# China's Two Tropical Architecture: Climate, Techno-Scientific Regime, and Global Socialism in Southern China and Sub-Saharan Africa, 1955-78

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## Abstract

Moving beyond the former architect-centric narrative, this paper offers an alternative techno-political history of Maoist China's two tropical architecture, i.e. its subtropical architecture in the hot-humid Southern China and its overseas architectural aid in the decolonizing Africa in the Cold War, in a transnational geo-political, cultural and techno-scientific context. Based on China's state archives, institutional grey literature, African local reports and other secondary sources, it looks into the much lesser-researched actors, practice and things, especially the agency of some non-architect experts and their institutions in the tropical knowledge production around industrial projects. Drawing on theories of Science, Technology and Society (STS) and critical temperature studies, it develops the notion of "techno-scientific regime of architecture" to reveal how China's two architecture was both concurrent and co-constitutive. It contributes to not only the existing literature of postcolonial urbanization differentiated by socialist actors, but also recent scholarly concerns about low-carbon cooling technologies in the built environment.

**Keywords:** Postcolonial Urbanization; China; Africa; Climate; Techno-Scientific Regime; Global Socialism; Tropical Architecture.

## Introduction

With the growing international attention devoted to China's contemporary development aid in Africa and Asia[1], the China-aided built environment in the decolonizing tropics in the Cold War has increasingly become the focus of recent architecture literature[2]. Meanwhile, in the contexts of globalization and Anthropogenic environmental crisis, with a rising demand of the developing world for its regionalist identity[3] and a more energy-efficient building climatic control[4], a greater number of architectural scholars have also shed new light on the trajectory of climate-responsive modernist architecture since the early-1950s in subtropical Guangzhou[5]. However, the existing scholarship tends to only focus on either Maoist China's internal or external tropics, but hardly teases out the transnational interplay between them. If any, those scholars primarily adopt "an architect-centric narrative", which assumes that "only architects produce architecture"[6], to trace the cross-border mobility of postwar architectural modernism between China and the South[7], while largely downplaying the involvement of other actors, such as thermal engineers, sanitary experts and building scientists, their institutions and expertise in shaping the production of the built environment.

Based on fresh sources from China's state archives, institutional grey literature, African newspaper reports and other secondary sources, this article offers a nuanced narrative of Maoist China's tropical architecture by scrutinizing a series of much lesser-researched actors, knowledge and things in a transnational geo-political, techno-scientific and institutional context. Drawing on theories of Science, Technology and Society (STS)[8] and critical temperature studies[9], I develop the notion of "techno-scientific regime of architecture" to demonstrate how Chinese architectural technologies, urban typologies and thermal knowledge were adapted to the climatic, geo-political and socio-economic conditions of postcolonial Africa. By revealing how China's internal and external tropical architecture were both concurrent and co-constitutive, it contributes to not only postwar urban histories of China[10] and the Third World differentiated by socialist actors[11], but also recent scholarly concerns about the sustainable built environment[12].

## China's External and Internal Tropics: The Techno-Scientific Regime of Architecture

It is not difficult to discern that the "tropics", "colonies", "developing world", "Global South" and "Third World" are often overlapped geographically and politically. Since the 18th century, the tropics, which constitutes nearly 40% of the globe, has been constructed by the European as both a pestilential and pastoral Other[13]. On one hand, the hot-humid climate was seen as the cause of Europeans' high mortality rates, and the tropics was thus rendered a negative place with inherent backwardness[14]. On the other, assuming the tropics as an Edenic paradise with rich natural resources legitimized Europeans' civilizing mission and colonial exploitation[15]. The complex of Euro-centric ideas, discourses and knowledge gave birth to a series of modern disciplines, such as tropical botany, medicine and architecture[16]. Thus, as a colonial construct, "tropical architecture" emerged from a transnational network of professionals, institutions and things between metropolis and colonies, through which various new ideas, techno-scientific knowledge and governmental strategies were experimented and institutionalized to ensure the ongoing metropolitan influence in the tropics even after decolonization[17]. However, to offset the influence, postcolonial tropical countries also strategically made use of assistance from other donors as alternative paths to modernity. The development aid by global socialist actors from Soviet Union and Eastern Europe, was accepted by the tropics for a new source of expertise and a better negotiation with other donors, which challenges the standard narrative of postcolonial urbanization merely as the result of global capitalism[18].

Since the postcolonial tropics was a contested arena with fierce competition among various old and new donors, recent scholarship has also shed light on a third category of emerging aid donors, such as Israel, socialist China and Japan[19], that are largely peripheral to the studies on either former metropolis or the socialist bloc. The unique role of socialist China in the global socialism, especially its political alignment and then conflict with Soviet Union[20], makes China's overseas aid increasingly become the focus of recent literature. In other words, Maoist China's engagement with the decolonizing tropics waxed and waned along with its internal and external geo-politics, including Cold War politics, its competition with Taiwan and dispute with Soviet Russia. In the early-1950s, as a junior member of the Soviet-led alliance, China's aid was largely confined to several socialist fraternal countries, including Vietnam, Mongolia and North Korea. Since the Bandung Conference (1955), the aid has been extended to more newly-independent Asian countries, such as Cambodia, Myanmar, Nepal and Sri Lanka. After the Sino-Soviet Split (1960) amid the conflict over the global leadership of communist revolutions, when China attempted to lead a united "Third World challenge" to two superpowers[21], Guinea became the first African nation-state to welcome China's technical assistance, followed by Mali, Ghana, Tanzania, Congo and others. By 1976, there have been over 60 countries worldwide receiving China's architectural aid, among which industrial infrastructures accounted for over 70%[22]. As pointed out in *Eight Principles* (1964), China's assistance is "never to deepen recipients' reliance on any blocs", but to help them "develop self-reliant national industries"[23]. However, recent scholarship on China's architectural aid mostly looks into monumental cultural projects rather than those industrial buildings.

