WORKING TOWARDS A FORECASTING MODEL AND FACTORS AFFECTING THE TANK CONTAINER MARKET

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Preface and Acknowledgements

This report is not confidential. The Graduate School of Business may use it freely.

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We certify that except as noted above, this report is our own work and all references used are accurately reported.

Signed:

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9. List of Abbreviations

APEC: Antwerp / Flanders Port Consultancy
CEFIC: European Chemical Industry Council
CMR: Convention for the Carriage of Dangerous Goods
IBC’s: Intermediate Bulk Container
IMDG: International Maritime Dangerous Goods Code
IMO: International Maritime Organisation
ISO: International Standards Organisation
ITCLA: International Tank Container Leasing Organisation
ITCO: International Tank Container Organisation
JIT: Just-in-time production
RSMSE: Root Square of the Mean Square Error
SATCA: South African Tank Container Association
SQAS: Safety and Quality Assessment System
TCA: Tank Container Association
teu: Twenty-foot equivalent unit
TCFS: Global Tank Container Fleet Size
WORKING TOWARDS A FORECASTING MODEL AND FACTORS AFFECTING THE TANK CONTAINER MARKET

EXECUTIVE SUMMARY

This study is an initial step towards the development of a forecasting model for global tank container demand. It initially discusses the demand side and supply side factors that have influenced tank container market in the past and are expected to do so in the future. With regard to the demand side, the main factors that were identified are chemical production, environmental regulation, national security and safety factors and logistical factors. The supply side factors that were discussed are over-capacity, durability of tank containers, pricing, incentives for investing in tank containers (limited to South Africa) and the threat of China as a emerging tank container manufacturer.

Having discussed the influence of chemical production on tank container demand, this study progresses to identify twenty high volume chemicals that are legislated to be transported in tanks. A statistical analysis of the relationship of the production volumes of these chemicals with global tank container fleet size was completed, using standard multiple regression and forward stepwise regression techniques. Six chemicals were found to significant predictors of global tank container fleet size. However, the analyses were adversely influenced by multi-collinearity between independent variables. The study concludes that the dependent variable, global tank container fleet size is a poor approximation of global tank container demand, due to the presence of over-capacity in the world tank container fleet. It offers recommendations for successive studies towards the development of forecasting model for global tank container demand.
1. INTRODUCTION

1.1 Overview

This study identifies the factors that influence tank container demand with a view to laying the foundation for the development of a forecasting model for global tank container demand. It identifies and discusses the demand and supply side influence that have impacted the tank container market in the past and are likely to do so in the future.

The following are identified as significant influences:

- the tank container industry is demand driven by the chemical production industry;
- there has been consolidation in the tank container operator industry;
- tank containers are ideally suited to take advantage of the JIT production trends, as well as environmental, safety and security legislation changes; and
- price is the most important determinant of transport mode choice for the transport of chemicals in Europe.

In terms of supply side factors in the tank container market, the following factors were identified:

- reasons for over-capacity in fleet;
- the downward pressure on pricing due to over-capacity, as well as a decrease in the price of tank container components and raw materials, particularly stainless steel; and
- the emergence of China as a potential major future competitor.

This report will also:

- identify twenty of the highest volume chemicals produced, that are transported in tanks;
- perform standard multiple regression analyses and show the shortcomings of this statistical method; and
• perform forward stepwise regression analysis in order to generate a model that predicts tank container fleet size, using 6 significant regressor chemicals, *ceteris paribus*.

Finally, this study will identify a way forward for successive studies of tank container demand forecasting.

### 1.2 Background

At present there is limited information regarding the contents and volumes of products shipped in tank containers. It is accepted that the main commodities travelling in tank containers consists of chemicals and high-value beverages, however, limited data exists on the actual quantities of these products transported in tanks. Of total world tank container production, more than one-third is located in South Africa, particularly by companies like Consani (one of the world's largest producers of tank containers) based in Cape Town and Welfit Oddy based in Port Elizabeth. South Africa was responsible for 35% of global tank container production in 2001, with an average production of 37% over the last five years. Presently the tank container manufacturing industry is experiencing depressed trading conditions, both in terms of the low prevailing market prices of tank containers, and the apparently decreasing demand for new tank containers. The South African tank container manufacturing industry thus finds itself in a situation where it needs to understand the drivers of tank container demand in order to be able to forecast what the future global demand for tank containers is likely to be.

The present world fleet of tank containers is 158,000 units. This figure is made up of approximately 140,000 ISO tank container units and around 18,000 swapbody tanks. The tank container industry structure is illustrated in the figure below. Tank containers are owned by either lessors, transport operators or investment houses. End users access these tank containers by contracting with one of these groups for the use of their tanks.

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1 Source: Rowe-Setz and Webb-Martin 2001, page 14
The figure above represents the tank container industry structure in South Africa, and according to SATCA, can be assumed to be similar to the structure of the tank container industry in the rest of the world.

1.3 Study Area

Research Question
This study aims to create an understanding of the factors that influence the tank container market, as an initial step towards developing a forecasting model for tank container demand. It comments on both demand- and supply-side effects. The report then undertakes an analysis of the chemical contents of tank containers. This is done by looking at UN and IMO legislation, as well as performing standard- and stepwise multiple regressions on the data, which includes global tank container fleet sizes from 1990 to 2001 obtained from Drewry Shipping Consultants (Drewry) and global production tonnages of the top 100 chemicals obtained from the European Chemical
Industry Council (CEFIC) and the American Chemical Association. This study will identify significant chemical contributors to tank container demand, and statistically analyse the relationship of the annual production quantities of these chemicals (over the period 1990 to 1999) with global tank container fleet size over the same period. Finally, this study will consolidate all the afore-mentioned points to make recommendations towards building a forecasting model for global tank container demand.

1.4 Methodology

Data Collection
At the commencement of this study, it was decided to acquire data of commodities that are predominantly or always transported in tank containers. In order to access this information it was decided to make enquiries with the European Tank Container Terminal, as well as the Ports of Antwerp, Rotterdam and Le Havre who handled significantly large quantities of all container traffic in the EU. The primary contact would be APEC (Antwerp/Flanders Port Consultancy), while secondary information sources would include local chemical producers and end-users (eg. South African Nylon Spinners, Sasol), as well as South Africa’s main tank container manufacturers: Consani and Welfit Oddy. Previous studies and reports relating to the tank container industry would also be used in this investigation.

This initial data search proved to be problematic as these initial primary and secondary data sources could only provide anecdotal or spurious information. Raw data was not available so it was decided to broaden our search to include international container operators, shipping lines, shipping consultants, as well as shipping, maritime, container and tank container associations. These included: ITCLA (International Tank Container Leasing Association), ITCO (International Tank Container Organisation), TCA (American Tank Container Association), World Cargo News, Antwerpse Scheepvaartvereniging (professional organization of shipping), BASF Antwerpen, Bayer Antwerpen, GAMU (association of shipping agents), VEA (professional association of freight forwarders), Drewry Shipping Consultants, CEFIC (European Chemical Industry
These parties were contacted and engaged by means of telephonic and Email interviews.

Although local shipping data for possible commodities that are transported in tank containers was obtained from the National Ports Authority of South Africa (NPA) and the South African Port Operators (SAPO), this data was not analysed as it represented too small a sample size. Furthermore, the South African data was only available for only two years and was not only subject to local effects (like the statistically skewed data due to the transport of wine and beverages in tank containers as South Africa is a major exporter of wines and deciduous fruit products), but shipping mode is not recorded by South African operators, so it would add little value to this study.

The data that was acquired included statistics on world tank container type and total fleet sizes, tank container production and disposal, tank container owner, tank container fleet by geographic region, tank container production by region, just-in-time publications, EU chemical production figures and world chemical production figures. This data was captured in Excel spreadsheets and graphs were plotted to yield further information and insights with regard to factors that influence tank container demand. Data was transformed and imported into Statistica so that multiple and stepwise regressions could be performed that would identify the demand drivers for tank containers. Statistical tests were performed on various parameters, particularly coefficients of correlation, coefficients of determination, p-levels, Beta values, partial and semi-partial correlations, residual analyses and collinearity. The Statistica software package was the primary tool used for performing the statistical analyses, while the statistical function in Excel was used to a lesser extent.
1.5 Assumptions & Limitations

Assumptions
In identifying the factors influencing tank container demand, it was assumed that the statement “tank containers are demand driven by the chemical production industry” made by both Drewry and Rowe is accurate, and has therefore been accepted as an axiom in this study.

In completing the statistical analysis, it was assumed that the standard multiple regression technique is suitable as an initial filtering mechanism for identifying significant variables to feed into the forward stepwise regression method. It is assumed that the top 100 basic chemicals (by quantity produced) has not changed significantly since 1999, both in terms of the chemicals are ranked in the top 100, as well as the relative proportions of the production quantities of these chemicals to each other.

Limitations
In identifying the factors influencing tank container demand, the initial telephonic and personal interviews and email questionnaires proved not to yield any hard data with regard to either tank container production or fleet statistics. For competitive reasons, the interview respondents were reluctant to disclose any operational statistics, so it was decided to pursue information from a qualitative perspective, but this search initially yielded very little and inconclusive information with regard to the slowing demand of tank containers in recent years, world tank container fleet sizes, tank container durability, and tank container contents. Drewry Shipping Consultants, SATCA, Hazardous Cargo Bulletin, American Chemical Association, International Marine Dangerous Goods code, Logiq and CEFIC are the main sources of information gathered. The interviews that we conducted yielded many interesting insights into the tank container industry, all of which are documented.
2. FACTORS INFLUENCING THE TANK CONTAINER MARKET

This section discusses the main factors that have affected the global tank container market in the past and which are expected to influence the market in the future. In so doing it identifies the main factors that would need to be considered when developing a forecasting model for tank container demand. It includes three sections, namely a tank container and competitor description section, a section on the demand side factors and, finally, a section on the supply side factors. The first section states the reasons for the development of the tank container and describes the basic types of tank containers that presently constitute the world fleet. It continues to identify the main competitor products of tank containers and their main advantages and disadvantages. The next section (demand side factors) initially discusses the main product groups that presently travel in tank containers and then goes on to describe the major factors that have influenced global tank container demand. It cites global chemical production, logistical factors, environmental regulation, as well as legislation, national safety and security as the main tank container demand drivers. It then continues to describe the factors that have influenced the choice of transport mode for the transport of chemicals in Europe. The last section (supply side factors) describes the major factors that have influenced the global supply of tank containers. It starts by discussing the over-capacity that has been present in the world tank container market over the past few years and the migration of the tank container manufacturing from Europe to developing countries, most notably South Africa. It then cites China as a major threat as a low cost / high volume manufacturer in the future. It continues to describe the financial incentives that have contributed to the proliferation of tank container investors in South Africa and possibly contributed to the present global over-capacity. Finally, it describes the tank container pricing issues that presently affect the market.

2.1 Tank Container and Competitor Description

“The tank container was designed to take advantage of the growing infrastructure for handling ISO freight containers and promote seamless door-to-door movements of liquid
products. Initially, at least, the product was marketed as an alternative to the transport of goods in drums inside freight containers. It was also apparent that a tank container offered additional security and product integrity, particularly for substances that were highly aggressive or toxic or those which, because of purity requirements, need to avoid contamination (eg. high value beverages, certain chemicals).”

The statement above describes the main reasons for the introduction of the tank container. Since its introduction, specialised product and transport needs have lead to the development of a number of varieties of tank containers. The main tank container groups are discussed below.

The global fleet of tank containers is primarily composed of ISO (International Standards Organisation) units, which are predominantly used for long haul on containership carriage, and swapbodies, which are use on shorter haulage distances. Because ISO units are used for long haul purposes and deepsea usage on container ships, their design is robust and there is no logistic distinction between these ISO tank container units and conventional containers. The robustness of the design allows ISO units to be stacked nine-high on container vessels.

