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REPORT
ON THE USE OF PLASTIC MATERIALS IN THE MASS-PRODUCTION OF LOW-PRICED HOUSES FOR DEVELOPING COUNTRIES 1/

by

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PURPOSE OF THIS REPORT

On behalf of the Industrial Technology Division of UNIDO extensive efforts were made to examine how non-traditional building materials and specifically plastics could have an influence in the future development of pre-fabricated respectively mass-produced houses in general.

Particular emphasis was given to the question how the use of plastics in construction could help developing countries to solve their housing problems. Additionally, it always has been kept in mind that especially the problems connected with existing slum areas have to be given serious thought.

In the following, it was undertaken to analyse the given situation regarding the use of plastics in pre-fabricated houses and all the questions connected with urbanisation problems and the future outlook on the manufacture of social homes.

All statements made by the author are of general nature and do not necessarily represent facts and figures applicable in specific geographical regions.

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A) MATERIALS

1. Introduction

The plastics industry as such has developed over the last 20 years from an industry of minor importance to the major section of the international petro-chemical industry.

While the major growth rates in the fifties were due to the rapidly expanding use of plastic semi-finished products and shaped articles in the automotive and applicance industry, the decade of 1960/1970 reflected clearly the influence of the rapidly growing packaging sector and the introduction of a broad range of especially thermo-plastic materials in this field. This relates, of course, primarily to the expansion in the polyolefin area where increasing steam cracking facilities and the construction of huge monomer and polymer plants allowed remarkable price reductions over these years, which again led to a great number of new applications and outlets for the major thermo-plastics as there are: PE, PS, PVC and PU.
This actually became the basic factor for the penetration of such plastic materials into an extremely potential and new market: the building industry.

In the sixties, plastics were used to a still limited extent for the manufacture of components for houses like floor-tiles, sound- and thermal insulation, piping, roofing and some other applications. In this particular period of time, with extremely few exceptions, plastics were never used as a construction material. However, extensive know-how and experiences have accumulated which are now extremely helpful within the scope of the work done to create non-traditional building systems by featuring plastics and other new type materials.

The last ones developed over approximately the last 10 years, were primarily designed to utilise locally existing waste materials like bagasse, mais-straw, cocos fibres, etc. It has been found, however, that these materials as far as the fabrication problems are concerned, proved to be not only complex to handle, but also did not allow to introduce construction systems other than the already existing traditional ones.

2. Description of products commercially available

Among the existing range of plastic materials, 5 products specifically lend themselves for the manufacture of low-density foams:

a) urea formaldehyd foam
b) phenolformaldehyd foam
c) polyurethane foam
d) polystyrene foam
e) PVC foam

Since they differ greatly performance-wise, it is undertaken in the following description to define some of the characteristics and the methods of manufacturing.

a) Urea Formaldehyd Foam

The resins are made out of urea formaldehyd by condensation method. For the manufacture of UF foam, two major components are necessary:

urea formaldehyd solution and tensid (foaming agent) which also contains a catalyst which acts as a hardening additive.

Both components are kept in separate containers. The premix is pumped into a foaming gun where the mixture is changing its consistency and is leaving the gun as a rapidly expanding foam.

The curing time is between 15 and 30 seconds.

UF foam may be handled on any location by using portable equipment and is not restricted by higher or lower outside temperatures.

b) **Phenolformaldehyd Foam**

The resins are manufactured out of phenolformaldehyd through condensation and are, after adding modifiers, ready for foaming. After the manufacture of the foam, an activator is added which starts an exothermal readion.

Phenolformaldehyd foam is made in blocks and cut into slaps and sections. The curing time is approx. 60 seconds.

The area of application is primarily inthe building industry and specifically for the maufacture of sandwich elements. For the manufacture of these sections very often unorganic fillers are also added.

c) **Polyurethane Foam** (PU)

Rigid PU foams, as commercially used in the building industry, are basically made by using diphenylmethane diosocyanate. Polyether and polyether alcohols with a varying amount of polypropylene oxyde are used as polyoles. Additionally, there is mostly added tri-beta-chlorethyl-phosphate and mono-fluor-trichlor-methane as blowing agents.

The rigid foam is produced by mixing DMT and polyoles and at the same time adding catalysts which , accompanied by an exotherme reaction leads automatically to the expansion of the product. At temperatures betwoen +10°C and +22°C this process may be executed "on the spot", which means you are able to foam "in place" and that is of significance if you want to make sandwich elements right at the construction area.

There are, however, still some difficulties to overcome which relate primarily to the exact metering and the fact that the curing time is still 15 minutes.

PU foam does not develop any kind of corrosion and is primarily used for the manufacture of sandwich sections, sound- and thermal insulation and shaped articles where PU is used as a structural foam.

d) **Polystyrene Foam**

Usually standard polystyrene plus expansion agents are used to manufacture slaps and contured blocks by using steam heated molds or fixtures at a temperature range of 105° to $115^\circ C$.
This process so far can only be handled at the factory and not "on the spot".

The area of application covers primarily thermal insulation in the housing industry if used as a sound insulating material, the sheets or slaps must be perforated and the PS foam is not very efficient for sound insulation because of the cell structure of the material.

e) **PVC Foam**

For the manufacture of PVC foam, PVC polymer granules or poyders plus plasticizer and other additives are used. This precompounded mix is brought into steel molds where under high pressure and temperature gas as a blowing agent is added.

The application is limited for cost and other reasons.

The range of application besides its extensive use in agriculture (which is not being dealt with in this report) covers particulsrly the whole building and construction industry serving as a multi-purpose product.

In the following table, figures are shown comparing the most significant properties for the products describes as far as their use in building is concerned.

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

PHYSICAL PROPERTIES AND OTHER CHARACTERISTICS OF PLASTIC FOAM

	UF	PF	PU	PS	PVC
Structure	rigid	rigid	rigid	rigid	rigid
Density - kg/m^3	8-10	30-100	30-200	13-100	40-100
Compression Strength kp/m^2	0.2-0.3	1.8-7.8	1.5-70	0.8-1.8	2.5-50
Shear Strength kp/m^2	--	0.8-4.5	1.5-60	8-18	
Tensil Strength kp/m^2	--	1-5.5	2-20	1.5-4.5	2-5
Shock Resistance	good	low	good	good	good
Heat Resistance	+120°C	+130°C	+100°C	+80°C	+70°C
Low Temperature Resistance	-200°C	-200°C	-50°C	-200°C	-100°C
Temp. Conductivity Factor at 22°C and Lowest Possible Density	0.025	0.025	0.023	0.025	0.040
Solvent Resistance	very good	very good	fair	poor	good
Dimensional Stability	good	very good	good	good	good
Behavior under High Temperature	very good	good	poor	poor	fair

Abbreviations: UF = Urea Formaldehyd Foam
PF = Phenol Formaldehyd Foam
PU = Poly Urethane Foam
PS = Polystyrene Foam
PVC = PVC Foam

3. Status of the use of plastics in the building industry

If one looks at the present status regarding the use respectively the application of plastics and specifically plastic foams in building and construction, one arrives at the following picture:

Looking at the various plastic materials and the shaped and semi-finished products, the various lines may be broken down as follows:

Foils for insulation purposes, for instance for foundations, made out of isobutylene, polyethylene and their compounds and up to a certain extent PVC for minor application in this area. There are, of course, also other materials used in this field, but they are of no significance quantity- and application-wise.

Sheets and tiles are primarily used for flooring purposes and widely accepted as a standard durable flooring material, made mostly out of PVC vinyl-acetate components. There is also used a number of plasticized PVC pastes, but here again the total usage is limited by the fact that for costs and other reasons this type of product lends itself only to very specific applications.

Roofing: in the roofing area, thermo-plastic materials in the past were only reluctantly applied and only recently the growth rates showed improving and encouraging figures. This is due to the fact that the materials used, and this relates primarily to PVC- and Isobutylene-compounds, had to undergo long-term field testing and a great number of stabilisation problems had to be overcome. However, the know-how generated by now is most encouraging and a rapid expansion of this portion of the thermo-plastic semi-finished products market may be expected.