China's internal tropics, the subtropical Lingnan region (today's Guangdong and Guangxi provinces), has also long been constructed as an unhealthy Other. Since the 13th century, the subtropical disease of *zhang* [miasma] has long been believed to be endemic in Lingnan, and mostly attributed to *re* [heat], *shi* [humidity] and *du* [poison] there[24]. In response to the heat and humidity, traditional Lingnan architecture, such as Xiguan houses with internal courtyards connected by shaded passages for cross-ventilation, embodied a strong site-specific feature of climatic adaptability. Due to the geographical remoteness, cultural marginality, long-term self-governance and international trade, Lingnan was also characterized as a cultural Other, with a unique hybridization of regionalism and cosmopolitanism. In the early-19th century, it was filled with eclectic-style architecture, such as a blend of Ionic orders and cast-iron components in traditional arcades[25]. However, after the Opium War, the British concession in Canton, i.e. Shameen Island, was built as an exceptional enclave for colonial lifestyles, which was surrounded by "unclean" and "uncivilized" Chinese masses living in squalor. Canton's extra-territorial built environment exposed Chinese intellectuals to Western techniques and knowledge, stimulating their strong nationalist sentiment of "cultural borrowing to cure China's socio-political ills"[26]. Canton thus became the laboratory of modern China for the localization of imported technologies, municipal regulations and political thoughts. In the republican era, Western-trained reformers boldly experimented with modern planning ideas, municipal systems, sanitary theories and regulative norms to build a hygienic, healthy and civilized Canton[27]. With the increasing need for construction expertise, more architectural schools, research institutes and professional organizations were established in the 1930s.

Different from the dominant Beaux-Arts-inspired pedagogy by Penn-trained Chinese architect Liang Sicheng at Northeast University (1928-), Lingnan's first architecture school, Xiangqin University (1932-) established by Lyon-trained Cantonese architect Lin Keming (1901-99), paid particular attention to architectural tectonics and practical engineering. Although the Chinese Renaissance style was defined by the Nationalist Government in 1927 as a stylistic guideline for all public buildings[28], modern architecture in Lingnan embodied an alternative modernist strategy of adapting Chinese-style forms and vernacular wisdom of passive cooling to the subtropical climate. For example, at Sun Yat-sen Memorial Hall (1931) in Guangzhou, the cool air from the basement could enter the auditorium via the underground tunnel, and the rising heated air due to the stack effect would thus be let out through a row of ventilating openings under the pitched roof overhang (figure 1). After PRC's taking over of Canton in 1949, with the reform of education system according to a Soviet model, Xiangqin University was renamed as South China Institute of Technology (SCIT) in 1952. However, SCIT continued its emphasis on a technology-oriented pedagogy, attracting German-trained Cantonese architect Xia Changshi (1903-96) and Chen Boqi (1903-73) to join in. Xia's 1950s climate-responsive modernist practice and subtropical knowledge production in Guangzhou, which departed from the Beaux-Arts doctrines of symmetrical composition, central axis and monumental volume and saw the local climate, topography and functional requirement as the dominant factors in the design of architectural forms, have been described by recent scholarship as an innovative endeavor of "*Lingnan Xuepai* [South China Style]" that constructed a transnational dialogue between global tropical architecture and Lingnan regional culture[29]. By tracing Xia's professional careers, these scholars reveal how Xia's climatic design adaptively absorbed the globally-circulated Tropical Modernism by French architect Le Corbusier in South Asia and Latin America, and then even set up a paradigm of climate-sensitive design language for the 1970s foreign-trade projects in Guangzhou by a younger generation of Cantonese architects.

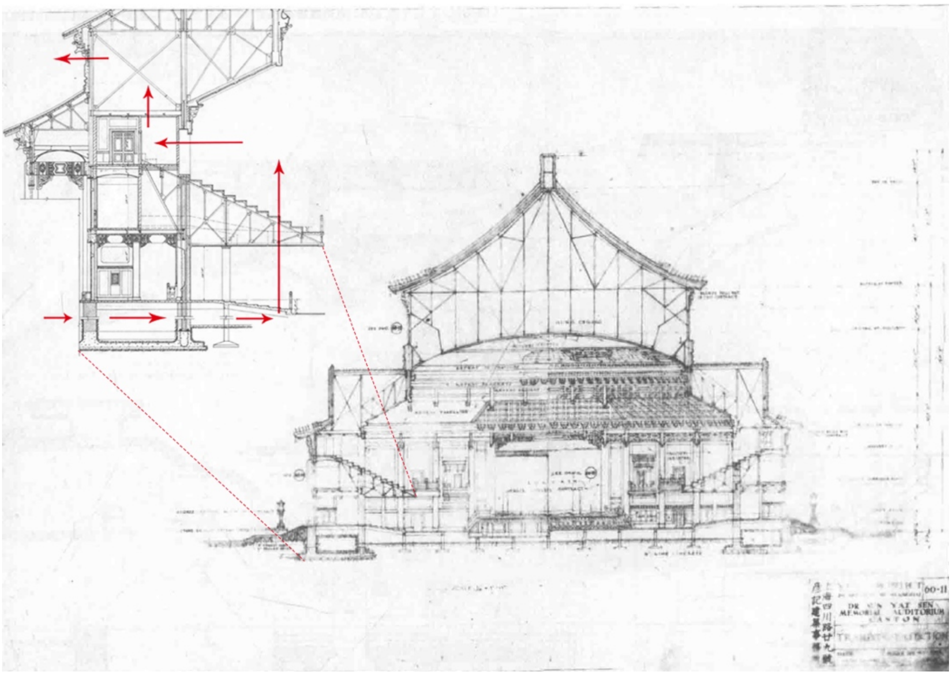

Figure 1: The diagram of cross-ventilation of Sun Yat-sen Memorial Hall, Guangzhou, 1931
Source: Redrawn by the author based on Guangzhou Municipal Design Institute Archives.