In contrast to the ISO units, the swapbody tank containers’ design specification is less robust, as these swapbody units do not have a standard ISO frame construction that protects the tank. Whereas the extremity of the ISO unit is the ISO frame itself, it is common that the tank of swapbody unit protrudes the frame construction. The usual absence of corner castings in the swapbody units not only prevents it from top lifting by conventional container terminal and ship lifting equipment, but this also restricts swapbodies from being multi-stacked on container ships or in terminal stacks. This physical trait precludes swapbodies from deepsea container ship usage and restricts swapbodies to usage on road, rail and inland waterways.

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2 Source: Drewry Shipping Consultants 2000, section 4
3 Source: Drewry Shipping Consultants Table 1.1, Figure 1.1 in Appendix A.
ISO tank container units are usually only manufactured in 20ft (teu or twenty foot equivalent unit), 30ft and 40ft variations. The most common type is the 20ft units which makes up 95.5% of the present global ISO tank container fleet and 84.3% of the present global total (combined ISO and swapbody) tank container. ISO tank containers comprise 88.3% of global total fleet, while swap bodies make up the balance of 11.7% fleet (see Table 1 below).

The most common swapbody type is the “Class C” length of approximately 24ft, which makes up 56.8% of the present global swapbody tank container fleet. Presently, 20ft and 40ft swapbodies make up roughly 20% each of the total swapbody fleet, while the big 40ft units make up only 3.2% of the world swapbody fleet. The 40ft units in either swapbody or ISO unit format are by far the most uncommon as together they contribute less than 1% of the entire tank container fleet. This is unlikely to change, as the growth rates in 40ft formats have been static over the last 3 years. The most common tank container format, the 20ft ISO unit has experienced an average growth rate of approximately 5% over the last 3 years.

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Figure 2

Global ISO Tank Container Composition

Figure 3

Global SWAPBODY Tank Container Composition

Figure 4

World fleet of tank container by type 1992-2001
The proliferation of 20ft tank containers is an indication of the maximum road axle weights or payloads imposed on vehicles. The 20ft tank container is the most effective tank for size / weight optimisation. It was found that in most cases the larger 30ft and 40ft formats are unable to be filled as the maximum payloads of road vehicles would be exceeded. Such 40ft units are therefore unlikely to be completely filled with product. These partially filled tank containers present an additional transportation hazard as the product slops around in the partially filled tank which can cause movement of the container in its ship stack. The larger 30ft and 40ft tank container formats have proved ideal for the transportation of lightweight or lower density products and pressurised gases.

Drewry 2002 quotes that the average life of a swapbody unit is between 12 and 15 years, whereas an ISO unit has an average life of around 15 years. SATCA 2001 states that the average life of ISO units will increase to around 20 years due to the improvements in both manufacturing techniques and materials. This is an indication that the replacement rates of the two tank formats vary significantly enough to impact the supply market of tank containers. Drewry states that prior to 1990 swapbodies were practically unknown, but that this format has increase six-fold in the last ten years since 1992.

The global tank container fleet is predominantly composed of units that comply with the IMO1, IMO2, IMO5 and IMO7 standards. IMO1 makes up the bulk of all individual tank container (ISO and swapbody) fleets.

- IMO1 is suitable for the transport of most liquid hazardous substances, which includes flammable liquids, oxidising substances and organic peroxides, toxic and infectious substances, as well as corrosive substances. The IMO1 category of tank containers has proven to be the most versatile as GTTL (Global Trade, Transportation and Logistics)\(^4\) indicate that this accounts for 4 of the 9 hazardous material transport

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classes. This IMO1 class currently accounts for approximately 75% of the global tank container fleet\(^5\).
- IMO2 class tank containers account for another 15% of the global fleet and this class caters for the transport of non-hazardous cargoes and predominantly foodstuffs and beverages.
- IMO5 are pressurised gas tanks making up approximately 7.5% of the world fleet. Explosives and gases are considered as 2 of the 9 hazardous material transport classes identified by Global Trade, Transportation and Logistics.
- IMO7 or cryogenic tanks contribute the 2.5% balance of world tank container fleet.

Competitor Products
The feasibility of using tank containers for the transport of products (mostly liquid) depends on a number of factors, including the volume of product to be transported. Beyond a certain threshold of volume, distance and value of product, bulk transport becomes a more economically efficient or logistically feasible option. The potential tank container market therefore covers a limited feasible range only, and within this range a number of alternative modes of liquid and chemical transport compete. Steel drums have been the traditional means by which smaller unit lots of these products were transported. Tank containers have presented an ideal intermediate size between drums and IBC’s (intermediate bulk containers). IBC’s form an important competitor product in that they are also able to serve as storage units. In fact some IBC manufacturers have started to promote the use of these tanks within the user’s production process. However, especially for longer haul routes, tank containers still have the advantage of being completely compatible with conventional freight containers in terms of both stacking and handling.

The advantages presented by drums is that they are cheap, disposable, capable of re-use and usually do not require specialist handling equipment. The latter characteristic is particularly important in under-developed and embryonic developing countries where the initial high capital investment costs of both tank containers and the relatively sophisticated handling equipment precludes the use of this particular mode of transport.

\(^5\) Source: Drewry Shipping Consultants 2002, section 5.1
Drewry’s\textsuperscript{6} analysis suggests that steel drums remain the largest single mode of (small batch) chemical transport. A distinct disadvantage of drums is the constraints of environmental regulations, as well as the labour intensive nature of handling breakbulk drums. In under-developed countries this labour intensive component may indeed favour and promote the use of drums.

Until recently, developing countries like China preferred that chemical imports be received in drums. This allowed local Chinese industries to re-use the drums for regional distribution as well as exports, due to the lack of tank container handling equipment and cleaning facilities. This has, however, changed in China’s recent emergence as a global producer.

It is noted that drums and the freight containers that carry them are considered as commodities. Tank containers, on the other hand, are specialised and relatively expensive. For this reason tank container operators try to ensure back-haul or return or onward cargoes so that the dead handling and storage costs of empty tank containers are minimised.

Rowe, Dow Chemicals, and Drewry imply that the recent global focus on Sustainable Development and the triple bottom line of economic prosperity, environmental stewardship and corporate social responsibility has caused an erosion of the drum market by competing products, like tank containers, due to stricter environmental policies and regulations being imposed. The drum manufacturing industry has responded by innovations in drum design that aims to optimise the packing density and configuration of drums in conventional freight containers.

In certain cases, especially in the transport of hazardous materials, the environmental and safety considerations outweigh the operators’ concerns for back-haul or onward cargoes. The shipment of hydrogen peroxide from the US to South America is a case where shipment is prescribed in tank containers with little hope of back-haul cargoes.

\textsuperscript{6} Source: Drewry Shipping Consultants 2002, section 4
2.2 Demand Side Factors & Drivers

This section describes the main factors that have created a demand for tank containers. It briefly describes the main product groups travelling in tank containers and then goes on to discuss each of the main factors that have influenced tank container demand, namely chemical production, logistical factors, environmental regulation, as well as national safety and security regulations. The last section lists and discusses the factors that influence the choice of transport mode for chemicals leaving Europe.

Tank Containerised Products
Since its introduction, the tank container has been used for the transport of two main product groups. Rowe states that according to SATCA, 80% of tank containers are engaged in chemical transport and 20% in foodstuffs and beverages. Drewry quotes the same source and statistics for world tank container contents. It should be kept in mind that South Africa produces more than 33% of the world’s tank containers and that the 20% figure quoted for beverages and foodstuffs might be a local effect. The combination of this local effect and the high tank container production (and subsequent export) volumes may skew the South African statistics from the global sample of products that are transported in tank containers. South Africa is a world-class producer of wines, so rather than shipping tank containers empty to the large tank container operator centres in the EU, tank containers are filled with wine on their maiden voyage. Local effects like these should be taken into account when quoting tank container contents. In an interview with an international tank container operator, a respondent stated that there has been an increasing trend for South African wines to be exported in plastic liner bags. Furthermore, many wine estates have recently chosen to export in retail bottles to safeguard quality and brand, as well as increase their brand awareness.\footnote{Source: LOGIQ 1999: Analysis of the decision making process in intermodal transport in the case of chemical products, page 17}
2.2.1 The Chemical Industry: Primary Driver of Tank Container Demand

As stated previously, the demand for tank containers derives primarily from the chemical industry with an estimated 80% of all tank containers being used for the transport and temporary storage of chemicals (Rowe). Globally, the chemical industry has been subject to two major trends over the past decade, namely: increasing globalisation and a focus on core operations. The former trend has seen major chemical producers expanding their markets internationally, making transport more complex. This move has also seen them enter highly competitive markets, making pricing and efficiency a fairly important aspect of their product offering. The latter trend (focus on core functions) has involved chemical companies outsourcing their transport and logistics operations completely to transport operators. These operators then take over more than just the transport and distribution services of the company. They also take over the complete management of inbound and outbound logistics of the company.

Another reason for this outsourcing is the fact that return on investment in transport equipment is considered relatively low. In seeking “transport partners”, the non-negotiables are safety and reliability. Order lead time is often very short, but nevertheless an important requirement of the end customer. This does not, however, always mean that transport speed needs to be fast. Often systems are developed that involve storage close to potential customers or more advanced logistics solutions like floating stock are created. Tank containers are considered ideal as a means of both quick transport to remote areas and as a means of short term storage. While these are both important aspects, due to the competitive nature of the chemical industry, price remains the overarching criterion.

Transport operators are forced to operate within the constraints that the competitive environments of their customers impose. Because of this and fluctuations in the chemical industry, there has been a general trend amongst operators to expand their coverage areas in order to meet the needs of their clients. Transport operators are also forced to comply with the safety, environmental and regulatory constraints placed on them through
chemical industry regulation. This requires significant capital investment, since equipment is expensive and highly specialised. In addition, personnel need to be highly qualified and regularly trained.

In line with the global trend towards mergers, both the chemical industry and transport operator industry have seen significant consolidation over the past decade. Hilfra Tandy, editor of Chemical Matters calculates that global Ethylene production, an important indicator of overall chemical production, stood at 80 mil tonnes pa in 1995, produced mostly by 20 companies. By 2000, the figure has risen to 104 mil tonnes, but due to consolidation, this capacity was provided by only 11 companies.

2.2.2 Logistical Factors Influencing Tank Container Demand

Another driver of tank container demand is its suitability both as a component in the Just-In-Time (JIT) production system and as a mode independent transport unit, suited to intermodal transport.

JIT is a technique and philosophy that originated in Japan in the early 1950’s that is associated with the Toyota motor company. It focuses on the elimination of waste in all forms, for example: inventory or waste associated with holding stock, defect or waste associated with defective items, overproduction, waiting time and transportation time. In its simplest form, it seeks to only move items through a production system when they are needed. A consequence of this is a general trend to a stockless environment on the supply side outside to the production system, as well as a stockless environment inside of the production process. This requires that inputs arrive and outputs leave a production process in optimum quantities.

The tank container is therefore ideally suited to this type of production environment, because its storage and transport characteristics allow it to be used at both the inbound and outbound ends of a production system without requiring manual labour for packing.

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8 Source: LOGIQ 1999: Analysis of the decision making process in intermodal transport in the case of chemical products
9 Source: Drewry Shipping Consultants 2002, section 4
and unpacking. Beasley\textsuperscript{10} states that “in a manufacturing operation, component parts could conceptually arrive just-in-time to be picked up by a worker and used. So we would at a stroke eliminate any inventory of parts, they would simply arrive just-in-time”.

The Western trend towards stockless production stimulates intermodal means of transport. Intermodal transport implies that cargo or freight is transported as an unbroken, amorphous, self-contained unit from source to destination, in a seamless movement from door-to-door. Intermodality is best described by the phrase “mobile pipeline”, it is not only a mode of transport, but also a mode of storage. Intermodality implies that cargo will be transported as a unit across various modes of transport, i.e. road, rail, air and sea. All forms of intermodal transport provide a remedy to the pressures exerted on suppliers of chemicals to JIT enabled clients. According to LOGIQ\textsuperscript{11} “the tank container is more or less mode independent, and very suited to use in intermodal transport chains”. Intermodality gives the supplier of chemicals buffer storage capacity in close proximity to their clients. With the ever-increasing demands place by the client in a customer-centric business environment, it is imperative that the supplier of chemicals can respond immediately to a call for raw materials. The intermodality presented by tank containers gives the suppliers a “floating stock” that can be easily and speedily deployed to the client. LOGIQ\textsuperscript{12} states that “intermodal transport could be a more expensive option if door-to-door transport of a single trip is considered, but due to the use of tank containers advantages in storage and quick access to remote regions can be achieved.”