Foam-insulating: this portion of the application of plastics in the building trade is by far the most important and possibly also the most advanced one. According to figures established by international institutions, in 1970 alone, 3 million tons of Polystyrene, PVC, PU and other foams were actually used. Even if this figure would be 25% out of line which is most unlikely, the remaining quantity represents a fascinating amount of material, especially if you take into account that only 2 to 3% of the whole quantity were used in actual construction work whilst the remainder went into the building and construction area mostly as a component and here again was used more or less exclusively as a sound- and thermal-insulating product.

Reinforced Polyester parts, as they may well be known today, already have found a number of applications, but they are more or less restricted to the manufacture of certain components of minor importance. However, reinforced polyester, as an extremely durable material, became a more and more important laminating material, specifically in areas where sandwiched sections were used in connection with thermo-plastics and other foams as the core respectively insulating element.

Shutters, blinds, window frames, doors, etc. are already made by utilizing an extremely broad range of plastic raw materials and will, like bathroom equipment and furniture not be part of this report.

This report, however, will concentrate on the use of plastic materials as the construction material for the manufacture of mass-produced houses.

4. Previous experience regarding plastics in building under restrictive factors application-wise

a) Thermo plastic foam

Physical properties

The difficulties initially experienced in the fifties regarding the use of plastics and especially thermo plastic foam in the building trade were basically due to the fact that no long term experience was available and the data published at that time was most unreliable. This relates specifically to the long term behavior of the mechanical properties and the aging characteristics which possibly were one of the major handicaps. Meanwhile the manufacture did not only considerably improve the quality of their products, but they also established reliable facts and figures which are accessible and specifically designed for architects and engineers in the building trade.

Furthermore it can be said that figures for the restricting limits of the application of for example PU sandwich elements and segments were established meanwhile, and therefore possibly one of the last hurdles taken.

Summarising it may be said that the mechanical behavior of the available thermo plastic foams today may be defined as being satisfactory. Further improvements in the physical properties which may be expected in the near future will additionally improve the whole picture and possibly broaden the range of application for such foams.

Heat resistance/inflammability

the heat resistance varies between the various products and within the product range can, in accordance with the formulations, in principle be considered satisfactory (see table on page11)

Recent surveys show that even the average construction engineer or architect is able to select the right material for the right purpose as far as the heat or low temperature problems are concerned.

The situation with regard to the inflammability and the heat distortion of thermo plastic foam seems to be rather different. This is particularly due to the fact that at least in the past the fire hazard problem in connection with plastic materials was looked upon only from the point of inflammability and only very little consideration was given to the fact that the inflammability as such is less significant than the emissions developed by the burning or distorting materials. Recent findings again proved that even so called flame retardant materiale may create damage and endanger life if not applied and used in accordance with their behaviour. The recent events in this direction - and this relates especially to the great Plaza fire in New York - led to the opinion that not the inflammability of foams, but the emission created during burning or distorting have disastrous consequences.

In the Plaza case, the smoke developed by the burning polystyrene foam made it practically impossible for the fire-fighting teams to work efficiently and, additionally, the poisonous cyanids developed by inflamed PU eliminated practically any efficient fire-fighting action.

Similar experiences could be noticed in a number of cases in Europe and especially during two fires in huge factories in Western Germany. As a result, underwriters in America and Europe thoroughly looked into the question whether and up to which extent restrictions for the use of plastic foams in building ought to be issued. This ought to be kept in mind, especially when applying thermoplastics in building and construction.

Humidity - corrosion

The thermo plastic foams are nearly 100% hydrophob and resistant against aggressive chemicals, except solvents. If applied in line with the instructions issued by the raw material manufacturers and when carefully studying the behaviour of the surrounding building material and possibly chemicals, the life time of the various thermo plastic foams is practically equivalent to many of the traditional materials.

b) <u>Thermosetting foam</u>
<u>Physical properties</u>

The physical properties of the thermosetting foams currently available, and this relates specifically to their structural strength, are yet well below the ones shown on table for thermoplastic foam materials. Recently, however, new modifiers are under way which supposedly will help to reduce the brittleness and improve the low elongation.

On the other hand, the fact that for instance UF foam may be "foamed in place" right in the building has proved to be an attraction for builders and is evidently responsible for the rapid growth rates of thie comparatively new product.

PF foam, however, can not yet economically be handled in a siilar manner and, therefore, at least for time being, will be of such less significance than UF inspite of the fact that the compression strength is considerably higher (see table page 11). The long term behaviour of both materials proved to be excellent and figures collected over the last 10 years did not show any declining of any of the physical properties.

<u>Heat resistance - inflammability</u>

Unlike thermo plastic foams, UF and PF foams behave in such a way under high heat or fire hasarde that the dangerous emiesione observed in case of PS or PU do not occur at all.

Especially the UF foam recently introduced showed such a remarkable performance that it became the only plastic insulating material accepted by the underwriters for applications in mines and other installations where extreme safety requirements are requested.

Burning UF foam does not generate poisonous or heavy smoke. It also does not melt (dripping) or tend to glow after the fire is extinguished. In the case of PF foam, the results are by far not that satisfactory, but this material is still superior by far compared to normal thermo plastic foam.

Humidity - chemicals

The original UF foam developed by BASF around 1938 as a substitute for cork showed an extremely high rate of water absorption whilst PF foam behaved quite well in this direction. Through technological improvements in the recent years, however, it was possible to reformulate UF in such a way that it practically became hydrophob. This, of course, was highly important since the humidity contents of any type of foam is directly responsible for the insulating properties. Additionally, coatings were developed which act most efficiently as additional vapor barriers.

PF and UF foams and especially the last one tend to create corrosion if applied "in place" and attached to non-galvanised steel. This, however, can be eliminated by applying a spray coat before the foaming process takes place.

5. Future outlook regarding the creation of new plastic raw materials

The before given explanations have purposely eliminated any details about especially designed plastic foams as for instance Polyimid-PUR-combinations because of being aware that for the building industry these particular materials, at least for a number of years, will for price and other reasons not be of any significance. However, every possible effort was made to determine what new plastic foaming materials could possibly influence or even change the whole picture within the next 10 years as regards marketing or application. The result of this survey is as follows:

Whilst in the beginning of the manufacture of cellular plastics understandably basically existing plastic raw materials were used in the mid-sixties worldwide the petro-chemical industry systematically was searched for new feedstock and improved polymers for the manufacture of plastic foam materials with improved physical characteristics.

Today it is already noticable that the effort of the chemical industry in this direction was quite successful and above and over the existing range of foamable plastic products a number of new materials will appeat most likely headed up by ICI's polymethylpentene. The feedstock for this material is reclaimed from by-products during crude oil refining and dumped or incinerated. Additionally, there are steps taken in order to manufacture this particular feedstock synthetically.

The manufacturing costs for this new combination of plastic materials which offers excellent properties to manufacture flame retardant foams and is heat resistant up to 200°C, will finally and theoretically be lower than any of the conventional available materials. It must, however, be recognized, if prices are compared that in any case these particular products can not be "foamed in place" but have to pass the stage of the semi-finished product before being finally applied in building.

Experts believe that it will take approximately 5 to 7 years before these foams are available in quantities.

Of less importance seem to be, at least for time being, products like

Polyimid	Monsato
Polyimid-PU-combination	Bayer
Light-weight concrete	
(PU Leverkusen)	Bayer
Polymethacrylimid	Röhm & Haas
silicate modified PS foam	BASF
syntactic rigid epoxy foam	UCC

At the moment, however, no statement regarding the areas of application which may develop for these plastic foam materials can be made. It seems, nevertheless, that they obviously will not be able to compete with the existing range of foam products at least price-wise.

They will establish their own outlets and their own areas of application but the quantities involved will certainly not compare in any possible respect with the huge amount of materials already used in the PU, PS, PVC, UF and PF areas.

