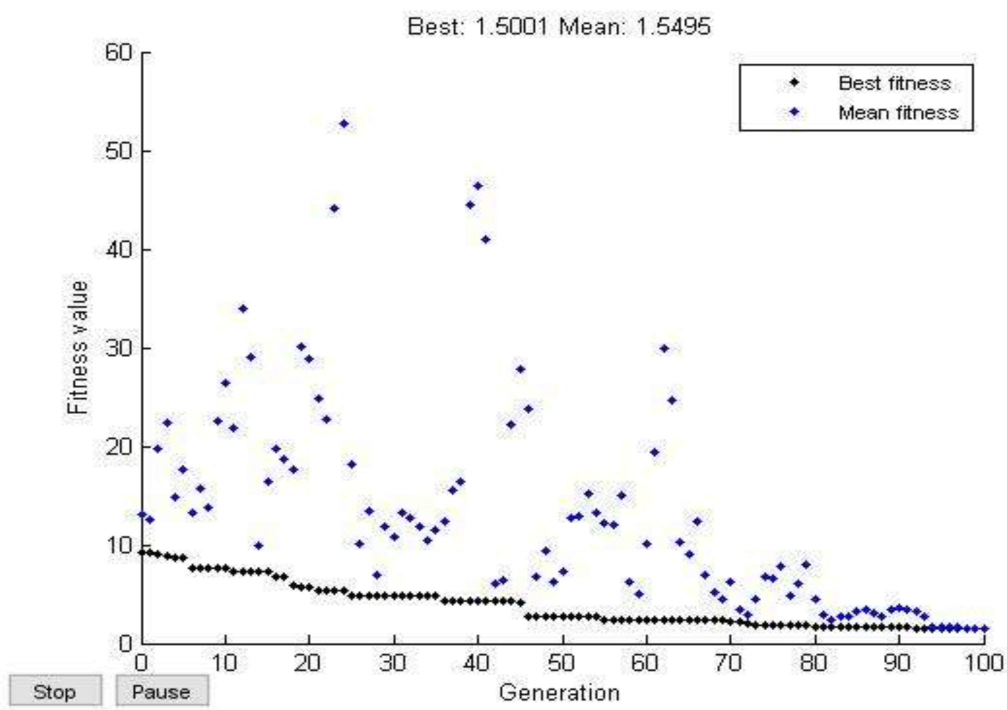


Figure B 37 GA analysis Vapi-Free State

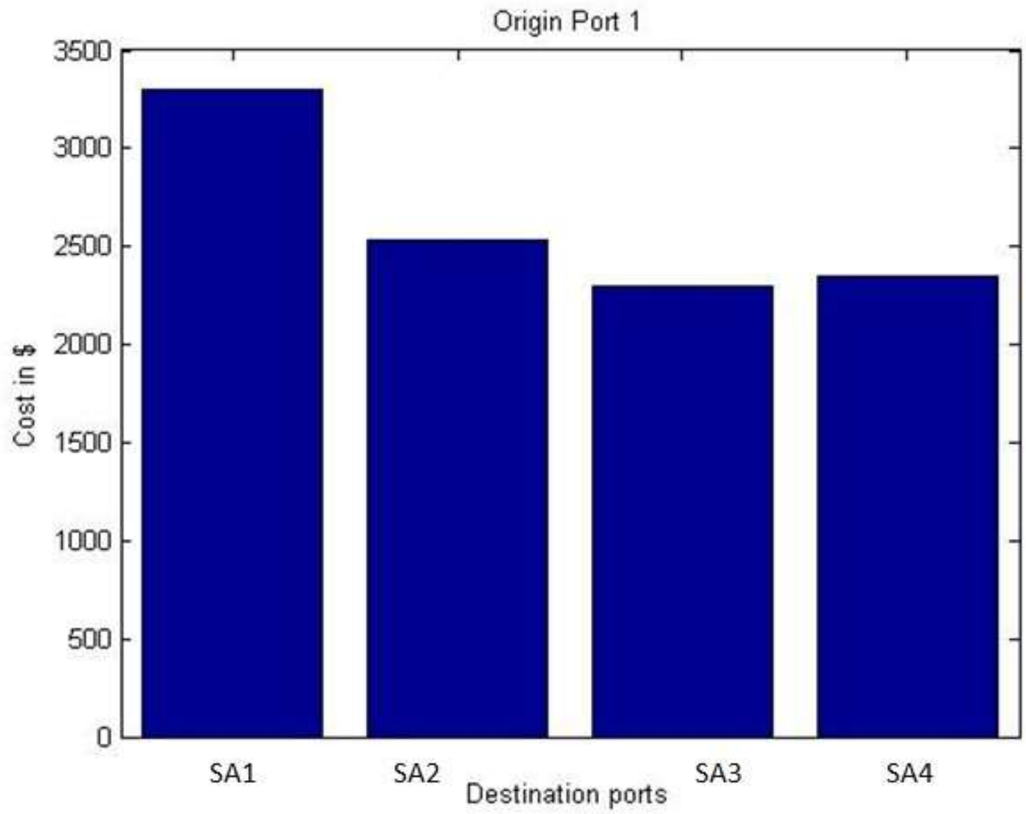


Figure B 38 Cost analysis Mumbai (I) – destination ports (SA)

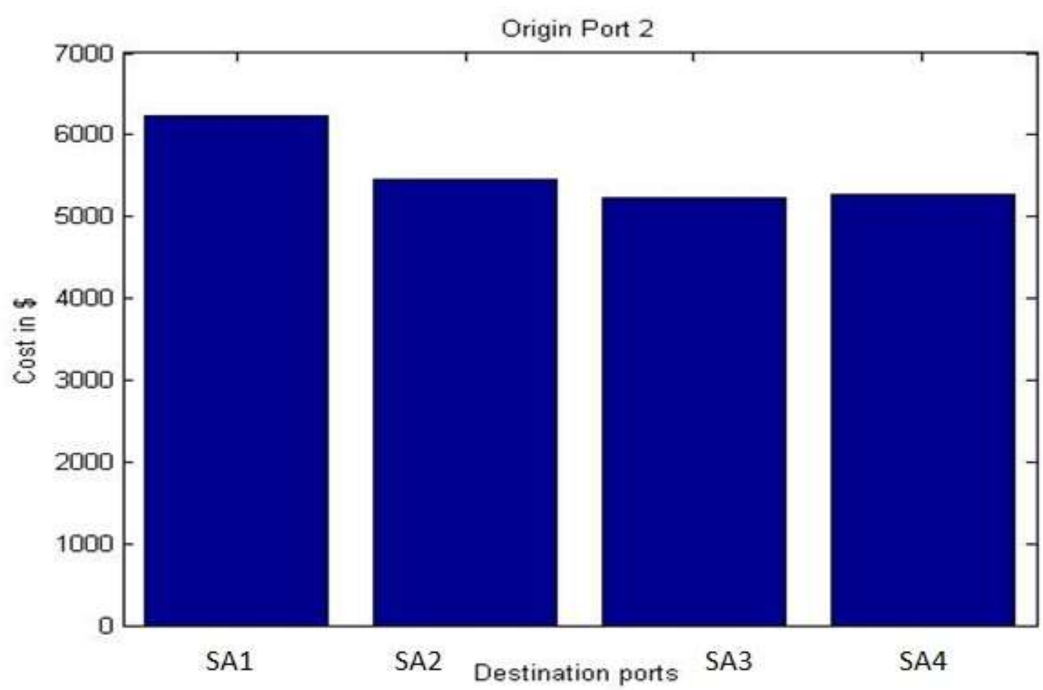


Figure B 39 Cost analysis Vishakhapatnam (I) – destination ports (SA)

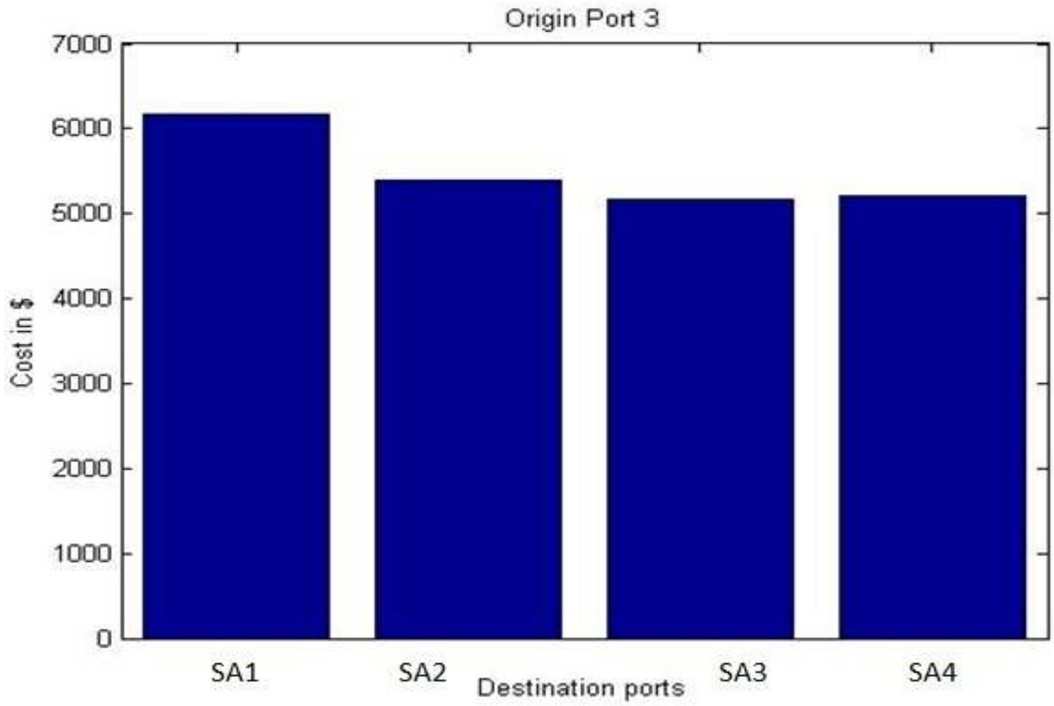


Figure B 40 Cost analysis Chennai (I) – destination ports (SA)

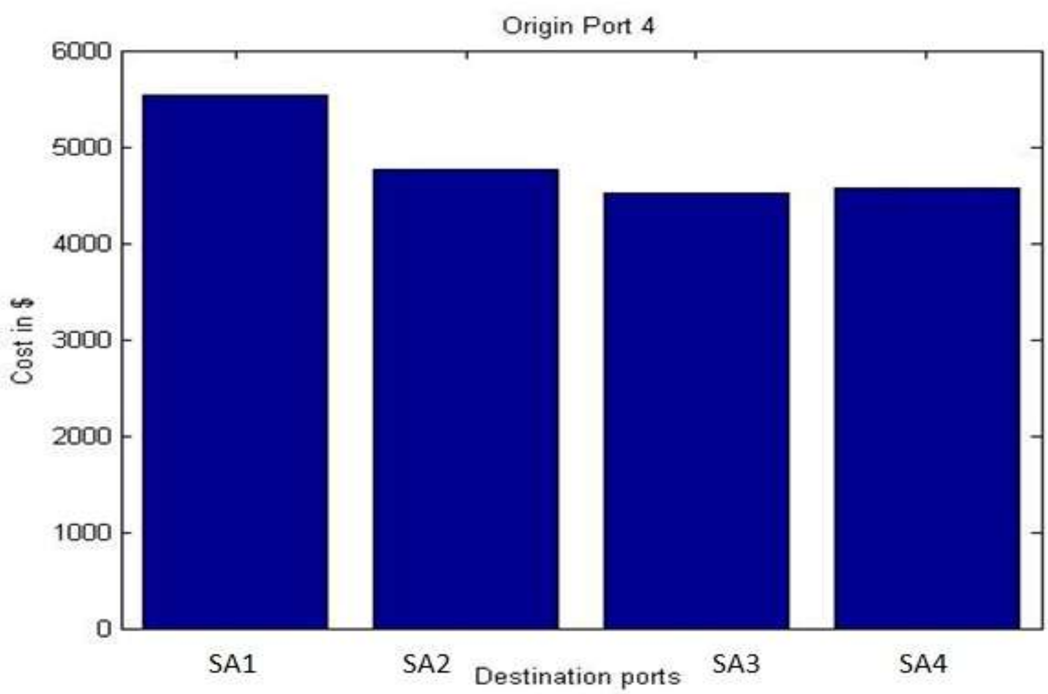


Figure B 41 Cost analysis Cochin (I) – destination ports (SA)
Optimized path: Vapi-Mumbai -East London-Free State

c) Ghaziabad-Gauteng

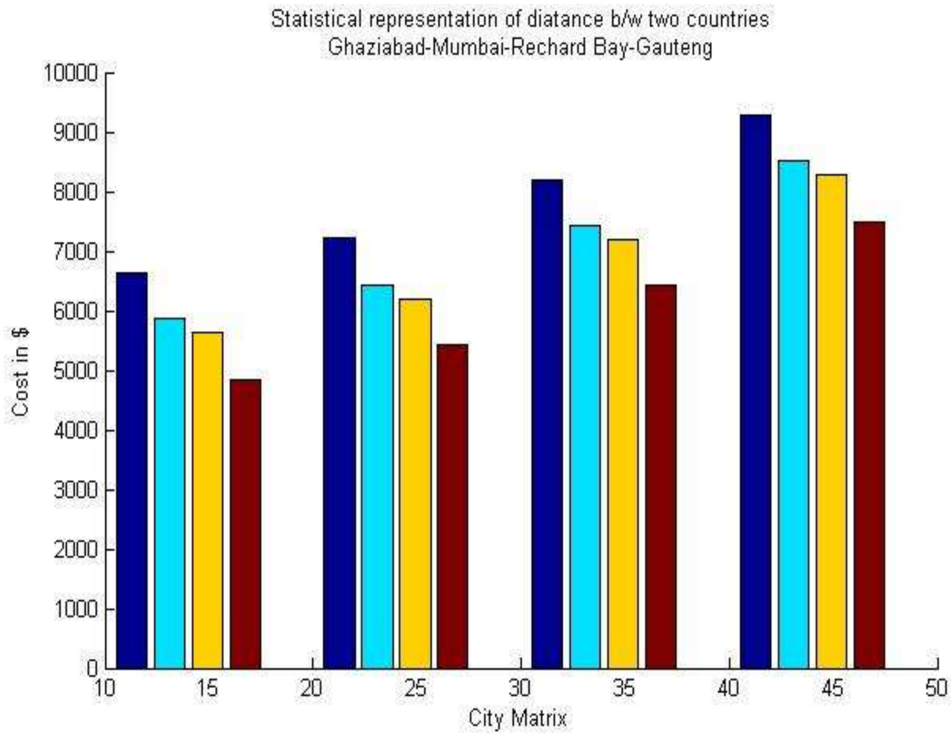


Figure B 42 Cost analysis Ghaziabad-Gauteng

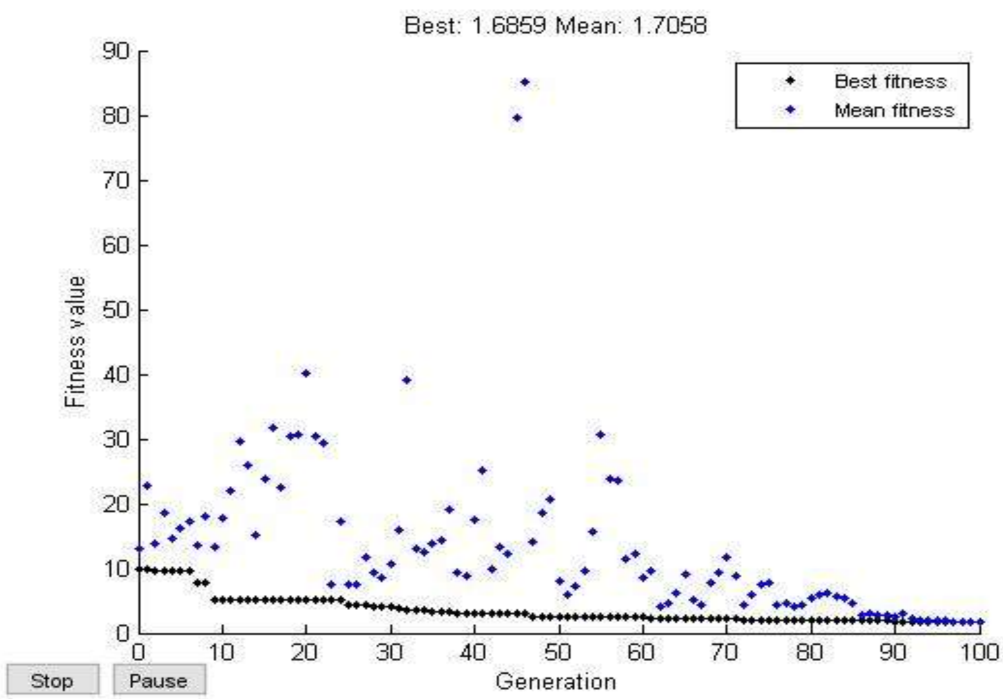


Figure B 43 GA analysis Ghaziabad-Gauteng

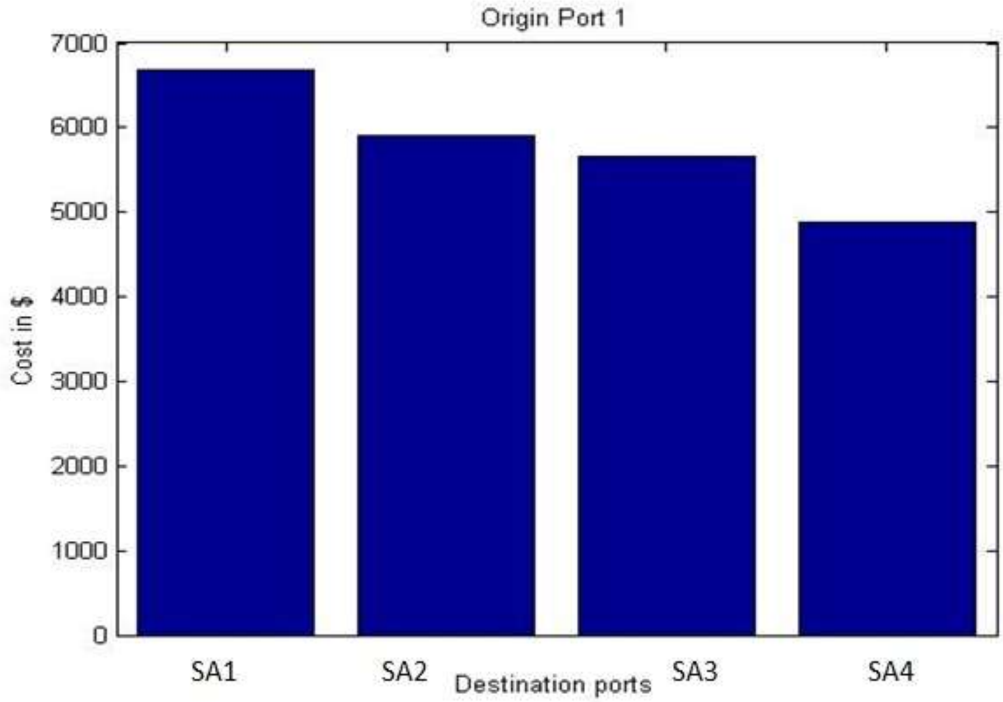


Figure B 44 Cost analysis Mumbai (I) – destination ports (SA)

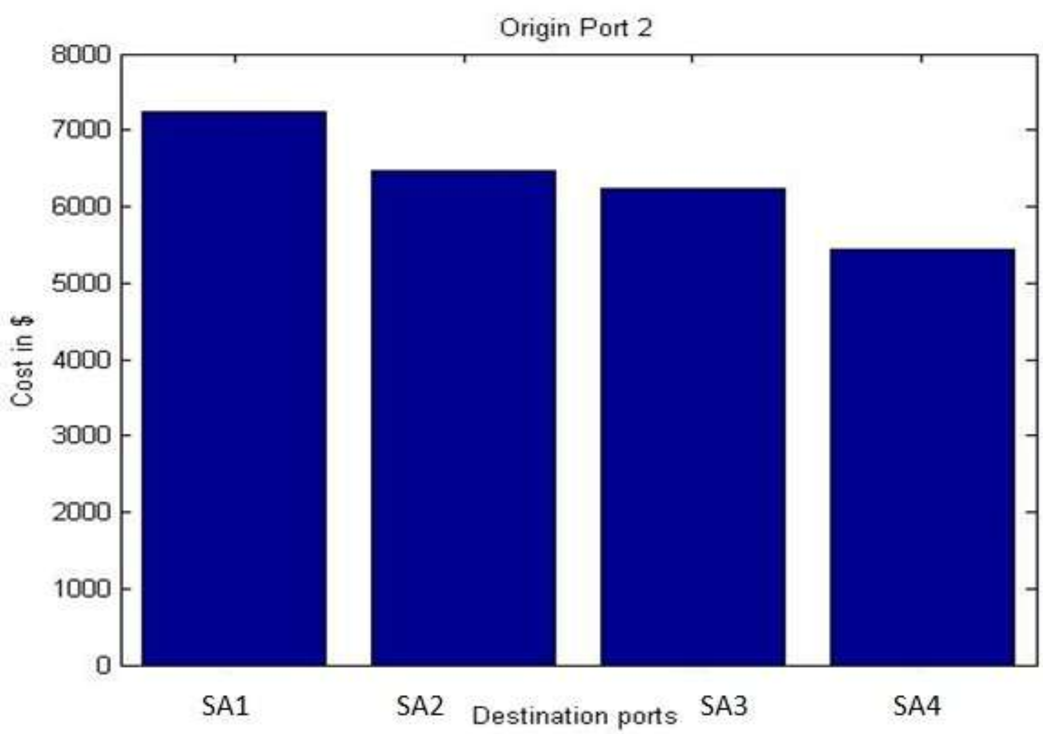


Figure B 45 Cost analysis Vishakhapatnam (I) – destination ports (SA)

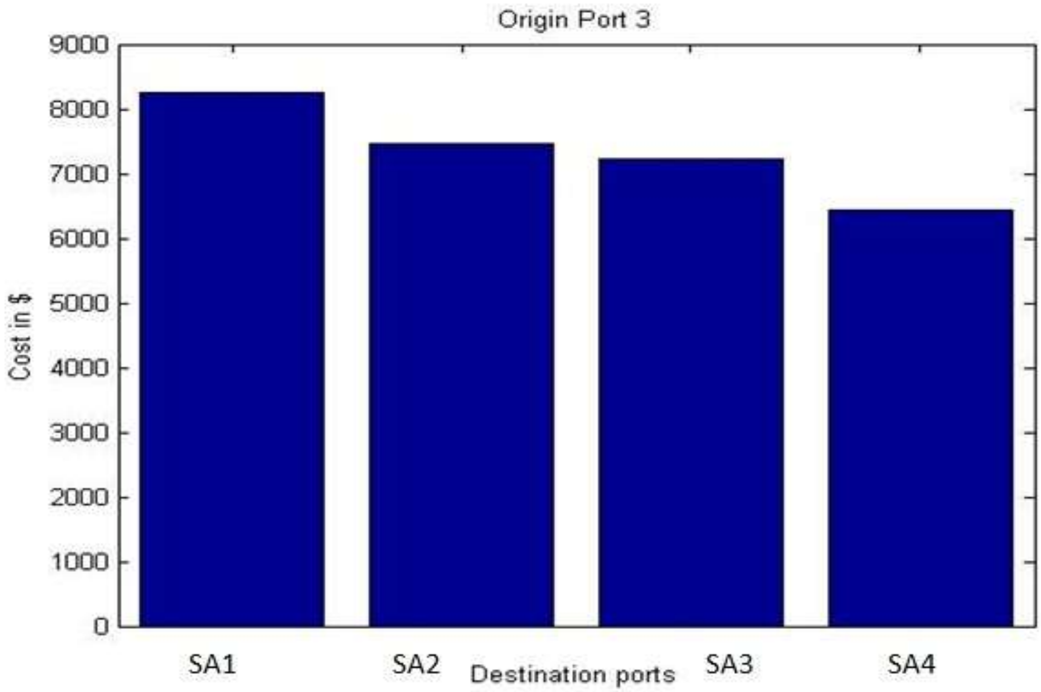


Figure B 46 Cost analysis Chennai (I) – destination ports (SA)

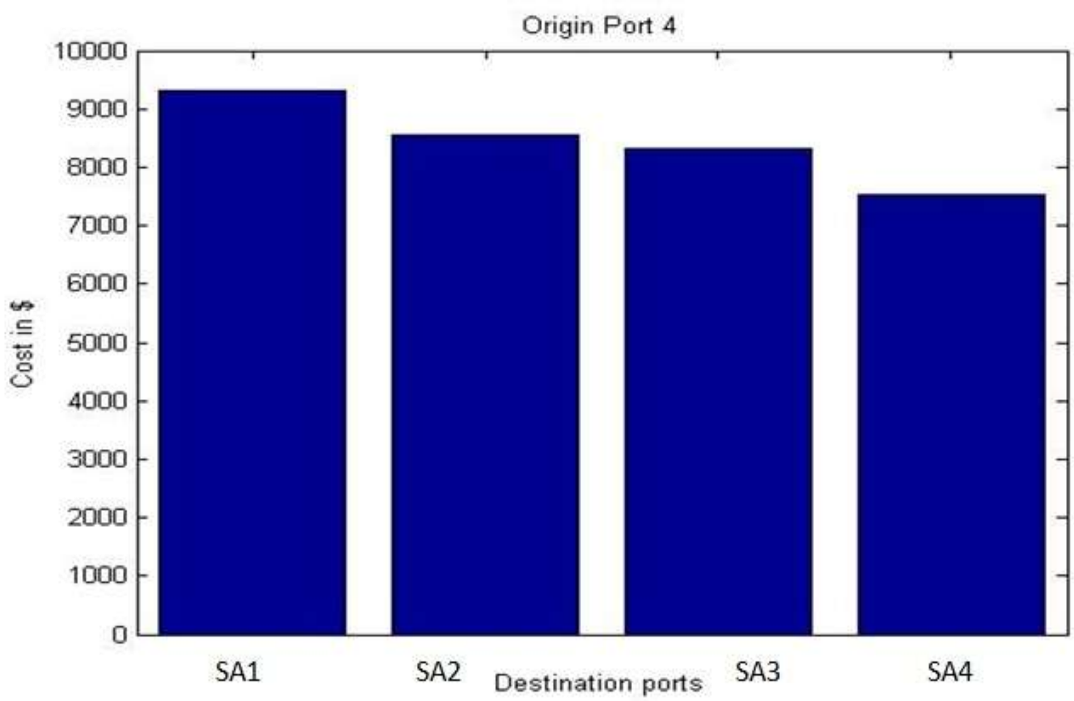


Figure B 47 Cost analysis Cochin (I) – destination ports (SA)

Optimized path: Ghaziabad-Mumbai –Richard Bay –Gauteng

d) Chandrapur-Eastern Cap

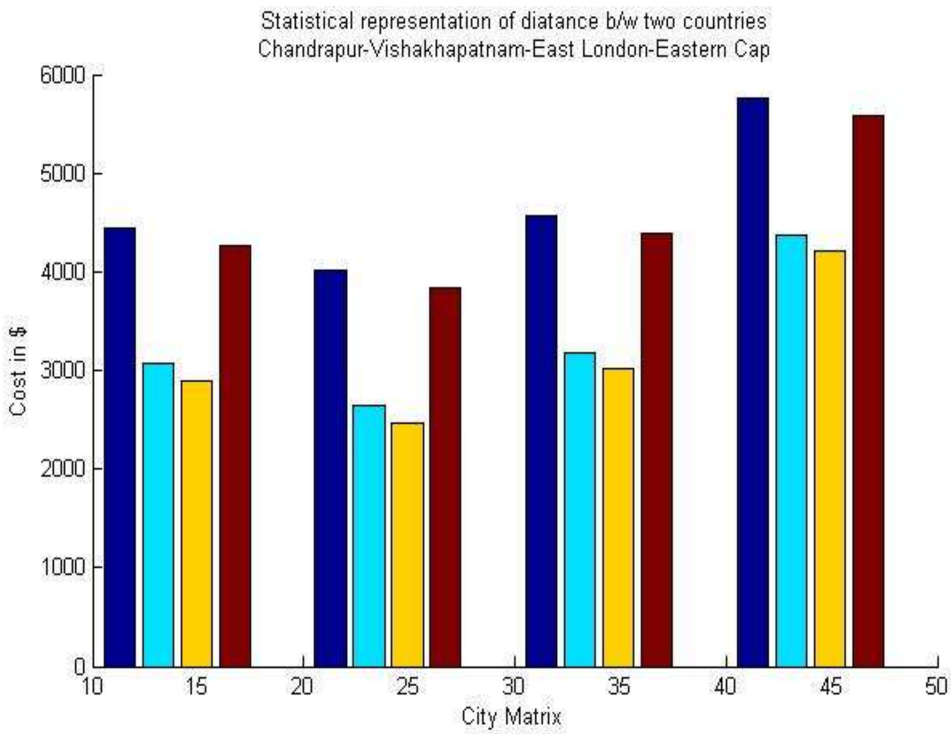


Figure B 48 Cost analysis Chandrapur-Eastern Cap

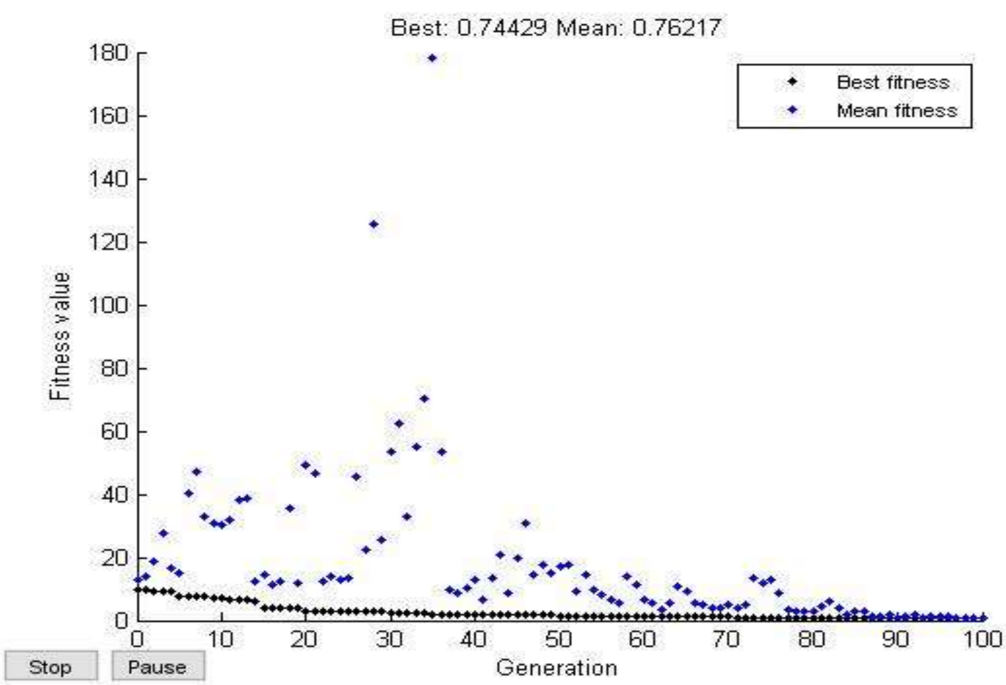


Figure B 49 GA analysis Chandrapur-Eastern Cap

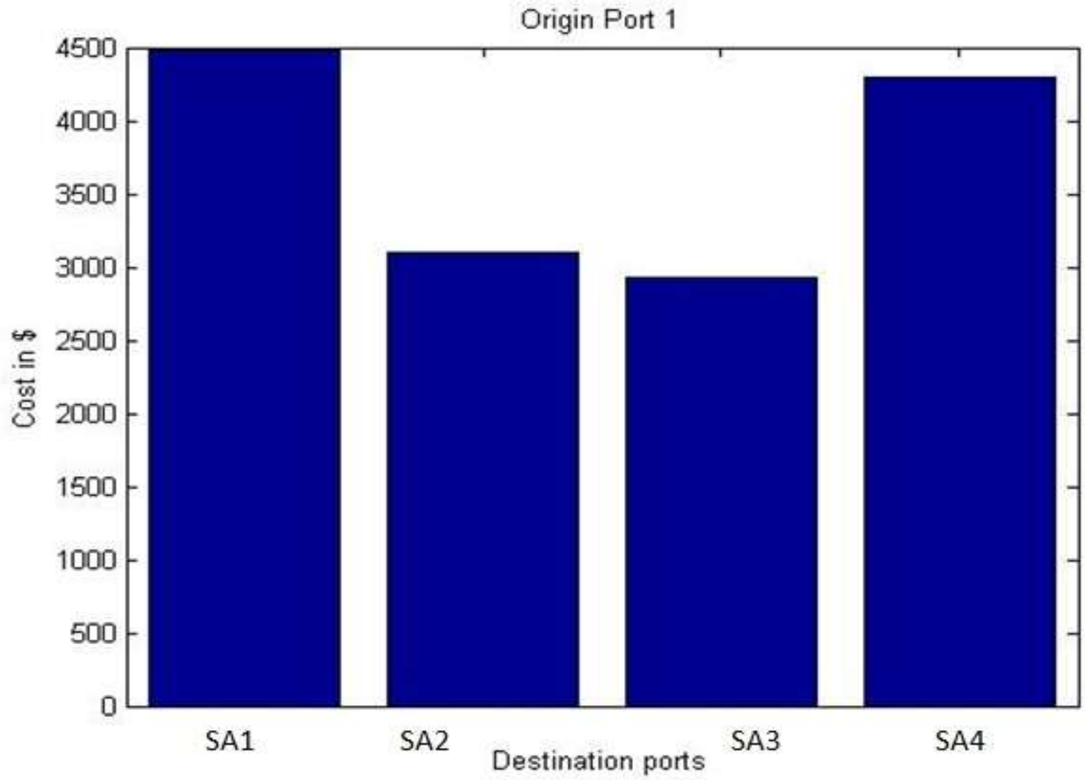


Figure B 50 Cost analysis Mumbai (I) – destination ports (SA)

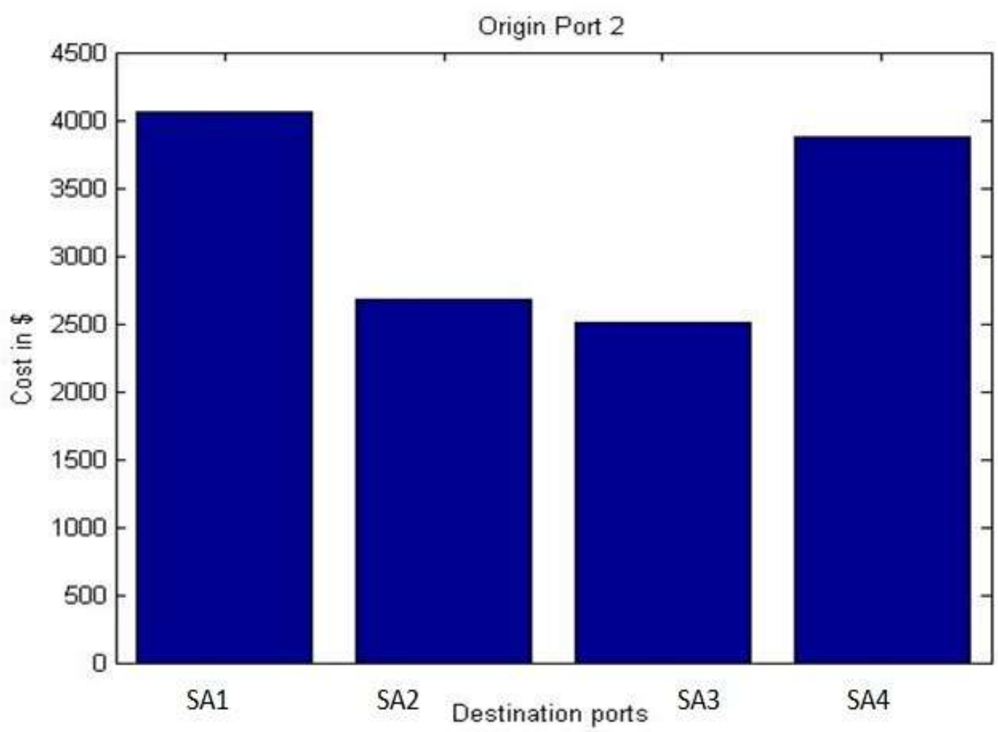


Figure B 51 Cost analysis Vishakhapatnam (I) – destination ports (SA)