Liveris (Business Group President, Dow Performance Chemical) emphasises the importance of the entire logistics chain in meeting the demands of the end-users or customers of chemicals. There is a need for a globally harmonised framework of chemical suppliers and distributors in a channel partnership. The chemical supply and distribution partnership will seamlessly deliver raw materials to the door of the client.

\textsuperscript{10} Source: JR Beasley, http://www.ms.ic.ac.uk/jeb/or/jit.html
\textsuperscript{11} Source: LOGIQ 1999: Analysis of the decision making process in intermodal transport in the case of chemical products
\textsuperscript{12} Source: LOGIQ 1999: Analysis of the decision making process in intermodal transport in the case of chemical products
This logistic chain is constrained by the critical or tightest path, be it financial, operational or regulatory. In regard to client requirements, a logistics chain that is not harmonised in terms of economics, operations and regulations will fail to optimally meet client demands, consequently impacting adversely on the supply partnership.

2.2.3 National Security & Safety

The events of September 11th are expected to heighten the security requirements at all world ports and transport nodes, especially in the USA. This will enhance the market for tank containers as they have a major advantage over other competing modes of transport of being inherently safe, with very few incidents of damage, leaks or spills being reported. Even incidents involving tanks falling during loading or unloading operations between ship and port seldom result in product spills.

With the initiative by US security agencies to gain greater oversight over the movement of dangerous goods (which they regard as potential weapons of mass destruction), given the ease of identification of a tank container as a carrier of dangerous goods, it is likely to be preferred by these agencies as a transport mode of choice, and perhaps even regulated as an compulsory transport mode for certain potentially destructive products. This could be to the advantage of shippers as well who, rather than be delayed by the constant inspection stops that conventional containers (carrying filled drums or plastic liners) are routinely subjected to at US ports, would experience smooth passage through these ports via tank container usage.

The US government has already created a provision that compels chemical producers to keep a closer account of the movement of their chemical goods throughout its journey. Considering that it takes approx. 100 drums to ship the same amount of product that can be carried in a tank container, the tank container is a far more suitable option in that it would require only one tracking per unit rather than the uncertainty of tracking a conventional freight container with no assurance that the goods inside will remain intact.

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13 Source: Global Trade, Transportation and Logistics 2002, page 53
14 Source: Drewry Shipping Consultants 2002, section 4
2.2.4 Environmental Regulation of Chemical Transport

This section discusses the environmental and safety regulations applicable to the transport of chemicals. It starts by describing the main international environmental regulations applicable to the transport of chemicals, then goes on to discuss the impact of regulation on the choice of chemical transport mode, and finally discusses the phenomenon of self-regulation by companies within the chemical industry.

Environmental Regulation in the Chemical Transport Industry

Due to the fact that a large proportion of chemical goods is considered hazardous, the transport of chemicals is subject to stringent regulations. While this is a significant driver towards tank containerisation and thus a positive influence to the industry, it can often also be a negative factor to operators who are forced to comply with efficiency-reducing regulated processes.

The global chemical industry (production and usage) is concentrated in the US, Europe and Japan and these are also the areas that are subject to the greatest degree of environmental regulation. The United Nations has initiated the development of uniform safety regulations for the transport of dangerous substances at both national and international levels. These regulations apply to all modes of transport (tank container and other) where dangerous goods (both hazardous chemicals and other dangerous substances) are concerned. This initiative is meant to create a uniform standard throughout transport routes which transporters will be expected to comply with. Within the United Nations, the Economic and Social Council Committee of Experts on the Transport of Dangerous Goods (ECOSOC) makes recommendations that are presented to government, for the creation of new regulations or amendment of existing regulations, and international organisations, who develop mode specific rules (e.g. IMO). The UN recommendations cover a number of aspects relevant to the tank container market, but most importantly, they cover the classification and listing of dangerous goods that require special treatment, as well as the packaging specifications required for the safe transport of these goods. Due to the high number of diverse goods that these regulations are meant to
cover, the classification is of great importance, since it is realised that it is not possible to
develop product specific regulations for each product. Classes of product have to be
considered as a group when dealing with these regulations. Although the regulations have
a multi-modal scope, they apply to tank container movement at every stage of its journey.
The most influential safety regulations (relevant to tank container products) that have
been developed for the transport of dangerous goods are given below:

- International Maritime Dangerous Goods Code (IMDG),
- Annex A and B of the European Agreement concerning the international carriage of
dangerous goods by road (ADR),
- Regulations governing the international transport of dangerous goods by rail (RID),
and
- European provisions for the carriage of dangerous goods by Inland Waterways
(ADN).

While these regulations apply to single mode transport only, the regulations in the case of
intermodal transport are hazier. There is no uniform system for liability in intermodal
transport, let alone in the case of dangerous cargo being transported intermodally. Once an
intermodal form of transport is chosen by a shipper for the transport of cargo, much of
the environmental and safety standards that will be complied with depend on the contents
of the contract between the shipper and the operator. The operator’s choice of transport
mode is also influenced by the national laws and regulations, which he will be subjected
to. It is noted that these regulations differ across country, product group and across
combined transport chain. Despite efforts by the UN to introduce uniform standards for
intermodal transport (eg. UN Intermodal Convention, UNCTAD / ICC Rules on
combined transport), each of these rules remain applicable to unimodal transport systems
only. In 1999, it was proposed to use the provisions of the International Convention on
Carriage of Dangerous Goods (CMR) as a default standard for intermodal transport. This
would mean that the CMR liability regime would apply throughout the whole of the
intermodal transport chain, unless a specific contract stated otherwise. This would give
clarity to shippers of dangerous goods, but would shift the responsibility of compliance to transport operators and other contracting partners inside the intermodal chain.

At a regional level, the European Union, the most influential regional organisation in Europe, implements international regulations within its own legislative framework. Its laws mainly involve the compliance of its member states with the international rules mentioned earlier, but also include the compliance of member states with its institutional requirements when transporting dangerous goods.

At a national level, in Europe, local or regional operators are expected to comply with international or regional regulation, but specific laws are also introduced in some cases. Sometimes a combination of laws is also chosen for operators involved in intermodal transport within a country, for example with road or overland transport being covered under one regulatory framework and air maritime transport being covered under another.

**The Impact of Regulation on Transport Mode Choice**

Differences in regulation between countries (or within countries between modes) may influence the choice of transport mode for hazardous chemicals, with the transport operator likely to choose the mode that provides the “lowest common denominator” or the “path of lest resistance”\(^\text{15}\) for all these regulations. Further, the impact of regulation can be twofold, either direct, causing physical bottlenecks or delays in the transport chain or restricting the use of a certain mode, or indirect, influencing the price or quality and consequently the attractiveness of the mode.

While influences are few (e.g. nations enforcing the use of certain modes for the transport of certain hazardous cargoes), the influence of indirect factors has been widespread. For example, regional or international regulation could result in one or more legs of an intermodal chain operating sub-optimally because of restrictions in another leg of the chain. In addition, the sum of individual liabilities in an intermodal chain total more than the single amount applicable in unimodal transport. With tank containers being so well

\(^{15}\) Source: LOGIQ 1999: Analysis of the decision making process in intermodal transport in the case of chemical products
suited to intermodal transport, these factors stand to influence the choice of shippers’/transport operators’ conversion to tank containerise.

**Self Regulation in the Tank Container Industry**

International regulations and national legislation around the transport of hazardous chemicals constitute a minimum standard for players in the chemical transport industry. Many companies have opted for a greater degree of safety when transporting their goods.

The reasons for this are generally twofold. Firstly, experience has shown that the costs of ensuring safety far outweigh the losses in sales and public image associated with unsafe transport or a serious accident. Secondly, with the move towards sustainable development globally, most corporations want to be seen as environmentally responsible, as this enhances their corporate image\(^\text{16}\).

A number of chemical companies worldwide have committed themselves to the “Responsible Care Programme”, a programme aimed at constantly improving the health safety and environmental performance of its participants. One of the tenets of this programme is the Safety and Quality Assessment Systems (SQAS), which has been developed by CEFIC, the European Chemical Industry Council. SQAS involves chemical companies checking the safety and environmental performance of their suppliers or transport operators via an independent assessment body.

Chemical companies can then use these assessments in selecting prospective suppliers and operators. In fact, following poor assessment results, chemical companies will often force operators to improve their services. The SQAS assessment criteria include measures of management practices and control, quality procedures and control, operational procedures and control, security measures and equipment specifications, maintenance and inspection. The voluntary provisions of SQAS are therefore also expected to influence tank container demand, since the inherently safe nature of tank

\(^{16}\) Source: LOGIQ 1999: Analysis of the decision making process in intermodal transport in the case of chemical products
containers is expected to give this mode a consistently higher score on the SQAS rating scales than older competitor modes.

2.2.5 Factors Influencing Mode Choice for Transport of Chemicals – European Perspective

According to LOGIQ\textsuperscript{17}, the main factors influencing the choice of a transport mode when planning to transport chemicals are economic factors, quality factors, logistics and added value services, technical aspects and legal aspects. Considering that each of these factors would therefore impact directly on tank container demand, they are discussed individually below.

2.2.5a Economic Factors

The decision of transport mode choice in the case of European chemical companies effectively amounts to a choice between pure road and intermodal transport. As mentioned previously, maritime tank containers are inherently suited to intermodal transport. With the chemical industry being as competitive as it is, \textit{ceteris paribus}, price has become the most important aspect when considering modal choice. According to LOGIQ\textsuperscript{18}, due to the highly competitive nature of road transport, the prices of road transport are generally lower than any other mode.

Another important factor with regard to price is related to dedicated closed loops of tank containers. In these dedicated “round trips”, empty tank containers are transported back to their place of origin without cleaning, as opposed to open loops where tank containers are cleaned, loaded and used for other destinations. The availability of cleaning facilities, the costs of cleaning and transporting empty tank containers have had adverse cost implications in the closed loop regime, but are sometimes necessary for the types of products being transported.

\textsuperscript{17} Source: LOGIQ 1999: Analysis of the decision making process in intermodal transport in the case of chemical products, page 23
\textsuperscript{18} Source: LOGIQ 1999: Analysis of the decision making process in intermodal transport in the case of chemical products, page 26
A further economic factor influencing mode choice is the differences in carrying weight allowed between road transport and intermodal transport. Presently the maximum allowable axle loads on European roads is 40 tons versus the intermodal possibility of 44 tons, reducing the cost per ton for the product being transported intermodally.

Transaction costs also influence the price differential between an intermodal choice of transport versus a pure road- or other alternative. Due to the multiple modes employed on intermodal journeys, the logistics and administrative effort is much greater on the part of the transport operator, making the transport of a small number of tank containers unfeasible.

Distance has an influence on the cost aspects of mode choice with intermodal options generally being considered viable on longer journeys only.

2.2.5b Quality and Safety Factors

Quality and safety factors relate mainly to the reliability and safety of the service offered by the transport operator when considering the type of products being transported. The inherently safe nature of tank containers rates highly with product owners. In some cases intermodal transport is chosen for reasons of safety when transporting hazardous goods through highly populated areas. In other cases pure road transport is used for the reason that the presence of a dedicated driver for each package transported was considered to be safer than intermodal transport where multiple handlers are used. With regard to reliability, in the European case, operators mentioned the relatively unreliable nature of intermodal transport in France due to strikes as well as unreliable barge services at some European ports, due to low water levels from time to time as deterrents.
2.2.5c Total Transport Time

According to LOGIQ, the total transport time of intermodal schemes is often poorer than competitor modes due to production processes and logistics not yet being completely adapted to intermodal services.

2.2.5d Flexibility

Contrary to what might initially be expected, intermodal transport is also considered less flexible than other modes. Operators are required to book storage and handling equipment well in advance. These equipment hire booking lead times decrease the flexibility of intermodal transport modes.