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REPORT
ON THE USE OF PLASTICS MATERIALS
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FOR DEVELOPING COUNTRIES[1]

Addendum

by

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6. Forecast of prices for plastic building materials over the next 10 years

In order to be able to visualize how plastic building materials and prefabricated plastic foams will or could influence the trends in the building industry, it has been most difficult to get first-hand information with regard to the cost development in this area, at least over a period of the next 10 years. The problem actually was not only to see how manufacturing costs of end products are going to work out long or short range and also how the costing of monomers and polymers will look are dominating factors. At the same time and especially with the aspects connected with developing countries and their interest to create own sources of supply, the following table seems to be representative long range for the costing of raw materials.

With the help of a computerized analysis the following cost escalation figures until 1980 were established:

	1971	1980	
urea formaldehyd	-.40	-.50	Dollar/kg
phenol formaldehyd	-.52	-.58	
polyurethane	-.70	-.82	
polystyrene	-.30	-.42	
PVC	-.33	-.46	

It has to be kept in mind that these figures do not only incorporate the forecasts for prices for feedstock and the increase in volume, but also take into account as far as possible the expected drastic changes for labor and other costs.

7. Investments and production costs for plastics and plastic semi-finished products

When looking more deeply into the possible use of the various plastic materials as construction materials, it became obvious that this report should be extended somehow in the raw material and semi-finished product area. Therefore, extensive data was collected and the facts and findings summarized inthe attached table (see page 23).

A special effort was made to get reliable information with regard to the minimum capacities to be set up in order to be able to work economically since to the auther's opinion at least some of the developing countries will plan to make some of the materials themselves.
In such cases all the necessary details can be made available immediately upon UNIDO's request.

Investments and Production Costs

	UF	PF	PU	PS	PVC
Minimum capacity to be established for economical production runs (Tons/Year)	1000	3000	15000	12000	6000
Investments per 1000 Tons/ Year capacity of raw material (US-Dollar)	125 M	175 M	325 M	225 M	425 M
Investments per 1000 Tons/ Year for convertion facilities (US-Dollar)	10 M	75 M	120 M	200 M	175 M
Raw material costs per kg for suitable components (US-Dollar)	0.40	0.55	0.70	0.30	0.35
Prices for finished products:					
a) foamed "in place" (only possible with UF and PU) (US-Dollar per m^3)	17.5-35.0	--	30-50	--	--
b) semi-finished products (US-Dollar per m^3)	15	35	35	20	45

Note: These figures show average costs which may differ from the actual ones obtained in special cases. They, however, represent a reliable basis for cost comparisons.

B) BUILDING SYSTEMS

1. Introduction

The development of building systems utilizing non-traditional building materials and methods started in the early fifties and especially made headway in the USA where pre-fabricated houses since then, besides mobil houses, became a major factor in the building industry. These systems, however, never really featured solutions enabling to mass-produce houses under industrial aspects. There was, however, to the best of the knowledge of the author, never made a real technical approach to develop such a system applicable technically and economically in developing countries.
This chapter B) is trying to analyze the given situation and also present a system which based on long term experience is offering all the advantages with regard to materials and mass-production of sections and components on one side and a unique way of pre-assembly and final erection.

2. Description of systems available and/or commercially used

Principally, three systems for the manufacture of pre-fabricated houses using non-traditional building materials are available and partly in use which will be described separately as follows:

a) The standard pre-fab system as already used in the United States, Canada, Japan, Germany and Scandinavia - just mention the major producing countries - is more or less showing common architectural features but allows to manufacture all the various sections (walls, ceilings, floors, windows, doors, etc.) which then are finally shipped to the final locations for erection where the assembly takes place.

The disadvantage of this method which only offers limited cost reductions in any case, if, if for instance applied to developing countries, that firstly the erection of the house requires highly skilled labor and secondly the fact that nearly always components are lost or disappear for other reasons. This system, however, for the first time in building history forced to implement standardization programs and therefore was extremely helpful in a number of ways towards mass-production of houses. It, however, in reality never led to mass-production itself primarily because for competitive reasons manufacturers had to offer so many different models that equipment, molds and fixtures, as required for mass-production investment-wise, were out of question. Consequently and inspite of the fact that those houses made are still called pre-fabs, prefabrication as such does actually not take place since all the segments and components are more or less nothing else than semi-finished products.

b) The sectional pre-assembled system which as a further step added to the pre-fab system a) a second operation by pre-assembling major portions of the house and shipping them to the building site for the final "put together".

The advantage of this method, provided the number of houses made of the same design is big enough, are unquestionably the savings obtained by the pre-manufacture of the "portions" on assembling lines.
The disadvantage, however, is certainly the fact that the shipping cost for the bulky sections absorb, at least in most of the cases, most of the savings achieved.

On the other hand, stealing of parts must be considered a minor problem only whereas the need for skilled labor is considerably reduced. It has to be recognized in general that this system was undoubtedly the first real move toward mass-production of houses.

c) Non-traditional pre-fabs

New impulses were given to the whole building trade by the introduction of plastics and especially plastic foams, and consequently to the companies and people involved worldwide in the development and design of low-priced pre-fab and also emergency houses.

The results obtained, however, so far present a number of more or less technically perfect solutions but did not generate even any small scale realization as far as the number of houses really built is concerned . The reasons for this are manifold. First of all, and this may be the main point, a house anywhere in the world and definitely in the developing countries is a status symbol and, therefore, has to look like a house and should show certain typical features (roof, windows, kitchen/kitchenette, etc.). Therefore, the "iglo-type" of dwelling and other similar looking shelters were rejected principally and regardless of the fact that these units technically represent an acceptable solution.

The author's opinion, with regard to this point, is that one of the major mistakes made at the beginning when launching this program, primarily chemists and plastic engineers were employed to direct these development programs instead of utilizing the skill, know-how and experience of companies and people involved worldwide in housing and urbanization projects and specifically active in developing countries.

3. Previous experience with systems in use

As already indicated in chapter B) 2. what ever had been done in the past looked like a highly improvised step towards mass-produced pre-fabs but not real action was taken to establish new systems and especially not for developing countries and also not regarding the replacement of existing slum areas by urbanization and rebuilding such areas in such a way that real residential conditions could be introduced.
While pre-fabs in general are accepted in the industrial countries, all efforts made trying to introduce such houses in developing countries more or less failed for the following reasons:

a) the architectual concept of the houses offered did in most cases not meet the domestic or local requirements. This specifically relates to problems like the generation problem. In most of the 49 countries where a survey was carried out in order to get first-hand information, three generations usually live under one roof. This is automatically asking for some kind of architectural separation between grand-parents, parents and children which could not be accomplished by introducing existing pre-fabs.

b) The cost for the houses offered and even by subsidising such projects through the help of international and welfare institutions, were so high that any further move in this field became obsolete.

c) The maintaining of such houses was normally so sophisticated that alone this fact would have reduced their lifetime to a limited number of years, since skilled in order to keep up such practically is not available yet.

Summarising, the author is inclined to say that the before-mentioned reasons plus the fact that no world-wide coordinating institution did exist in the past, all work done so far was piece-work and it is his firm opinion that UNIDO or a subagency of UNIDO would only be able to handle such a program.

4. The NEW IDEA

and the system developed in accordance was fundamentally built on experiences, facts and figures accumulated over the recent years and is utilizing technical improvements so far publically unknown.
This system which will be called the "WELZ method" was developed for one single purpose:

to mass-produce and erect houses especially in developing countries.

It combines the use of standardized partitions with a unique way of pre-assembling the houses. In order to disclose part of the background of this work done, please note the following:

Studies carried out in the sixties showed that the use of plastic foams, if applied in accordance with the technological performance and abilities in housing, will become a major tool in the hands of designers and engineers helping to develop sophisticated building systems primarily for housing and dwelling units tailored for mass-production only.

The main features of the WELZ building method are defined as follows:

instead of manufacturing all sections and particions necessary to build a house and ship to the area for assembling, the house as such is already pre-assembled in the factory and simply folded together into a container sized box as may be seen on drawing No. 1.

The dimensions of the container for the selected housing unit (floorspace of 30 m^2) is approx.

2.43 m x 2.43 m x 4.21 m

and therefore shipped and handled using standard container moving equipment.