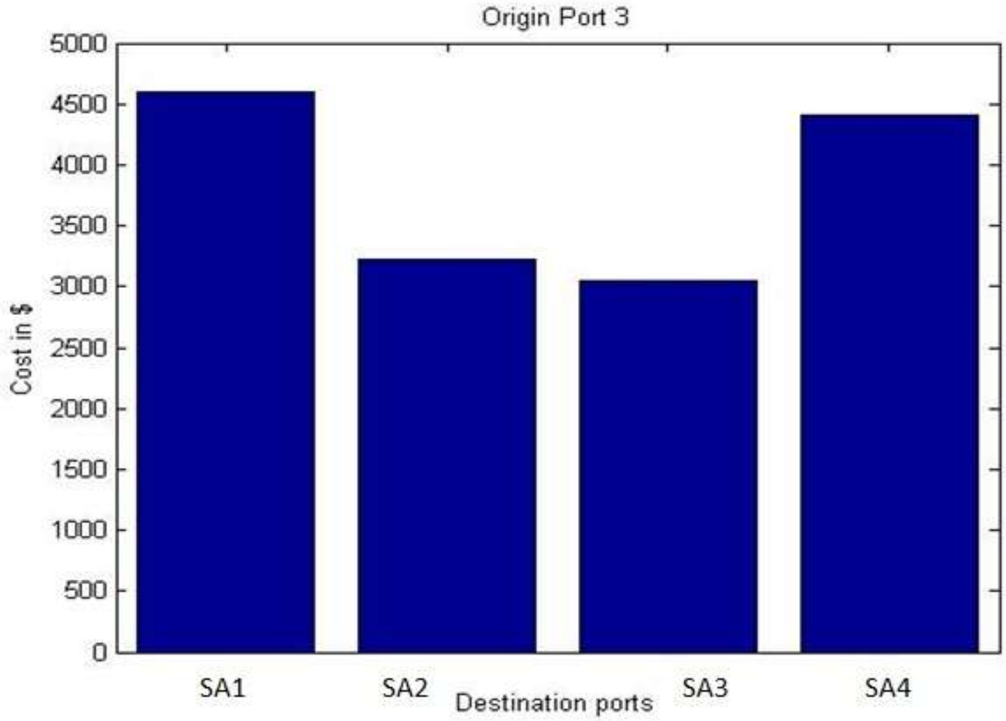


Figure B 52 Cost analysis Chennai (I) – destination ports (SA)

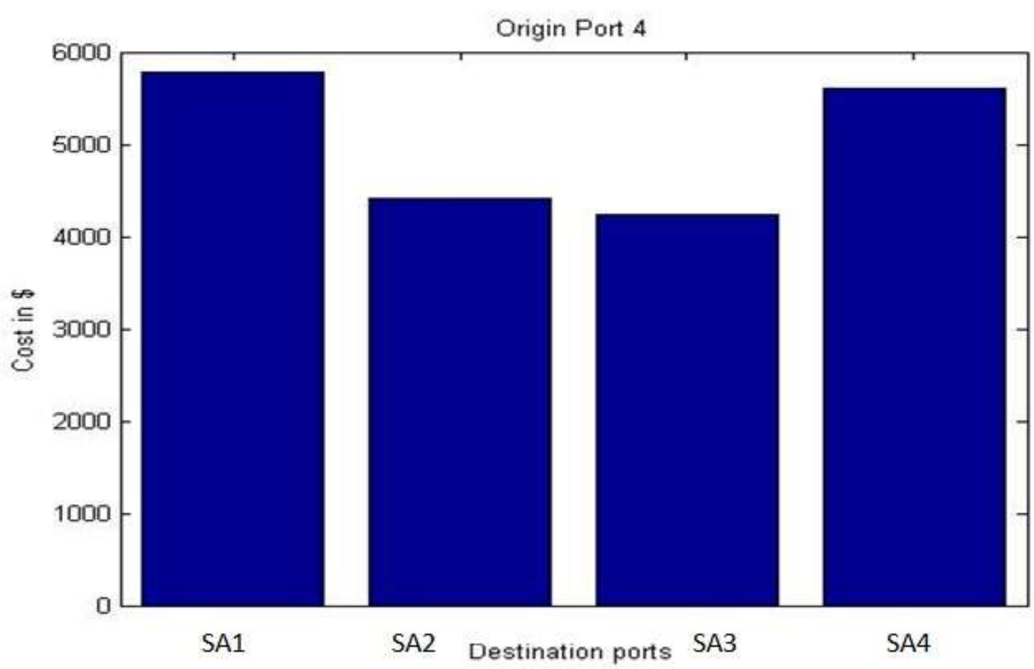


Figure B 53 Cost analysis Chennai (I) – destination ports (SA)

Optimized path: Chandrapur-Vishakhapatnam-East London-Eastern cap

Illustration 4. Russia to South Africa

b) Samara-Free State

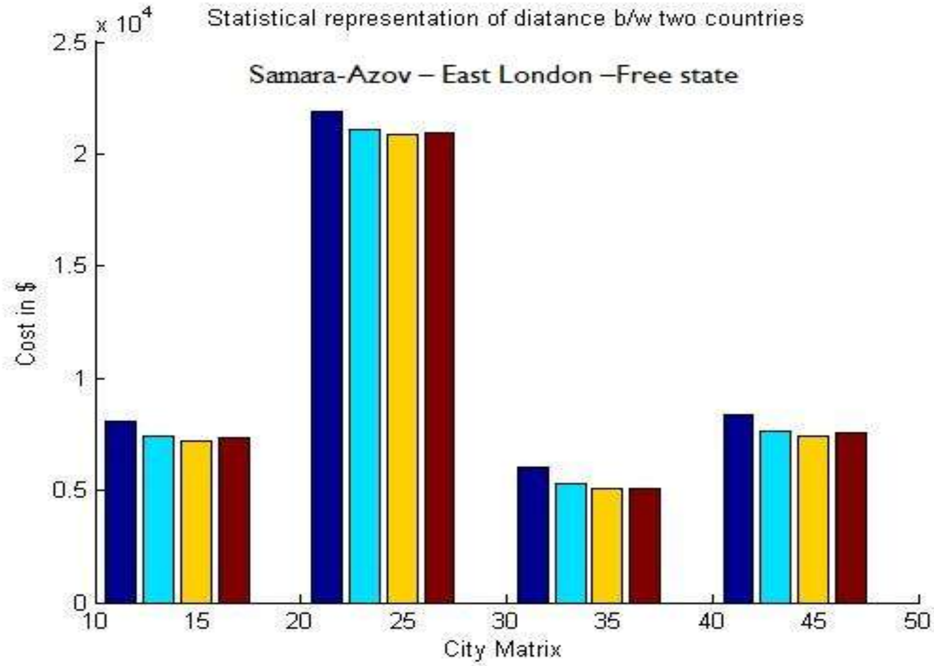


Figure B 54 Cost analysis **Samara-Free State**

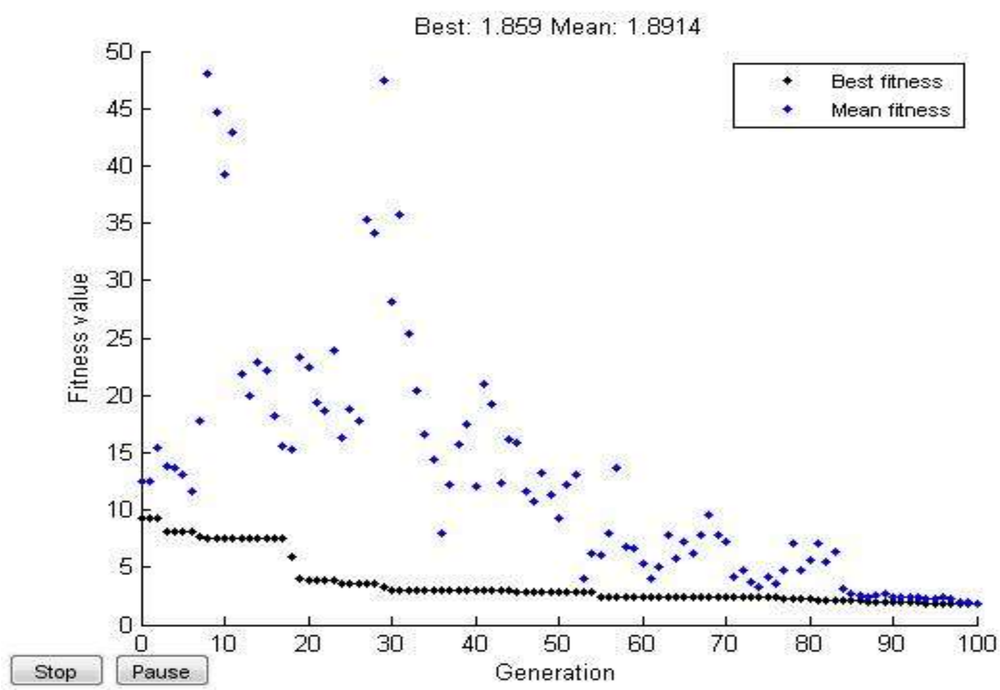


Figure B 55 GA analysis **Samara-Free State**

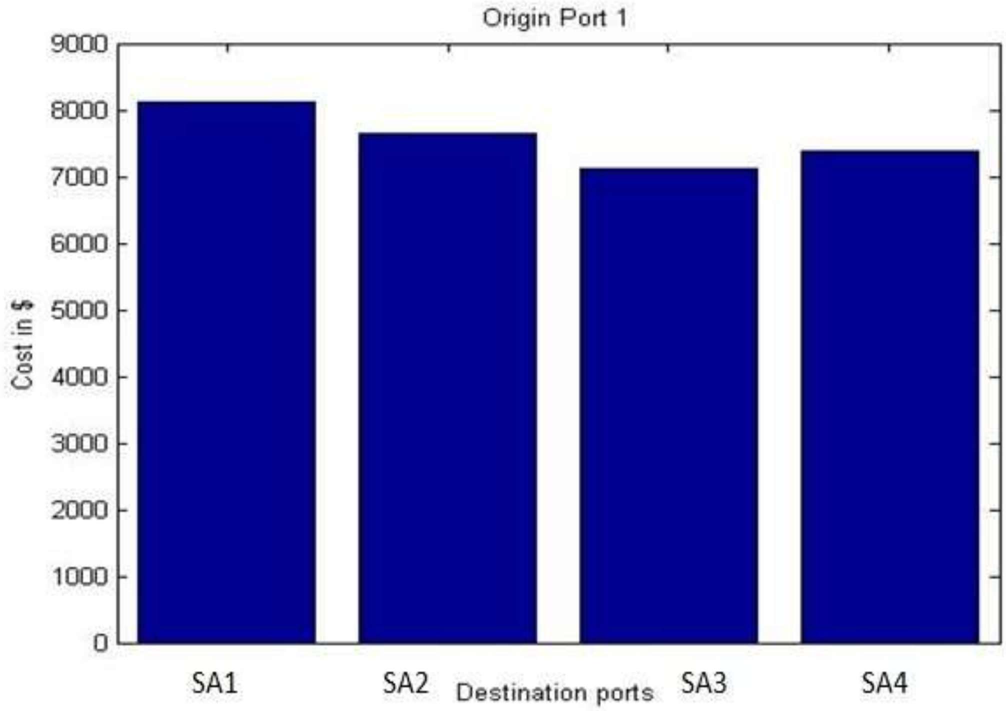


Figure B 56 Cost analysis Kaliningrad (R) – destination ports (SA)

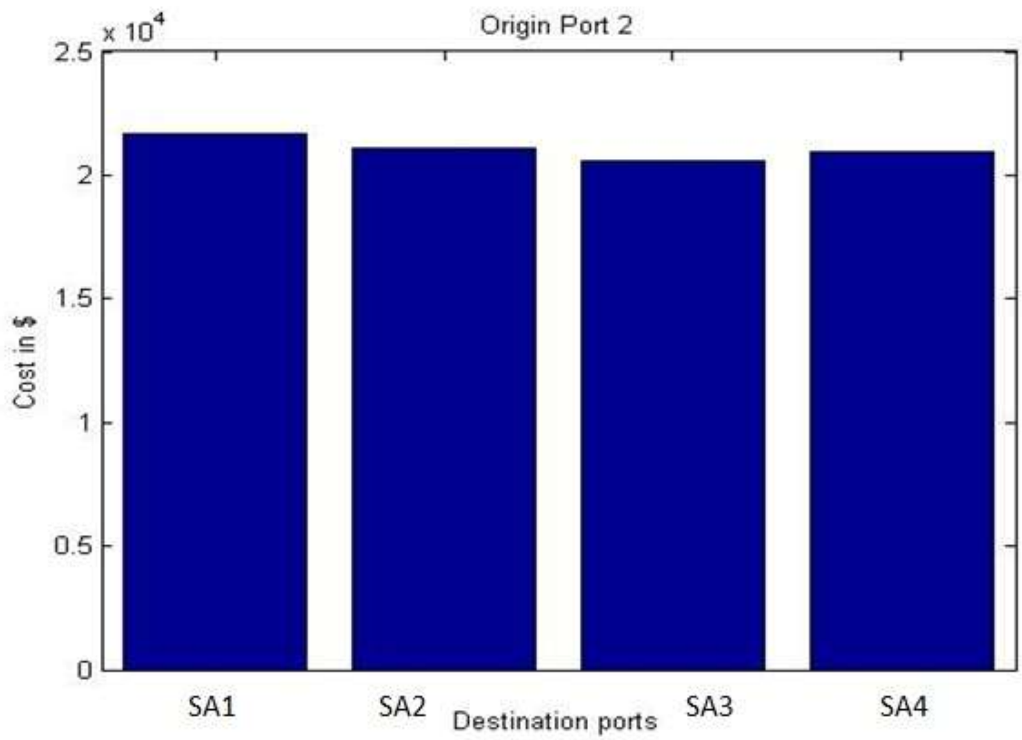


Figure B 57 Cost analysis Poronaysk (R) – destination ports (SA)

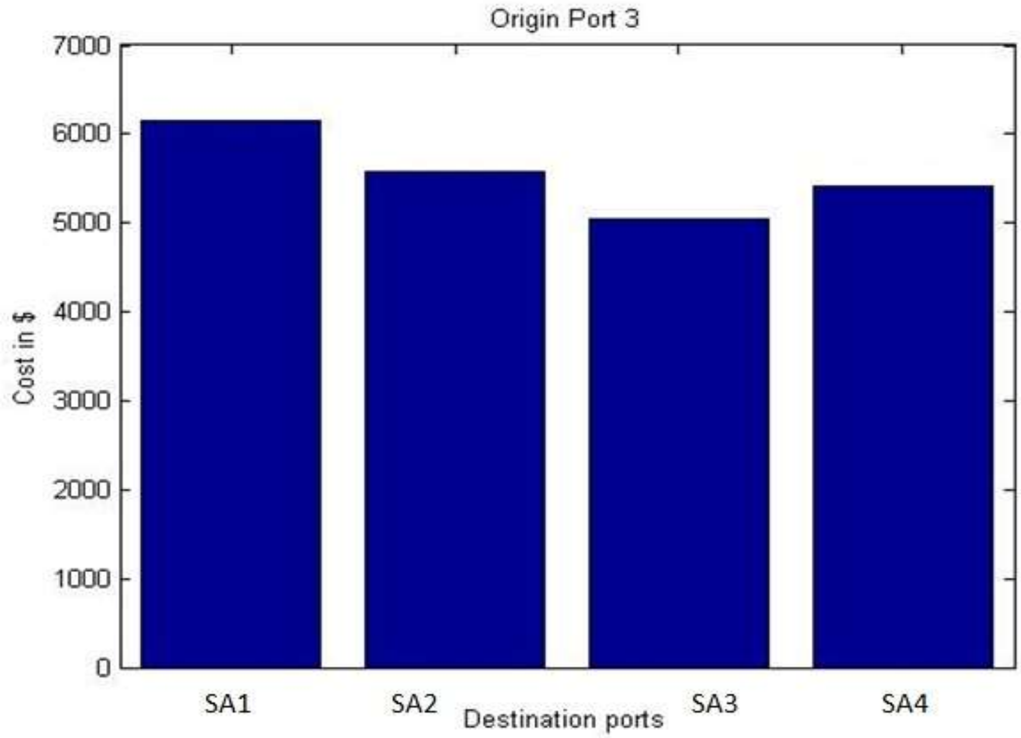


Figure B 58 Cost analysis Azov (R) – destination ports (SA)

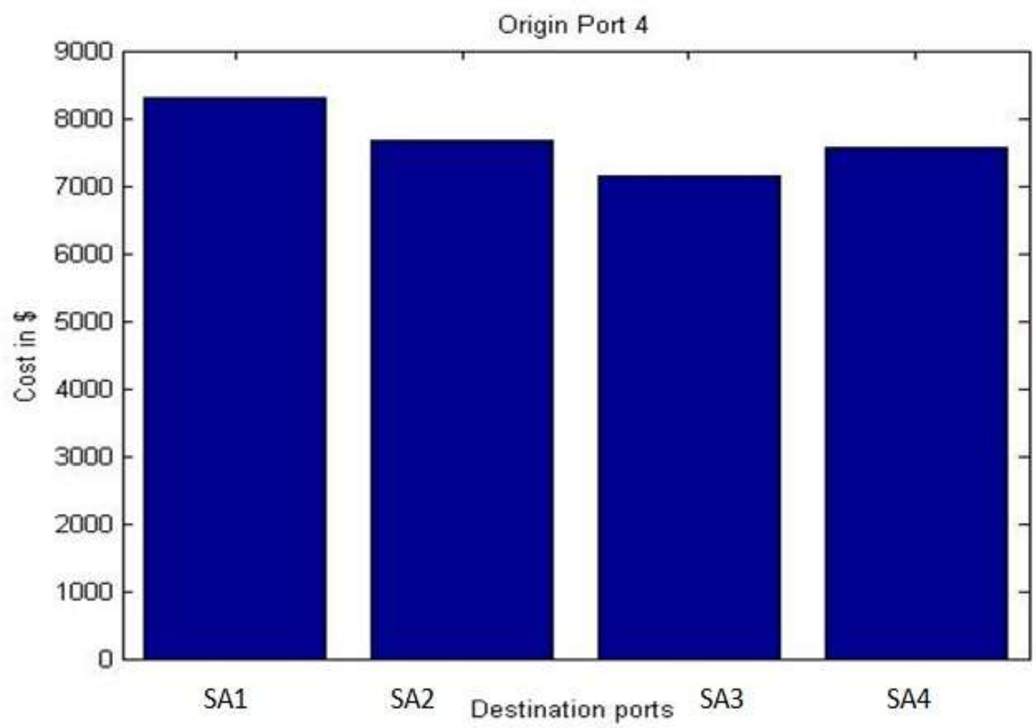


Figure B 59 Cost analysis Naryan-Mar (R) – destination ports (SA)

Optimized path: Samara-Azov – East London –Free State

c) Yekaterinburg - Gauteng

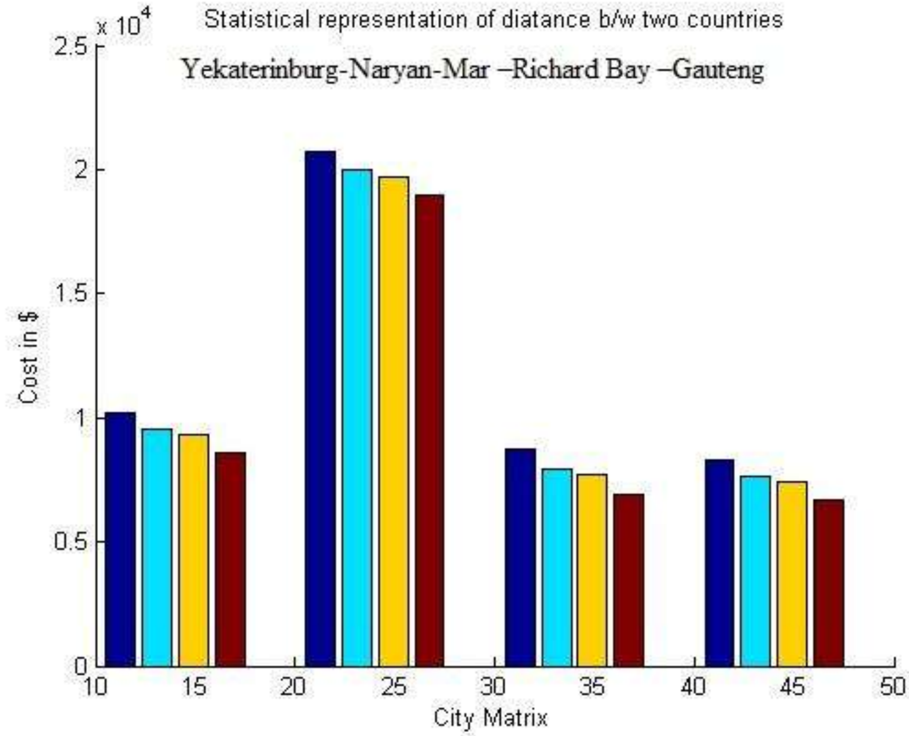


Figure B 60 Cost analysis Yekaterinburg - Gauteng

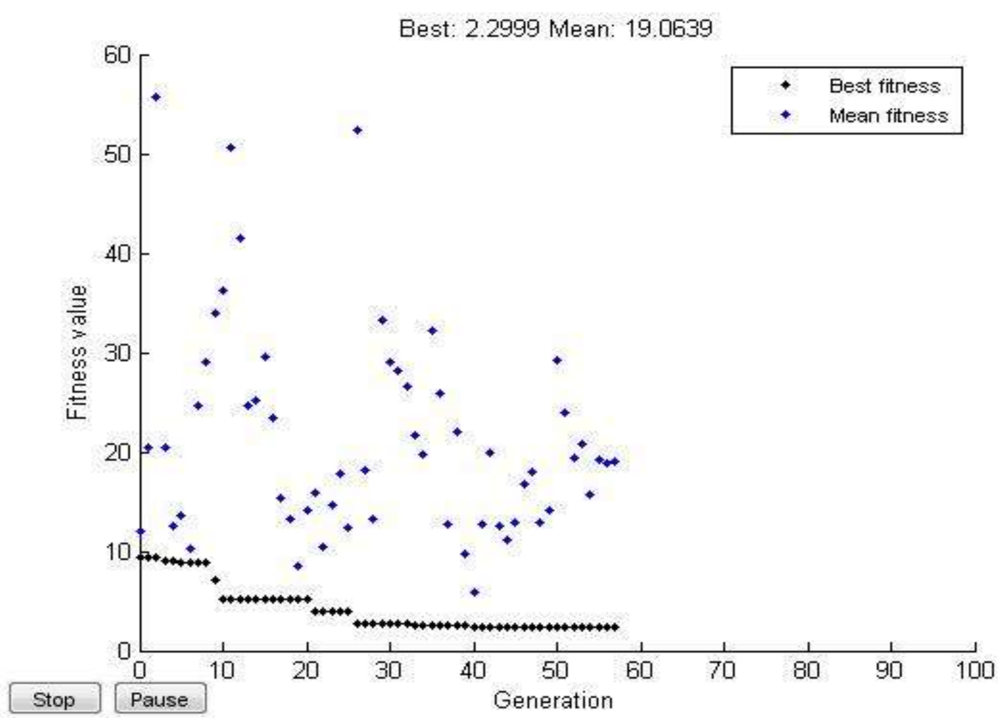


Figure B 61 GA analysis Yekaterinburg - Gauteng

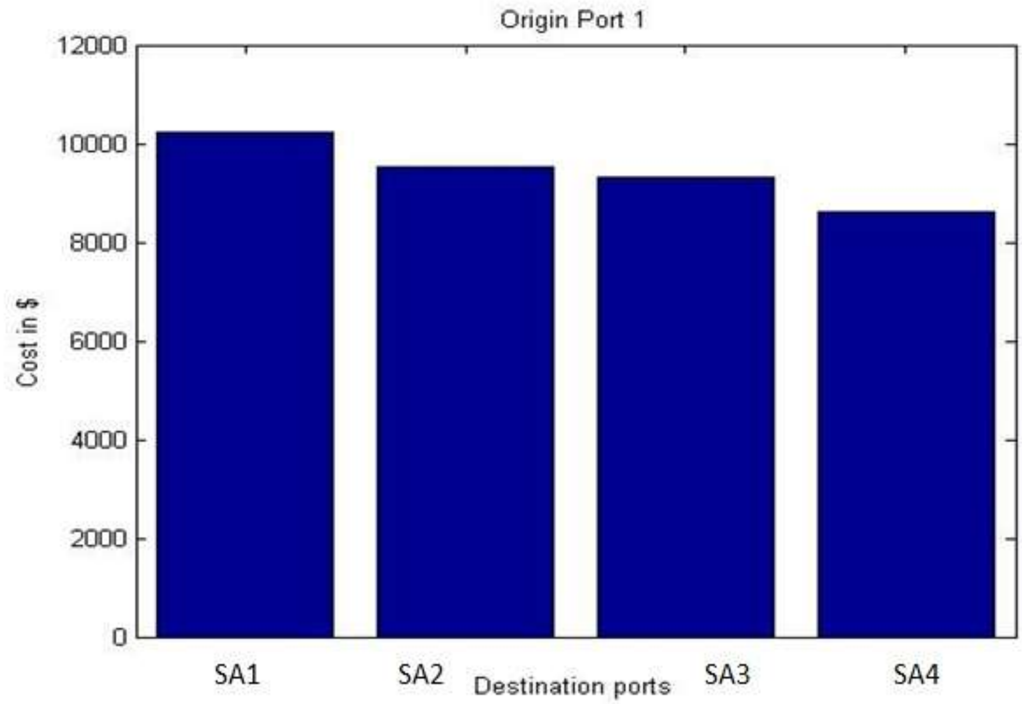


Figure B 62 Cost analysis Kaliningrad (R) – destination ports (SA)

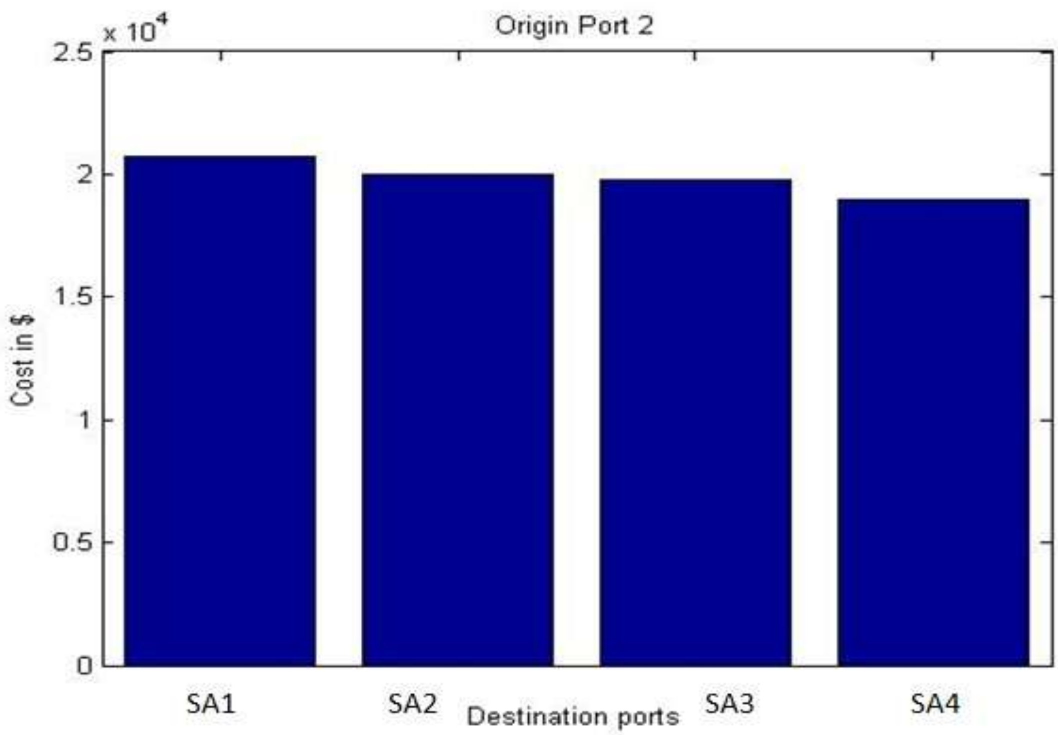


Figure B 63 Cost analysis Poronaysk (R) – destination ports (SA)

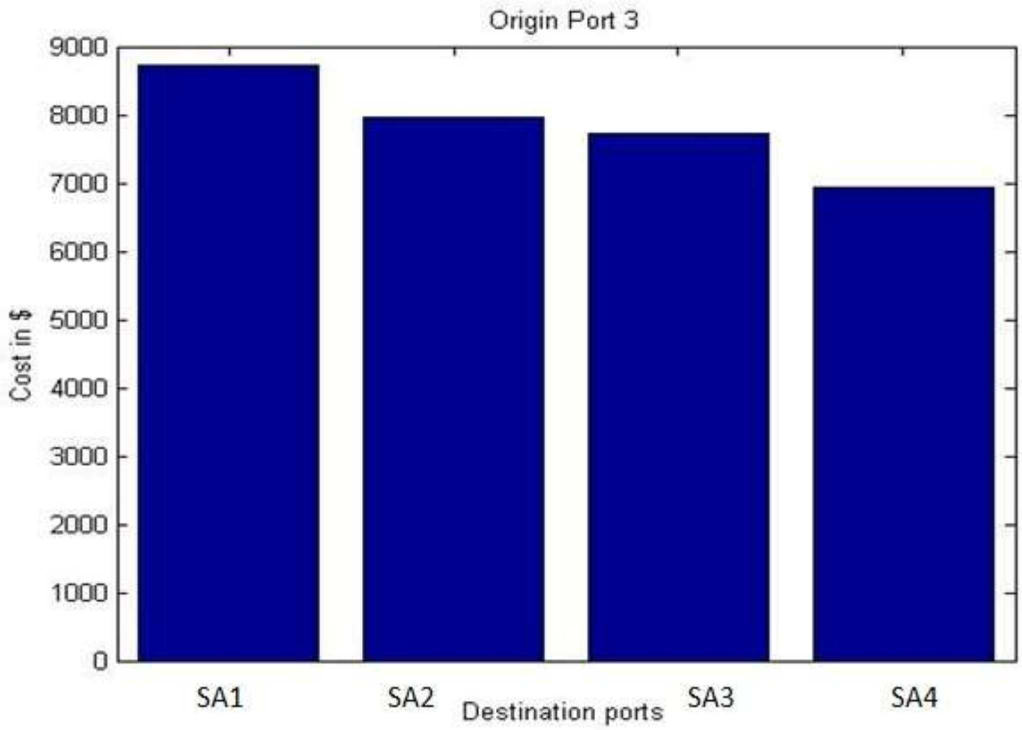


Figure B 64 Cost analysis Azov (R) – destination ports (SA)

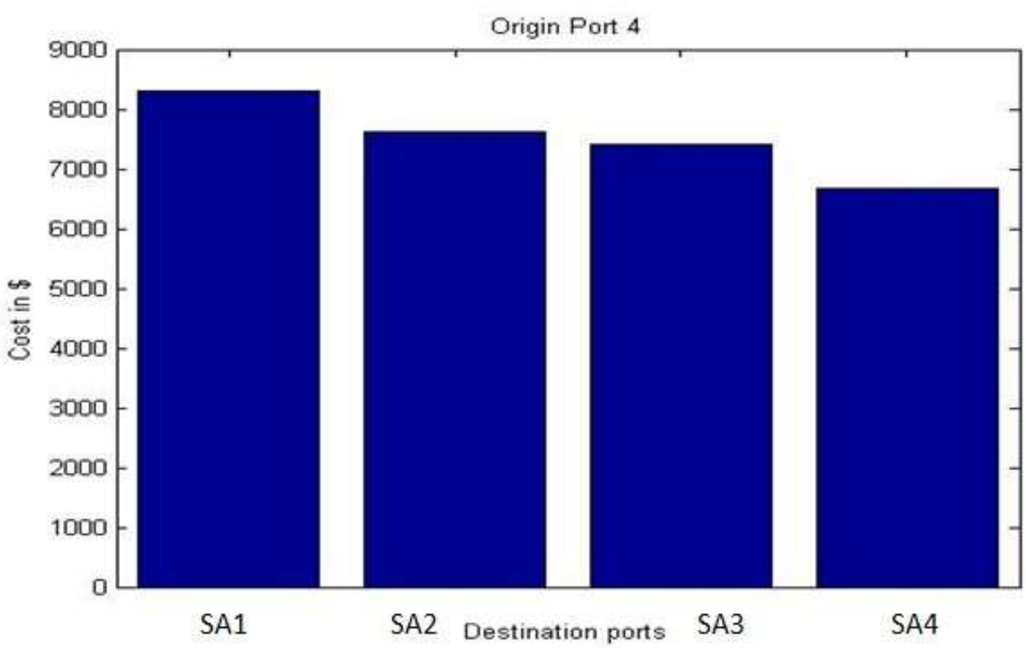


Figure B 65 Cost analysis Naryan-Mar (R) – destination ports (SA)