Since China's internal and external tropical architecture took place almost concurrently, a few scholars have started to investigate potential transnational exchanges between them, and showed how Chinese architects exported a domestic form of "Chinese-ness" in the postcolonial tropics while absorbing climate-sensitive modernist styles there to facilitate Lingnan's modern architectural development[30]. However, they still tend to largely overemphasize the agency of a few architects at the expense of that of other non-architectural experts and institutions in the architectural production. This partly explains why they primarily focus on aesthetic qualities of iconic cultural buildings, while industrial projects which constituted the backbone of Maoist China's tropical architecture, don't get enough scholarly attention. Thus, this paper offers a nuanced understanding of the techno-politics of China's two tropical architecture, by looking into less-researched actors, practice, knowledge and things, including the involvement of not only non-architect experts like sanitary experts and thermal engineers, whose activities were situated in a broader transnational techno-scientific network of trans-disciplinary institutions, but also other techno-scientific knowledge related to the production of industrial buildings, such as sanitary discourses of thermal comfort, and environmental technologies of sun-shading, insulating and ventilating.

To move beyond the architect-centric narrative, the notion of "techno-scientific regime of architecture" is developed as a metallurgical approach to aligning architectural and non-architectural, and human and non-human actors into a contingent network. The term "regime", i.e. a coherent set of regulative, normative and cognitive rules that guide a complex of activities of both technical and non-technical groups[31], has been increasingly adopted by social sciences scholars[32] to capture the "entanglement of institutions, people who run them, their guiding ideologies, technical artefacts produced by them, and political goals they pursue" in the exercise of power[33]. In this article, the notion is used to better understand the interlinked sets of individuals, their institutions, architectural technologies, thermal comfort standards, sanitary discourses, geo-political agendas, labor arrangement, regulative norms and a body of expertise that work together to govern the production of China's two tropical architecture. Through the techno-scientific regime, the tropics became a testing field to prove the global transferability and applicability of Maoist China's path to industrialization and modernity, rendering China a new center of development expertise.

## Subtropical Lingnan: Heat, Climatic Design and Industrialization

Instead of idealizing Xia as a design genius who set the climate-responsive paradigm in Lingnan, this article argues that his practice could be seen as inextricably linked with Maoist China's state-led subtropical building research in the 1950s and 60s. With the booming of urban construction during the First Five-Year Plan (1953-57), to improve efficiency and avoid wasting resources[34], China Academy of Building Research (CABR) was set up in 1956 to take charge of all building research programs to figure out how to better suit local conditions, lower the cost and serve the industrial production. Under the Party's goal of "a greater, faster, better and more economical socialist construction", the mid-1950s research on the building climatic zoning, which attempted to collect climatological data and establish site-specific design norms for public buildings in various climatic zones nationwide, became an urgent task[35]. As pointed out at the Conference of National Building Climatic Zoning (1958) in Beijing, to ensure the "highest efficiency and productivity of everyone in the *Great Leap Forward*", we must work on the building climatic zoning to create the "ideal working environment for all laborers, especially those in hot-humid areas…However, our subtropical climate is rarely found in Russia, which makes it impossible for us to directly adopt Soviet norms"[36]. Trans-disciplinary experts from different state-owned institutions were involved at the conference, including the architect Xia Changshi and building scientist Lin Qibiao (1925-2006) from SCIT, thermal engineer Hu Lin from CABR, and sanitary expert Yang Mingsheng from Shanghai Medical College.

At the conference, Xia shared his design experience through long-term subtropical practice. As he wrote, "people living in the hot-summer-and-warm-winter climatic zone of Lingnan often used bamboo curtains or pergolas for cooling, which is fire-prone and not economical, the sun-shading design in Guangzhou is thus of great importance"[37]. According to Xia, the sun-path diagram, solar altitude and azimuth of Lingnan should be carefully scrutinized to precisely calculate and flexibly adjust the specific size, location, orientation and angle of shading devices, which not only makes use of the natural light to illuminate certain spaces, but also selectively shields other rooms from the strong sunshine. In his design of Physiology Building (1953) at Zhongshan Medical College (ZMC), the façades were covered with a blend of horizontal and vertical cast-in-situ concrete shading panels, which themselves had small air openings for letting heat out. At the First Affiliated Hospital of ZMC (1955), Xia firstly experimented with the design of prefabricated concrete louvers, which were fixed on the cast-in-situ concrete beam, to lower the cost and shorten the construction time. It was not until the design of Basic Building of ZMC (1957) did Xia use prefabricated concrete in the construction of all shading devices, with horizontal louvers for offices in the east wing, and integrated horizontal-and-vertical louvers for laboratories in the west one to prevent the glare from affecting the use of microscopes. Xia's subtropical practice was producing a systematic body of prefabricated techniques to realize better shading performance with a lower cost (figure 2), that could be seen as part of the pursuit of "a greater, faster, better and more economical socialist construction".

