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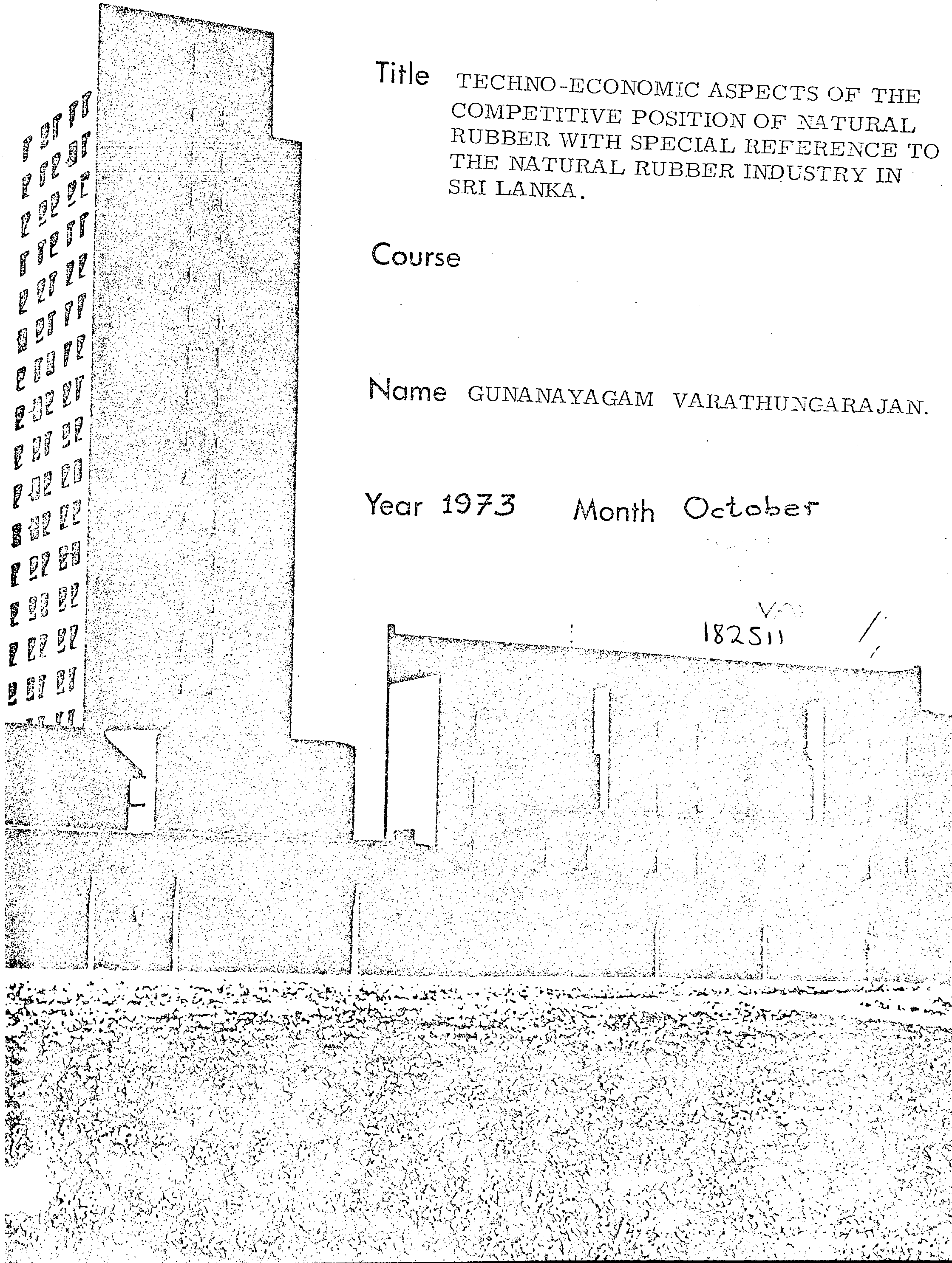

Title TECHNO-ECONOMIC ASPECTS OF THE COMPETITIVE POSITION OF NATURAL RUBBER WITH SPECIAL REFERENCE TO THE NATURAL RUBBER INDUSTRY IN SRI LANKA.

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TECHNO-ECONOMIC ASPECTS OF THE COMPETITIVE POSITION OF NATURAL RUBBER WITH SPECIAL REFERENCE TO THE NATURAL RUBBER INDUSTRY IN SRI LANKA.

by

GUNANAYAGAM VARATHUNGARAJAN.

A Thesis Submitted for the Degree of Doctor of Philosphy of the University of Aston in Birmingham Under the Inter-disciplinary Higher Degree Scheme.

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SUMMARY

This study explores the technological and economic aspects of the competition between natural rubber and the synthetics of the general purpose class. The first part of the thesis reviews the overall competitive position of natural rubber and its future prospects. The effects of the structure of the rubber producing industry (natural and synthetic), economics of production, characteristics of demand and some aspects of marketing on the short and long term competitive position are analysed. It is concluded that natural rubber can remain competitive in all aspects if, greater co-operation between the natural rubber producers can be achieved to formulate a unified programme of production, research and development and marketing.

In view of certain problems peculiar to Sri Lanka, the second part analyses the state of the rubber industry in Sri Lanka in respect of the changes taking place in other natural rubber producing countries, the developments in the synthetic rubber industry and the changing technological requirements of the rubber consuming industries. The commercial, economic and technical viability of certain projects in Sri Lanka and the areas for future research at the Rubber Research Institute of Sri Lanka are briefly explored. Since Sri Lanka is the largest producer of premium grade pale crepe rubber and in view of the declining demand for this rubber, the competitive position of pale crepe is studied in some detail and some recommendations are included to improve its competitive position. In view of the anticipated strong demand for natural

rubber in the future, it is recommended that Sri Lanka should plan now to increase rubber production at a faster rate by 1980's. It is also concluded that it is desirable to produce more special purpose premium grades of natural rubber in Sri Lanka than to produce more complex derivatives in the short term and a long term approach towards producing powdered rubber, liquid and thermoplastic rubber from latex is necessary.

The work described herein was carried out at the University of Aston in Birmingham between October 1970 and September 1973.

It has been done independently and submitted for no other degree.

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PART I

1. INTRODUCTION.

1.1 General.

Before World War II natural rubber (NR) was a unique material. As an agricultural producer, the industry was mainly concerned with keeping the supply in balance with the demand and, as far as possible, avoiding any large scale fluctuations in price. Like other basic raw materials the demand was highly sensitive to social, economic and political circumstances. Any imbalance thus created was inevitably aggravated by the six to seven-year lag between planting and tapping. There were several schemes which sought to control this imbalance and maintain a reasonable and steady price; notable among these were the Stevenson Restriction Plan of 1922 and the International Rubber Regulation Agreement of 1934. Under the stimulus of high prices following these schemes, the search for synthetic substitutes was revived in Germany and the U.S.A.

The importance of rubber as a strategic material was realised during World War II. With the Japanese occupation of the Far East, a synthetic rubber (SR) industry was rapidly developed, producing an inferior styrene-butadiene rubber (SBR); and a new industry was born. Although the technically superior NR was once again available at the end of the War, it was not in sufficient quantities to meet the rapidly increasing demand for rubbers. Several important technical improvements in the early SBR led to its establishment as an important rubber and is often called the work-horse of the SR industry. The massive research and development programmes that followed the sale of Government SR plants to private firms in the U.S.A. has led to the establishment of the SR industry in an important position. A constant search for new elastomers has produced a variety of synthetic polymers to meet the varying needs of the rubber fabricator.

A different situation confronts natural rubber today - its singularity as a general purpose rubber has disappeared and it has become one - though still an important member - of a large family of rubbers. The development of stereo-regular rubbers and the commercial production of the synthetic duplicate of NR - synthetic polyisoprene - in the early sixties led to much speculation regarding the future of NR. So far, the industry has survived the ever increasing threat from the synthetics. This is proved by the fact that every pound of NR produced since the end of the War has been sold, and the consumption has increased from 1.9 million tons in 1950 to just over 3 million tons in 1970. Nevertheless, the increase in NR consumption has been achieved with a more than corresponding fall in average prices. Although there has been a steady increase in the consumption of NR, its actual share of the markets has been rapidly decreasing from about 70% in 1950 to under 40% in 1970.

This raises the question: "Has the NR industry a future?"

While the SR industry has strengthened its competitive position through several technological innovations, as a well established producer the NR industry has been slow in adapting itself to the changes in the modern business operations. The most important single fact about the economic background in which modern business operates is the tremendous pace of technological, economic and social change. In such an environment, "Established producers are under frequent pressure to adapt themselves to new demands and technical methods. The way lies open to the innovator and the business of the routineer becomes insecure." writes Allen.[1]

This poses the question: "How can the NR industry improve its competitive position, maintain a steady growth and obtain reasonable profits for its products?" The two most important functions of business management as argued by Drucker[2] are marketing and innovation. This is particularly true in the case of a chemical raw material such as rubber which sells to a technically oriented market. A three-fold approach is mentioned by Reubensaal[3] to meet these changing markets and manufacturing patterns to enlarge NR's markets and increase profits. Namely:

1. improve profit margins through cost cutting techniques;
2. improve inherent qualities and win back increasing shares of existing markets;
3. enlarge consumption of NR through development of completely new markets.

Several important developments are now taking place in the production, marketing and processing of NR to improve its competitive position; these are discussed in subsequent chapters.

Recent advances and technical progress in the NR industry have come mainly from the Malaysian industry and its research organisations in Malaysia (The Rubber Research Institute of Malaya) and Britain (The Natural Rubber Producers' Research Association). While these advances have vastly improved the competitive position of NR, only Malaysia has exploited the advantages of these developments on any big scale. Although the problems facing the NR industry are basically the same in all producing countries, there are some problems which are peculiar to each country due to certain social, economic and political differences.

A vast amount of published information is available on the technological and economic aspects of competition between natural rubber and the synthetics. Most of the information is published by the SR producers of U.S.A. and is based on the American situation and is often biassed towards the synthetics. While those published by the NR producers are largely based on the Malaysian situation. No attempt has been made to study the competitive prospects and the future of Sri Lanka rubbers. Although a study of the overall competitive position of NR gives some aspects of the competitive prospects and the problems facing the NR industry in Sri Lanka, it does not give the whole picture. At the same time it is impossible to isolate the NR industry in Sri Lanka and study it on its own.

This study endeavours to explore the technological and economic aspects of competition between NR and the synthetics. The first part of this study reviews the overall competitive position of NR and the second part is mainly concerned with the competitive aspects of the NR industry in Sri Lanka. Such a study of the present status and future prospects is essential to plan the short and long term research strategy of the Rubber Research Institute of Sri Lanka. The second part looks at some specific areas of research and development and explores the commercial, economic and technical viability of such projects in Sri Lanka. However, the latex crepe manufacturing industry and its future are discussed in greater detail in the second part.

1.2 Competition.

Most competitive behaviour may be broadly viewed as taking the form of: -

(a) pricing;

(b) product differentiation;

(c) innovation;

(d) promotional activity.[4]

This study is essentially limited to competitive behaviour under the above broad headings and attempts to explore the relationships between market structure and market performance. The major elements of market structure considered are

(a) the number and size distribution of buyers and sellers;

(b) the characteristics of demand;

(c) the nature of price structure;

(d) the marketing and distribution channels utilised;

(e) the geographical distribution of supply and demand;

(f) the conditions of entry into industry.

Similarly the elements of market performance that are considered are

(a) price behaviour;

(b) capacity - output relationships;

(c) progressiveness;

(d) the level of profits;

(e) selling expenses.[5]

1.3 Types of Rubbers.

To study the competition between NR and the synthetics, it is essential to consider those rubbers that compete directly with NR and its end use applications. Essentially NR is a general purpose rubber, which finds its main application in tyres and other general rubber goods. Over 60% of all rubbers are consumed in tyre applications and over 90% of all rubbers compete with each other in the tyre and general rubber goods sector. The price, performance (i.e. processability of elastomer as well as the performance of the end product) and market volume are inter-related. Natural rubber, styrene/butadiene rubber, polybutadiene, butyl rubber, synthetic polyisoprene and ethylene/propylene rubbers make up the bulk of the general purpose rubbers. Table (1.1) shows the production volumes and average prices of these elastomers. Thus, the main discussion would be limited to the above rubbers. However, in recent times several plastics materials such as polyvinyl chloride (PVC), polyethylene, polyurethane, thermoplastic rubbers and other rubbers have replaced NR from several of its traditional uses, and hence a brief discussion of these materials is also included. At this stage a brief sketch of the general characteristics and main areas of application are outlined.

TABLE (1.1)

rge Tonnage General Purpose Rubbers:

Production and Average Prices

		Production* (000 Tons)	Price (US $ per ton)
Natural rubber	NR	3,000	400-600
Styrene/butadiene	SBR	4,200	380-550
Polybutadiene	BR	800	420-580
Synthetic polyisoprene	IR	400	450-650
Ethylene/Propylene	EPM/EPDM	200	450-850
Butyl	IIR	300	570-700

* Production figures are rough estimates for 1971.

Natural rubber is perhaps the most versatile general purpose rubber which can be suitably compounded for a variety of applications. Due to its long history it is still used as the reference material for the evaluation of other elastomers. Its high resilience, high strength and superior dynamic flexing properties make it most suitable for highly demanding applications as in engineering components and large tyres. However, it suffers from poor resistance to weathering.

Styrene/butadiene rubber is consumed more than any other rubber and accounts for around 40% of all rubber consumed. Its excellent wearing characteristics and good wet-road holding properties make it most suitable for passenger car treads. However, due to its low resilience and poor fatigue performance it cannot be substituted for NR in engineering applications and in large tyres.

Butyl-rubber is used mainly for applications where low gas permeability is required and thus finds major use in the inside of tubeless tyres and tubes. The rubber is self-reinforcing and has better weathering characteristics than NR. But it suffers from low resilience and difficulty in curing.

Synthetic polyisoprene, which is almost a chemical duplicate of NR has similar properties to NR and finds similar applications. Due to low green strength and poor tack it is still considered inferior to NR in many applications and often used in blends with NR.

Polybutadiene rubbers possess high resilience and are used in blends with NR and SBR. In general they possess poor processing characteristics.

Ethylene/propylene rubbers have extremely good resistance to oxygen, ozone and heat; but in general they are not very compatible with other general purpose rubbers and are difficult to vulcanise.

The last three classes of general purpose rubbers are sometimes called the second generation rubbers due to their stereo-regularity. While SBR has displaced NR in several applications and established itself as a large tonnage rubber; the above stereo-regular rubbers and some newer ones offer the greatest competition to NR. However, amongst these synthetic polyisoprene must be considered the most serious threat to NR due to its near chemical duplicity.

2. RUBBER PRODUCTION INDUSTRY.

2.1 Natural Rubber Industry.

Today, the rubber plantations cover just over 6 million hectares, of which about 5.5 million hectares are in South-East Asia. Even at the depressed average prices in 1971, the 3 million or so tons of NR produced were valued at over U.S. $ 1,000 million. 92% of the world's supply comes from South-East Asia; with Malaysia's 44% share leading that of Indonesia (28%), Thailand (10.5%) and Sri Lanka (4.5%). The rubber industry is vital to economic well-being and its contribution to the employment in the rubber growing countries such as Malaysia, Indonesia, Thailand, Sri Lanka, Liberia, Cambodia and Vietnam is also vital; with the exception of India, Brazil and Philippines, all NR producing countries export a very large proportion of their output. The export of NR accounts for a substantial share of export earnings in these countries. It is estimated that around 2.5 million persons are directly employed by the industry.[6] Thus, NR production has become an important industry to millions of people in the developing countries, principally in South-East Asia. In the words of Bateman[7] "The plantation industry is involved to a remarkable extent with those multiple factors, economic, technical, commercial and sociological; which are at the heart of the day-to-day life in these regions and the hope for the future."

2.1.1 Structure of the Industry.

2.1.1.1 Distribution.

The geographical distribution of NR production is determined by two factors: climate and economics. The production of NR is labour-intensive and wages may constitute as much as 75% of the total cost of producing the rubber. The necessary climatic conditions and cheap labour co-exist in certain parts of Asia and Africa. This places NR at a disadvantage over SR, for

(1) the days of cheap labour in these areas are rapidly disappearing;

(2) the producers are separated from the consumers by thousands of miles and the transportation costs, which account for a considerable share of the total cost of the NR, are increasing steadily.

Table 2.1 gives the estimated planted area and the current output in the major producing countries. Certain facts seem obvious from the table, for example Malaysia's output which accounts for 44% of the total is produced from 34% of the total planted area for rubber. While Indonesia's plantations, which account for 33.4% of the total rubber area, produce only 28% of the total output.

2.1.1.2 Plantations.

NR comes from two sources: smallholdings and estates. In actual practice smallholdings are about two or three hectares, cultivated by a self-employed peasant

TABLE 2.1 Natural Rubber Production, Area Under Rubber Plantations And The Average Productivity For The Different Natural Rubber Producing Countries in 1971.

	NR Production (000 tons)	NR Production As % Of Total NR Production.	Area Under Rubber (000 Hectares)	Area Under Rubber As % of Total World Rubber Area.	Average Productivity.
Malaysia	1,324	44.0	2,020	34.0	657
Indonesia	834	28.2	1,987	33.4	420
Thailand	316	10.5	735	12.3	430
Sri Lanka	141	4.6	230	3.8	609
India	99	3.2	203	3.5	487
Other Asia	62	2.0	260	4.4	237
Total Asia	2,776	92.5	5,435	91.4	510
Liberia	74	2.5	107	1.7	692
Nigeria	50	1.7	240	3.9	208
Zaire	40	1.3	93	1.6	430
Other Africa	31	1.0	50	1.0	620
Total Africa	195	6.5	490	8.2	394
Brazil	24	0.7	20		1,200
Other Latin America	7	0.3	5		1,400
Total Latin America	31	1.0	25	0.4	1,240
World Total	3,002	100	5,950	100	504

farmer. The distribution between estates and smallholdings varies widely from country to country. In Thailand, all of the plantations are smallholder-owned, while in Vietnam and the Khmer Republic it is 100% estates, and in most other countries it is somewhere between these two. Historically, the smallholder has been associated with the production of poor quality rubber and inefficiency. The efficient production of consistent and good quality rubber is essential for the well-being of the NR industry - particularly as it is in competition with SR, which can be very precisely controlled during production as regards quantities, quality, kinds and specifications in general.

Estates in general are well organised and managed by professional managers. The larger estates in Malaysia and Sri Lanka are largely European owned and run by agency houses. This kind of ownership has its advantages, since these foreign companies also have well established trading or marketing organisations in the major consuming countries. However, this kind of ownership accounts for only 16% of the rubber plantations in Malaysia and 12% in Sri Lanka. Unlike the SR industry, where the major rubber fabricators have considerable ownership of SR plants, there is very little vertical integration by the rubber fabricators in the NR industry. Only about 7% of the NR production facilities are owned by rubber fabricators, a large proportion of which is produced as latex concentrate.

2.1.2 Developments in the Plantation Industry.

2.1.2.1 Replanting.

Several important advances have taken place in the plantation industry since the end of the War. The most important step towards meeting the increasing demand was the large scale replanting schemes started in Malaysia and Sri Lanka. Mature uneconomic trees have been systematically replaced with high yielding trees in these countries, since the early 50's. Such well organised replanting schemes did not start till the early 60's in the other major producing countries - mainly Indonesia and Thailand.

The establishment of superior planting material is the most important single branch of research which has benefited the industry. Several high yielding clones have been developed since the original seedlings were introduced into the rubber growing areas. The development of such high yielding clones is important to meet the increasing demand for NR and increase productivity and thus reduce costs. Today, there are clones producing well over 3000 Kg/ha/year; this is a six to seven-fold increase over the original seedling trees. In actual practice, one cannot expect to achieve this high yield on an average. There are other secondary characteristics besides the yield and a balance has to be struck between yield and secondary characteristics - such as soil conditions, resistance to diseases, etc. On the whole the average yields have increased tremendously and further moderate increases can be expected over the next few years. The increase in yields obtained from different clones over the years is shown in figure 2.1 from Sekhar.[8]

Figure (2.1) Increase in the Average Yields over the Years and the Performance of Contemporary Clonal Types.

2.1.2.2 Smallholders.

The economic and political importance of the smallholder sector can be appreciated by the fact that 4,152 million hectares of the total 5,950 million hectares of the world rubber area are classified as smallholdings. This accounts for just under 70% of the total planted area. However, the smallholder sector accounts for only about 50% of total NR output. This clearly shows the importance of improving the smallholder industry and the potential from this sector. While the large estates have been quick to exploit the advantages of replanting with high yielding trees, modern methods of processing the latex and marketing; the smallholders have been slow to adapt themselves to the changes in the plantation industry.

The typical smallholder is a self-employed subsistence farmer and in most cases the farmer also cultivates other crops - mainly food crops. The reluctance of these farmers to invest in costly replanting programs or change to modern methods of processing is mainly due to the uncertainty attached to the NR market. Historically, the smallholder has played an important role in stabilising the supply and demand situation. At times of low prices - usually associated with low demand, these farmers temporarily stop collection and processing of latex and concentrate on food crops etc. Similarly, when prices are high they increase the output to its maximum. In recent times, continued low prices for NR has made several smallholders to look for more profitable and quicker cash return crops, like oil-palm plantations in Malaysia.

With the cloud of uncertainty surrounding the NR markets, it would be too optimistic to expect the smallholders to invest in replanting or modern methods of processing. Government subsidised replanting schemes have been in progress for some time in most producing countries. It is essential that all smallholder latex should be processed in central factories under Government sponsored or Government subsidised schemes. Such schemes would not only help the smallholders to produce quality rubbers but also give them sufficient time to concentrate on other crops as well. Any over-dependence on rubber plantations should be minimised and the farmers should be encouraged to diversify into other crops.

2.1.3 Natural Rubber Production.

NR output between 1950-55 was virtually static due to the presence of large acreage of uneconomic plantations. Following the replanting schemes of the early 50's the output grew very gradually and at present the growth rate is around 4% (figure 2.2). While the total planted area has remained virtually constant, the production of NR has increased by over 50% since 1950.

The biggest increase in this period has come from Malaysia as a result of a systematic and well organised replanting scheme. Although the estate sector accounts for less than 40% of the total planted area over half the production comes from this sector. This is not surprising since over 90% of the planted area in the estates have been replanted with high yielding trees, while the corresponding figure for the smallholder sector is 65%. The present replanting and establishment of central processing units in the smallholder sector in Malaysia, will make the smallholder sector the largest producer in Malaysia. Thus a substantial increase in Malaysian production can be expected before 1980.

In Indonesia, the second largest producer with

Figure 2.2. Production and Consumption of Rubber, 1950 - 71.

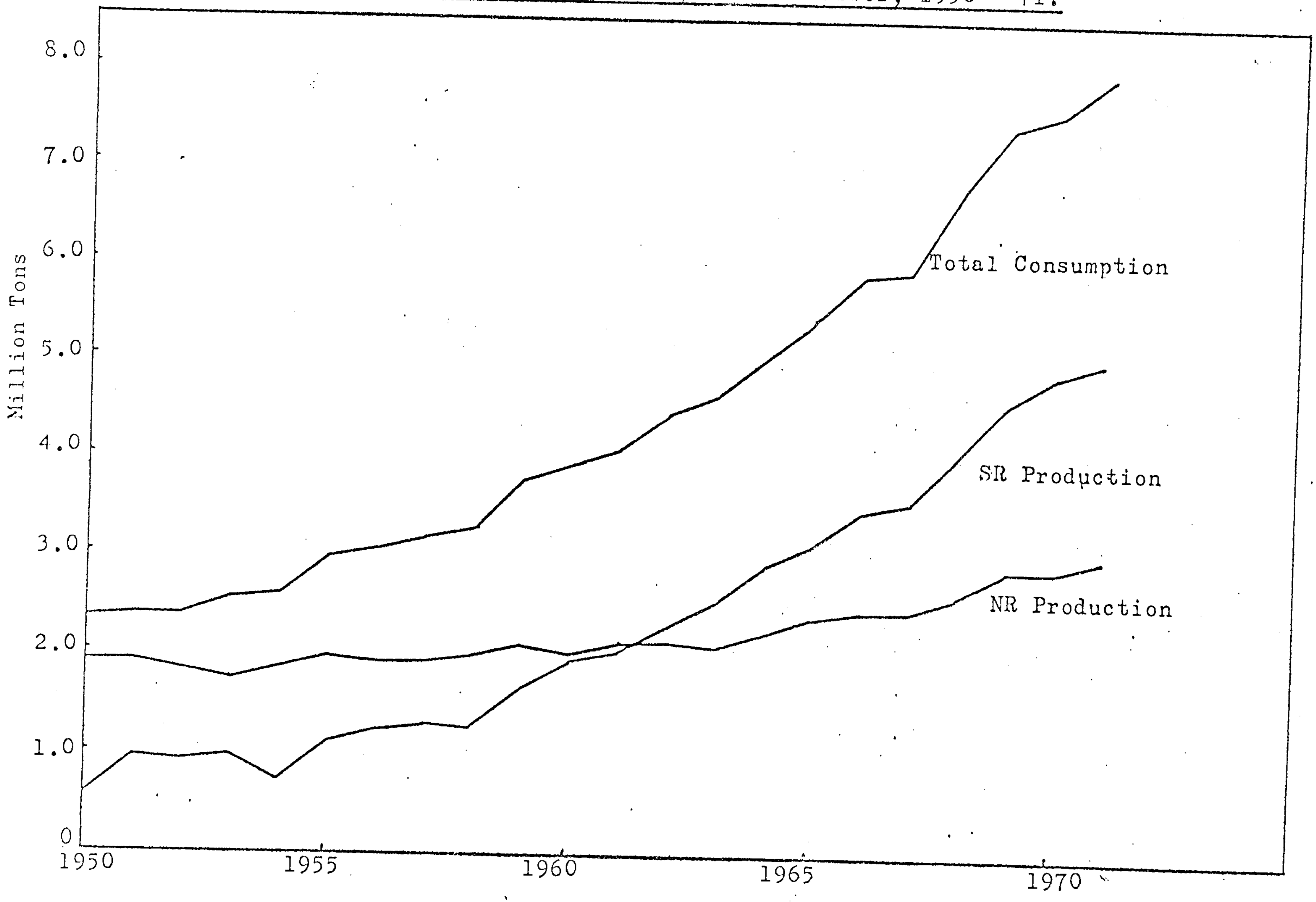
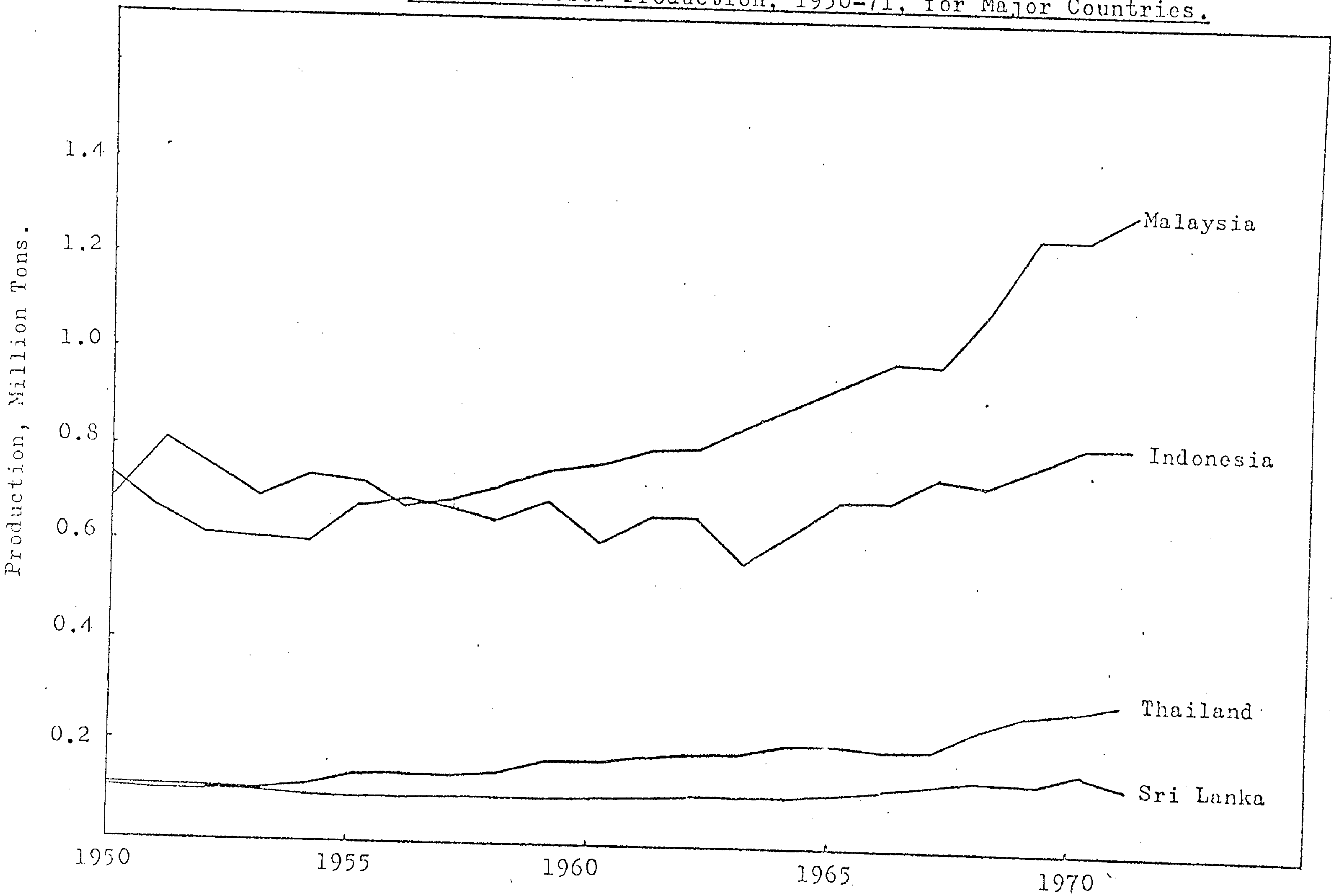


Figure 2.3 <u>Natural Rubber Production, 1950-71, for Major Countries.</u>



about the same planted area as in Malaysia, the production has been erratic (figure 2.3). The growth in the output has been very small compared to Malaysia. Poor organisation of the rubber industry and political uncertainties have been the main cause for the slow growth. Large scale replanting did not start till about 1963, even the replanted trees which account for about 25% are still not mature. Indonesia has the best potential to increase NR output. The present signs indicate a steady growth in output from Indonesia.

Amongst the other countries, Thailand has the largest planted area but the productivity is low. Because of the presence of a 100% smallholder industry, production increase is not likely to grow at the same rate as in Malaysia unless large scale Government assistance is provided.