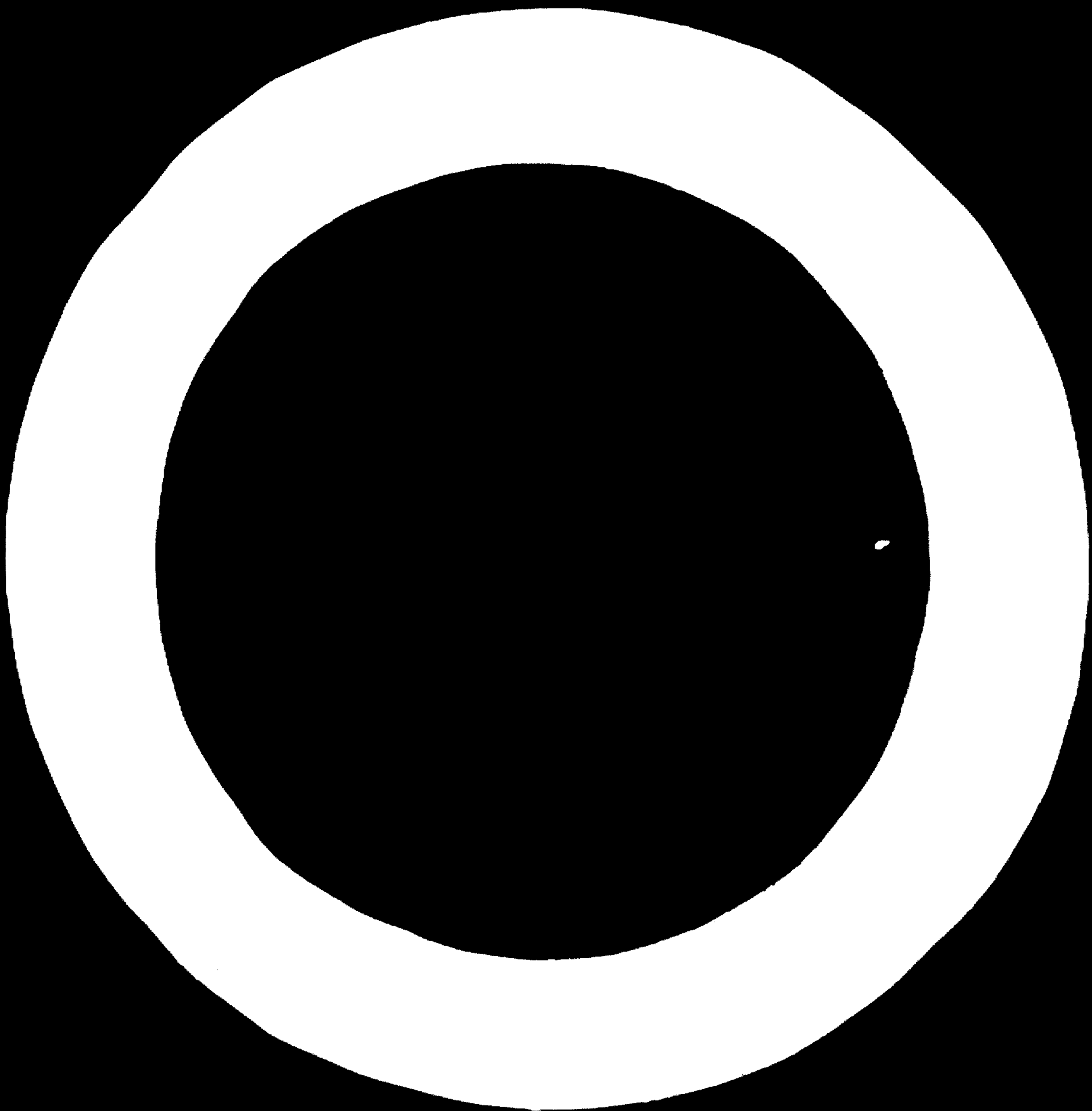
On the building site the container is set on ground and unfolded (see drawing No. 2 to 6).

At this point it is considered necessary to explain why the proposed layout of the house was finally selected.

When getting more deeply into the situation related to developing countries and the elimination of slum areas, it became obvious that several factors exist which have to be very carefully kept in mind. As, for instance, the fact that in slum areas in very many cases three generations are living together in one house, this point requires special attention. As a matter of fact, this has been the major reason for selecting a comparatively small housing unit which may be multiplied in order to serve this particular purpose.

Also, even in slums the house symbolizes a personal status and, therefore, has to look like a house as far as shape and layout are concerned.

In addition, the costs to build and maintain such a house must definitely be in line with the income which in 49 developing countries is registered with an average of 280 Dollars per year/person employed (these figures, of course, are somewhat misleading because they only give the statistical average and do not reflect the lowest income level actually existing).



UNIDO's intention to select four different types of houses has been realised by developing one standardised small unit which by addition or multiplication allows to build not only four different types of houses but also a number of architectural variations.

The same unit also allows to build schools, cultural centers, nurseries and nursing homes and any other buildings necessary to accommodate these specific areas.

A standardisation of the building sections respectively the dimensions of the semi-finished product and/or shaped articles is under way and will be made available to UNIDO as soon as necessary. It, however, has to be kept in mind that it will take at least another two months to complete this very important portion of this program. However, as far as the various material combinations are concerned, please note that the various sections demonstrated only represent a limited number of the possible variations. This, of course, will also have an impact on the final manufacturing costs which will be looked upon more deeply in paragraph 5 of this chapter.

Another point to be mentioned in this connexion is the question of maintenance connected with housing in general and specifically with such ones build in slum areas. The experiences accumulated so far seem to indicate that plastic materials like reinforced polyester show much more durability than the majority of the materials used today (wood, steel and other sheets, etc.). It, therefore, appears justified to believe that maintaining cost for houses like the proposed one may be considerably lower.

Another important factor which should not be overlooked, is the possibility to move the house from one spot to another by simply reversing the whole erection process which at a maximum will only be a matter of hours, arriving again at an easy to handle container.

5. Concept for the establishment of manufacturing facilities

a) Locations

When originally looking into the problem of the development and eventually the manufacture of mass-produced houses, featuring primarily plastic materials, it had been visualised to split up the participating developing countries into approximately 20 regions worldwide. It also had been considered to set up petrochemical complexes wherever it would have been necessary to manufacture feedstock and plastic raw-materials. In the recent past, it however became obvious that considerable spare capacities for monomers and polymers existed worldwide and, therefore, sizable investments in this area could be eliminated. Furthermore, and this was found after an accurate survey had been carried out, it was realised that to split up the manufacturing end into so many regions would not only result in multi-billion dollar investments but also bring up the production costs much above the investments and end prices obtained if manufacturing took place in, for instance, only two regions which should be located both next to already existing petrochemical complexes (at least in the beginning of an internationally applicable housing scheme(. Even if shipping costs are taken into consideration, the final costs for the pre-assembled house, utilizing the WELZ system as already described, will possibly be fifteen to twenty per cent lower in cost than products manufactured in a number of regions. The reason for these findings are manifold but basically due to three major points:

1. the considerably lower depreciation rates
2. the extremely higher possible utilisation per plant installed
3. the availability of all facilities and highly skilled staff enabling the manufacture of high quality products at the lowest possible costs.

It, nevertheless, is certainly viable to manufacture in Algeria or Chile locally but if the real intention of this housing program is to provide shelter in large quantities, it definitely would be of much more advantage to start for instance, in Sardinia (Italy) or Spain to supply Africa and part of the East, and on the west coast of America to serve Latin-America and other parts of the world.

This statement may seem to be misleading regarding the participation of the developing countries themselves having available a high percentage of unemployed man-power but as indicated in some of the following paragraphs, the amount of labor still to be provided for the erection of the houses and the urbanisation and preparation of the building sites will most likely be more as they are able to handle without any help from outside.

b) <u>First Stage</u> (short range)

Taking into consideration the complexity involved when introducing the final mass-production scheme, it seems desirable to start out with the smallest size plant possible, however, still big enough to enable the manufacture of houses in a small but realistic and economical scale.

