Int. J. Engng Ed. Vol. 11, No. 3, pp. 195–205, 1995
Printed in Great Britain.

0949–149X/91 $3.00+0.00

Physical Development and Planning of the NTU Campus

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Comprehensive and extensive new physical developments in the NTU campus are discussed. The nature of the developments, and the rationale for development and implementation in phases are covered. A brief historical background is also given. Issues relating to the development and actions necessary to ensure orderly development are indicated. The physical developments are also shown in relation to the increasing student population and the expansion in courses.

INTRODUCTION

THE MAIN campus of Nanyang Technological University (NTU) at Jurong has a spread of some 200 hectares. It is situated towards the western part of Singapore, approximately 26 km from the city. The visual image of the campus is one of extensive development spread amidst lush greenery. As part of a continuing expansion programme, major new physical developments are in progress. At the same time, further plans are being made for future developments.

The need for continuing expansion was envisaged at the outset of planning for the new campus. Professor Kenzo Tange, who prepared the initial master plan for the campus in 1981/82, expressed the opinion that: 'An institution of higher learning is like a living organism . . . growing and changing with time. For any such institution to survive, it must allow for growth through the years.'

The developments are designed to keep pace with the rapidly growing student population as well as the introduction of new courses of study. These developments include numerous large new building projects as well as the continuing upgrading of infrastructural services. Some major renovations of existing buildings are also periodically carried out. These developments are discussed in this paper. The spread of development is shown on the campus map (see Fig. 1).

Another aspect of development is the provision of up-to-date teaching and research equipment, including computer systems, for the various laboratories and other teaching facilities. Some of the major factors relating to this aspect of development are also outlined in this paper. However, the detailed needs and problems are different among the various Schools of Engineering. The different approaches reflecting the diversity of problems encountered by the various Schools of Engineering are discussed in a separate paper 'Development of Laboratories and Computing Facilities'. The development and planning of the infrastructure for information technology by the Computer Centre is also discussed in that paper.

HISTORICAL BACKGROUND

In 1981, the then newly established Nanyang Technological Institute (predecessor to the NTU) took possession of the campus with an assortment of old buildings left over from a previous institution. These old buildings, ranging between one and six storeys in height, had been refurbished to enable the initial three Schools of Engineering (Civil and Structural Engineering; Mechanical and Production Engineering; Electrical and Electronic Engineering) to commence teaching activities immediately. Some of the old buildings were converted to teaching and administrative blocks. An old library building was subsequently converted into an administration annexe. Amongst the old buildings there were also hostels which were grouped into three halls of residence for students. Some old staff-quarters also existed at scattered locations within the campus. Figure 2 indicates the extent of old buildings left over from the previous institution.

However, the various spaces provided by the old buildings were not sufficient to cater for the planned student population, which was initially projected at about 3000 for the coming years. Further developments of physical facilities were called for.

THE NATURE OF THE DEVELOPMENTS

The new building works comprise large teaching complexes, research facilities, residential halls for students and housing developments for foreign staff. Views of various developments are shown in Figs 3–8. The buildings are spread out extensively