Forecasting the future production volumes is often made difficult by the changes in technical, economic, social and political factors. Some estimates of NR production in 1975 and 1980 are given for the various NR producing countries in table (2.2), based on the present growth rate and other factors such as area under small-holdings, presence of high yielding trees, etc. World average of 1200-1500 Kg/ha/year is within the reach of the plantation industry before the turn of the century and the world NR output should reach 6 million tons per year by 2000 A.D.

TABLE (2.2)

Estimate of World Natural Rubber
Output in 1975 and 1980 (1,000 tons)

Country	1975	1980
Malaysia	1,500	1,900
Indonesia	950	1,200
Thailand	380	450
Sri Lanka	180	230
India	150	220
Africa	240	300
Others	150	200
World Total	3,550	4,500

2.1.3.1 Productivity in Plantations.

Being a labour intensive industry, most of the changes were in the intensification of long-term trends towards greater efficiency. The productivity in plantations has been increased steadily by replanting with high yielding trees - this is of course a long term approach - usually taking about 6 - 7 years between replanting and tapping and reaching peak yield around the 12th year. The use of yield stimulants is an important new development which is likely to short-cut this long term approach. The absence of a plugging effect is considered to be the reason for high yielding clones.[9] Certain ethylene releasing hormone type chemicals (such as 2-chloro ethyl phosphoric acid - called 'Ethrel') have been found to produce the anti-coagulant effect. The use of 'Ethrel' has been found to produce spectacular effects on the yield.[10] This introduces the possibility of enhanced tree productivity and greater flexibility of NR supply would certainly seem within reach. The long term effects of 'Ethrel' application on the productivity are not yet known. Continued application of the yield stimulant is likely to shorten the economic life of the tree. However, 'Ethrel' could be profitably used on low yielding uneconomic trees or during the period of declining yield. The most important application would be to boost the yield during periods of high demand.

2.1.3.2. Tapping and Collection.

During the years after the War, tapping costs alone accounted for about 75-80% of the f.o.b. costs and exercised a direct influence on volume output. Even today, in a well managed estate with an average yield of about 1000 Kg/ha/year, the tapping and collection cost may account for 50% of the total cost of production. This shows the economic importance of tapping and collection, as the means of harvesting the latex crop in the NR industry. The aim is to obtain as high a yield as possible with fewer tappings. Increasing costs of labour are a real threat to the industry. So far, increased productivity has been tackled from three directions:

(1) high-yielding trees;

(2) improved tapping systems;

(3) use of yield-stimulants.

In times of low prices and high costs of labour, productivity per tapper is of greater significance than the yield per hectare. Spectacular increases in the average yield as in the past 25 years are unlikely. Thus any future improvements should be towards labour-saving methods. Already several methods are being studied to reduce the number of tappings and collections. One method would be to reduce the number of tappings and at the same time boosting the yield using powerful yield-stimulants. Another method being studied at present is to allow the latex to coagulate automatically as it flows into a polythene bag and collect at infrequent intervals.[11,12]

2.1.3.3 Processing of Dry Rubber.

Processing of NR is changing from an art into a modern science. The NR producers have been aware of the needs of the rubber fabricator and NR processing is becoming consumer orientated. Although it is not possible to control or alter the fundamental properties of the natural product, it is possible to some extent to vary the properties of the resultant product to suit the fabricators' needs by certain variations in the methods of processing. More research in this area would be necessary to meet the varying needs of the fabricators. The most important development in the processing of NR is the 'new process' rubber to technical specifications and presented in a suitable form for the fabricator. The best known rubber of this type is Standard Malaysian Rubber (SMR).

Conventional grades and new process rubbers are produced from field latex and natural coagulum. Figure (2.4) shows the different types of rubbers produced from field latex and natural coagulum. About 85% of dry rubber is produced from field latex and in general the rubber produced from field latex is consistent in quality. The production of conventional grades of NR still account for over 80% of the total production. The SMR type of rubbers should account for around 25-30% of the total NR output by 1975. Of the conventional grades, smoked sheet is by far the most important type and may account for as much as 90% of these rubbers.

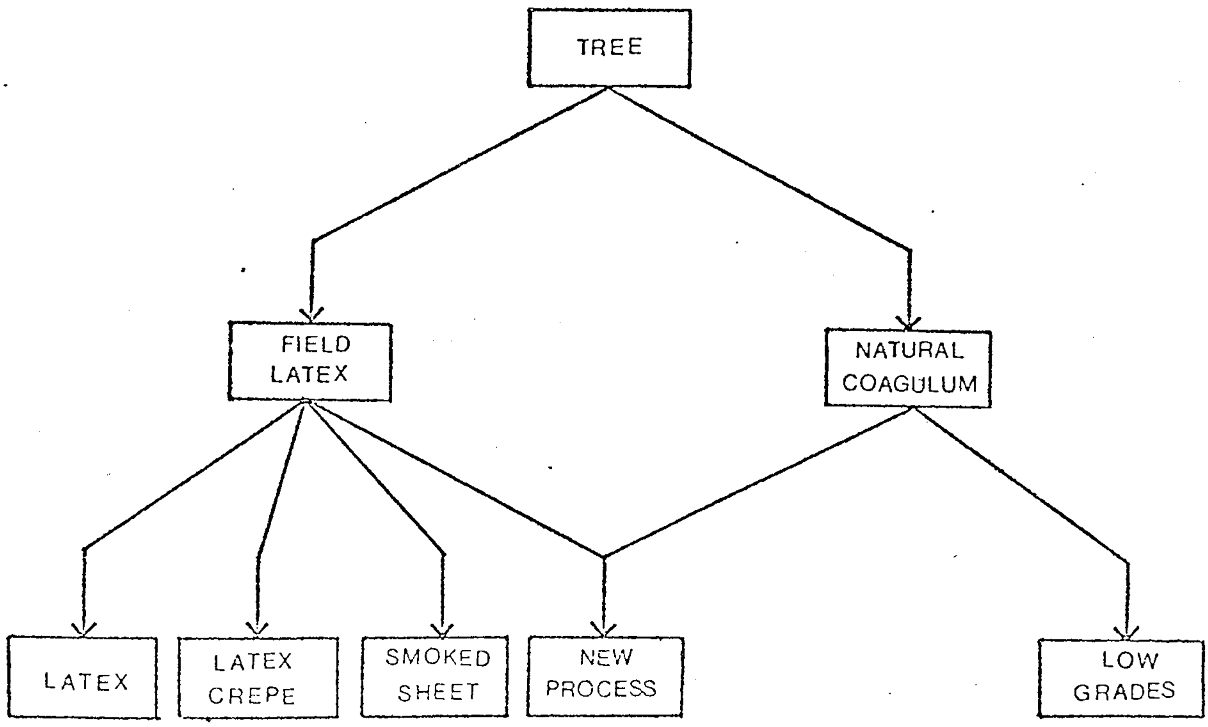


Figure (2.4): Production of Different Types of Natural Rubber from Field Latex and Natural Coagulum.

Processing of conventional grades of NR uses very simple, inexpensive and sometimes primitive equipment; the process is slow, uneconomical and less flexible to accept different feedstocks or to produce different types of rubbers. The rubbers produced are visually graded according to the "Green Book".[13] There are 8 different types based on the feedstocks and the type of preparation, these are further subdivided into 35 grades based on colour, dirt and visual blemishes. The absurdities of this system are summarised by Bateman.[14]

2.1.3.4 New Process Rubbers

The need to produce good quality rubber faster, economically and with some degree of flexibility arose to improve the image of the NR industry. This along with the revolutionary technical grading system gave rise to the introduction of new process rubbers. There are several methods of producing these rubbers.[15, 16, 17] In principle, all these methods involve the conversion of the coagulum into granular form either by mechanical means or using a chemical crumbling agent (castor oil). The granular form is more suitable for easy washing and fast drying. The process can be made continuous and automated to some extent, thus reducing the excess labour involved in the conventional methods. The final product is made into $33^{1}/3$ Kg bales and palletised for easy handling and storage. This process offers several advantages to the consumer as well as the producer. The main advantages to the producer being:

(1) suitability of the plant to accept different forms of feedstocks such as field latex, natural coagulum or unsmoked and partly smoked sheet;

(2) flexibility of the process to extend itself for the manufacture of oil-extended master-batches and low viscosity rubbers;

(3) processing costs are minimal.[18, 19]

However, this suffers from two major disadvantages, (a) high capital costs compared to the traditional processes, (b) minimum economic size of processing plant. Although this form of NR is being accepted as the best form of NR by the consumers, with the exception of low viscosity grades the premiums fetched by the equivalent grades over No. 1 smoked sheet are either marginal or none at all. Thus there is no incentive to change from simple inexpensive equipment to costly equipment. Even if the new process rubbers do not fetch a premium over the equivalent grade of smoked sheet, it is necessary to change over to new process rubbers to improve the long term competitive position.

The technical specification system, which is based on simple technological properties of some significance to the consumers, is the main feature of the new process rubbers. The essential features of this system are summarised in Table (2.3). This system reduces the number of grades from 35 to just 6 main grades. Viz. SMR EQ, 5L, 5, 10, 20 and 50.

TABLE (2.3)

Some Features of the SMR Specifications.[20]

Criterion	EQ	5L	5	10	20	50
Dirt retained on 44μ aperture (Max, % wt)	0.02	0.05	0.05	0.10	0.20	0.50
Ash Content (Max, % wt)	0.50	0.60	0.60	0.75	1.00	1.50
Nitrogen Content (Max, % wt)	0.65	0.65	0.65	0.65	0.65	0.65
Volatile Matter (Max, % wt)	1.00	1.00	1.00	1.00	1.00	1.00
PRI (Min, %)	60	60	60	50	40	30
Wallace rapid plasticity - min. initial value (Po)	30	30	30	30	30	30
Colour limit (Lovibond Scale, Max)	3.5	6.0	-	-	-	-

This has eased some of the problems of marketing arising from the multiplicity of grades. The most important features of the technical specifications are dirt content and plasticity retention index (PRI). The dirt content gives a positive measure of a deleterious agent, while PRI gives a measure of the susceptibility of the rubber to oxidative degradation. Additional specifications such as mooney viscosity and cure characteristics, which to some extent are within the control of the producers, also need to be supplied. (CV and LV rubbers are viscosity stabilised rubbers and cure rates will depend on the source material and processing method). These two properties are of prime importance to the compounder. So far, the technical specifications have been mainly supplied with the new process rubbers. These specifications can be easily supplied for the conventional grades. Such specifications would improve the image of smoked sheet significantly.

2.1.4 Production Economics.

It is often easy to be hypnotised by the concept of economies of scale. While it is true that considerable economies in processing costs may be achieved by using extremely large processing units, these are often offset by other costs which increase with the size of the processing plant. The bigger the central processing plant, the greater is the catchment area supplying the central factory and in turn the greater is the distance from which the raw material feedstocks (mainly latex containing about 70% water) must be transported. Additional expenses are also incurred due to larger quantities of chemicals being necessary to prevent coagulation during transportation. It is estimated that no great savings could be achieved by transporting latex of more than 10 tons of dry rubber equivalent per day[19] to a central factory producing new process rubber in Malaysia and probably less in Sri Lanka.

Bauer suggested as early as 1948 that, in view of the simple equipment used for processing latex, large scale operations are severely limited and centralised factories for areas in excess of 2,000 hectares are a doubtful proposition.[21] While this still holds good for the production of conventional grades of NR, somewhat higher areas are necessary for new process rubbers. The results of Barlow and Kheong[22] suggest an even smaller holding for smoked sheet production. Their results show that little economy in scale is achieved above 400 hectares while considerable cost reductions are achieved with increase in yield per hectare.

Although no definite conclusions can be drawn regarding the most economic size of a rubber holding, there is a minimum economic size for a processing unit. Economic considerations such as minimum daily output, capital cost and labour requirement are compared in table (2.4) for the production of new process rubber, smoked sheet and pale crepe in Sri Lanka. On the basis of minimum latex required for the different processing units, it is possible to estimate the approximate area of a rubber holding necessary to supply this quantity of latex for different average yields. (Table 2.5).

TABLE (2.4) Some Economic Considerations of Processing Latex, for the Manufacture of Smoked Sheet Pale Crepe and New Process Rubbers[23]

Type of Rubber	Minimum daily economic capacity (in Kg)	Approximate Capital Cost (US $)	Number of Employees per ton of rubber
Smoked sheet	250	5,000	28
Pale crepe	2,000	125,000	18
New Process	10,000	400,000	4

TABLE (2.5) The approximate minimum area necessary to supply field latex to central processing unit at different average yield levels.

Minimum Daily Capacity of Plant (Kg)	Minimum area of holdings (hectares) for different yield levels (Kg/hectare/year)				
	500	1,000	1,500	2,000	2,500
250 (smoked sheet)	200	100	65	50	40
2,000 (pale crepe)	1,600	800	530	400	320
10,000 (new process)	8,000	4,000	2,700	2,000	1,600

This shows that extremely large plantations are necessary for the economic production of new process rubbers. However, this problem can be overcome by the establishment of central factories and the necessary latex supplied from contiguous units or a concentration of smaller estates or smallholdings. One of the biggest advantages of new processes is their ability to accept both field latex and coagulum. Thus, freshly coagulated field latex collected from several points (this overcomes the problem of transporting latex containing 70% water) or natural coagulum stored over long periods can be used as feedstocks.

A complete change-over to new process rubbers is not likely to take place for several years. This is due to the existence of a large number of small and segmented plantations where good quality smoked sheet or latex crepes are produced profitably. On purely economic considerations it would not seem profitable to change over to new process rubber production where good quality latex crepes or smoked sheets are produced. But it is essential for the NR industry to upgrade the low grades of conventional forms into new process rubbers. Firstly, because these can be converted to more consistent and better quality rubbers by improved washing of scraps; secondly, the final product is technically specified and presented in a form acceptable to the fabricator. And finally, in general these rubbers fetch a premium over the equivalent grades of conventional rubbers.

2.1.4.1 Costs.

The cost of producing NR varies so widely that the average cost of production is of little significance. There is no common meaning for cost of production between the smallholder sector and the estate sector. Of concern to the smallholder is the highest possible cash return for his efforts. To an estate, the cost of production has its usual significance. The cost of production of smoked sheet in a well managed estate, exclusive of return on investment, replanting costs and export duties and cesses, is likely to be anything between 8 - 14 U.S. cents per lb. (7.5 to 13 pence per Kg), broken down as follows:

Field upkeep	11%
Tapping and Collection	52%
Management	10%
General Charges	13%
Processing, packing and despatch	14%
	100%

To this must be added about 4 - 6 U.S. cents per lb. (3.5 - 5.5 pence per Kg) depending on the port of origin and the final destination, for export duties and cesses, freight, etc.

Considerable reductions in tapping and collection costs may be achieved with increased average yields. It is estimated that for every 100 Kg increase in the yield per hectare per year, the estate costs of production are reduced by an average of 1.5 U.S. cents per lb. (1.4 pence per Kg). Thus a rise in yield from 500 to 1000 Kg per hectare should show a lowering of 7.5 U.S. cents per lb. (7.0 pence per Kg).[24] This seems a highly optimistic figure. The results of Barnard[25] as summarised in figure (2.5) show that the greatest reduction in tapping cost is achieved up to a yield of about 1000 Kg/ha/year.

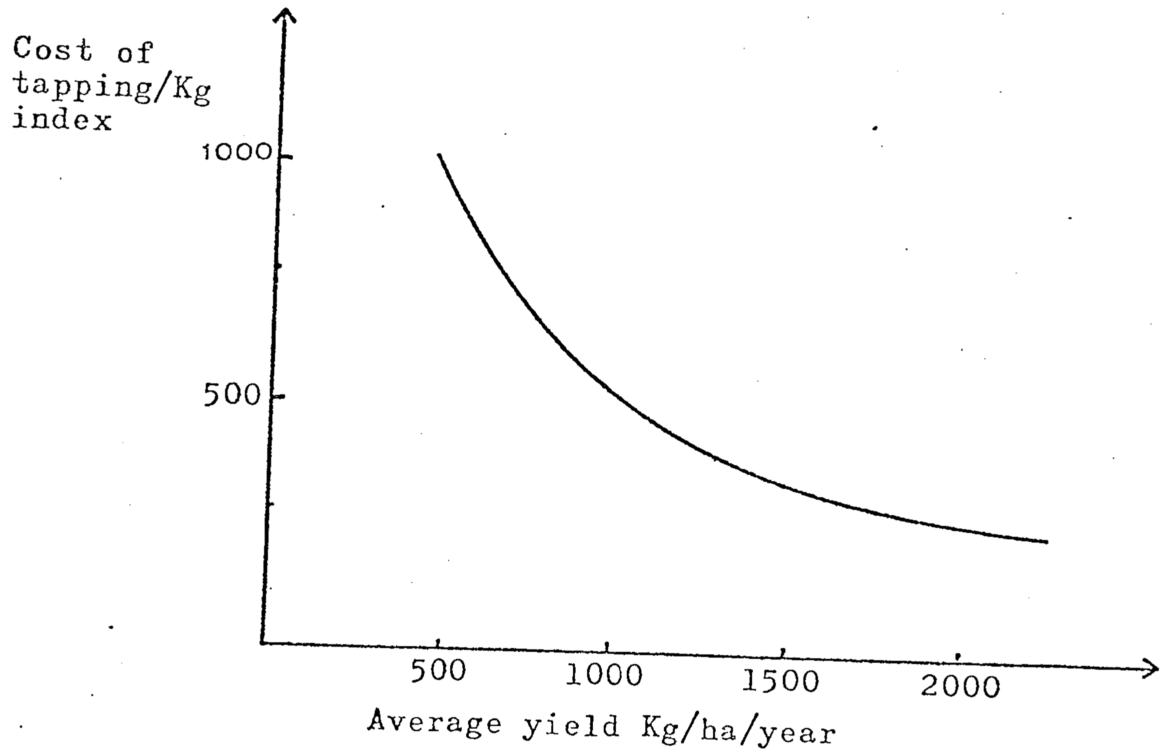


Figure 2.5 Cost of tapping as a function of yield.

2.1.4.2 Profitability.

The production of NR is often considered less capital intensive compared to the production of SR. This notion is disputed by Allen.[26] He argues that the capital costs per unit output of rubber may not be very different from that required for SR production. Due to the minimum economic size required for a SR plant, the initial capital can be extremely high. In comparison a new plantation for NR production can be established by gradually increasing the size and thus spreading the costs over several years.

A recent profitability study on replanting in Malaysia, shows that the total capital can be realised over the 36 year economic life of the tree, discounting at 13%.[27] This is based on a 2000 Kg/ha/year average yield and an average f.o.b. price of 90 Malaysian Cents per Kg. (12 - 13 U.S. Cents per lb) for the smoked sheets. In practice, even with the application of yield-stimulants, it may not be possible to achieve the 2000 Kg/ha/year average yield over the whole period. Past experience shows that it is impossible to forecast the average price of NR. Even when discounting at 8%, it takes about 18 years to realise the capital involved in replanting.

This raises serious doubts about the profitability of investment in rubber plantations. In terms of possible alternatives, it may be more profitable to invest in short term cash crops like oil-palm or the much needed food crops in these countries. Under these circumstances it is unlikely that any large scale new plantations would be open, except perhaps under state sponsorship. Although it may not be profitable to invest in large scale replanting or new planting; in terms of national economies, rubber plays a vital role as a foreign exchange earner in most of the rubber producing countries. While it is essential to diversify; in view of the dwindling raw materials situation in the SR industry it is essential to increase the growth rate of NR production. In future, greater assistance in the form of subsidies would be needed to maintain this growth in the rubber producing countries.

2.2 Synthetic Rubber Industry.

The structure of the SR industry is in no way similar to the NR industry's. The essential differences which bring out some important features in the short and long term competitive position are listed below:

1. The industry is one of a few large scale sellers (Oligopoly).
2. Large scale ownership by rubber manufacturing industry and raw materials suppliers.
3. The geographic location and capacity of SR plants.
4. The minimum economic size of SR plant and capital investment.

It was estimated that 44% of the free world's SR capacity was owned by the rubber manufacturing industry (mainly tyre manufacturers) and 42% by the petrochemical industry.[28] This kind of partial vertical integration of SR producers, either back to raw materials, or forward to end use, is a powerful stimulus to the development of improved manufacturing methods and tailor made rubbers to suit end uses. The minimum economic size and high capital investment necessary for a SR plant are often a barrier for new entry into the industry. The geographic distribution of SR plants is centred alternatively around (1) raw material sources; (2) major consuming sources; or (3) other factors such as intermediate point for economic transportation facilities, Government incentives, etc.

2.2.2.1 Synthetic Rubber Production.

While NR output is growing at the rate of about 4% per year, the SR production has been increasing rapidly at the rate of over 7% per year. Several changes in the production trends have taken place in the SR industry. Till the end of the 50's, emulsion SBR was the most important class of general purpose SR; while neoprene, nitrile and butyl were the important rubbers produced in any large volumes. The new class of stereo-regular elastomers - polybutadiene, synthetic polyisoprene, ethylene/propylene rubbers and solution SBRs - were introduced in the early 60's. SBR continued its growth during the 60's and the present signs are that its growth is slowing down. The share of the SBR output is declining from 63% of total SR output in 1969 to 57% at present. This decline is due to the increased share from the stereo-regular rubbers. This tendency is likely to continue. At present about 90% of the SR production facilities are accounted for by SBR (57%), polybutadiene (16%), polyisoprene (8%), ethylene/propylene (4.5%) and butyl (4.5%). Neoprene and nitrile account for a large proportion of the rest.[29]

SR production has been dominated by North American producers for a long time. U.S.A. still ranks as the leading producer but the growth rate is slowing down. SR production in Japan has been growing rapidly and is the second largest producer. The countries of the European Economic Community and the U.S.S.R. are the other important producers. Economic nationalism and other factors such as access to raw materials will in future favour the European producers. This would be an unfavourable situation for the NR industry since the European rubber fabricators have in the past been consuming a larger percentage of NR than their American counterparts.

2.2.1.1. Production Process.

NR industry is mainly concerned with the finishing operations. All SR production is concerned with three main operations:

(1) production of monomers,

(2) polymerisation of monomers,

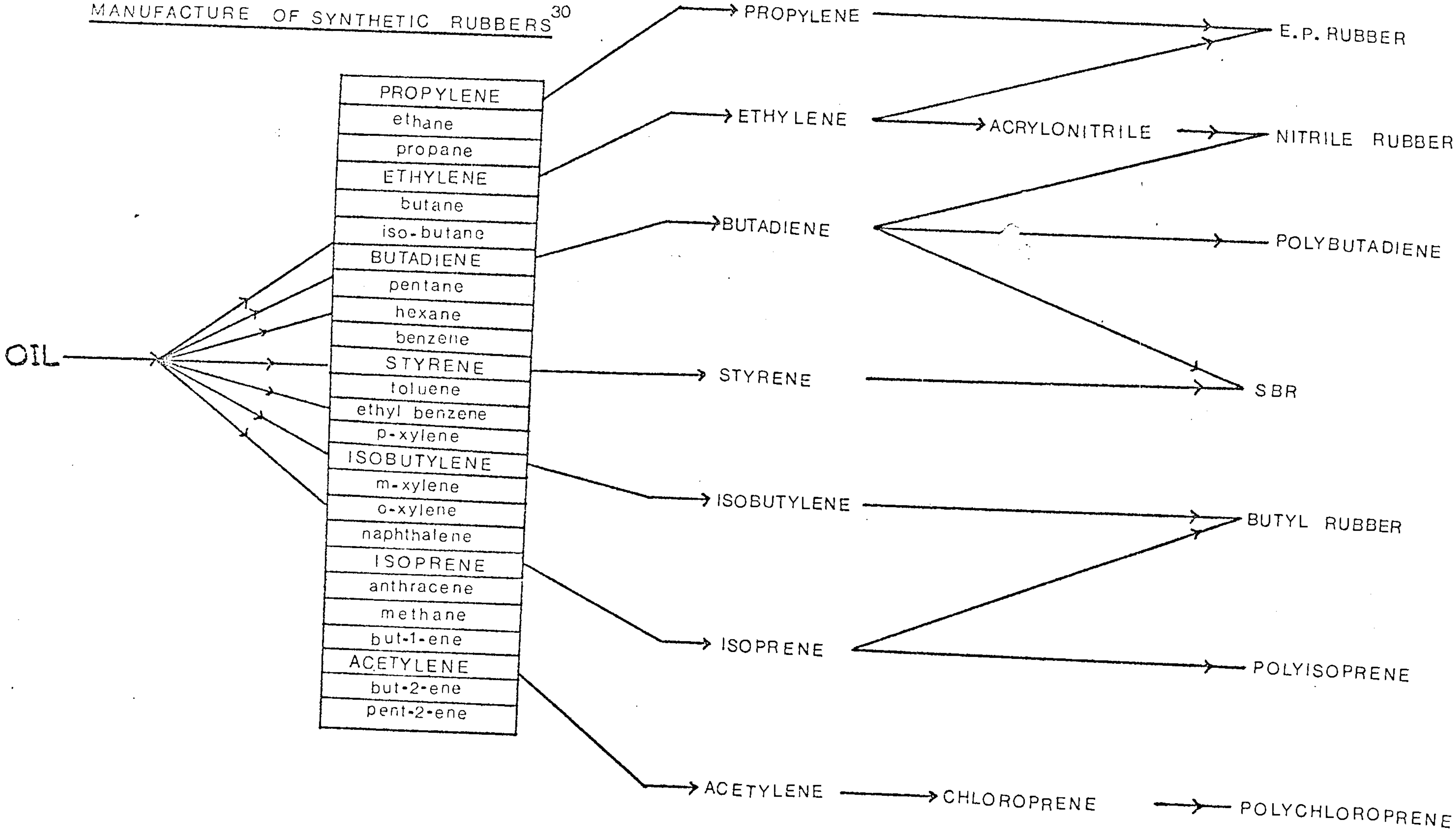
(3) finishing operations.

The first two operations are vitally important in the manufacture of SR. These are characteristic of the monomer or polymer produced in respect to production technologies and associated economics. It would be futile to attempt to describe the production process and the associated economics for the range of elastomers and each monomer associated with these. Some of the essential features and their effect on the competition are discussed.

2.2.1.2 Monomers.

The cost of monomers may account for as much as 50 - 60% of the total cost of the rubber. Thus the cost of the monomers play an important role in the overall economics of SR production. Monomers for all large scale synthetic polymers are derived from petroleum industry and

FIG.2.6. THE FAMILY OF HYDROCARBONS FOR THE MANUFACTURE OF SYNTHETIC RUBBERS[30]



this makes the SR industry virtually dependent on the petrochemical industry. Figure (2.6) shows the family of hydrocarbons derived from petroleum oil for the manufacture of SR's. Several routes are generally available for the production of a hydrocarbon. The choice between these depends on factors such as access to technology, economies of scale, capital costs, the nature of feedstocks, the demand for by-products etc. Some of the essential monomers (mainly isoprene and butadiene) are produced as coproducts of ethylene during the cracking of naphtha and gas-oil. The ratio of the different by-products are in general determined by the nature of feedstocks and severity of cracking. Ethylene being an important starting material for plastics and a wide range of intermediate chemicals thus dictates the route to the other by-products. Non-petrochemical routes for the production of monomers, via alcohol produced by fermentation of natural products, are considered uneconomic. However, petrochemical routes may become more expensive as the oil supplies become scarcer. This would favour a swing back to the alcohol route and more to NR.

2.2.1.3 Polymerisation.

Emulsion polymerisation accounts for the bulk of SBR produced. With increasing demand for stereo-regular rubbers, the solution polymerisation process has become more important. Emulsion process is somewhat cheaper and simpler than solution process. In emulsion process, the monomers are emulsified in water using emulsifying agents and the polymerisation is initiated by catalysts. The resultant latex is similar to the natural latex, is finished similar to NR. The latex can also be used for oil extension or masterbatching.

In the solution process, the polymerisation is carried out in organic solvents using "stereo-regular caralysts". Two important classes of catalysts are used:

(1) Ziegler catalysts

(2) Anionic catalysts.

Solution polymerisation offers great versatility in the manufacture of synthetic elastomers. The structure of the polymer could be controlled to required levels by the choice of catalyst systems and polymerisation conditions. Several problems and difficulties arise during the solution process from the use of these catalyst systems. One of the main problems is the need for extremely pure monomers and solvents. These problems are discussed by Duck and Ridgewell.[31]

2.2.2 Production Economics.

Availability and cost of raw material feedstocks for monomer production, production technology, economies of scale, captive production, capital and operating costs, return on investment etc. are some of the more important factors which are likely to have a very strong influence on the long-term competitive prospects of all SR's. The present short supply of styrene monomer has had a marked effect on the price of SBR. It is forecast that this shortage of styrene will exist in 1975.[32] The shortage is due to the short supply of benzene. Price increases in the petrochemical feedstocks for monomer production will affect the cost of monomer.

Several factors that are likely to affect the price of the petrochemical feedstocks are summarised below:

(1) Increasing dependence of the U.S.A. on eastern hemisphere for crude oil supplies;

(2) The threat of an energy crisis;

(3) Escalating crude oil price from the OPEC settlement;

(4) Increased freight rates.

2.2.2.1 Economies of Scale.

"Economies of scale are reflected in a decline of the production and distribution costs per unit output as the plant is increased in designed production capacity and if at the same time it actually produces at the same successively larger designed capacities".[33] The scale of a plant is increased to take advantage of economies and to meet the anticipated increased demand, this has often led to excess capacity and higher costs or a tendency to increase plant loadings resulting in a lowering of price. This situation has often been experienced in the SR industry, and on the average, SBR plants have been operating around 80 - 90% of their designed capacities. Economies of scale exist for monomer and SR production as in the production of most large volume chemicals. Considerable cost reductions have been achieved in the past 20 years for the production of a large number of chemicals by the introduction of new technology and larger plants. The economies of scale have become more important as changes in technology have pushed the total average cost curve and the minimum point to the right.

The minimum economic size of a SR plant in a developed country is estimated to be around 40,000 tons per year.[34] This figure may be somewhat low for the production of emulsion SBR in N. America, W. Europe or Japan. The newer plants that have come into operation in these areas are in excess of 100,000 tons per year output, and often are a part of an integrated petrochemical complex or partly owned by rubber fabricators or both. The average size of a plant for the production of solution rubbers is somewhat smaller. This may be due to the smaller demand for these rubbers at present and problems associated with solvent recovery. Technological innovation and increased demand is likely to increase the size of solution rubber plants to achieve the economies of scale.