It, therefore, is recommended to build a plant able to handle all kinds of the commercially available raw-materials with a total output rate of approximately 10 to 20 houses per day. The location for this plant ought to be selected by UNIDO. It, however, should be kept in mind that this particular plant will easily serve as a training center and the location selected should preferably be within reach of UNIDO's head-quarters in Vienna.

The equipment (including buildings) required is specified based on the layout followed:

	Price
1 multi-platen-press table size: 5000 x 3000 mm max. pressure: 2.5 Tons number of heatable platens:6 incl. heat exchanger units	140
1 trimming and cutting unit	12
1 unit to manufacture corrugated Polyester/Glasfiber sheets	65
1 clamping unit (multi-platen)	45
1 foaming unit PU	10
1 foaming unit PF	8
1 foaming unit PS	15
1 steam generator max. 1 t/h	14
1 PS foam sheeting device	40
1 extruder 3 1/2" 24 ∅ incl. dies and take-off suitable to extrude foam as well as profiles and sheets	75
1 assembly set of fixtures	15
1 overhead crane	20
office equipment	11
others	10
contingency	25
building approx. 1200 m^2 + 50 m^2 office	125
	Dollar 630 M

Manpower requirements:

2 shifts = 15 men each + supervisor

The operating costs for stage one will be for 10 houses per day, including depreciation:

		30 m²	+ 30 m² (see note)
Raw materials			
insulation	UF 6.75m³/12=81kg	32.40	27.--
Glasfiber	450 kg/per unit	225.--	185.--
Poyester	450 kg/per unit	135.--	115.--
PVC flooring	42 kg	25.20	28.--
PVC profiles	175 m	11.50	8.50
doors	4 m²	16.--	9.--
windows	4 m²	30.--	30.--
steel reinforcement	126 m	10.50	8.75
bathroom equipment		22.50	-.-
kitchen		20.--	-.-
lighting fixtures		8.50	8.50
utilities:			
steam	4.50 Dollar per t	3.50	3.50
electricity	-.04 dto. per KW/h	2.75	2.75
water	-.10 dto. per m³	1.--	1.--
manpower 1)	semi-finished products assembly, total 15 men	26.50	17.50
supervision 1)	2 men	5.40	2.70
floorspace		6.--	6.--
depreciation		21.--	21.--
royalties		10.--	10.--
Total per house = (packed on the floor)	Dollar:	612.75	484.20

Notes:

(without kitchen + bathroom equipment)

1) Wages: Dollar 1.75 per h + 35% fringe benefits

Salaries: 600.-- per month + 35% fringe benefits
180 h/man per month

e) The second stage (long range)

The second stage should start out by establishing at least one central point of manufacturing in a location where the major raw materials required are available and where sufficient labor is already on hand.
At the moment, Sardinia (Italy) and the west coast of America (USA or Mexico) seem to be the most favorable ones. The Spanish territory could also be visualised but since Spain itself is still in a developing stage to a high degree, Sardinia was finally selected for the following cost evaluation which is based on a daily minimum output rate of 100 respectively 300 units manufactured on one highly mechanised and standardised line. By setting up additional lines, the total capacity may be boosted up to any number required.

The equipment necessary (including buildings) is specified based on the layout (page No. 37) attached:

		Houses per day 100 $ M	Houses per day 300 $ M
	Space requirement: 3500 m^2 (5000 m^2) (incl. heating etc.) (the costs include provisions for additional off sites)	420	600
	Warehousing facilities for raw materials (Polyester, Glasfiber, Foam)	25	40
	Premix system for reinforced Polyester	8	16
4	(10) manufacturing lines for the outer layers of the section, drawings 101-106, consisting of: impregnating section, curing section, trimming and cutting, printing rollers, heating and cooling device, automatic stacking, incl. weving equipment to use rowings; Each: $ 60 M	240	600
1	(3) UF-foaming unit, including premix system and metering device	15	45
2	(5) multi-platen clamping units (6 stations) clamp pressure 50 T/max., heated platens, including heat-exchanger and temperature control equipment, selfcontained, dimensions max. 5000 x 3000 mm Each: $ 55 M	110	275
4	(12) finishing and machining devices (taylor-made) Each: $ 12 M	48	144
1	(3) set of assembly fixtures, including all devices necessary to pre-assemble sections and components	45	135
1	(3) assembly line (pilgrim-step), including all power-tools and other equipment	65	195
1	overhead crane system (three independent-(3) ly operating cranes)	35	105
1	steam generation plant, capacity 2 Ts/max./per h	20	20
2	(4) extruding lines, 3 1/2" ∅, including dies for profiles and sheets, take-off, etc. Each: $ 55 M	110	220
	other equipment (estimated)	15	25
	office equipment	20	20
	contingency approx. 10%	124	210
	Total: Dollar	1,300 M	2,600 M

These costs do not provide for the factory site and loading facilities (rail, ship, etc.)

As far as the manufacturing costs are concerned, estimations indicate that at a production rate of 100,000 units per year and at linear depreciation, costs will be considerably lower since

a) the costs for raw materials are reduced by making own premix formulations

b) the labor costs go down approximately 50% because of the installation of fully mechanised manufacturing lines

c) the costs for components bought from outside, will be reduced since the quantities required are much higher and

d) the depreciation per unit manufactured will go down from approximately $ 21.-- to $ 13.--

Summing up these facts the costs will be as follows: (page No. 39)

		Houses per day	
		100	200
- insulation		27.--	25.50
- Glasfiber		195.--	182.50
- Polyester		125.--	115.--
- PVC flooring		22.50	21.--
- PVC profiles		10.--	9.--
- doors		12.--	10.50
- windows		24.--	22.--
- steel reinforcements		10.--	9.50
- bathroom equipment		20.--	18.50
- kitchen		19.--	18.--
- lighting fixtures		8.--	7.50
utilities:			
- steam		3.--	2.75
- electricity		2.50	2.25
- water		1.--	1.--
- manpower		14.50	13.--
- supervision		2.70	2.--
- depreciation		4.--	2.60
- royalties		10.--	10.--
- flooerspace		5.--	4.--
Total per house: (packed on the floor)	Dollar	515.20	476.60

At this stage, however, it is extremely difficult to arrive at accurate figures since a number of suppliers of basic raw materials and components will have to be consulted and firm quotations obtained.

d) Alternatives

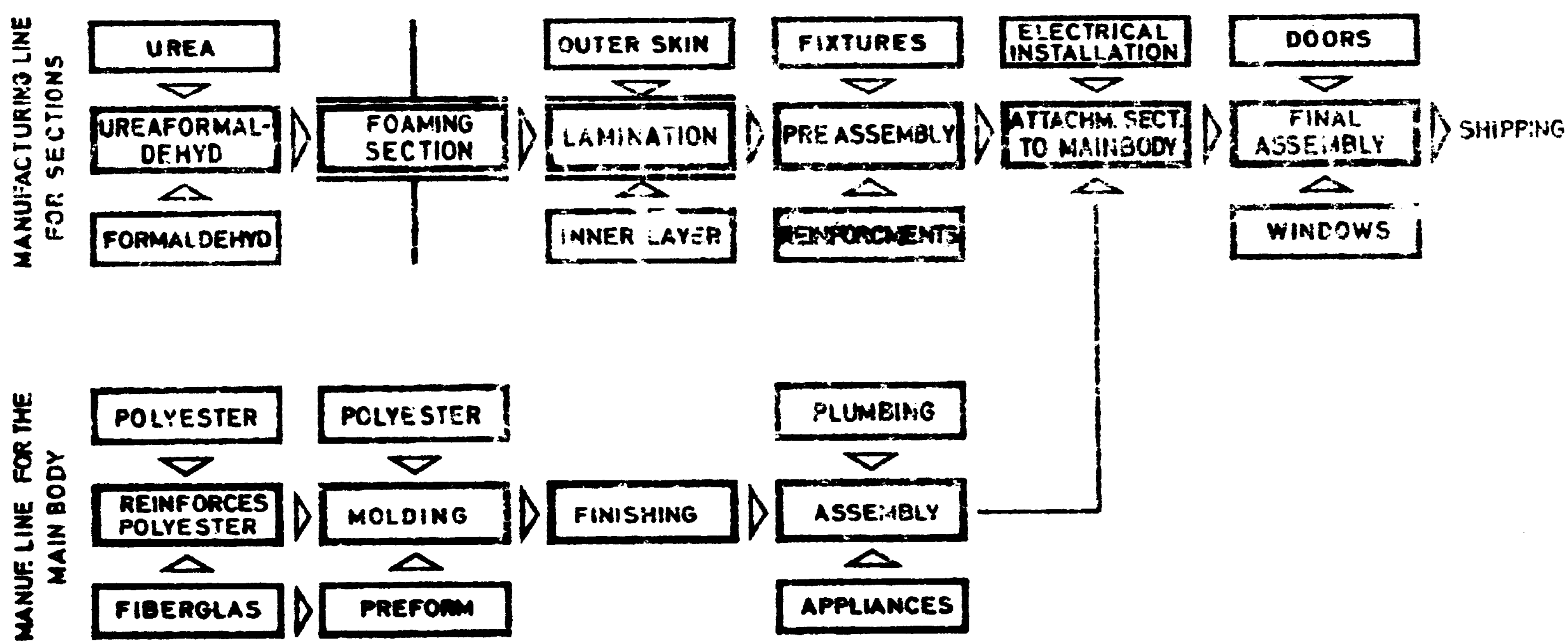
There are, of course, a number of alternatives but all of them are connected with much higher investments and considerably higher costs for the finished house. Extensive studies have shown that, for instance, the costs for molds and fixtures are independently of the output rates more or less the same.