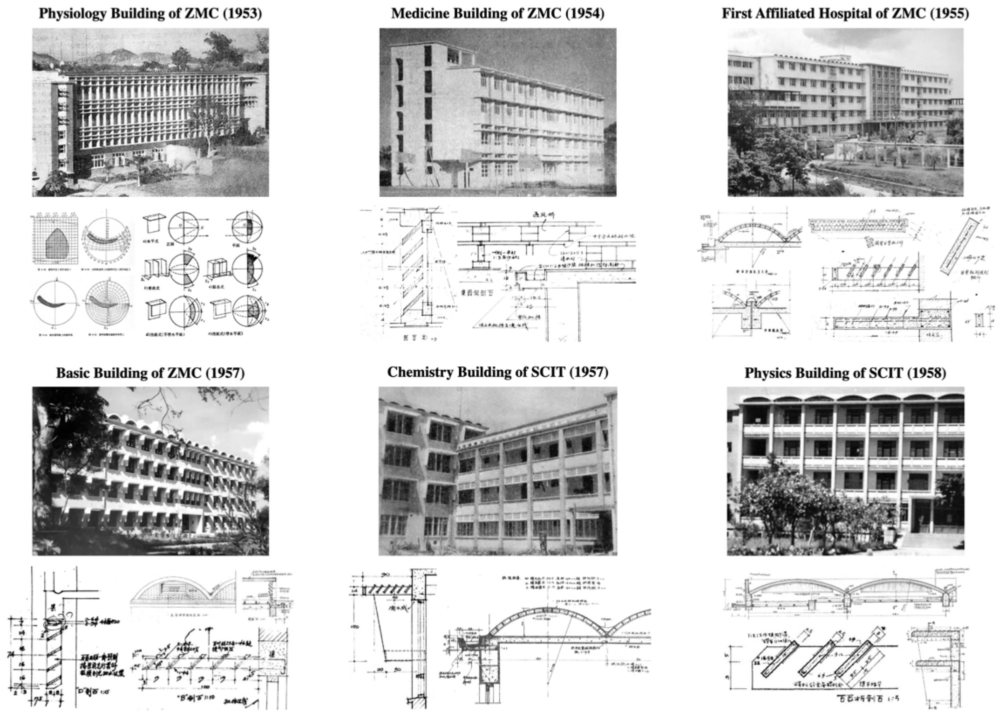


Figure 2: Xia Changshi's climate-responsive projects at Zhongshan Medical College and South China Institute of Technology, Guangzhou, 1953-58.
Source: Compiled by the author based on South China University of Technology's Architectural Archives.

In 1958, the Subtropical Building Research Laboratory (SBRL) was co-founded by Xia and his 2 colleagues at SCIT, i.e. Chen Boqi and Lin Qibiao, to focus on the more efficient environmental technologies of sun-shading, ventilating and insulating that could be widely-applicable in the subtropics. Different from Xia, Chen paid particular attention to how the layout, interval, orientation and open space of buildings in the entire district could influence the cooling performance[38], while Lin led a team of students to conduct the on-site measurement and calculation on thermal parameters of building components with different sizes and materials in self-built laboratories[39]. Their research benefited Xia's improvement of his subtropical practice. Inspired by Lin's finding of the influence of the height of elevated roof on the indoor temperature, the quadrant brick arched roof of the First Affiliated Hospital (1955) was transformed into the semi-circular one with insulating layers of the Basic Building (1957), which was built with the reusable sliding formwork[40]. Besides SBRL, Xia's practice was inextricably intertwined with the research at another institution, i.e. Xi'an Institute of Architecture and Construction (XAIAC).

With Soviet Union's large-scale technical assistance for China's socialist industrialization, a series of Soviet experts, including Soviet thermal engineer G.A. Maksimov and Soviet physiologist M.S. Goromosov, were invited by CABR to guide Chinese professionals in the subtropical building cooling research. In early-1958, Maksimov, together with the faculty at XAIAC, such as Xia Yun and Wang Jianhu, surveyed 27 industrial buildings across Guangzhou, Shanghai, Nanjing and Wuhan. They primarily focused on the passive cooling strategies adopted by ordinary Chinese users in their everyday practice[41]. As Xia Changshi recalled, the Basic Building of ZMC was also surveyed by them, and Maksimov suggested that Xia could add an air opening on top of the arched roof, which would facilitate cross-ventilation without costing too much. The suggestion was well received by Xia[42]. However, as Maksimov pointed out at the Conference of Building Cooling Issues (1958) at XAIAC, the most urgent issue for Chinese professionals is to firstly "set the criteria of the ideal indoor microclimate in hot-humid regions through the collaboration of both architects and sanitary experts". According to him, "people's feeling of thermal comfort is mainly determined by the heat balance of human body. If the balance is broken, abnormal physiological responses will emerge. Thus, maintaining an interior microclimate within the comfort zone is what architects should do"[43].

The heat-balance theory, along with other thermal notions like "effective temperature" (ET) and "heat stress index" (HSI), was accepted by Chinese professionals. As Wang Jianhu argued, "the notion of ET, that captures the influence of a linked set of air temperature, relative humidity and air velocity on people's sensation of warmth, tells us that the immoderate temperature, humidity, airflow and radiant heat would all destroy the heat balance of human body. To keep laborers comfortable and lower their fatigue in hot-humid regions, these variables should thus be comprehensively considered when working on the building climatic zoning"[44]. Wang and his colleagues adopted the notion of HSI, which refers to the thermal strain on the human body whose thermoregulatory system responds to a rising temperature[45], to evaluate the working environment. In this notion, the building is reduced to a sealed box that could be controlled by a few well-defined parameters, while the body is seen as a 170cm-65kg-35°C skin-sealed machine of radiator, thermostat and humidifier. The higher the HSI is, the poorer the working environment will be.