Economies of scale for monomer production via petrochemical routes are quite critical. Butadiene and isoprene obtained as coproducts of ethylene during the cracking of naphtha and gas-oil are considered the cheapest route for these monomers in Western Europe. However, these are only produced in small proportions. Thus, to obtain economic quantities of the valuable coproducts at one location, extremely large plants are necessary. About 15 per cent of butadiene can be expected as a coproduct of ethylene[35] and in order to extract 20,000 tons of isoprene annually from the C_5 fraction, it would be necessary to have an ethylene capacity of 800,000 tons per year.[36] Although the C_5 fractions could be collected from several cracking plants, any cost advantages of processing may be offset by transportation costs.

2.2.2.2 Monomer Costs.

Monomer costs depend not only on the process of manufacture but also on the overall supply and demand position. Except isoprene, other monomers for general purpose rubbers such as styrene, butadiene, ethylene and propylene, find a market in the manufacture of non-rubber materials - mainly plastics. Styrene market is dominated by the polystyrene demand and over 85% of the monomer is used in polystyrene and ABS. Thus, any shortage in styrene is likely to have an adverse effect on the cost of SBR. The present shortage of the aromatic fraction for styrene manufacture makes it impossible to quote a firm price for the monomer. Since the cost of benzene accounts for about 40% of the total cost of styrene, the future cost of styrene will be determined by the cost of benzene. Butadiene demand is dominated by four rubbers - SBR (65%), polybutadiene (24%), nitrile (4%) and chloroprene (3%). The rest is consumed by ABS, Nylon 12 and other materials. The cost of making butadiene in a 40,000 tons per year plant by dehydrogenation is estimated to be around 10 U.S. Cents per lb. at 20% return on investment and 10% depreciation.[37] But the cost of butadiene as a coproduct of ethylene is reported to be around 8 - 9 Cents/lb.[35] Isoprene monomer for solution polymerisation is possibly the most expensive among the three monomers in discussion. Since at least seven established routes are available for isoprene production, there is no single cost. The required selling price at 20% return on investment and 10% depreciation was reported to be between $11\frac{1}{2}$ - 14 Cents/lb. for a 20,000 tons/year plant and about 2 - 3 cents cheaper for a 40,000 tons/year plant.[38] The present average price of isoprene monomer is around 10-12 Cents/lb. It is argued that the cheapest route for isoprene is by acetonitrile extraction of the C_5 stream, and is likely to cost slightly less than 10 Cents/lb. And this method also has additional advantages, since useful byproducts are obtained along with isoprene, which can be used as starting material for monomers used in other synthetic rubbers. These are:

(1) cyclopentadiene for trans polypentenamer (TPP);

(2) cyclopentadiene for dicyclopentadiene and ethylidene norbornene which are used as termonomers in EPDM;

(3) piperylene for propenyl norbornene which is used as a ternonomer for EPDM.[39]

However, this method suffers from the fact that only 12-15% of isoprene is present in the C_5 stream. And thus, to establish a plant for the extraction of isoprene, large quantities of C_5 stream should be available at one location. It is likely that large scale extraction plants would be established in areas where a concentration of cracking plants are available. This would of course, depend on future NR prices.

2.2.2.3 Polymer Costs.

Very little published information is available on the cost of manufacturing synthetic elastomers. These costs are likely to vary considerably depending on process technology, plant size and location. However, certain generalisations can be made on the costs of polymer manufacture. The total cost of making the solution polymer is more than that for the emulsion polymer. Higher cost for plant, processing and catalysts are likely to contribute to these higher costs. Monomer cost may account for about 40 - 60% of the total cost. Some economies are achieved by polymer manufacturers for bulk purchase of monomers.

It is doubtful if the smaller producers can expect to make sufficient return on their investment at current prices for the solution rubbers, especially operating below 100% capacity at times of over-production. It is likely that the smaller plants may be operating near full plant capacity at all times. However, the bigger firms with larger plants can be expected to make sufficient profits operating around 90% plant capacity. Such firms can expect to achieve considerable economies via vertical integration and plant size. The profitability of smaller plants in developing countries is questioned by Lamberson.[40]

In conclusion it may be said that three factors influence manufacturing costs:

(1) plant size;

(2) raw materials;

and (3) technology.

In the past 20 years inflation in wages and construction materials have been offset by technological changes. Inflation rates have escalated and may continue at high levels. The petroleum feedstocks that have escaped inflation in the past are now likely to be subject to the same pressures as other costs. It is argued that the future growth of the petrochemical industry for the manufacture of olefins is likely to face problems such as availability and cost of raw material feedstocks, industrial over-concentration with its ecological and labour problems, availability of capital for investment and profitability.[41] It would thus seem optimistic to expect any drastic cost reductions in the polymer manufacture, except perhaps to a small extent in the case of the new solution rubbers. Here, the increasing demand is likely to create bigger plants and newer technology with some cost reduction. Competition within the SR industry is fierce and smaller producers will find it increasingly difficult to compete with large scale manufacturers. High capital costs and size of plant will remain a barrier to new entry unless drastic reduction in cost can be achieved via new technology. The future of polyisoprene rubber and to a smaller extent that of polybutadiene and ethylene/propylene rubbers would of course depend on the price of NR. Continued high price for NR would act as a stimulus to develop these rubbers to even bigger scale. The present cost of NR manufacture in an efficient plantation would match that of any large scale SR.

3. RUBBER CONSUMPTION.

3.1 Rubber Demand.

The demand for raw rubber is derived from the demand for various rubber products. The importance and the growth of rubber is closely related to the growth of the car industry. Tyres alone account for over 60% of all rubber consumption. In addition to the tyres several kilograms of a variety of elastomers are used for various components in the passenger car and other vehicles. The transportation industry alone may account for over 70% of rubber consumption. This makes the rubber industry virtually dependent on the transportation industry and naturally, the demand for rubbers is closely related to the output of passenger cars, buses, lorries, trucks and other forms of vehicular transportation.

There is a multitude of rubber products, and it is impossible to classify these systematically into various categories. Since tyre and tyre-products consume about 65% of all rubbers, rubber consumption is generally broadly classified into the tyre and non-tyre sectors. Table (3.1) brings out some of the more important classes of products. This leaves out a large number of important products due to the lack of detailed statistics on the breakdown of rubber consumption by end-products. This table gives an overall guide to the use of the variety of rubbers. The choice of the type of rubber in these applications is discussed later.

TABLE (3.1) An estimate of the breakdown of rubber consumption into some product groups.

Product group		Percentage of total rubber consumption.
Tyres and tyre products		65.0
Mechanical and industrial goods		13.0
Belting	(3.0%)	
Hose and tube	(3.0%)	
Rubber bonded components	(2.0%)	
Other	(5.0%)	
Footwear		5.5
Latex foam products		3.5
Latex carpet backing		3.0
Wire/cable covering		1.5
Adhesives		1.0
Other miscellaneous goods		7.5
		100.0

3.2 Consumption Trends.

The demand for rubbers, being dependent to a large extent on the motor car and other consumer goods, will therefore depend to some extent on the economic conditions prevailing in the major consuming countries. It is shown that the rate of growth of rubber consumption is closely related to the growth of GNP in a developed country.[42] The total rubber consumption is growing at an annual rate of about 6-7%, while NR output is growing only at the rate of about 4% per year.

The consumption trends vary quite considerably from one country to another. Thus, the rubber consuming areas are divided into four main groups depending on market volumes, similarities in technological and economic development and geographical distribution. These are:

(i) U.S.A.

(ii) Western Europe.

(iii) Eastern Europe and China.

(iv) Rest of the World.

The rest of the world group includes Japan which, is the second largest consumer of all rubbers after U.S.A. and hence a separate discussion for Japan is included.

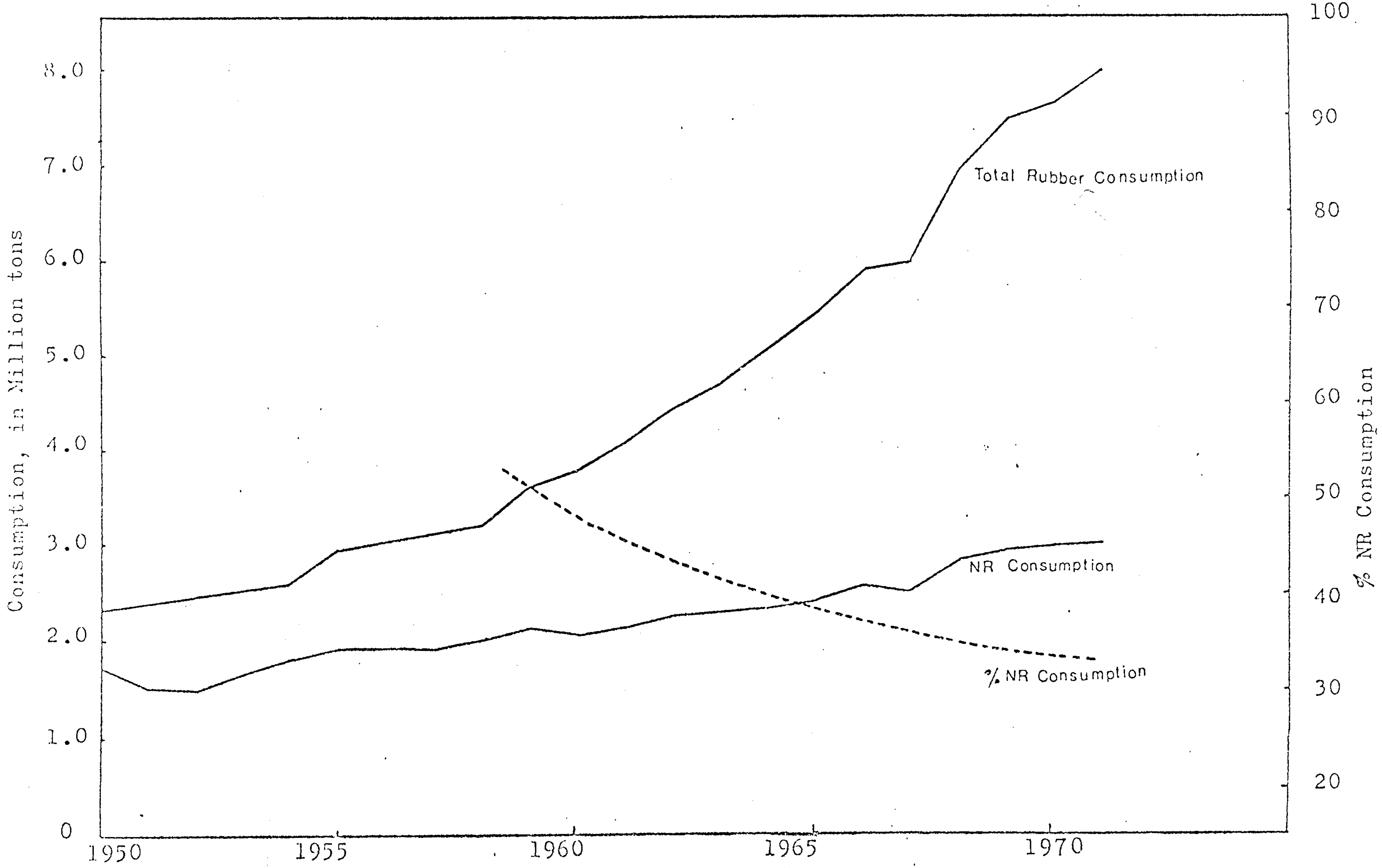
Although NR consumption is increasing at about 4% annually, its share of the total rubbers has decreased from 48% in 1960 to 34% in 1970. There is a definite downward trend in the share of NR, but this is not as marked as in the period between 1965-70. Extrapolating this trend to 1975, NR should maintain a market share of about 30-32% (Fig.3.1). Table (3.2) reveals some interesting characteristics of the nature of rubber consumption in the different country groups.

TABLE (3.2) Market Shares of World Rubber Consumption.

	% of total rubber consumption		% of total SR consumption		% of total NR consumption	
U.S.A.		35		43		20
W. Europe		30		30		30
U.K.	5.9		5.6		6.3	
France	5.4		5.4		5.3	
Germany	7.0		7.4		6.4	
Italy	3.8		4.1		4.0	
E.Europe & China		10		4		22
China	2.4		0.6		5.5	
Rest of the World		25		23		28
Japan	11		12		11	
		100		100		100

U.S.A., which accounts for 35% of all rubber consumption, uses only 20% of the total NR output. While Eastern Europe and China, which consume 10% of all rubbers, use about 22% of the total NR consumption. In W. Europe and the rest of the world groups the distribution is more even. Such extremes are obviously due to the availability of SR production facilities within each country. This tends to suggest that in U.S.A., large scale usage of SR up to the limit of technological substitution, may be the result of captive consumption of SR and availability of SR

Figure (3.1) World Rubber Consumption, 1950 - 71



from a home based industry. The lack of SR production within the socialist block of countries is the reason for these countries to depend to a greater extent on NR. Any large scale establishment of SR production facilities in these countries would have an adverse effect on NR.

The percentage of NR used in U.S.A. has decreased and has almost levelled off around 23% (Fig. 3.2) in the last 4 or 5 years. This levelling off has taken place even with large scale increase in the consumption of the stereo-rubbers. This tends to suggest that the limit of technological substitution may have been reached in U.S.A. The increase in the stereo-rubber consumption has taken place at the expense of SBR rather than NR. There is a similar tendency to use decreasing share of NR in W. Europe and the Rest of the World group (Figs. 3.3 and 3.4). At the same time the actual NR consumption is growing steadily and faster than in U.S.A. There are large fluctuations in the rubber consumption in the socialist block of countries and the reliability of the statistics is questionable. It is safe to say that while NR's share is decreasing, this decrease is now slowing down.

Figure (3.2) Rubber Consumption in U.S.A. 1950-71

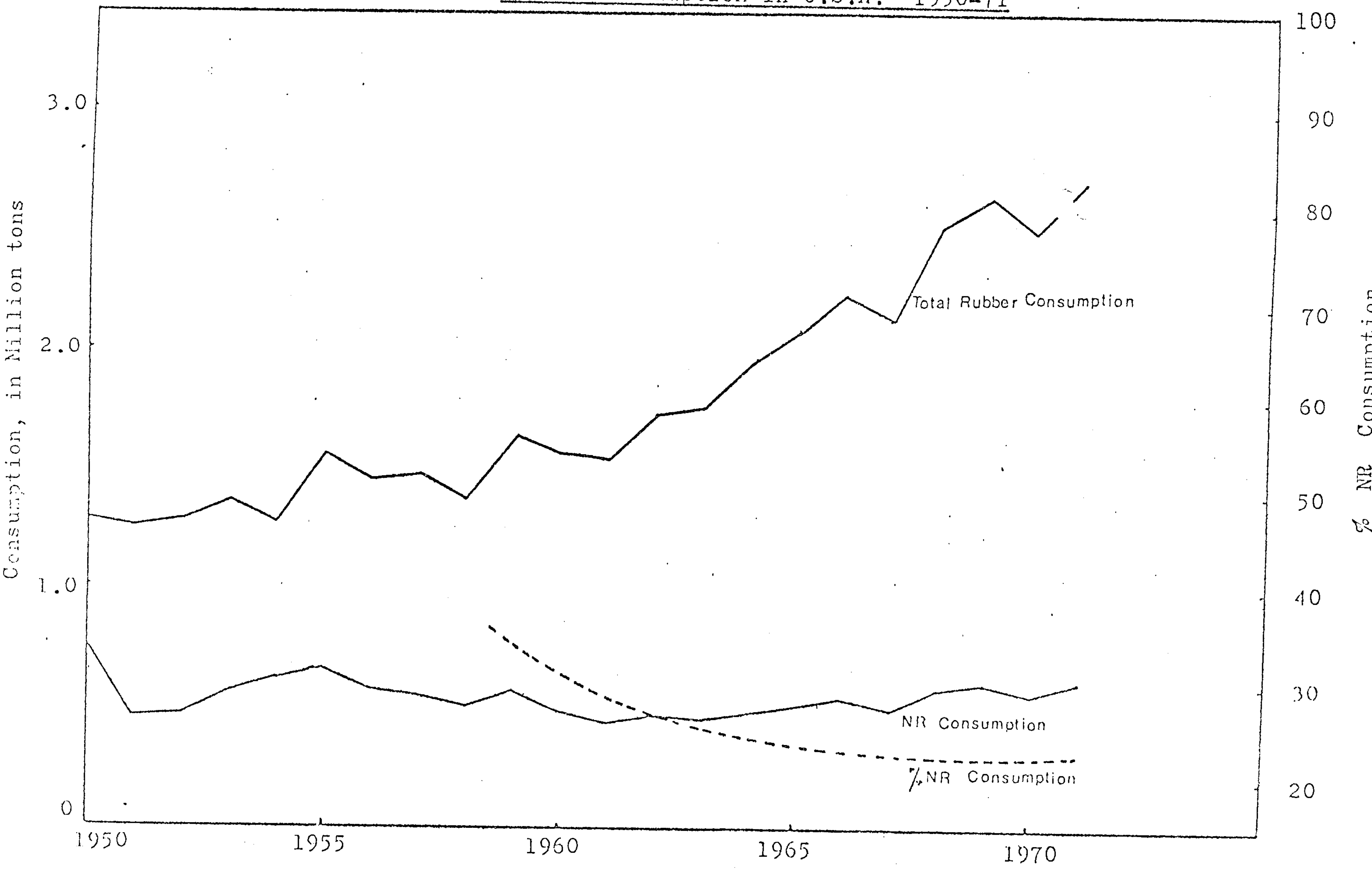


Figure (3.3) Rubber Consumption in W. Europe, 1950-71

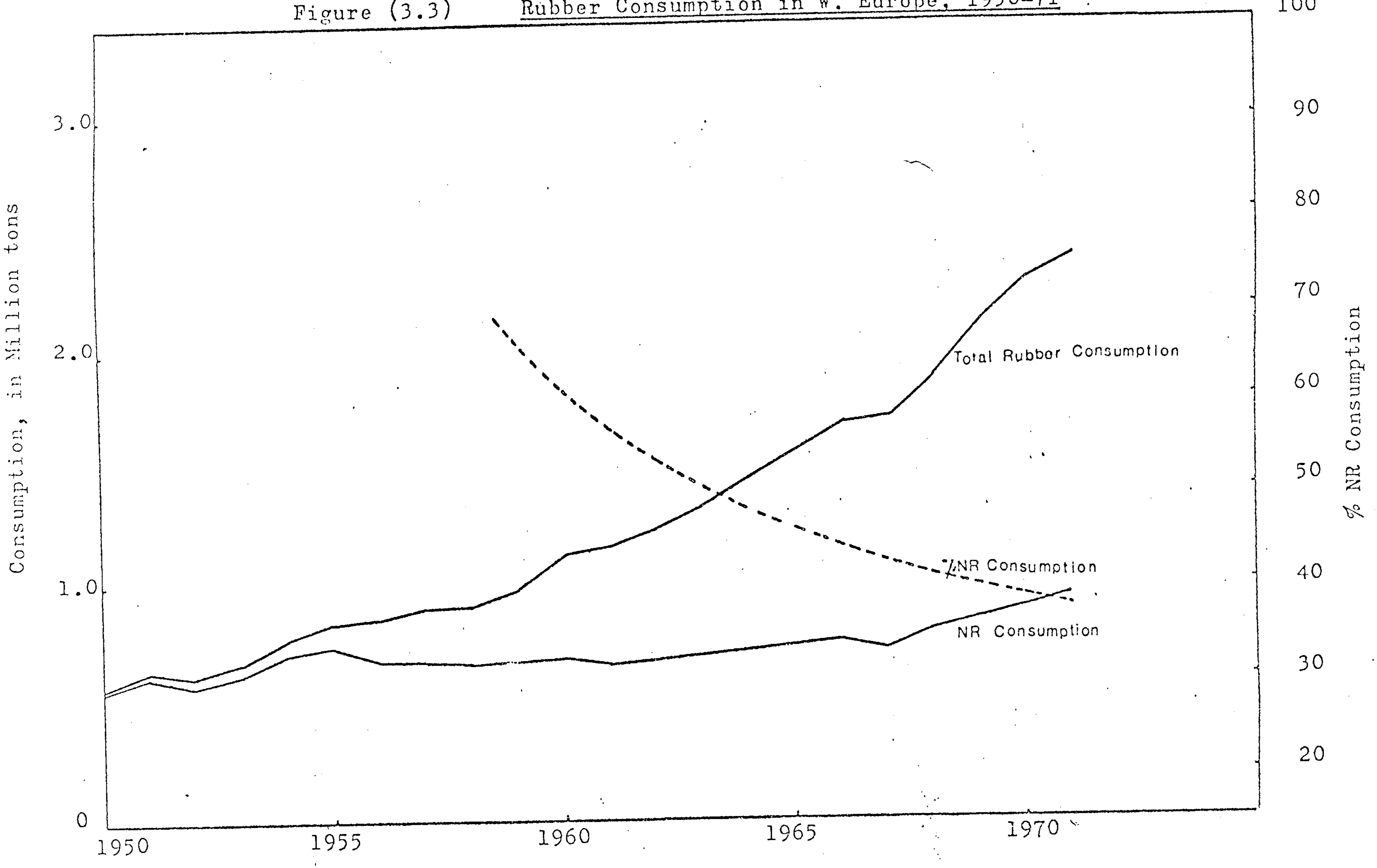


Figure (3.4) Rubber Consumption in 'Rest of World', 1950-71

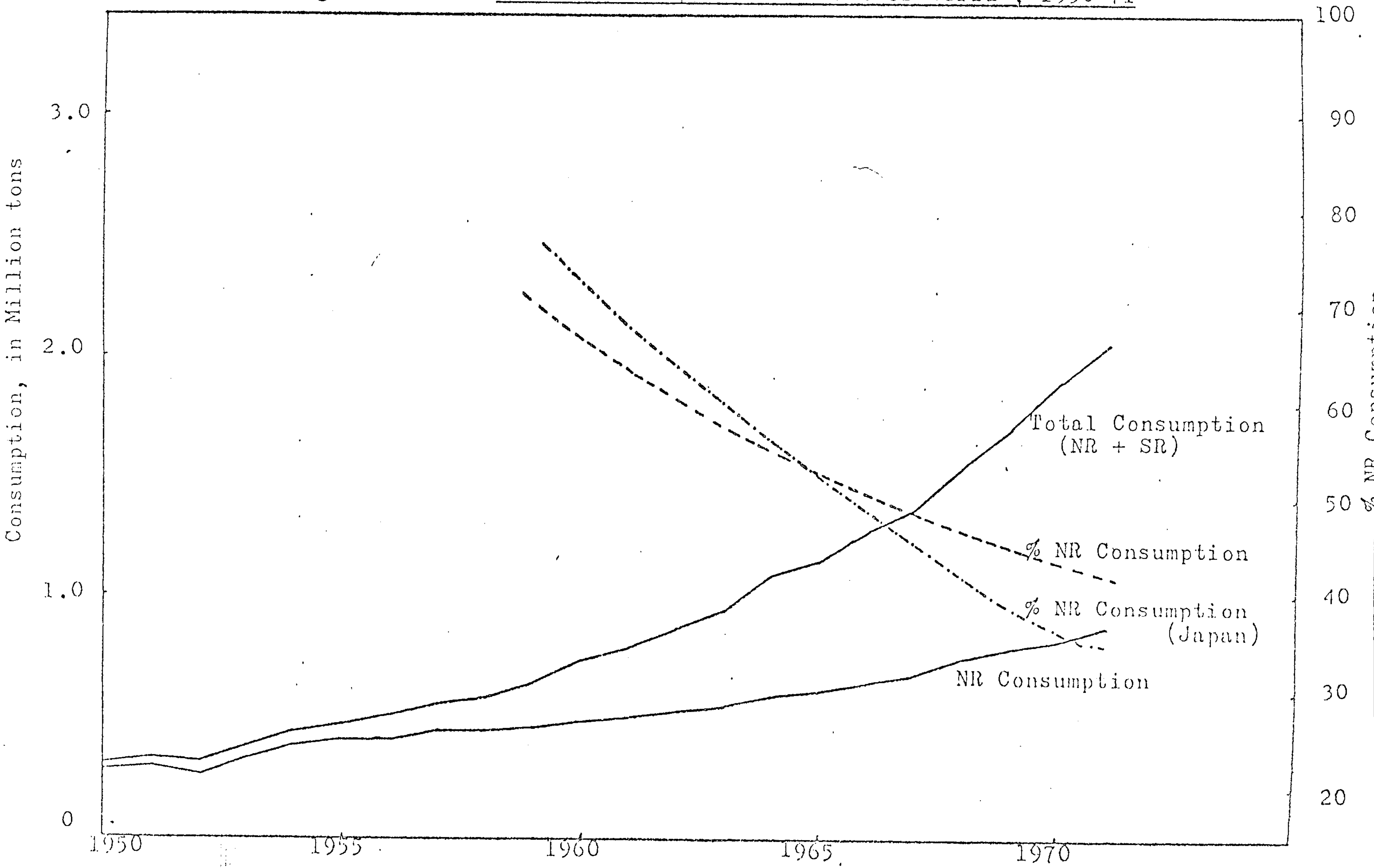
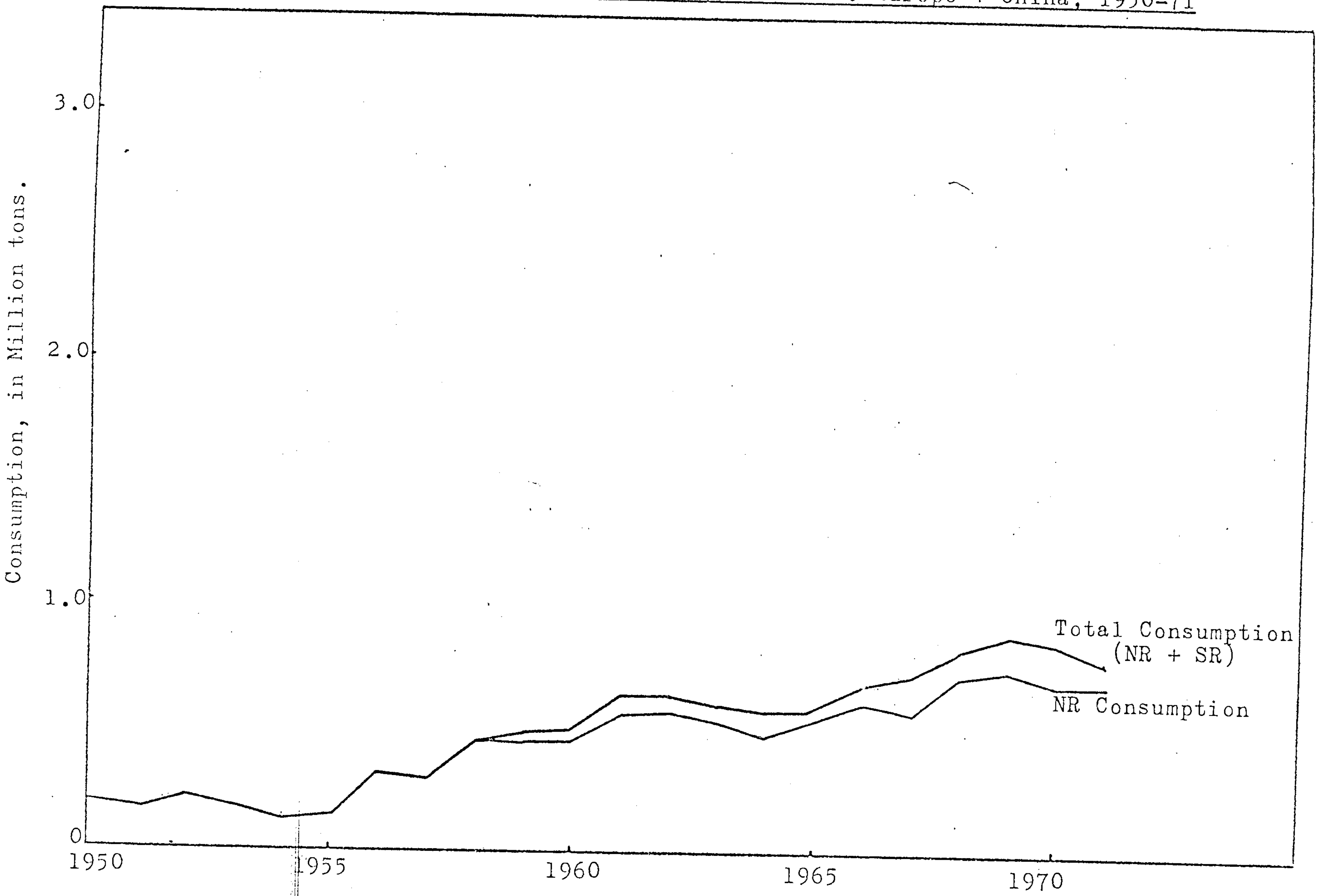


Figure (3.5) Rubber Consumption in E. Europe + China, 1950-71



The amount of NR or any other elastomer that goes into a tyre varies considerably from one country to another or within a country from one consumer to another. The amount of a particular rubber that goes into a tyre will also depend on the type of tyre and tyre technology. In general higher proportions of NR are required in heavy duty tyres than in passenger car tyres. And a radial-ply tyre will require more NR than a cross-ply tyre. There is no published statistics on the use of various polymers in the variety of tyres and tyre-products manufactured. However, there are some statistics on the use of the various rubbers in the tyre sector as a whole in U.S.A. It is thus possible to analyse the consumption pattern in U.S.A. in some detail. Although it is dangerous to extrapolate these trends to other developed rubber consuming countries, past experience shows that the trends in U.S.A. follow in W. Europe and Japan to some extent at a slower rate.

It is estimated that about 68% of NR consumed in U.S.A. goes into tyres, of this around 40% is used for truck, bus, tractor and aeroplane tyres while the rest is used in passenger car tyres. In the tyre sector in U.S.A. the share of NR has decreased from 34% in 1960, and has almost levelled off around 24% since 1968. But the actual consumption in the tyre sector has increased from 300,000 tons to 400,000 tons in the same period. The corresponding decrease in the share of SBR is even greater, from 65% to just over 50%. The stereo-rubbers in the same period have made substantial gains, increasing their share from 2% to 20%. This increase has taken place at the expense of SBR more than

NR. There is a similar tendency in other major consuming countries (Fig. 3.6), but the NR/SR ratio is much higher. This may be due to:

(1) The major tyre manufacturers in the U.S.A. are also some of the leading SR manufacturers and hence a large volume of SR finds a captive market;

(2) Large scale SR production in U.S.A., which makes the rubber consuming industry to be less dependent on imported NR.