Another very important point to be looked upon is the availability of specialists and highly skilled labor which is still obtainable if the manufacturing activities are concentrated in a small number of areas.

Things, of course, are going to change if one thinks 10 to 20 years ahead of time in which the developing countries, at least under regional aspects, will build up petrochemical and other industries and consequently create the skill and talent to handle such and similar projects.

FLOW SHEET
PRE FABRICATED HOUSES

(UTILIZING UREA FORMALDEHYDE FOAM)



6. Shipping and Erection of the House

As already indicated in § 4 of this section, if applying the WELZ system, shipping costs are reduced to an absolute minimum. It additionally was found that the international freighter fleet (tankers excluded) usually is loaded up to 100% incoming into highly developed areas but outgoing only carries 60-70% of the given capacity. This means that transport space can not only be provided for without any difficulties but also at the lowest cost possible. Since the pre-assembled house folds together into a container-size package, unloading, no matter where, and transporting by train or lorry does not represent any problems.

On the building site no foundations are required but heavy fastener may be used to make the house stay solidly on the ground in case of heavy storms or floods.

The costs involved to unfold the unit and complete all necessary steps of erection will depend upon the nature and shape of the ground and is expected to be between $ 50 and $ 100.

7. How local Firms can participate in this Program

When looking more deeply into the actual housing problems and requirements in nearly 50 developing countries, it became evident that a housing program utilizing mass-production schemes and non-traditional building systems and materials, can only be realized if domestic institutions and companies participate to the utmost possible extent. This relates particularly to the whole urbanization and infrastructure scheme which has to be introduced as a major factor in order to prevent new residential areas turning into slums again after a very short period of time. Therefore, parallel to the preparations made to provide facilities for the manufacture of houses, steps should be taken to train and educate talented people in the following areas:

a) handling of infrastructural problems
b) urbanization schemes and planning
c) implementation of urbanization programs, and
d) development of urbanization and off-sites standards.

The training should preferably take place by delegating people from developing countries to companies and organisations already active in this area and located primarily in Europe, North America and Japan.

If this is not a satisfactory way to accummulate the necessary know-how and skill, UNIDO should possibly sub-contract such projects to knowledgable companies as a short range move in order to close gaps showing up within the startup period of the whole housing scheme.

For further details regarding this very important field directly connected with any housing program, refer to § C).

c) URBANISATION PROBLEMS AND COSTS

1. Introduction

The houses of the accepted type (WELZ) are fundamentally designed for mass-production and, therefore, produced at the lowest possible costs. A large number of these houses are urgently needed in all major agglomeration areas, worldwide, because of the prevalent housing shortage.

This housing shortage is caused by the high rate of immigration into the existing agglomeration areas and the incapacity of the local authorities to cope with the problem. This is primarily due to the fact of lack of capital, lack of technical assistance and shortage, and, in a number of cases, inavailibility of building material. Moreover, non-traditional material will not be commercially available in most of the regions for some time to come.

Since the immigration flowe up to now could not be checked the people had to find shelter in shacks, in most cases without sanitized water and waste disposal. In a great number of cases no road system, no schools, no health facilities could be made available. This, together with the extreme shortage of employment, resulted in starvation, health problems in general and extreme social tensions. Under these circumstances, programe of social welfare do not offer the utterly needed remedy.

In the following it is undertaken to analyse and define the general problems connected with slum areas and the steps necessary for a satisfactory solution.

In the past substantial studies and surveys, including such done by UNO-agencies, collected extensive material dealing with urbanisation problems in slum areas and specifically related to developing countries.
So far, however, very little was done with regard to the development of slum areas by implementing highly standardized urbanisation and housing systems.

It is the purpose of this section to close this gap and provide the information necessary to evaluate the situation.

2. The conventional approach of planning in slum areas

The basic approaches to handle the problem are as follows:

a) the bulldozer-solution. This has proved to be ineffective, because slum-dwellers will squatter elsewhere near the area, or even go back to the same ground after the bulldozer have left.

b) The low-cost housing scheme. At least in the past this approach showed to be too expensive for the average employee (10 to 20 times his years earnings, which usually is just enough for feeding and dressing his family), not talking about people who have to live on welfare. Additionally, it was found that this approach was unable to cope with local demand and growth rates. Furthermore, in most of the cases, the design of the house was not adjusted to domestic requirements, because it was based on European standards. In addition, high urbanisation costs were involved, which actually doubled total investment per house.

c) The self-help housing scheme. Because only roofing and basic building components is the only investment to be paid for and otherwise local building materials and the working capacity of the future owner are employed, this approach is of course, considerably cheaper than b). The procedure as such is extremely slow, especially at the beginning, because of its reliance on persuasion and training of the individual. The implementation of such scheme is not possible without skilled help recruited from outside (volunteers) It usually represents low quality in building, the technics not lending themselves for modernisation in the future. As a rule the urbanisation costs are considerably higher than in approach b), because of unqualified planning.

d) The restriction of immigration by numerous clauses This actually means police action, lest to allow people to penetrate into urban areas.

In addition to the defects pointed to all these approaches tackle the problem spatially isolated and separated from the economic context. Consequently, social costs, which are as a rule increasing proportionally to size and density of an agglomeration are not taken into consideration.

3. <u>The new concept</u>

It has to be understood that the population increase in developing countries is in the neighbourhood of 3%. However, the annual rate of growth of heavily agglomerated urbain areas is around 8% and even more. The difference is made up by immigrants.

Migration and fluctuation as such is a good sign, because it shows that the people are leaving the old, static subsistance economy. They are attracted to towns, because towns repesent progress and they are therefore willing to accept poor accomodation in slum areas as a price for a better future. First, they usually live with relatives or friends until they get work. Subsequently they can afford a better home, supporting relatives or friends in their turn. Yet, the more people find work, the more are attracted, the better houses and services of the quater are, the more people are able to wait for a job, thus creating overpopulation there.

The urbanisation is connected with increasing employment in administration and industry, followed by employment in trade and service. Immigrants are attracted and compete for this employment. Therefore, additional accomodation has to be provided.

In order to provide housing, firstly infrastructure, existing services and places of employment have to be looked at thoroughly. Secondly, with regard to the social costs, the size and structure of the urban unit has to be determined, and thirdly, because of the different needs of the physical environment and of the material resources available, the technical infrastructure has to be looked at carefully.
These 3 points constitute the study of location.