2.2.5e Technical Factors

Technical factors were not found to have a decisive influence on the decision of transport mode. However, a few operators mentioned that the additional features of newly developed tank containers to be a positive influence.

2.2.5f Logistics Services

Due to the fact that many chemical companies outsource the transport of their products completely to transport operators (especially in the EU) these transport operators, in turn, tend to centralise their decisions around mode choice for a number of transport operations, probably for reasons of achieving economies of scale. These decisions are strategic in nature, affecting modal choice on a national and even regional basis.
2.3 Supply Side Factors

This section discusses the factors that have affected the supply of tank containers in the past and which are expected to do so in the future. It starts by discussing the global over-capacity of tank containers that exists presently and continues to discuss the durability of tank containers and its implication for replacement of tank containers in the future.

2.3.1 Global Tank Container Over-capacity

Figure 5

Major sources\textsuperscript{19} state that the global tank container market has been oversupplied since the about the mid-1990’s. This has resulted in depressed trading conditions since lessors are willing to accept lower rates on their equipment to prevent them from standing idle. A further reason for these negative conditions is the fact that the chemical industry itself has been experiencing a downturn, causing a decrease in the volume of commodities that are being transported, as well as pressurising chemical companies to find cheaper ways to

\textsuperscript{19} Sources: Drewry Shipping Consultants 2000, 2001, 2002  
Rowe-Setz and Webb-Martin 2001
transport their products. This has resulted in operator and lessor profits being continuously eroded to the point where it has become unfeasible for many of them to continue operating (due to low profits plus the low utilisation of their tanks). The result has been a continuing consolidation in both the operator and lessor industries, with many transport operators and lessors selling their entire fleets to better positioned competitors.

Another factor contributing to the depressed trading conditions has been the proliferation of tank container manufacturers in various areas of the world. While much of the world’s tank container manufacturing capacity still exists in Europe, European producers have steadily lost ground throughout the 1990’s to the now maturing South African contingent, who have grown their market share from an insignificant share pre-1990 to about 35% of world ISO tank container supply presently. The highly competitive South African manufacturers have contributed to the commoditisation of tank containers and so indirectly contributed greatly to the depressed market conditions. The country’s relative competitive strengths (relatively low labour and material, mostly stainless steel costs) has put consistent pressure on new tank prices and taken business away from their European counterparts. The European response has been to focus on more specialised tank production.

For the reasons stated above, it can be concluded that the global tank container fleet has not been fully utilised and has not mirrored the demand for chemicals over the past decade. While this has created a highly competitive market, it has also created strained market conditions.

An attempt to establish a relationship between the global production of chemicals and the world fleet size at any particular time would therefore include a considerable amount of “noise” resulting from the uncertainty about the utilisation rates of the existing equipment. A number of tanks would, naturally, be standing idle or have low utilisation levels at any particular time.
2.3.2 Durability

According to Drewry\textsuperscript{20}, approximately 20% of the world fleet is older than ten years and is still in use. The average age of tank containers has been found to be around 6 years. From discussion with industry, it was found that once tank containers reach an age where they are unfit for the transport of goods, they are used as short term storage units. SATCA reports that improved recycling / re-manufacturing capability is extending the life of tanks. Disposal rates have been relatively modest over the past few years, and according to Drewry, are expected to remain fairly modest in the foreseeable future. There has been a once-off large-scale clearance of redundant tank containers in recent years, following the widespread rationalisation of the tank container industry. This has possibly created the conditions for ongoing slow to moderate disposal over the next few years. Disposals of swapbody tanks are, however, expected to continue at a higher rate than maritime tanks, due to their differing manufacturing specification.

2.3.3 Tank Container Investment Incentives (Limited to SA Manufacturers)

As stated previously, the entry of South African manufacturers into the market has been swift and forceful. Given that the returns on transport equipment are not as high as those from many alternative investments (the chemical industry, for example), a brief study was undertaken to identify the investment incentives that have assisted the proliferation of South African tank container investors.

One of the major drivers of tank container investment in South Africa has been the need to overcome the effect of exchange controls that limit the amount of capital South African citizens are allowed to invest offshore to R 750 000. In a depreciating currency, despite the relatively low returns on transport equipment from a European perspective, the South African investor still stands to gain from the favourable effects of a strengthening foreign currency when the revenue from the tank container operations are converted back to Rand terms. This effectively amounts to exporting and benefits from exchange rate differentials.

\textsuperscript{20} Source: Drewry Shipping Consultants 2002, section 5
A further incentive to the South African investor, according to an acknowledged tax specialist from a large financial services company, are the tax benefits that can be enjoyed by those investors expecting to receive a taxable lump sum payment within two years of a tank container investment being made. Because the tax rate applicable to the lump sum payout is equal to the higher of the individual’s effective income tax rates over the last two tax years, such an investor would stand to benefit from the nett effects of a loss in the early stages of a tank container investment, which results from the customary accelerated depreciation of tank assets. This has the nett effect to the tank container investor of causing an income tax rate drop, enabling him to enjoy the same lower rate when paying tax on his lump sum payment. Further details of this scheme are given in Appendices. These phenomena have been contributing factors to the market imperfections in the tank container market and the resulting over-capacity that is creating depressed trading conditions.

2.3.4 Pricing

The market conditions mentioned previously have put steadily increasing pressure on newly built tank container prices. This has added an additional dimension to the competitive situation, with prices dropping below profitable threshold levels for many European manufacturers, forcing them to seek alternative products for their productive capacity.

As can be seen the figure below, tank container new-build prices remained relatively high throughout the early- to mid-1990’s, in line with similar high prices in the conventional freight container and reefer container markets\textsuperscript{21}. This was caused by high materials costs, as well as a lack of price driven competition amongst manufacturers during this period.

\textsuperscript{21} Source: Drewry Shipping Consultants 2002, section 5
The drop off in price, post-1995 can be attributed to three factors. Firstly, the over-capacity created in the mid-1990’s created a buyer’s market with the resultant depressed prices. Secondly, the cost of the single largest material input into the production of tank containers, namely stainless steel, fell significantly over the late 1990’s putting further downward pressure on prices. Thirdly, the oversupply of tank containers and tank container productive capacity globally has caused the commoditisation of the product. This is evidenced by the fact that most European producers have shifted their production to focusing on specialised tanks only – this effectively amounts to product differentiation, a common response of competitors in a commoditising market in order to maintain profitability.

The situation has been worsened by the fact that freight rates for chemical and beverage products commonly transported in tank containers have come under increased pressure over the past few years. The chemical industry has been experiencing a period of weakness over the past 2-3 years as the global economy has faltered and this has had some adverse effects on the tank container market.
3.3.5 China – Competitor and Chemical Demand Driver

An additional competitive pressure that the global tank container market is set to experience emanates from the emergent Chinese container manufacturing industry. Shell International “builds a set of global scenarios every 3 years to explore the overarching challenges arising from changes in the business environment. These scenarios provide a useful context for testing the strategies and plans to help anticipate significant changes in the world”. The Shell International Scenario Planning Unit recognises the new global presence of China as a major player in changing the world’s business environment. These overarching change drivers of China are discussed in “Business Class” and “Prism”, two of Shell International’s scenarios of the world till 2020.

Above, CEFIC\(^2\) illustrates the flows of world chemicals in 1998 and chemical production in 1999. We observe that the EU and the US are the major producers of chemicals, each producing around €405billion annually, the East (Asia and Japan)
follows closely with €375billion. In terms of imports, the East tops the world with €39.8billion, while the US and EU follow with €34.4billion and €30.4billion of chemical imports respectively. The EU, US and the East export €52.3billion, €44.9billion and €22.2billion respectively. We can clearly see that traditionally chemical flows are West (EU and US) to East (Asia and Japan). With the new emergence of China as an “Asian Dragon economy” and the drive towards increased production and manufacturing, it is likely that the picture of chemical flows around the world will change substantially. Rowe states that “Shanghai is building the third largest chemical cluster in the world at this time”. The relatively low costs of production have accelerated investment in the production and manufacturing sectors in China. These factors are likely to drive an increase in both the production of- and flows of chemicals to and from this region. CIEC (China International Economic Consultants) states that China’s Tenth Five-Year Plan (2001 - 2005) is focussed on speedily increasing production of petrochemicals and chemicals with increased foreign investment in these sectors. In support of this, Shell International Scenarios talks of “herd-like capital flows (into) China”. According to Arora, Landau and Rosenberg “the chemical industry is a leading indicator of economic development” and “the chemical processing industry underlies all manufacturing”, so the increasing industrial development will lead an analogous increase in chemicals processed in China.

World Cargo News reports that China has finally brought its first dedicated tank container production facility online. World Cargo states that China has managed to take over most of the world’s reefer container production in a matter of 5 years and it is likely that they will show the same determination in trying to dominate the tank container manufacturing industry. Already CIMC (China International Marine Containers Group) has brought a new tank container facility online in Nantong under licence from UBH (Universal Bulk Handling). A second major tank container production facility, Zhongshan Zhonghua Tank Containers, has started up in Gungdong, under licence from

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22 CEFIC 2000
23 Shell International 2001 “Exploring the Future”, page 72
24 Source: Rowe-Setz and Webb-Martin 2001, page 58
25 Shell International 2001 “Exploring the Future”
Sea Containers – Yorkshire Marine Containers Ltd. The rated capacity of each of these plants has been set at 2,000 units per annum. With the world’s current production capacity sitting at approximately 20,000 teu per annum, with world production peaking at approximately 17,000 teu in 1998 and decreasing to 10,500 teu currently, it is likely that China could provide this production capacity within the next 5 years. This growth seems reasonably synchronised with China’s recent take over of reefer container production. The lower production costs in China spells price competition on the world tank container supply market. These reasonably predicted price wars should exert continued downward pressure on tank container prices, which may have adverse consequences on existing tank container producers in South Africa and the EU, who may suffer due to the higher costs of production in these regions.

2.4 Conclusions: Factors Influencing Tank Container Demand

This section has discussed the main factors that have affected the global tank container market in the past and which are expected to influence the market in the future. Chemical production remains the major driver of tank container demand, in conjunction with mandatory transport legislation and environmental regulation for the transport of hazardous chemicals. The major chemical trade flows occur between the EU, US and Japan and these routes represent the major areas where tank containers are presently deployed.

The logistical advantages offered by tank containers both in terms of their suitability for JIT production and their suitability for intermodal transport, have been additional drivers of tank container demand. Despite these advantages, an EU study has found price to be the most important criteria used by cargo owners when deciding on transport mode type. Another factor that may prove to be an important driver of the industry conversion to tank containers, is its inherent safe nature when transporting dangerous cargo. This is true especially after September 11th, with increased focus and legislation passed by US authorities to try and control any risks to US national security. The US security
regulations and legislation will have an affect on goods both entering and leaving the country and so impact on all the US trading partners.

Over-capacity presently exists in the tank container market and this has significantly decreased fleet utilisation, putting pressure on new tank container prices and eroding profit margins in the tank container transport sector.

The introduction of China into the tank container manufacturing market is expected to put additional pressure on the manufacturing industry.
3. A STATISTICAL ANALYSIS OF THE RELATIONSHIP BETWEEN THE PRODUCTION OF 20 BASIC CHEMICALS AND GLOBAL TANK CONTAINER FLEET SIZE

3.1 Introduction

The section is a statistical analysis of the relationship between the global production of 20 basic chemicals (which are produced in high volumes) and global tank container fleet size (TCFS). Considering that the need for chemical transport is the primary driver of tank container demand, the establishment of a statistically significant relationship between the production of high volume basic chemicals and TCFS would form the first step towards developing a forecasting model for global tank container demand. The following section shows the results of a standard multiple regression of the annual production volumes of 20 basic chemicals with TCFS, using 10 years of data for these variables (1990 –1999). This is followed by a forward stepwise regression with the most significant regressors. The results show that only three of the chemicals display a statistically significant relationship with TCFS, while an additional three exhibit borderline significance.