It is clear from fig. (3.6), that there is a definite tendency for the share of NR in tyres to be levelling off in the last four years. This tendency may be due to several reasons:

(i) the lower prices of NR during the last few years compared to the stereo-rubbers;

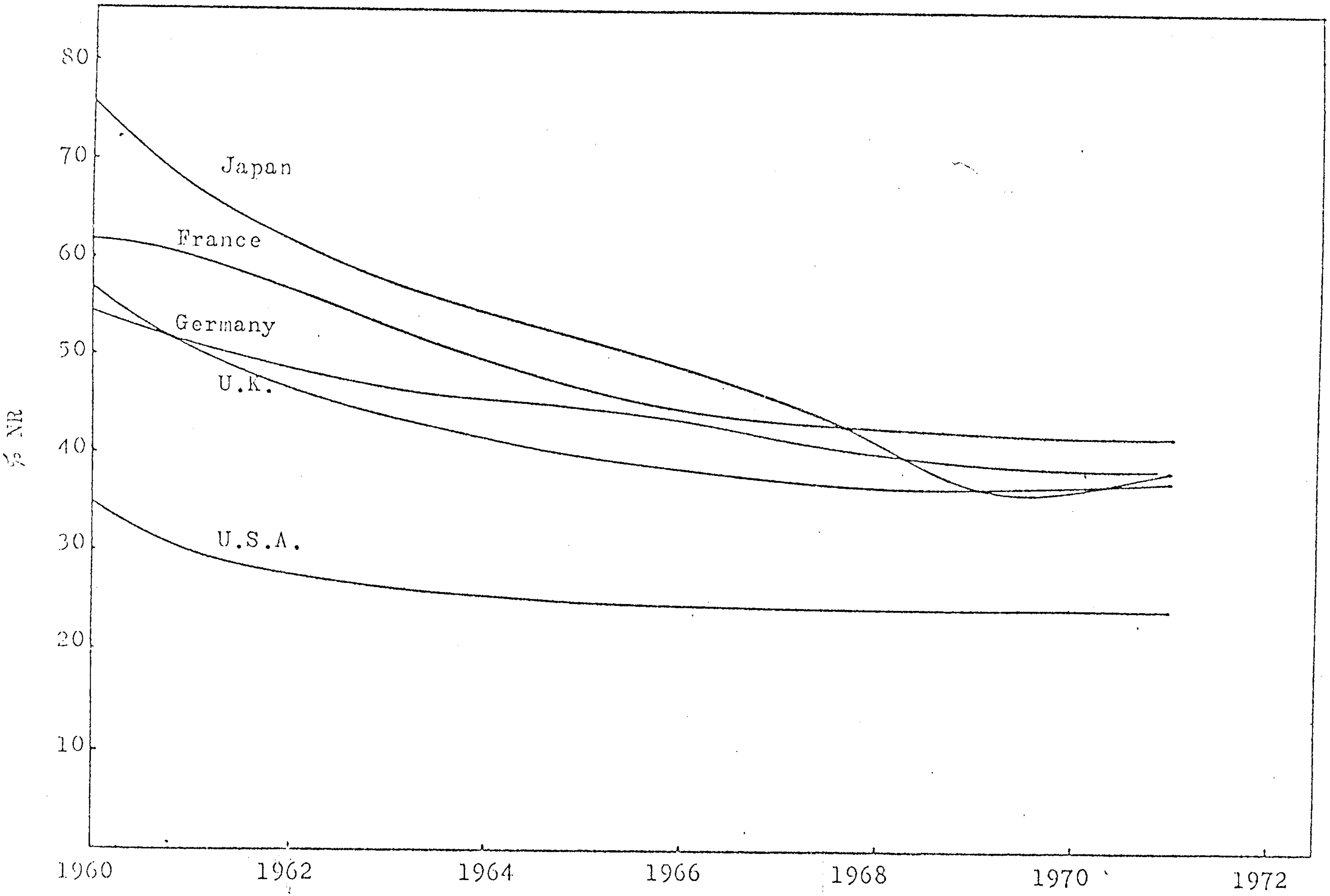
(ii) technological limit of substitution by synthetics,

(iii) non-availability of sufficient quantities of stereo-rubbers.

All these are inter-related to some extent. The lower price of NR in the past has discouraged any large scale production of synthetic substitutes for NR such as synthetic polyisoprene and polybutadiene.

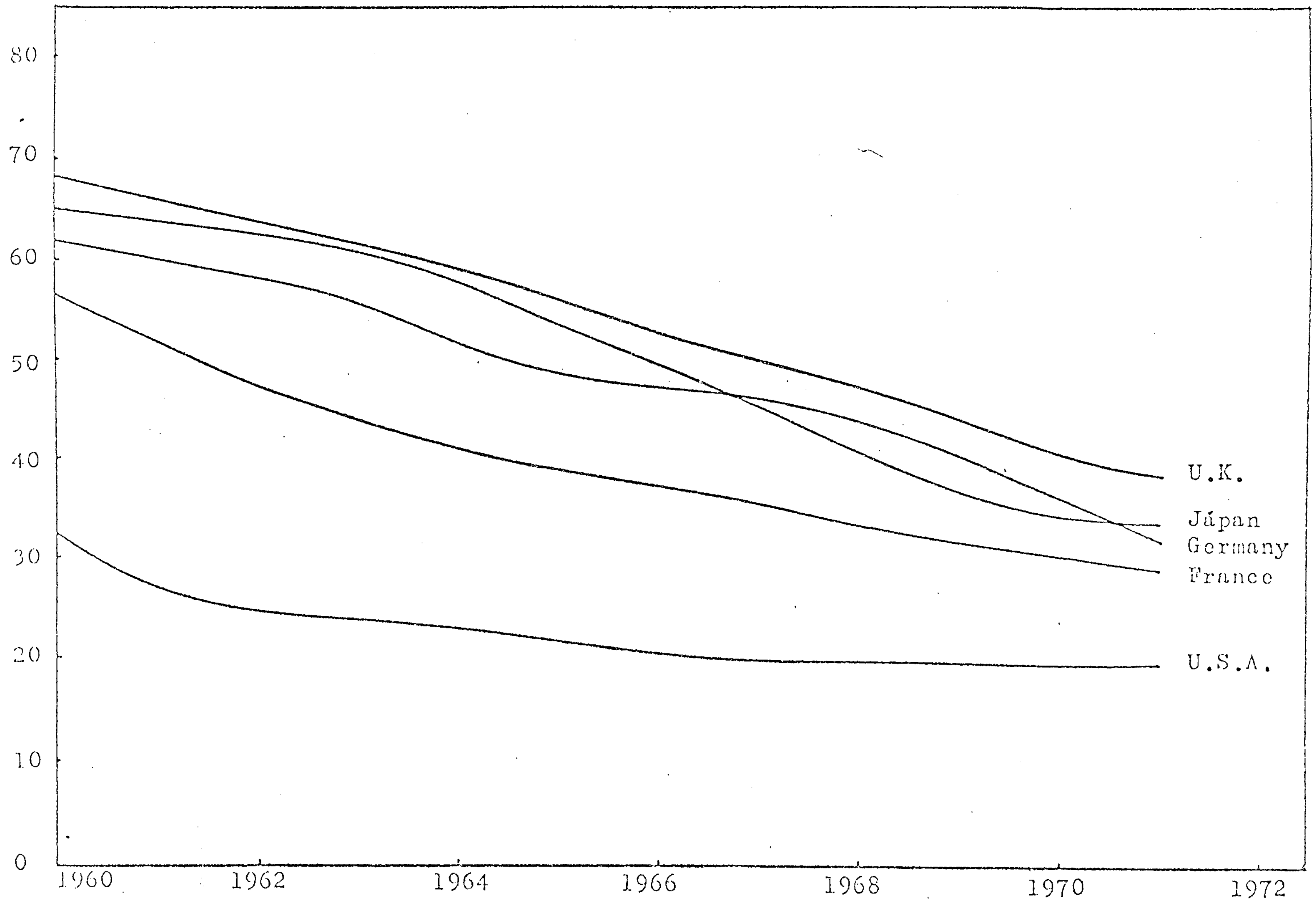
In the non-tyre sector, the performance of NR has been even worse. Its share has not only decreased rapidly but also decreased in absolute quantities in some countries mainly in W. Europe. In U.S.A., NR consumption in this sector has virtually levelled off around 20%, while

Figure (3.6) <u>% NR in tyres in major producing countries 1960-71</u>



in other developed countries this is still falling off (fig. 3.7). This tendency is almost inevitable, since NR was originally the only elastomer which had the desirable properties for the fabricator. Now, there are a large number of 'tailor made' elastomers which are technologically and economically more suited for some of these rubber products. It is in this area where more attention is necessary from the NR producers for new developments and innovations. In tyre applications NR, would continue to find its place without much effort from the producers due to its technological qualities compared with the non-tyre applications.

Figure (3.7) % NR in non-tyre products in major countries, 1960-71.



3.3 The choice of Rubbers.

Competition amongst rubber products manufacturers is severe and in such a business environment the outlook for increased profits will depend on the industry's ability to improve its productivity. Materials play a vital role in the economics and productivity in the manufacture of an end-product. Firstly, because the raw materials cost constitute a very high proportion of the total cost inputs. Secondly, because the processability of materials place basic physical constraints on the manufacturing process and so determine the level of other inputs - machinery, manpower and money.

The whole manufacturing process can be considered as a sequence of technical operations in the conversion of raw materials into final products, and the total cost would be the summation of the individual operations. Thus the choice between alternative rubbers is not merely a choice based on the raw polymer cost or technological requirement to produce a marketable end-product. The cost of the raw polymer is only the starting point. The form in which the rubber is received, the ease of handling and warehousing, suitability of the physical form for automation, processability, the amount of oil-extension it will stand, ability to blend with other polymers, etc. are all factors that will determine the ultimate cost. It is not only a question of whether an elastomer can be used to make something, but also whether it can be made economically. There has been a certain amount of erosion of the rubber markets by plastics in some traditional applications. This has occurred despite superior material cost position. The problem has been the higher cost of processing rubbers characterised by high labour, high investment and low throughput.

Bearing these basic facts in mind, the research tactics of the rubber manufacturers should be to meet the changing economic and technological needs of the rubber fabricators. Several approaches are being made by the raw material suppliers, machinery manufacturers and rubber consumers to meet the changing needs of the processor. Some of the approaches are outlined below and are discussed in detail later.

(1) To produce completely new elastomers tailor made to meet the individual needs of the processors.

(2) To produce physical or chemical modifications of existing polymers to reduce processing costs such as powdered rubbers, liquid rubbers or low viscosity rubbers.

(3) To develop completely new techniques of processing, which overcome some of the existing costly operations.

(4) Development of new processing machinery for automation and continuous processing.

The SR manufacturers have made significant advances which have enhanced the image of their product in the eyes of the consumer.

3.4 Manufacturing Technology.

It is essential to look at the basic processes required to convert raw rubber into finished product to identify the cost centres and technological problem areas. In general there are four basic stages of operations in the processing of dry rubber into finished products. These are:

(i) initial preparation of the raw rubber;

(ii) mixing of the polymer with various processing ingredients;

(iii) shaping;

(iv) vulcanisation.

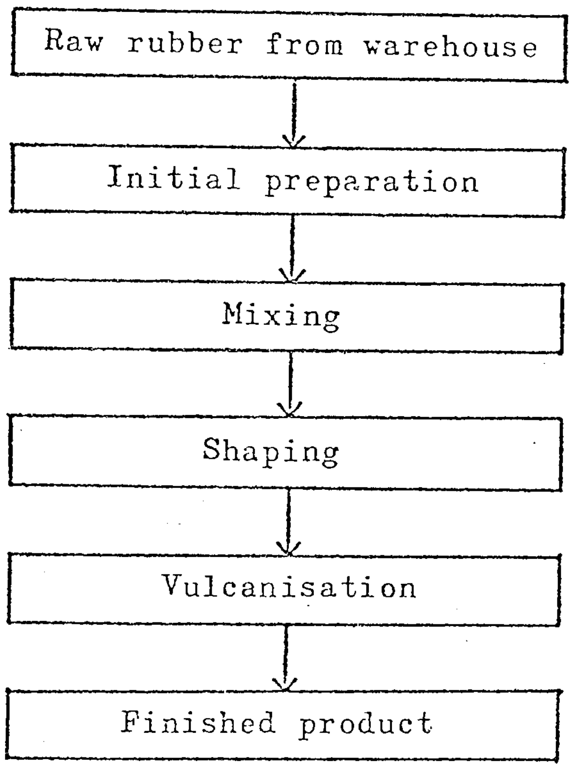


Figure (3.8) Sequence of Operations necessary to convert raw rubber into finished products.

The sequence of operations are shown in fig. (3.8). Each of these stages can be sub-divided into other possible operations depending on the raw rubber and the final product. Each of these operations are considered in greater detail and wherever possible the basic differences between NR and the synthetics are discussed. Possible alternatives and present developments are also discussed.

3.4.1. Initial Preparation.

Initial preparation is necessary to get the raw rubber into a condition suitable for mixing. Bekema[43] has compared the initial processing steps of NR with that of SR. NR requires four additional steps:

(i) cleaning bale surfaces;

(ii) hot room treatment to thaw the crystallized rubber;

(iii) bale cutting for efficient handling;

(iv) plasticizing to reduce initial high viscosity.

Packing of NR in smaller polythene wrapped bales and palletising the bales has overcome the deficiencies of handling problems, bale cleaning and cutting. Crystallization at low temperatures resulting from the highly regular molecular structure of NR, can be minimised by introducing a small degree of isomerisation. But this must be optimised with the loss in raw lack which takes place with reduced crystallisation. Some methods of introducing a minor degree of isomerisation are reported.[44, 45, 46] One method uses a thiol acid for the treatment of the latex and this may be the most economically feasible method and needs further investigation.

Plasticising by premastication or using peptizers - chemical agents which promote the breakdown - is a costly operation and also destroys the desirable high molecular weight. The high initial viscosity of NR arising from storage hardening and high molecular weights has been overcome to some extent by the introduction of viscosity stabilised rubbers.[47] Storage hardening is inhibited by the use of hydroxylamine in the constant viscosity grades, where the viscosity range of 55-65 is produced.[48] This range is suitable for the elimination of the pre-mastication stage, with the retention of the high molecular weight. Since this method of producing a viscosity stabilised rubber does not work with some clonal types, a method using mineral oil as a physical plasticiser and a peptizing agent has been proposed.[49] Since the peptizer has a positive effect on the molecular breakdown this method must be optimised with the loss in physical properties of the final product.

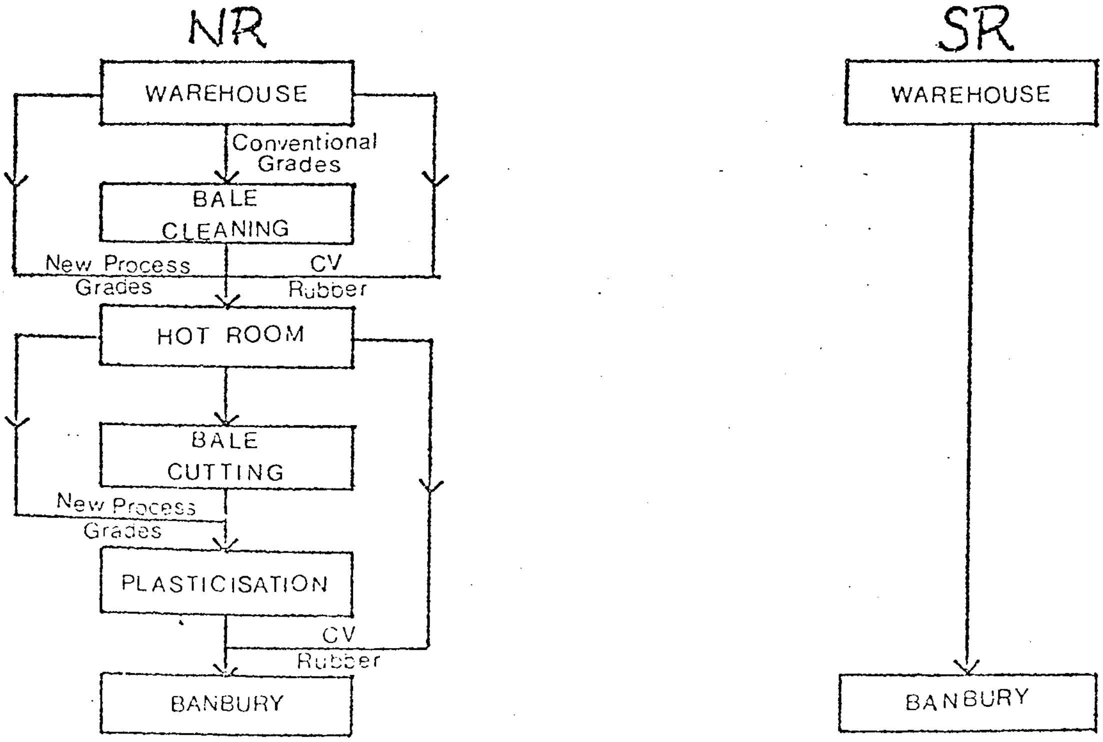


Figure (3.9) Model of Primary Processing Operations.

A model of the primary processing operations showing the main cost centres are compared for NR and SR in fig. (3.9.) This shows the additional steps necessary for conventional grades of NR and how these have been overcome in the new process rubbers.

3.4.2 Mixing.

This operation is necessary to obtain a good dispersion of the various processing ingredients - carbon black as filler, oil as extender or processing aid, vulcanising and protective agents. This operation can be very costly requiring large internal mixers or two roll mills and consuming considerable amount of power. Some of these ingredients can be easily dispersed in the latex during the rubber manufacture and produced in the form of master-batches. Already oil extended and carbon black masterbatches are produced by many SR producers. The future trend would be, for the rubber manufacturers to produce such masterbatches including other processing ingredients to close specifications of the fabricator. Thus, avoiding the costly operations in the consumers' factory. This would be a saving on capital equipment, reduction in the number of inventory stations and saving on factory area. The SR producers are in a better position to develop such innovations; especially since some large scale SR manufacturers are also the manufacturers of other raw materials and consumers of rubber. This is a stimulas to develop such masterbatches to suit the fabricators' needs. In addition, the geographic location of large scale SR producers, raw materials suppliers and rubber fabricators makes it possible for all three to work closely with each other. Oil extended or carbon black masterbatches are also possible to be produced by NR producers but, these may not be economically feasible. Since most of the oil and carbon black has to be imported and then re-exported in the form of masterbatches, and the output from the NR processing units may not be sufficient to produce masterbatches of consistent properties.

Another approach to overcome the excessively costly mixing operations is to produce powdered rubbers which can be compounded in the dry form similar to PVC or liquid rubbers which would not require heavy mixing equipment.

3.4.3. Shaping.

The shaping operations can be of several types depending on the final product. The common operations are:

(i) calendering;

(ii) extrusion;

(iii) compression, transfer or injection moulding.

(iv) manual building operations.

In all these operations the rheological properties of the compounded rubber are essential in the economics of production and quality of products. The synthetic polyisoprene in general has superior flow properties to NR and this may be due to the crystallizability of NR and its broad molecular weight distribution. Injection moulding is likely to replace compression and transfer moulding in the future, for increased productivity. Synthetic polyisoprene will replace NR to a large extent in such processes due to its better flow properties. Thus, it is necessary to investigate fully the nature of the flow properties of NR. In the manual building operations NR possesses superior green strength and raw tack. These properties have often dictated the choice of NR over synthetics. But this situation may not last very long as the SR producers have often overcome such technological problems and continued research efforts may produce solutions to these shortfalls.

3.4.4 Vulcanisation.

Conventional vulcanisation methods using sulphur or peroxide curing systems are expensive. The temperature and time are critical to obtain optimum physical properties of the products. NR is a fast curing rubber due to the presence of non-rubber materials present in the latex. The curing characteristics depend on the clonal type and the method of manufacturing the rubber. This is often a disadvantage due to the batch to batch variation in NR and it is necessary to test each batch. This has been overcome in some NR grades where some curing characteristic is introduced as a specification. By the proper choice of the methods of processing NR latex it should be possible to produce NR with desirable curing characteristics. NR is usually vulcanised at 140^{o}C and accelerated curing at higher temperatures is detrimental to the final product. This is an inherent weakness in the polyisoprene chain, which is a disadvantage of both NR and IR, compared with other general purpose rubbers.

Any polymer which does not require any vulcanisation at all or less expensive alternative curing system or process, will find considerable applications if the desirable properties can be achieved. Several curing systems using sulphur or sulphur donors or peroxide are available for specific applications. Curing systems which enhance the final product properties or processing characteristics are likely to improve the use of existing polymers for specific product applications. One such system is the urethane cross-linking system to NR, which improves the dynamic properties of the vulcanisate.[50] Thermoplastic rubbers that overcome vulcanisation and liquid rubbers which require an alternative curing process are discussed in detail later.

3.5 Market Distribution.

The fabricators' choice of elastomers is based on technical and economic considerations. The elastomer usage is split into three groups, based on these considerations:

(i) where a particular SR would be used for its technical qualities;

(ii) where NR would be used at any price for its technical qualities;

(iii) where the choice is open and largely based on price and availability.

There is no sharp division in this distribution and tends to vary from country to country and often blends of various rubbers are used to obtain the optimum properties. Some of the important technological properties, new developments and applications of NR are compared with the more important general purpose rubbers. These help to identify the areas of technological competition, the inherent advantages and disadvantages, to plan for future research and development.

3.5.1 Natural Rubber.

NR is considered the most versatile general purpose rubber. Its easy processability and good balance of physical properties such as, high tensile strength, crystallisation on stretching, resistance to dynamic flexing, high resilience and low heat build up make it suitable for very demanding applications such as engineering and industrial components. Superior green strength and raw tack are useful and important properties where manual building operations and good adhesion to a substrate are necessary as in the tyre. Some of the disadvantages of NR are the inconsistency in properties, crystallisation at low temperature which requires thawing, high initial viscosity which requires plastication and poor resistance to weathering.

During recent years, the NR industry has recognized the varying needs of the consumers and has taken some steps to meet them. It is impossible to meet the requirements of every type of consumer. However, some of the essential general requirements are already being met. Since over 60% of the NR goes into tyres, most of these developments have been directed towards this market. One such development is the tyre rubber. A tyre manufacturer for reasons of economics, blends a mixture of grades of NR, to obtain the optimum processing and product properties. The tyre rubber in effect, is a blend of field coagulam (30%), unsmoked sheet (30%) and co-coagulated latex-oil mixture (40%) to obtain the

required properties.[51] The success of this innovation would of course depend on the economics. Although it would be possible to produce such a rubber profitably and at a selling price attractive to the tyre manufacturer, in a free market system it is impossible to fix a price which is determined by the supply and demand. This would remove the present flexibility in the choice of various cheaper grades.
As already seen, statistics indicate that the performance of NR in the tyre sector has been much better than in the non-tyre sector. While it is true that the competitive position of NR in tyre applications should be strengthened, it is also necessary to win back or find new applications for NR in the non-tyre sector. This would require 'tailor made' grades of NR for specific applications.

Several conventional low grades of NR are still produced in large quantities and have certain merits.[52] Especially since they satisfy the needs of many fabricators and offer a certain amount of flexibility in the choice during market fluctuations. One of the most important innovations of the NR industry is the presentation of technically specified new process rubbers of the SMR type. Although this has improved the image of NR tremendously, it is argued that this is producer orientated rather than being consumer orientated and some improvements to the existing scheme are suggested.[53] These are:

(i) to improve consistency and uniformity of quality within a grade;

(ii) include some means of indicating the quantity of coarser dirt which is detrimental to the rubber;

(iii) improve packaging,

(iv) include some means of indicating the hydrocarbon content of the rubber.

Any chemical or physical modifications to NR, to produce a tailor-made rubber will not be economically feasible unless this modification is carried out in the latex stage before coagulation. Any modification to the dry rubber will involve additional costs over the cost of processing the latex. Any such modifications can be made by the synthetic rubber producers during the polymerisation stage more economically.

Oil extension of NR (OENR) was investigated and found quite successful as early as 1954.[54] The problems of presenting the OENR on a commercial scale were not overcome till the introduction of the new process rubbers.[55] OENR has been found to be suitable for passenger car tyre treads[56] and particularly in winter tyres.[57] It is doubtful if any economic or technical advantages can be achieved by the addition of oil in the plantations rather than in the fabricators' factory. Although it is possible to produce oil extended carbon black masterbatches in the plantations,[58] the economics seem uncertain unless cheap carbon black and oil are available in the producer countries.

Viscosity-stabilised NRs are available on a commercial scale with a specified low mooney viscosity level. The CV rubber is the most popular amongst the newer rubbers as it can be used similar to SRs without pre-mastication and savings in processing costs of up to U.S.$ 30.00 (£12.00) per ton may be achieved over conventional grades.[59] Several peptized rubbers with low viscosity have been available for some time but have not been commercially successful. Other special forms of rubbers are discussed later.

3.5.2 Synthetic Polyisoprene.

Synthetic polyisoprene (IR), due to its chemical identity with NR, is perhaps the only existing synthetic elastomer that could be technically interchangeable with NR. However, NR still remains superior to IR in some properties and so far has remained cheaper than IR. Two types of IR are commercially available. One is produced using a lithium alkyl type of catalyst and has a linear structure with 92% cis 1,4 content (Shell type). The other uses a Ziegler-Natta type of catalyst system and has a slightly branched structure with about 96% cis content (Natsyn type). NR, in comparison is very much similar to the Natsyn type but possesses a cis content of over 98%. Some of the desirable properties of NR, such as green strength and raw tack are due to this high cis content. The difference in vulcanisation and weathering properties are due to the presence of non-rubber constituents of NR, mainly proteins and naturally occurring antioxidants.[60] IR generally possesses uniformity in quality and slightly higher resilience than NR. The Shell type of IR has completely different processing characteristics to NR and cannot be considered a technical substitute for NR. IR, due to its resilience, particularly the Shell type, has to some extent penetrated into some of the main applications of NR, namely in the truck and other heavy duty tyres. Since IR lacks in green strength and raw tack it is almost always blended with NR, especially in tyres to obtain the desirable processing characteristics and product properties. The existing disadvantages of IR are likely to be overcome by the research efforts of the producers and would eventually become completely interchangeable with NR. Already some modified techniques of compounding IR to overcome its deficiencies in green strength and raw tack are available.[61]

3.5.3 Styrene Butadiene Rubber (SBR)

Emulsion SBR has remained the most popular SR for several years. With the large scale introduction of the newer solution rubbers, SBR is likely to lose its present share of the market. Developments in polymerisation techniques and oil extension up to about 30% by weight without loss in quality made it suitable for passenger car tyre treads with its superior tread wear and road holding properties. In general oil extended NR has better overall properties but the steady price of SBR has made it a tread rubber where heat build up is not a major problem. Unless an acute shortage of SBR develops, it is highly improbable that NR will replace it in passenger car treads.

3.5.4 Polybutadiene (BR).

Three types of solution BR are commercially available, with cis 1,4 content of 40, 92 and 96%. The difference in cis 1,4 content result from the different catalyst systems used. This rubber possesses high resilience, good low temperature performance and resistance to groove cracking. It was originally developed as the ultimate rubber to replace NR. However, it is seldom used alone and is used in blends with NR and SBR. It has poor processing characteristics such as low tack and green strength, poor mill breakdown behaviour and poor curing characteristics. Its main weakness is its low tensile which limits its use on its own or in moderate levels in tyre treads. It is reported that even with high regularity, it is unlikely to achieve the desirable tensile properties, since a cis-trans reversion takes place during sulphur vulcanisation.[62] It would continue as a function modifier for SBR and NR in tyre treads and in some engineering applications.

3.5.5 Ethylene/Propylene Rubber.

There are two types of ethylene/propylene rubbers. One is a copolymer of just ethylene and propylene (EPM) and has the structure of saturated polyisoprene chain. The other contains a third diene monomer for normal sulphur type vulcanisation (EPDM). These rubbers have exceptional resistance to ozone, oxygen and heat. The EPM is not compatible with the common general purpose rubbers and requires peroxide type of curing. Thus, it cannot be covulcanised with the other general purpose rubbers using conventional sulphur curing systems. This is a serious disadvantage and is overcome to some extent in the EPDM, by introducing up to about 10% of a diene monomer. The termonomer plays a vital role in the overall economics and the technical properties of this rubber. Thus, to a large extent the future of EPDM will depend on finding a suitable cheap termonomer. At the existing price, it cannot become a general purpose rubber but only find specialised applications where superior weathering resistance is necessary. It tends to replace butyl rubber rather than NR.

3.5.6. Other Rubbers.

Solution SBR is gaining popularity as a general purpose rubber,mainly in tyre tread applications. Solution polymerisation in general offers a high degree of control of the microstructure of the polymer and thus gives rise to a range of polymers with varying properties.[63] Solution SBR is faster curing, has higher resilience and superior fatigue resistance than emulsion SBR. The basic principle of SBR is that it combines some of the desirable properties of emulsion SBR and solution BR in one polymer.[64] Thus, it replaces the SBR/BR blends in tyre treads and should eventually overtake emulsion SBR in terms of consumption.

Several other elastomers with interesting characteristics which hold promise as general purpose rubbers are reported. Two of the more important rubbers of particular importance are the 'Alfin' rubbers and 1,5 trans polypentenamer (TPP). The 'Alfin' polybutadiene and SBR are reported to have desirable properties to be used in tyre treads.[65] These rubbers can only find application in blends with the existing large tonnage rubbers such as emulsion SBR and NR. TPP, which is prepared by the ring opening polymerisation of cyclopentene is reported to have superior green strength than NR. With its superior green strength it would replace NR in radial tyres. However, the heat build up is claimed to be too much to replace NR in truck and other large tyres.[62]

3.5.7. Thermoplastic Rubbers.

Thermoplastic rubbers combine the easy processability of thermoplastic materials and 'rubberiness' in one polymer. These rubbers are a first step in fundamentally changing the character of the rubber industry from its conventional processing methods. The complex, labour intensive and expensive vulcanisation is abolished with such materials. They can be produced in a way similar to common thermoplastic materials, and do not require vulcanisation or fillers but possess the general characteristics of a vulcanised general purpose rubber. The common thermoplastic material is a linear block copolymer of the A-B-A type. Where A is a common thermoplastic block polymer, such as styrene, and B is an elastomeric block polymer, such as butadiene or isoprene. In the styrene/butadiene block copolymer, at ambient temperatures a two phase system of polystyrene domains in a polybutadiene matrix is present. The polystyrene domains are connected by butadiene chains. Thus, an elastomeric network is formed where polystyrene domains act in a way similar to chemical cross-link and filler particles as in fig. (3.10).