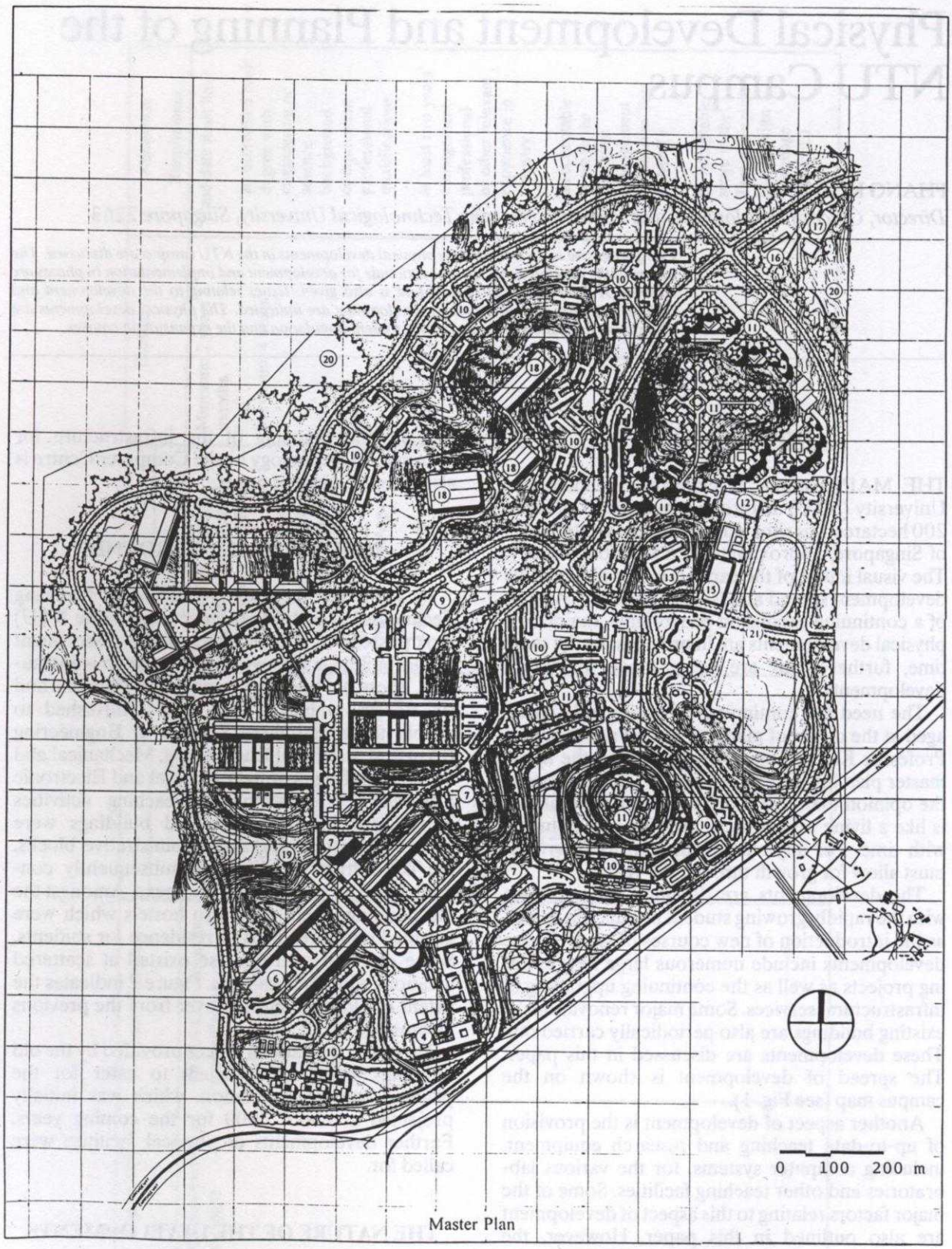

Fig. 1. Campus map.

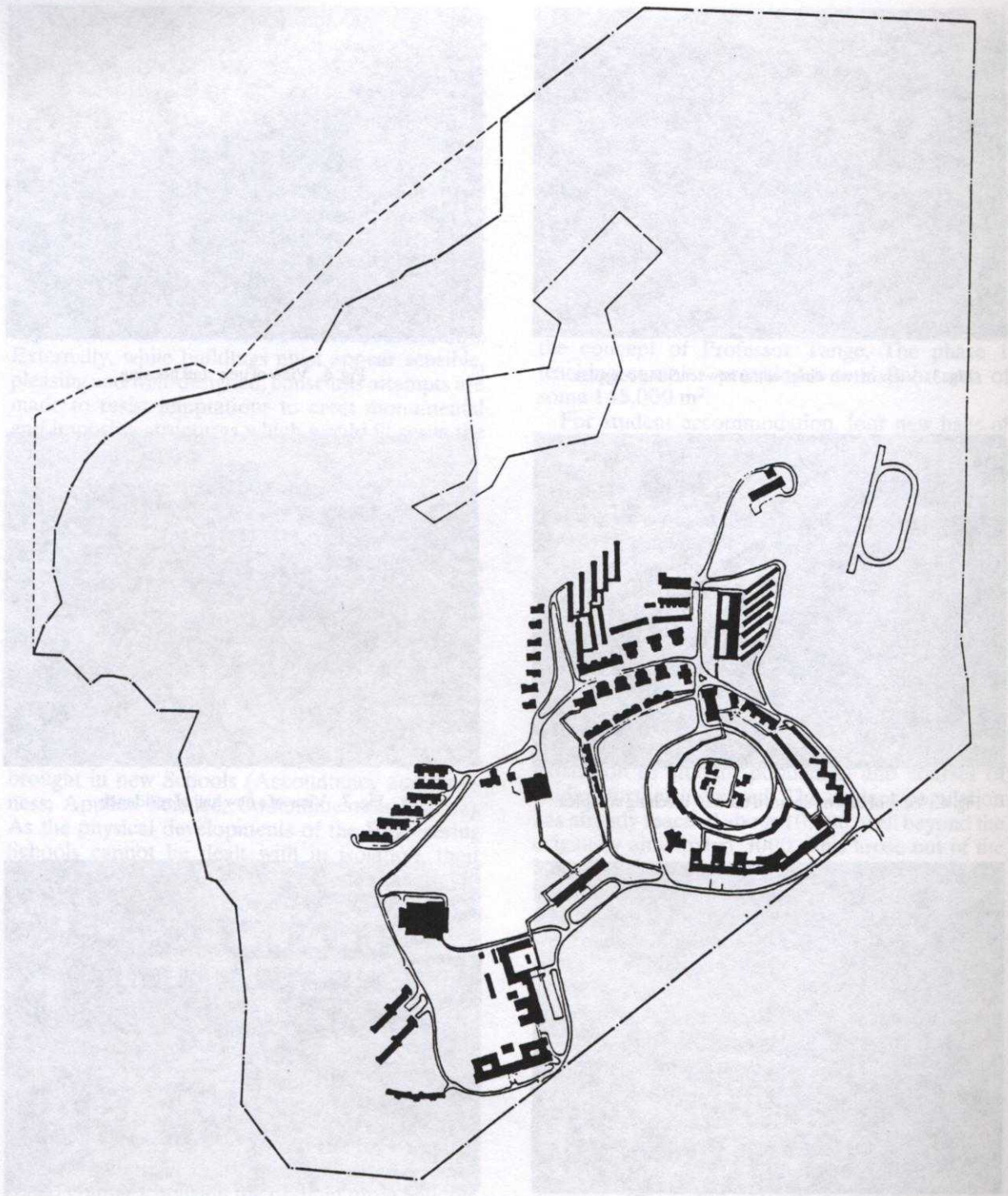

Fig. 2. Old buildings before the first phase of development.

and comprise low- to medium-rise structures which blend in with the existing environment and terrain.