Optimized path: Yekaterinburg-Naryan-Mar –Richard Bay –Gauteng

d) Saint Petersburg - Eastern cap

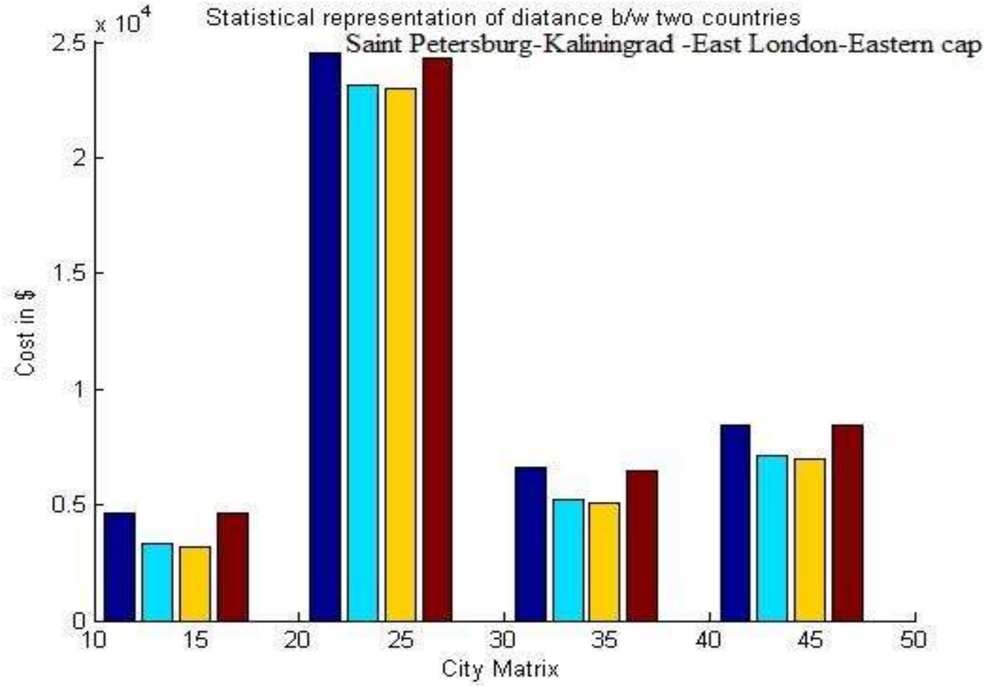


Figure B 66 Cost analysis Saint Petersburg - Eastern cap

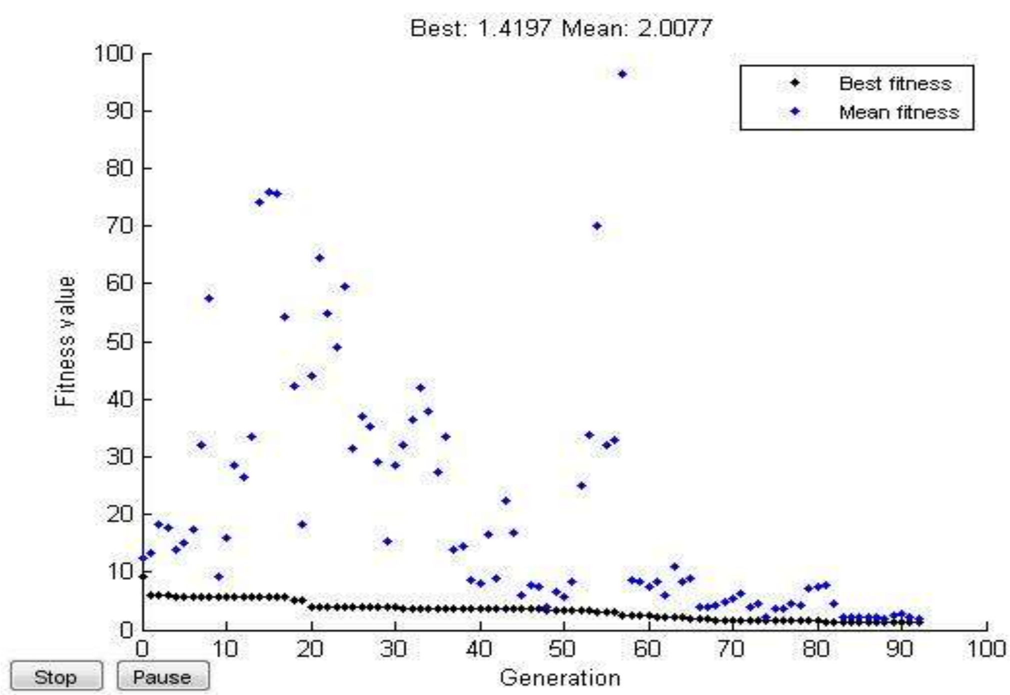


Figure B 67 GA analysis Saint Petersburg - Eastern cap

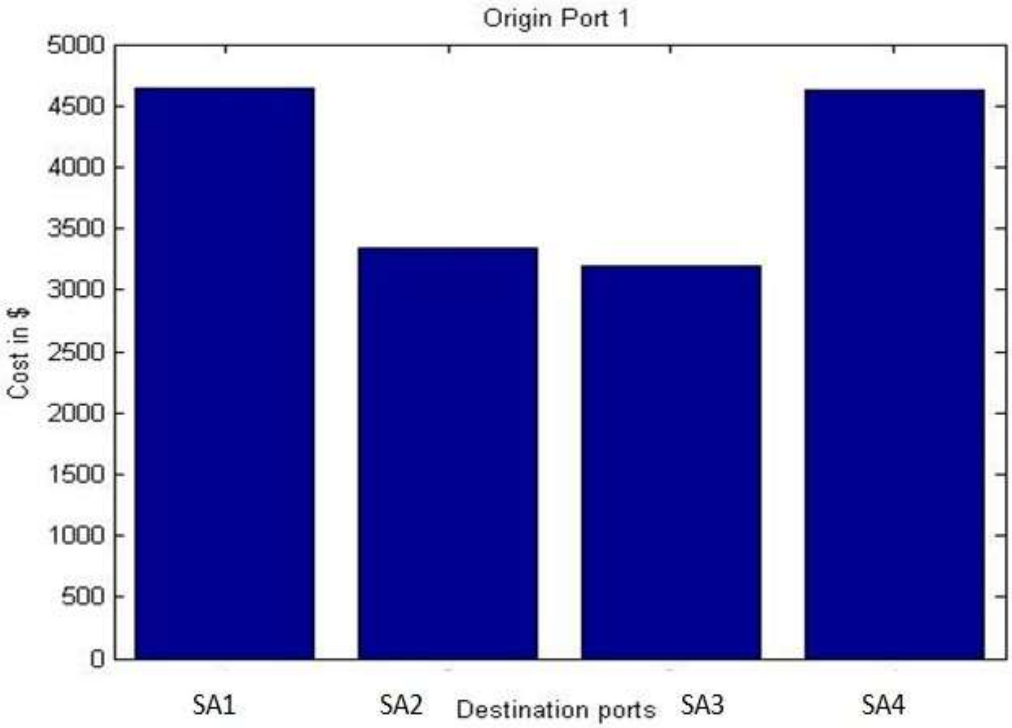


Figure B 68 Cost analysis Kaliningrad (R) – destination ports (SA)

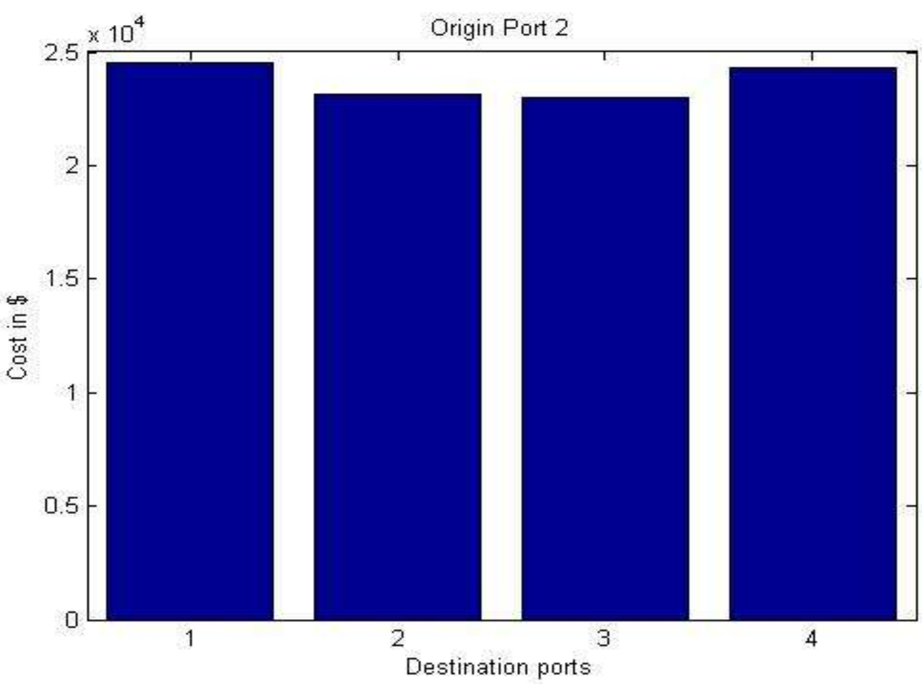


Figure B 69 Cost analysis Poronaysk (R) – destination ports (SA)

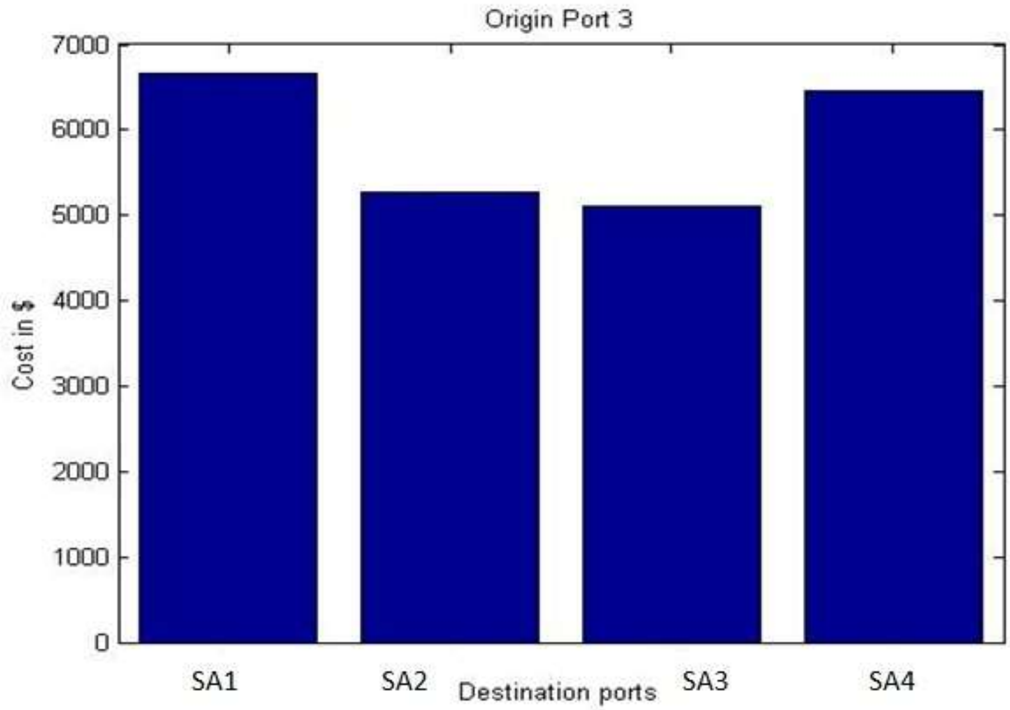


Figure B 70 Cost analysis Azov (R) – destination ports (SA)

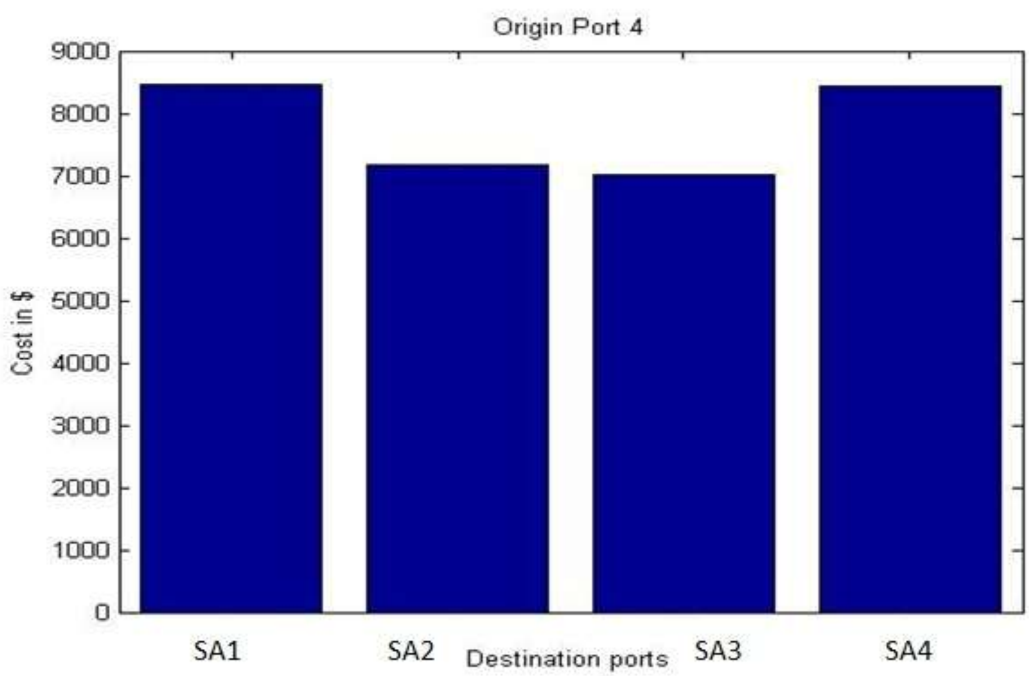


Figure B 71 Cost analysis Naryan-Mar (R) – destination ports (SA)

Optimized path: Saint Petersburg-Kaliningrad -East London-Eastern cap

Illustration 5. Russia to China

b) Samara-Beijing

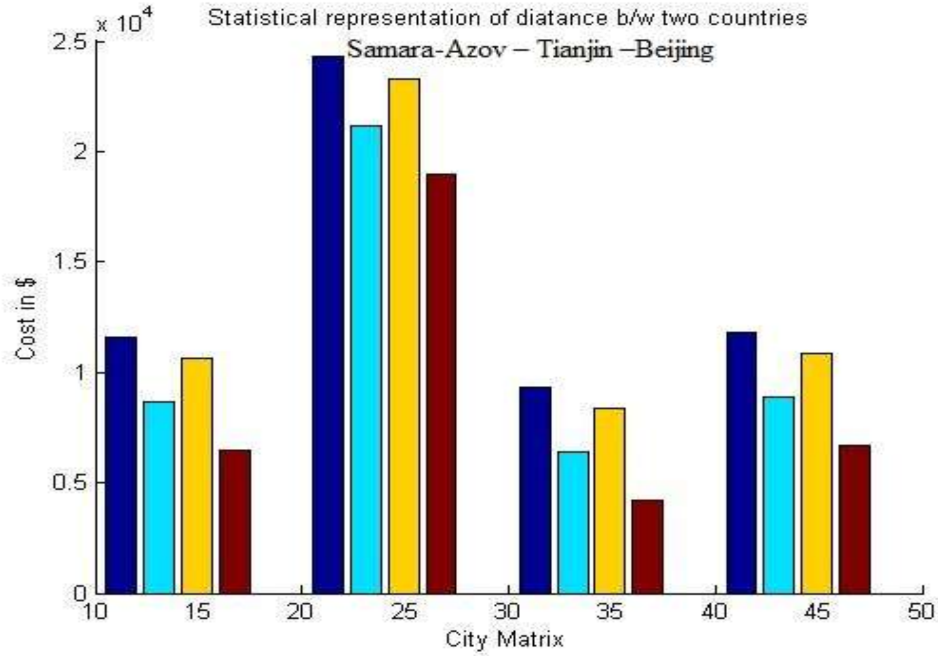


Figure B 72 Cost analysis Samara-Beijing

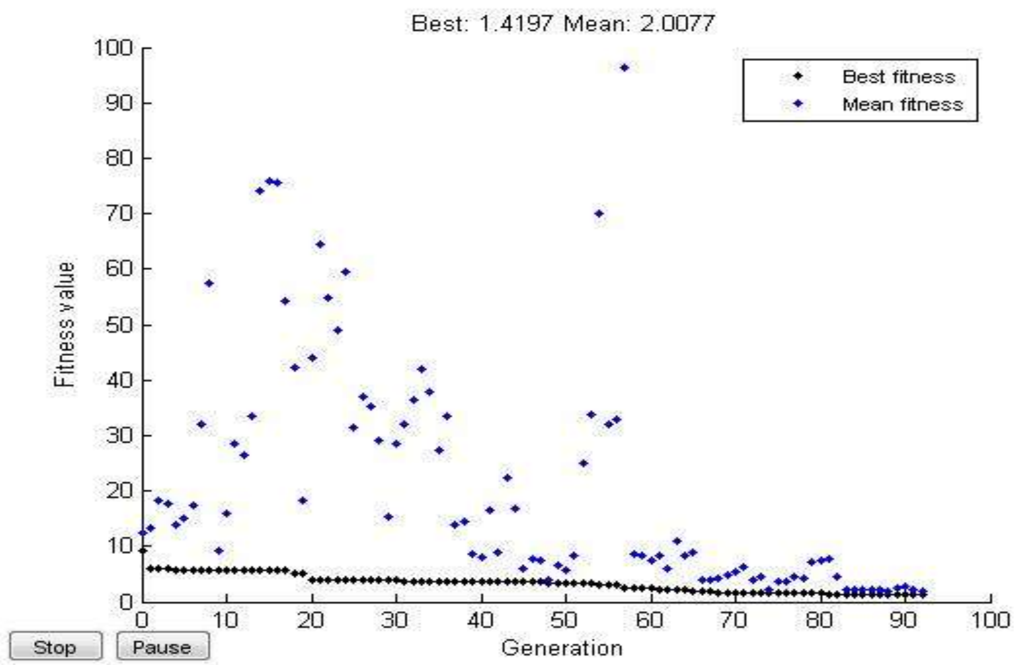


Figure B 73 GA analysis Samara-Beijing

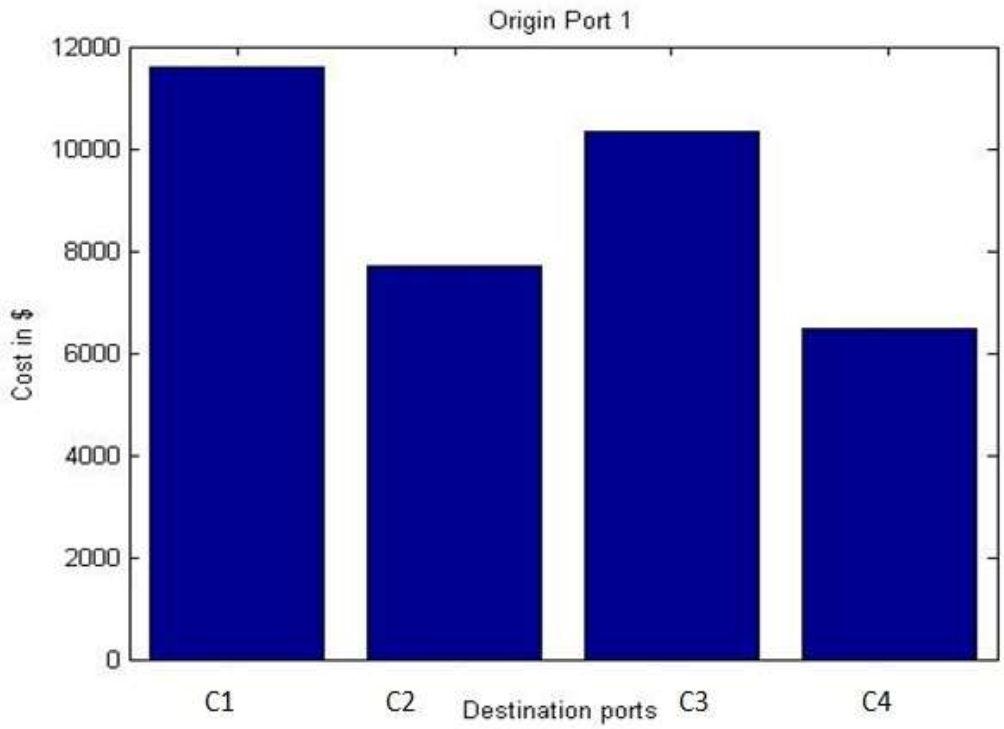


Figure B 74 Cost analysis Kaliningrad (R) – destination ports (C)

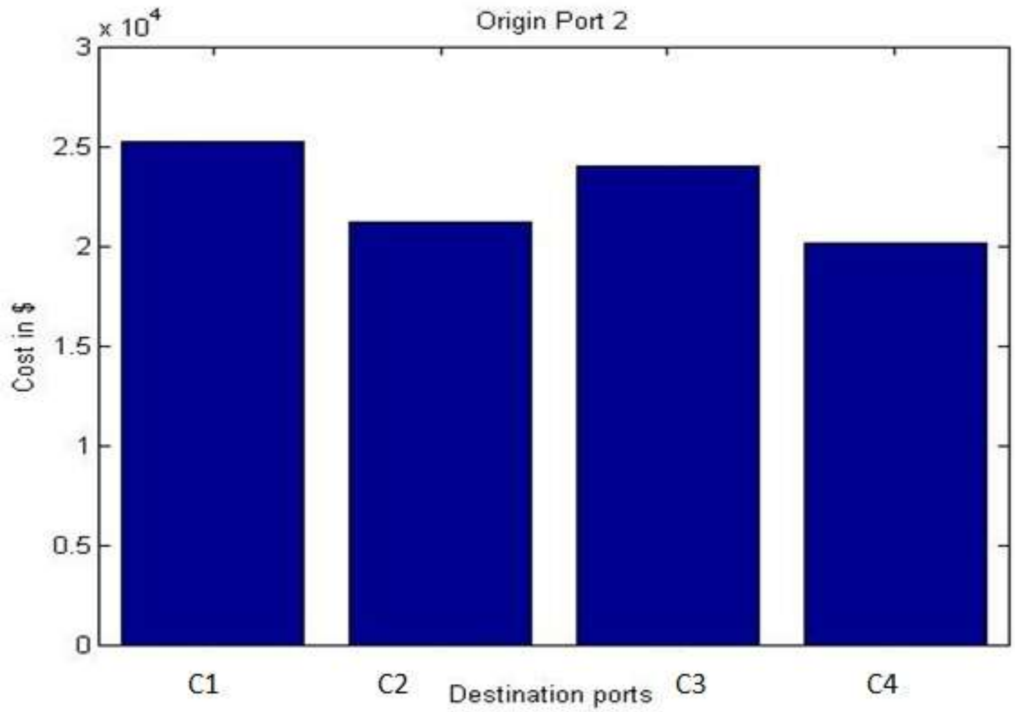


Figure B 75 Cost analysis Poronaysk (R) – destination ports (C)

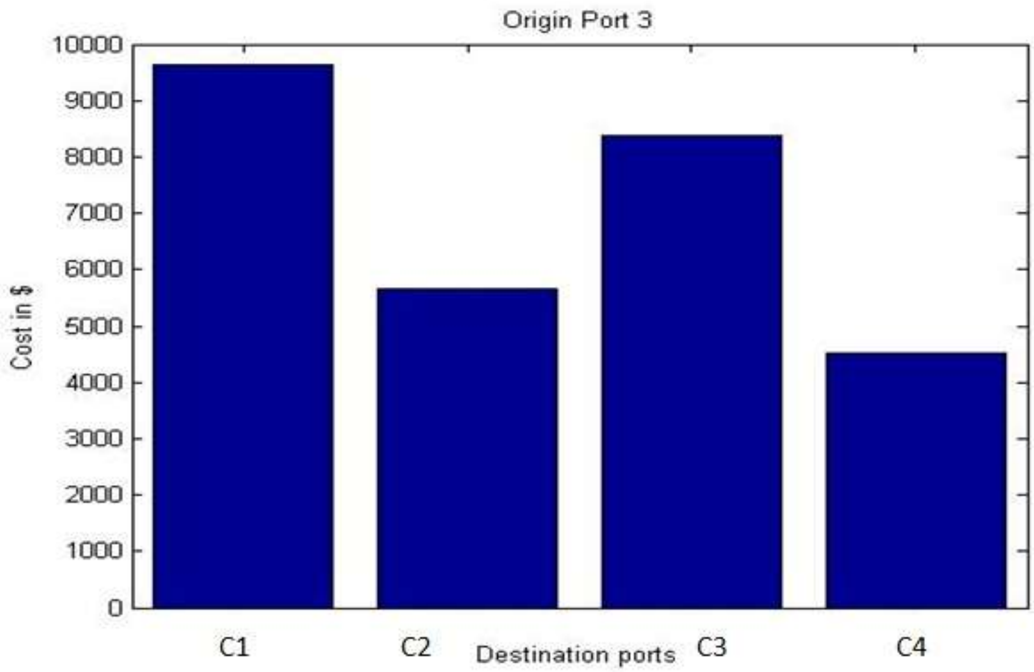


Figure B 76 Cost analysis Azov (R) – destination ports (C)

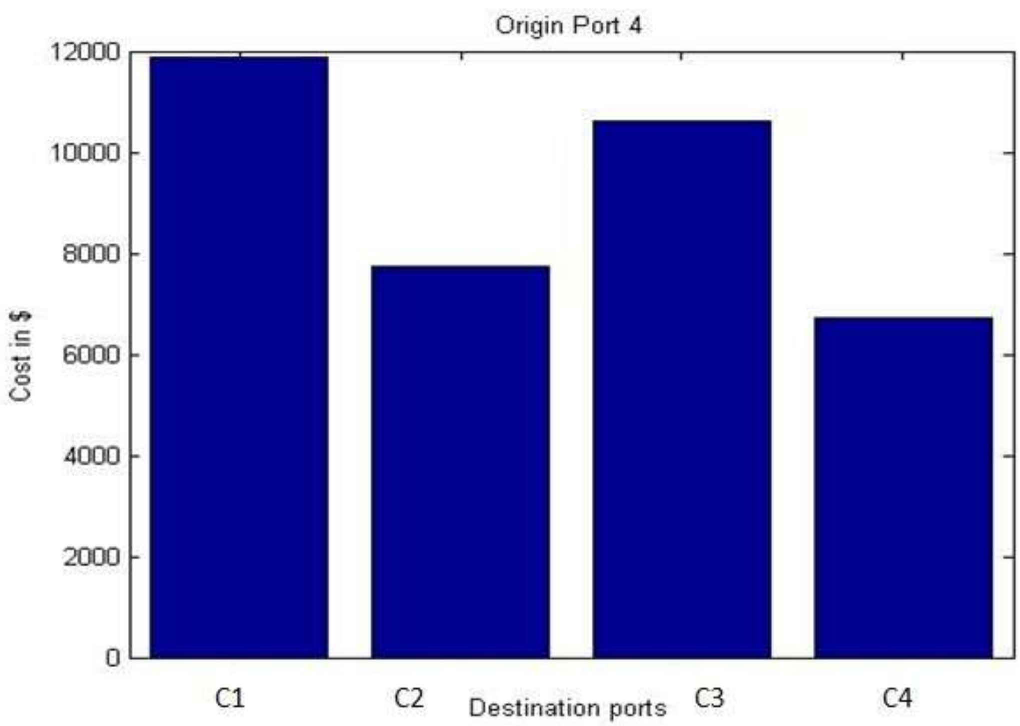


Figure B 77 Cost analysis Naryan-Mar (R) – destination ports (C)

Optimized path: Samara-Azov – Tianjin –Beijing

c) Yekaterinburg-Shenzhen

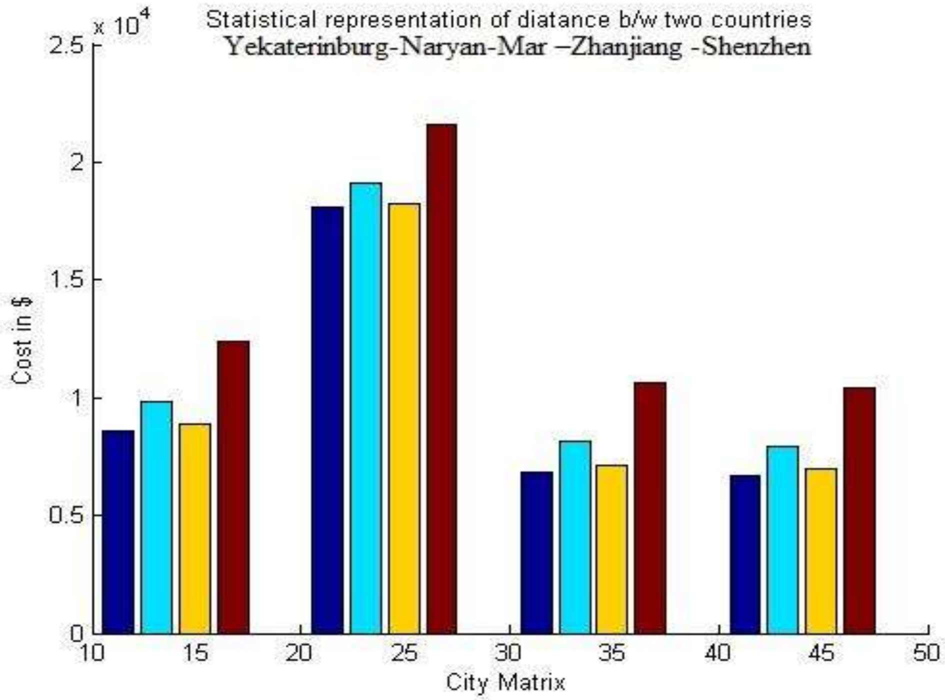


Figure B 78 Cost analysis Yekaterinburg-Shenzhen

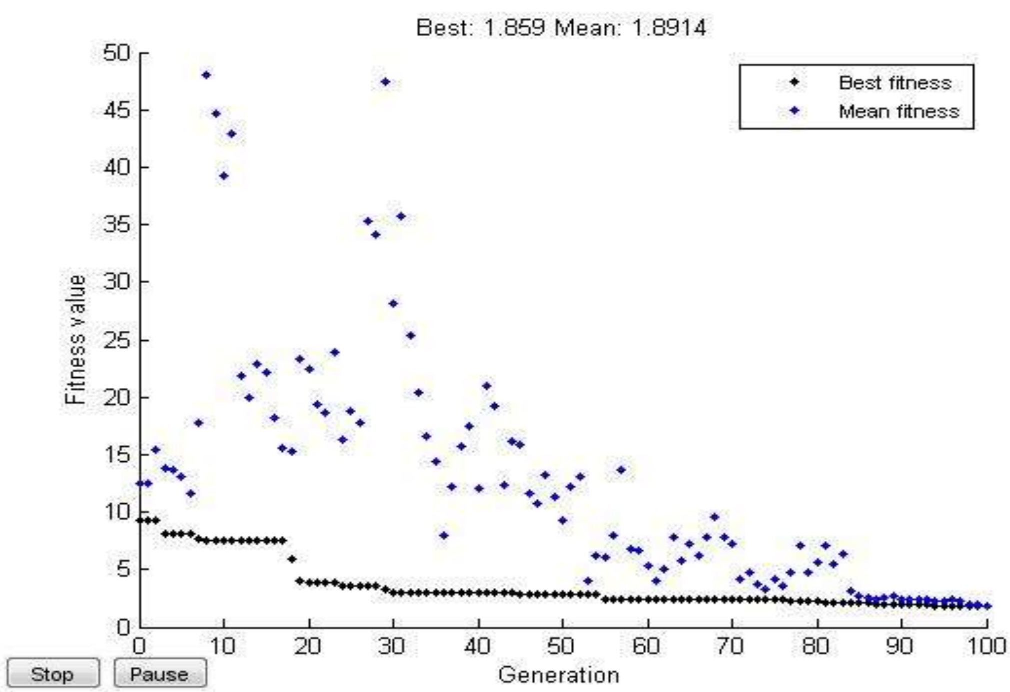


Figure B 79 GA analysis Yekaterinburg-Shenzhen

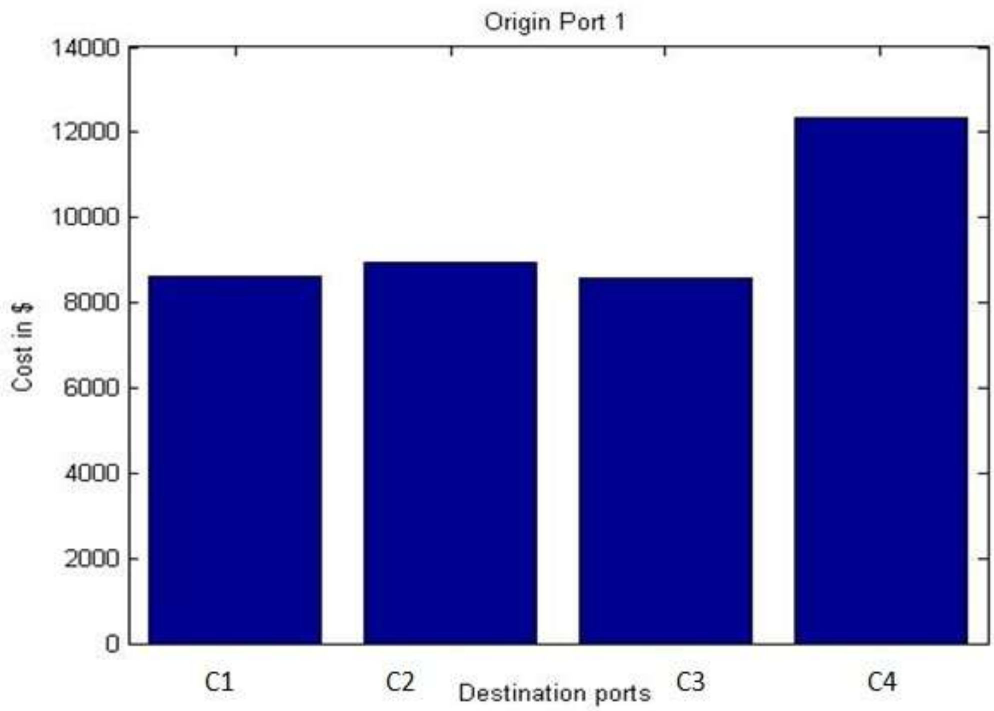


Figure B 80 Cost analysis Kaliningrad (R) – destination ports (C)

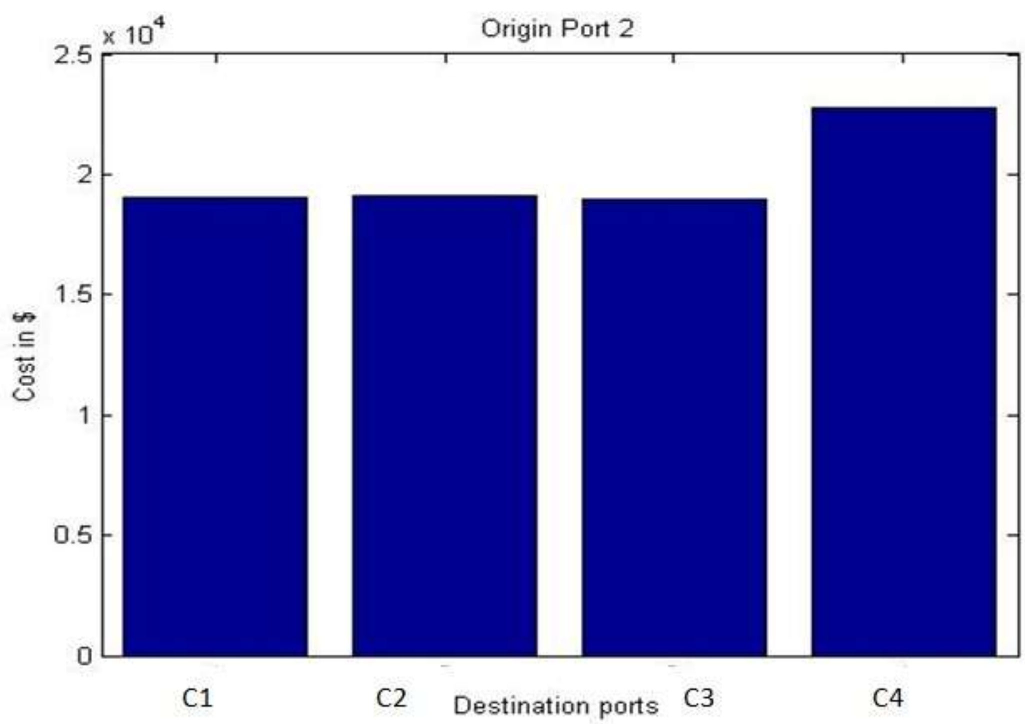


Figure B 81 Cost analysis Poronaysk (R) – destination ports (C)

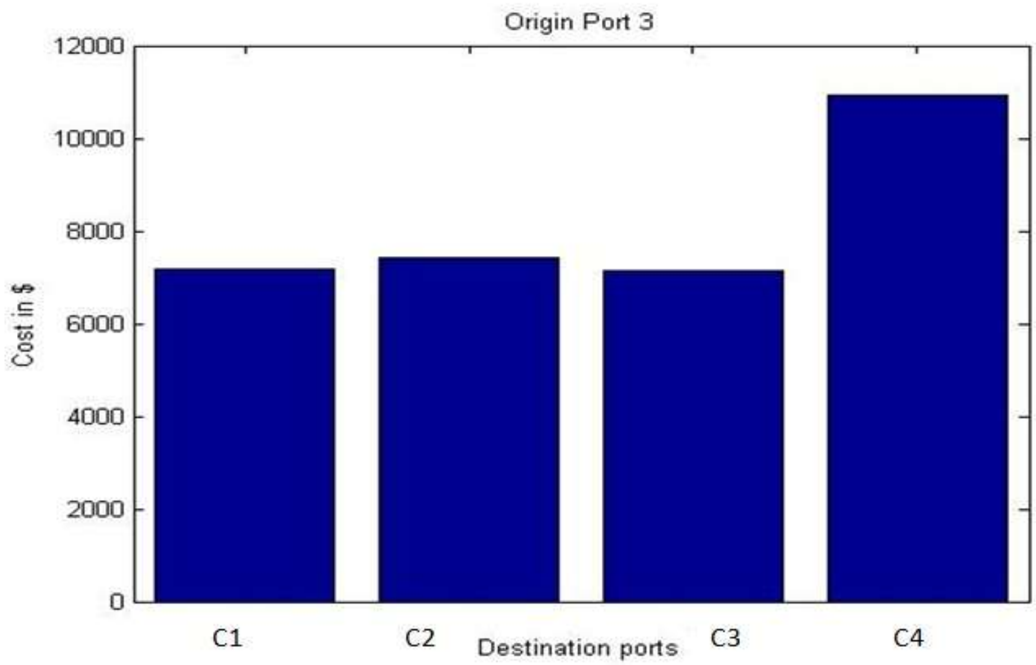


Figure B 82 Cost analysis Azov (R) – destination ports (C)