From the statistical analysis, it will be shown that:

- The standard multiple regression techniques are inadequate in determining significant predictors of tank container fleet size.
- These inadequacies are primarily due to collinearity relationships that exist between the independent variables that reflect chemical production.
- The forward stepwise regression techniques are better suited to determine significant predictors of tank container fleet size.
- The independent variables: Acrylic Acid, Cumene, Ethanolamines, Toluene, para-Xylene and Hydrochloric Acid are statistically significant predictors of tank container fleet size, ceteris paribus.
Methodology

A list of the top 100 basic chemicals produced globally (by quantity) were obtained from the Guide to Business Chemistry\textsuperscript{27} together their production quantities for the years 1990 to 1999. The International Maritime Dangerous Goods (IMDG) Code was then consulted in order to determine those chemicals that required mandatory tank container transport. The IMDG code lists tank and IBC instructions for all chemicals and specifies the type of tank that is required for the transport and storage of each chemical. From the top 100 chemical list, 20 chemicals were found to require mandatory transport by IMO tank container type 1, 3 or 4. Other chemicals were found to have different tank instructions, however, these are not included in this study. In order to determine which of the 20 chemicals showed the greatest correlation with TCFS, a multiple linear regression analysis was performed between the production volumes of each of these chemicals and TCFS. From the results of this regression, the 6 chemicals that exhibited the strongest relationship with TCFS were selected and regressed against TCFS in a stepwise linear regression. The table below lists the 20 chemicals used in this study together with their production volumes in 1999. The column titled IMO tank code is the instruction that presently applies to the transport of the particular chemical. The UN code column is the instruction that will come into effect in the year 2010.
Table 2: Twenty High Volume Basic Chemicals Legislated to be Transported in Tanks

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Properties</th>
<th>UN Tank Code</th>
<th>IMO Tank Code</th>
<th>1999 Production ('000 short tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylbenzene</td>
<td>Flammable gas, slightly lighter than air.</td>
<td>None</td>
<td>None</td>
<td>6615</td>
</tr>
<tr>
<td>Methanol</td>
<td>Colourless liquid, volatile, miscible with water.</td>
<td>T7</td>
<td>T4</td>
<td>6090</td>
</tr>
<tr>
<td>Styrene</td>
<td>Colourless, oily liquid, Immiscible with water, irritating to skin, eyes and mucous membranes</td>
<td>T2</td>
<td>T1</td>
<td>5975</td>
</tr>
<tr>
<td>Ethanol</td>
<td>Colourless volatile liquid.</td>
<td>T4</td>
<td>T1</td>
<td>4950</td>
</tr>
<tr>
<td>HCl</td>
<td>Colourless liquid, highly corrosive, causing burns to skin, eyes and mucous membranes</td>
<td>T8</td>
<td>TP28</td>
<td>4526</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Colourless liquid, suffocating odour, causes burns to skin eyes, mucous membranes</td>
<td>T4</td>
<td>T1</td>
<td>4425</td>
</tr>
<tr>
<td>p-Xylene</td>
<td>Colourless liquid, immiscible with water</td>
<td>T4</td>
<td>T1</td>
<td>4375</td>
</tr>
<tr>
<td>Toluene</td>
<td>Colourless liquid, immiscible with water</td>
<td>T4</td>
<td>T1</td>
<td>4170</td>
</tr>
<tr>
<td>Cumene</td>
<td>Colourless liquid, Chloroform odour, immiscible with water</td>
<td>T2</td>
<td>T1</td>
<td>3450</td>
</tr>
<tr>
<td>Ethylene Glycol</td>
<td>Colourless liquid, ethereal odour, immiscible with water</td>
<td>T4</td>
<td>T1</td>
<td>2975</td>
</tr>
<tr>
<td>Phenolic Resins</td>
<td>Molten liquid, strong odour, toxic if swallowed.</td>
<td>T7</td>
<td>T4</td>
<td>2194</td>
</tr>
<tr>
<td>Acetone</td>
<td>Colourless liquid, clear, mint odour</td>
<td>T4</td>
<td>T3</td>
<td>1490</td>
</tr>
<tr>
<td>Acrylic Acid</td>
<td>Colourless liquid, flammable, acid odour</td>
<td>T7</td>
<td>T4</td>
<td>1000</td>
</tr>
<tr>
<td>Butanol</td>
<td>Colourless liquid, disagreeable odour</td>
<td>T4</td>
<td>T1</td>
<td>920</td>
</tr>
<tr>
<td>Aniline</td>
<td>Colourless liquid, oily, volatile, toxic, reacts with acids</td>
<td>T7</td>
<td>T4</td>
<td>780</td>
</tr>
<tr>
<td>Phthalic Acid</td>
<td>White powder, dust</td>
<td>T4</td>
<td>T3</td>
<td>570</td>
</tr>
<tr>
<td>O-Xylene</td>
<td>Colourless liquid, immiscible with water</td>
<td>T4</td>
<td>T1</td>
<td>565</td>
</tr>
<tr>
<td>Potassium Hydroxide</td>
<td>Colourless liquid, reacts violently with acid.</td>
<td>T7</td>
<td>T3</td>
<td>475</td>
</tr>
<tr>
<td>Ethyl Hexanol</td>
<td>Colourless liquid, characteristic odour, miscible with water</td>
<td>T2</td>
<td>T1</td>
<td>440</td>
</tr>
<tr>
<td>Ethanolamines</td>
<td>Colourless liquid, corrosive, burns skin % eyes.</td>
<td>T4</td>
<td>T3</td>
<td>435</td>
</tr>
</tbody>
</table>

Multiple Regression of 20 Basic Chemicals with TCFS

The Statistica software package was the primary tool used for performing the statistical analyses, while the statistical function in Excel was used to a lesser extent.

It was decided to use a standard multiple regression so that inferences could be made regarding the relationship between the dependent variable, TCFS, and chemical production. It is the intention to determine a regression equation for TCFS, which can be used to predict values of TCFS, given certain chemical production figures. The multiple regression method was used to determine which of the top 100 chemicals that are specified to travel in tanks are the best predictors of TCFS. A limitation of all regression techniques is that relationships can only be ascertained, but in most cases clarity on causal mechanisms can never be established.

The multiple regression method is outline as follows:

- Choose variables and input data.
- Review means and standard deviation of sample to determine if outliers are present in the data.
- Check that data set fulfills the conditions of normality.
- Check individual correlations of variables to determine if collinearity exists.
- Check the matrix scatterplots to verify the absence of collinearity.
- Review result of the multiple regression to determine the statistical significance of the overall regression.
- Check statistical significance of the individual regressors or variables.
- Perform a residual analysis to determine and confirm that outliers have not biased the regression.
- Identify the best regressors or predictors of TCFS.
- Feed these regressors into a forward stepwise regression to control for collinearity.
3.2 Standard Multiple Regression Analyses

Choose Variables and Input Data

Tank Container Fleet Size was chosen as the dependent variable for the multiple regression. Ethylbenzene, Styrene, Ethanol, Hydrochloric Acid (HCl), Formaldehyde and p-Xylene were chosen as independent variables. TCFS is measured in teu (twenty-foot equivalent units) and the global chemical production figures for Ethylbenzene, Styrene, Ethanol, Hydrochloric Acid (HCl), Formaldehyde and p-Xylene are measured in short-tons (2000 pounds). The raw data set named “RR mr T1.1 data” is shown in the table below:

<table>
<thead>
<tr>
<th>Year</th>
<th>TCFS</th>
<th>Ethylbenzene</th>
<th>Styrene</th>
<th>Ethanol</th>
<th>HCl</th>
<th>Formaldehyde</th>
<th>p-Xylene</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>55491</td>
<td>4185</td>
<td>4009</td>
<td>3341</td>
<td>3140</td>
<td>3360</td>
<td>2600</td>
</tr>
<tr>
<td>1991</td>
<td>61772</td>
<td>4436</td>
<td>4057</td>
<td>3521</td>
<td>3301</td>
<td>3306</td>
<td>2675</td>
</tr>
<tr>
<td>1992</td>
<td>70400</td>
<td>5554</td>
<td>4500</td>
<td>4273</td>
<td>3610</td>
<td>4139</td>
<td>2828</td>
</tr>
<tr>
<td>1993</td>
<td>77525</td>
<td>5879</td>
<td>5032</td>
<td>4593</td>
<td>3492</td>
<td>4094</td>
<td>2896</td>
</tr>
<tr>
<td>1994</td>
<td>84800</td>
<td>5935</td>
<td>5635</td>
<td>4760</td>
<td>3754</td>
<td>3915</td>
<td>3114</td>
</tr>
<tr>
<td>1995</td>
<td>94600</td>
<td>6250</td>
<td>5695</td>
<td>5075</td>
<td>3904</td>
<td>3998</td>
<td>3130</td>
</tr>
<tr>
<td>1996</td>
<td>106100</td>
<td>6625</td>
<td>5940</td>
<td>3658</td>
<td>4116</td>
<td>4075</td>
<td>3140</td>
</tr>
<tr>
<td>1997</td>
<td>120900</td>
<td>6450</td>
<td>5700</td>
<td>4408</td>
<td>4569</td>
<td>4188</td>
<td>3925</td>
</tr>
<tr>
<td>1998</td>
<td>133700</td>
<td>6415</td>
<td>5705</td>
<td>4835</td>
<td>4659</td>
<td>4313</td>
<td>3860</td>
</tr>
<tr>
<td>1999</td>
<td>142700</td>
<td>6615</td>
<td>5975</td>
<td>4950</td>
<td>4526</td>
<td>4425</td>
<td>4375</td>
</tr>
</tbody>
</table>

Table 3: Raw Data Set “RR mr T1.1 data”

Review Means and Standard Deviations of the Sample

The means and standard deviations of the sample are indicated in the table below:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Means and Standard Deviations (RR mr T1.1 data)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylbenzene</td>
<td>5834.40 874.96</td>
<td>10</td>
</tr>
<tr>
<td>Styrene</td>
<td>5224.80 769.16</td>
<td>10</td>
</tr>
<tr>
<td>Ethanol</td>
<td>4341.40 627.23</td>
<td>10</td>
</tr>
<tr>
<td>Hydrochloric Acid</td>
<td>3907.10 544.67</td>
<td>10</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>3981.30 371.59</td>
<td>10</td>
</tr>
<tr>
<td>p-Xylene</td>
<td>3254.30 595.79</td>
<td>10</td>
</tr>
<tr>
<td>Fleet Size</td>
<td>94798.80 30269.88</td>
<td>10</td>
</tr>
</tbody>
</table>
TCFS has a mean of 94,799 teu with a standard deviation of 30,270 teu.

Check for Normality

It is important to check the sample to ensure that the condition of normality is reasonably fulfilled. This is indicated in the plot of “Number of Observations vs. Fleet Size” below:

It is noted that the presence of outliers in the data can substantially inflate or deflate the correlation coefficient. All the observed data values fall within the range for normality, i.e. mean ± 3 * standard deviation. From the figure it can be seen that all the data points fall comfortably with the range [3,980; 185,600], so no outliers were identified and we proceeded to use the entire data set in the multiple regression as the data set has fulfilled the condition that it is normally distributed.
Check Individual Correlations of Variables

The correlation matrix below shows that the individual correlations of TCFS to Ethylbenzene, Styrene, Ethanol, HCl, Formaldehyde and p-Xylene is 0.8432, 0.8508, 0.5956, 0.9749, 0.8120, and 0.9632 respectively.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ethylbenzene</th>
<th>Styrene</th>
<th>Ethanol</th>
<th>Hydrochloric Acid</th>
<th>Formaldehyde</th>
<th>p-Xylene</th>
<th>TOTAL FLEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylbenzene</td>
<td>1.000000</td>
<td>0.956286</td>
<td>0.695877</td>
<td>0.851755</td>
<td>0.912632</td>
<td>0.740914</td>
<td>0.843173</td>
</tr>
<tr>
<td>Styrene</td>
<td>0.956286</td>
<td>1.000000</td>
<td>0.674474</td>
<td>0.838324</td>
<td>0.795400</td>
<td>0.752278</td>
<td>0.850810</td>
</tr>
<tr>
<td>Ethanol</td>
<td>0.695877</td>
<td>0.674474</td>
<td>1.000000</td>
<td>0.573488</td>
<td>0.744235</td>
<td>0.601418</td>
<td>0.595637</td>
</tr>
<tr>
<td>Hydrochloric Acid</td>
<td>0.851755</td>
<td>0.838324</td>
<td>0.573488</td>
<td>1.000000</td>
<td>0.814025</td>
<td>0.931108</td>
<td>0.974869</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>0.912632</td>
<td>0.795400</td>
<td>0.744235</td>
<td>0.814025</td>
<td>1.000000</td>
<td>0.764585</td>
<td>0.812019</td>
</tr>
<tr>
<td>p-Xylene</td>
<td>0.740914</td>
<td>0.752278</td>
<td>0.601418</td>
<td>0.931108</td>
<td>0.764585</td>
<td>1.000000</td>
<td>0.963150</td>
</tr>
<tr>
<td>TOTAL FLEET</td>
<td>0.843173</td>
<td>0.850810</td>
<td>0.595637</td>
<td>0.974869</td>
<td>0.812019</td>
<td>0.963150</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

Table 5: Correlation Matrix for Data Set “RR mr T1.1 data”

Here it is noted that Ethylbenzene, Styrene, HCl, Formaldehyde and p-Xylene are highly correlated with TCFS, as the correlations are > 0.7. On the other hand Ethanol is well correlated to TCFS, as this correlation of 0.5956 falls in the specified range of 0.4 to 0.7 for well correlated regressors. These observations are only an interpretation of the individual correlations between variables and the presence of collinearity is not taken into account.