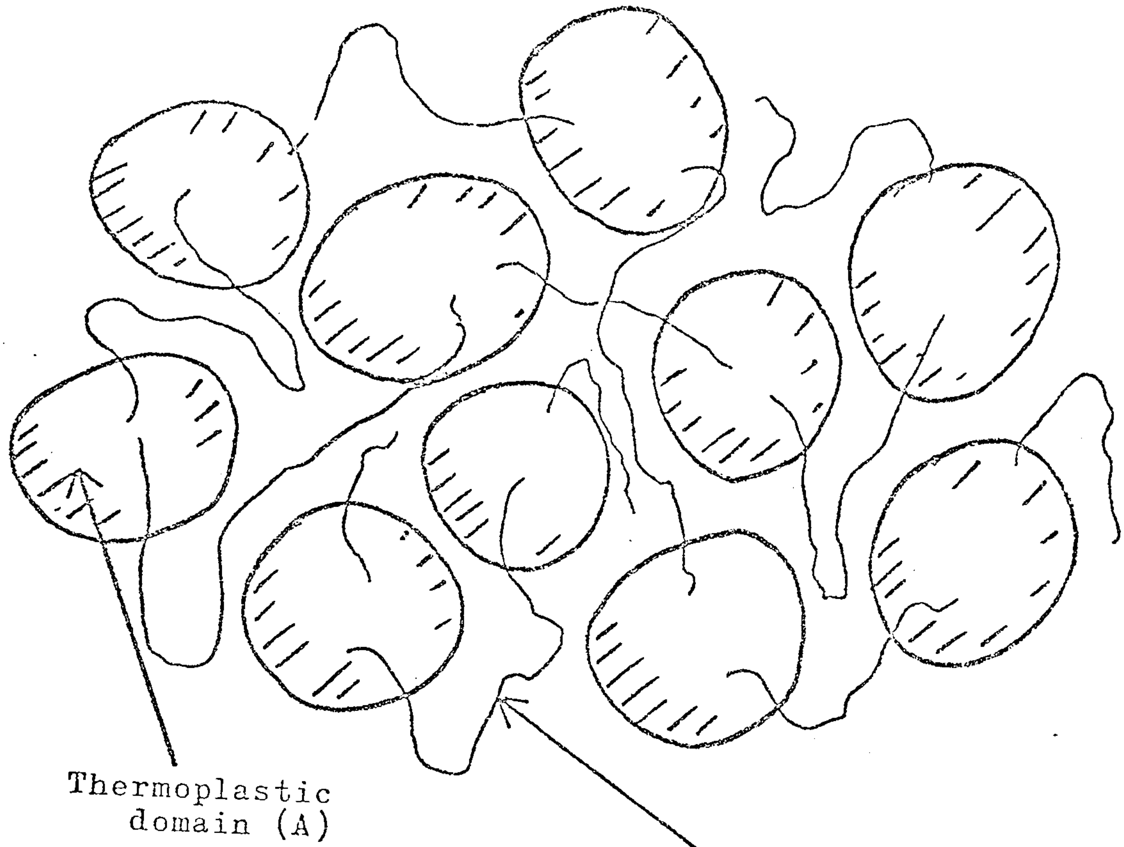
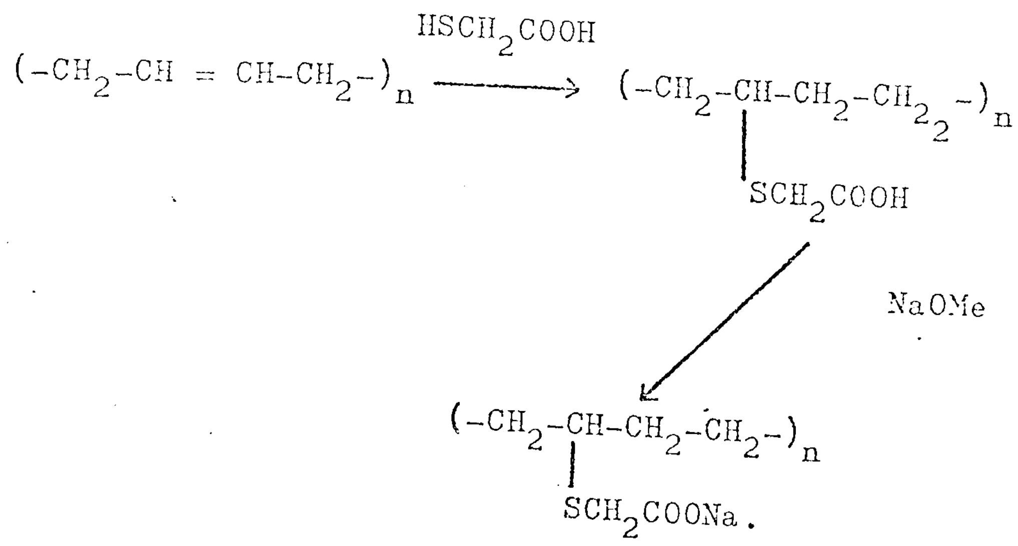


Figure (3.10) Model of A - B - A Block Copolymer.

Although the thermoplastic block copolymers are solution polymerised, they are totally different from the conventional solution polymerised counterparts as in SBR. While conventional solution SBR is a single phase, random copolymer exhibiting one glass-transition temperature (Tg) around $-40^{o}C$, the thermoplastic SBR is a two phase, block copolymer exhibiting two Tg's around $-70^{o}C$ and $+90^{o}C$ corresponding to the polybutadiene segments and polystyrene domains respectively. The limitations of the present thermoplastic rubbers are, like most common thermoplastic materials, that they cannot be used at elevated temperatures. However, it is likely that the polymer chemists will be able to exploit this concept to push the temperature of applications above the present limits. Another important weakness arises from the nature of the 'cross-links'. Since these are essentially physical cross-links, the material cannot be used for demanding applications and is susceptible to attack by organic solvents. It is likely that some of these deficiencies may be improved by the use of completely different monomer systems or other methods, but not overcome completely. At present, the thermoplastics are mainly used in adhesives and other injection moulded or extruded goods.

If some degree of thermoplasticity can be introduced along the chain ends of a NR polymer, leaving an elastomeric segment in the middle, the resulting polymer may be expected to exhibit some thermoplasticity in a way similar to the block copolymers of styrene/butadiene. This would require a method of chemically modifying the polymer selectively along the chain ends. Cyclisation of NR to produce a thermoplastic material is quite well known and this may be one way of introducing the thermoplasticity. Another approach would be to introduce some pendant groups along the polymer chain which could form ionic domains at ambient temperatures and allow easy processing at elevated temperatures. One such approach is already reported to produce a thermoplastic polybutadiene.[66] In this method, thioglycollic acid is introduced as a pendant group per hundred double bonds and the acid groups are converted into metal salts as shown below:



The $-SCH_2$ COONa groups act as ionic domains in a polybutadiene matrix. However, it is doubtful if the product would have the desirable physical properties due to the nature of the ionic domains, which differs from the thermoplastic domains present in the block copolymers.

Another approach being investigated by the NRPRA is to modify NR to produce a thermoplastic rubber by cross-linking it into a network with special cross-links, which 'close' at ambient temperatures and 'open' at elevated temperatures. Thus providing a reversible transition from an elastomer at low temperature to a plastic at higher temperature as shown in fig. (3.11)[67]

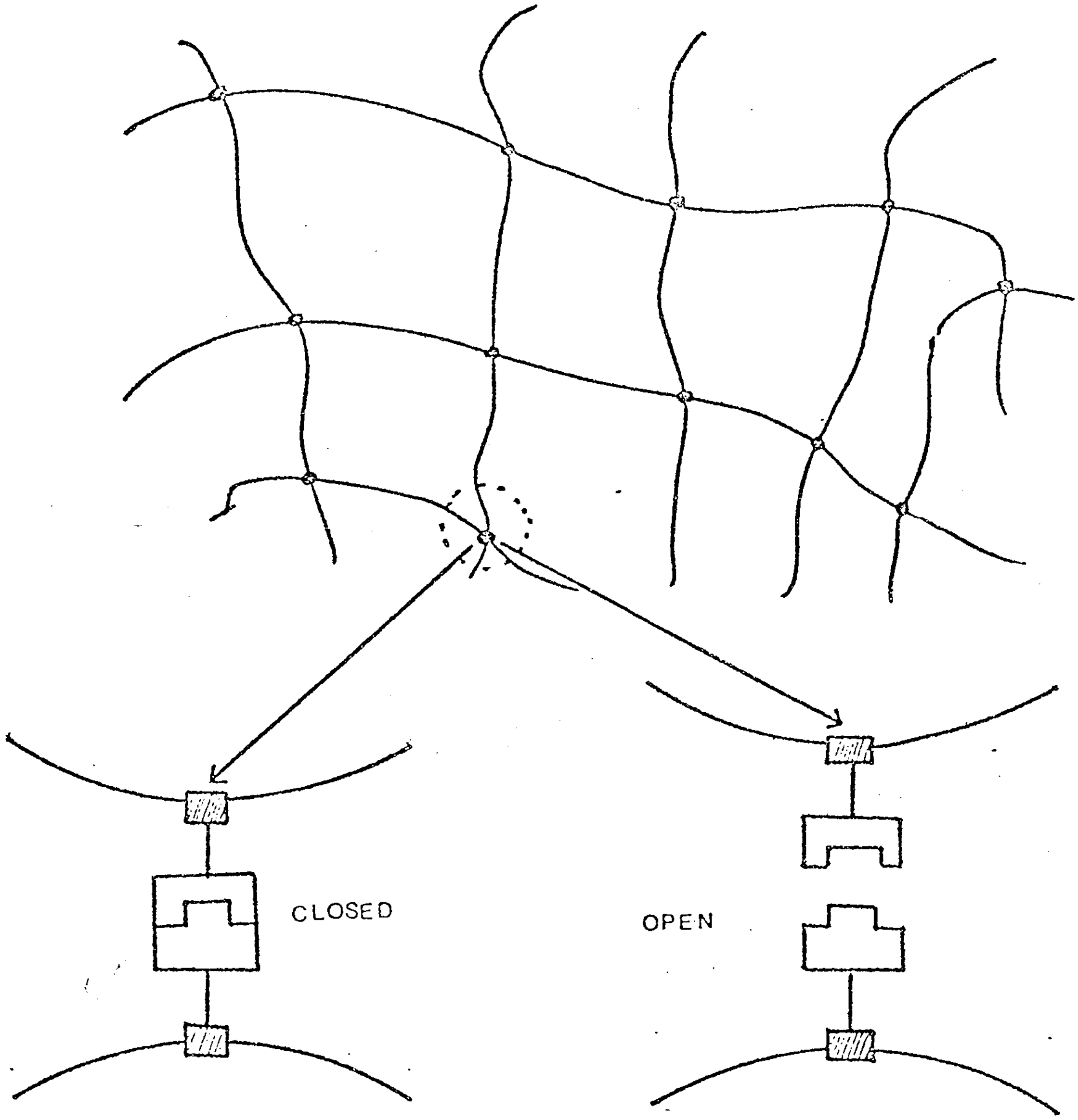


Figure (3.11). <u>Model of NRPRA's Reversible Cross-Links.</u>

It is likely that the NRPRA cross-linking may involve a reversible covalent bond. This would require some reactive pendant groups along the polymer chain and a chemical cross-linking agent which acts reversibly - cross-linking at low temperatures and 'opening' at elevated temperatures.

3.5.8. Liquid Rubbers.

High capital investment, considerable manpower requirements and low throughputs associated with conventional processing methods of converting dry rubber into finished products can be overcome by the use of liquid polymers. A liquid rubber would enable casting, potting or injection moulding. With liquid rubbers, the rubber industry could be streamlined similarly to the plastics industry and increase productivity. Liquid rubbers can be of two types. One is a low molecular weight polymer of the existing rubbers which can be cross-linked by existing methods. There is no great advantage in using this type of polymer since:

(1) the existing sulphur type or peroxide type of vulcanisation is necessary;

(2) the molecular weight of the polymer may not be high enough to produce a strong vulcanisate with the usual properties.

This rubber can only find limited applications in producing soft, flexible vulcanisates. The main advantage of this rubber is, that it does not require heavy mixing equipment.

The other type of liquid rubber seems more promising. Here the liquid polymer has reactive chemical groups on the polymer chain which facilitate chain extension or cross-linking. Three types of such liquid polymers are possible.[68]

Type (i) Liquid polymers with flexible backbone containing terminal and internal groups. The terminal groups provide sites for chain extension and the internal groups for cross-linking.

Type (ii) Liquid polymers containing reactive internal functional groups exclusively and cross-linking is by these groups.

Type (iii) Liquid polymers containing reactive terminal groups only. In this case chain extension and cross-linking are carried out using a tri-functional or poly-functional agent.

The most common liquid polymers are the polyurethanes. They offer a wide range of properties depending on the main chain and the cross-linking agent. The urethane elastomers are produced as castable, millable or thermoplastic materials. The castable polymer goes into products which are hard-wearing such as cast tyres for fork-lift trucks, shoe heels etc. Urethane foams and components for the motor car industry are some of the other products. An elastic fibre based on urethanes called 'Spandex', permits the use of finer deniers due to its high modulus and toughness. This has the potential of replacing NR latex thread and cut thread in garments. The urethane elastomer cannot be used as a general purpose rubber due to its high cost and low resistance to heat build-up. Some technological improvements to increase service performance, developing reinforcing fillers and engineering certain processing improvements along with cost reductions are anticipated.[69] This is likely to increase urethane's market share in non-tyre applications.

In the above urethanes, the main chain is a polyether or a polyester. Hydroxyl, bromine or carboxyl terminated liquid polybutadienes are commercially available. These can be chain extended and cross-linked. Similar hydroxyl terminated polymers can be produced by ozone depolymerisation of NR and hydroxyl groups can be introduced by epoxidation along the chain. A technical and economic study of the commercially available liquid rubbers concludes that, the existing premiums of these rubbers over the corresponding dry raw rubber is much larger than any savings in processing costs.[70] The future of the liquid rubbers depends on several factors, the most important being the production of a general purpose type with the properties similar to the existing general purpose rubbers at the right price. Firestone Rubber and Tyre Company has announced a process to manufacture cast cordless tyres. Using a chain extendable and cross-linkable liquid rubber.[71] This is probably a butadiene prepolymer with reactive groups. The economic advantages of such a process to the fabricator are obvious. If such a revolutionary process is a commercial success, the consequences will be considerable. It is highly unlikely that such a process will be used for making medium or large tyres.

3.5.9 Powdered Rubbers.

Powdered rubbers based on nitriles or high-styrene SBR have been known for some time. A precompounded NR is also commercially available. A free-flowing powdered general purpose rubber for tyre treads is being investigated by Hüls of Germany.[72] A recent investigation into the use of powdered nitrile rubber concludes that considerable economic advantages are achieved by the use of these rubbers.[73] These include:

(i) Short mixing time coupled with improved dispersion of black;

(ii) Lower labour costs;

(iii) Lower consumption of power;

(iv) Fewer rejects;

(v) Possibility of automation;

(vi) Increased productivity with low additional capital investment.

However, the Du Pont Delphi study concludes that very little savings is achieved in the mixing of powdered rubber and most of the savings are achieved in the weighing areas. The same study also suggests that the powdered rubbers could carry a premium of about 3 U.S.Cents/lb. over the bale form. The development of a dry blending technique in a way similar to the dry blending and processing of PVC would be advantageous. Powdered rubbers in solution applications such as adhesives would be easier to dissolve.

The preparation of powdered rubbers would require the precipitation of latex in a powder form and the resultant powder must be prevented from sticking together. This would require the co-precipitation of a compounding ingredient with the rubber. The tackiness of NR may be a serious problem in forming a powdered rubber in this way. A starch xanthide filled elastomer which is prepared as a powdered rubber and which can be processed directly to a cross-linked reinforced elastomer without the addition of any other ingredients is recently reported.[74] The rubber is prepared by coprecipitation with a starch xanthide. The rubber latex is dispersed in starch xanthate solution and the mixture is acidified under oxidizing conditions when the coprecipitation of rubber and starch takes place. Such a method would be economically feasible to be produced in the rubber producing countries.

3.6 Products.

As far as products are concerned, very few original, major new uses of rubbers have been developed since the large scale introduction of NR and the products are virtually the same as a half a century ago. The tyre has remained the most important outlet for rubber, consuming over 60% of the total output. This situation is unlikely to alter in the foreseeable future. Here NR has retained its position as the principal elastomer in heavy duty tyres and the trend to change from cross-ply to radial-ply will favour the use of NR even in passenger car tyres.[75] In the radial tyre, the superior green strength of NR would be required in the topping compounds to prevent breaking during shaping. The NR compounds are self reinforcing and therefore give good results during the stretching.[76] In the non-tyre products, the rubber industry has lost a considerable share to other materials: mainly to plastics. Due to the availability of several 'tailor made' rubbers for specific applications, NR has lost a large market share in this area to the synthetics. This tendency of "a rubber for each application" will continue to increase.

To examine the possible areas for future product innovations, Allen has divided the present range of non-tyre products into four loosely defined groups:[77]

Group (i) products which require a small proportion of rubber combined with other materials. The incorporation of a small quantity of rubber enhances some property of the other material. Use of rubber in bitumen in road surfacing, rubberised gypsum plaster and the use of rubber latices in soil stabilisation are some of the major areas in this group. These applications will only be able to take very small quantities of rubber as the increase in the product performance may not be sufficient to account for the higher costs. Even if rubber is used in this group of products, cheap emulsion polymerised synthetic elastomers would take a bulk of the market share.

Group (ii) products which require only a small degree of rubberiness. This is, of course, the area where rubber is likely to lose completely to thermoplastic materials. Already, several products have gone over to thermoplastic materials like polyethylene, plasticised PVC, polyvinyl acetate, urethanes etc. These products include garden hose, cable and wire covering, shoe soles etc. In addition to the obvious advantages in processing economics, these materials also offer visual appeal. The development of thermoplastic rubbers could regain some of the markets already lost.

Group (iii) products which make full use of the basic attributes of rubber and which have been made of rubber since the product first came into use. This group contains a large number of traditional rubber products, such as latex products, industrial and mechanical products, motor car components and a variety of consumer goods. The competition between the various types of rubbers in this area is severe and NR is likely to lose further to various tailor made polymers except where its exceptional properties are desired. Although this group is possibly the biggest in terms of volume consumption of rubber, there is very little likelihood of a fast growth.

Group (iv) products in which rubber replaces some other way of performing a function. The products represent new uses for rubber, making full use of its technical and economic assets. Applications in this group fall mainly into engineering applications. In this area a potentially large outlet for rubber exists. The elastic and strength qualities of NR can be fully exploited with significant advantage over some traditional materials. Already, NR is finding large scale use in bridge bearings, anti-vibration mountings, elastic suspensions in trains and other vehicles, shock absorbers, rubber bumpers in passenger cars and several other engineering applications.[78] In terms of product performance, IR also has similar properties and can compete with NR in such applications.

3.7 Competition and Future Trends.

So far, no new large scale outlet of the size of the tyre market has appeared for rubbers. This has directed most of the attention towards the tyre market in terms of processing technology and raw materials development. No revolutionary process has appeared for the existing raw materials. All developments in machinery have been to improve mixing efficiency and mill room productivity. These developments suggest that the existing rubbers in the solid form are likely to continue for several years.

The choice of a rubber for an end-product application is governed by three factors: price, processability and product performance. So far, no new rubber or rubber in a more suitable physical form has been developed at the right price and product performance of the existing general purpose rubbers, which short cuts the existing processes with considerable cost reduction. The powdered rubbers, thermoplastic rubbers and liquid rubbers hold promise for the future. It has been pointed out that the existing powdered rubbers are mainly special purpose rubbers and require most of the conventional processing steps with little cost reduction. The alternative to this would be the development of a powdered rubber which can be dry blended similar to PVC and processed similar to the thermoplastics. If thermoplastic or liquid rubber is developed as a general purpose rubber for tyres, the consequences will be considerable:

(1) The industry which produces tyre reinforcing materials, rayon, nylon, polyester and steel cord will have to look for alternative markets;

(2) Almost the entire carbon black industry will have to close down;

(3) Large scale obsolescence of costly equipment;

(4) Necessity to develop new processing equipment;

(5) The SR industry must reorientate to meet the raw materials development;

(6) The virtual disappearance of the NR industry.

It is highly unlikely that any large scale change over to such a material would take place unless drastic reductions in cost can be achieved. However, in the non-tyre applications this may have a considerable effect on the existing general purpose rubbers than in the tyre application. It is possible that Firestone's cast tyre could be used in a moderate scale on small passenger cars after 1980, but it is not likely to be used for making larger tyres.

Thus, the tyre industry will continue to depend on the few existing general purpose rubbers and the present processing technology. It is, of course, a Utopian dream of the polymer chemist to produce a single elastomer which would satisfy the needs of every rubber fabricator, in terms of price, processability and product properties. NR is perhaps the only elastomer which comes close to meeting all these requirements. But it has several inherent weaknesses and any attempt to improve one such weakness results in deterioration of some other desirable property or increases the cost. NR being the only general purpose rubber in existence for over 50 years, the rubber technologist has learned to overcome most of these problems by the proper choice of compounding techniques to exploit the full assets of its properties.

Since there is no single elastomer which satisfies all the needs of the fabricator, often a blend of two or more elastomers are used to obtain the optimum processability, product properties and cost. In this respect, NR and SR tend to compliment rather than compete with each other. The use of rubber blends in tyres is a typical example. The compound compositions differ according to the part of the tyre for which they are intended and the application for which the tyre is designed. The rubber blends in the different regions have to meet different physical requirements during the service life of the tyre. Most of the rubber is found in three regions: the carcass, the tread and the sidewalls.

Since tyres account for the bulk of rubber consumed, it is essential to analyse the usage trends in this sector. In the passenger car tread a blend of SBR and BR is used and little or no NR is used. The carcass is the main strength of the tyre and the compound must provide good bond to the reinforcing materials, low heat build up and good heat durability. NR meets most of these requirements and thus, this is the main region in the passenger car tyre where NR is used. Here, it is blended with both

SBR and BR to improve some final properties and reduce cost. In the radial-ply tyre, the requirements of the compound are more stringent and hence a greater proportion of NR is used. In the sidewall compound, very little NR is used except in the radial tyres. In the larger tyres NR is used in much larger proportions.

Although there are differences between NR and IR in the raw polymers and processing characteristics, the vulcanisate properties are virtually identical for both polymers. Thus these two rubbers compete primarily on processing and cost basis. So far, NR has excelled in both aspects. Despite these advantages, IR has been used in blends with NR in tyres. This can only be explained in terms of captive consumption and price stability. If the present high prices continue, greater amounts of substitution of NR will take place by IR, BR and solution SBRs. The future trend would be to produce polymers which would have the combined effect of the physical blends. Already the solution SBR is an example of this type of elastomer which possesses the desirable properties of emulsion SBR and BR in one polymer. It is, of course, possible for the polymer chemist to produce an elastomer with the required final properties, but any such new elastomer to be used as a general purpose rubber must be considerably cheaper or possess some processing advantages over the existing rubbers, or both. Thus the present general purpose rubbers are likely to continue unless a considerably cheaper elastomer with some processing advantage is found.

3.8 Some Aspects of the Marketing of Rubber.

To operate a successful business, it is necessary to plan its development to keep the correct balance between its present market and its potential markets; present production and future production. To do this successfully it is necessary to identify the customer, establish what his needs are, anticipate the changes in the needs and meet the constantly changing needs. The role of marketing in a highly technically oriented rubber industry is vital and the success of the SR industry is often attributed to its modern methods of marketing. Marketing of NR is in no way similar to that of SR. While SR is marketed as an industrial raw material direct to its consumers, NR is 'traded' similar to most commodities.

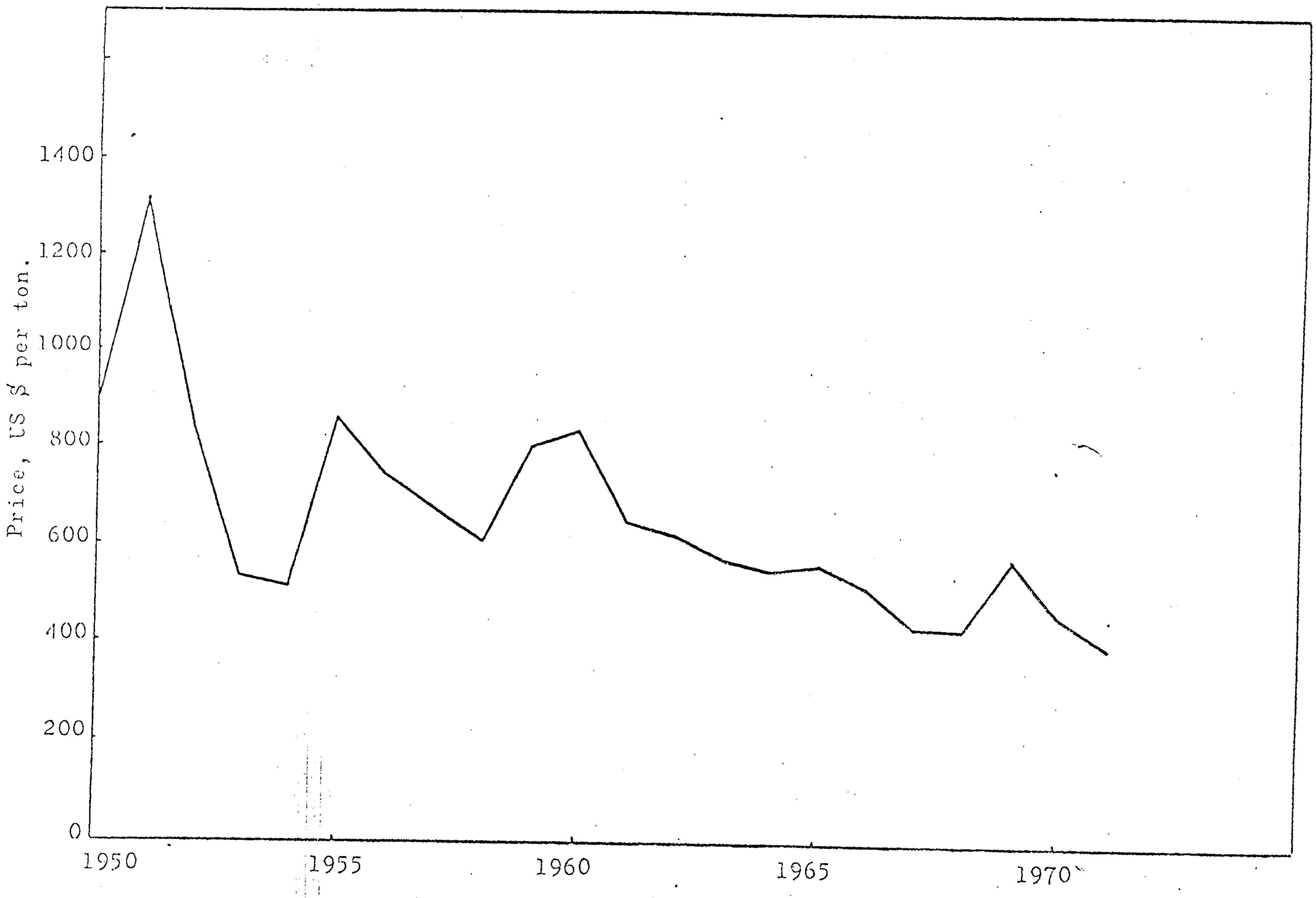
3.8.1 Price.

From a competitive viewpoint, an important aspect of performance is the price behaviour of the industry. Like most commodities, NR is traded via the international commodity markets, from a large number of producers to a large number of consumers. The NR market displays most of the features of perfect competition. Under these conditions the price of NR cannot be fixed and must accept the market price. Historically, NR prices have borne little or no relationship to production costs. The supply of NR has been relatively inelastic in the short term, largely due to the 6-7 year waiting period between planting and tapping. Although supply and demand position is the primary factor which influences the price, large fluctuations in price occur which are subject to the vagaries of the commodity market. The price instability can be frustrating for a consumer to establish a cost price for his end product well in advance.

The most important single factor affecting the long term price of NR, is the general economic conditions in the consuming countries which influence the purchase of consumer goods particularly automobiles. In the past, several other factors have also affected the price of NR: political disturbances in the producing countries, strikes in the consuming industries, large scale purchases by socialist countries, barter agreements, stockpile releases, international monetary problems, shortage or overproduction of SR, etc. The price instability is often speculatory. There is no trend in the movement of price and thus, it is impossible to forecast the price movements. (fig. 3.12).

Before the introduction of stereo-regular elastomers, NR commanded a fairly substantial premium over SBR which was a technically inferior substitute for NR in several applications. With the emergence of the stereo-rubbers, especially IR, have tended to present NR with an effective ceiling price. This has had a stabilising effect on the price of NR and its long term price will be closely related to that of IR. The lower price of NR in the past few years has avoided large scale substitution by IR and other stereo-rubbers. NR price has decreased gradually and has failed to enjoy any degree

Fig. (3.12) Average RSS1 Price (New York), 1950-71



of price inflation over the years, meanwhile SR producers have maintained relatively stable prices by reducing costs. However, the SR production costs are likely to rise faster and any price rises of SR would also favour NR.

3.8.2 Natural Rubber Marketing.

The transfer of SR is usually carried out directly from the producer to the consumer by a technical salesman at fixed prices. The marketing of NR is much more complex. The supply lines are longer and the variety of grades and types of rubbers, produced by a large number of producers of varying types in several countries are eventually brought to the consumer, by different channels. The rubber may pass from the producer to the consumer via several 'middlemen'. While most estates are able to operate fairly well in the international markets through agency houses or in some instances directly with the ultimate consumers, the smallholder does not have the ability to do so. The smallholders' rubber usually passes via a greater number of 'middlemen' in the long chain of market operators before reaching the export market. In this way, it is doubtful if the smallholders get maximum returns for their product. This and the poor quality rubber associated with the smallholders can only be overcome by the establishment of central processing units for smallholders' latex. These central processing units will play an important role as direct sales to the consumer will become very important in the future.

One of the biggest problems of the present system of marketing NR, is the speculative nature of the markets and therefore prices are unstable. The wild fluctuations in prices are considered a bigger problem than the absolute prices by some consumers. The instability of the prices in the past have induced many consumers to seek substitutes for NR, even though these have been technically undesirable. Large fluctuations and unrealistically high prices will act as a stimulus for the SR producers to increase IR production facilities and improve the existing synthetic isoprene rubbers to match NR in technical qualities. These developments would tend to keep the price of NR down. It is likely that IR would be developed as a complete technical substitute for NR and when this happens, the two rubbers would compete purely on price and marketing support offered by the producers. It is therefore necessary to market NR as a modern industrial raw material in the future.

Although there are several deficiencies in the present system of 'trading' NR, a great weight must be attached to some advantages, notably the inherent mechanisms for: -

(i) buying any producers' rubber, in any quantity virtually at the point and time of production;

(ii) financing stocks in the producer-consumer pipe-line;

(iii) hedging against price movement.

The NR markets have served their customers admirably in the past, but what part they can play in a highly competitive technically oriented market in the future is questionable. In a technically based, competitive industry, close interaction between producer and consumer is essential especially when the rival materials whose market entry and encroachment are deliberately fostered in just this manner. The producing industry is now becoming increasingly consumer orientated and several innovations are being directed towards end-use. Any new developments such as the viscosity stabilised rubbers, tyre rubbers etc. must bypass the existing commodity market and be presented direct to the consumer at fixed prices with the usual marketing support. Any marketing system developed must be such that it gives full benefit to the producers, particularly the small ones.