The corresponding upgrading of infrastructural services covers expansion and improvements to the electrical power supply system, including building of a new electrical substation; a water supply system, including new water-storage tanks, drainage system and sewerage system; and telecoms and computer networks. Teaching equipment varies with each School. The combination of new building developments, upgrading of infrastructural services and teaching equipment is designed to provide a conducive environment for teaching, learning and research.

The major renovations of existing buildings are to augment the supply of floor space and to enable the buildings to meet up-to-date requirements of current building regulations and to cater for highly technological functions.

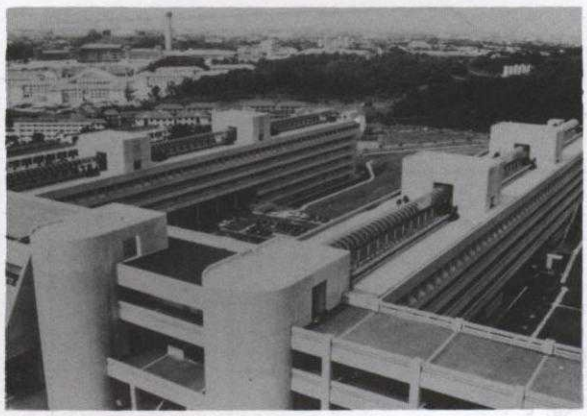

Fig. 3. View of two wings of the new teaching complex.

Fig. 6. View of new staff housing.

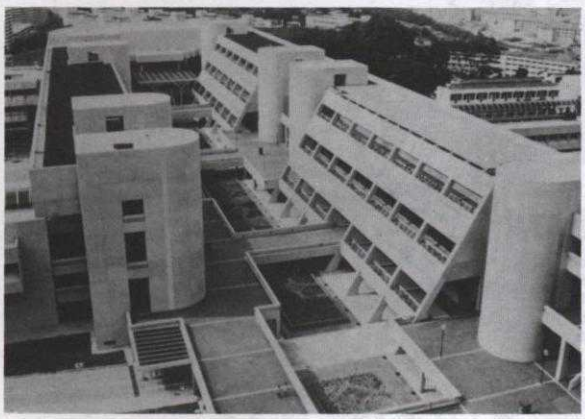

Fig. 4. View of central spine of the new teaching complex.

Fig. 7. View of a new hall of residence.

Fig. 5. View of a new research building.

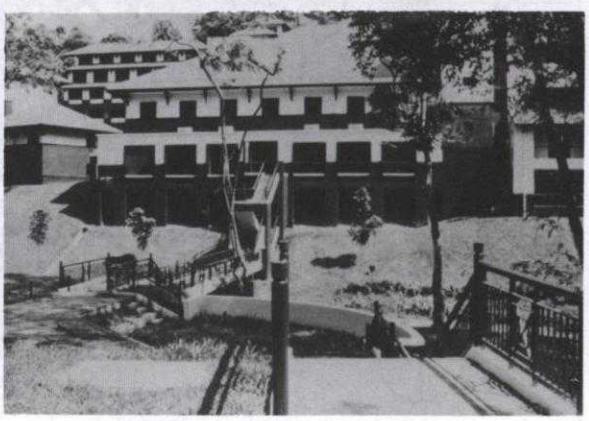

Fig. 8. View of a new hall of residence.

THE RATIONALE FOR DEVELOPMENT

In a forward-looking and rapidly progressing society, the need to provide advanced education for the population is a prime concern. The developments at the NTU are basically to respond to such a need.

The core of the development, therefore, is the construction of buildings to provide adequate floor space catering for teaching and research functions. This would require the construction of lecture theatres, tutorial rooms, workshops and laboratories of diverse nature. To support the teaching and research functions, however, other facilities also need to be provided. These supporting facilities include libraries, computer systems and audio-visual facilities which would also require adequate floor space.

As the campus is located quite some distance from the urban area, NTU policy is to provide residential facilities for foreign staff and for a sizeable proportion of students. Corresponding recreational and sports facilities as well as canteens are also provided.

The standard of development is aimed at providing an environment of reasonable comfort which is sufficiently conducive to the acquisition and transfer of knowledge. A safe and healthy environment is assured by full compliance with building regulations.

However, in order not to waste public funds, it is important to avoid lavish or luxurious furnishings. Externally, while buildings must appear sensible, pleasing and well-designed, conscious attempts are made to resist temptations to erect monumental and imposing structures which would ill serve the educational purpose.

PHASED EXPANSION

The development of the campus has been and is being carried out in phases to keep pace with demands as student population and courses expand. This phased development is in line with the architect Professor Kenzo Tange's design concept that a university should be flexible and that it should be capable of growing and extending.

While the NTU initially started with the three Schools of Engineering, subsequent developments brought in new Schools (Accountancy and Business; Applied Science; Communication Studies). As the physical developments of the Engineering Schools cannot be dealt with in isolation, their developments need to be considered in relation to other Schools and the overall development of the campus viewed *in toto*.

Phase 1 development

A master planner (Professor Kenzo Tange of Japan), working jointly with INDECO Consultants of Singapore, was engaged to formulate a master plan to guide the development of the campus. The master plan provided for the development of low-rise buildings to blend in with the existing ground terrain. Phase 1 of the new teaching complex, which was completed in 1986, comprised an integrated complex housing the original three Schools of Engineering as well as common facilities. The configuration and location of the Phase 1 teaching complex is shown in Fig. 9.