In fact, these notions were firstly developed by American Society of Heating and Ventilating Engineers (ASHVE) based on their thermal comfort experiments in a sealed chamber, in which all these environmental variables, such as temperature, humidity and airflow, could be strictly controlled by their air-conditioning technologies[46]. As the U.S. thermal researcher Douglas H.K. Lee observed, "three modes of heat exchange between the body and its surroundings are radiation, conduction and water vapor transfer…Thus, the net effect of temperature, humidity, air movement and radiation is called the heat stress upon the individual… When man fails to lose heat at the same rate as gaining heat, the results are disastrous"[47]. According to assumptions of heat-balance model, building-machine and body-machine, ASHVE's thermal researchers, such as C.P. Yagloglou, believed that the bodily heat regulation could only be maintained by measuring the "heat inputs" of environmental conditions of the laboratory and "heat outputs" of people's physiological responses[48]. When a broad field of possibilities of the complex world was simplified to a narrowly-defined set of quantifiable variables, ASHVE's thermal comfort zone was defined in "a quite narrow range of environmental variables" and was quickly standardized as the universalized measure for almost all climatic zones worldwide. A variety of climatic types worldwide classified by ASHVE, whether the hot-humid or hot-dry climate, were deemed as always uncomfortable, and people living there thus cannot keep comfortable without the proper intervention of certain environmental technologies. Since no natural climate could deliver the ideal man-made weather produced by air-conditioning, the entire world became potential markets for the air-conditioning industry[49]. Similarly, for Chinese professionals at SCIT and XAIAC, these notions which prove the causality between indoor micro-climate, thermal comfort and industrial productivity (figure 3), could help them legitimize and promote their expertise of thermal engineering and climatic design as a system of widely-accepted subtropical knowledge in the context of *Great Leap Forward* (1958-62).

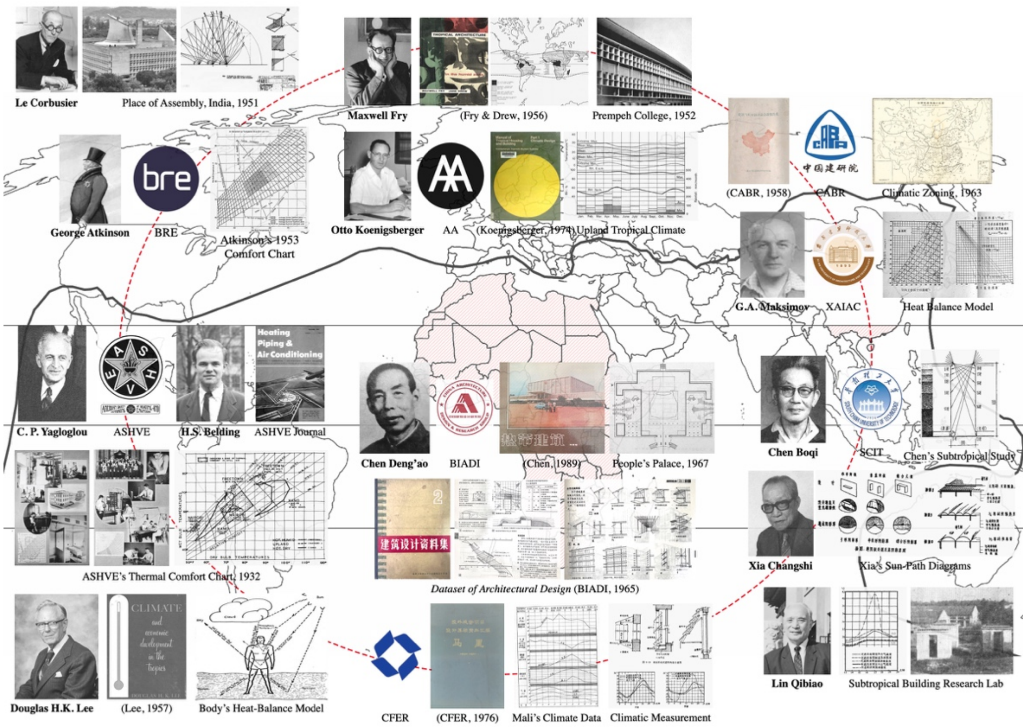


Figure 3: The global circulation of thermal comfort knowledge among North America, Western Europe, Soviet Russia, China and West Africa.
Source: Mapping compiled by the author.

However, in the early-1960s, influenced by Soviet physiologist M.S. Goromosov, Chinese professionals started to realize the failure of ASHVE's narrow comfort standards to consider the regional climatic disparity and people's different physiological adaptation[50] As Goromosov argued, when establishing the criteria for an ideal interior microclimate, it is necessary to "consider not only thermo-metric data, but also different settings of people's thermoregulatory system, such as cardiovascular reactions, muscle tone and sweat secretion processes, in different climatic zones[51]". Through the fieldwork across Guangzhou, Wuhan and Haikou, Chinese professionals discovered that inhabitants in Wuhan had a much wider range of thermal adaptability than those in Guangzhou, while people's genders and occupations didn't significantly influence their thermal sensations. They highlighted the cooling power of the flowing air rather than the narrow comfort zone, which was not so different from the argument of European industrial physiologists in the 20th century that "natural ventilation creates a greater sensation of freshness, and a workplace should be diverse in its temperature rather than monotonous[52]". However, despite acknowledging that inhabitants in some regions might feel comfortable even at a higher temperature than ASHVE's comfort zone, the human body was still seen by them as a passive physiological recipient without any agency, while the thermal comfort was still understood as a naturalized attribute measured by heat gains and losses, rather than a socio-culturally-constructed category. Therefore, Chinese professionals took for granted the "direct correlation between a good working environment and workers' efficiency[53]" and the industrial productivity could thus be increased through reconfiguring building layouts, redesigning louvered windows or installing mechanical fans in the workshops. This facilitated the systematization of China's climatic design norms in the subtropics, including a series of arrangements of building layouts, intervals, orientations, type plans, walls, roofs, windows, doors, verandahs, courtyards and shading devices according to the comfort zone of an ideal indoor microclimate.