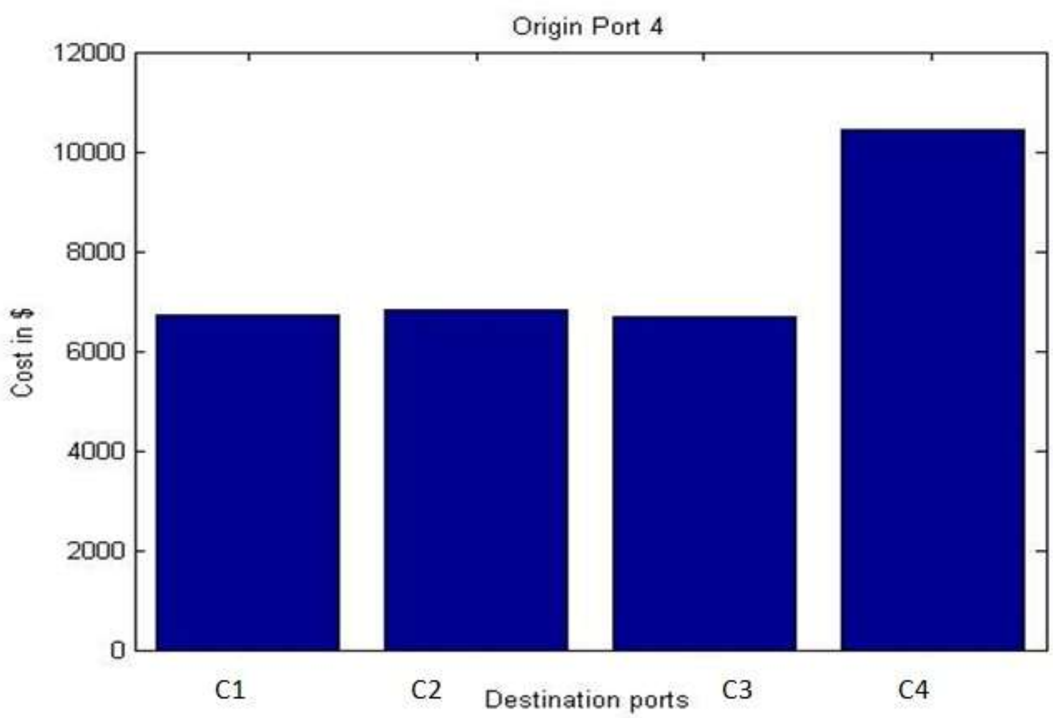


Figure B 83 Cost analysis Naryan-Mar (R) – destination ports (C)

Optimized path: Yekaterinburg-Naryan-Mar –Zhanjiang –Shenzhen

d) Saint Petersburg-Suzhou

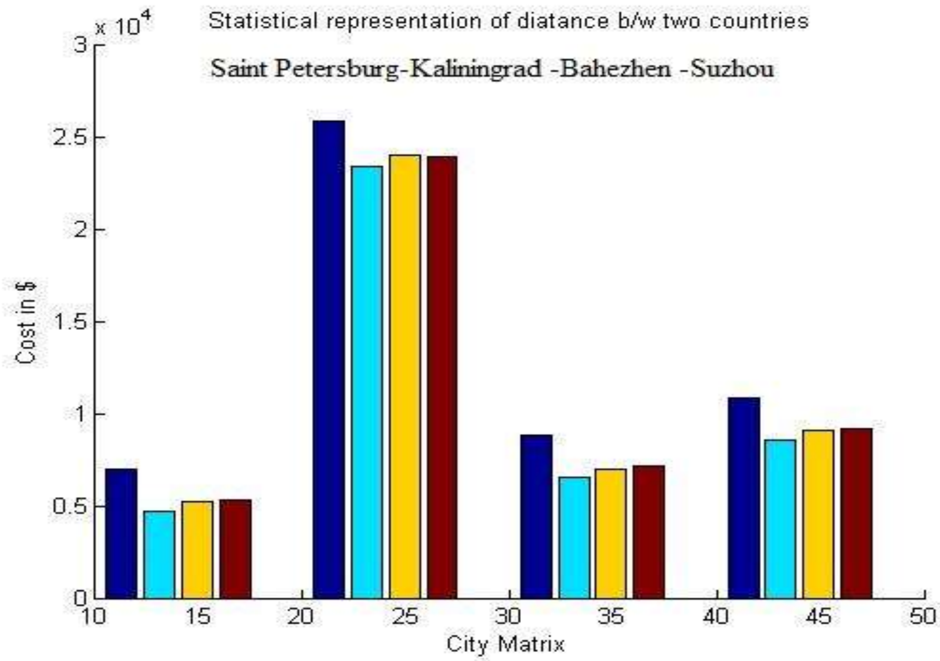


Figure B 84 Cost analysis Saint Petersburg-Suzhou

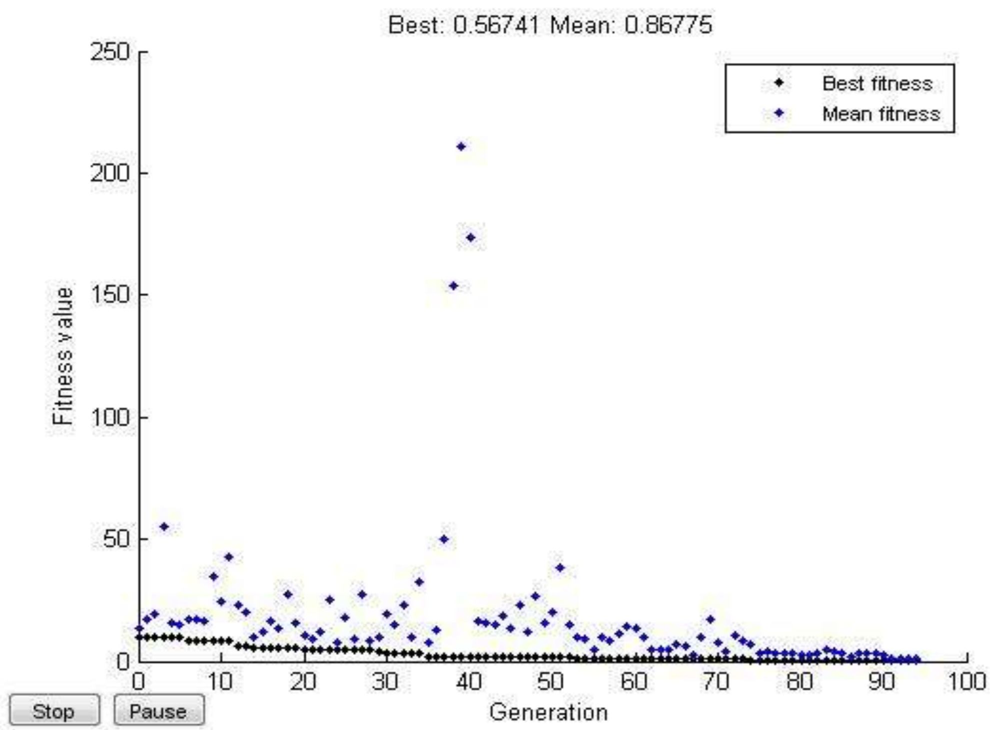


Figure B 85 GA analysis Saint Petersburg-Suzhou

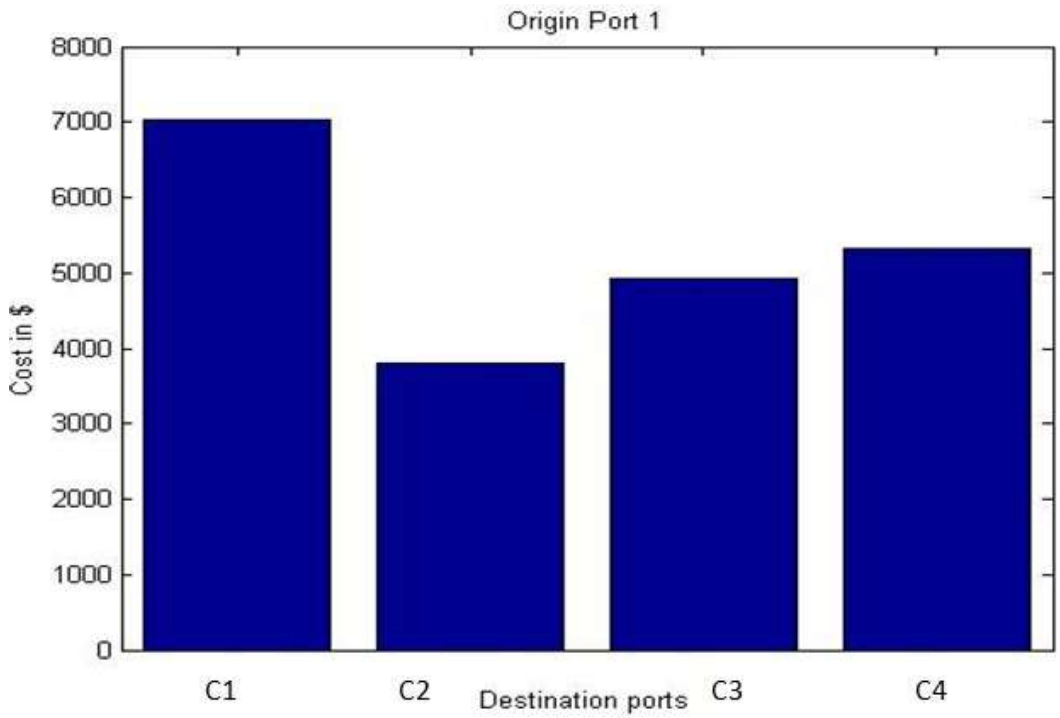


Figure B 86 Cost analysis Kaliningrad (R) – destination ports (C)

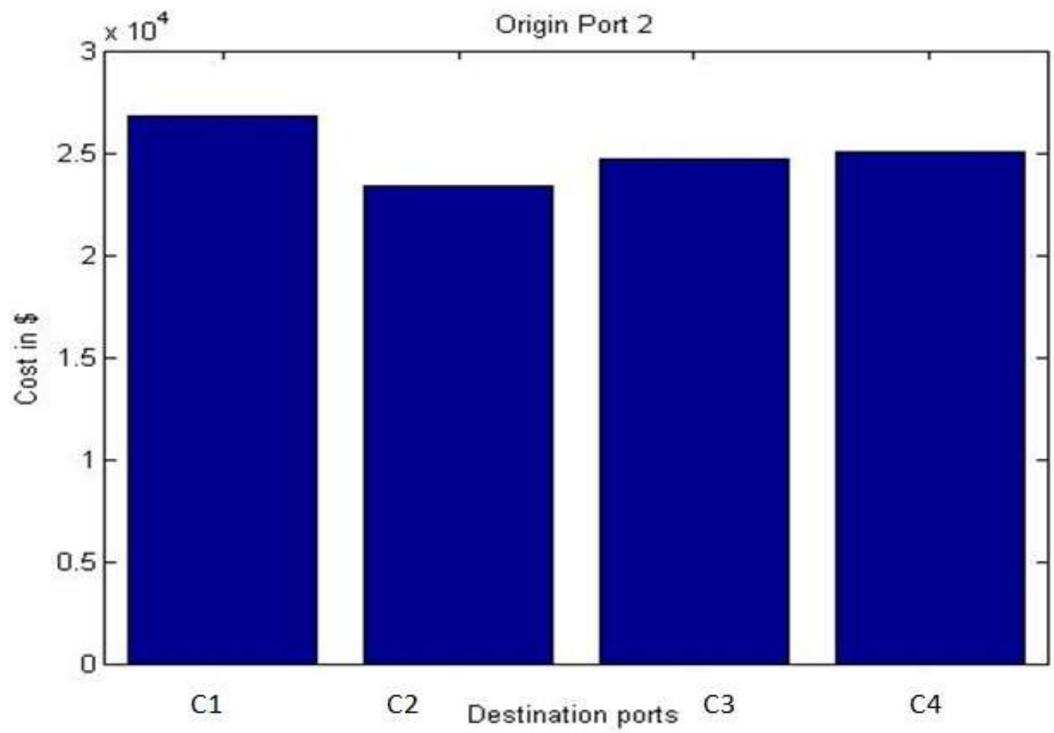


Figure B 87 Cost analysis Poronaysk (R) – destination ports (C)

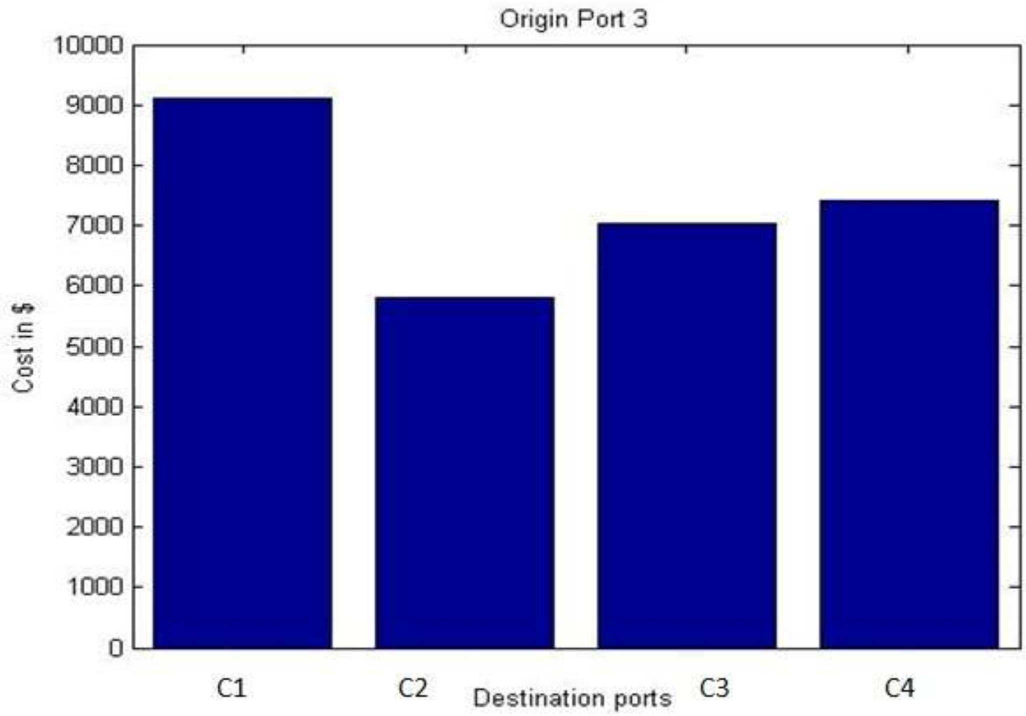


Figure B 88 Cost analysis Azov (R) – destination ports (C)

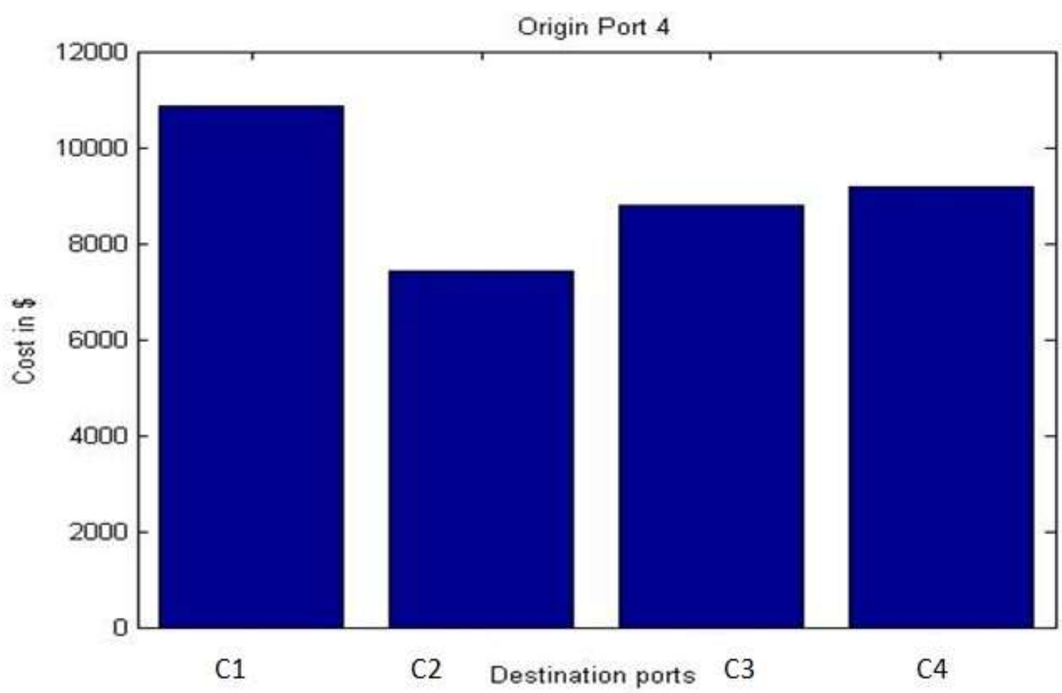


Figure B 89 Cost analysis Naryan-Mar (R) – destination ports (C)

Optimized path: Saint Petersburg-Kaliningrad -Bahezhen -Suzhou

Illustration 6. Brazil to Russia

b) Sao Paulo-Samara

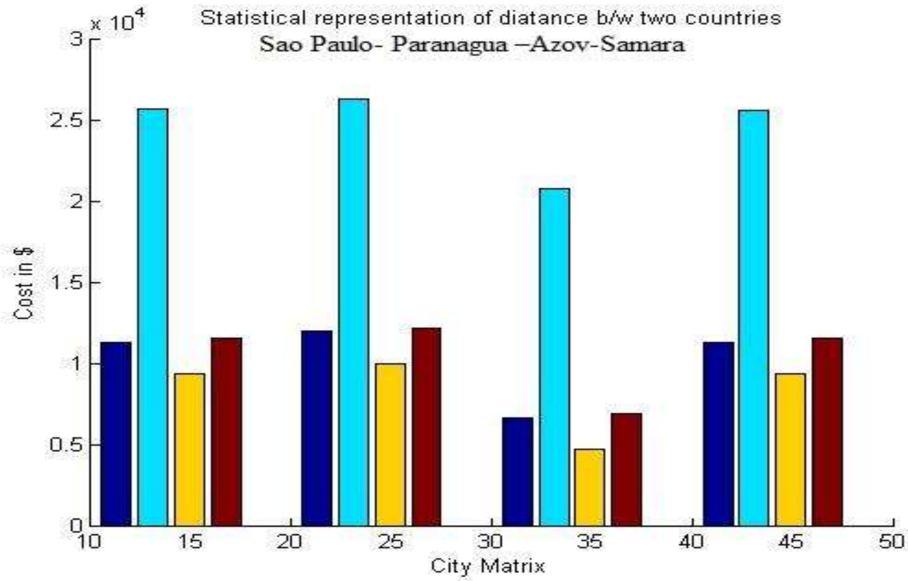


Figure B 90 Cost analysis Sao Paulo-Samara

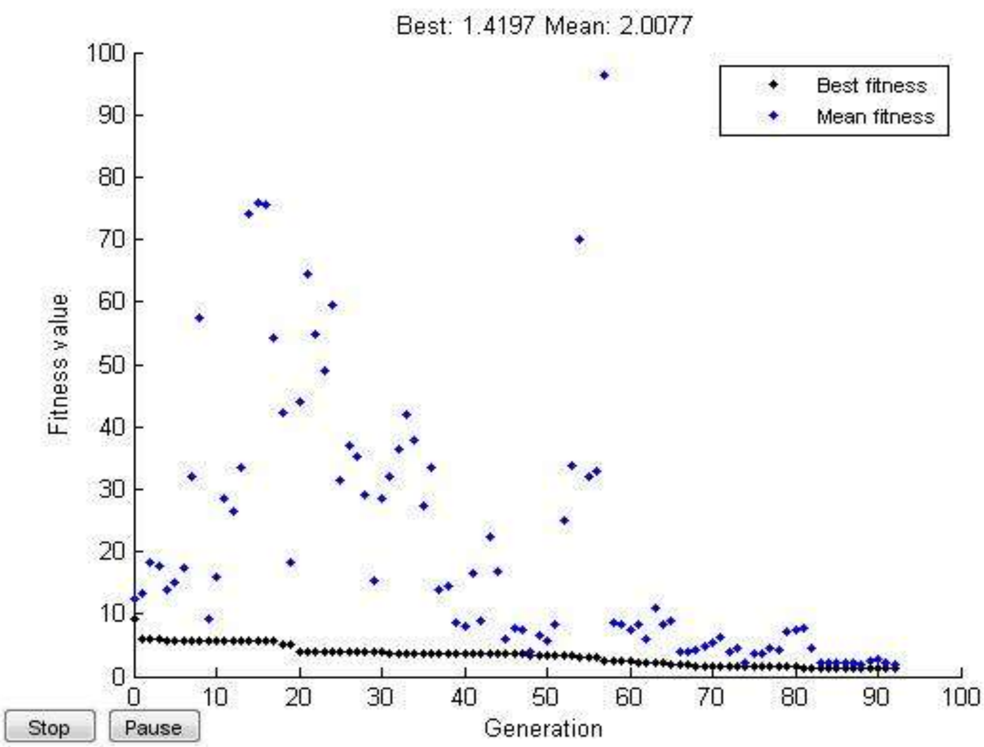


Figure B 91 GA analysis Sao Paulo-Samara

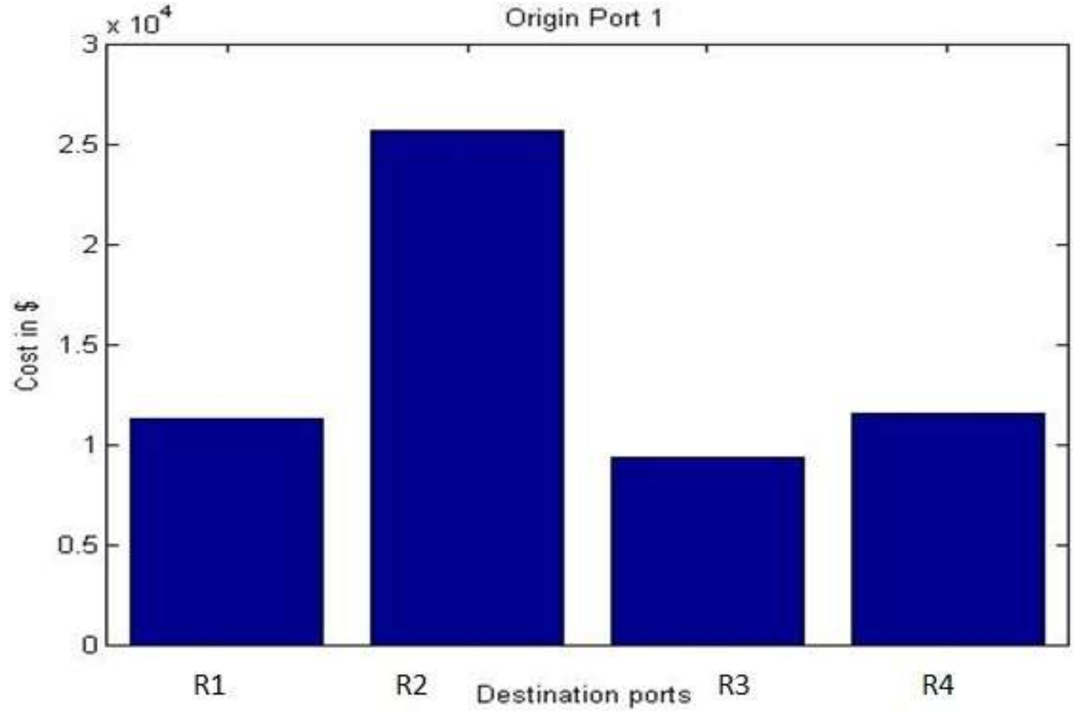


Figure B 92 Cost analysis Belem (B) – destination ports (R)

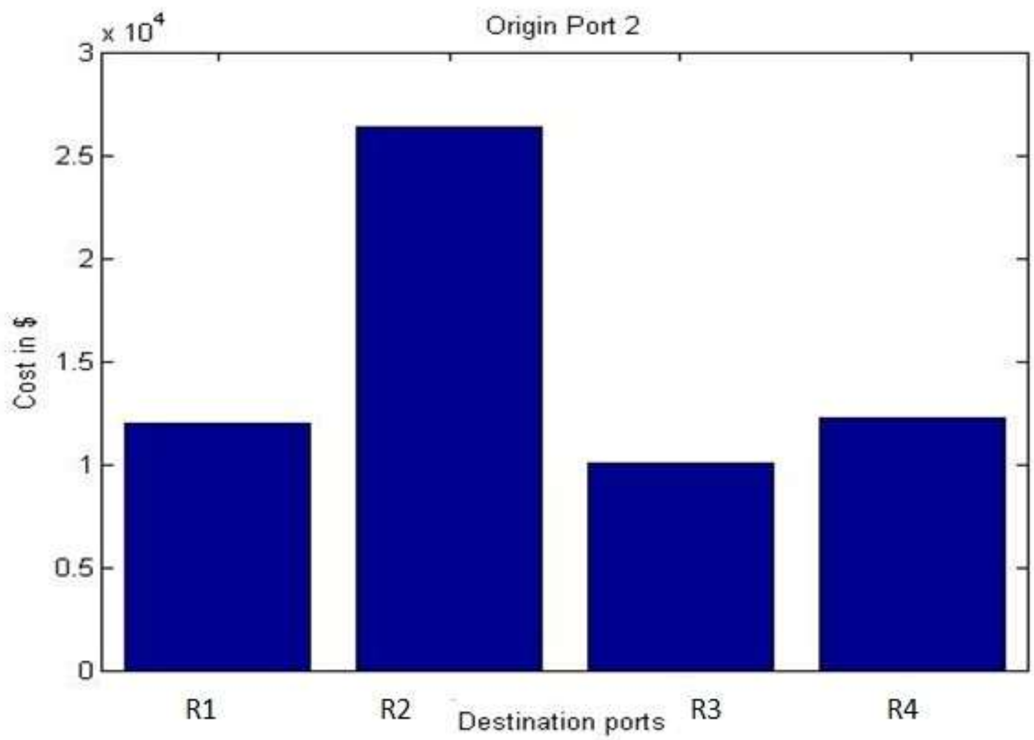


Figure B 93 Cost analysis Fortaleza (B) – destination ports (R)

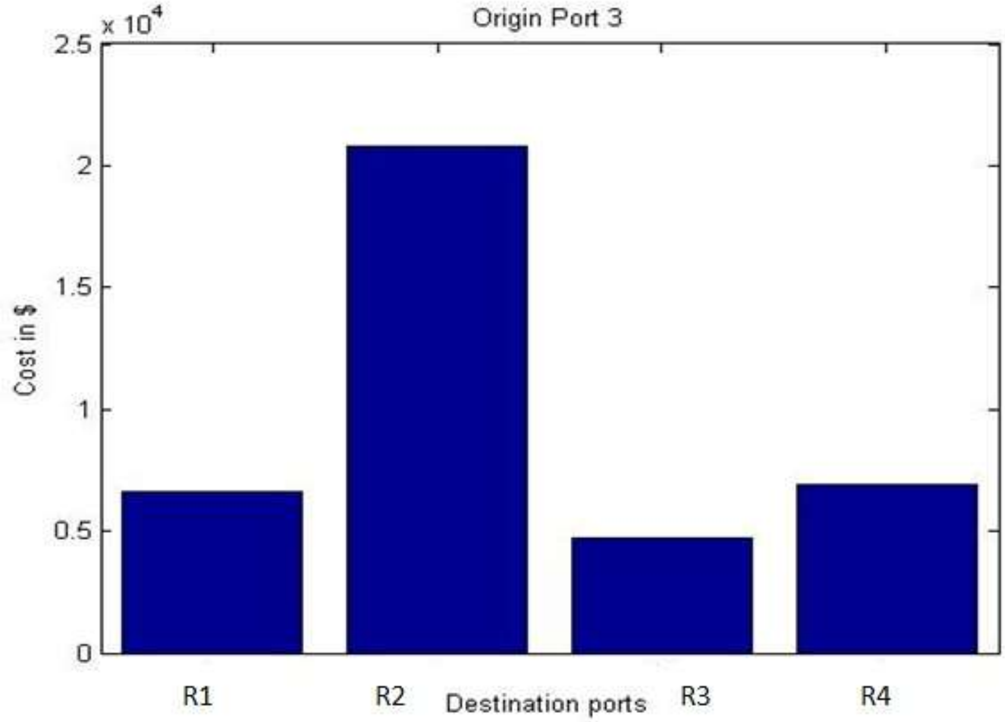


Figure B 94 Cost analysis Paranagua (B) – destination ports (R)

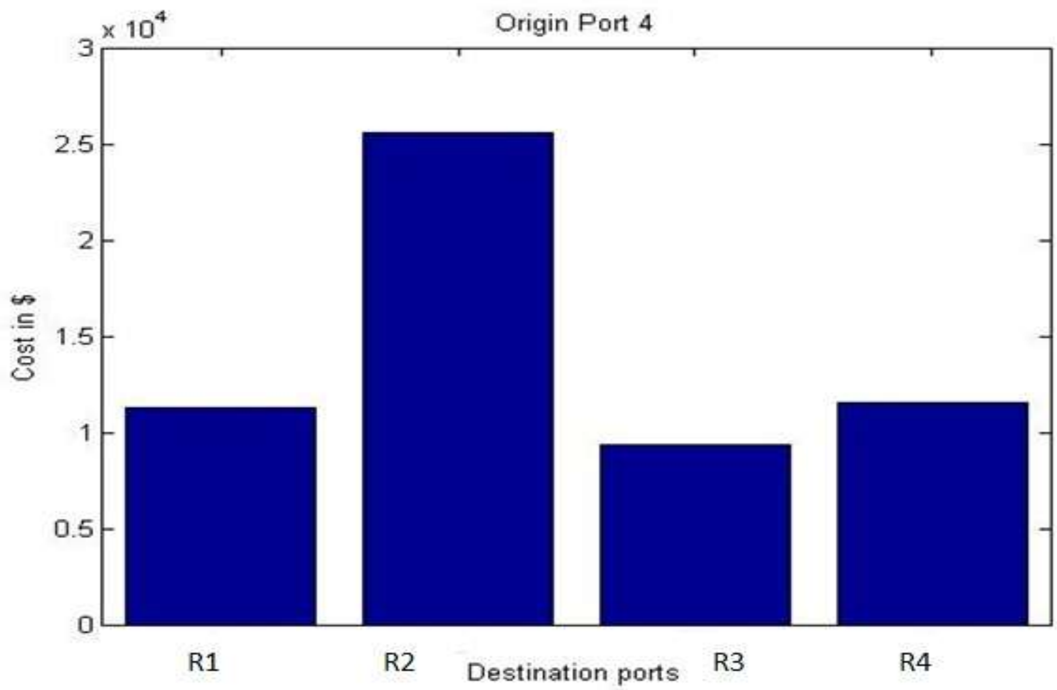


Figure B 95 Cost analysis Recife (B) – destination ports (R)

Optimized path: Sao Paulo- Paranagua –Azov-Samara

c) Rio de Janeiro -Yekaterinburg

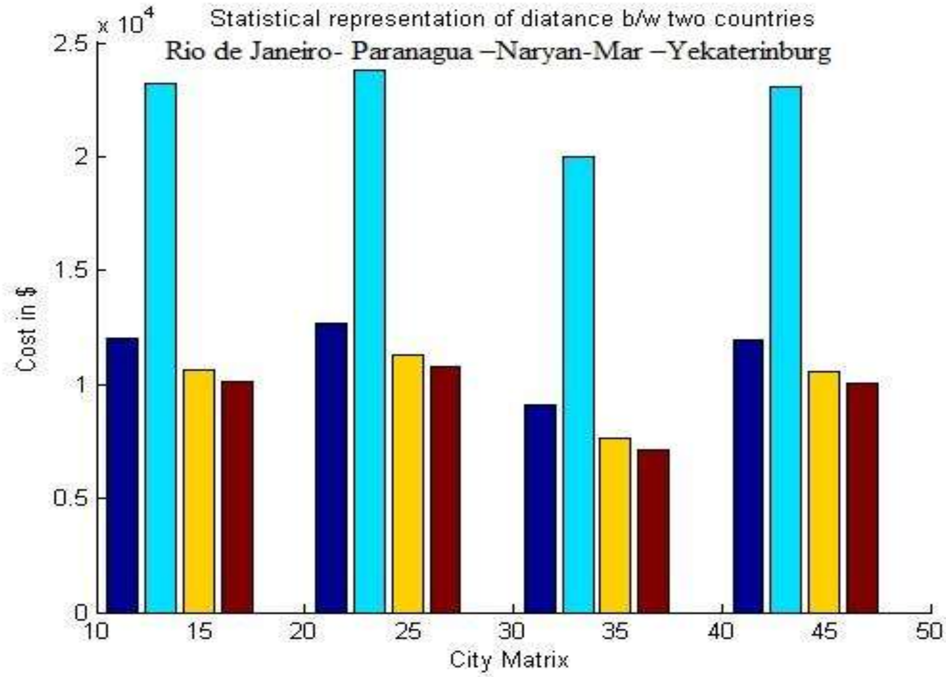


Figure B 96 Cost analysis Rio de Janeiro -Yekaterinburg

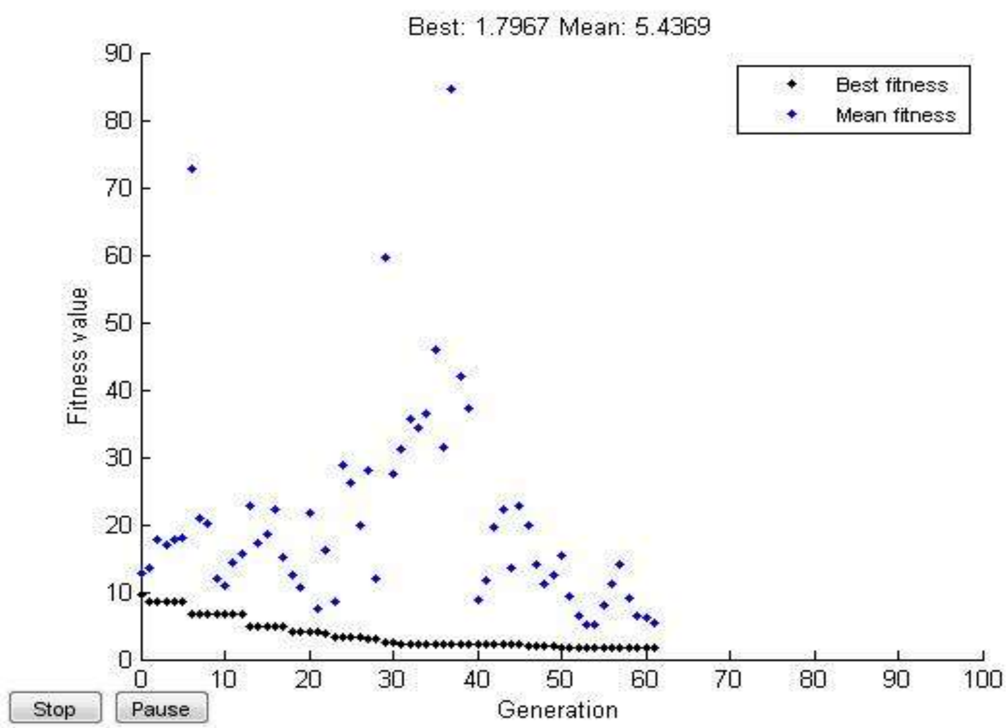


Figure B 97 GA analysis Rio de Janeiro -Yekaterinburg

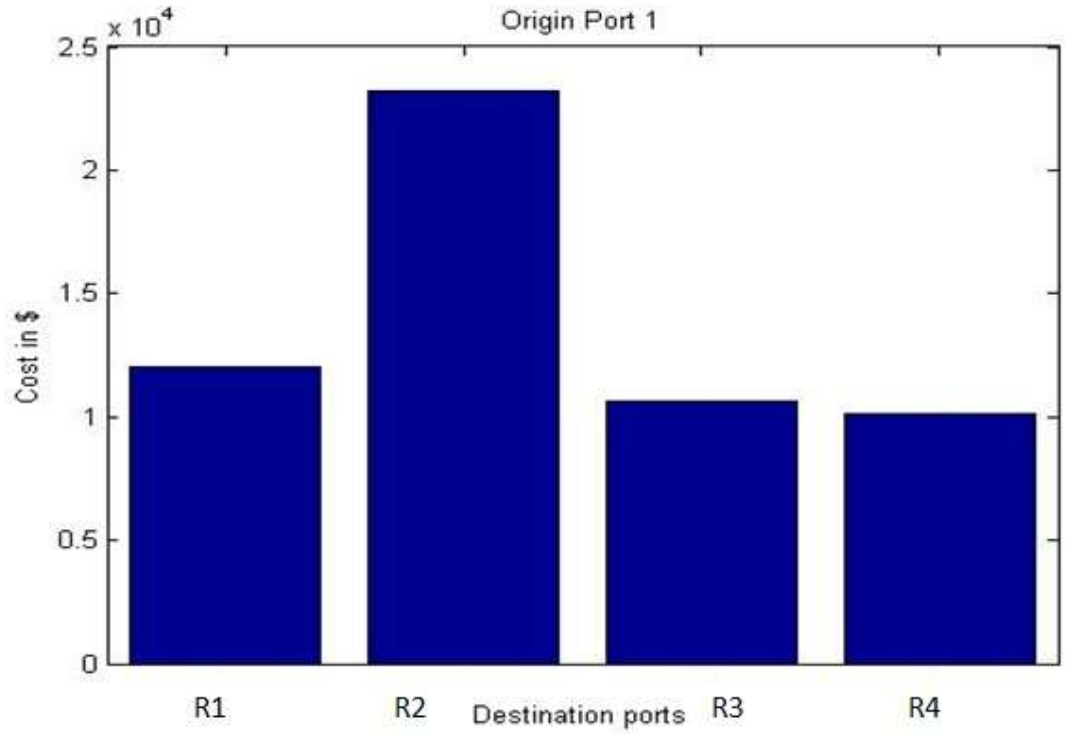


Figure B 98 Cost analysis Belem (B) – destination ports (R)