Technically and theoretically, a marketing system similar to that of SR seems the most attractive and the best. In practice many obstacles may impede its effect. There are several basic differences between the SR and NR industries which, make a similar system a practical impossibility. SR originates mainly from the consuming countries themselves, there are a relatively small number of large SR producers and it is easy to adjust the supply and demand. In comparison, NR is produced by a large number of producers of all sizes in varying qualities in several countries thousands of miles from the consumers. For a marketing system of the type similar to that of the SR, it would be necessary for all NR producing countries to get together, pool their financial resources, and organise an effective scheme that would be acceptable to all producers. The problems of organisation and cost will be enormous. Unless this system replaces the existing system completely, it is unlikely to be successful. Although a changeover to this system is most desirable it is a practical impossibility in the forseeable future.

An alternative arrangement is to seek some form of agreement between the producers and consumers to minimise the impact of fluctuations in supply and demand. Under normal conditions such a scheme is beneficial to both buyer and seller, as it invariably fixes the price bracket. Thus, the producers can treat the lower limit of the bracket as a guaranteed selling price and plan their output accordingly. Similarly, the consumer can cost his own output according to the upper limit. For the successful operation, the scheme would require adequate stocks to be held in both producing and consuming countries. Several organisational and cost problems exist. All NR producing countries must get together and form a single organisation which would be responsible for the operation of the scheme. The multiplicity of grades must be reduced and only one internationally agreed specification must be arrived at. The Tin Council agreement is often quoted as a model of this system. One of the main advantages was that the scheme was self-financing, as the margin between the upper and lower limits was sufficient to cover the stock-holding and administrative costs involved. The scheme worked perfectly well for some time until the demand outstripped the supply and there was insufficient stocks to meet this demand. The result was a free market where the prices reached a more realistic level. The position of NR is more complex, it is a bulky material and is liable to undergo deterioration during storing which would require constant rotation of stocks.

In view of the many problems, an alternative system can be adopted on a smaller scale without much delay. This would require a mechanism by which a producer or a group of producers or an agency house would deal directly with the consumer, completely by-passing the commodity market. This of course would require some form of contract between the producer and consumer. Whatever system is developed it must meet the following basic requirements:

(1) Supplies must be easily available;

(2) Rejections must be speedily replaced and remedial measures must be promptly implemented;

(3) Credit facilities must be available;

(4) Adequate technical data should be supplied;

(5) Consistency in standards must be assured;

(6) After sales technical service must be provided; and

(7) A mechanism must be available to communicate specific technological requirements of the consumer to the producer.

3.8.3 Marketing Support.

The rubber market is highly competitive and demands a high level of technological competence of its suppliers. Technology is therefore a prime resource for any supplier. The present system of marketing NR does not have the mechanism to communicate with the technologically oriented consumers and transmit the industry needs to the producers or to be able to solve the consumers' problems. Technical and after sales service has become an import feature of the SR industry.

The technical differences between NR and IR are narrowing down, promotional and technical service aspects would play an important role in improving the competitive position of NR. At present, some technical service and promotional activities are carried out only by the Malaysian producers through the Malayan Rubber Fund Board offices throughout the major rubber consuming areas. While this kind of service has benefited the NR industry as a whole, compared with any SR of equal volume output, this may be only a small service. Although there is some co-operation between the NR producing countries, this has not gone far enough to improve NR's competitive position. In future a single organisation of all NR producing countries would be necessary to bring about co-ordination of production and marketing in order to maintain a stable and fair price. The formation of the Association of Natural Rubber Producing Countries in 1970 is the first step towards achieving this goal. It is also necessary for all NR producing countries to pool their financial resources to establish a single research organisation that would be responsible for all research and development in the use of NR and customer service.

4. CONCLUSION.

The future of NR, will depend largely on its quality, cost and price. The demand for NR will continue to increase at the present rate of around 3 to 4% per year but its share of the total rubber market will continue to decrease to around 25%. The main outlet for NR will continue to be in large tyres. Large scale change over to radial tyres in the U.S.A. and other countries will favour the demand for NR and at the same time the price of NR would be more favourable to the producers. It is doubtful if NR output in the next few years would be sufficient to meet the increasing demand for all rubbers. NR will continue to lose its market share in the non-tyre sector to a variety of new 'tailor made' polymers. The growth in the absolute consumption of NR in this sector is not likely to be very much.

While the quality and presentation of NR has improved by the introduction of new process rubbers with technical specification, these improvements have taken place on a small scale. The quality and consistency of the SRs are superior to those of NR. Thus, it would be necessary to improve the quality of the lower grades of NR, especially those produced by the smallholders. There is no general purpose SR which matches NR in its product performance and processability except perhaps the high cis polyisoprene. However, the SR producers have the ability to produce polymers to suit the fabricators' requirements. While it is impractical and uneconomic to alter the inherent properties of NR, it would be necessary to produce more consumer oriented forms, especially for non-tyre applications. Low viscosity rubbers, tyre-rubber, oil extended NR, superior processing NR, pale crepe, sole crepe, etc. are some of the more promising consumer oriented grades of NR. The SR producers have the ability to produce any 'tailor made' elastomer to suit the end use, but the acceptance of any such polymer for any product application would depend on the cost.

Some of the most efficient NR producers can profitably produce NR at a cost below that of isoprene or even butadiene monomer. Production costs in well managed estates planted with high yielding trees can be around 10 US cents/lb. Labour costs account for about 50% of the total production costs and in the long term labour costs will outpace any economies achieved via increased estate productivity. However, in the short term labour costs can be offset by replanting with the highest yielding clones, use of yield stimulants and labour saving methods. In the SR industry, cost of monomers may account for as much as 50% of the total cost of manufacturing the polymer, while about 20% may be in the form of financial costs in the form of plant depreciation and provisions for working capital. Scarcity of petrochemical raw materials and inflation in raw material costs, will have a marked effect on the cost of SRs in the future. Further reductions in the cost of SR production via economies of scale as in the past 20 years is unlikely and high rates of inflation of capital will influence the operating costs. Thus, the SR producers are facing a major escalation of costs which will be faster than in the NR industry.

The price of NR in the consuming countries is important when considering price competition with the synthetics. The synthetic rubbers have had a depressing effect on the price of NR and in the long term, the price of high cis polyisoprene will place a ceiling on the price of NR. So far, no cheap route has been found for isoprene monomer production and hence high cis polyisoprene would continue at a price of about 22 - 23 US cents/lb. or even higher. A more realistic price for NR would be around this price range. The low price of NR in the past few years has held the price of synthetic polyisoprene down and has discouraged large scale production of polyisoprene. The f.o.b. price paid for the rubber in the producing countries is important when considering the profitability in the plantations. While a large number of efficient producers can expect a modest profit at an f.o.b. price of about 12-13 US cents/lb., this may not be an attractive price for the smallholders or small inefficient estates. An f.o.b. price of 15 US cents would be a more realistic price for the producers and adding about 5 US cents for various cesses, freight, handling and agents charges; the price of NR in the terminal markets would compare favourably with that of poly isoprene. The present shortage of SBR has pushed the price of NR to a record peak since the Korean War. The total rubber production may not be sufficient to meet the increasing demand for rubbers unless new SR production is available. In the long term, with the petrochemical raw materials getting scarcer and inflation rates rising faster in the Western countries, it would be necessary for the NR producers to increase production. With the diversification programs taking place in the producing countries, the increase in production must be expected from high yielding trees and yield stimulation rather than by opening new plantations.

It would be necessary to avoid any large scale fluctuations, obtain reasonable prices for NR and maintain steady growth. This can be achieved if all NR producers get together to form a single organisation and pool their financial resources to strengthen their research efforts and market NR as a modern industrial raw material.

PART II

5. THE RUBBER INDUSTRY IN SRI LANKA.

5.1. General

The structure of the industry in Sri Lanka is very much similar to that in Malaysia. However, the industry has failed to keep abreast with the progress in the Malaysian industry. Rubber production in Sri Lanka has failed to match the growth in other major producing countries. The types and grades of rubber produced have not changed since the beginning of the industry. Although replanting has been in progress since 1953, the actual planted area in Sri Lanka has decreased from 275,000 ha. in 1960 to 230,000 in 1970.

The reasons for the failure of the rubber industry to achieve better growth and to keep abreast with other NR producing countries in terms of modernisation are not hard to find. Development in the private sector has been lacking due to the threat of nationalisation of estates and lack of foreign investment. Sri Lanka has an acute balance of payments problem as a result of the declining price of traditional export commodities and the increasing price of imported food and other items. Thus priority is given for the production of food and import substitution. Although rubber is second only to tea as Sri Lanka's principal source of foreign exchange, which accounts for over 16% of the total foreign exchange earnings, the industry is given low priority for development. Thus, any development in the plantation industry must be achieved without the use of extensive foreign exchange. Therefore the rubber industry must concentrate on techniques of improving quality, increasing efficiency and the development of premium grades of rubber without the use of expensive or sophisticated equipment.

5.2. Structure of the Industry.

Sri Lanka has a planted rubber area of 230,000 ha of which 112,500 ha are classified as estates and 117,500 ha as smallholdings (holdings below 4 ha). Between 1953 and 1972, 122,000 ha have been replanted with high yielding clones.[79] The average yield in 1970 was 690 Kg/ha/year, which compares favourably with the 700 Kg/ha/year of West Malaysia. However, the average yield dropped to around 600 Kg/ha/year in 1971 and 1972, due to the internal disturbances and poor climatic conditions. Table (5.1) illustrates some important features of the rubber holdings in Sri Lanka. The most

TABLE (5.1). Some features of the rubber holdings in Sri Lanka (1968)[80]

Size of holding (ha)	Registered area (ha)	Average area per holding (ha)	Percentage of high yielding trees
Below 4	84,400	0.6	42
4 - 40	62,000	10.7	52
40 - 200	59,000	89.0	60
200 and over	62,000	365.0	60
All holdings	267,000	1.8	50

important factor illustrated by the table, is the presence of a large number of smallholdings with an average area below 1 ha and these account for over 30% of the total rubber area. These are highly uneconomic due to the high labour intensity and are also associated with the production of inconsistent and poor quality rubbers. The Malaysian study of Barlow and Kheong concludes that the most economic size of a family holding is around 3 ha.[22] On the other hand, large scale estate production is not essential for efficiency, although some economy in processing can be achieved. However, even for the production of smoked sheet which requires the smallest processing unit, the minimum daily production should be 250 Kg. This would require latex from about 100 ha of rubber holdings with an average yield of 1000 Kg/ha/year. Therefore it is necessary to establish central processing units to process latex produced by all holdings below 100 ha. Whitelaw and Perera recommended in 1947, that the Government should establish central factories to cater for 1000 - 2000 ha. of rubber holdings to manufacture smoked sheet, latex crepe and concentrated latex.[81] Due to the fragmented nature of rubber holdings in Sri Lanka, the economics of operating central factories to cater for large areas are a doubtful proposition. But it would be possible to establish smaller central factories where contiguous rubber holdings are available.

5.3 Rubber Production.

Rubber production in Sri Lanka is largely confined to the three main types:

(1) Smoked sheet (RSS)

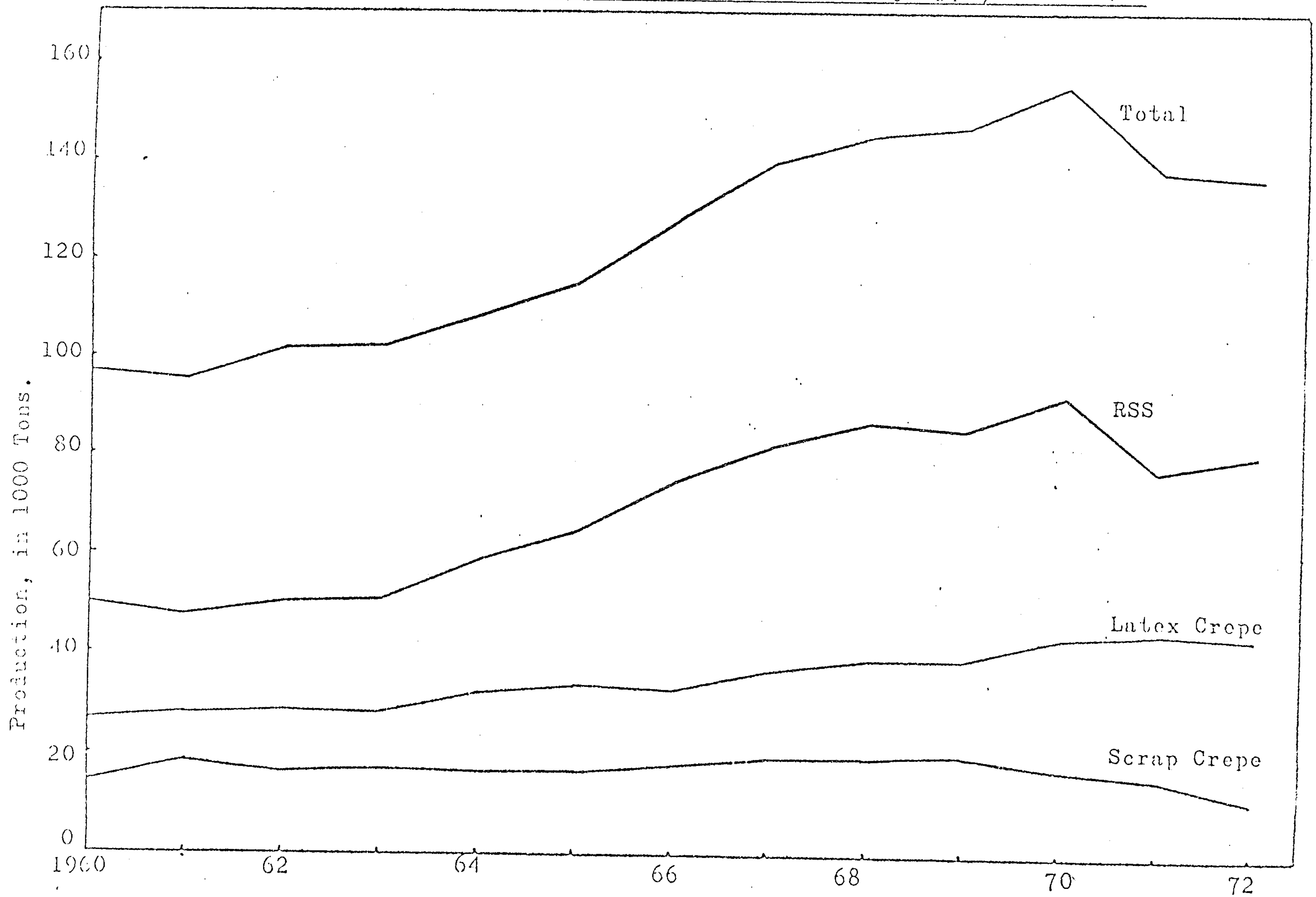
(2) Latex crepe (including sole crepe);

(3) Scrap crepe.

New process rubbers are produced in two factories on a small scale. Production of latex concentrate continues on a small scale for local consumption and export of NR latex ceased in 1968. The production and the growth of various types of rubbers in Sri Lanka are shown in table (5.2) and fig. (5.1). The sharp decline in 1971 and 1972 are largely due to the internal disturbances and poor climatic conditions. Sole crepe production in this period has increased with the decline in pale crepe production. However, total latex crepe production has maintained its growth. This is a result of the very high premiums obtained for sole crepe over pale crepe whereby some pale crepe producers switched over to sole crepe production. If factors such as climatic conditions, political influences and price are favourable, the upward trend in the rubber output between 1960 to 1970 will continue.

Some important features of rubber production in Sri Lanka are shown in table (5.3), which shows the distribution of various types of rubber produced under different holding sizes. Latex concentrate and latex crepe are largely produced by large estates in excess

Fig. (5.1) Rubber Production in Sri Lanka by type, 1960 - 72



of 200 ha. While medium and smallholdings (below 40 ha) produce only smoked sheet and scrap crepe. This shows the degree of sophistication and economies of scale associated with latex and latex crepe production. The fragmented nature of rubber holdings and the production of latex crepe in large estates, have special significance in the establishment of new process factories or other developments to upgrade the quality of rubbers in Sri Lanka. These are discussed later.

5.4. Future Developments.

Several possibilities exist for future developments in the rubber industry in Sri Lanka. These can be broadly classified into three categories:

(i) Continue production of existing forms with improvement in quality, presentation and efficiency.

(ii) Production of consumer oriented forms of NR already available commercially or completely new forms or both.

(iii) Production of chemically modified forms of NR.

However, the commercial, economic and technical viability of each project must be critically analysed. Market demand, changes in the rubber fabricating industry, innovations in the SR industry and developments in the other NR producing countries, are some of the external factors that have to be considered first. Secondly, TABLE (5.2) Rubber Production in Sri Lanka (in tons).

Year	Smoked Sheet	Pale Crepe	Sole Crepe	Scrap Crepe	Latex	New Process	Total
1960	55,315	26,470	460	14,591	441	–	97,277
1961	48,232	27,992	628	18,650	545	–	96,047
1962	56,056	28,070	844	16,855	578	–	102,403
1963	56,596	27,628	911	17,349	613	–	103,097
1964	59,573	31,559	1,235	16,782	651	–	109,800
1965	65,307	32,988	1,112	16,377	658	–	116,442
1966	76,186	32,366	1,132	18,618	643	–	128,945
1967	83,727	35,745	1,245	19,464	761	–	140,942
1968	87,038	37,527	1,203	19,854	748	–	146,370
1969	86,879	39,977	1,059	19,796	741	–	148,452
1970	94,187	41,729	2,159	17,842	728	–	156,645
1971	78,488	41,736	3,176	15,231	496	49	139,176
1972	82,168	39,388	3,821	11,029	497	810	138,153

TABLE (5.3) Distribution of Various Types of Rubber Produced Under Different Holding Sizes (1968) [82]

Total Rubber Produced (in ,000 tons)									
Small Holdings (Below 4 ha)		Medium Holdings (4 - 40 ha.)		Small Estates (40 - 200 ha)			Large Estates (Over 200 ha)		
RSS	Scrap	RSS	Scrap	RSS	Scrap	Latex Crepe	RSS	Scrap	Latex & Latex Crepe
33	5.5	28	5	23	4	4.5	5.5	6.5	35.5
38.5		33		31.5			46.5		

internal factors such as the availability of capital, equipment, raw materials and other economic, social and political factors need consideration. In Sri Lanka, these factors are much more critical than the external factors. Any new projects must be considered under one main condition - lack of foreign exchange. Thus, priority will be given to projects that are likely to save foreign exchange by import substitution or those products which are likely to earn extra foreign exchange, like the premium grades of rubber.

New developments can be further classified into short, medium and long term projects. The short term projects are those projects that are likely to increase the short term revenue through premium grades, improvement of the quality of existing grades, improving the image of the existing grades, cost reduction through increased efficiency and increasing the output of any existing types to meet the anticipated market needs. These projects in general will make use of existing equipment and technology without excessive additional expenses. Thus, in the short term it would be necessary to increase productivity in the plantations and evaluate the future of scrap crepe, smoked sheet, latex and latex crepe. Since Sri Lanka is the largest producer of premium grade latex crepe and the production of latex crepe accounts for a third of Sri Lanka's rubber production, the position of latex crepe is discussed in detail separately.

Other short or medium term projects should include new process rubbers, low viscosity rubbers, tyre rubber and other consumer oriented forms of NR. The medium to long term projects should include physical or chemical modifications of NR and creating new markets by technological innovations.

5.5. Scrap Crepe.

The scrap crepes have found a small market as low grade NR in the past. This situation is changing with the consumer preference for the equivalent technically specified SMR grades. The production of scrap crepe in Sri Lanka has declined with the improvement in the efficiency and quality of production. A very large proportion of the scraps are produced by small and medium holders. These scraps are more suited for the manufacture of new process rubber. The quality of the scrap rubber can be upgraded in such a process due to the ease of washing. The lower cost of processing and the higher price for equivalent low grades of new process rubbers should also favour this change. The main advantages to the consumer are the technical specifications, considerable improvement in the consistency of quality and better presentation.

5.6. Smoked Sheet.

Although the new process rubbers are considered to be more consumer oriented, smoked sheet still has a strong demand, particularly from the small and older rubber fabricators. Technologically, there is little or no difference between RSS and the SMR grades. In fact

RSS may possess a higher antioxidant activity since, excessive washing of the crumbs in new process rubber production tends to remove some of the naturally occurring antioxidants. However, the technical specifications and the form of presentation make the SMR grades more attractive to the consumer.

Several factors which are peculiar to Sri Lanka, make it desirable to continue production of RSS. Namely:

(i) The presence of a large number of small and segmented holdings which are not suitable for large scale production of new process rubbers.

(ii) The large estates in Sri Lanka profitably produce premium grade latex crepe, good quality RSS and some latex concentrate.

(iii) The new process rubbers in general have demanded little or no premiums over the equivalent grades of RSS.

(iv) Over a third of Sri Lanka's rubber output is sold to China under a bilateral trade agreement. Under this agreement, China pays a premium for RSS 1 over the prevailing Singapore price; this is usually well above the price of equivalent SMR grades.

(v) The high cost of capital equipment and the lack of foreign exchange to purchase the necessary machinery and equipment for new process rubber production.

Under these conditions there is no incentive to change over from RSS production to new process rubber production at present. However, in the long term, the competitive prospects of NR will be improved considerably by large scale change over to new process rubbers.

The present bilateral trade agreement with China is favourable only to the producers of RSS 1. In a well managed estate factory around 90% of the RSS can be produced as RSS 1, while in small and medium holdings only about 20% is produced as RSS 1.[82] To obtain maximum revenue from the small and medium holdings, it would be necessary to upgrade the RSS produced. This can be done effectively by organising groups of small and medium holders to process their latex in central processing units. All low grade RSS 4 and other scraps must be reprocessed as new process rubbers.

The image of smoked sheet can be improved considerably by introducing some form of technical specifications similar to the SMR specifications and presenting the rubber in a more attractive form. This would require the RSS to be packed in small polythene wrapped bales and palletised for easy handling and storage. It is estimated that a saving of £7 per ton is achieved in the total cost of handling, shipping, warehousing etc. from the port of origin (Singapore) to the end user's factory in England; by using palletised form of NR over the conventional large bare-back bales of RSS.[83]

With the existing equipment for the production of RSS, it may be possible to alter the processing methods to produce some consumer oriented forms of NR and this needs further investigation. It has been found that latex can be coagulated using some bacteria and the resulting rubber is faster curing and possesses high tensile strength.[84] This rubber would find a small market where high tensile strength is required. The use of acids or bacteria for the coagulation of latex results in the coagulation of not only the rubber hydrocarbon but also the proteins present in the serum. The presence of proteins increase the heat build up properties in the rubber. Low protein NR is useful in applications where high resilience and low heat build up are required as in large tyres and engineering applications. An economic and practical method of coagulating the rubber in the latex without the simultaneous precipitation of proteins needs to be investigated. The use of papain as a coagulant has been found to give rise to a rubber with low protein content.[85] Another method being used in Malaysia makes use of some enzymes to break down the proteins before coagulation.[86] The constant viscosity grade of NR is produced only in the new process forms, methods of producing a low viscosity grade of RSS without the use of peptisers needs to be investigated.

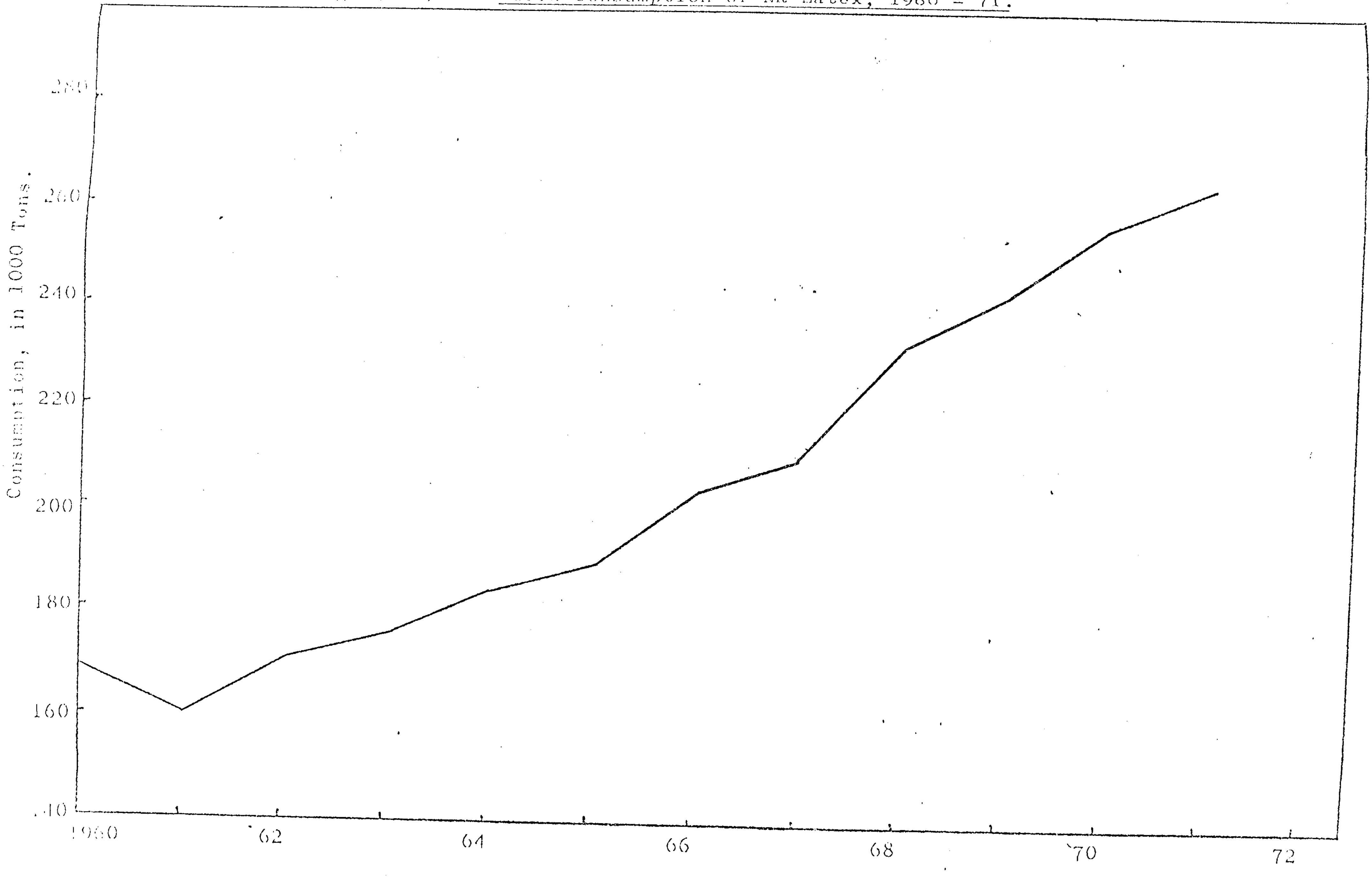
5.7. Latex Concentrate.

The demand for NR latex in the world markets has been increasing steadily. The consumption of NR latex has increased from 160,000 tons in 1961 to almost 270,000 tons in 1971 (fig. 5.2). The strong demand is also reflected by the high price of latex concentrate in the last 5 years;

during this period, latex concentrate has fetched an average premium of around 20% over the RSS 1 price. NR latex is used mainly in carpet backing, foam products, dipped goods, adhesives and latex thread. It is only in the dipped goods application that NR latex has considerable technical superiority over the synthetics, due to its good tear resistance and high tensile strength. However, this accounts only for a small share of the latex market and the bulk of it is used in carpet backing and foam, where it possesses little or no advantage over SBR latex. Under these conditions, NR latex will have to compete mainly on lower price. It is predicted that the NR output will be insufficient to meet the rapidly growing demand.[87] This would encourage further substitution. SBR latex has already found large scale outlet in the carpet industry and foams. Thus, it would be necessary to increase the output of NR latex and reduce the price in the World Markets.

Around 15,000 tons of rubber in the form of latex concentrate was produced annually between 1951 - 56 by Dunlops Ltd. in Sri Lanka for export. Following the barter agreement with China, the price of field latex in Sri Lanka was well above the world price and Dunlops were forced to close down their latex concentration plant. Sri Lanka ceased to be an exporter of latex concentrate since 1968. An important feature of the latex concentrate production is the large scale ownership of the production facilities by the final consumers. It is unlikely that foreign investors would be encouraged to set up such concentration plants in Sri Lanka and hence any new production facilities must be

Fig. (5.2)   World Consumption of NR Latex, 1960 - 71.



expected from the Government or local firms. The present production of latex concentrate in Sri Lanka is around 700 tons per year and the total capacity is estimated to be around 1,500 tons per year.[88] The latex producers, who are also the consumers in Sri Lanka, have maintained an artificially high price of latex within the country by maintaining their output well below the total capacity. This has also resulted in the slow growth of the latex goods manufacturing industry.

Past experience shows that it is possible to produce latex concentrate in Sri Lanka on a large scale for export and local consumption. Latex production offers some degree of flexibility as regards to supply and demand. During periods of low demand the latex can be used for dry rubber production or used in applications locally, where NR latex would be otherwise considered too expensive such as in latex-bitumen road surfacing, soil stabilization, latex-cement mixes etc. NR latex also offers some possibilities of minor chemical modifications to meet specific demands of the consumers. It would be desirable to produce latex with minor modifications to meet specific needs of the smaller markets such as dipped goods, latex thread and adhesives. These possibilities are discussed later.

6. LATEX CREPE.

6.1 Introduction.

Latex crepe is a special purpose, high quality premium grade NR. Due to its light colour and high level of cleanliness, it is used as a special purpose rubber and finds a limited market. It is generally used where light or bright colour and cleanliness are important in the finished product, e.g. in the manufacture of surgical and pharmaceutical goods, cut thread, adhesives, adhesive tapes, chemical derivatives of NR and a variety of coloured articles. Sri Lanka is the largest producer of high quality latex crepe, producing about 40,000 tons annually. This accounts for about 65% of the World's production and the rest being produced by Malaysia. The future of latex crepe is threatened by increasing substitution by the synthetics and some new grades of NR. Thus, it was necessary to explore the competitive position of latex crepe and recommend necessary action to improve its competitive prospects.

Latex crepe has generally commanded a substantial premium over smoked sheet. The export of latex crepe (including sole crepe) accounts for around 30% of the overall exports of rubber from Sri Lanka. The export earnings from these rubbers was around 40% of the total export earnings from rubber in 1971. The price of latex crepe has been most unpredictable, the price fluctuations are more marked than for smoked sheet. Several consumers started looking for cheaper alternatives when the price was high. In some applications several synthetics such as, synthetic polyisoprene, EPDM, polyurethanes, thermoplastic SBR and others have the ability to compete with latex crepe purely on price.