**Tropical Africa: Climate, Global Socialism and Development**

This body of subtropical knowledge in Lingnan was also covered in the *Dataset of Architectural Design* (1965) compiled by Beijing Industrial Architecture Design Institute (BIADI), which was involved in the design of many China-aided projects across Asia and Africa. As Chen Deng'ao (1916-99), who was the principal architect of BIADI and designed the Conakry People's Palace (1967) in Guinea, wrote in his book *Redai Jianzhu [Tropical Architecture]*, "China has conducted many studies on modern architecture in hot regions, which benefits a lot our overseas practice in the tropics. The design experience from Africa and Middle East could also facilitate our domestic architectural development[54]". It is clear that there has long been a techno-scientific network between Chinese institutions working in both Lingnan and Africa, through which architectural expertise was produced, translated and circulated (figure 4). However, the institutionalized of China's tropical knowledge system was filled with ups and downs. In the initial stage of China's overseas aid, due to the insufficient design data, some spaces in China-aided Hanoi Matches Factory (1955) in Vietnam were built with extravagant volumes, small windows, thick columns and poor ventilation[55]. In Cambodia, the bulky reinforced-concrete structures of China-aided Textile Factory (1961) were also critiqued as both uneconomical and unsuitable for the tropical climate[56]. In the early-1960s, the Commission of Foreign Economic Relations (CFER) was established to coordinate with other state-owned professional institutions in collecting the field data from the tropics. More and more Chinese specialists, including architects, engineers, agricultural scholars and sanitary experts, were dispatched to the Global South, and their fieldwork reports were later compiled as a series of *Yuanwai Chengtao Xiangmu Sheji Jichu Ziliao Huibian [Basic Design Data on China-Aided Projects]* in the 1970s. These technical manuals and handbooks, which covered the detailed information of climatology, geology, hydrology, natural resources, vegetation and infrastructures in every single African country, were disseminated among various Chinese design institutes, universities and research centers.

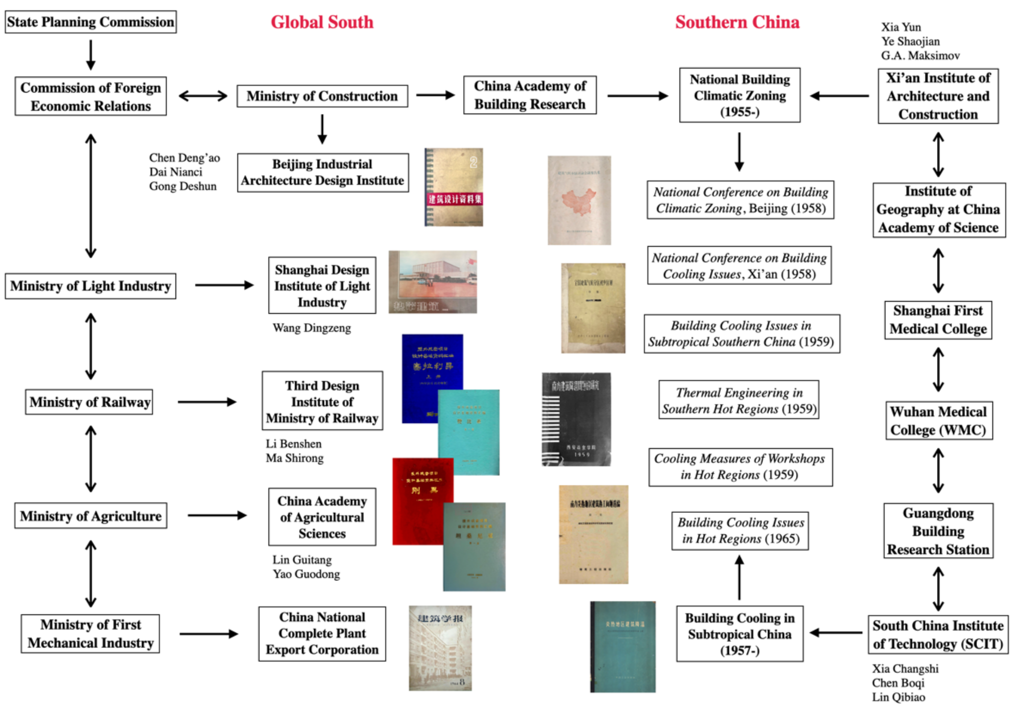


Figure 4: The institutional framework of the circulation of Maoist China's tropical knowledge between Southern China and the Global South.
Source: Drawn by the author.