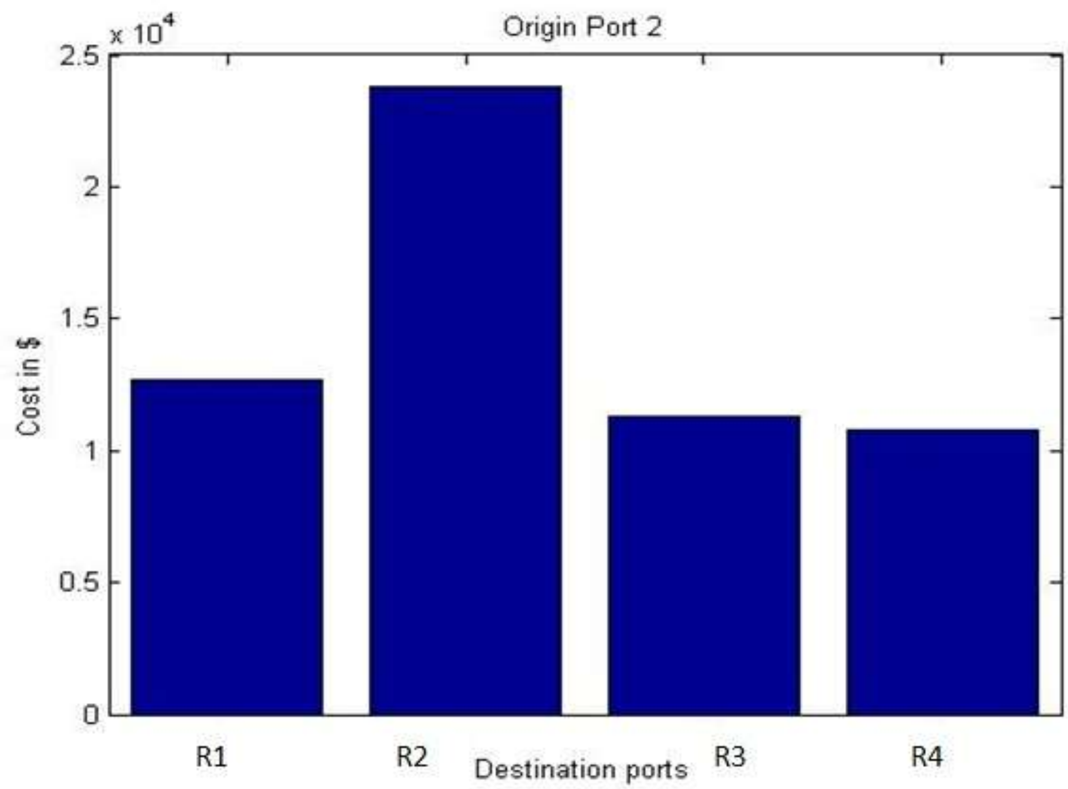


Figure B 99 Cost analysis Fortaleza (B) – destination ports (R)

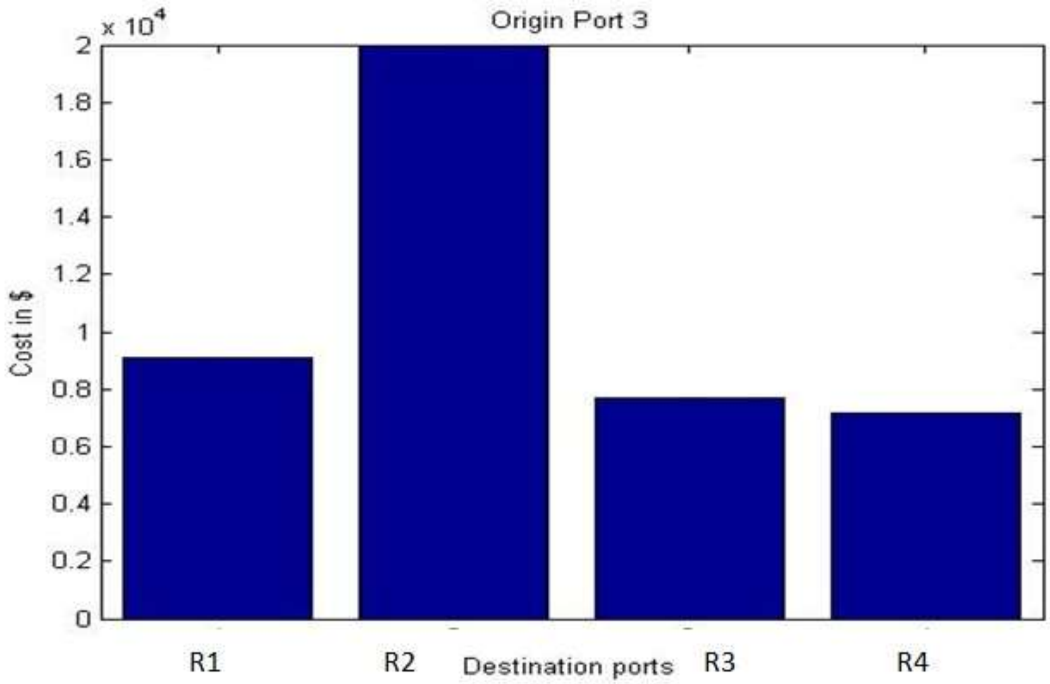


Figure B 100 Cost analysis Paranagua (B) – destination ports (R)

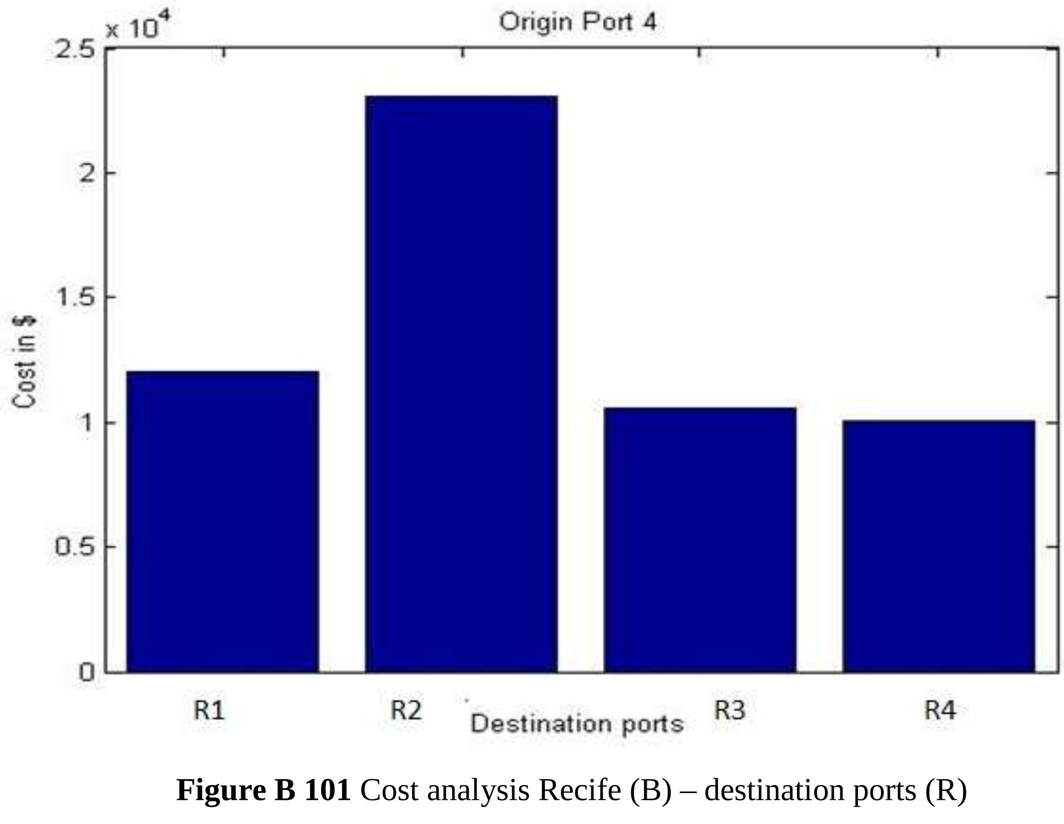


Figure B 101 Cost analysis Recife (B) – destination ports (R)

Optimized path: Rio de Janeiro- Paranagua –Naryan-Mar –Yekaterinburg

d) Belo Horizonte-Saint Petersburg

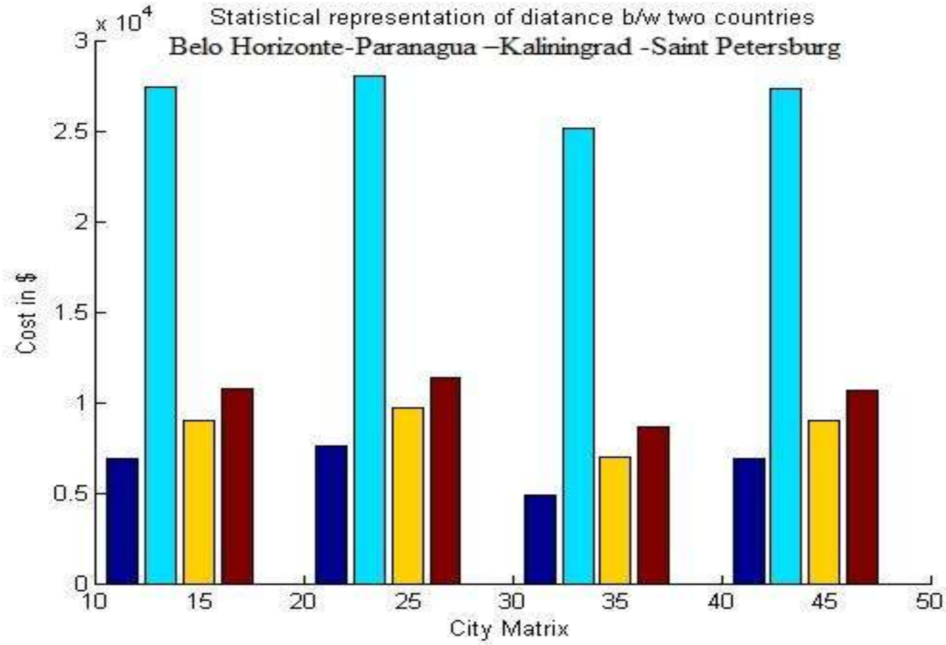


Figure B 102 Cost analysis Belo Horizonte-Saint Petersburg

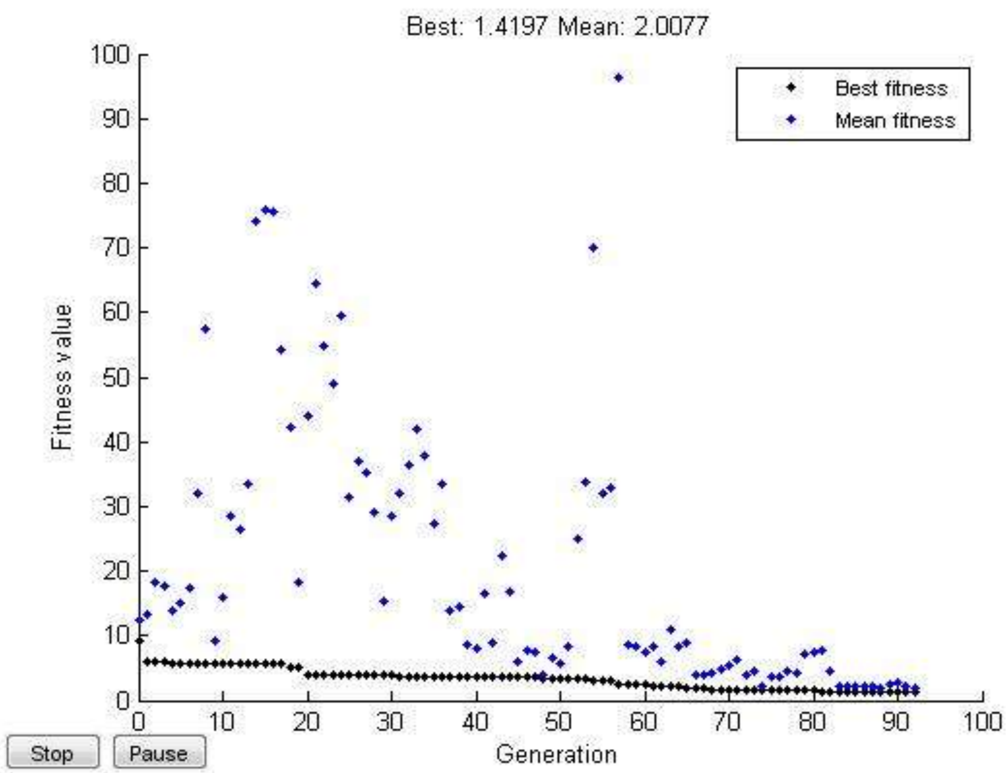


Figure B 103 GA analysis Belo Horizonte-Saint Petersburg

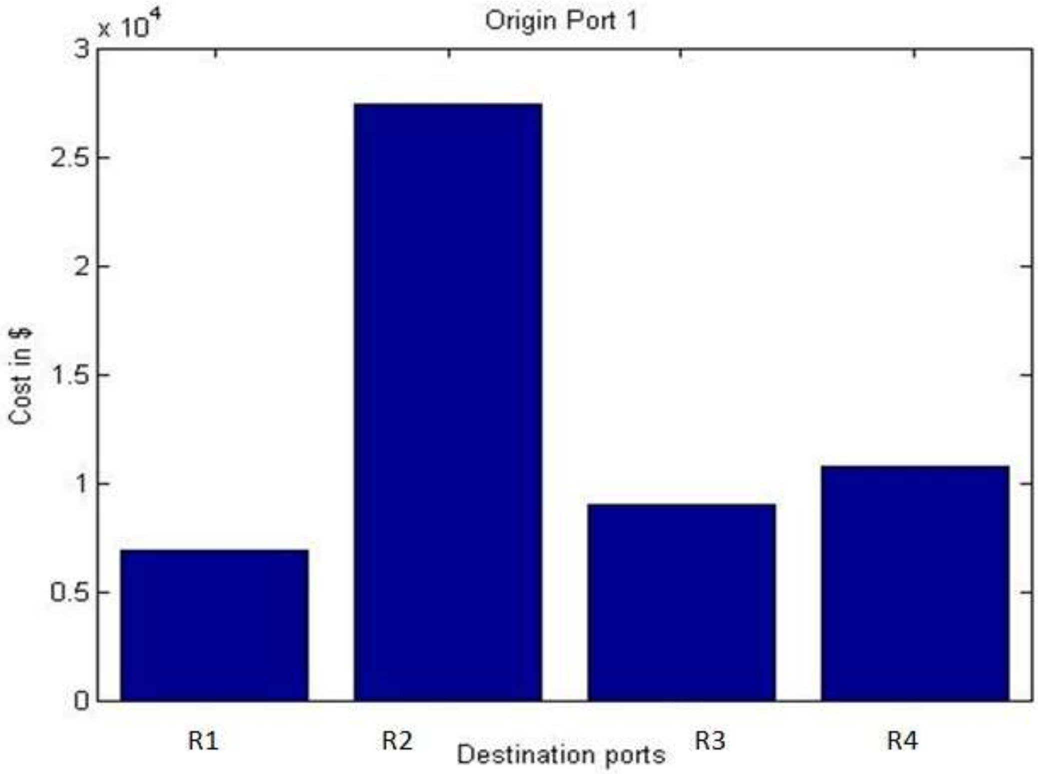


Figure B 104 Cost analysis Belem (B) – destination ports (R)

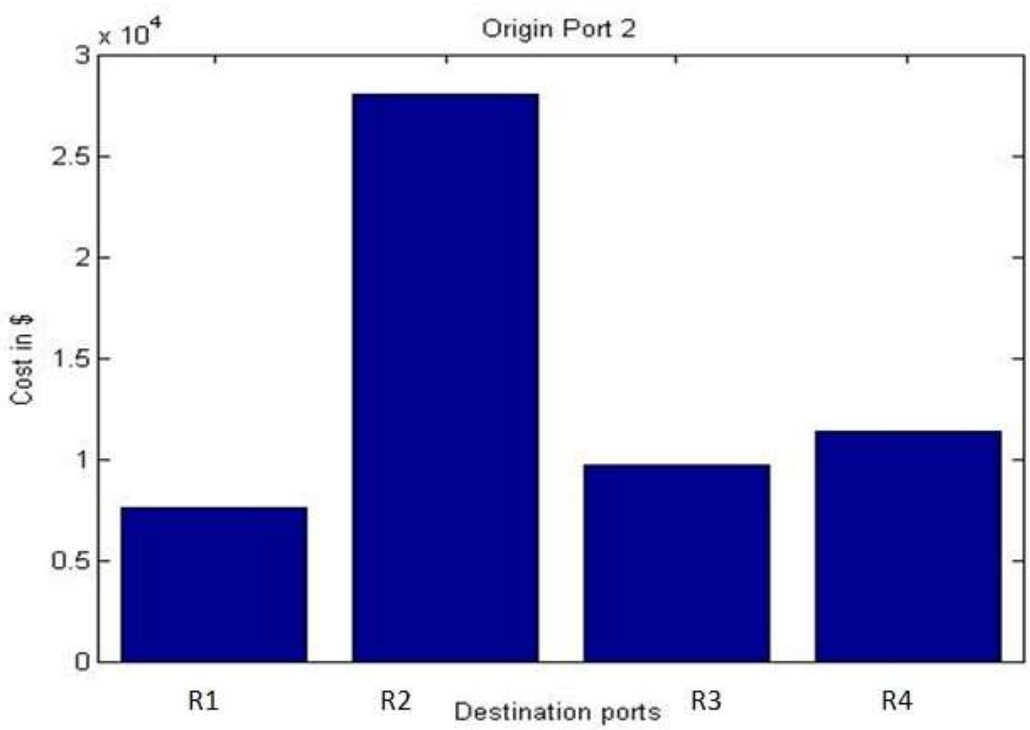


Figure B 105 Cost analysis Fortaleza (B) – destination ports (R)

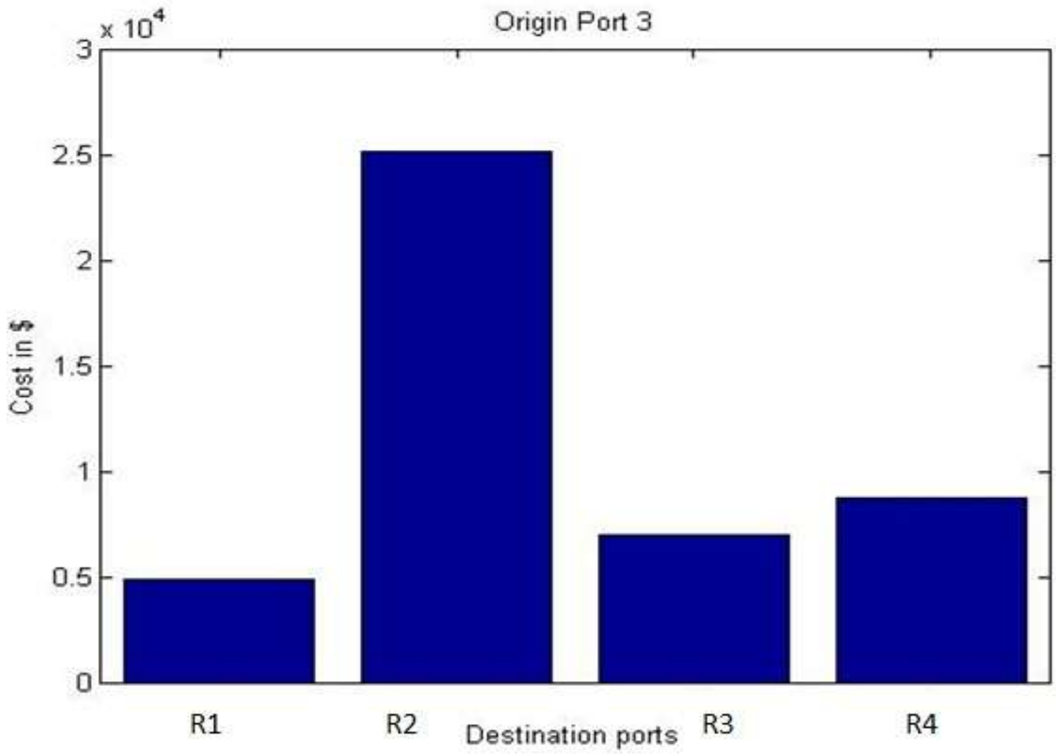


Figure B 106 Cost analysis Paranagua (B) – destination ports (R)

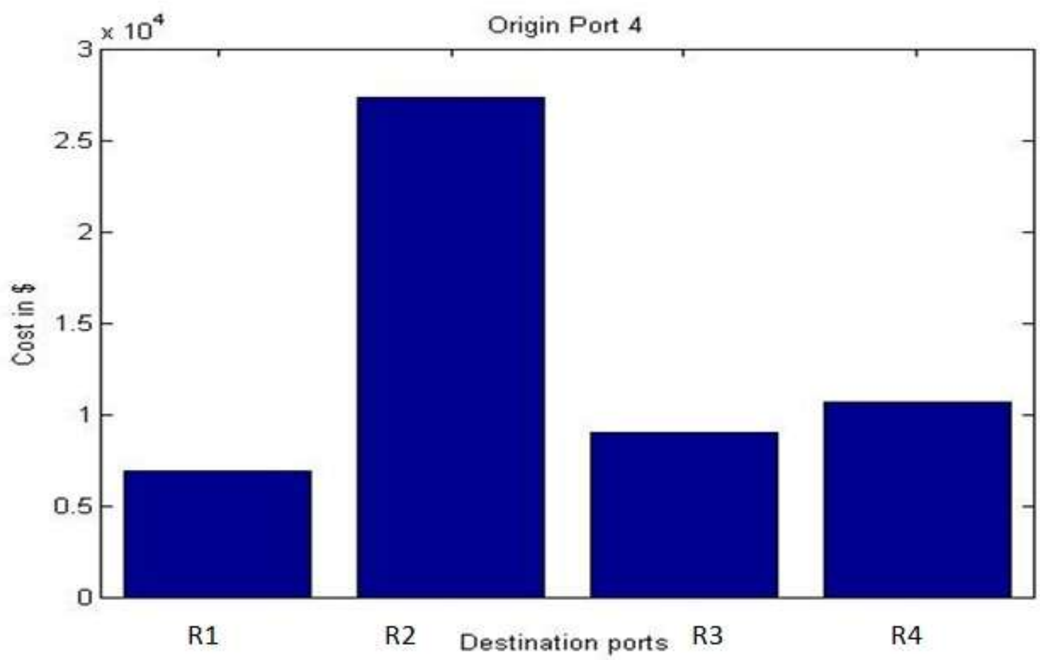


Figure B 107 Cost analysis Recife (B) – destination ports (R)

Optimized path: Belo Horizonte-Paranagua –Kaliningrad -Saint Petersburg

Illustration 7. Brazil to South Africa

b) Sao Paulo -Free state

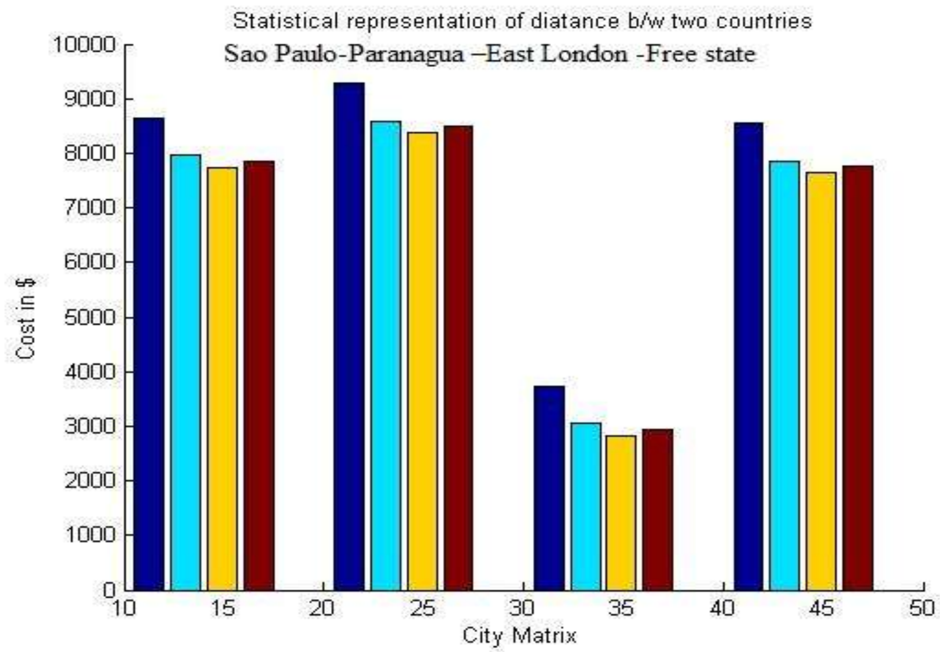


Figure B 108 Cost analysis Sao Paulo -Free State

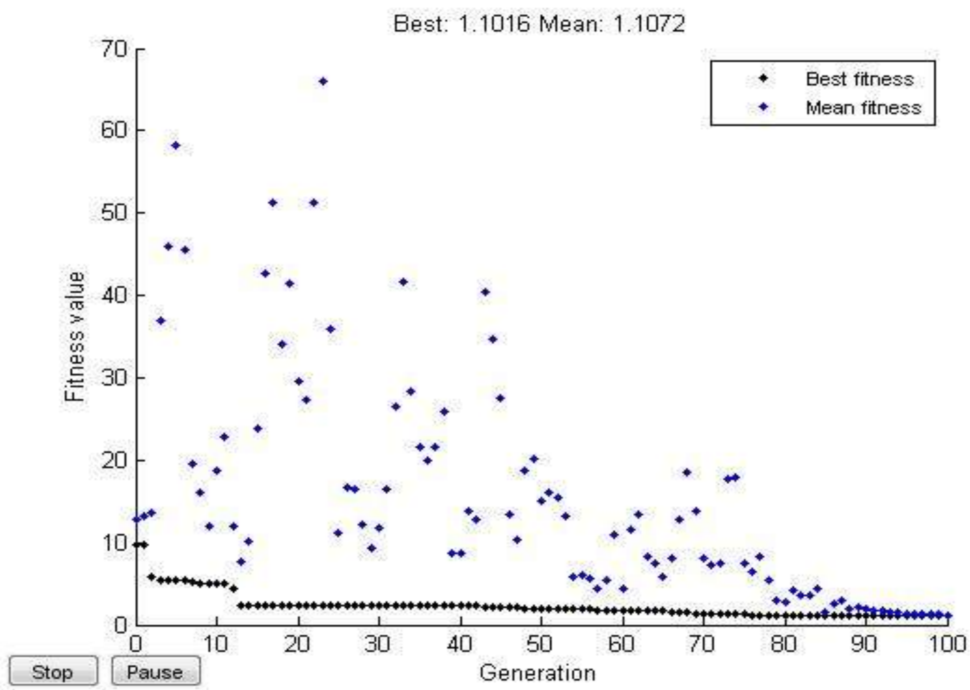


Figure B 109 GA analysis Sao Paulo -Free State

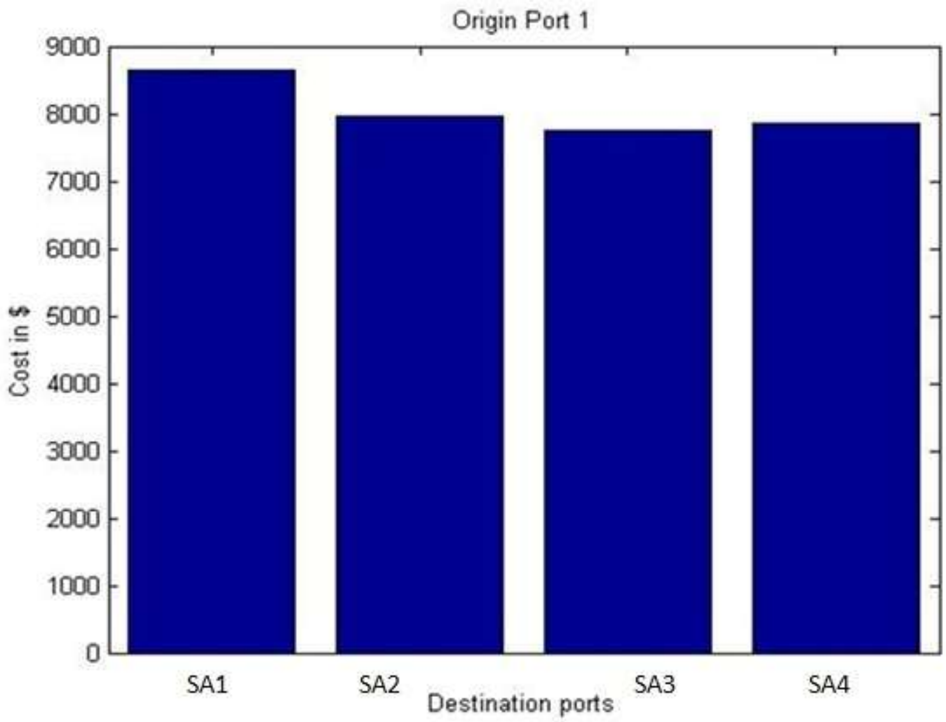


Figure B 110 Cost analysis Belem (B) – destination ports (SA)

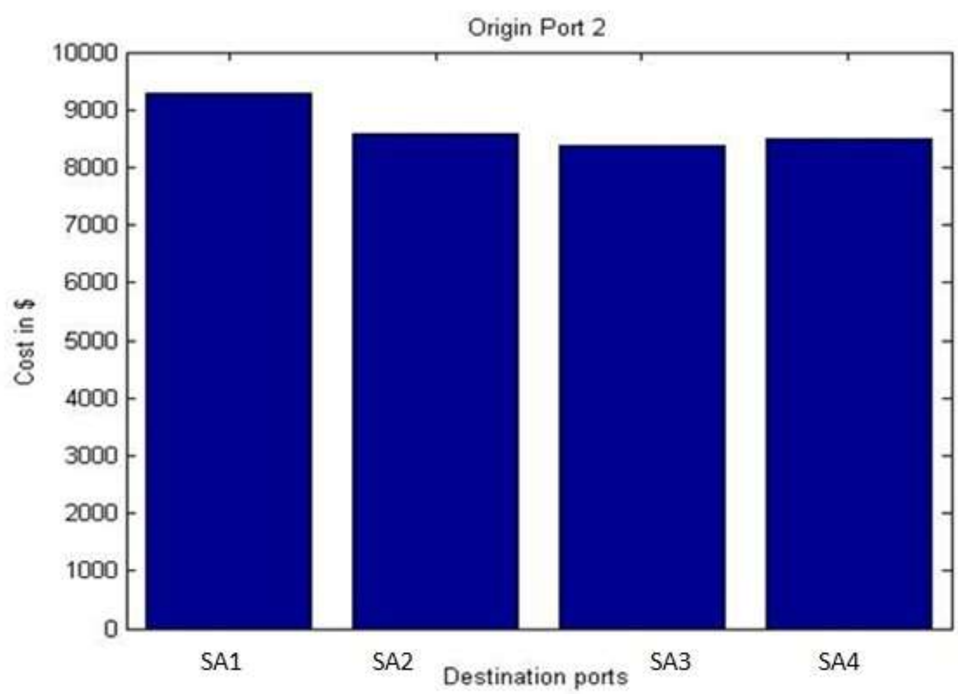


Figure B 111 Cost analysis Fortaleza (B) – destination ports (SA)

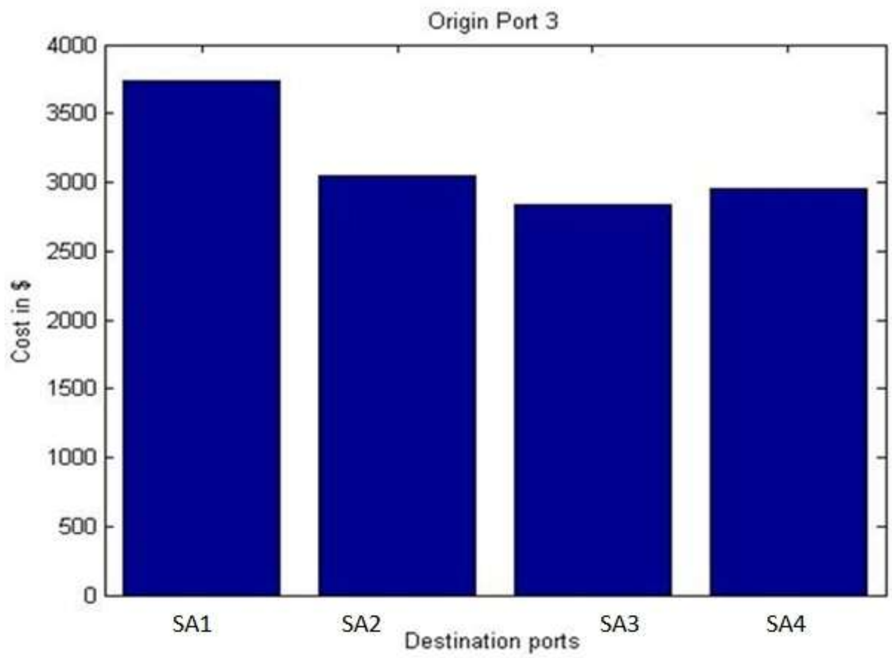


Figure B 112 Cost analysis Paranagua (B) – destination ports (SA)