Already, a large number of traditional markets have been lost to plastics and some substitution by the synthetics and other grades of NR (viz. SMR 5L and EQ) is taking place. The SMR grades with a slightly inferior colour are able to compete with the crepes. This is mainly due to a lower price, technical specifications, better presentation and technical service offered by the Malaysian producers. SMR EQ, which is being produced specifically to compete with latex crepe, and IR offer the greatest competition to crepe.

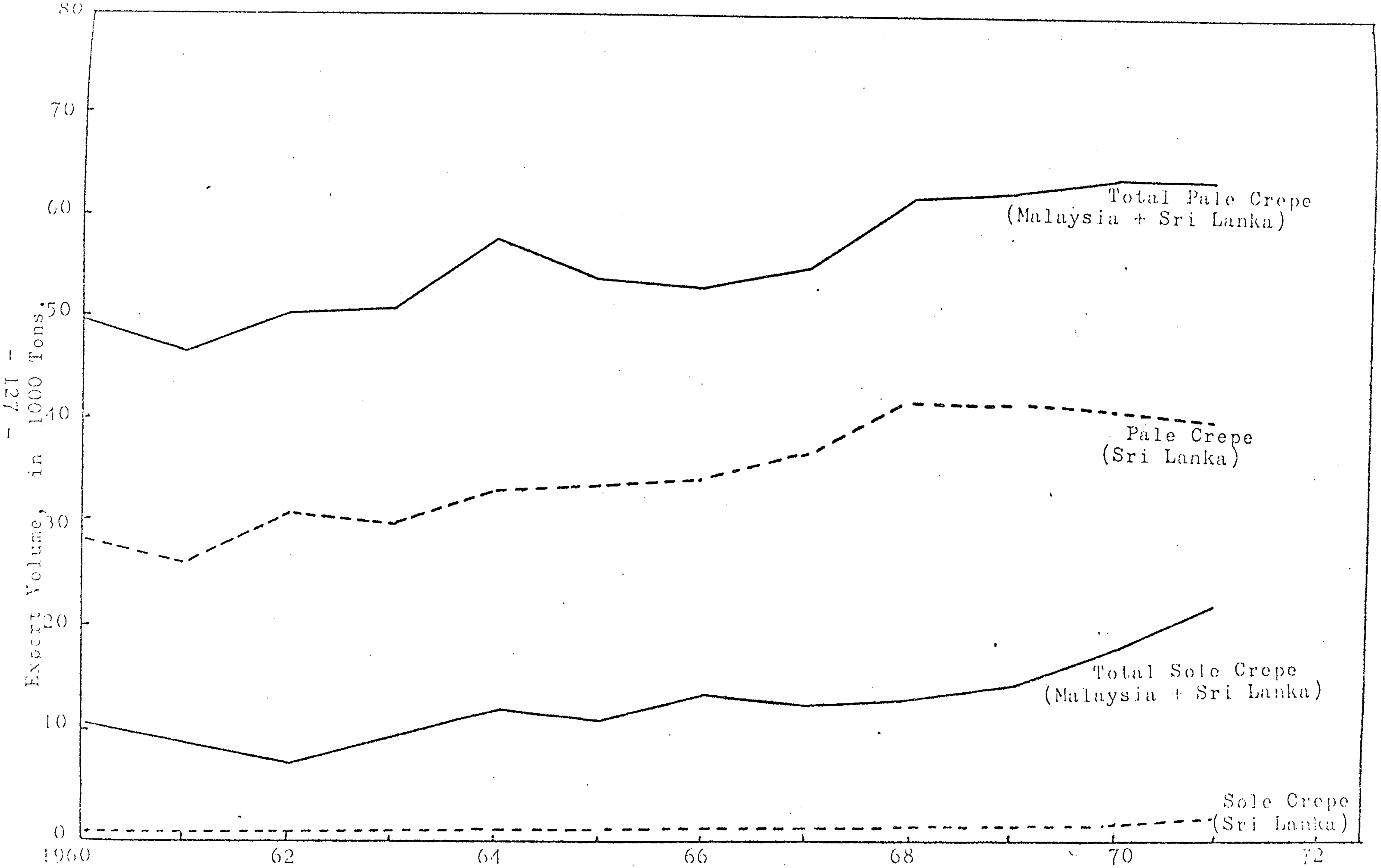
Although synthetic substitutes have been available since the mid-sixties, only very slight substitution had taken place previously. And this too on a temporary basis, when the price of crepe was too high. The present switch over by many consumers from crepe to other materials both synthetic and natural, seems to be a more permanent one. This tends to suggest that the use of latex crepe is based to some extent on historical reasons rather than technical or economic reasons. The commercial, economic and technical requirements of the consumers have changed significantly. However, the producers have not changed the methods of production, presentation or improved the product technically since the start of the industry.

It is often said that, very little communication between the NR producers and consumers exist. To effectively meet the wide and varying needs of the consumers, it is necessary to identify the consumers and their requirements. With this in mind a brief survey of the different industries, which consume crepe, in the U.K. was carried out.

6.2. Supply and Demand.

The total exports of pale crepe from Sri Lanka and Malaysia increased from about 50,000 tons in 1960 to around 63,000 in 1968. Since 1968, the increase in the exports was virtually zero. This shows the declining demand for pale crepe. However, the exports of sole crepe during this period, increased from around 10,000 tons to 22,000 tons (Fig. 6.1). The exports of sole crepe from Sri Lanka increased from 500 tons in 1960 to 3,000 tons in 1971. There is a certain amount of flexibility in the supply of latex crepes. Latex crepes are produced by large estates and some of these estates have the facility to switch over from pale crepe to sole crepe and vice-versa, depending on the price of the product. The substantially higher premiums obtained for sole crepe has made several producers to change over to sole crepe production from pale crepe. This has resulted in a shortage of pale crepe and pushed the price to unusually high levels. As a result the consumers have changed over to substitutes.

Fig. (6.1) Export of Latex Crepes from Sri Lanka and Malaysia, 1960 - 71.



The supply and demand situation has been often disturbed by the large scale sale of pale crepe to the Eastern European countries under barter agreement from Sri Lanka. These unusually large scale purchases have had adverse effect on the price. Since pale crepe is a special purpose rubber with a limited demand, any supply - demand imbalances would have a marked effect on the price. The demand for pale crepe is likely to increase around 1,000 to 1,500 tons annually, if the price remains favourable. It is likely that more producers of pale crepe would change over to sole crepe production. Thus, it would be necessary for Sri Lanka to establish new processing facilities to increase the production of pale crepe to meet the anticipated demand. Due to the economies of scale associated with pale crepe production, it would be necessary to establish central factories to process smallholders' latex.

6.3. Characteristics of Consumption.

There are a large number and variety of products made from pale crepe. There is no published statistics on the use of crepe in the various end products. However, these products can be broadly classified into three groups, namely:

1. Products requiring solution process. These include mainly adhesives and adhesive tapes. Crepe is also used as a starting material for the manufacture of chemically modified forms of NR.

2. Light coloured translucent products. This group includes very special products which require freedom from toxic compounds and smell. The products include surgicals or pharmaceuticals and products that are likely to come into contact with food.

3. General rubber products requiring pastel shades. This group contains a large number of consumer goods and components which require visual appeal. These include bathing caps, hot water bottles, elastic thread, white wall of tyres, etc.

In solution processes, low cis IR has found large scale acceptance as the starting material for chemical modification, particularly in the manufacture of chlorinated rubber and rubber hydrochloride. The main reasons being: (i) freedom from gel, (ii) consistency in quality (iii) no initial mill break down is necessary since the polymer can be produced to the required molecular weight, and (iv) relatively low and stable price. In adhesives and pressure sensitive tapes NR is still preferred over IR. However, several types of adhesives are available for specific uses. In pressure sensitive adhesive tapes, pale crepe is still considered the best polymer available, due to its good surface tack, peel adhesion and cohesion. This is one of the major applications of pale crepe in adhesives.

The main disadvantages of using crepe in pressure sensitive tapes are:

(i) high cost of polymer and the price variations;

(ii) the polymer requires premastication for the elimination of problems arising from gel and for easy dissolution in the solvent;

(iii) the solubility of the polymer is low to give the required viscosity (i.e. low solid content in solution);

(iv) the solvent recovery is expensive and only about 85% of the solvent is recovered.

These problems may drive the consumers to look for alternative processes or polymers. Polymerisation in situ or liquid polymers which can be chain extended and cross-linked via reactive groups may find some applications. Thermoplastic rubbers or ethylene vinyl acetate may be used as hot melt coatings. Already some block copolymers of styrene/butadiene are used in adhesives due to higher solubility.

In pharmaceutical applications the cleanliness of the polymer is the main criterion. The articles are usually hand built and the cost of the polymer does not matter very much. Although the high cis IR has the necessary product properties, there has been very little substitution by other elastomers in these applications. The main disadvantage of IR is its low green strength and raw tack since, most of these articles are hand built.

It is in the general coloured rubber products that crepe finds a large market. Competition between various rubbers in this market is high. The main advantage of crepe in these applications is its light colour. In addition to this, it also possesses all the technical advantages of NR. Thus, other light coloured grades of NR, mainly SMR EQ and SMR 5L have the ability to compete with crepe. These rubbers have the advantage of being technically specified and in general are lower in price. Already some substitution of crepe by these rubbers is taking place where colour is not so important.

Where colour is more important, both types of IR are used in blends with crepe to reduce cost and improve flow properties of the compound, particularly in injection mouldings, extrusions and where intricate shapes are required. The low-cis IR cannot be used as a complete substitute for crepes, since this requires completely different processing techniques. Changing compounding and processing techniques in a factory can be costly and a large number of the smaller factories do not have the facilities to fully test new compounds before changing over. However, the high-cis IR is somewhat better than the low-cis IR and closely resembles pale crepe in most properties. Its main disadvantages are poor green-strength and hot tear resistance. As a result of this large number of rejects take place in the factory. Thermoplastic rubbers and common thermoplastic materials have replaced pale crepe in some of the traditional applications. Urethane elastic fibre competes with cut elastic thread despite the generally higher costs. This is due to the finer denier fibre that can be produced from urethane elastomer.

At present, the main disadvantages of pale crepe in all applications are its high price and price variation. The pre-mastication necessary for NR puts it at a disadvantage over the synthetics. Thus, it would be necessary to produce a low viscosity crepe for some applications. The batch to batch variation in curing characteristics and other properties is a serious defect with all the grades of NR. This is inevitable since pale crepe and other grades of NR originate from a large number of sources. There is no single standard method of processing these rubbers and there are differences in the quantities and nature of non-rubber constituents arising from the clonal differences. These are largely responsible for the inconsistency in properties. Pale crepe is visually graded according to the "Green Book" and in most instances, they are still presented in large bare back bales; while the SMR grades are technically specified, presented in small polythene wrapped bales and usually some technical service is provided. Unless some of these deficiencies of pale crepe are overcome, it will continue to lose its market share.

6.4. Technical Specifications.

Some technical properties of a large number of pale crepe samples from different estates in Sri Lanka were compared with the corresponding properties of some samples of SMR 5L and SMR EQ. These tests were essentially limited to some of the more important SMR tests which are of special significance to the consumers of crepe. The results are summarised in table (6.1).

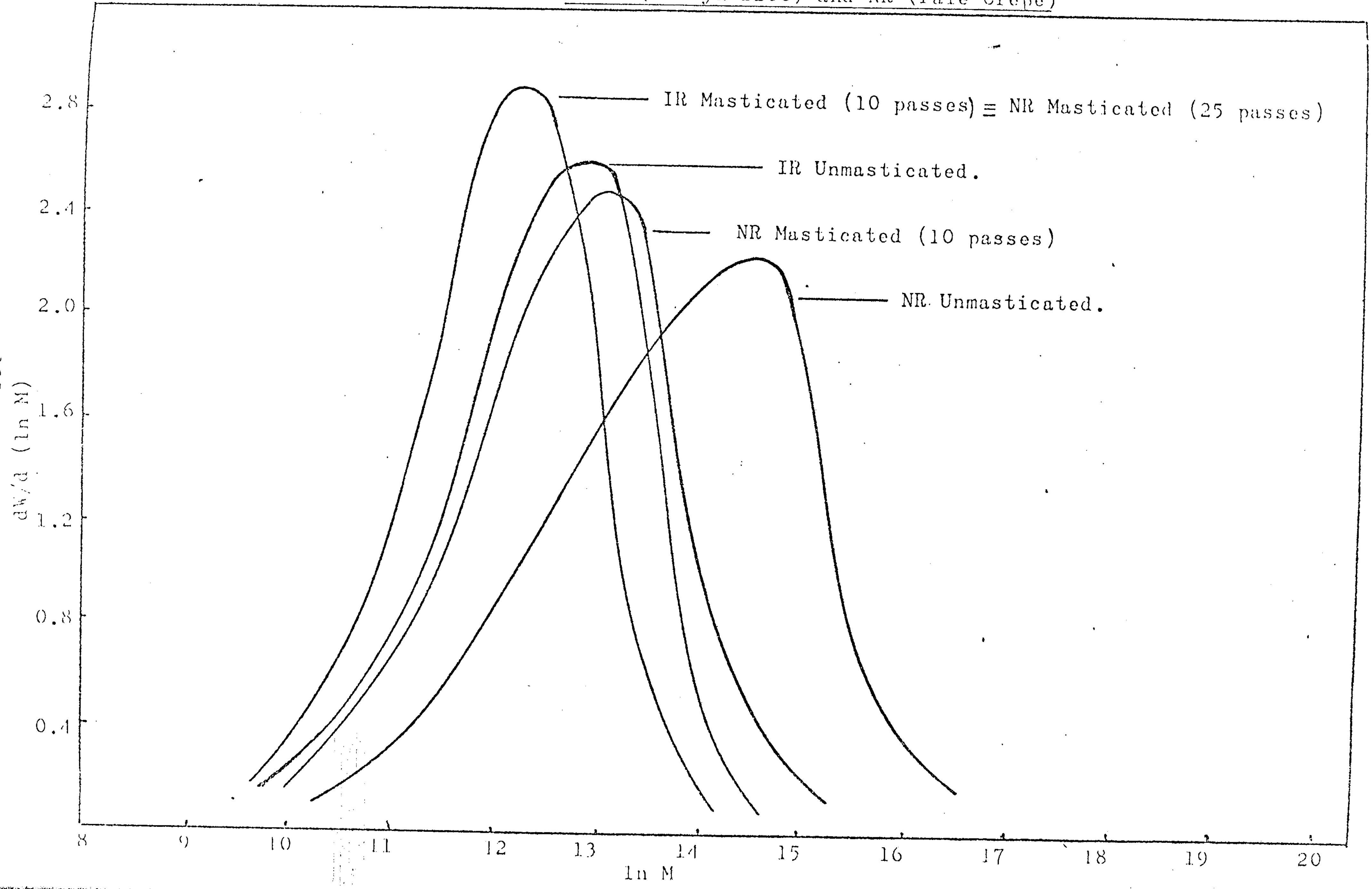
Table (6.1). Comparison of some of the SMR type specifications of Crepe, SMR EQ and SMR 5L.

Criterion	Pale Crepe 1 x, 1 & 2	Pale Crepe 3	SMR EQ	SMR 5L
Dirt (retained on 44μ sieve) (% wt)	0.15	0.15	0.20	0.50
Ash (% wt)	0.10-0.15	0.10-0.20	0.50	0.60
Nitrogen (% wt)	0.20-0.25	0.25-0.30	0.65	0.65
Colour (Lovibond Unit)	2.5 - 3.5	3.0 - 4.0	3.5	6.0
Volatile matter (% wt)	0.2 -0.28	0.25-0.35	1.0	1.0
Wallace plasticity	50	50	30	30
Cure indicator (MR 100 value)	5.0	5.3	6.2	6.0-7.5

Although there were variations in the properties of the samples from different origins, these were relatively small. The biggest differences in the properties were observed in the lower grades of crepe. The average dirt content of all grades of crepe (1x, 1, 2 and 3) was less than 0.15%, compared with 0.2% of SMR EQ and 0.5% of SMR 5L. The initial Wallace plasticity of crepe was slightly higher than those of SMR grades but there was very little difference in the molecular weight or molecular weight distribution. A significant difference in the molecular weight and molecular weight distribution was observed between the crepes and high-cis IR (Natsyn 2200). The crepes exhibited a higher molecular weight and broader distribution. The difference in the mill break-down behaviour was clearly illustrated by the molecular weight and molecular weight distribution of samples subject to various degrees of mill break-down (fig. 6.2). It was necessary to break down the crepe by passing it 10 discrete times between the tight nips of a two roll mill to obtain a similar average molecular weight and distribution as that of Natsyn 2200. Even after break-down, the crepe contained a substantial amount of high molecular weight component. 25 discrete passes of crepe gave a similar distribution as that obtained for Natsyn after 10 passes. The initial high molecular weight is a disadvantage since, the crepe would require pre-mastication. However, during compounding, Natsyn would tend to break down faster giving a weak vulcanizate. Crepe is always used in non-black products where very little reinforcement is produced by the fillers and the strength of the vulcanizate is mainly produced by the high molecular weight of the polymer.

The main differences between pale crepe and the SMR grades, were in colour, nitrogen content, volatile matter and vulcanization behaviour. These properties may

Fig. (6.2). The Effect of Milling on the Molecular Weight Distribution of IR (Natsyn 2200) and NR (Pale Crepe)



all be inter-related and give rise to some of the important properties of crepe. The colour and nitrogen content are due to the non-rubber constituents present in NR. These are variable according to the source and method of processing the latex. Three factors affect the colour of NR.

(i) The yellow colour in NR is due to the presence of carotenoid type of pigments.[89]

(ii) The tendency for the latex to darken is due to the oxidation of the naturally occurring phenols by enzymes of the polyphenol oxidase type.[90]

(iii) Discolouration of the dry rubber during storage is thought to be due to the slow reaction of metal salts such as magnesium with free amine type compounds.[91]

Precautions are taken during the manufacture of pale crepe to minimise colour defects arising from these factors. The higher grades of crepe (1x, 1 and 2) are lighter in colour than SMR EQ (2.5 - 3.5 Lovibond units compared with 3.5 for SMR EQ and 6.0 for SMR 5L) but Natsyn 2200 is even lighter than pale crepe 1x (2.0 Lovibond units). The freshly prepared pale crepe is very much lighter in colour and some storage discolouration may be taking place.

The nitrogen content arises, largely as a result of the presence of naturally occurring proteins in NR. The proteins tend to absorb moisture and can cause deterioration of vulcanized products. The SMR grades possess a much higher nitrogen and moisture content. It is claimed that the differences in scorch time, cure time, modulus, heat build-up and hot tear strength between NR and high cis IR are due to the presence of the naturally occurring proteins. It is also suggested that the proteins are chemically bonded to NR and that these combined proteins are largely responsible for the formation of gel in NR.[92] Thus, the presence of proteins in NR can be both an advantage as well as a disadvantage depending on the end use. In solution applications, gel is a disadvantage and the removal of the proteins could improve the rubber in such applications where low heat build up is necessary, the removal of proteins would improve the resilience and at the same time moisture absorption will be minimised.

The main advantages of the presence of proteins are the fast cure, high modulus, hot tear resistance and the anti oxidant activity they impart to the rubber. In non-black compounds, the cure behaviour of the raw rubber is important. The cure behaviour of raw rubber is specified using a cure indicator in the SMR scheme. This makes use of the relaxed modulus (Kgf/cm^2) at 100% elongation (MR 100), determined using the ACS 1 test mix (given below) cured for 40 mts at $140^{o}C$.

ACS 1 Mix	
Rubber	100
Zinc Oxide	6
Stearic Acid	0.5
Sulphur	3.5
Mercaptobenzthiozole (MBT)	0.5

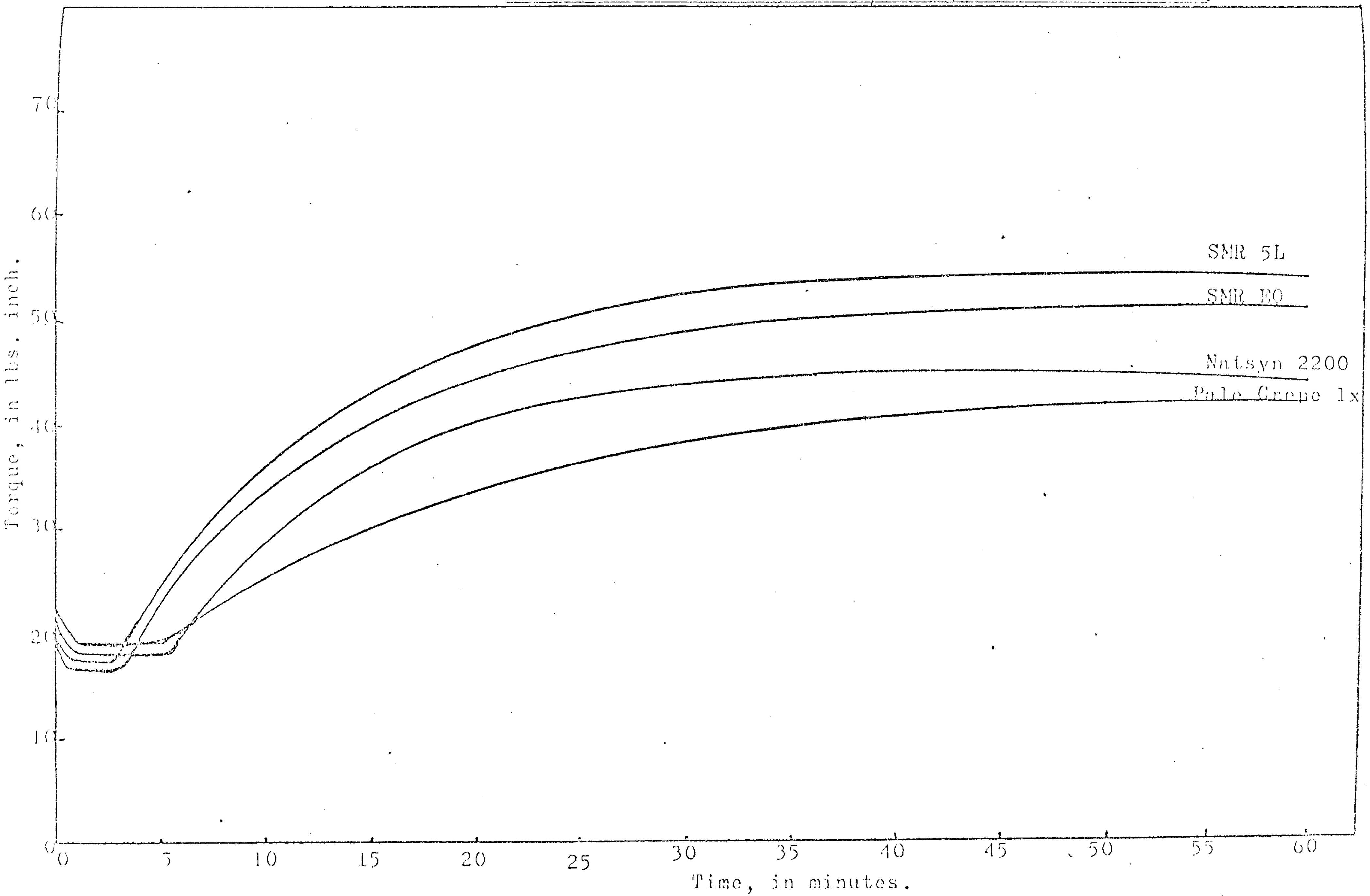
Three categories of vulcanization behaviour within the SMR scheme have been established. These are designated MOD 5, MOD 6, MOD 7 and denote:

Category	MR 100 range (Kgf/cm^2)
MOD 5	4.5 - 5.49 (slow cure)
MOD 6	5.5 - 6.49 (medium cure)
MOD 7	6.5 - 7.49 (fast cure)

The technical significance of this parameter, is the decreasing scorch time, decreasing time to optimum cure and increasing maximum modulus is generally exhibited for several formulations with increasing MR 100 value.

According to this classification the lighter grades of crepe (1x and 1) were found to be slow curing with MR 100 value of 5.00. These grades were very consistent in the cure behaviour and this was confirmed by the Monsanto Rheometer plot. The Monsanto Rheometer plot of the cure behaviour of the rubbers are summarised in fig. (6.3). The low grade crepes (No. 3), were slightly faster curing and less consistent. The cure rate was comparable with that of Natsyn 2200. The SMR grades were medium to fast curing and were inconsistent in their cure behaviour. The MR 100 value for SMR EQ was around 6.2 while that for SMR 5L was in excess of this value. The slow cure behaviour of crepes is a disadvantage to the rubber fabricator in general rubber goods.

Fig. (6.3) The Monsanto Rheometer Plot of the Cure Behaviour of some Grades of NR and Natsyn 2200, using ACS 1 mix at 140°C.



6.5. Production Process.

No significant changes have taken place in the manufacture of crepes in the last 25 years or so. Most of the changes have been in the improvement of efficiency, drying techniques and colour. According to the "Green Book", latex crepe must be prepared from freshly coagulated field latex. The dry rubber is graded No. 1x, 1, 2 and 3 according to differences in fine shades of colour by visual examination. Although colour and other visual defects are the main characteristics of crepe, in a competitive and technically oriented market it would be necessary to modify processing methods and grading system to suit the end use requirements. As already seen, the pale crepe market can be broadly divided into three groups. The first group requires an extremely clean and extremely light coloured rubber free from gel for solution applications. The second group requires a similar rubber (the presence of gel does not matter) for pharmaceutical applications. The last group requires a clean, light coloured and reasonably fast curing rubber for general rubber products. It is possible to alter the processing methods to meet these end use requirements.

Latex crepe is manufactured from field latex which is relatively free from yellow pigments and other compounds which cause discolouration or darkening of the dry rubber. The most common clone used for the manufacture of crepe in Sri Lanka is PB 86. This is considered the best available clone for optimum colour and hardness.[93]

Since almost all the crepe produced in Sri Lanka is from this clone, there is a certain degree of consistency in quality of the dry rubber; but at the same time, there is no single standard method for the manufacture of crepes and this tends to give rise to some of the differences in the technological properties of crepe. The flow chart showing the various stages in the manufacture of crepes is shown in fig. (6.4). The three important steps which affect the properties of the rubber significantly are: fractionation, bleaching and coagulation. The yellow fraction containing a large proportion of non-rubber constitutents is sometimes removed by preferential coagulation. A substantial quantity of rubber containing the gel and some useful products such as the naturally occurring anti-oxidant and proteins are removed in this yellow fraction.[94] The fractionated or unfractionated latex is strained and bleached using xylyl mercaptan. It is claimed that bleaching with xylyl mercaptan also reduces the gel content.[95] The advantage of the rubber produced from unfractionated latex is that it contains the naturally occurring anti-oxidants and other non-rubber constituents which accelerate or activate vulcanization.

The rubbers produced from fractionated bleached latex and fractionated unbleached latex can be marketed as special grades for solution applications and pharmaceutical products respectively. The yellow fraction rubber can be sold as a low grade, fast curing and high

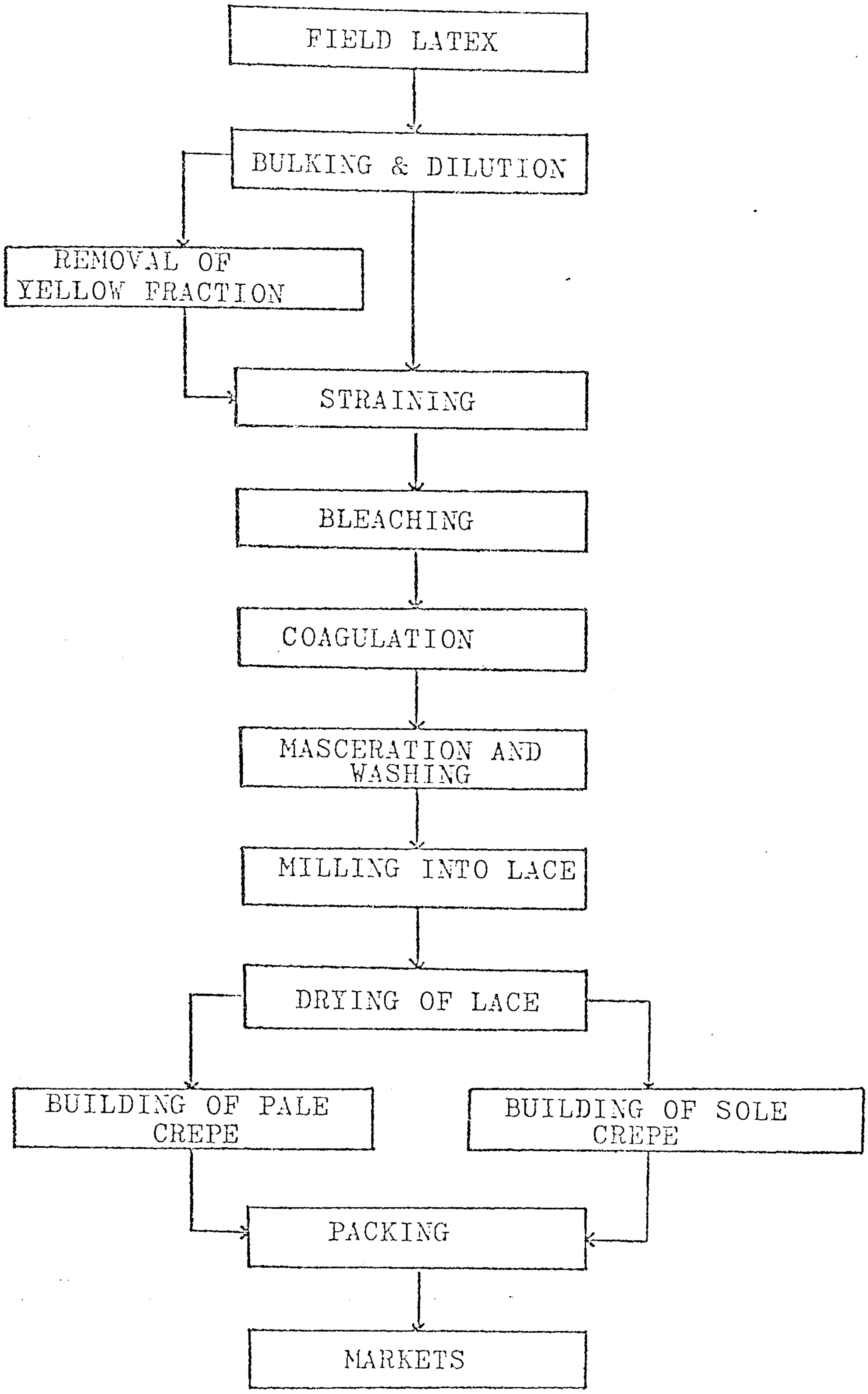


Fig. (6.4) Flow Diagram for the Production of Latex Crepe.

tensile rubber. The rubber produced from unfractionated and bleached latex can be marketed as medium or fast curing light coloured rubber for general coloured goods. The same rubber can also be used for the manufacture of sole crepe. Since the presence of proteins in large quantities can give rise to some undesirable properties, it would be worth exploring some method of partial removal or break-down of the proteins without fractionation. One approach would be to use some enzymic method of deproteinisation. A possible system of manufacturing and grading crepe for specific end-use applications is schematically shown in fig. (6.5).