Chen Deng'ao was merely one of these Chinese specialists. Since 1961, Chen and his colleagues at BIADI have conducted the fieldwork across Guinea, Sierra Leone, Tanzania, Congo and Kuwait, and a number of fieldwork reports were published[57]. His reports covered typical cases of modern tropical architecture produced by either socialist or capitalist actors, such as the French-built Hotel de France (1953) and the Soviet-built Polytechnic Institute of Conakry (1964) in Guinea, whose porous building layouts, light-weight steel-frame roofs and prefabricated shading devices offered valuable references for Chinese professionals to amend former shortcomings in Vietnam and Cambodia. Moreover, China-aided projects in Africa were also compared by Chen with subtropical architecture in Guangzhou. For example, the ground-floor open spaces, internal courtyards, sun-breakers, lattice panels and roof overhangs of Dongfang Hotel in Guangzhou (1962), People's Palace in Guinea (1967), TAZARA Railway Station in Tanzania (1976) were compared to understand how the Chinese design experience in Lingnan and Africa could benefit each other[58]. Besides architectural projects, Chen's reports also referred to several books written by late-colonial tropical architects, such as British architect Maxwell Fry and German architect Otto Koenigsberger, both of whom played a crucial role in the mid-1950s institutionalization of tropical architecture at the Department of Tropical Studies (DTS) of AA London. These tropical architects mostly believed that the heat stress in the tropics would "create feelings of discomfort, increase fatigue, decrease efficiency and affect health", while the climatic design of architecture could mitigate these drawbacks and thus "reshape the future of tropical nation-states[59]". However, according to them, the tropics was always a negative zone with the inherent thermal stress and backwardness.

When a team of Chinese experts arrived at Mali in 1961, they were shocked by the colonial spatial pattern of Bamako: "for private enjoyment, French colonizers built many non-industrial buildings here, including Art-Deco theaters, Neo-Classical churches, Tropical Modernist hotels and Western-style bungalows, while there were almost no industrial buildings, except a few small-scale processing plants monopolized by foreign capital with the extremely terrible working environment for African laborers. The sharp contrast between the shabby industrial buildings and well-designed non-industrial ones in Bamako demonstrated that colonizers saw Mali as a pastoral place only for their exploitation of resources, without the need for industrial development[60]". This was also a prevailing phenomenon in Sierra Leone, Congo and Tanzania[61]. Therefore, in Mali, most of daily necessities, including sugar and tea, could not be produced by itself. In 1961, Mali spent much of its foreign currency in importing over 2.5 million dollars of sugar from Europe and 600 tons of tea from China[62]. After decolonization, many African leaders believed that a socialist command economy, the nationalized major industries and centralized planning might become the means of rapidly realizing modernization[63]. China's emphasis on the self-reliant national industries, including the Friendship Textile Mill (1966) for Tanzania's cotton industry, the Sevare Rice Mill (1969) for Mali's agricultural development and the TAZARA Railway Station (1976) for Zambia's export of copper, was thus well received by them[64]. According to Mali's First Five-Year Plan (1960-65), the rice, sugarcane and cotton would be cultivated along Niger River, and a great number of textile, tobacco and sugar industries were to be established in Bamako.

However, it was discouraged by the French director of Mali's Institute of Rural Economy, who insisted that "it was impossible to grow sugarcane and tea in Mali due to its hot-dry climate[65]". In 1962, with the help of Chinese agricultural experts, the first tea tree was successfully cultivated in Sikasso, which scotched the French assumption of Mali as unsuitable for the growth of tea[66]. With the tea-processing techniques and machinery introduced by Chinese experts, the Sikasso Tea Factory (1972), which was China's earliest innovative blend of agricultural product processing, technical training and industrial assistance in its overseas aid, was built in Mali according to the design experience of Anxi Tea Factory (1952) in Fujian and Yingde Tea Factory (1958) in Guangdong[67]. As discussed before, according to ASHVE's reductive understanding of thermal comfort and classification of climatic types, Bombay, Singapore, Guangzhou, Tanzania, Ghana and Guinea could be seen as sharing the hot-humid climate, while Iran, Sudan, Mali, Libya, Iraq and Egypt shared the hot-dry one (figure 5). From the viewpoint of Chinese professionals, in terms of the climate, cities that have never been juxtaposed before could be comparative to each other now[68]. Based on the climatological data of temperature, humidity and airflow of Mali, the systematic body of Chinese subtropical building norms, prefabricated elements and type plans in Lingnan, could be flexibly modified to suit the changes of site-specific conditions in Africa. Since Guangzhou shared the hot-humid climate with many other locations in West and East Africa, China's domestic thermal comfort standards, indoor microclimate criteria, architectural technologies and urban typologies were believed to be able to adapt to various climatic zones after appropriate modifications[69].