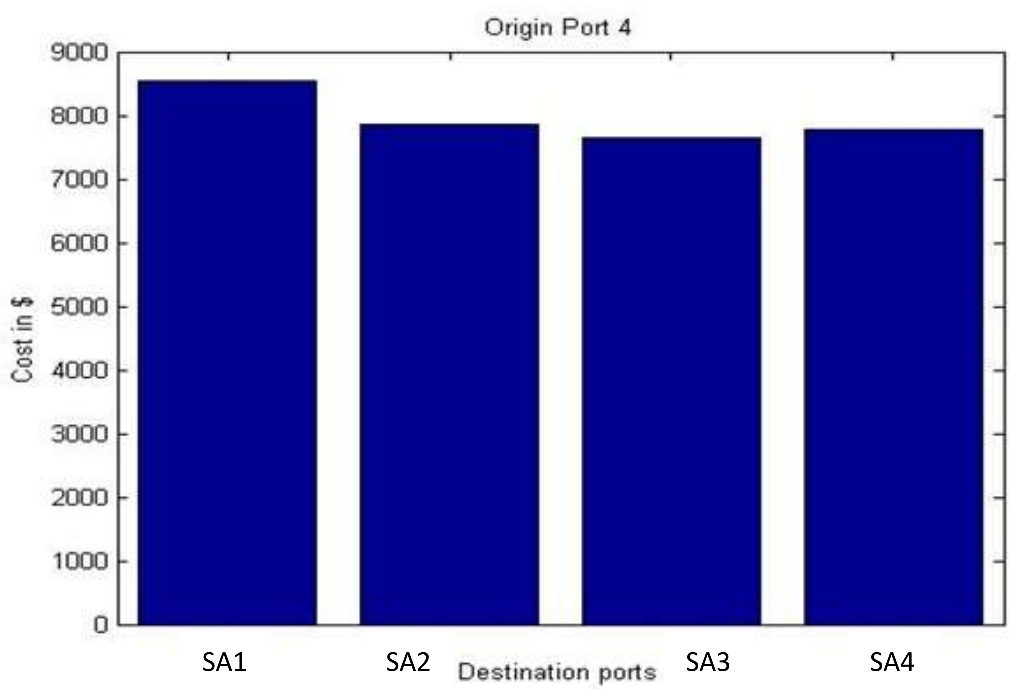


Figure B 113 Cost analysis Recife (B) – destination ports (SA)

Optimized path: Sao Paulo-Paranagua –East London -Free State

c) Rio de Janeiro-Gauteng

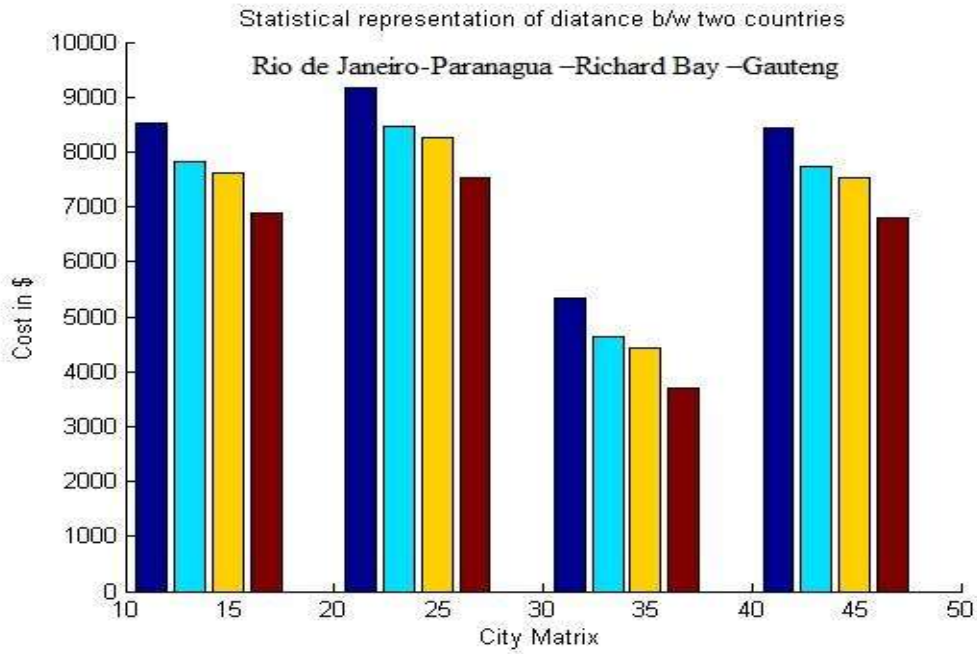


Figure B 114 Cost analysis Rio de Janeiro-Gauteng

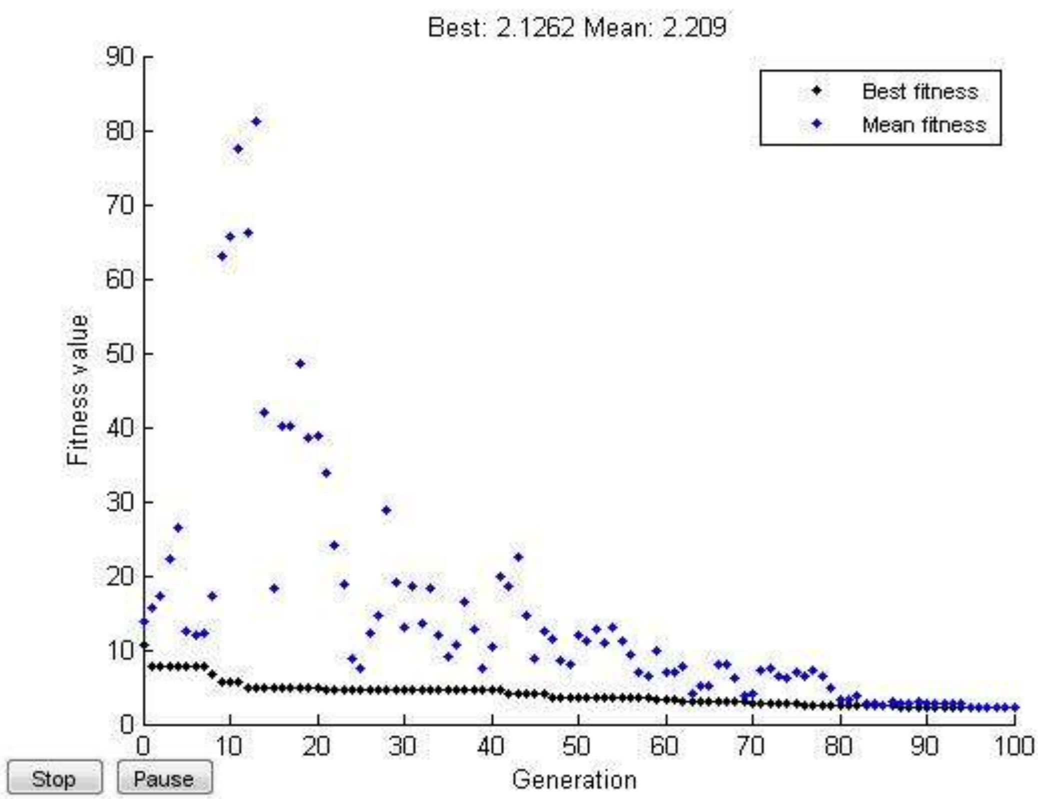


Figure B 115 GA analysis Rio de Janeiro-Gauteng

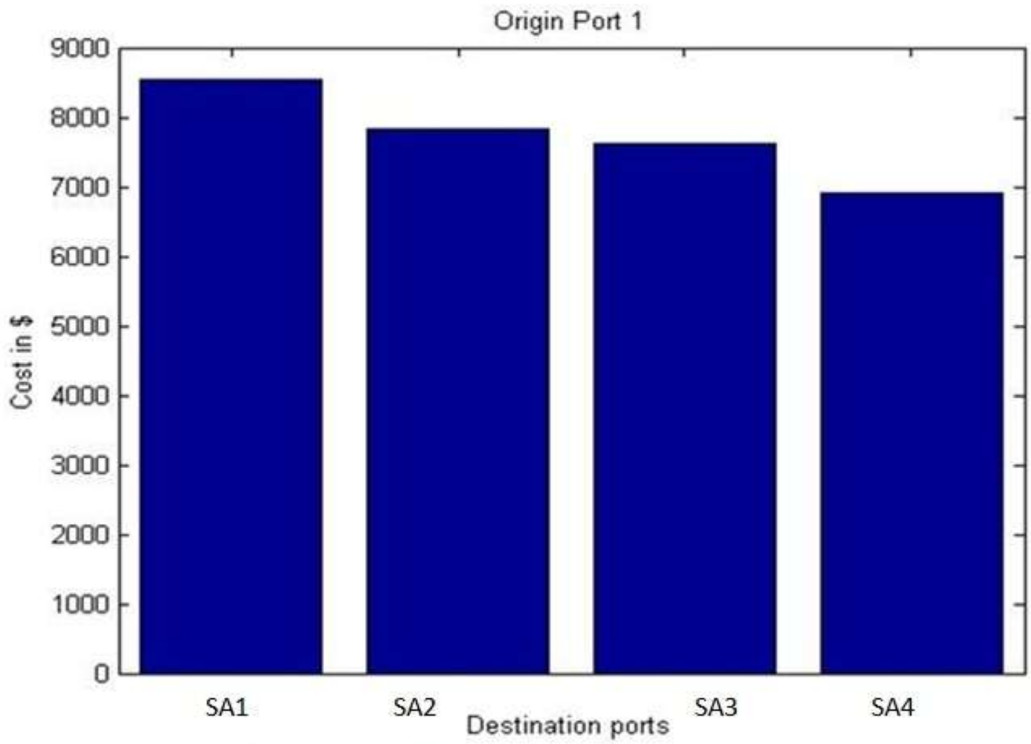


Figure B 116 Cost analysis Belem (B) – destination ports (SA)

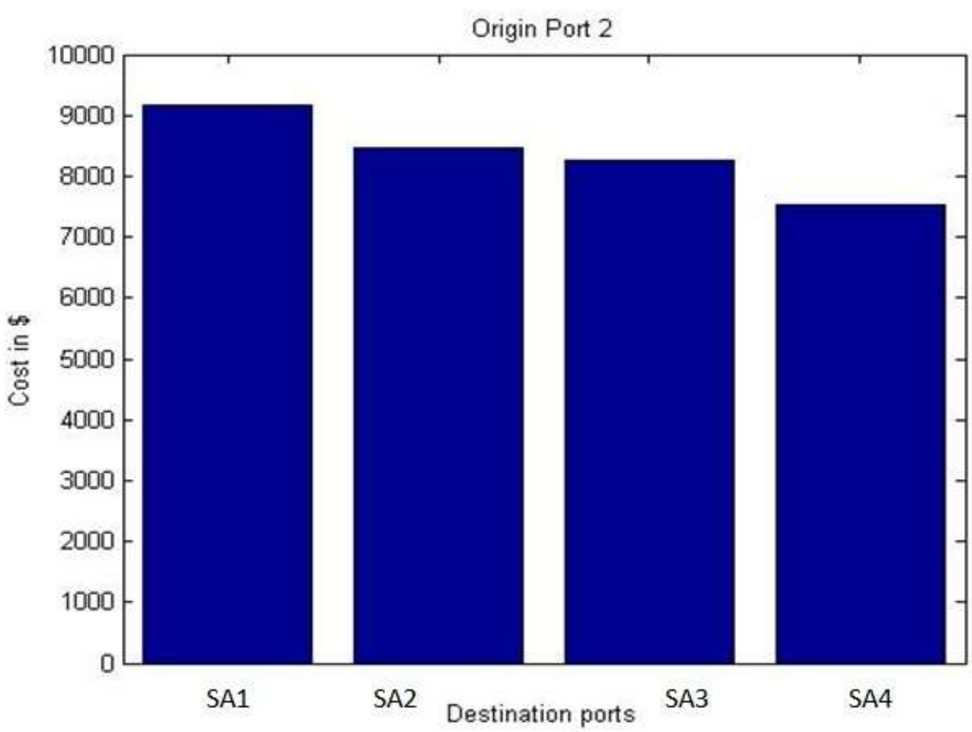


Figure B 117 Cost analysis Fortaleza (B) – destination ports (SA)

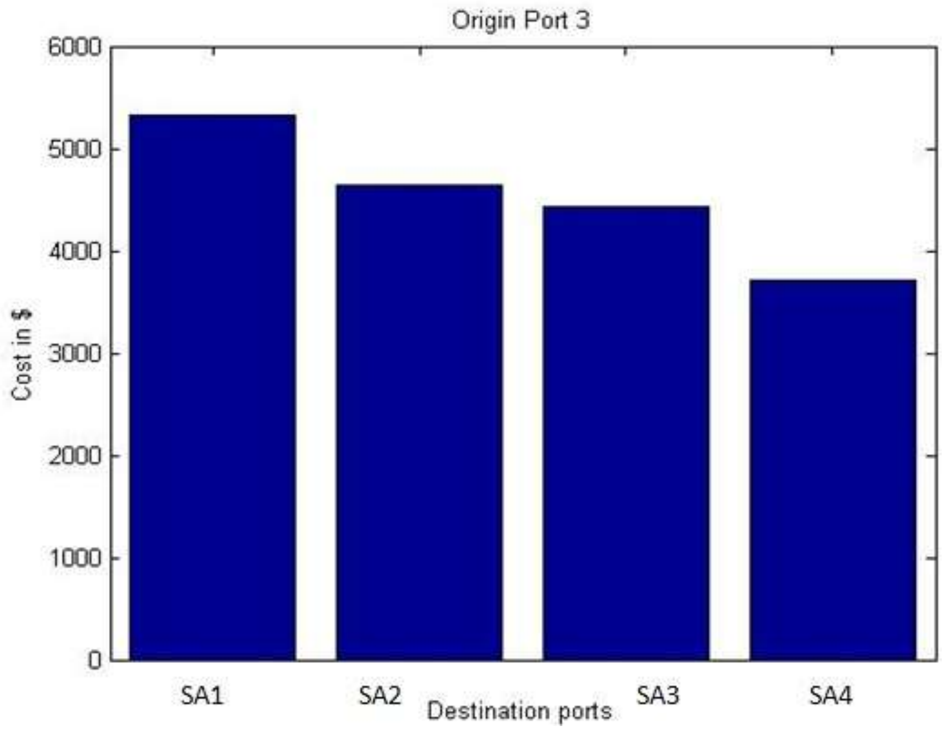


Figure B 118 Cost analysis Paranagua (B) – destination ports (SA)

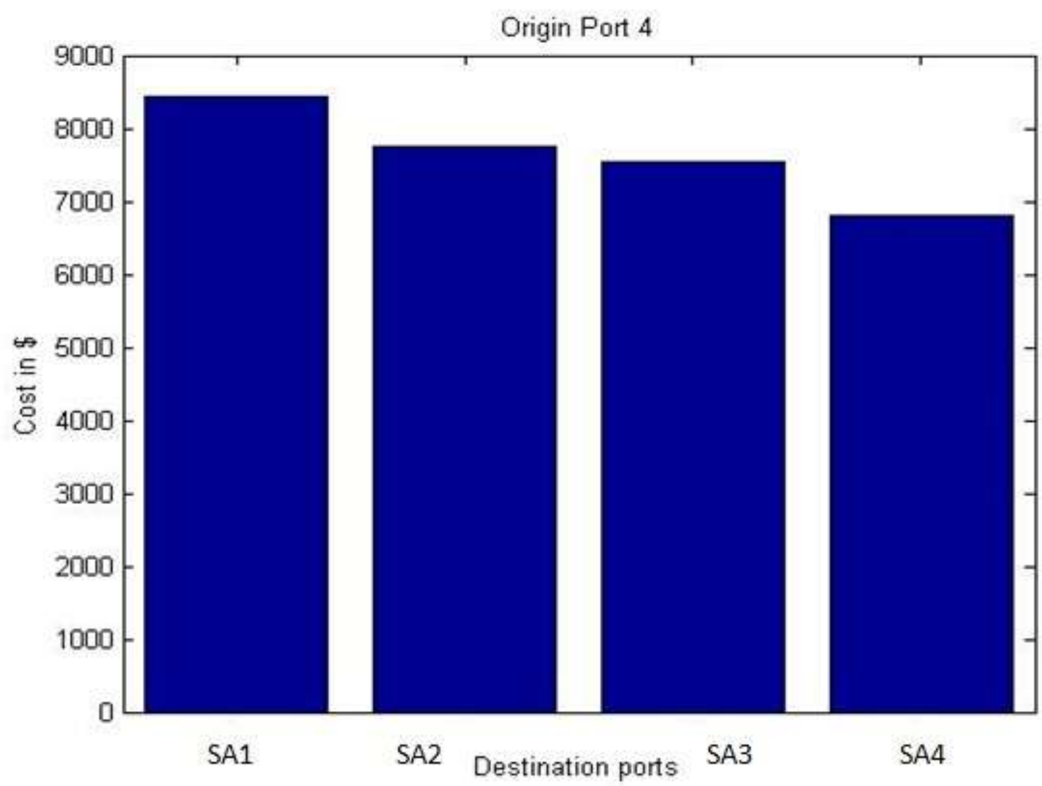


Figure B 119 Cost analysis Recife (B) – destination ports (SA)

Optimized path: Rio de Janeiro-Paranagua –Richard Bay –Gauteng

d) Belo Horizonte-Eastern cap

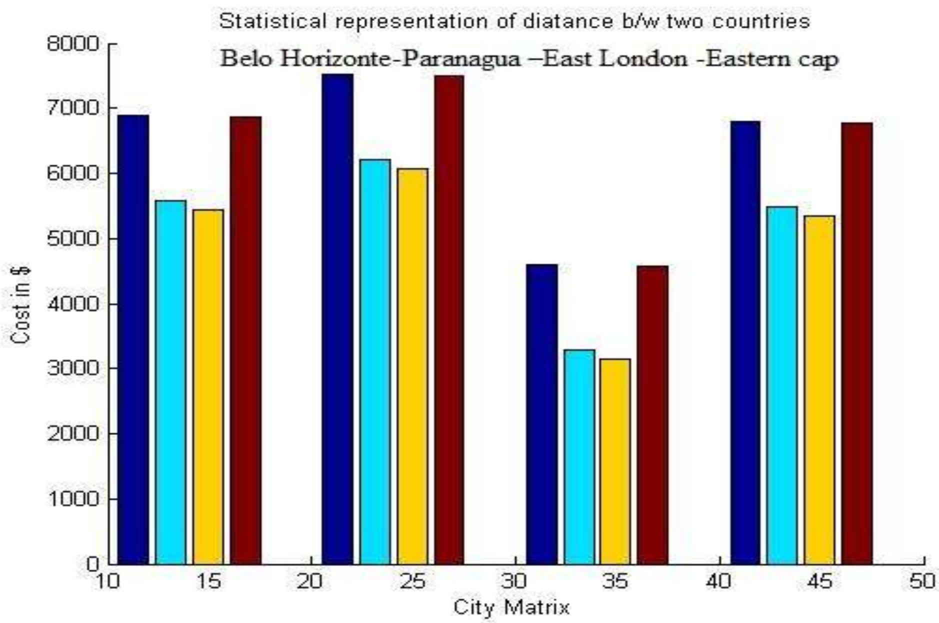


Figure B 120 Cost analysis Belo Horizonte-Eastern cap

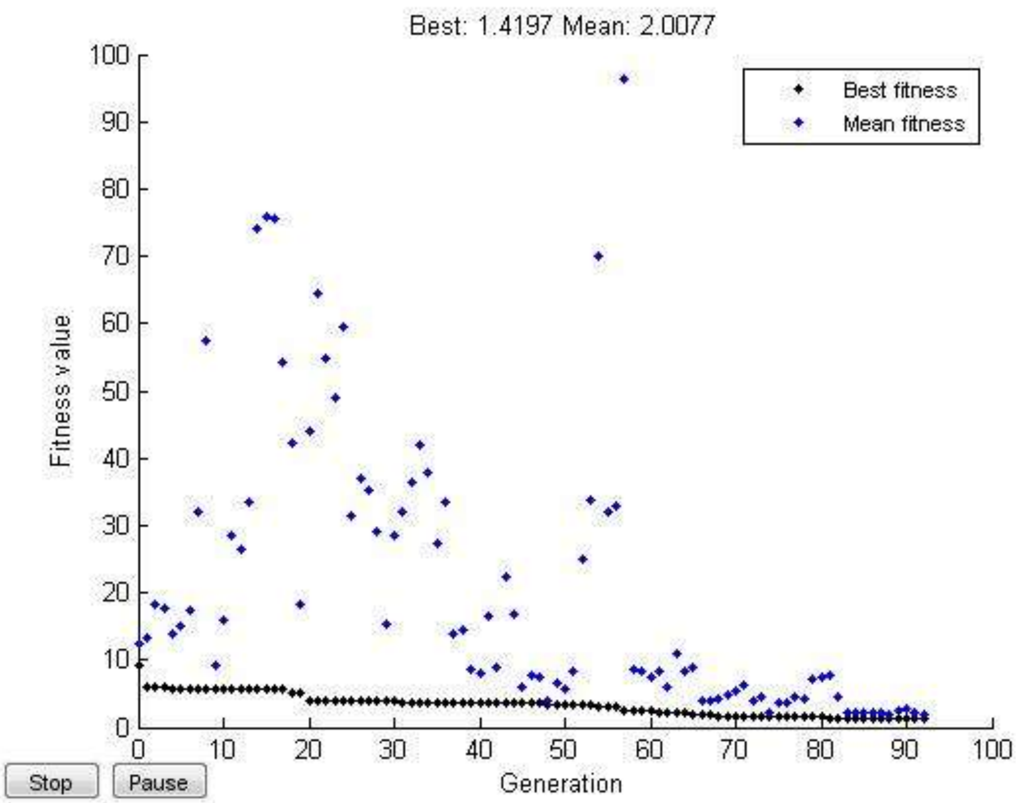


Figure B 121 GA analysis Belo Horizonte-Eastern cap

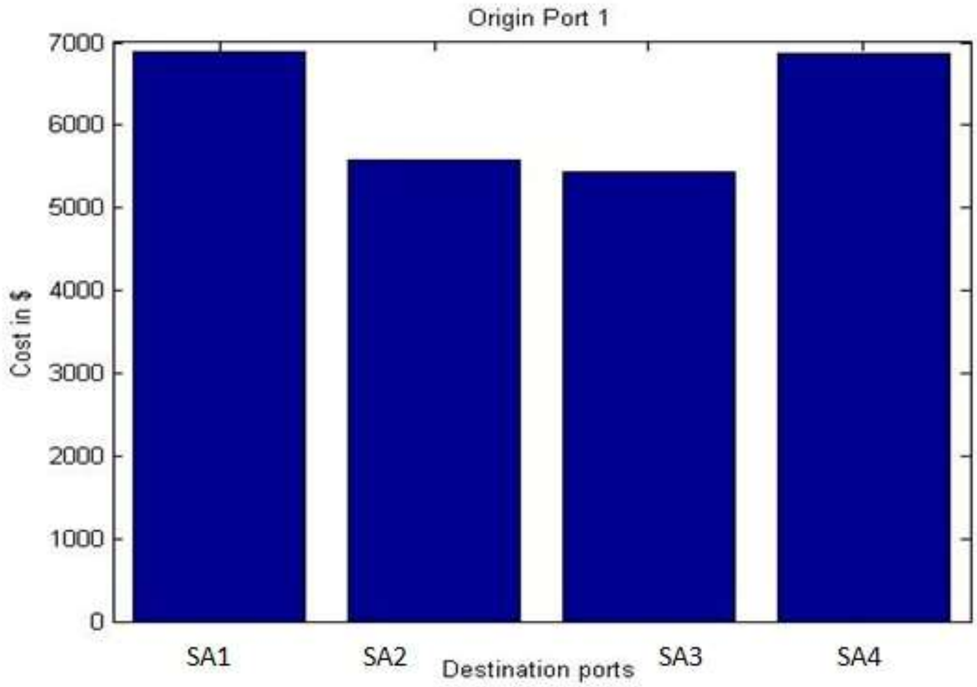


Figure B 122 Cost analysis Belem (B) – destination ports (SA)

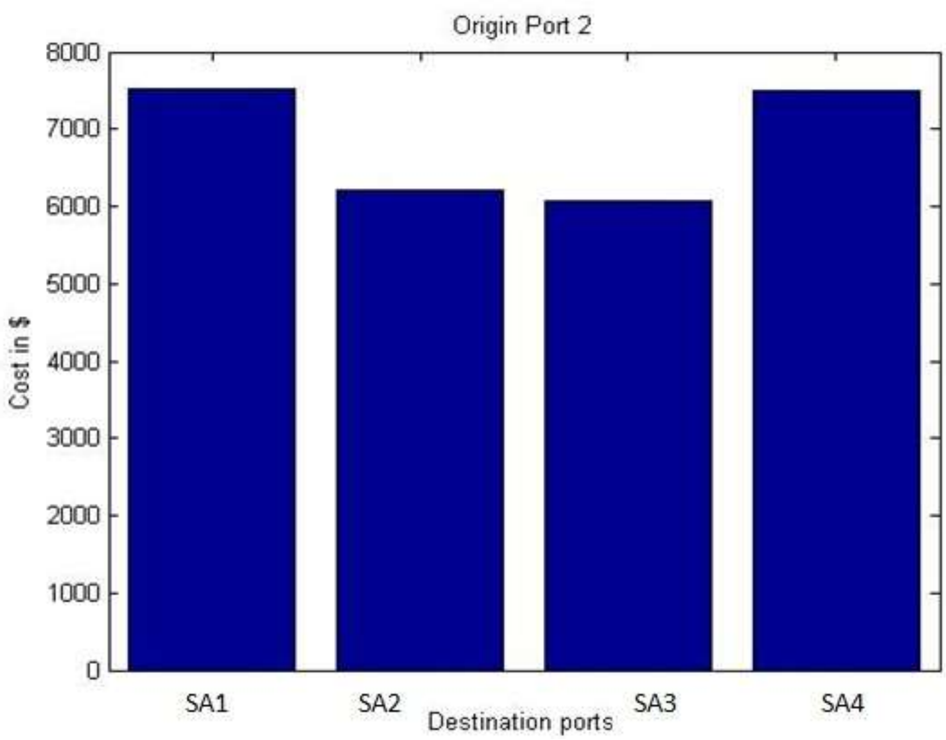


Figure B 123 Cost analysis Fortaleza (B) – destination ports (SA)

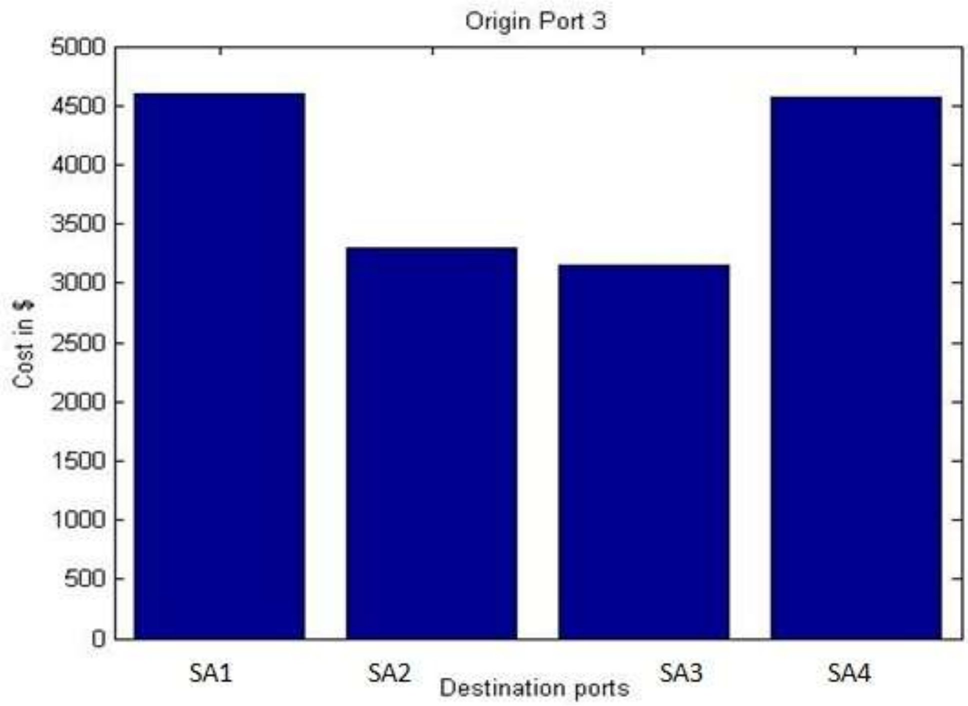


Figure B 124 Cost analysis Paranagua (B) – destination ports (SA)

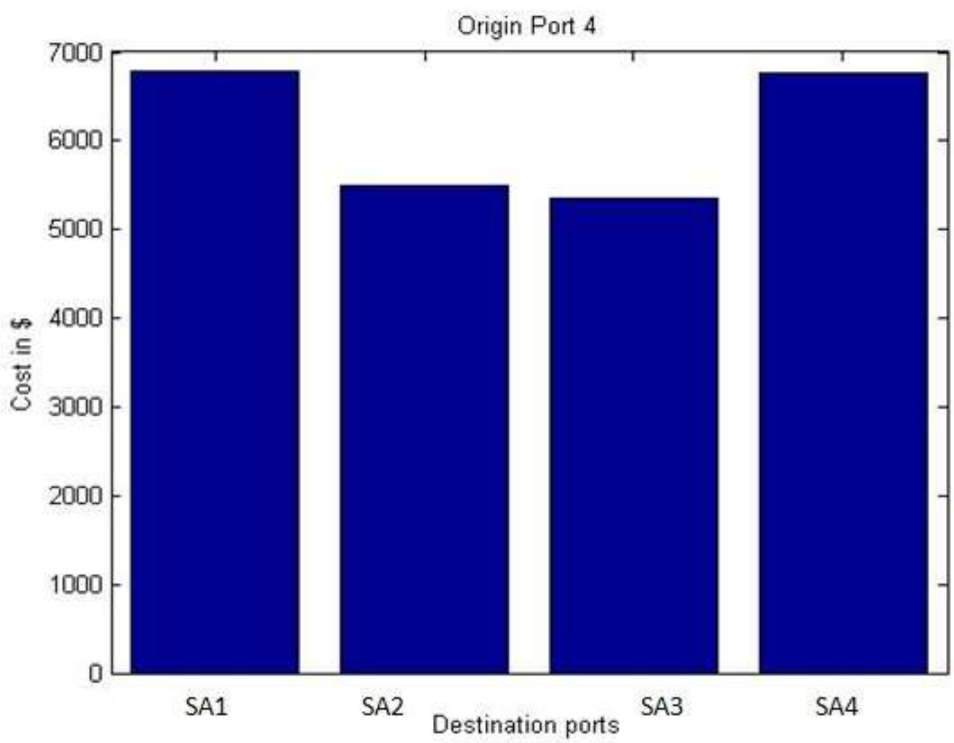


Figure B 125 Cost analysis Recife (B) – destination ports (SA)

Optimized path: Belo Horizonte-Paranagua –East London -Eastern cap

Illustration 8. Brazil-India
b) Sao Paulo-Vapi

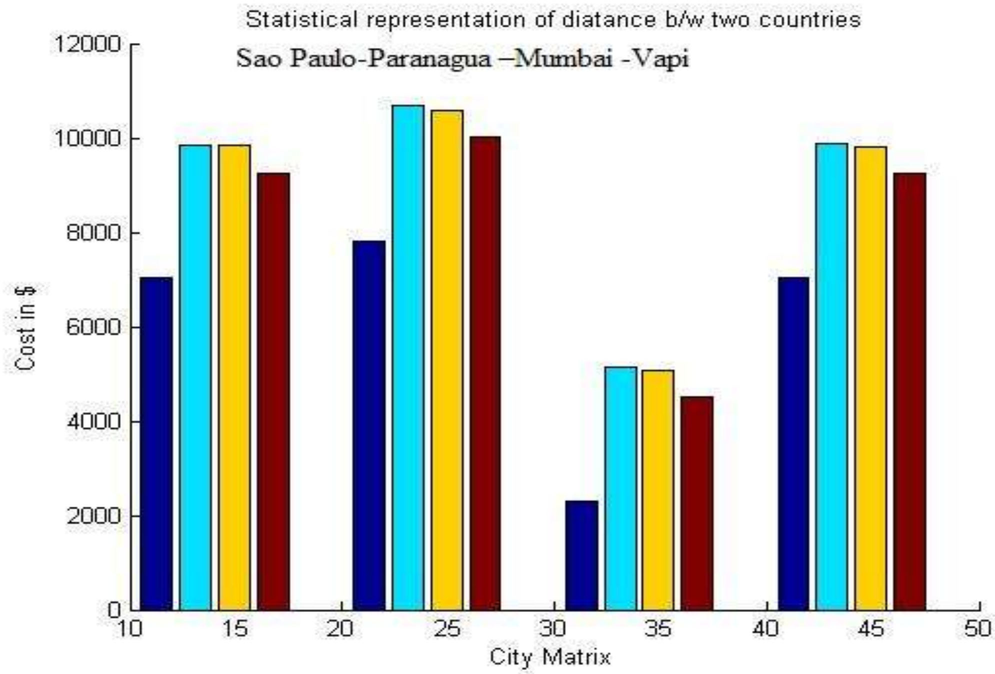


Figure B 126 Cost analysis Sao Paulo-Vapi

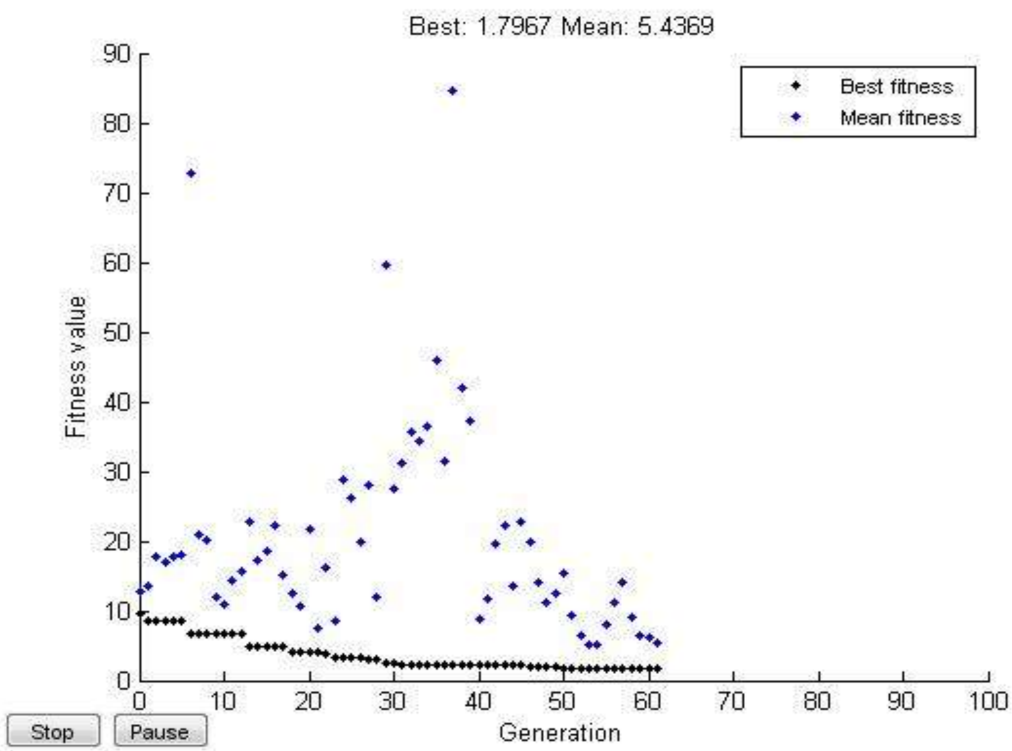


Figure B 127 GA analysis Sao Paulo-Vapi

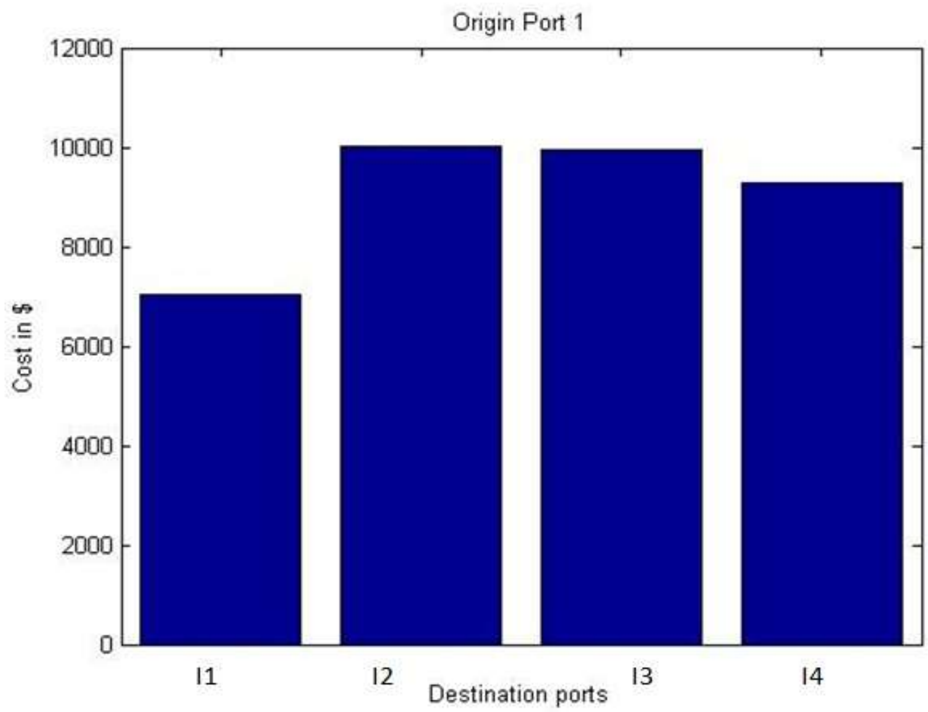


Figure B 128 Cost analysis Belem (B) – destination ports (I)