Of particular interest in the correlation matrix is the correlation figures between the independent variables: Ethylbenzene, Styrene, Ethanol, HCl, Formaldehyde and p-Xylene, indicated in yellow. We note that all these correlations are > 0.7 and this means that the independent variables are highly correlated to one another. Typically, values > 0.7 indicate high correlation, 0.4 – 0.7 well correlated, and < 0.4 weak correlation. The excessive high correlations that exists between the independent variables (indicated in yellow) is an indication that these “independent” variables, are in fact “related” or “dependent” on each other. In other words, if one independent variable is changed the collinear variables will change along with it, or an “independent” variable is in fact a function of a series of other independent variables.
(Interpretation: Multi-collinearity between chemicals could mean that these chemicals are being used in certain fixed proportions by the same industry. Adding additional collinear variables to the TCFS forecasting equation therefore fails to add any new information and fails to explain any more of the variation in TCFS.)

Collinearity between independent variables is an indication that the multiple regression may be weak. Collinearity or multi-collinearity has the effect of decreasing the t-statistic (which is used for multiple regression), which implies that there is no linear relationship between the collinearly affected independent variables and the dependent variable, TCFS\(^{28}\).

The data set “RR Mr T1.1 data” is clearly adversely affected by collinearity for the purposes of performing standard multiple regression analysis.

**Check Correlation Matrix Scatterplot**

It is evident from the figure below that the highest collinearity exists between Ethylbenzene and Styrene, indicated by the least amount of scatter. In contrast, the “lowest” collinearity in the data set occurs between Ethanol and HCl, indicated by the relatively large degree of scatter. From the figure below it is apparent that the sample and regression is subject to the effects of multi-collinearity.

Therefore, it has been graphically confirmed that the independent variables Ethylbenzene, Styrene, Ethanol, HCl, Formaldehyde and p-Xylene are either highly correlated or well correlated to one another, leading to problems of collinearity between these variables.

\(^{28}\) Keller and Warrack 2000, page 679-730
Figure 9: Correlation Matrix Scatterplot

<table>
<thead>
<tr>
<th>Ethylbenzene</th>
<th>Styrene</th>
<th>Ethanol</th>
<th>HCl</th>
<th>Formaldehyde</th>
<th>p-Xylene</th>
<th>Fleet</th>
</tr>
</thead>
</table>

Correlations (RR mr T1.1 data 7v*10c)
Review Results of Multiple Regression

From the regression model screen captured above, it is observed that the coefficient of correlation, $R = 0.99105$ and the coefficient of determination, $R^2 = 0.98218$. The p-level for the overall regression, $p = 0.010185$. The p-value represents a decreasing index of the reliability of the results of the multiple regression. The higher the p-level the less one can accept that the observed relation between the dependent and independent variables is a reliable indicator of the population. The p-level for the overall regression of the data set, $p = 0.010185$ indicates that there is a 1% probability that the relationship:

$$TCFS = -113790 -0.14\text{Ethylbenzene} +0.279\text{Styrene} -0.7\text{Ethanol} +0.401\text{HCl} +0.103\text{Formaldehyde} +0.450\text{paraXylene}$$
Is due to pure chance or coincidence. Typically, p-levels $\leq 0.05$ are considered to be borderline statistically significant. P-levels $\leq 0.01$ are considered as statistically significant, and p-levels $\leq 0.005$ are considered highly significant. So given the independent variables Ethylbenzene, Styrene, Ethanol, HCl, Formaldehyde and p-Xylene, TCFS can be predicted with 1% probability of error. A cautionary note here is that these observations only hold for the summary or overall regression. It is critically important that the regression coefficients and the p-levels of the individual independent variables are checked. This has been done in the section below.

Check Regression Coefficients

The figure above is the regression summary for the dependent variable: TCFS. The Beta coefficients show that the independent variables p-Xylene, HCl and Styrene are the most important predictors of TCFS (for the data sample). However, the p-levels for these three independent variables are large (all the independent variable p-levels are greater than 0.05), which indicates that none of these variables are statistically significant. This is a direct result of collinearity between the independent variables: Ethylbenzene, Styrene, Ethanol, HCl, Formaldehyde and p-Xylene.

It is noted that when the regression coefficients and individual independent variable p-levels, the resulting p-levels of the summary overall regression in the previous section are
refuted, so Ethylbenzene, Styrene, Ethanol, HCl, Formaldehyde and p-Xylene are in fact not statistically significant in predicting TCFS.

Perform Residual Analysis

Figure 11: Residual Analysis

The regression line expresses the best prediction of the dependent variable TCFS, given the limited independent variables used in this model. The regression line is never a perfect prediction and the deviation of any particular observed data point from the regression line (or predicted value) is the residual value.
The smaller the variability of the residual values around the regression line, the better the prediction of the dependent variable. The residual analysis, indicated in the figure above, allows one to easily identify any outliers that could seriously bias the regression line, thus leading to biased regression coefficients. It is observed that none of the residuals lie beyond one standard deviation from the mean, therefore none of the residuals were identified as outliers. It was therefore not necessary to remove outlier residuals and re-perform the regression.

It was noted that the normal probability plot of residuals (indicated in the figure below) is an alternative graphical representation of the residual analysis. It was observed that none of the residual values stray significantly from the regression line.

This concludes the multiple regression of the first data set (6 chemicals) against TCFS. What follows is a multiple regression for the remaining 3 data sets (data sets: RR mr
T1.2, RR mr T3, RR mr T4), as well as a regression of the combination of the best 6 regressors out of the complete set (T_Selection).

Standard multiple regressions were carried out on an additional 4 data sets. These data sets are named:

- “RR mr T1.2 data” which contains chemicals that are transported in IMO type 1 tank containers, similar to data set “RR mr T1.1 data” that has just been analysed;
- “RR mr T3 data” which contains chemicals that are transported in IMO type 3 tanks;
- “RR mr T4 data” which contains chemicals that are transported in IMO type 4 tanks; and
- “T_Selection” which contains data for the best predictors of TCFS taken from the results of the preceding four standard multiple regressions.

A summary table of the results is shown below:

Table 7

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Test for Normality</th>
<th>Box &amp; Whisker Plots to confirm absence of Outliers</th>
<th>Correlation Matrix Test for Colinearity</th>
<th>Regression Summary</th>
<th>Residual Analysis</th>
<th>Normal Prob. Plot of Residuals</th>
<th>Chemical Predictors Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR mr T1.1</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>p-Xylene</td>
<td>HCl</td>
<td>Styrene are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T1.2</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Cumene</td>
<td>Toluene</td>
<td>Ethylene Glycol are most important predictors of FLEET Toluene are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T3</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acetone</td>
<td>Ethanolamines</td>
<td>Phthalic Acid are most important predictors of FLEET Ethanolamines are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T4</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acrylic Acid</td>
<td>Acrylic Acid</td>
<td>Aniline High Significance</td>
<td></td>
</tr>
<tr>
<td>T_Selection</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acrylic Acid</td>
<td>Acrylic Acid</td>
<td>Cumene High Significance</td>
<td></td>
</tr>
</tbody>
</table>

T1.2, RR mr T3, RR mr T4), as well as a regression of the combination of the best 6 regressors out of the complete set (T_Selection).

Standard multiple regressions were carried out on an additional 4 data sets. These data sets are named:

- “RR mr T1.2 data” which contains chemicals that are transported in IMO type 1 tank containers, similar to data set “RR mr T1.1 data” that has just been analysed;
- “RR mr T3 data” which contains chemicals that are transported in IMO type 3 tanks;
- “RR mr T4 data” which contains chemicals that are transported in IMO type 4 tanks; and
- “T_Selection” which contains data for the best predictors of TCFS taken from the results of the preceding four standard multiple regressions.

A summary table of the results is shown below:

Table 7

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Test for Normality</th>
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<th>Residual Analysis</th>
<th>Normal Prob. Plot of Residuals</th>
<th>Chemical Predictors Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR mr T1.1</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>p-Xylene</td>
<td>HCl</td>
<td>Styrene are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T1.2</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Cumene</td>
<td>Toluene</td>
<td>Ethylene Glycol are most important predictors of FLEET Toluene are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T3</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acetone</td>
<td>Ethanolamines</td>
<td>Phthalic Acid are most important predictors of FLEET Ethanolamines are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T4</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acrylic Acid</td>
<td>Acrylic Acid</td>
<td>Aniline High Significance</td>
<td></td>
</tr>
<tr>
<td>T_Selection</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acrylic Acid</td>
<td>Acrylic Acid</td>
<td>Cumene High Significance</td>
<td></td>
</tr>
</tbody>
</table>

T1.2, RR mr T3, RR mr T4), as well as a regression of the combination of the best 6 regressors out of the complete set (T_Selection).

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<th>Chemical Predictors Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR mr T1.1</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>p-Xylene</td>
<td>HCl</td>
<td>Styrene are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T1.2</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Cumene</td>
<td>Toluene</td>
<td>Ethylene Glycol are most important predictors of FLEET Toluene are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T3</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acetone</td>
<td>Ethanolamines</td>
<td>Phthalic Acid are most important predictors of FLEET Ethanolamines are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T4</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acrylic Acid</td>
<td>Acrylic Acid</td>
<td>Aniline High Significance</td>
<td></td>
</tr>
<tr>
<td>T_Selection</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acrylic Acid</td>
<td>Acrylic Acid</td>
<td>Cumene High Significance</td>
<td></td>
</tr>
</tbody>
</table>

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<th>Normal Prob. Plot of Residuals</th>
<th>Chemical Predictors Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR mr T1.1</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>p-Xylene</td>
<td>HCl</td>
<td>Styrene are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T1.2</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Cumene</td>
<td>Toluene</td>
<td>Ethylene Glycol are most important predictors of FLEET Toluene are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T3</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acetone</td>
<td>Ethanolamines</td>
<td>Phthalic Acid are most important predictors of FLEET Ethanolamines are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T4</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acrylic Acid</td>
<td>Acrylic Acid</td>
<td>Aniline High Significance</td>
<td></td>
</tr>
<tr>
<td>T_Selection</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acrylic Acid</td>
<td>Acrylic Acid</td>
<td>Cumene High Significance</td>
<td></td>
</tr>
</tbody>
</table>

T1.2, RR mr T3, RR mr T4), as well as a regression of the combination of the best 6 regressors out of the complete set (T_Selection).

Standard multiple regressions were carried out on an additional 4 data sets. These data sets are named:

- “RR mr T1.2 data” which contains chemicals that are transported in IMO type 1 tank containers, similar to data set “RR mr T1.1 data” that has just been analysed;
- “RR mr T3 data” which contains chemicals that are transported in IMO type 3 tanks;
- “RR mr T4 data” which contains chemicals that are transported in IMO type 4 tanks; and
- “T_Selection” which contains data for the best predictors of TCFS taken from the results of the preceding four standard multiple regressions.