While each School mainly occupied a wing of its own, these wings were connected to a central spine which housed common facilities such as lecture theatres, tutorial rooms, library and canteen. The central spine facilitated intermingling of staff and students of all Schools. In the words of Professor Kenzo Tange:

> The main structure of the new Academic (Teaching) Complex consists of a 'spine' with three 'fingers' spreading from it. This Academic Spine contains the communal facilities grouped around a central plaza where students, professors and lecturers can gather, interact, exchange knowledge and enjoy being together in a very relaxed social space. The 'fingers' which are in the form of 'bridge' structures have been designed to span across the many hillocks, . . ., these narrow man-made 'bridge' structures across the valleys will allow the existing natural undulating environment to be retained, and the natural beauty of the site to be enjoyed.

Subsequently a fourth 'finger' was added to the teaching complex of phase 1. Figure 10 illustrates the concept of Professor Tange. The phase 1 teaching complex provided a total floor area of some 145,000 m^2.

For student accommodation, four new halls of residence were built, each hall providing living accommodation for 500 students. This brought the total number of halls of residence to seven. In the process, two old buildings, which had temporarily served as drawing-office blocks, were demolished to make way for the halls of residence. A staff housing complex of 96 units were also erected to cater for foreign staff. These facilities are shown on the campus map. The spread of developments at phase 1 is shown in Fig. 9.

Phase 2 expansion

The original master plan provided for further expansion as student population and courses of studies further increased. The student population has already reached about 10,000, well beyond the originally anticipated 3000. This arose out of the increase in intake for each course of study as well as the introduction of new courses of studies. By the end of 1994, the massive phase 2 developments were near completion. As shown in Fig. 11, the phase 2 teaching complex is of the same magnitude as the phase 1 teaching complex. It provides an additional 111,000 m^2 of floor space for teaching facilities, laboratories, staff offices and ancillary facilities. The configuration of the phase 2 teaching complex is similar to that of the phase 1 teaching complex, comprising a new central spine for common facilities and attached wings for various Schools.

While Figs 9 and 11 progressively provide the pictorial representation of the growth in development, Fig. 12 shows graphically the increase in floor area provided in relation to the increase in student population.

Recently, four new halls of residence for students (each hall to accommodate 600 students) have also been completed. The completion of these four halls brings the total number of halls of residence to 11. A 12th hall of residence is at present being designed. Construction works for another staff housing complex of 200 units are also well in progress and are expected to be ready by mid-1994. The extent of development when phase 2 is completed is shown in Fig. 11.