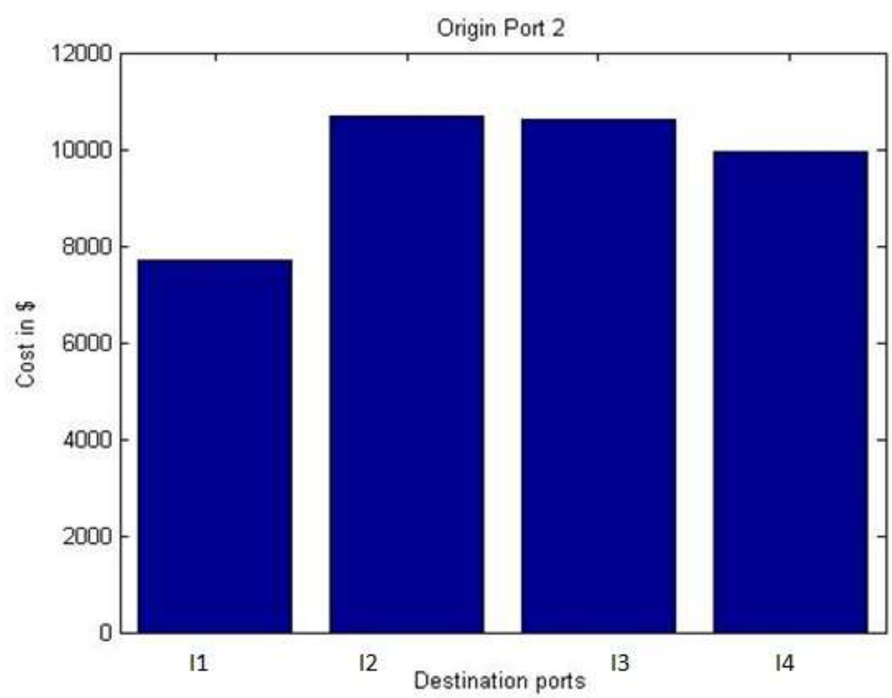


Figure B 129 Cost analysis Fortaleza (B) – destination ports (I)

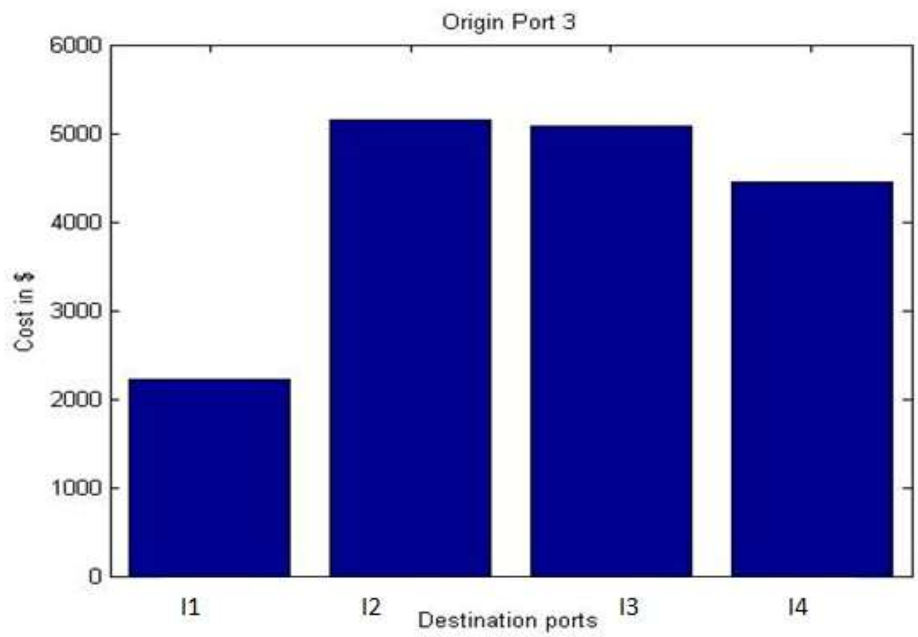


Figure B 130 Cost analysis Paranagua (B) – destination ports (I)

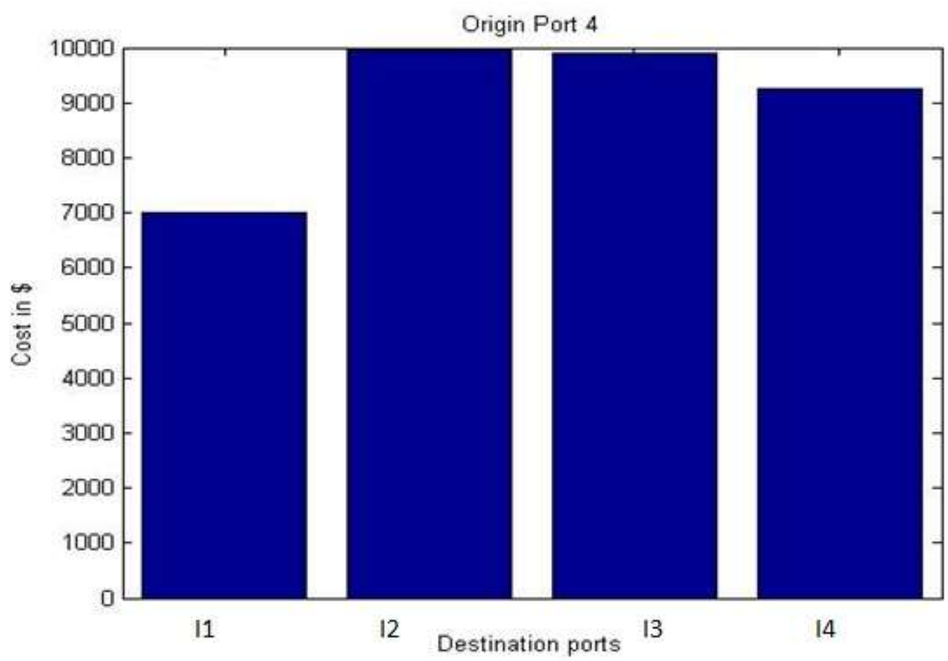


Figure B 131 Cost analysis Recife (B) – destination ports (I)

Optimized path: Sao Paulo-Paranagua –Mumbai –Vapi

c) Rio de Janeiro -Ghaziabad

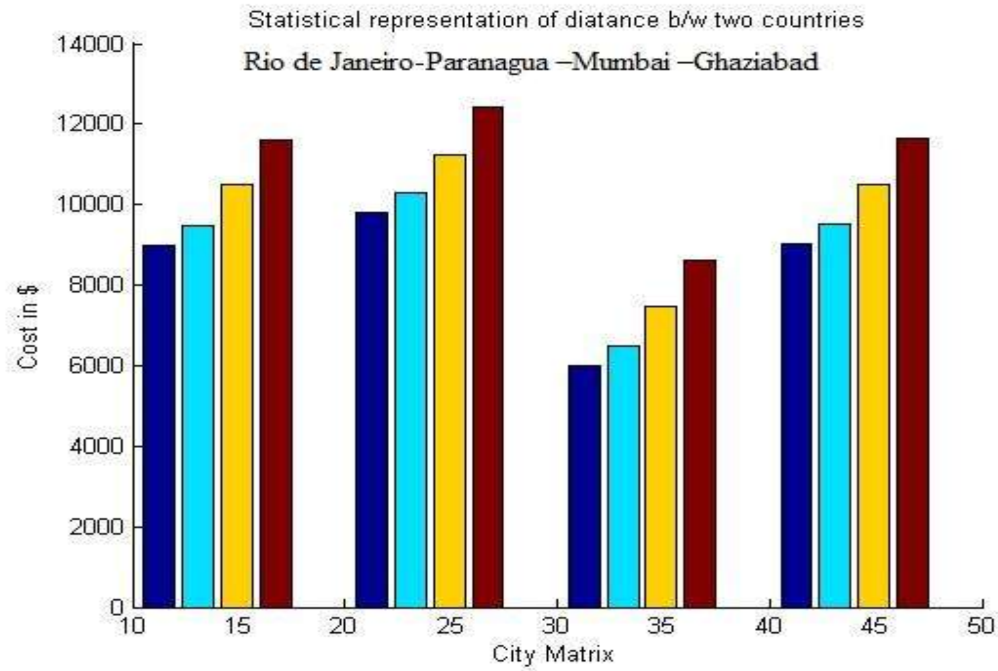


Figure B 132 Cost analysis Rio de Janeiro -Ghaziabad

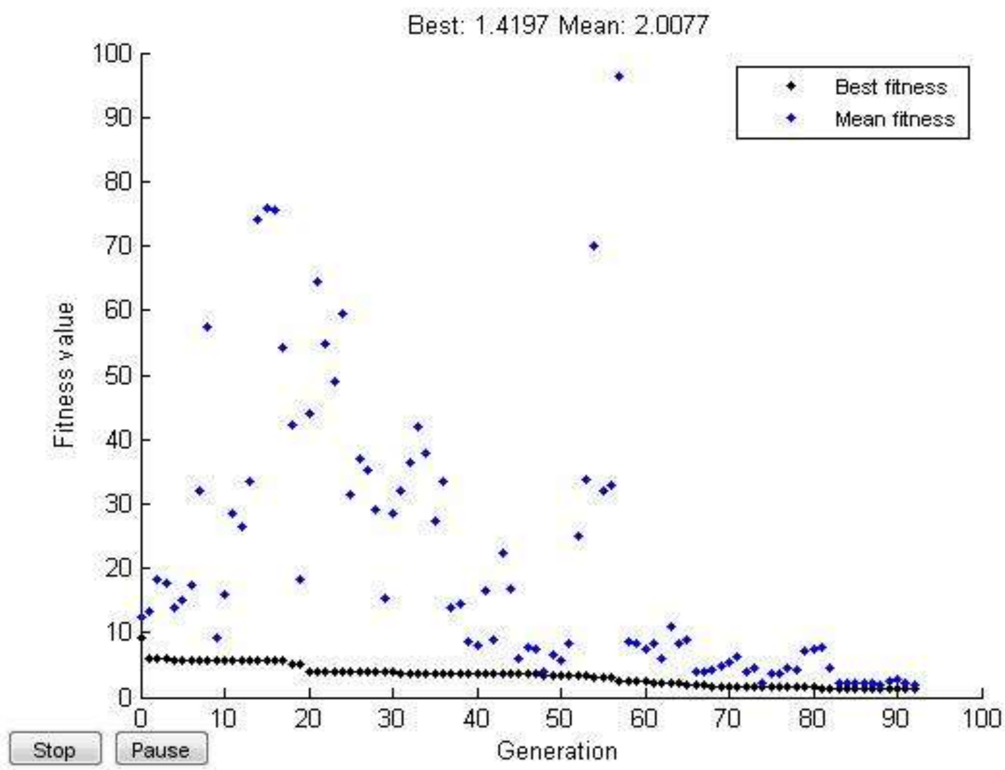


Figure B 133 GA analysis Rio de Janeiro -Ghaziabad

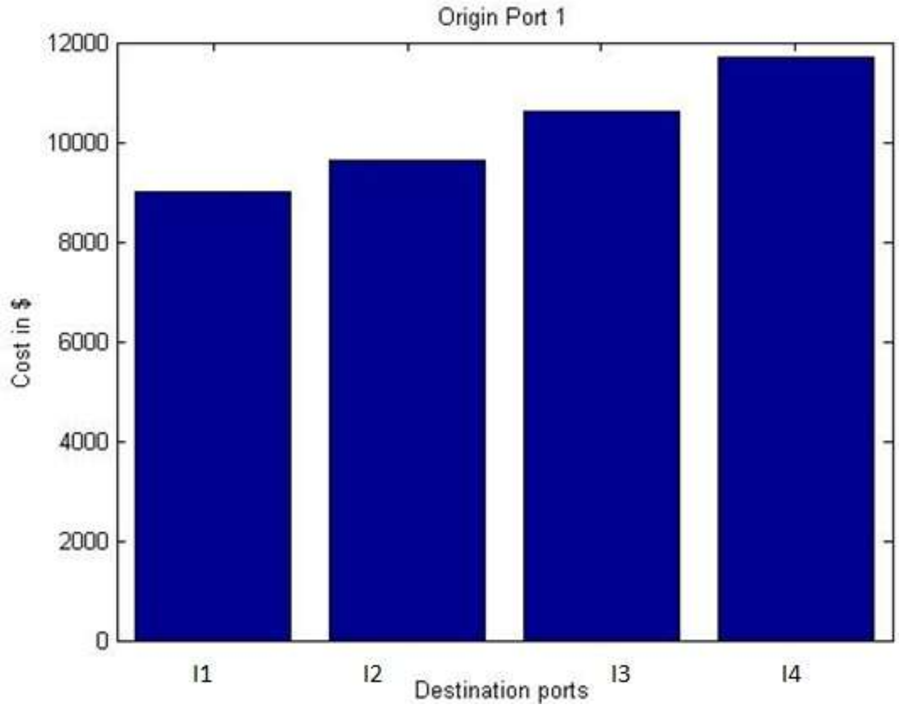


Figure B 134 Cost analysis Belem (B) – destination ports (I)

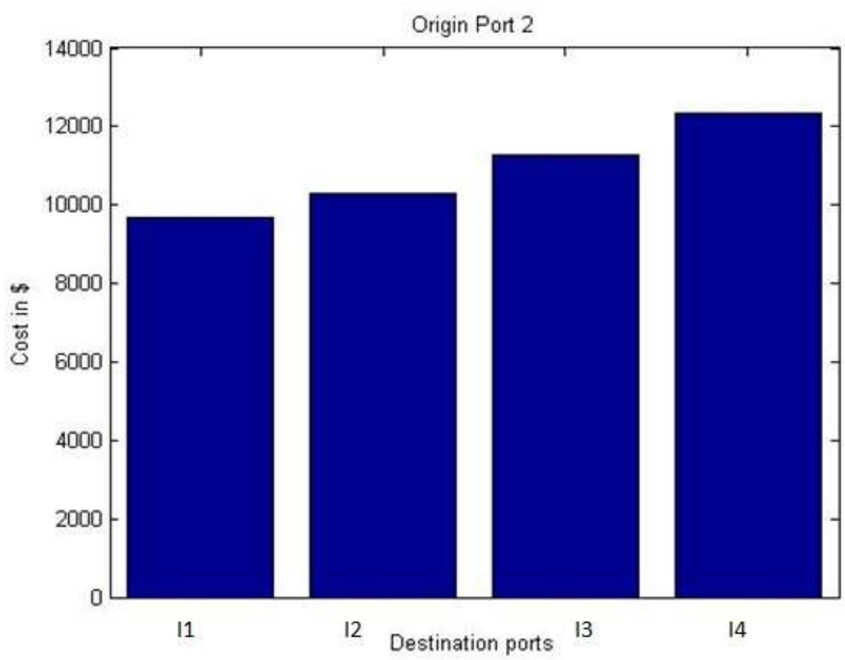


Figure B 135 Cost analysis Fortaleza (B) – destination ports (I)

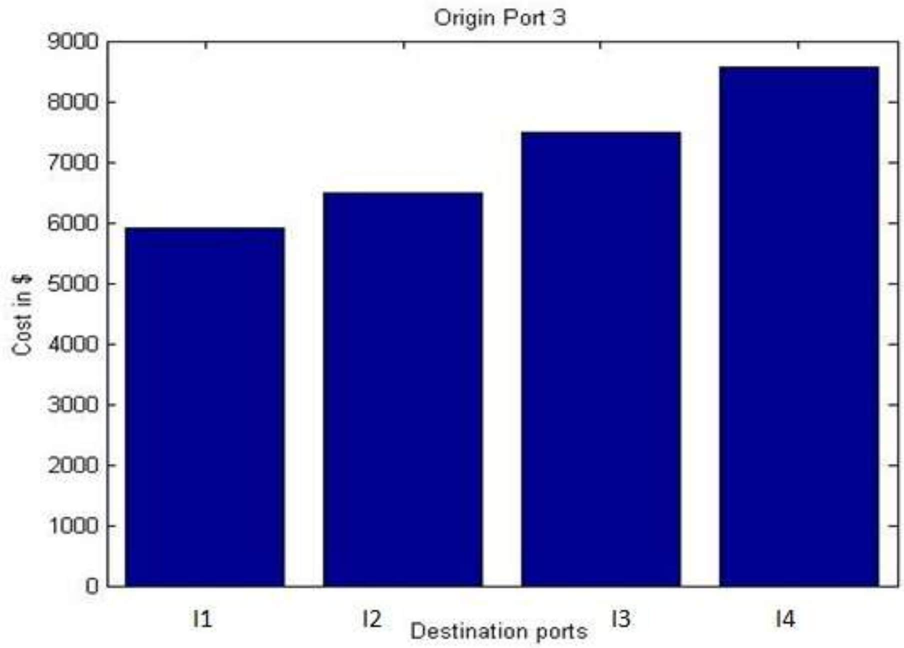


Figure B 136 Cost analysis Paranagua (B) – destination ports (I)

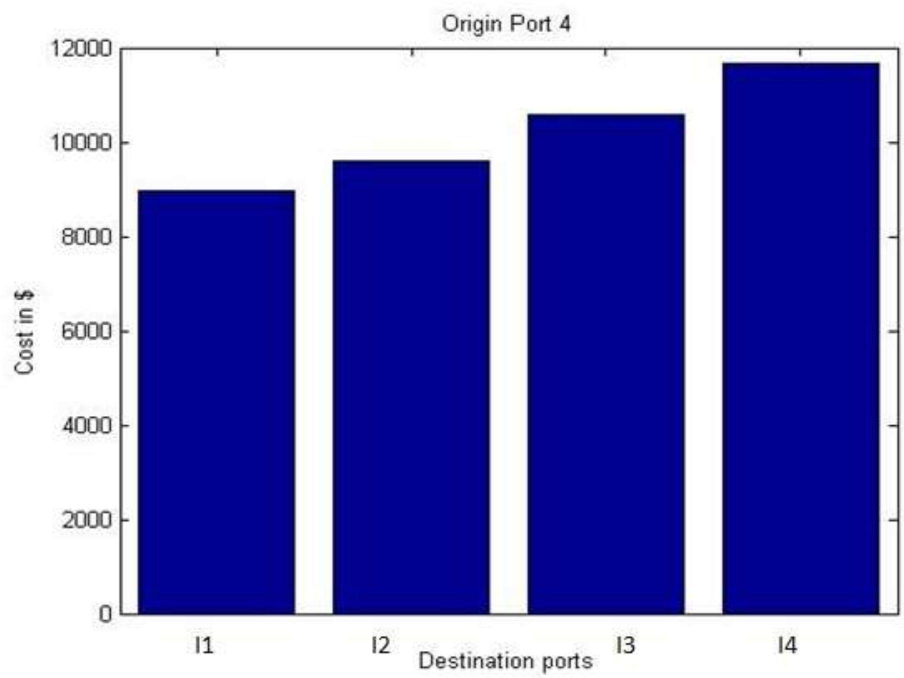


Figure B 137 Cost analysis Recife (B) – destination ports (I)

Optimized Path: Rio de Janeiro-Paranagua –Mumbai –Ghaziabad

d) Belo Horizonte-Chandrapur

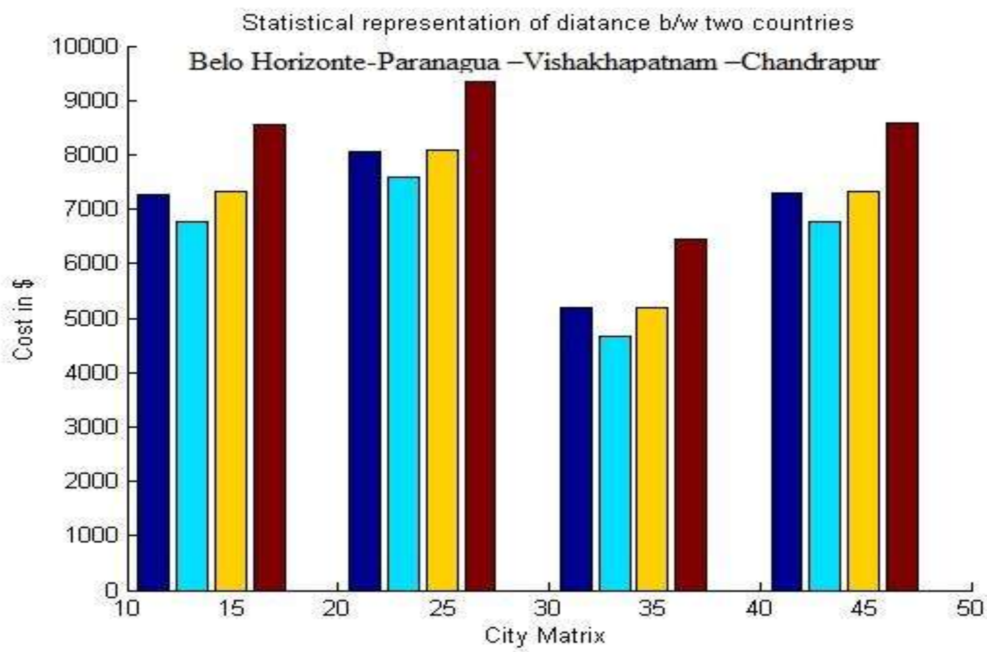


Figure B 138 Cost analysis Belo Horizonte-Chandrapur

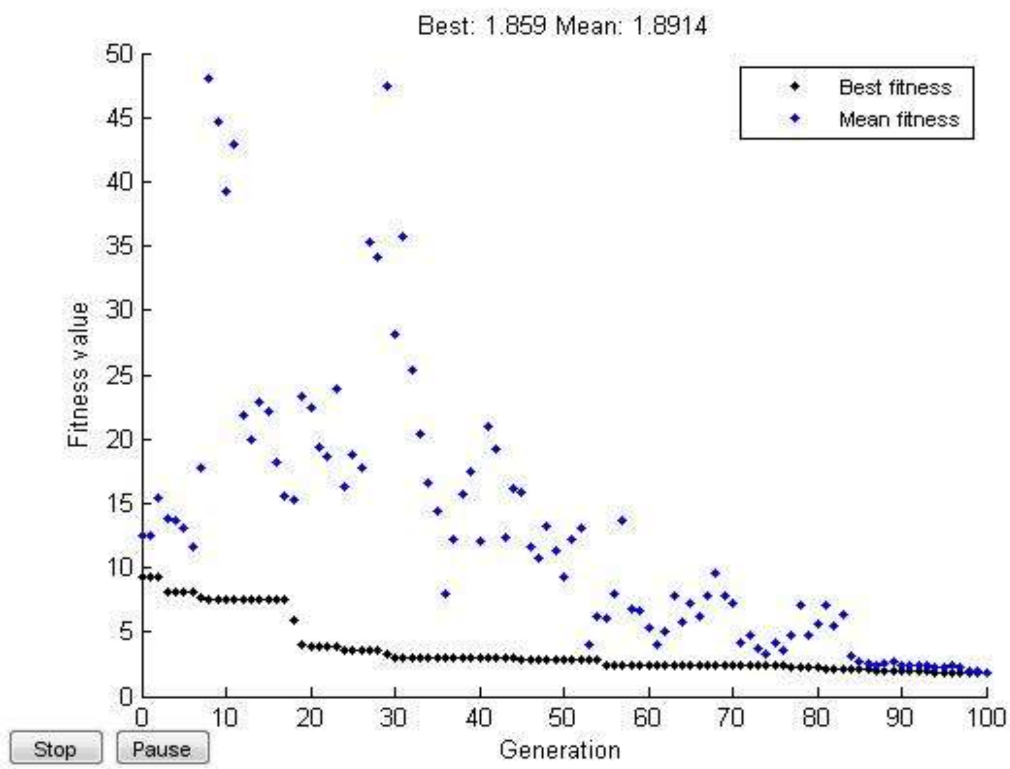


Figure B 139 GA analysis Belo Horizonte-Chandrapur

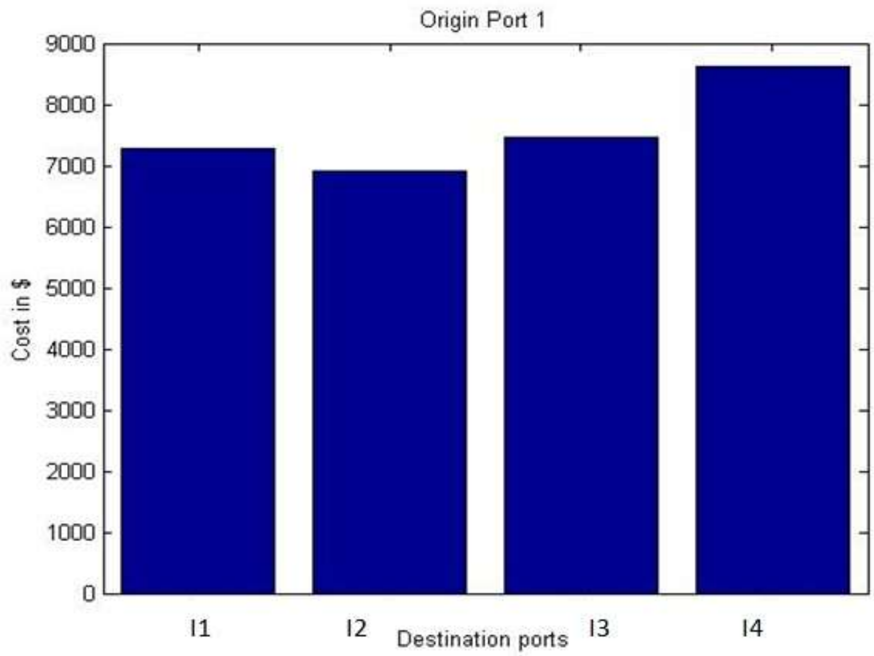


Figure B 140 Cost analysis Belem (B) – destination ports (I)

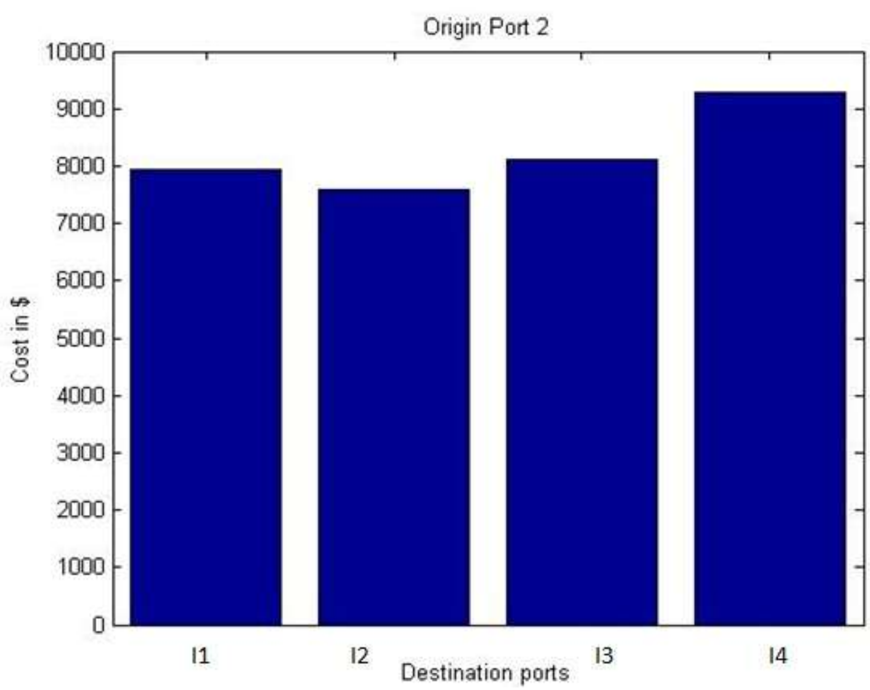


Figure B 141 Cost analysis Fortaleza (B) – destination ports (I)

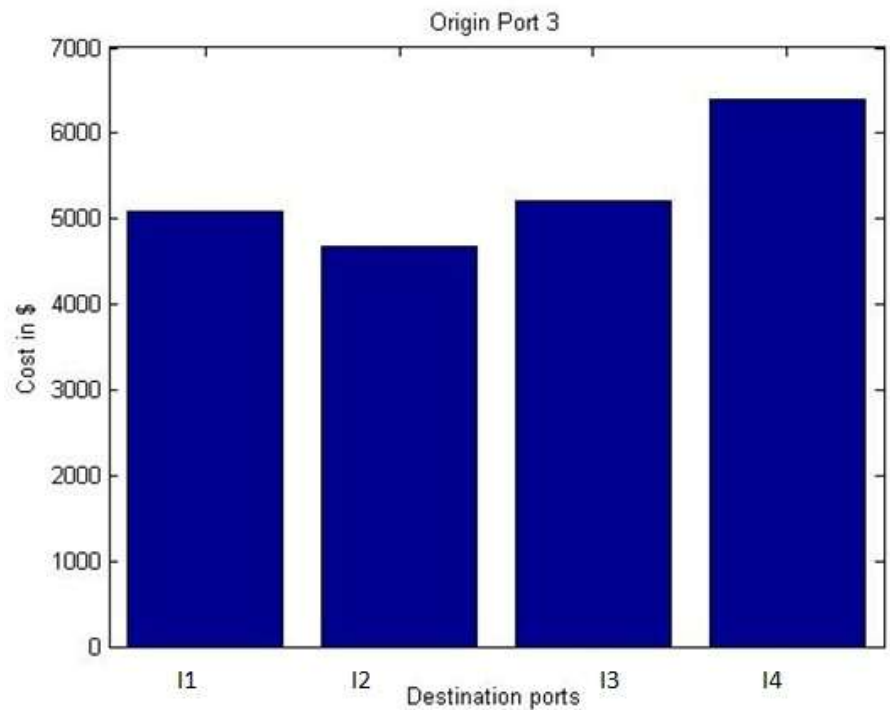


Figure B 142 Cost analysis Paranagua (B) – destination ports (I)

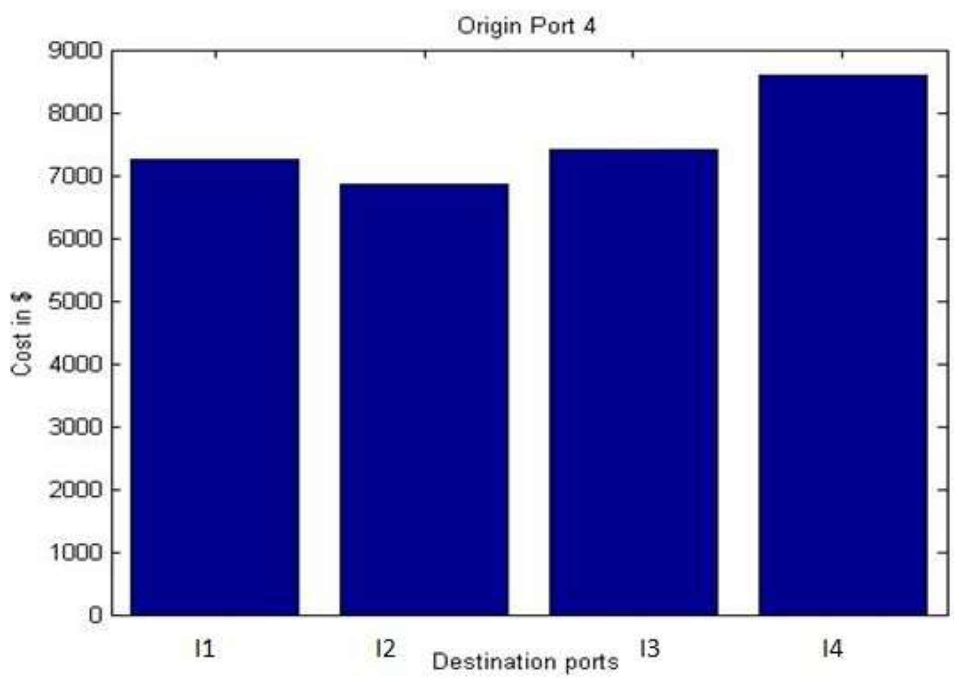


Figure B 143 Cost analysis Recife (B) – destination ports (I)