A summary table of the results is shown below:

Table 7

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Test for Normality</th>
<th>Box &amp; Whisker Plots to confirm absence of Outliers</th>
<th>Correlation Matrix Test for Colinearity</th>
<th>Regression Summary</th>
<th>Residual Analysis</th>
<th>Normal Prob. Plot of Residuals</th>
<th>Chemical Predictors Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR mr T1.1</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>p-Xylene</td>
<td>HCl</td>
<td>Styrene are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T1.2</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Cumene</td>
<td>Toluene</td>
<td>Ethylene Glycol are most important predictors of FLEET Toluene are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T3</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acetone</td>
<td>Ethanolamines</td>
<td>Phthalic Acid are most important predictors of FLEET Ethanolamines are most important predictors of FLEET not significant</td>
<td></td>
</tr>
<tr>
<td>RR mr T4</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acrylic Acid</td>
<td>Acrylic Acid</td>
<td>Aniline High Significance</td>
<td></td>
</tr>
<tr>
<td>T_Selection</td>
<td>normal</td>
<td>no outliers</td>
<td>Multi-collinearity exists. High R high R squared p-level no outliers no outliers</td>
<td>Acrylic Acid</td>
<td>Acrylic Acid</td>
<td>Cumene High Significance</td>
<td></td>
</tr>
</tbody>
</table>
From this table it is noted that even though the Regression Summary indicates high values for R (coefficient of correlation) and high $R^2$ (coefficient of determination) values, the significance- or p-levels indicate that regressions for data sets representing IMO Type 1 and IMO Type 3 tank containers are not statistically significant. So even though p-Xylene, HCl, Styrene, Toluene, Acetone, Ethanolamines and Cumene have been identified as the most important predictors of TCFS, they are not statistically significant.

Regressions that were completed for IMO Type 4 and the combination of the best regressors (T_Selection) shows that the variables Acrylic Acid and Cumene are good predictors of the dependent variable, TCFS, with high statistical significance. The high p-values indicate that there is a high probability that the samples chosen (10 years of production data) are not representative of the entire populations from which they originate (past, present and future production data for these chemicals).

It is noted that all of the independent variables in all of the regression sets are collinear, which adversely affects the results obtained by the standard multiple regression technique.
3.3 Forward Stepwise Regression

It was decided to use a Forward Stepwise Multiple Regression to establish a model that would predict TCFS. The Standard Multiple Regression method does not adequately deal with independent variable collinearity or multi-collinearity.

Forward stepwise regression brings independent variables into the equation one at a time. Only if an independent variable improves the model’s fit is it included. If two independent variables are strongly correlated (collinear), the inclusion of one of them in the model makes the second unnecessary. Stepwise regression is, by definition, a procedure that eliminates correlated or collinear independent variables\(^\text{29}\).

The data set called “T_Selection” was used to perform this Stepwise Regression, and included the independent variables HCl, p-Xylene, Toluene, Cumene, Acetone, Ethanolamines and Acrylic Acid to predict the dependent variable TCFS. As stated previously, these seven independent variables exhibited the most satisfactory results in the standard multiple regression analyses and for this reason they were selected for inclusion in the forward stepwise regression.

Checks for Normality and the Presence of Outliers

The data complies with checks for normality, and no outliers are present in the sample.

\(^{29}\) Source: Keller and Warrack 2000, page 704, pages 758-764
Interpret Results of Stepwise Regression

The results of Step 1 of the regression are shown below:

At this step of the regression it is observed that the independent variable Acrylic Acid has been accepted into the stepwise regression equation. Acrylic Acid exhibits a Beta = 0.998, with an equivalent significance p-level = 0.00000. Therefore, Acrylic Acid is a good predictor of TCFS and it is highly statistically significant.

The results of Step 2 of the regression show that Acrylic Acid has a Beta = 0.770 and Cumene has a Beta = 0.234, with an equivalent significance p-level = 0.00000. This
again indicates that both Acrylic Acid and Cumene are good predictors of Tank Container Fleet Size and are statistically highly significant.

This stepwise regression is continued and all the results of the stepwise regression are displayed in the table below:

<p>| Summary Table of Stepwise Regression |
| Variables in Regression Equation | Beta Values |</p>
<table>
<thead>
<tr>
<th>Acrylic Acid</th>
<th>Cumene</th>
<th>Ethanolamines</th>
<th>Toluene</th>
<th>p-Xylene</th>
<th>HCl</th>
<th>p-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step0</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Step1</td>
<td>0.998</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Step2</td>
<td>0.770</td>
<td>0.234</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Step3</td>
<td>0.784</td>
<td>0.278</td>
<td>-0.06</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Step4</td>
<td>0.728</td>
<td>0.309</td>
<td>-0.09</td>
<td>0.050</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Step5</td>
<td>0.772</td>
<td>0.347</td>
<td>-0.100</td>
<td>0.047</td>
<td>-0.07</td>
<td>n/a</td>
</tr>
<tr>
<td>Step6</td>
<td>0.845</td>
<td>0.389</td>
<td>-0.120</td>
<td>0.067</td>
<td>-0.09</td>
<td>-0.09</td>
</tr>
</tbody>
</table>

At the final step of the regression it is observed that the Beta values of Acrylic Acid, Cumene, Ethanolamines, Toluene, p-Xylene and HCl are 0.845, 0.389, -0.120, 0.067, -0.09 and –0.09 respectively. The significance level of this stepwise regression is <<1% and therefore highly significant. Of particular concern here is the fact that the Beta values for Ethanolamines, p-Xylene and HCl are negative, which is an indication that as these chemicals increase in volume, the TCFS decreases. At first glance this may be interpreted as an error, but what must be kept in mind is that all regression techniques are limited to ascertaining relationships between independent and dependent variables and in most cases clarity on causal mechanisms can never be established. So an interpretation of the presence of negative Beta values is that in the past it was observed that whenever Ethanolamines, p-Xylene or HCl increased, tank container fleet sizes decreased, and vice versa.
Check Partial and Semi-partial Correlations

The semi-partial correlation is the correlation of the independent variable adjusted by all other variables. Partial and semi-partial correlations are indicated in the table below:

Table 9: Partial and Semi-partial Correlations

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic Acid</td>
<td>0.844632</td>
<td>0.993886</td>
<td>0.111704</td>
<td>0.017490</td>
<td>0.982510</td>
<td>15.59151</td>
<td>0.01248</td>
<td>0.000573</td>
</tr>
<tr>
<td>Cumene</td>
<td>0.388820</td>
<td>0.980405</td>
<td>0.061758</td>
<td>0.025228</td>
<td>0.974772</td>
<td>8.62007</td>
<td>0.00381</td>
<td>0.003283</td>
</tr>
<tr>
<td>Ethanolamines</td>
<td>-0.124823</td>
<td>-0.952041</td>
<td>-0.038611</td>
<td>0.095684</td>
<td>0.904316</td>
<td>-5.38933</td>
<td>0.00149</td>
<td>0.012517</td>
</tr>
<tr>
<td>Toluene</td>
<td>0.066857</td>
<td>0.869065</td>
<td>0.021800</td>
<td>0.106319</td>
<td>0.893681</td>
<td>3.04279</td>
<td>0.00048</td>
<td>0.055744</td>
</tr>
<tr>
<td>p-Xylene</td>
<td>-0.087387</td>
<td>-0.845866</td>
<td>-0.019679</td>
<td>0.050710</td>
<td>0.949200</td>
<td>-2.74761</td>
<td>0.00039</td>
<td>0.070938</td>
</tr>
<tr>
<td>HCl</td>
<td>-0.093471</td>
<td>-0.822005</td>
<td>-0.017912</td>
<td>0.036721</td>
<td>0.963279</td>
<td>-2.50009</td>
<td>0.00032</td>
<td>0.087699</td>
</tr>
</tbody>
</table>

It is observed that the semi-partial correlation figures are relatively small, with their respective partial correlations relatively large. This is an indication that the independent variables, Hydrochloric Acid, para-Xylene, Toluene, Cumene, Acetone, Ethanolamines and Acrylic Acid, all predict a unique and discrete portion of variability in the dependent variable, TCFS.

Perform Residual Analysis

Checking the normal probability plot of residuals showed that there were no outlier residuals present, so all the independent variables were accepted as predictors of TCFS.

The Forward Stepwise Regression summary is shown in the table below:

Table 10: Forward Stepwise Regression Summary

<table>
<thead>
<tr>
<th>Regression Summary of Dependent Variable: Fleet</th>
</tr>
</thead>
<tbody>
<tr>
<td>R = 0.99992300  Rsquare = 0.99984601</td>
</tr>
<tr>
<td>F(6;3) = 3246.5  p &lt; 0.000001  Std. Err. of Estimate: 650.60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta</th>
<th>Std. Err. of Beta</th>
<th>B</th>
<th>Std. Err. of B</th>
<th>t(3)</th>
<th>p-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-29338.3</td>
<td>5706.501</td>
<td>-5.14121</td>
<td>0.01248</td>
<td>0.014259</td>
<td></td>
</tr>
<tr>
<td>Acrylic Acid</td>
<td>0.844632</td>
<td>0.054173</td>
<td>153.6</td>
<td>9.850</td>
<td>15.59151</td>
<td>0.000573</td>
</tr>
<tr>
<td>Cumene</td>
<td>0.388820</td>
<td>0.045106</td>
<td>24.6</td>
<td>2.858</td>
<td>8.62007</td>
<td>0.003283</td>
</tr>
<tr>
<td>Ethanolamines</td>
<td>-0.124823</td>
<td>0.023161</td>
<td>-104.0</td>
<td>19.306</td>
<td>-2.74761</td>
<td>0.00149</td>
</tr>
<tr>
<td>Toluene</td>
<td>0.066857</td>
<td>0.021972</td>
<td>5.2</td>
<td>1.717</td>
<td>3.04279</td>
<td>0.055744</td>
</tr>
<tr>
<td>p-Xylene</td>
<td>-0.087387</td>
<td>0.031815</td>
<td>-4.4</td>
<td>1.616</td>
<td>-2.74671</td>
<td>0.070938</td>
</tr>
<tr>
<td>HCl</td>
<td>-0.093471</td>
<td>0.037387</td>
<td>-5.2</td>
<td>2.078</td>
<td>-2.50009</td>
<td>0.087699</td>
</tr>
</tbody>
</table>
It is observed that the independent variables Acrylic Acid, Cumene and Ethanolamines are the most important predictors of Tank Container Fleet Size. Acrylic Acid and Cumene are statistically highly significant, Ethanolamines is statistically significant, and Toluene, p-Xylene and Hydrochloric Acid are borderline statistically significant. Although it is usual to set p-levels <= 0.05 to show borderline significance, these values are slightly arbitrary, so it was decided to set the constraint that p-levels that approximate 0.05 are borderline statistically significant.