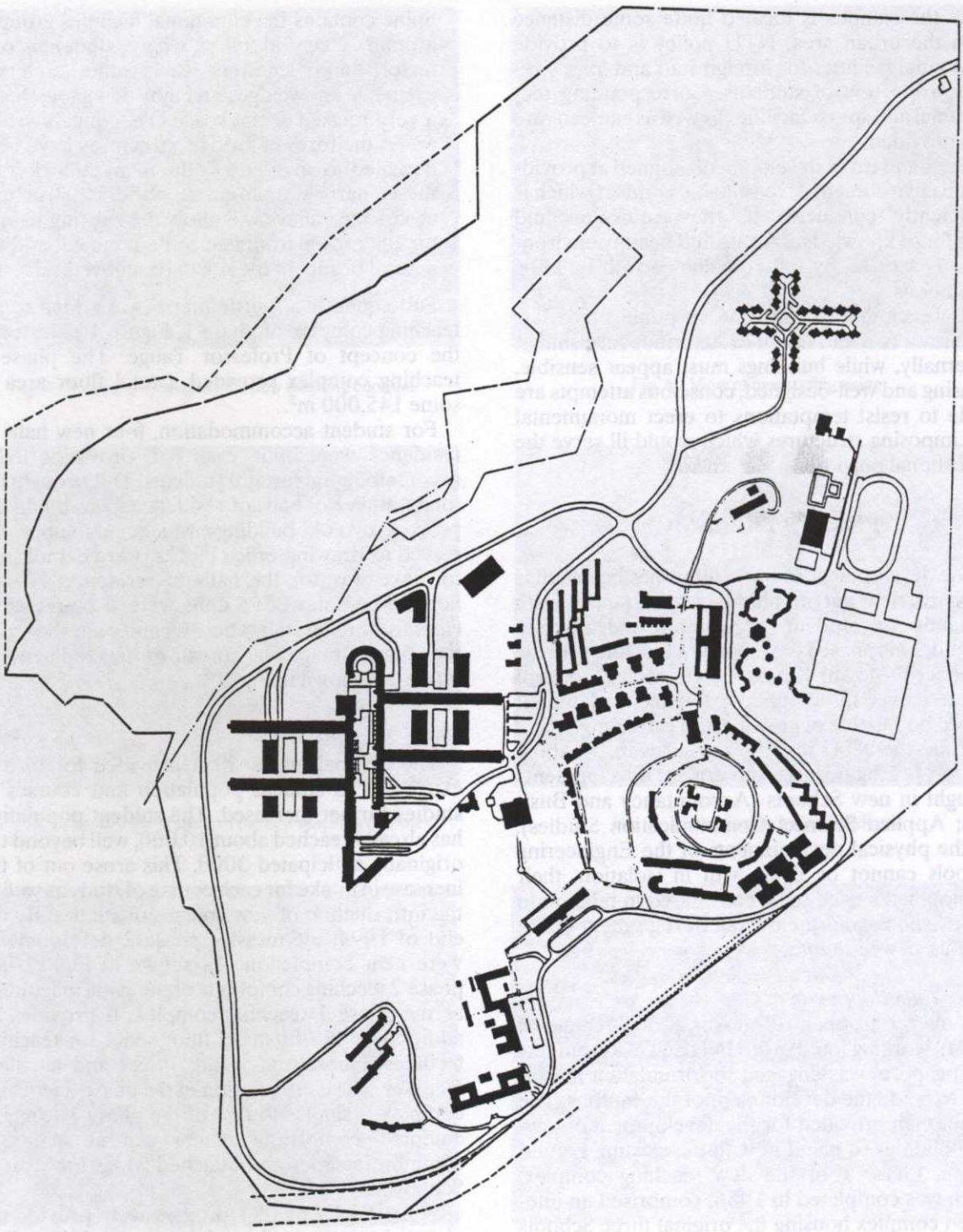

Fig. 9. Buildings up to phase 1.

Concurrently, the infrastructural services are being expanded or upgraded to keep pace with the building works.

Phase 3 expansion

As the student population is expected to continue to grow, plans are being made for further expansion. In accordance with the recommendations of a specially appointed Committee on the University's Future Directions, the student population is expected to expand to 15,000 in the next few years.

Consultants (Kallmann McKinnell & Wood Architects, Inc., of Boston, USA, working jointly with INDECO Consultants of Singapore) have been appointed to prepare a new master plan for the campus. The new master plan is to take into consideration the integration of new facilities with existing facilities and to allow for orderly expansion.

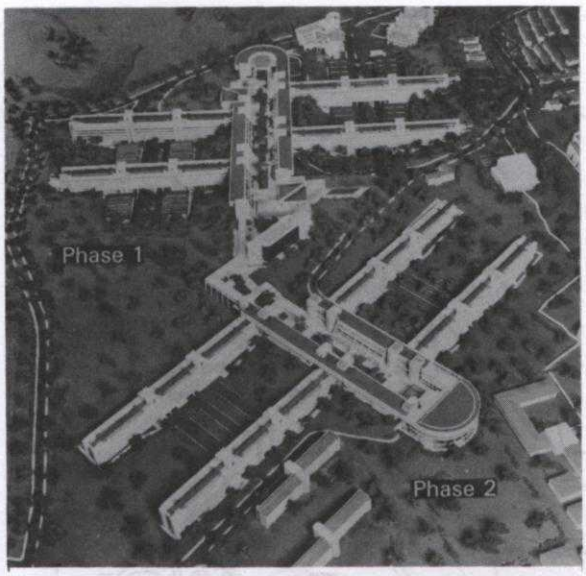

Fig. 10. Configurations of teaching complexes phases 1 and 2.

The new plans will cover further teaching complexes, halls of residence for students, staff quarters, and expansion of supporting facilities such as sports and recreation facilities (see Fig. 1). Various other related issues are also being studied. These include problems such as vehicular traffic flow within as well as in and out of the campus, and pedestrian movements.

INFRASTRUCTURAL SERVICES

As the words imply, infrastructural services are provided for the purpose of serving other developments. They do not normally constitute independent projects even when installed under separate construction contracts. Accordingly, the development of infrastructural services is linked to the requirements of the other developments that they serve. Each building project may require diverse services, such as electrical power supply, water supply, gas supply, sewerage system, telecoms system, drainage and roadways.

There are two main aspects for consideration in the provision of infrastructural services: (i) the particular requirements for detailed implementation; (ii) the broad programme of development.

Particular requirements

For each building project, the specifications for infrastructural services are based on the particular needs of the building project which is to be served by the services. The diverse nature of the infrastructural services calls for different specialist knowledge in each case. This generally results in separate construction contracts for installation of infrastructural services. Each service may also be implemented at a different time to tie in with the main building schedules. As the services generally extend beyond the building worksite, their installation often results in inconvenience to the general public. This inconvenience could be spread out over quite a period of time.

Broad programme

As the campus building programme progresses in phases or stages, the infrastructural requirements generally increase. It would be ideal if infrastructural requirements could be projected ahead. The seeming advantage would be that the services could be provided for and installed ready for use whenever required. There are difficulties, however. The projected plans may change substantially, rendering any installed services useless. Providing well ahead of time would also require financial resources which are normally not yet available.

One other possibility which has often been mooted is the construction of common underground tunnels with the view of accommodating all future services. This would have the advantage of avoiding the inconvenience, especially to road users, of periodically opening up roadside or roadways for installation of services as the demands arise. However, in practice, it is often not possible for different services to share a common tunnel or to be installed at adjacent parallel tunnels as there are requirements of keeping certain services away from each other. For example, for health reasons, sewer lines must be kept well away from water-supply lines. Generally, telecom lines have also to be kept apart from power-supply lines to avoid interference. Different regulatory bodies also require different depths and gradients for services they are concerned with. Hence, in addition to the difficulty of obtaining advance funding, technical requirements would also pose difficulties to the implementation of common service tunnels.