3.1 The final proposals are based on the following standards, based on general facts and findings, applicable in developing countries.

a) <u>Population density.</u>
Under this heading is to be regarded:

- <u>Size of the household,</u> which is depending on the ethnic and social structure, which means in average 5 to 10 persons per dwelling unit.
- <u>Size of site,</u> depending of the size of the household, and the necessity of other facilities like garden, stable, workshop. Since too small premises hinder a future reshaping, the average size of a site should be 150 to 300 m^2.
- <u>Roads,</u> parking space, pedestrian precincts, etc. These cover around 20% of total surface.
- <u>Public facilities,</u> including schools, sport and recreation cover around 20% of total surface.
- <u>Commercial facilities,</u> except industrial site for privat development which have to be regarded separately, cover 10% of total surface.

The overall density results in a figure of around 250 pop/hectar, which is reasonable for effective public transport and the other urban services. By laying out the necessary facilities provision has to be made for a certain increase in activity and/or density at local points.

b) <u>Public utilities.</u>

- <u>Energy</u> is to be provided usually in form of electricity produced by aggregates of the size needed.
- <u>Water supply,</u> consumption varies around 250 l per household/day, the minimum being 20 l per person/day. (Industry up to 100 times as much per work-place).

74.10.1

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SUMMARY

REPORT ON THE USE OF PLASTICS MATERIALS IN THE MASS PRODUCTION OF LOW-PRICED HOUSES FOR DEVELOPING COUNTRIES [1/]

by

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A range of plastics in relation to their potential applications in building constructions is reviewed. Also, the WELZ system of pre-fabricated and pre-packaged dwelling units is described.

The properties of glass fibre reinforced plastics, urea formaldehyde, phenol-formaldehyde, polyurethane, polystyrene and polyvinylchloride foams is described in relation to their potential use in building construction. A proposal is made for the manufacture of units, based upon glass reinforced plastics foam sandwiches in oonjunction with other plastics ancilliaries, suitable for mass production and containerised

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

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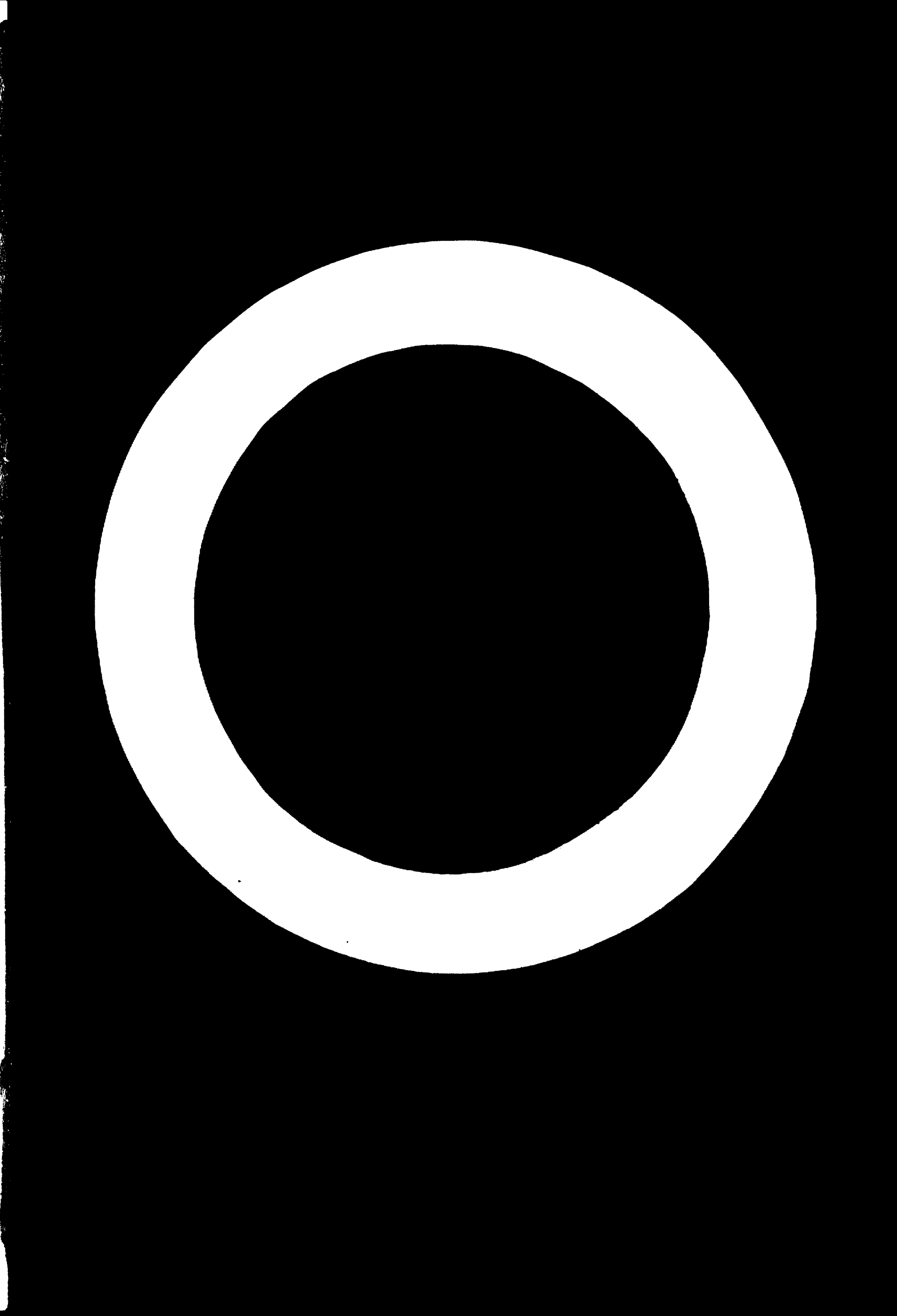
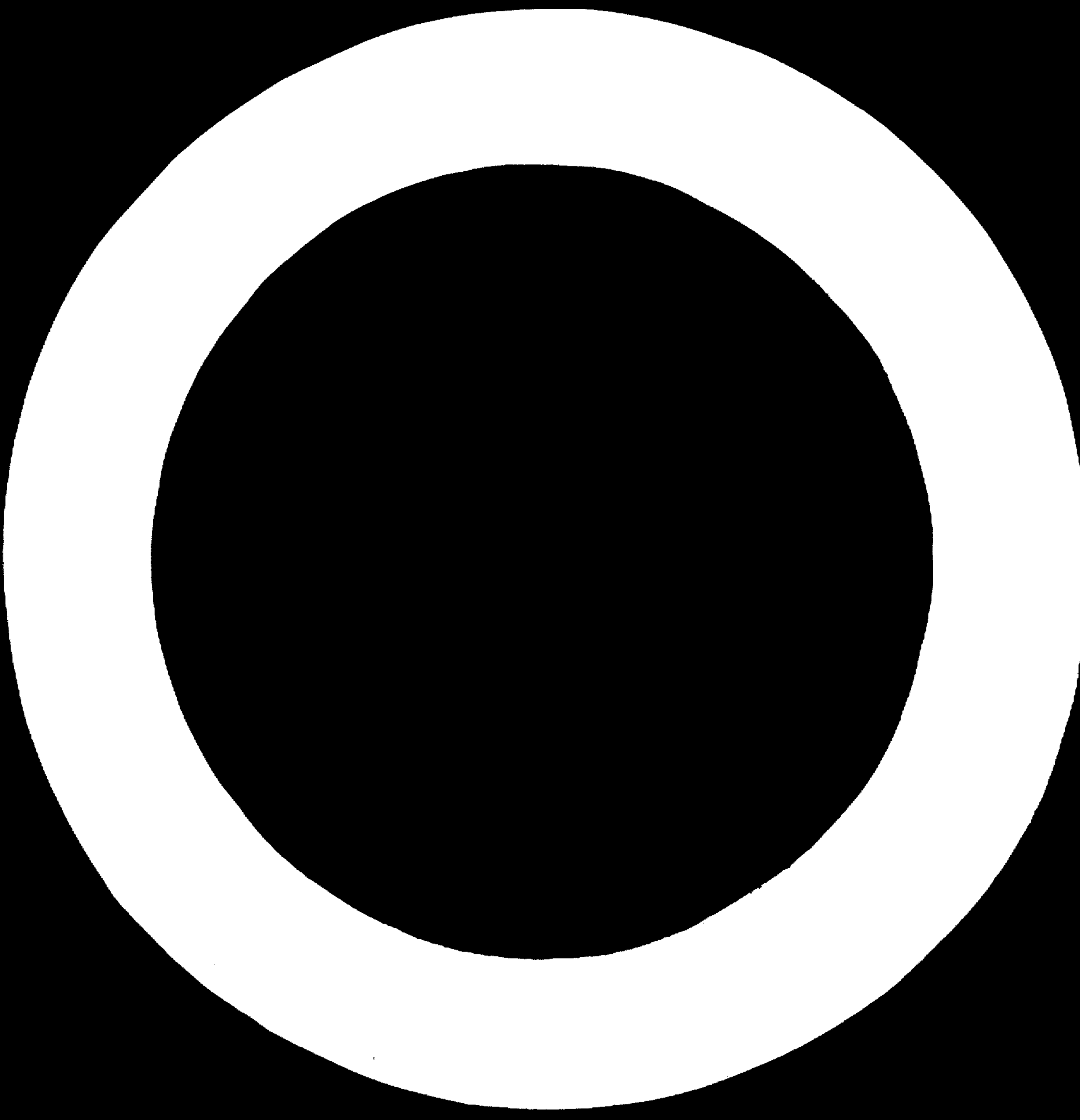
packaging in a folded state. It is suggested that manufacture is effected on a regional basis at sites, situated in the vicinity of petrochemical complexes, geographically distributed for convenient transportation to specified development areas. Investment and operating costs are given on the bases of the manufacture of 10, 100 and 300 houses per day.