Optimized path: Belo Horizonte-Paranagua –Vishakhapatnam –Chandrapur

Illustration 9. China to South Africa

b) Beijing-Free State

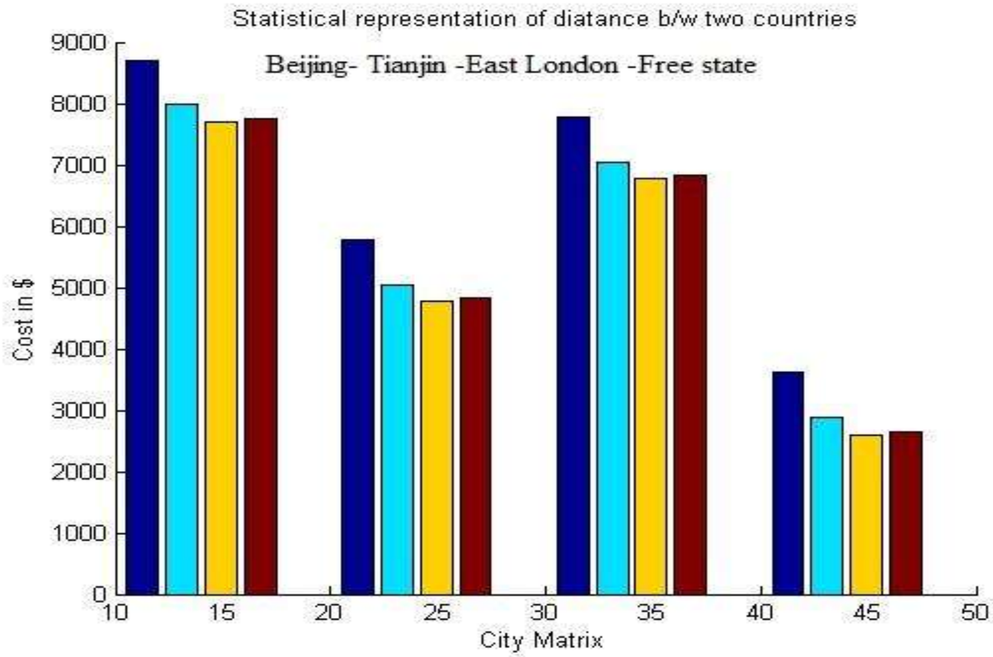


Figure B 144 Cost analysis Beijing-Free State

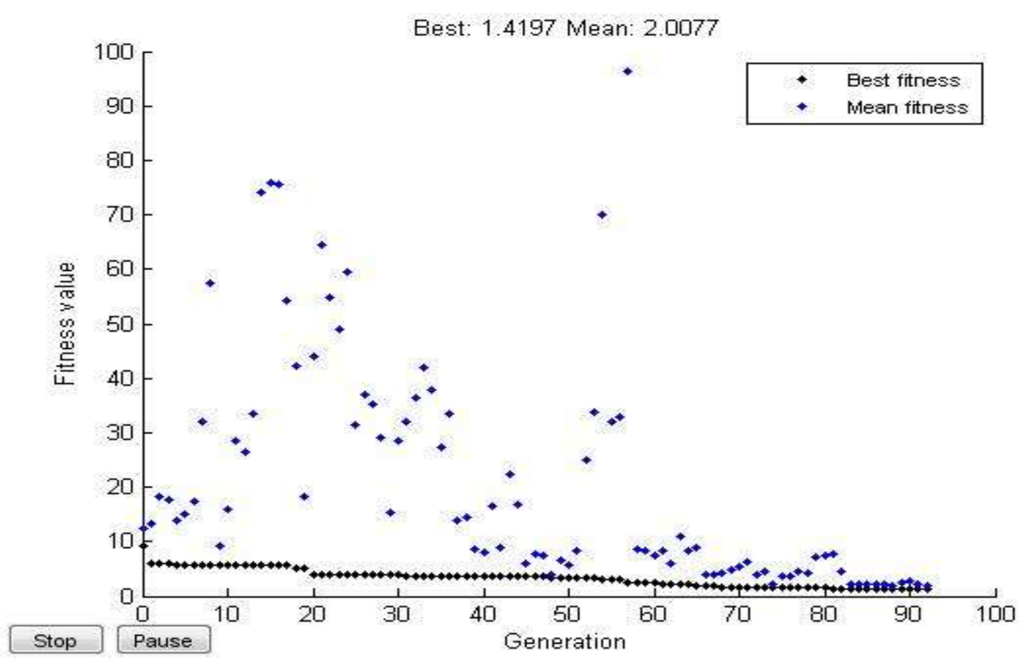


Figure B 145 GA analysis Beijing-Free State

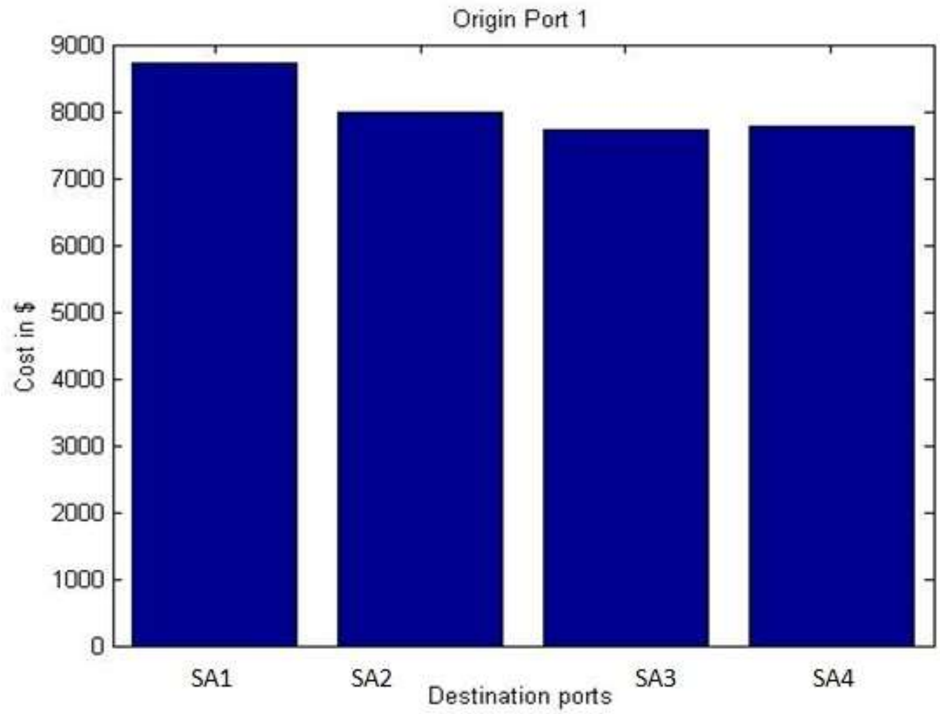


Figure B 146 Cost analysis Zhanjiang (C) – destination ports (SA)

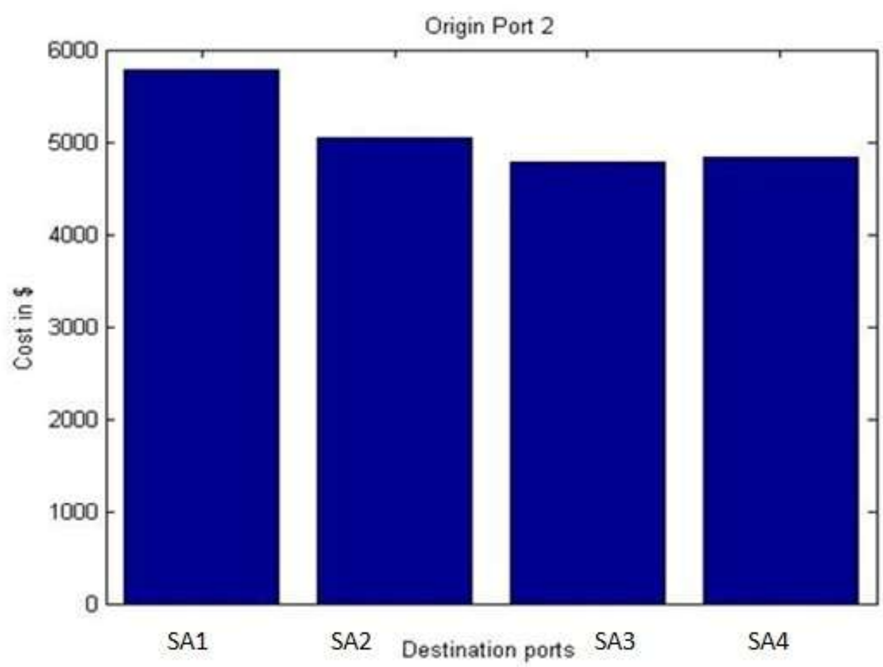


Figure B 147 Cost analysis Bahezhen (C) – destination ports (SA)

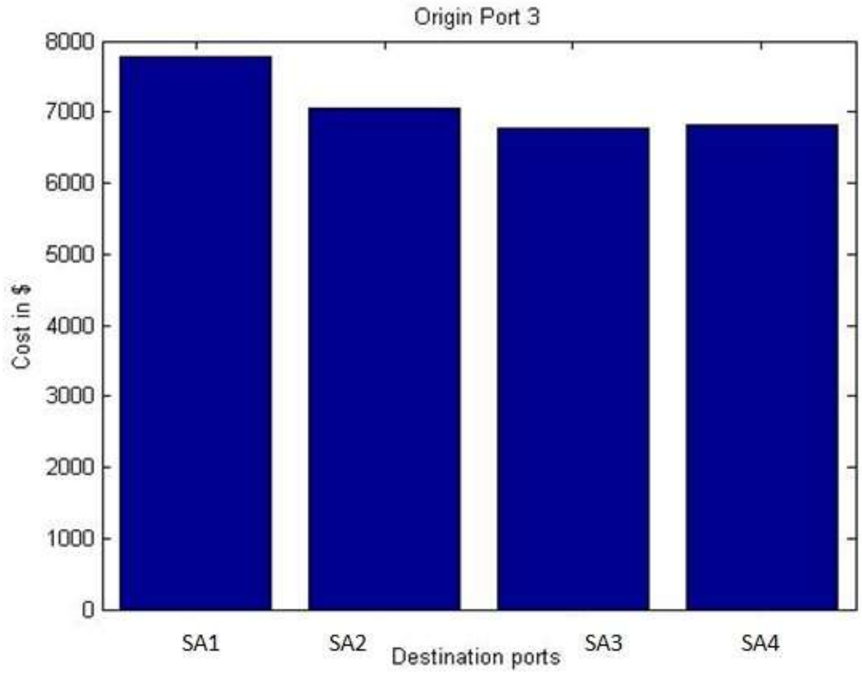


Figure B 148 Cost analysis Port of Xiamen (C) – destination ports (SA)

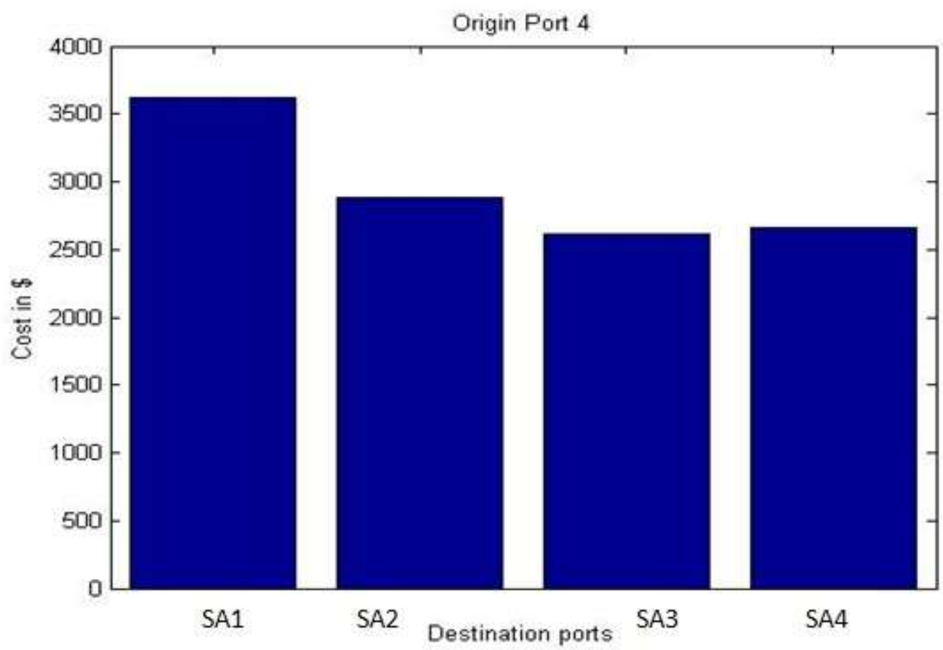


Figure B 149 Cost analysis Port of Tianjin (C) – destination ports (SA)

Optimized path: Beijing- Tianjin -East London -Free State

c) Shenzhen-Gauteng

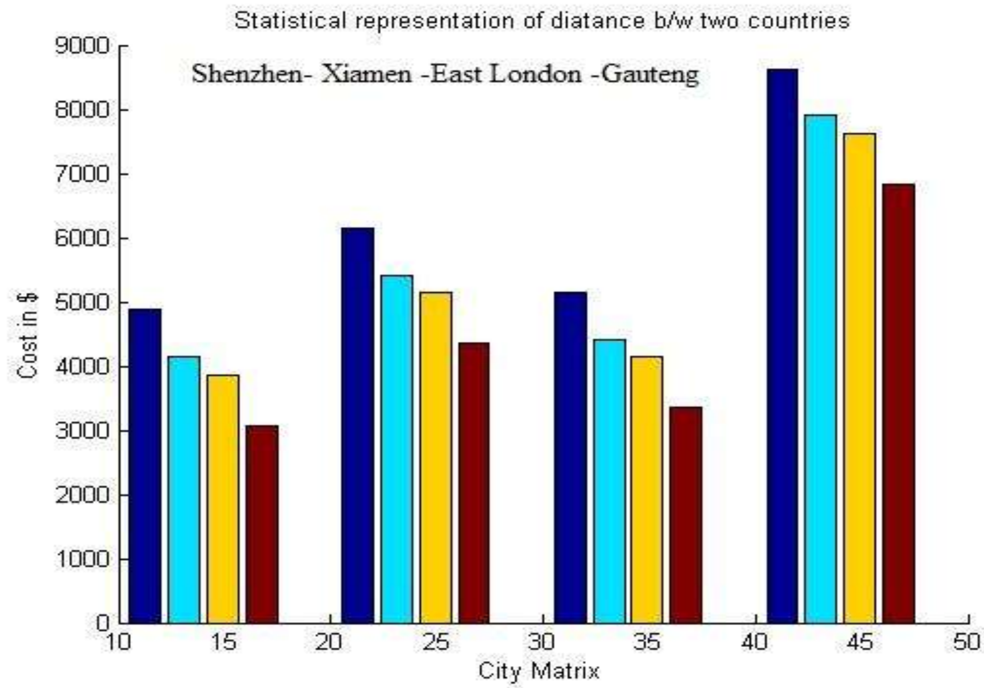


Figure B 150 Cost analysis Shenzhen-Gauteng

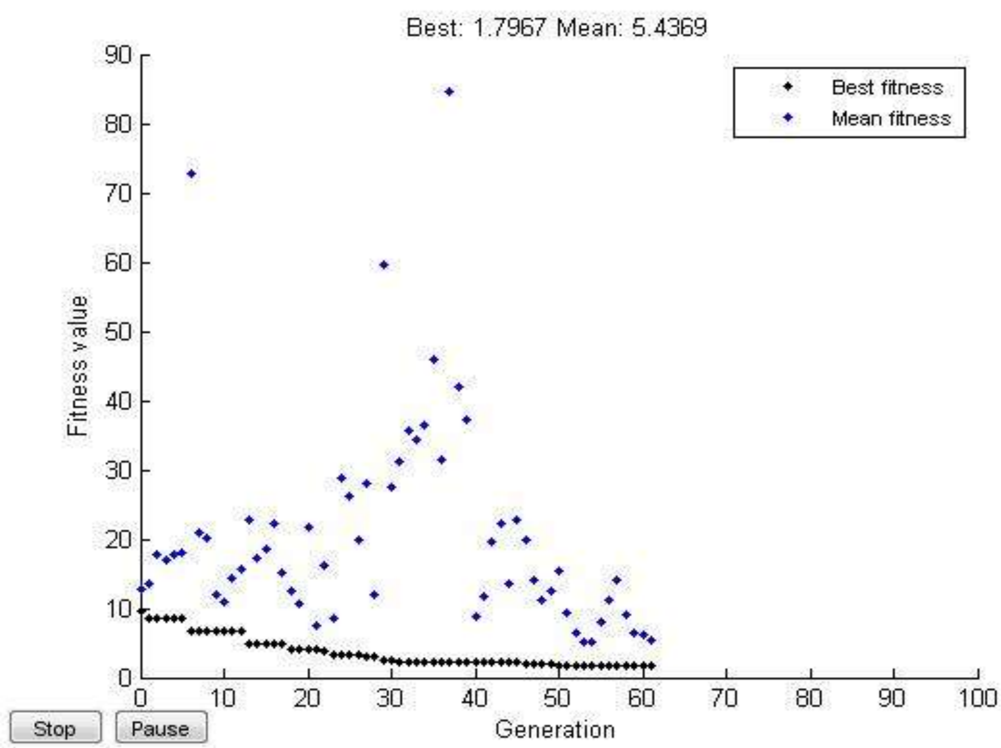


Figure B 151 GA analysis Shenzhen-Gauteng

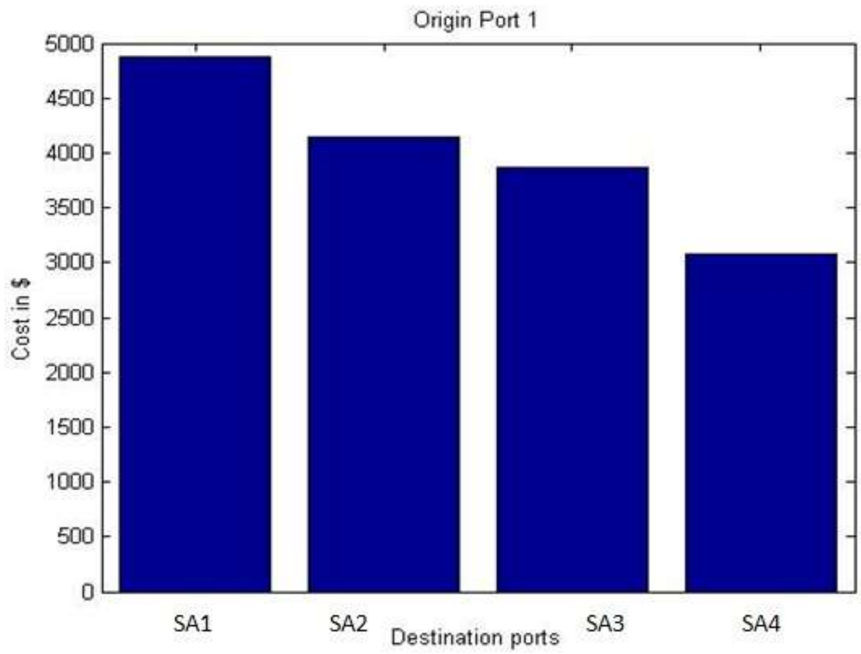


Figure B 152 Cost analysis Zhanjiang (C) – destination ports (SA)

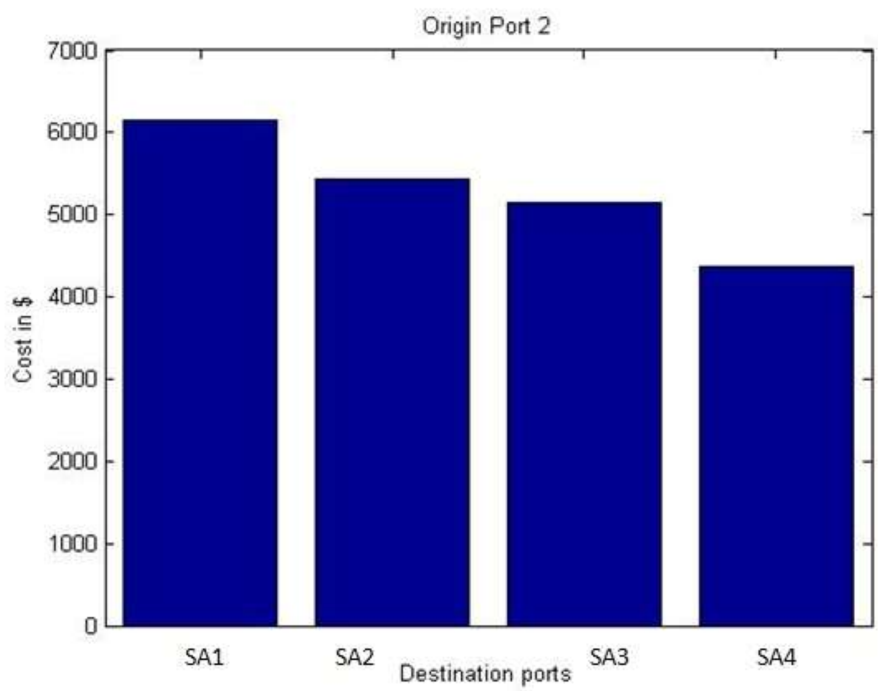


Figure B 153 Cost analysis Bahezhen (C) – destination ports (SA)

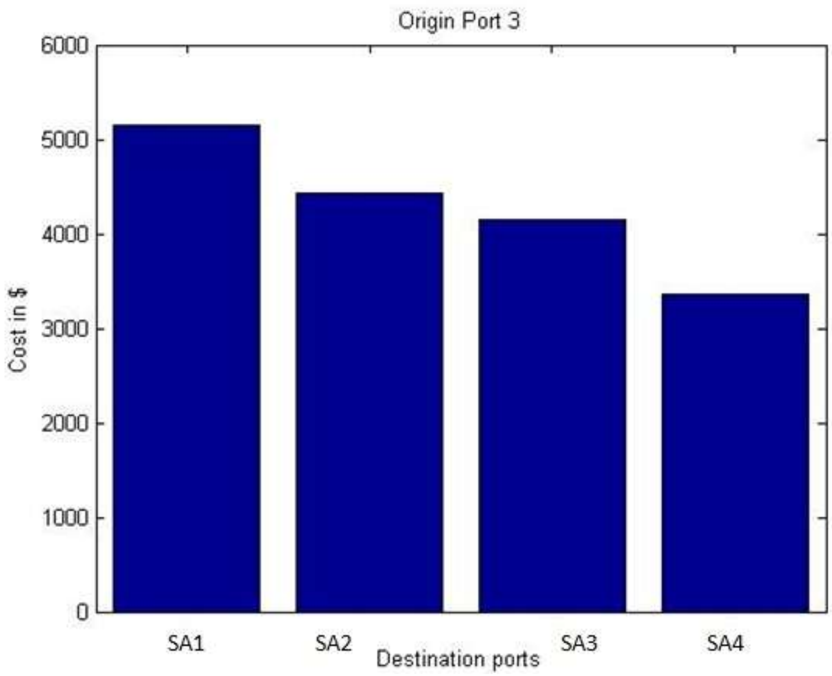


Figure B 154 Cost analysis Port of Xiamen (C) – destination ports (SA)

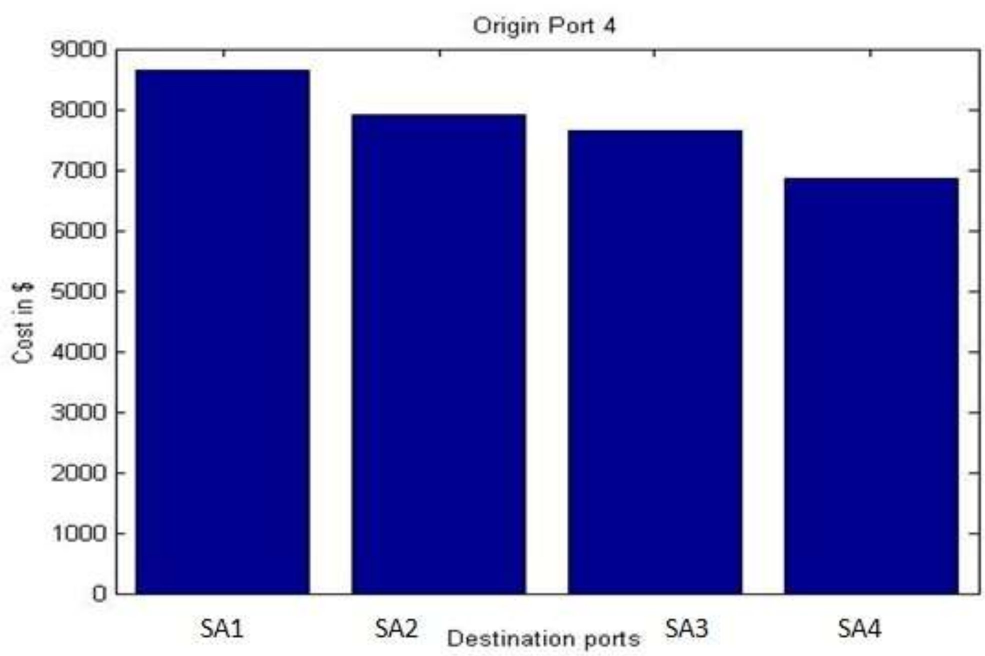


Figure B 155 Cost analysis Port of Tianjin (C) – destination ports (SA)

Optimized path: Shenzhen- Xiamen -East London –Gauteng

d) Suzhou-Eastern cap

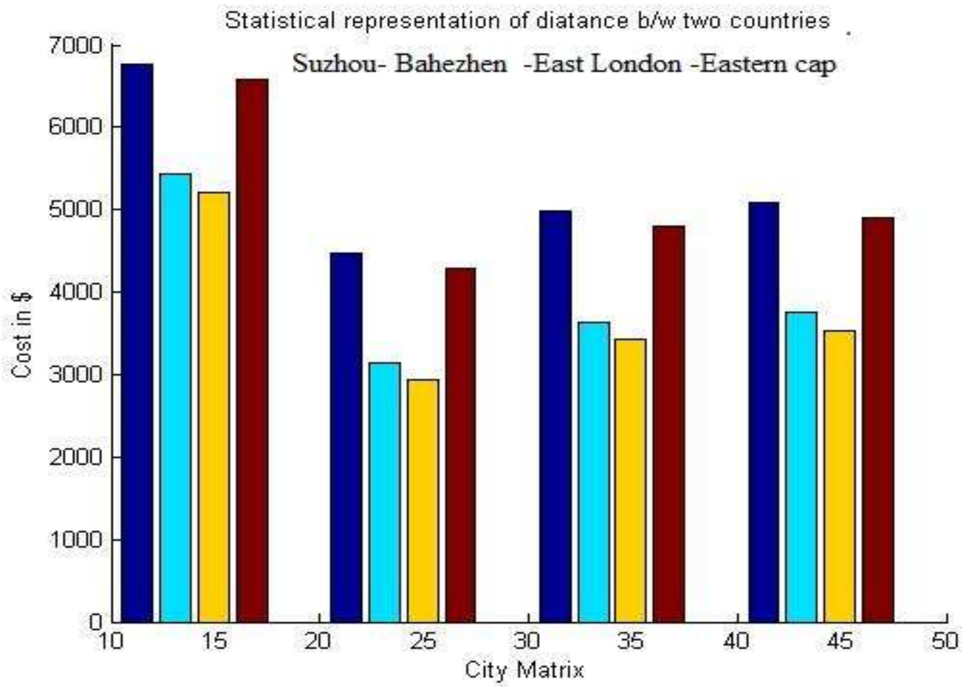


Figure B 156 Cost analysis Suzhou-Eastern cap

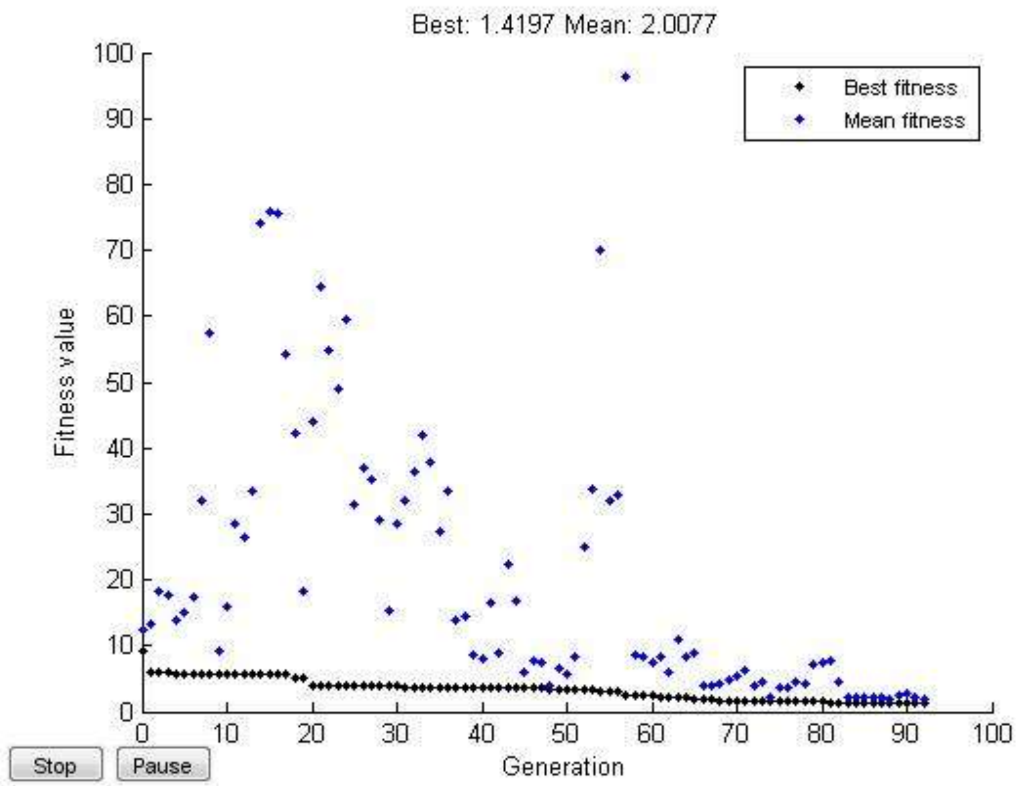


Figure B 157 GA analysis Suzhou-Eastern cap

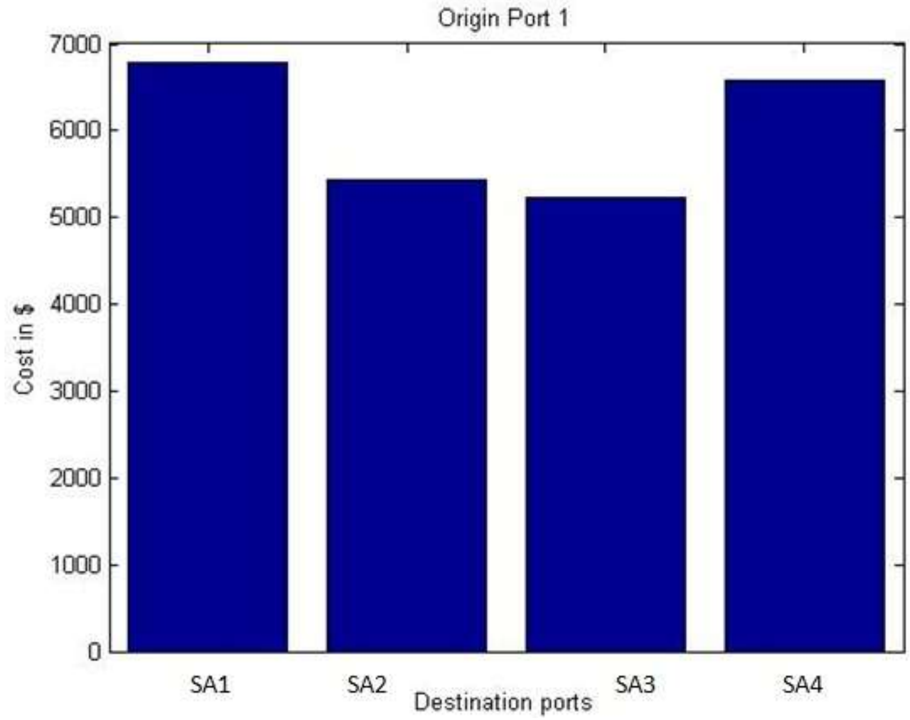


Figure B 158 Cost analysis Zhanjiang (C) – destination ports (SA)

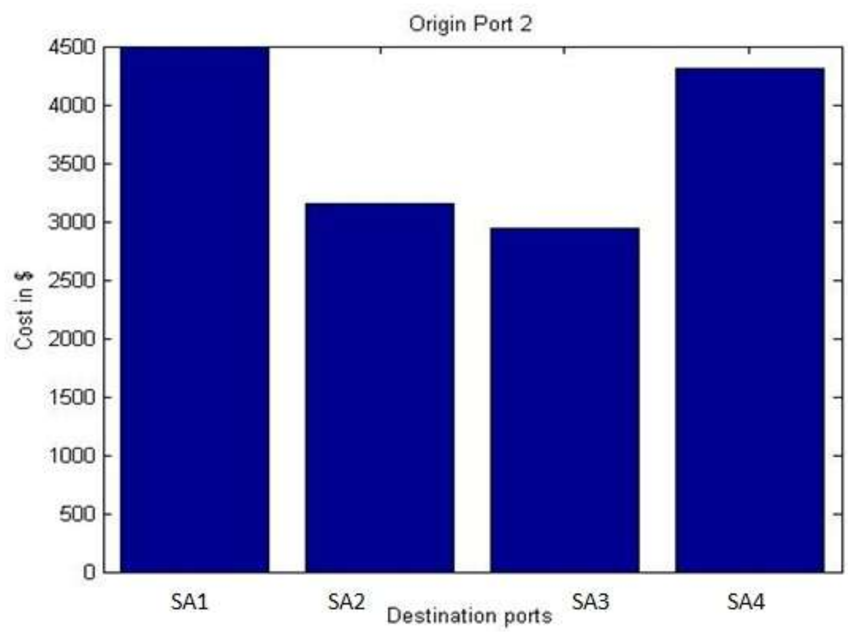


Figure B 159 Cost analysis Bahezhen (C) – destination ports (SA)

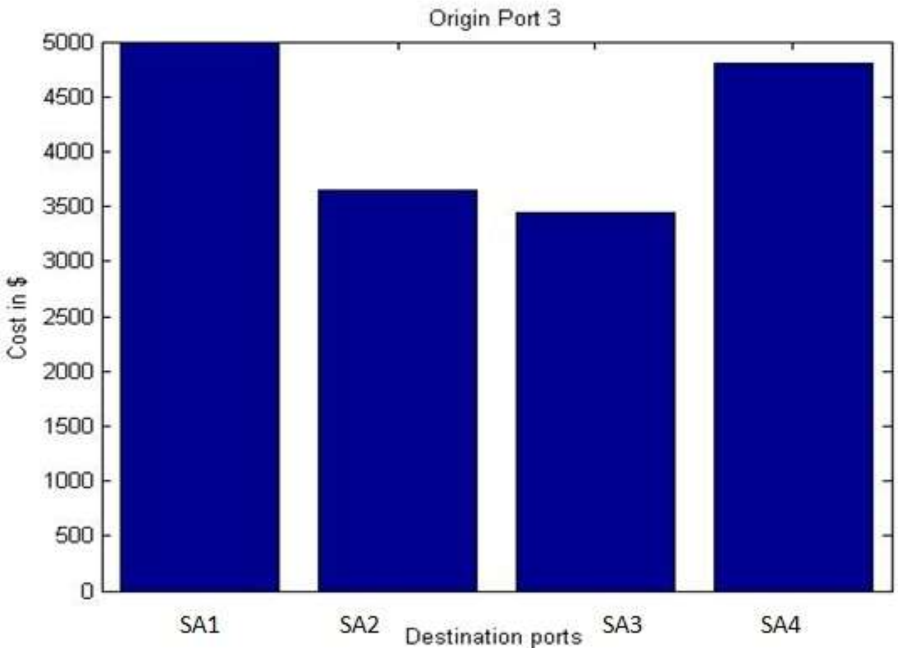


Figure B 160 Cost analysis Port of Xiamen (C) – destination ports (SA)

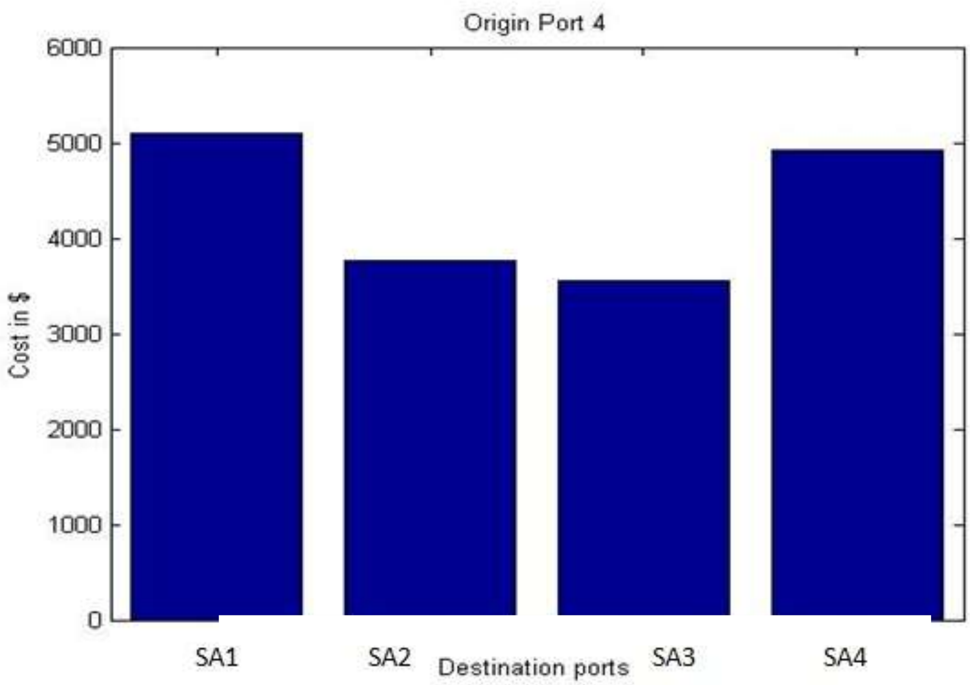


Figure B 161 Cost analysis Port of Tianjin (C) – destination ports (SA)

Optimized path: Suzhou- Bahezhen -East London -Eastern cap