LABORATORIES AND COMPUTING FACILITIES

The development of laboratories is under the control and direction of the respective Deans of the Schools. With the emphasis on practice-oriented engineering, the NTU places great importance on laboratory development. At the initial stages of planning, the Schools were presented with a rare opportunity to develop laboratories afresh. In order to benefit fully from this opportunity staff members visited many laboratory facilities of overseas universities and engineering research stations to gather information relevant to the design and development of the NTU's laboratories. Advice was also obtained from many prominent visitors.

As it was difficult to predict precisely future needs, flexibility was built into the design of the laboratories. This was reflected in the freedom of space which could cater for different equipment or different arrangements of equipment.

Correspondingly, sufficient service outlets such as power-points were provided to meet possible

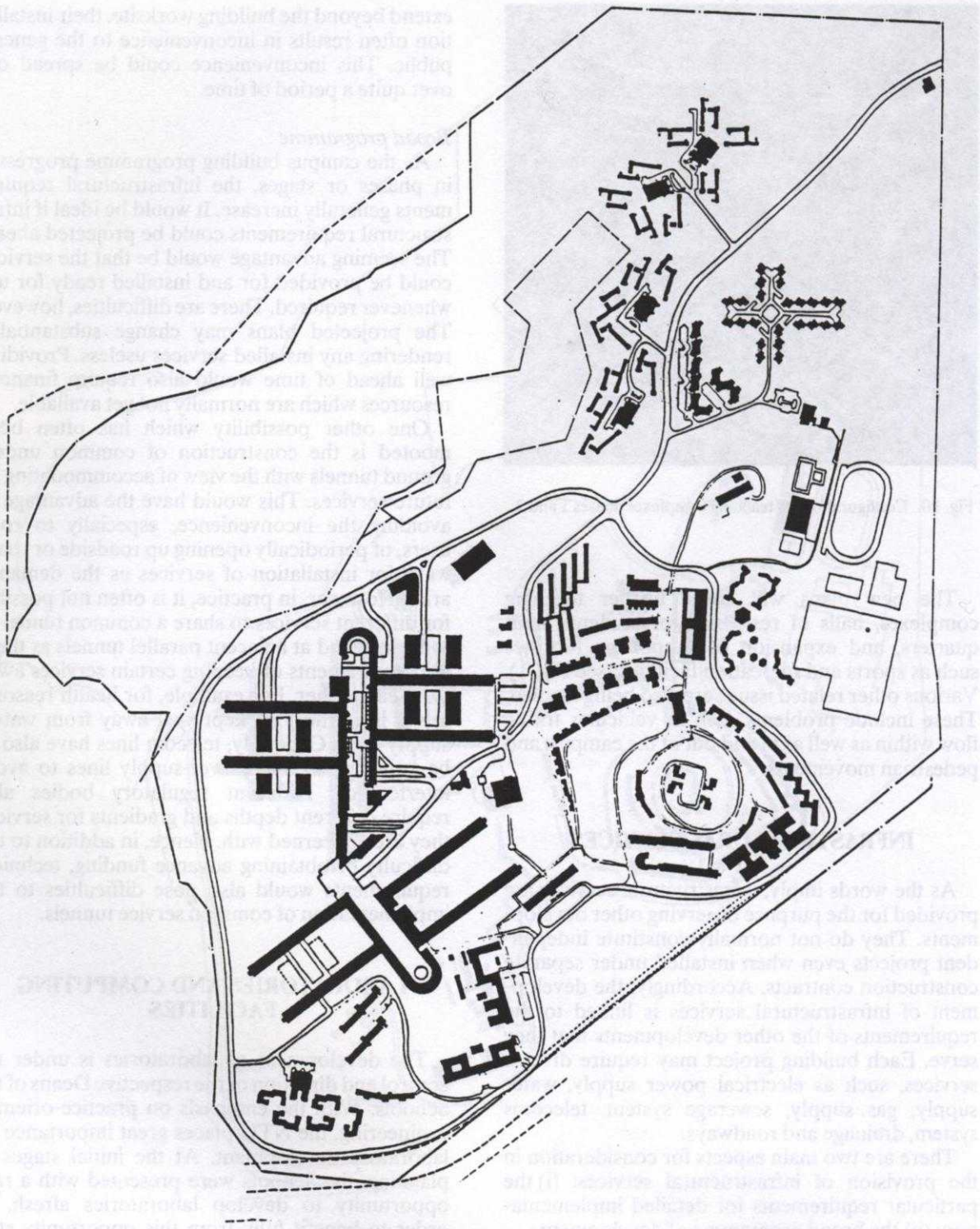

Fig. 11. Buildings up to phase 2.

future needs. Other requirements which were ascertained included provision of sufficient storage space and convenient access and overhead lifting facilities for movement of materials and heavy equipment in and out, as well as within, the laboratories.

The phased development of the campus includes provision for corresponding increases in laboratory space. However, new design and construction works necessarily take a considerable time to complete. In the interim periods, one of the concerns of some Schools is shortage of laboratory space until the new facilities are completed. This appears to be an ever-present phenomenon in an institution which is growing rapidly.