Should such a system prove technically sound and economically viable, it could significantly contribute to the realization of urbanization projects in the developing countries.





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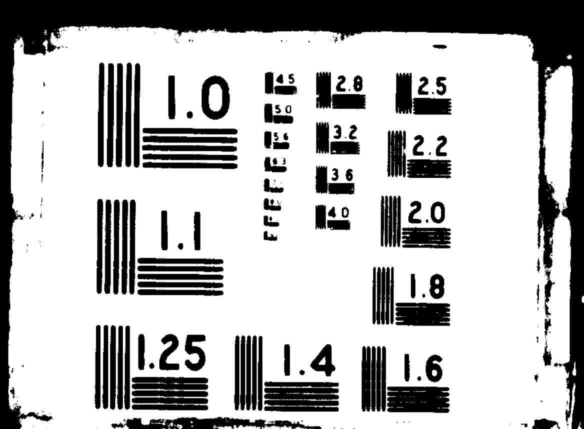

Piping and installation of cost-reducing plastic. The implementation through self-help-schemes is possible. Small capacity at the beginning, later on under growing demand it could be replaced by or incorporated into a high capacity system.

- Sewage and waste disposal, at first disaggregated systems under use of plastics, which, however, have to take into account the amount of water supplied. This system could depend on labor-intensive collection, later on to be incorporated into fully developed network leading to sewage-works designed for the spedific situation. Solid waste should be biologically reused.
- Roads, at first tarred only where necessary. Space left for parking at future stage. Paving of pedestrial precincts in self-help possible or financed by commerce.

The gradual improvement of these utilities has to be envisaged.

c) Public facilities

The number of schools, nurseries, clinics, helath centers, etc. differs according to the national standard. Their distribution has to follow accessibility. The erection could be done partly by self-help under use of pre-fab elements. Provision has to be made for gradual improvement.

Space for administration services, churches, etc. has to be provided.

d) Commercial facilities

Enough space of good accessibility for retail trade is to be envisaged as well as for restaurants, bars, etc. These facilities are to be reasonably concentrated at local points, yet in walking distance of the flats. The use of pre-fab elements for these buildings is to be propagated.

e) **Artisans and small industries** are to be concentrated in suited situations either by local authorities under leasehold conditions or on subsidised premises. These, preferably flexible, structures could be erected likewise with pre-fab elements.

3.2 Repercussions on agriculture

The increasing demand of food of a growing and better-off population offers opportunities for developing the agricultural production in the neighbourhood. This more industrialised agriculture in turn develops demand for services, situated in the town. These beneficial repercussions have to be taken into account for the choice of location and the lay-out of the traffic network.

4. Implementation of new concept

4.1 Preliminary studies

The first step of implementation is the preparation of a thorough study in order to define the terms of reference for any further action. The aim is to avoid dead lock or detours and to optimize the means to be employed.

This study is two-fold;

a) Location study, which is composes of

- an analysis of the suitable place for housing, local supply of staple food and industry with respect to climate, topography, resources of water and local building material especially for infrastructure.
- an analysis of the existing regional infrastructure
- a feasibility study of infrastructure to be constructed
- a feasibility study of improvement possibilities in local agriculture

- a feasibility study of industrialisation.

The aim of this study is to find the place with overall minimum need of investment for the measurements envisaged.

b) Survey of actual situation, where this is necessary, owing to the restraints of existing settlements and existing trends of the population. It analyses the factors:

- demographic and social structure
- employment, income
- housing, food, supply
- migration, flows
- habits and technics prevalent in population with respect to dwelling and urbanisation.

4.2 Proposals

Without being in possession of this necessary information, any proposal must be diagrammatic, which, however, because of the general nature of paper may suffice. The proposals are layed down in the drawings attached.

a) Arrangement of dwelling units

It shows flats of different size and organisation, suited for high-density living quarters. The net density of a one-story development is around 550 pop/hect. Although two-story development is principally possible, a higher density is not advisable, exept by mixing with highrise buildings (viz drawing d).

b) Urbanisation unit

It shows diagrammatically an urbanisation unit of 5.000 population in connection with industry of at least 500 basic employment, showing groupement of public facilities, commercial facilities, high-rise, high density development and basic roads and service.

c) Settlement on a slope

This sector of a settlement on a slope takes advantage of topographic situation. The basic service network is shown more in detail.

d) Redevelopment of slum area

This diagramme of redevelopment of a slum area shows the gradual transformation under the conditions of resettlement, especially with a density considerably higher than before.

The cost of urbanisation can be roughly estimated from the conventional approach. Taking into account a wide range of costs per dwelling unit, due to climate topography, availability of natural resources etc., the costs of urbanisation can be reckoned to be about as high as the costs of the dwelling unit itself. Through careful planning the costs of urbanisation could be reduced considerably. This reduction, however, means a proportional increase in planning time and costs. Since planning cost are only a small portion of the total, the overall savings by careful planning are evident.

5. Summary

The facts, findings and suggestions layed down justify the realisation of the urbanisation projects in connection with the mass-produced housing project.

D) PRELIMINARY CONCLUSION

Due to the fact that mass production seems to be a decisive factor for providing houses at lower cost than otherwise available, large scale co-operation within regions will be of importance.

The existing housing gap and forthcoming requirements for housing indicate that both traditional and new materials must be mobilized to solve the problems involved in securing adequate housing in papidly growing industrial areas. Only plastics will bring along the properties required for mass production and long distance transportation. The amount of work for the production of the house is reduced to a minimum, and the urbanisation activity will be able to progress in ratio with land preparation, which can be promoted as labor-intensive or equipment-intensive, according to local needs. The organisation of the entire activity will therefore be dependent upon region co-operation so the necessary standardization of types can be achieved from the beginning.

It is therefore recommended that the interest of the developing countries be examined on the basis of figures from the present study. Each country indicating interest could be included in an advisory "board" which would assist the UN in solving the problems and promoting decisions of interest for the developing countries. UNIDO would, in co-operation with the UN Center for Housing, Building and Planning, act as secretariat for the advisory board and expedite requests and provide experts and consultants according to UN rules.

The first task of the advisory beard would be to decide upon unite requirements for first stage of production, so that a pilot plant of reasonable sise could be located and examined.
Based upon the detailed construction requirements for a complete plant worked out by an independent consultant hired for the purpose on a competition basis, a final decision for further UN assistance will be taken in accordance with existing possibilities.

74.10.15