The results of the Forward Stepwise Regression yield the following as the regression equation for predicting the TCFS:

\[
\text{Tank Container Fleet Size} = -29338.3 + 153.6 \text{ Acrylic Acid} + 24.6 \text{ Cumene} - 104.0 \text{ Ethanolamines} + 5.2 \text{ Toluene} - 4.4 \text{ paraXylene} - 5.2 \text{ HCl}
\]

RSMSE

The table below was used to calculate RSMSE (root square of the mean square error):

<table>
<thead>
<tr>
<th>Year</th>
<th>FLEET observed</th>
<th>Intercept -29338.3</th>
<th>Acryl. 153.6</th>
<th>Cumene 24.6</th>
<th>Ethano. -104</th>
<th>Toluene 5.2</th>
<th>paraXyl. -4.4</th>
<th>HCl -5.2</th>
<th>FLEET PREDICTED</th>
<th>Yi-Yf (Yi-Yf)^2 / N</th>
<th>RSMSE = square root [(Yi-Yf)^2 / N] =</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>55491</td>
<td>527</td>
<td>2156</td>
<td>364</td>
<td>3105</td>
<td>2600</td>
<td>3140</td>
<td>55168.5</td>
<td>-322.5</td>
<td>104006.3</td>
<td>359.2936</td>
</tr>
<tr>
<td>1991</td>
<td>61772</td>
<td>564</td>
<td>2084</td>
<td>329</td>
<td>3149</td>
<td>2875</td>
<td>3301</td>
<td>61782.1</td>
<td>10.1</td>
<td>144324</td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td>70400</td>
<td>599</td>
<td>2333</td>
<td>347</td>
<td>3466</td>
<td>2828</td>
<td>3610</td>
<td>70779.9</td>
<td>379.9</td>
<td>144324</td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>77525</td>
<td>650</td>
<td>2245</td>
<td>353</td>
<td>3670</td>
<td>2896</td>
<td>3492</td>
<td>77199.9</td>
<td>-325.1</td>
<td>105690</td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td>84800</td>
<td>679</td>
<td>2582</td>
<td>393</td>
<td>3888</td>
<td>3114</td>
<td>3754</td>
<td>84596.5</td>
<td>-203.5</td>
<td>41412.25</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>94600</td>
<td>760</td>
<td>2615</td>
<td>408</td>
<td>3873</td>
<td>3130</td>
<td>3904</td>
<td>95361.5</td>
<td>761.5</td>
<td>579882.3</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>106100</td>
<td>805</td>
<td>2800</td>
<td>413</td>
<td>3963</td>
<td>3140</td>
<td>4116</td>
<td>106626.1</td>
<td>-473.9</td>
<td>224581.2</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>120900</td>
<td>905</td>
<td>2990</td>
<td>413</td>
<td>4113</td>
<td>3925</td>
<td>4569</td>
<td>120630.5</td>
<td>-269.5</td>
<td>72630.25</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>133700</td>
<td>945</td>
<td>3315</td>
<td>420</td>
<td>4063</td>
<td>3860</td>
<td>4659</td>
<td>133599.5</td>
<td>-100.5</td>
<td>10100.25</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>142700</td>
<td>1000</td>
<td>3450</td>
<td>435</td>
<td>4170</td>
<td>4375</td>
<td>4526</td>
<td>142790.5</td>
<td>90.5</td>
<td>8190.25</td>
<td></td>
</tr>
</tbody>
</table>

Sum of (Yi-Yf)^2 = 1290919
(Yi-Yf)^2 / N = 129091.9
RSMSE = square root [(Yi-Yf)^2 / N] = 359.2936

30 Source: Statistica Help Files, STATISTICA/Elementary Concepts in Statistics/What is “statistical significance” (p-level)?
The values of predicted TCFS (generated by the regression equation) are highlighted in yellow. The closeness of these values to the observed (actual) TCFS values highlighted in lavender gives an indication of the accuracy of the regression equation over the analysis period. The accuracy of the overall regression equation is best expressed in terms of RSMSE. The RSMSE for this analysis equals 359.29, which summarises the error in the regression equation for predicting the TCFS.
3.4 Conclusions: Statistical Analyses

This regression analysis shows that the chemicals chosen exhibit strong collinearity. This indicates that certain chemicals are, in fact, functions of others. In order to develop a relationship between the production quantities of basic chemicals and TCFS, the problem of collinearity would need to be overcome. Possible ways of doing this will be discussed in the next section.

The forward stepwise regression analysis identifies 3 chemicals as statistically significant regressors of TCFS, namely, Acrylic Acid, Cumene, Ethanolamines, as well as an additional 3 chemicals that exhibit borderline statistical significance, namely, Toluene, para-Xylene and Hydrochloric Acid. Collectively, these six regressors seem to predict TCFS reasonably well (this is shown by the relatively small value of RSMSE). However, it must be borne in mind that regression analysis merely identifies mathematical relationships between variables and is not able to identify causal relationships with certainty.

Although the regression equation provides what seems to be a reasonable tool for predicting TCFS within the period of analysis, it cannot be concluded that the regressor chemicals used in this equation were the major drivers or causes of the trend in TCFS. However, while causality cannot be concluded from this regression analysis, these 6 chemicals may well be demand drivers of tank containers – it just cannot be proven using this technique.

There is a conceptual difference between what defines a predictor and what defines a driver. Drivers explain causality while predictors merely exhibit a correlation, whether this is as a result of a causal relationship or not. The forward stepwise regression used in this analysis is thus limited in this regard. Its application is valid, if and only if, all the conditions that prevailed during the analysis period (1990 – 1999) remain constant. It is known that these conditions have, however, not remained constant. In order to account for the effects of these changing conditions,
additional variables would have to be included in the regression analysis. The most important additional variables that would need to be included derive directly from the factors identified in this report in the section “Factors Influencing Tank Containers Demand”.

4. OVERALL CONCLUSIONS AND THE DEVELOPMENT OF A FORECASTING MODEL FOR TANK CONTAINER DEMAND

The factors that were identified in this report as having the greatest influence on global tank container demand are chemical production, environmental regulation, national security and safety initiatives and logistical factors (JIT and intermodality).

Having identified and discussed these factors, this study has attempted to establish a relationship between the production of 20 high volume basic chemicals (that are legislated to be transported in tank containers or IBC’s) and tank container fleet size over the period 1990 – 1999. During the course of this analysis, it became evident that collinearity between chemicals created significant problems with the standard multiple regression analysis. In order to account for this problem, a stepwise multiple regression analysis was used. The results of this analysis show a strong correlation between the production of 6 of these chemicals and tank container fleet size.

This forms a first step towards developing a forecasting model for tank container demand. However, it is limited in its application because it includes only a limited number of regressors and does not account for the effects of over-capacity in the tank container industry.

The next step in refining the forecasting model would therefore involve establishing quantitative measures of the remaining demand driving factors (namely, additional chemicals, the effects of environmental, national security and safety regulation and logistical factors) and including these in the regression equation.

The problem of over-capacity distorting tank container fleet size as a measure of tank container demand. In order to determine the real effects of the factors mentioned above on tank container demand, the utilisation rates of world tank container fleet needs to be determined in order to calculate the over-capacity. over-capacity is analogous to the under-utilisation of existing tank containers in the industry.

The next step in refining the tank container demand forecasting model would then involve subtracting the over-capacity from observed TCFS in order to determine the actual number of tank containers deployed, i.e. the real demand for tank container.
This will have the effect of controlling for the statistical noise created by over-capacity. This was not possible during this study, due to the difficulty in obtaining this information from individual operators and lessors, who consider this to be confidential competitive information. It is recommended that successor studies establish the utilisation rates by engaging with the most significant operator, lessors and investment houses.

It is recommended that future studies involving the development of a forecasting model for tank container demand include the following:

- Obtain the most recent data for tank containers, as far back as the early- to mid-1980’s when significant volumes of tank containers emerged.
- Mine the IMDG code in order to obtain a comprehensive list of all chemicals that are legislated to be transported in tanks.
- Determine which chemicals or commodities require mandatory tank containerisation in terms of the recent developments in national security legislation, and add these commodities to the list above.
- Obtain production data for all chemicals and commodities identified above for the same period, as far back as the early- to mid-1980’s.
- Obtain the utilisation rates of individual tank container fleets over the period of analysis by contacting operators and lessors. A comprehensive list of operators and lessors can be found in the Containerisation International Yearbook (2001) or Hazardous Cargo Bulletin (1998). Trends in the Tank Container Business.
- Use these figures to control for the effects of over-capacity in the world tank container fleet in order to obtain “corrected tank container demand”.
- In order to control for collinearity, identify chemicals that exhibit collinearity with other chemicals and rank all chemicals them in terms of their “independence” (lowest to highest collinearity).
- Feed the most “independent” variables into a suitable means of analysis i.e preferably forward regression or time series analysis.
Bibliography

2. APEC Contact (1999). Quarterly Newsletters.
3. APEC Contact (2000). Quarterly Newsletters.


Appendix 1

Tax Avoidance And The Use Of Tank Containers In The Context Of Lump Sums Accruing From Retirement Funds in SA

1. Lump sums accruing from retirement funds are taxed at the taxpayer’s average rate. The relevant formula is contained in section 5(10) of the Income Tax Act. The effect of the formula is to determine the taxpayer’s average rate of tax, which is then applied to the taxable portion of the lump sums.

2. Prior to the amendments to the Income Tax Act in 1995, it was possible to manipulate the average rate of tax. It was often possible to reduce the average rate of tax right down to the lowest permissible rate by generating an “artificial” deduction by taking 15% of the taxable portion of the pension lump sums as a single premium contribution to a retirement annuity in the year of retirement. This loophole was closed in 1995 by the introduction of a new rating formula (the formula to determine the average rate) which neutralised the effect of the single premium retirement annuity deduction. Thus sophisticated taxpayers needed alternative methods to reduce their average rates.

3. Tank containers, with their favourable depreciation basis and a possible balloon payment method of financing produce deductions in the first few years which far exceed income. The result is a tax loss which can be very usefully applied in the reduction of the average rate.

4. There are no anti avoidance provisions which could easily nullify the above scheme. Section 5 (10) is drafted solely with a view to neutralising the effect of single premium RA’s and does not contain any provision designed to neutralise any other tax deductions achieved in any other way. The general anti-avoidance provision, section 103 as amended recently (1999?) provides that where a transaction is entered into for no other apparent reason than for the generation of a tax benefit, in other words, if it has no
business purpose, revenue are entitled to disallow the tax effect of the scheme. The view taken by a taxpayer purchasing a tank container at retirement, to avoid the imposition of section 103, would be that he intends to derive foreign income generated by its lease and that the tax losses generated upfront are merely incidental.

5. In order for the scheme to work, the taxpayer would have to purchase the container during the tax year prior to retirement as section 5(10) provides that the higher of the average rate of the year of retirement or the year before has to be used in taxing the lump sums.

6. It is said that tax savings are for the brave. There are no known challenges by revenue to the use of tank containers as sketched above, but should revenue choose to attack this scheme, the taxpayer would have to tread carefully around section 103. One factor could save him, the depreciating Rand. If the courts would accept an argument that the primary intention of the taxpayer in purchasing the container is to earn hard currency then perhaps revenue’s charge could be foiled.
World production and disposal of liquid bulk tank containers by type 1990-2001
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Source: Drewry Shipping Consultants Ltd

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Source: Drewry Shipping Consultants Ltd
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| **SWAPBODY** |       |       |       |       |       |       |       |       |       |       |       |       |
| EU         | 0.5   | 1.0   | 1.0   | 0.4   | 1.3   | 2.2   | 2.2   | 1.8   | 1.7   | 1.3   | 1.7   | 1.9   |
| South Africa and other | 0.0  | 0.0   | 0.0   | 0.1   | 0.2   | 0.3   | 0.3   | 0.2   | 0.2   | 0.3   | 0.1   |
| subtotal   | 0.5   | 1.0   | 1.0   | 0.5   | 1.5   | 2.5   | 2.5   | 2.0   | 2.0   | 1.5   | 2.0   | 2.0   |

| **TOTAL** | 8.0   | 7.5   | 8.0   | 9.0   | 11.0  | 13.5  | 15.5  | 16.5  | 17.0  | 15.5  | 11.5  | 10.5  |

Source: Drewry Shipping Consultants Ltd

**SA as % of ISO production**

|        | 20.0  | 22.1  | 22.9  | 23.5  | 26.3  | 31.8  | 40.8  | 40.7  | 37.9  | 32.6  | 35.3  |

**SA as % of total production**

|        | 18.8  | 20.0  | 20.0  | 23.3  | 24.5  | 28.1  | 36.1  | 37.0  | 37.6  | 35.5  | 29.6  | 29.5  |
### Growth of Publications in JIT

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- **Cumulative 1983-1987**: 14
- **Cumulative 1987-1989**: 31
- **Cumulative 1989-1999**: 44

Source: JE Beasley, Imperial College
Figure 5.2 ISO: Production and disposal of bulk tank container 1990-2001

- Production
- Disposal
- Nett Increase
Figure 5.6 South Africa as percentage of ISO and Total Tank Container Production

SA as % of ISO production
SA as % of total production
Figure 5.7 EU Chemical Production and Growth

Production Index
Industry Annual Growth
Nett Increase