The specific issues of the Schools are discussed in detail in the paper 'Development of Laboratories and Computing Facilities' which indicates the

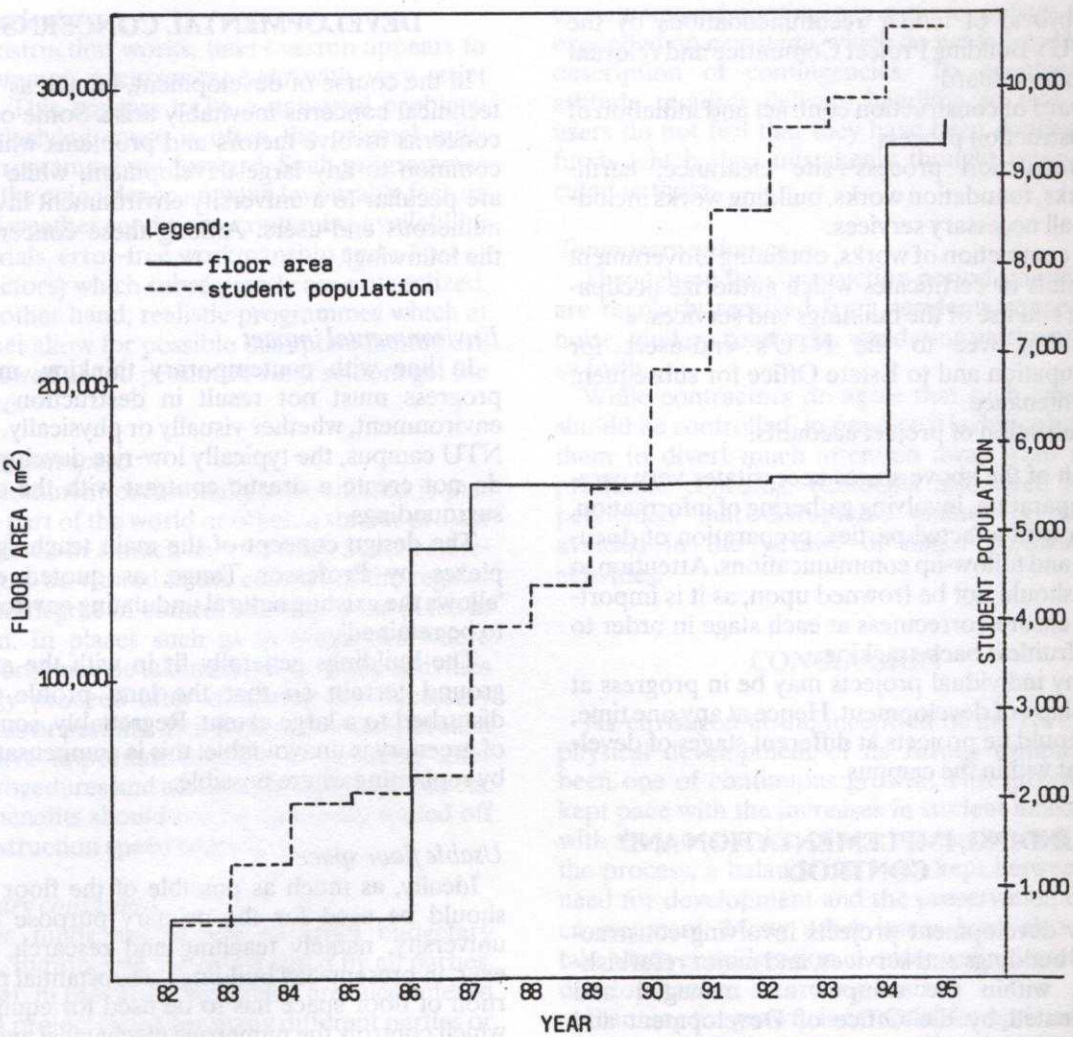

Fig. 12. Increase in floor area and student population.

variation in approaches among the various Schools.

Computing facilities have also been continuously expanded and upgraded to meet increasing needs and to move towards the realization of an intelligent campus. Details on this aspect of development are also contained in the paper 'Development of Laboratories and Computing Facilities'.

DEVELOPMENT PROCESS

When the need for a new development has been established, the development process is initiated. For building development projects, the development process goes through many stages. Some stages can only proceed upon the successful outcome of a preceding stage; whereas other stages may overlap or proceed in parallel in order to save time.

In brief, the major stages are:

- Appraisal of requirements of the eventual end-users.
- Identification of site location and physical configurations.
- Preparation of preliminary estimates.
- Application for funding. (Application is made to relevant Government bodies with detailed justifications.)
- Subject to the successful outcome of the funding application, briefing of consultants on detailed requirements and constraints.
- Preliminary investigations such as site surveys, geotechnical investigations and location of existing utility services.
- Preparaton of concept plans and estimates.
- Presentation of concept plans and estimates to the NTU's Building Project Committee.
- Approval of concept plans and estimates by the NTU's Building Project Committee.
- Obtaining approvals from relevant governmental authorities which regulate planning provisions and building provisions.
- Detailed design.
- Preparation of construction tender documents.
- Obtaining competitive tenders.
- Tender evaluations and recommendations.

- Approval of tender recommendations by the NTU's Building Project Committee and relevant Tenders Board.
- Award of construction contract and initiation of construction process.
- Construction process—site clearance, earthworks, foundation works, building works including all necessary services.
- On completion of works, obtaining Government permits or certificates which authorize occupation and use of the buildings and services.
- Handing-over to the NTU's end-users for occupation and to Estate Office for subsequent maintenance.
- Finalization of project accounts.

Each of the above stages necessitates very careful preparation, involving gathering of information, liaison with affected parties, preparation of documents and follow-up communications. Attention to detail should not be frowned upon, as it is important to ensure correctness at each stage in order to avoid fruitless back-tracking.

Many individual projects may be in progress at each phase of development. Hence at any one time, there could be projects at different stages of development within the campus.