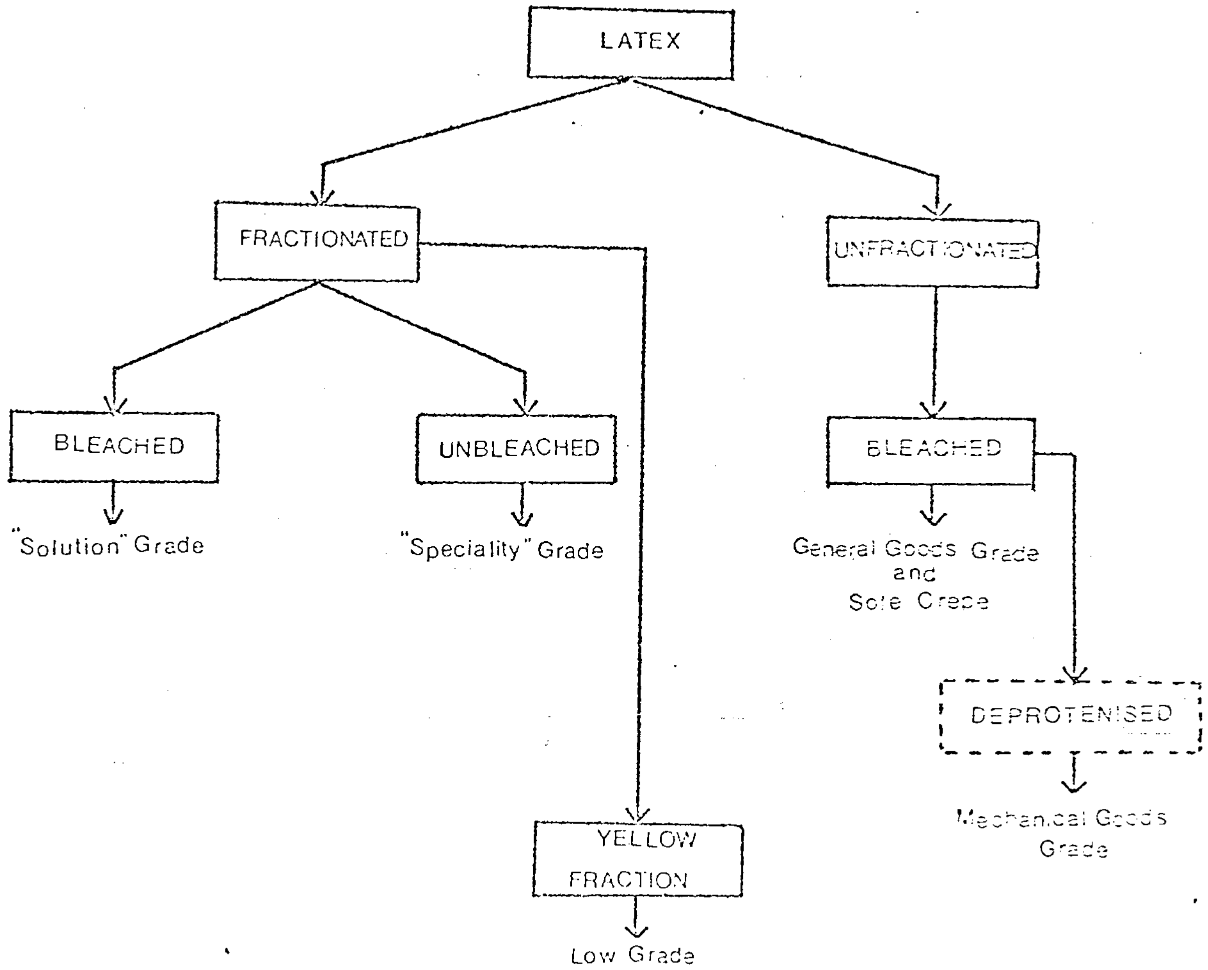


Fig. (6.5) A Possible System of Manufacturing and Grading Crepe for Specific End-use Applications.

6.6. Some Aspects of the Marketing of Crepe.

In a technically oriented and highly competitive market, it is necessary to market pale crepe to technical specifications. Any technical specifications for crepe must highlight its speciality properties in addition to the technical properties of other grades of NR. As already seen, the SMR specifications give some useful characteristics of the rubber to the consumer. As an extra clean and light coloured rubber, some indication on the size of dirt and colour must be included in such a technical specification scheme. An additional dirt specification would require the measurement of dirt using a smaller sieve than the present 44μ aperture sieve. The main problem regarding the specification of colour using the Lovibond scale is the change in colour that takes place between production and consumption in the factory. Any colour specification would be meaningless unless the problem of storage darkening can be fully overcome. A cure indicator similar to that of the SMR scheme would also be of use to many consumers.

Although the present sheet form is considered the most desirable form of crepe rubber by most consumers, since it is easy to examine these sheets for colour, dirt and other visual defects; At present a large proportion of crepe is still presented in bulky unattractive bales. It is necessary to improve packaging to create a new image. Ideally, crepe should be packed in small polythene coated paper bags and palletised for convenient handling, storage, etc.

The most serious problem facing crepe in the future is its high price and price fluctuation. Unless this is controlled, the consumers will continue to substitute cheaper and more price stable materials even with some sacrifice in quality. The price fluctuations in the past have been largely due to the imbalances in supply and demand. As a speciality rubber with a limited demand, the price is very sensitive to changes in the supply and demand situation. The price of all grades of NR follow the price movements of smoked sheet. Thus, it is almost impossible to stabilise the price of crepe without stabilising the price of NR as a whole. However, the price premium of crepe over smoked sheet also fluctuates and this can be controlled to some extent if, the right marketing system is developed.

Crepe is sold to an extremely large number of consumers of all sizes in various parts of the World from a few producers mainly in Sri Lanka and Malaysia. An effective marketing system should ideally, incorporate all the producers in Sri Lanka and Malaysia into a central organisation which would be responsible for co-ordinating the production and marketing of crepe. In practice it may be impossible to include the Malaysian producers. However, since Sri Lanka is the largest producer of pale crepe, it is possible to establish such a central organisation in Sri Lanka. The central organisation should be in the form of a consortium of all crepe rubber producers and the Government of Sri Lanka. Past experience shows that it is almost impossible to forecast the demand for crepe with any accuracy. To ensure a continuous supply of the rubber at a reasonably steady price, it would be necessary to establish a buffer stock. It would be impossible to fix the price of crepe when other grades of NR fluctuate freely in a free market. However, a minimum price must be established based on the cost of production and all producers must be guaranteed this minimum price. A ceiling on the price cannot be fixed due to the fluctuation of the price of smoked sheet. But if substantial stocks are held, the price can be held down to some extent at a fair premium above the RSS price by releasing sufficient quantities from buffer stocks.

A central organisation will also help to establish better communication between the producers and consumers. At present very little technical service is provided by the producers of crepe and practically no promotional activities are carried out. Due to the very large number of consumers all over the World, it is a practical impossibility to provide adequate technical service to all consumers. It would be necessary to utilise the existing services provided by the Malaysian Rubber Fund Board (MRFB). Therefore it would be necessary to negotiate with the MRFB to use their facilities to provide technical service to crepe rubber consumers.

6.7. Conclusion.

The use of pale crepe is largely dependent on historical reasons rather than technical or economic reasons. Due to the long experience in the use of NR, several consumers of crepe are reluctant to substitute synthetics, even when they are technically and economically possible. This is particularly true in the numerous small manufacturing industries. However, this tendency will gradually change with the increasing amount of technical services provided by the SR producers. Already partial substitution of crepes by synthetic polyisoprene, SMR 5Z and SMR EQ takes place, particularly in larger industries. It is unlikely that the growth in the consumption of pale crepe will match the 4% overall growth of NR consumption. Unless crepe is produced to specific requirements of the consumers and marketed as a modern industrial raw material at a stable and competitive price, it will continue to lose a considerable share of its markets.

7. SPECIALITY RUBBERS AND RUBBER DERIVATIVES BASED ON NATURAL RUBBER.

NR prices have often been depressed by an over supply caused by the production of SR in excess of the demand. Therefore to maintain a fair price and increase the revenue derived from the export of NR in the producing countries, it would be necessary to:

(i) produce modified forms of NR to meet the specific requirements of the rubber fabricator to create new and increased demand;

(ii) produce completely different materials by modifying NR;

(iii) find new outlets for NR in the producing countries for use during periods of low demand;

and (iv) explore possibilities of manufacturing finished goods for local consumption and export.

Several possibilities of introducing simple or more complex modifications of NR are well known. Simple physical modifications include the production of crumb rubbers, oil or black masterbatches, powdered rubbers, depolymerised rubbers etc. Chemical modifications can be introduced by classical organic reactions involving isoprene units such as addition to double bond, substitution at active methylene group and halogenation. More complex modifications such as graft copolymerisation, cyclisation and oxidative depolymerisation are also well known.

For major modifications, NR may be inconvenient and expensive. In these modifications, none of the inherent advantages of NR are required or retained and hence there is no real advantage in using NR over IR. In fact the SR may be more suitable for such modifications since, it is a much 'cleaner' rubber which does not contain excessive non-rubber materials which can interfere with the chemical reactions and the polymer can be produced to the correct molecular weight and molecular weight distribution to suit the process. There is no great economic advantage in modifying NR in a producing country like Sri Lanka except perhaps if this modification can be achieved in the latex stage using simple and inexpensive equipment. Minor modifications to NR which do not alter the inherent properties of NR significantly but produce rubbers to suit the specific requirements of the rubber fabricators are more promising than more complex modifications. The commercial, economic and technical prospects of producing various modified forms of NR in Sri Lanka are discussed in this chapter.

7.1. Physical Modifications.

Simple modifications such as oil extension, carbon black masterbatches, viscosity stabilised NR, etc. can be produced in Sri Lanka. These forms are more conveniently produced using the new process methods than by traditional methods. However, these forms are produced from field latex and as already discussed, the establishment of a large number of central factories to produce new process rubbers from field latex in Sri Lanka is doubtful. Since carbon black and oil are imported raw materials the economics of mixing these in the producers' factory for export is a doubtful proposition.

Viscosity stabilised rubbers which do not require premastication in a way similar to synthetic rubbers have become increasingly popular and will greatly improve the competitive position of NR. At present almost all the viscosity stabilised rubbers are produced by Malaysia. These are produced from field latex and are sold to SMR type specifications in two classes:

(a) CV rubbers in which storage hardening is inhibited by the addition of hydroxyl amine hydrochloride;

(b) LV rubbers in which storage hardening is inhibited and 4 parts per hundred rubber of non-staining naphthenic oil for easy processing in the consumers' factory.

These rubbers are usually produced with a Mooney viscosity in the range of 50-75 units. In Sri Lanka, it would be more profitable to produce the viscosity stabilised grades in the existing new process factories. It would also be worthwhile exploring the possibilities of producing these rubbers from natural coagulum.

7.2. Powdered Rubber.

Powdered rubbers have been known for some time, but their use has been largely limited to adhesives due to the problems of particle re-agglomeration. Interest in powdered rubbers has been revived for use as general purpose rubbers. The trend to use powdered rubbers will increase by the end of 1970. It is therefore necessary for the NR producers to investigate methods of producing a free flowing NR powder from latex, to keep abreast in the technological race and to meet the anticipated demand. The existing methods include grinding at low temperatures, spray drying, flash drying and particle encapsulation.[96] The last three methods make use of latex and all these methods use some kind of partitioning agent to prevent particle re-agglomeration.

The smaller the particle size the greater will be the amount of partitioning agent required and excess of this can be undesirable. Grinding methods of producing powdered rubber and zinc stearate as the partitioning agent have been found to give the best results.[97] A long term approach towards producing a powdered rubber from field latex in Sri Lanka is necessary. Due to the high raw tack of NR, it would be necessary to contain large amounts of the partitioning agent such as zinc stearate in the latex for flash or spray drying. The technique of encapsulation seems more promising and already, starch xanthide encapsulation is fairly well established.

7.3. Chemical Modifications.

7.3.1. Binding Pendant Groups.

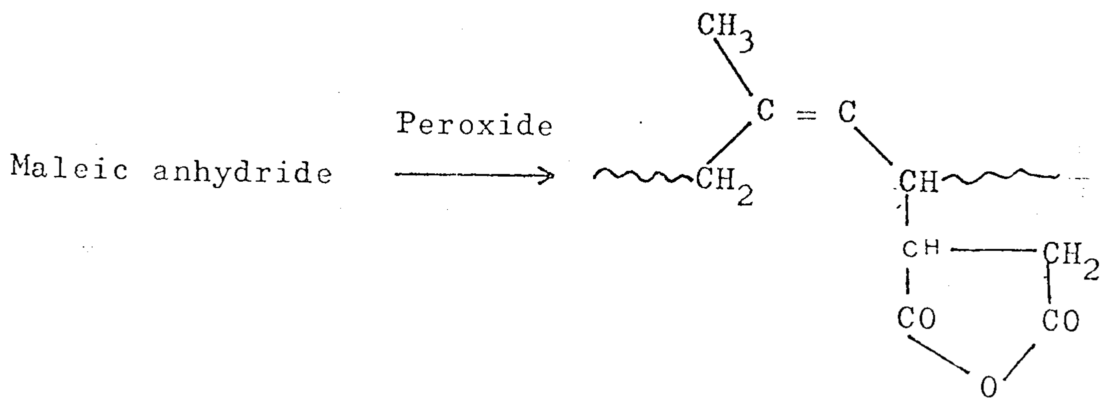
Methods of binding simple pendant groups to the polymer chain in the latex state without altering the main properties of NR, hold promise in introducing antioxidants or some groups which could be subsequently used for cross-linking the rubber by non traditional methods. Methods of introducing pendant groups to the polymer chain are also important in producing a thermoplastic NR with a reversible exchange cross-link. Two methods of attaching pendant groups are available:

(a) addition to double bond;

(b) substitution at active methylene group.

Esters of mercapto acids $HS(CH_2)_n$ COOR have been added to NR latex.[98] It may be possible to hydrolyse the ester and produce a vulcanisate at the same time, using a dibasic metallic oxide, containing ionic cross-links of the type $-COO^{\ominus}\ M^{2\oplus}\ {}^{\ominus}OOC-$.

This introduces the possibility of producing a latex of the type similar to the carboxylated SBR latex for use in carpet backing. However, thiol compounds in general act as peptisers and further investigation would be necessary. Another possible method of introducing carboxyl group is by the substitution of maleic anhydride.[99]

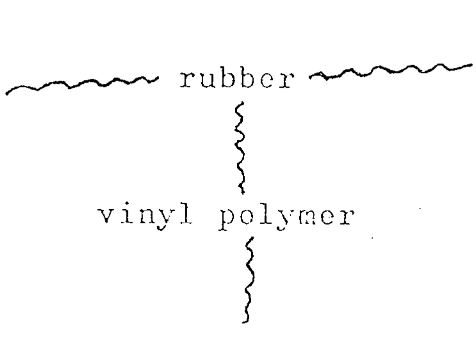


The introduction of the acid groups is likely to interfere with the stability of NR latex. It is desirable to produce a NR latex with reactive pendant groups which could be cured using some chemical agent without the use of sulphur or other traditional methods.

These methods also provide some means of binding antioxidants on to the polymer to produce leach resistant antioxidants. Latex with bound antioxidant will be particularly useful for use in latex thread for use in garments where unbound antioxidants are likely to be leached during laundering. If the method of binding these antioxidants are economic, dry rubber with bound antioxidants can also be produced for special applications where the finished product is likely to come into constant contact with water or other fluids which can extract the unbound antioxidants. Binding phenolic type antioxidants via a vinyl group or a thiol ester are two of the possible methods.

7.3.2. Graft Copolymers.

Polymerization of vinyl monomers can be carried out with the rubber as a solid, in solution or as latex.[100] Several common vinyl monomers have been successfully graft copolymerised on NR in the presence of a free radical initiator to produce a compound with the following structure:



A polymer-modified rubber containing equal parts of NR and polymethylmethacrylate is commercially produced in Malaysia from field latex under the name Heveaplus MG 49; other Heveaplus materials containing less polymethyl methacrylate are also manufactured.[101] The average composition of Heaveaplus MG 49 is claimed to be 80% graft polymer, 10% free polymethylmethacrylate and 10% free rubber. In latex form or in solution it is used as an adhesive for rubber/PVC, rubber/textiles, rubber/leather, etc. The dry rubber can be blended with ordinary NR and processed in the usual way. The Vulcanizates have excellent physical properties at high hardness levels, good flow properties and good electrical properties. They can be used in the manufacture of rigid mouldings. The manufacturing methods of Heaveaplus MG are well established and it can be produced in Sri Lanka on a small scale for local consumption and exports.

7.3.3. Cyclized Rubber.

Isomerisation of NR in the solid form, in solution or latex by the action of strong acids or Friedel-Crafts catalysts to produce a cyclic structure have been known for several years.[102] Several methods of producing the cyclized rubber are reported and the physical form and properties of the product also depend on the method of preparation.[103] Cyclized and partially cyclized NR have been used for shoe soling, hard mouldings, adhesives, printing inks and surface coatings.[104, 105] Cyclized rubber behaves in a way similar to high-styrene SBR and has been replaced by SBR in shoe solings and hard mouldings for economic reasons. Thus, cyclized rubber finds only a limited market. In Sri Lanka, cyclized rubber may be produced at a higher cost than high styrene SBR as a substitute for the imported high styrene SBR.

7.3.4. Superior Processing Rubber.

Pre-vulcanized NR latex and partially cross-linked superior processing (SP rubbers) grades of NR are marketed as special purpose rubbers. These can be produced using simple inexpensive equipment and chemicals in Sri Lanka. Pre-vulcanized latex is produced by vulcanizing the centrifuged latex using a dispersion of sulphur and zinc diethyl-dithiocarbomate at 70°C.[106] The pre-vulcanized latex is used for the manufacture of very thin dipped articles. SP rubbers are produced by coagulating and processing in the normal manner a mixture of NR latex and pre-vulcanized latex.[107] SP rubbers are designed to assist rubber manufacturers in processing operations and is similar to the SBR that has been partially cross-linked with divinyl benzene during the polymerisation stage. The unvulcanized compounds have considerable dimensional stability and are used to greatest advantage in extrusion processes. A limited demand for these speciality grades exist for the production of extruded articles and since these fetch a high premium over conventional grades of NR, the production of SP crepes and SP smoked sheets in Sri Lanka seem promising.

7.3.5. Chlorinated Rubber and Rubber Hydrochloride.

Chlorinated rubber is produced by the chlorination of NR or IR and is largely used in chemical and water resistant paint formulations, printing inks and adhesives. Similarly rubber hydrochloride is produced by the hydrochlorination of isoprene rubbers and is used as a strong, flexible and moisture proof film for wrapping. The basic raw materials - NR, chlorine and HCl are freely available in Sri Lanka and thus it should be possible to produce these derivatives in Sri Lanka. However the economics of producing these materials in Sri Lanka for export seem doubtful. These are produced as special purpose plastics materials and find a very limited market. As there are a very few well established producers the entry into the market is extremely difficult unless they can be produced considerably cheaper or with improved properties or both. Economies of scale would not permit the production of these derivatives solely for local consumption since the local demand is only a few tons per year. However, if satisfactory products can be produced starting from field latex using simple inexpensive equipment, it may be possible to produce these materials on a small scale to meet the local demand.

Although several patents and literature are available on the use of latex as the starting material for the manufacture of chlorinated rubber and rubber hydrochloride, none of these methods are used for the[108, 109] commercial production of these materials. In actual practice low cis-IR is preferred to NR due to the low gel content, freedom from excessive non-rubber materials, consistency and uniformity of properties and the availability of the polymer in the correct molecular weight to give the desired final product properties. Commercially, chlorinated rubber is produced by the direct chlorination of isoprene rubber in an inert solvent at about 80°C. It is claimed that the product with about 68% Cl content is the most stable material, while products with less than 65% Cl are susceptible to degradation.[110] So far, methods involving the direct chlorination of NR latex have failed to produce a satisfactory product as regards to stability and solubility. To produce a material with the desired solubility it is necessary to use large quantities of a peptiser to break down the NR in latex. It is also necessary to use fractionated latex, free from excessive non-rubber materials to avoid interference during chemical reactions. Similar care is also necessary for the hydrochlorination of NR in latex. Thus, the technical and economic prospects of producing these derivatives from latex in Sri Lanka seem doubtful. It is claimed that there is only negligible difference between chlorinated polyisoprene, chlorinated polyethylene and chlorinated polypropylene and hence the cheapest base material would be used increasingly to produce the chlorinated polymer.[111]

CONCLUSIONS.

The present strong demand for NR and high prices will continue in the next few years due to the current shortage of styrene monomer for SBR. Unless new SR production facilities are available to meet the shortage of some of the essential general purpose rubbers, this trend may continue for longer periods. In the long term, with the threat of an energy crisis more real than ever and the rapid escalation of raw materials and other costs in the SR industry, the availability and costs of SRs seem unfavourable. Under these conditions, the NR producers must plan now to increase the output of NR at a faster rate than at present in the 1980's. Even in the short term, unless NR prices are brought down by increased production, the high price of NR will act as a stimulus to establish new IR production facilities and other stereo-rubbers such as TPP. The NR industry must also be prepared to meet the changing needs of the rubber fabricator especially with a strong trend towards liquid rubbers, powdered rubbers and thermoplastic rubbers in the future.

The development of the rubber industry in Sri Lanka is given low priority due to the lack of foreign exchange. This may be a short-sighted policy of the Government of Sri Lanka since, the rubber industry may become a very important source of foreign exchange in the long term. Firstly, because NR will occupy a more important position among the general purpose rubbers and the prices will be generally high. Secondly, because the tea industry will be declining due to oversupply. However, with the limited funds available for development of the rubber industry, the industry in Sri Lanka must concentrate on projects that are likely to increase the export revenue in the short term. These should include the upgrading of the quality of existing grades and increasing the output of premium grade rubbers such as latex crepes, latex concentrate etc. which can be produced using existing equipment or simple inexpensive equipment. In the medium term it would be necessary to produce consumer oriented forms of NR such as new process rubbers, viscosity stabilised rubbers, superior processing rubbers, graft copolymers of NR etc. The technology of producing these rubbers are already well established and the demand for these rubbers is promising. A long term approach towards producing powdered rubber, liquid rubber and thermoplastic rubber from NR is essential to meet the changing demands. As a small producer of NR, it is desirable for the industry in Sri Lanka to concentrate on speciality grades of NR rather than produce conventional smoked sheets.

Several factors place NR produced in Sri Lanka at a disadvantage over NR produced in other countries. Some of these factors arise from: currency and exchange regulations, uncertainty of supplies resulting from bilateral trade agreements, poor packaging and shipping arrangements etc. These and other associated factors affect the competitive position of Sri Lanka rubbers and further investigations are necessary to overcome these defects.

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IMPLICATIONS FOR THE RUBBER RESEARCH INSTITUTE (SRI LANKA)

Natural Rubber Output

The short term styrene shortage for SBR and the long term effect of the dwindling raw materials situation and rapidly rising costs in the SR industry will favour NR in the future. The NR industry in Sri Lanka must exploit this situation to achieve the full benefits. The plantation industry must therefore plan immediately to take the necessary action to increase rubber production in Sri Lanka systematically and at a faster rate than at present. A three way approach is suggested for this purpose:

(i) Immediate increase of the rubber output by the extensive use of yield stimulants. Particularly, on trees which have past the peak yield or on trees which are considered uneconomic and are about to be cut down for replanting.

(ii) Faster rate of replanting uneconomic plantations with high yielding clones; maintaining the clones suitable for pale crepe and wherever possible to replant with high yielding clones suitable for latex concentrate.

(iii) Investigate the possibilities of opening new plantations where land which is suitable only for rubber plantations is available.

A thorough investigation of the use of yield stimulants on the local clones is urgent since, yield stimulation has the potential of increasing the rubber output in the short term and also gives a certain amount of flexibility as regards to the supply of NR from Sri Lanka. Although the long term effects of yield stimulants on the tree are not yet known, an economic assessment of the use of yield stimulants is necessary. One likely effect of yield stimulants is to shorten the economic life of the tree. The economic study must assess the break even point where the decrease in the life of the tree is likely to be offset by increased output in this time.

Latex

Sri Lanka, as a small producer of NR must concentrate on premium grades or speciality gradeswhich are likely to increase the export revenue. One such premium grade is latex concentrate. The demand for total latex is increasing at about 10-11% per year. The present styrene shortage for SBR latex has already increased the demand for NR latex. The price of NR latex and the profit margins will remain very favourable to the producers. There is a need to increase the latex concentrate production in Sri Lanka immediately. The initial increase in the production of latex could be around 2,000-5,000 tons annually. The economics of producing latex based goods in Sri Lanka for export seem favourable since, transportation and storage of NR latex (containing large quantities of water) is expensive.

Pale Crepe

Pale crepe in the future will compete with its substitutes mainly on price. In the short term EPDM and low cis-polyisoprene are likely to remain price competitive in the very small area of applications while high cis-polyisoprene is likely to continue to be more expensive. However, in the long term all synthetic substitutes will become more expensive. Therefore, the light coloured grades of SMR will continue to remain competitive with pale crepe in several "lessspecialised" areas of applications (Chapt. 6. Section 3). It is therefore necessary to bring down the price of pale crepe immediately by increasing the output. The short term styrene shortage for high styrene SBR and PVC for soling material will favour the demand for sole crepe and thus it should be possible to increase the sole crepe production immediately without seriously affecting the output of pale crepe. Pale crepe production in Sri Lanka could be increased at the rate of about 2,000--3,000 tons per year to about 50,000 tons initially.

Large fluctuations in price of crepe is one of its big disadvantages. The present system of marketing and the imbalance in supply and demand are responsible for such price fluctuations. An alternative system of marketing the crepes must be investigated. A possible system is to organise all crepe rubber producers in Sri Lanka into a single organisation with Government participation. This central agency would be responsible for coordinating production and marketing (Chapter 6. Section 6).

Although production of crepe to suit the end use requirements is desirable, it is not too urgent (Chapter 6, section 5). However, the improvement of the form of presentation and some form of technical specifications for pale crepe are quite important (Chapter 6. Section 4).

General Purpose Rubbers

Wherever new process rubber production facilities are available, these should be used first, to up grade the low grade smoked sheets (RSS4 and lower grades) and scrap crepe. (Chapter 5. sections 5 and 6). Secondly, where latex is likely to be used as the feedstock for new process rubbers it is desirable to produce consumer oriented premium grade block rubbers. The most profitable of these rubbers is the CV rubber. The viability of producing CV rubber, tyre rubber and oil/black masterbatches must be explored. It is also desirable to produce tyre rubber and oil/black masterbatches on a pilot plant scale and the economic and technological viability of producing these rubbers investigated in collaboration with the Tyre Corporation, since these rubbers are likely to become commercially popular soon.

Due to the fragmented nature of rubber holdings and the presence of a large number of small holdings in Sri Lanka, smoked sheet production is likely to continue for several years. It is therefore desirable to improve the packing and presentation of smoked sheet and to provide some form of technical specifications for RSS. (Chapter 5. Section 6).

Chemically Modified Rubbers

Among the chemically modified forms of rubber, materials with minor chemical modifications are more promising than complex modifications. However, cyclized rubber is an exception. There will be a shortage of high styrene resin rubber for soling and other uses. Therefore, cyclized rubber has good chance of commercial success immediately. Unless a breakthrough in the production of a technically acceptable product from latex is achieved within the next few months, commercial production of this material by well established methods must be investigated.

A limited demand for some chemically modified forms of NR latex exist. It is desirable to produce some of these materials on a small scale within the next 2 or 3 years. These include prevulcanised latex and superior processing pale crepe from the prevulcanised latex, Heveaplus MG latex and Heveaplus MG dry rubber and a low protein CV type of rubber. It is important to set up a pilot plant to produce Heveaplus MG latex as early as possible since, the same process methods and technology for graft copolymerising other monomers and grafting various pendant groups will be similar. Grafting of other monomers and various pendant groups will become increasingly important. (Chapter 7, sections 3.1 and 3.2).

Long term research in the graft copolymerisation of other monomers and attaching pendant groups such as antioxidants and cross linking agents in the latex stage is necessary.

Technical Service

Since only a limited amount of applied research in the use of pale crepe is carried out by the Malaysian Producers, possibilities of establishing some technical service and further applied research in collaboration with the Malaysian Producers must be investigated. If Sri Lanka establishes large scale latex concentration facilities for export, a limited amount of development work in the use of latex in Sri Lanka must be carried out. Although latex concentrate may be considered too expensive at present for soil stabilisation for agricultural purposes, prevention of soil erosion, latex/bitumen road surfacing, paper coating, etc. in Sri Lanka; it is likely that there would be periods of low demand and outlets must be found for the surplas latex. Thus, there is a need to fully investigate the use of latex in these areas.

Complex Modifications

Even in the long term, the economics of complex modifications of NR seem doubtful. A long term approach towards producing a powdered rubber and thermoplastic rubber from field latex can be investigated. It is not desirable to produce chlorinated rubber or rubber hydrochloride in Sri Lanka.

Government Control Regulations

Currency and exchange regulations, uncertainty of supplies resulting from bilateral trade agreements, poor packaging and shipping arrangements are some of the factors that have placed the NR produced in Sri Lanka at a disadvantage over NR produced in other countries. The stringent currency regulations and the "red-tape" associated with it makes it almost impossible for a dealer or consumer to get any refunds for any substandard deliveries. Large scale buying by the Eastern European countries under bilateral agreements in the recent years have made the supplies uncertain, particularly in the case of pale crepe. Poor packaging and shipping arrangements have in the past resulted in the consignments of rubber picking up dirt, tea dust etc and has also resulted in long delays. The port of Singapore and some ports in Malaysia have container handling facilities to reduce cost of freighting and reduce the long delays. Such container handling facilities are not available in any of the ports of Sri Lanka. There is an increasing tendency to change over to containerised shipping of cargo. All these problems have to be carefully studied and necessary steps should be taken to improve the competitive position of Sri Lanka rubbers.