FUNDING, IMPLEMENTATION AND CONTROL

New development projects involving construction of buildings and services, and major refurbishments, within the campus are managed and coordinated by the Office of Development and Planning which was set up within the NTU in 1991. The office liaises with end-users (Schools or Departments for which the facilities are to be developed) to obtain their particular requirements necessary to preset applications for funding.

Consultants (architectural, engineering and quantity surveying) are engaged to design the projects and supervise their construction. They also act on behalf of the NTU in submission of plans to relevant governmental authorities and to obtain their approvals and permits.

Key issues are referred to the NTU's Building Project Committee. Strict financial control is exercised, as in all cases where public funds are employed for development. All tender recommendations are submitted for the consideration and approval of the Building Project Committee and the relevant Tenders Board.

The extensive and continuing developments require heavy capital investment. These developments have been possible because the Government places importance on investing in educational facilities which contribute to the development of the skills needed for a dynamic economy. Funds are provided on the basis of the needs of approved courses of study and on the student intakes. The funds are for buildings and services, teaching and computer equipment, and library materials.

DEVELOPMENTAL CONCERNS

In the course of development, human as well as technical concerns inevitably arise. Some of these concerns involve factors and problems which are common to any large development, while others are peculiar to a university environment involving numerous end-users. Among these concerns are the following.

Environmental impact

In line with contemporary thinking, material progress must not result in destruction of the environment, whether visually or physically. At the NTU campus, the typically low-rise developments do not create a drastic contrast with the natural surroundings.

The design concept of the main teaching complexes by Professor Tange, as quoted earlier, 'allows the existing natural undulating environment to be retained'.

The buildings generally fit in with the existing ground terrain so that the land profile is not disturbed to a large extent. Regrettably, some loss of greenery is unavoidable; this is compensated for by replanting where possible.

Usable floor space

Ideally, as much as possible of the floor space should be used for the primary purpose of the university, namely teaching and research. However, in present-day buildings, a substantial proportion of floor space has to be used for equipment which controls the numerous mechanical and electrical services. As far as possible, such equipment should use space located away from prime areas.

Furthermore, in a university with large pedestrian movements, substantial allowance needs to be made for circulation space, which also reduces the actual teaching and research space.

Coping with end-users' changes

Again, ideally, the facilities should be designed to meet fully the end-users' requirements. However, in practice, these requirements never seem to be completely known at the time of design. This results in requests for changes being brought up while construction works are well in progress.

This could be quite disruptive to the construction schedule and could contribute to cost overrun. The problem appears due to the combination of three major factors: (i) project implementation necessarily takes place over a period of time; (ii) rapid technological developments give rise to new requirements even before the project can be completed; and (iii) changes in personnel representing end-users. Each new representative of the end-user seems to have a different opinion of what are the essential requirements for the project. This difficulty can only be minimized by the exercise of strict discipline.

Project schedules

In construction works, time overrun appears to be a common occurrence, even with very strict control. This appears to be a universal problem. The underlying cause is often the original optimistic programme put forward. Such programmes assume the coincidence of many favourable factors (normal weather conditions, continuing availability of materials, error-free workmanship and a host of other factors) which subsequently are not realized. On the other hand, realistic programmes which at the outset allow for possible disruptive factors are often viewed as too pessimistic and seldom get the go-ahead.

Construction speed

One comment occasionally encountered is that in some part of the world or other, a similar project is completed in a much shorter time. Such a statement must be viewed in the context of the regulations and degree of control existing in the place in question. In places such as in Singapore where regulations must be taken seriously, some activities can only proceed after obtaining the necessary approvals or permits. This more cautious approach does have important benefits in ensuring safer work procedures and acceptable finished products. These benefits should not be recklessly traded off for construction speed records.

Budgetary constraints

Public funds are subject to strict budgetary control. In principle, this is accepted by all parties. However, in practice great strains are encountered where a project caters for many different parties or end-users. The sum total of all expectations would normally exceed what the budget can support. It requires careful restraint of all parties in order to keep costs (and tempers) under control.

Provision for contingencies

In the face of uncertainties, project budgets allow for contingencies for unforeseen circumstances. However, it is a common occurrence for end-users to view unused contingency sums as savings to be expended on new items which do not fall under the description of contingencies. To counter this attitude requires delicate handling so that end-users do not feel that they have been deprived of funds which they mistakenly thought were allocated to them.

Temporary nuisance

Throughout the construction period, complaints are regularly received from residents concerning noise, mud on roadways, wandering workmen and so forth.

While contractors do agree that such nuisance should be controlled, in practice it is difficult to get them to divert much attention away from more profitable concerns. Residents also need to be persuaded that disruptions cannot be totally avoided in the vicinity of major construction activities.

CONCLUSION

As envisaged at the inception of the NTU, the physical development of its Jurong campus has been one of continuous growth. This growth has kept pace with the increases in student intake and with the introduction of new courses of studies. In the process, a balance has been kept between the need for development and the preservation of the environment. Many other issues have also been taken into consideration in order to implement the development on an orderly basis.

Planning for growth is essential for optimum use of land and efficient operation. For orderly development, there must constantly be co-ordination between consultants, contractors and user Departments or Schools.

Acknowledgements—Information on laboratory development was provided by the Deans of the Schools of Civil and Stuctural Engineering, Electrical and Electronic Engineering, and Mechanical and Production Engineering.

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