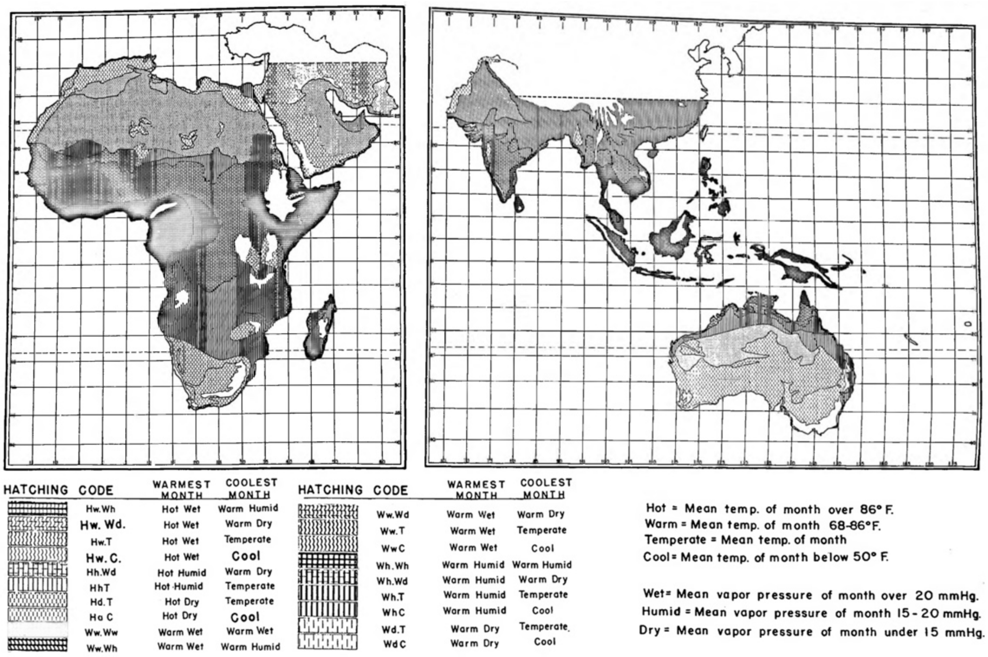


Figure 5: The climatic types of Africa and Asia classified by Douglas H.K. Lee, 1953.
Source: Douglas H.K. Lee, *Physiological Objectives in Hot Weather Housing: An Introduction to Hot Weather Housing Design* (Washington, D.C., Department of Housing and Urban Development, 1969).

At the Sikasso Tea Factory, the jacketed steam boiler was firstly adopted in the tea roasting workshop to increase efficiency and lower the indoor temperature, while the steel-frame louvered windows were designed to keep the tea rolling workshop well-ventilated and shady. From the asbestos cement sun-breakers of the First Sugar Factory (1966) to prefabricated concrete shading devices of Friendship Textile Mill and light-weight steel louvers of Sikasso Tea Factory, the labor-intensive structures were increasingly replaced by a system of prefabricated environmental technologies that could be easily manufactured in China and then replicated and assembled in Africa[70] (figure 6). These prefabricated systems based on climatological data constituted the prerequisite for the standardization and institutionalization of Chinese architectural expertise and tropical knowledge, which could be stably transferred to Africa without any distortion. As German architect Georg Lippsmeier wrote, compared with the “import-dependent materials and technologies” adopted by Western modernist architects, Chinese techniques were praised by the local as “more suitable for Africa’s self-reliant maintenance[71]”. Under China’s foreign-aid guideline of “smaller investment, faster construction and larger profit”, the frugalness of Chinese experts, who lived in self-built shelters and worked together with African laborers, was in a sharp contrast with the excessive material demands of their Soviet and Eastern European counterparts. To ensure Tanzania’s self-sufficiency and help cultivate local technicians, two machine tools workshops were built in the 1960s as classrooms for training African railway workers through practice, and in the 1970s, Tanzanian textile workers from the Friendship Textile Mill were even trained as interns at the Shanghai Cotton Factory[72].

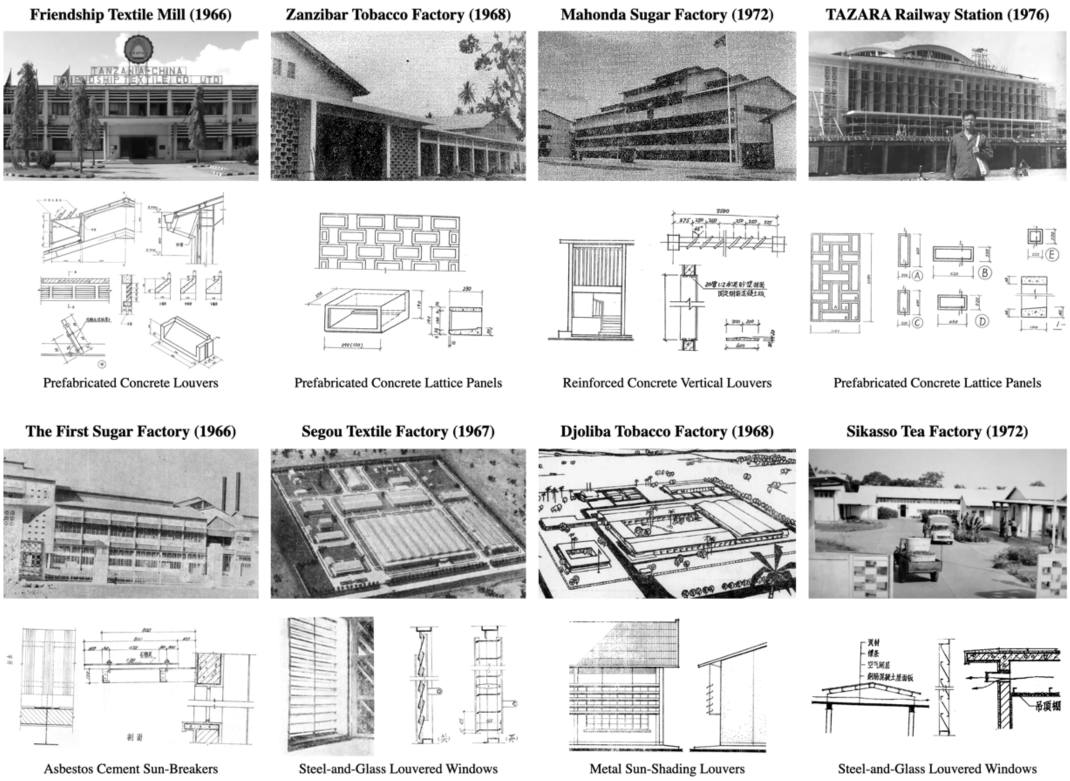


Figure 6: The transformation of the design of sun-shading devices of China-aided industrial projects in Tanzania and Mali, 1966-76.
Source: Compiled by the author based on China's Commission of Foreign Economic Relations, *Yuanwai Chengtao Xiangmu Jichu Ziliao Huibian [Basic Design Data on Foreign-Aid Projects in Mali]* (Beijing, Commission of Foreign Economic Relations, 1976); China's Commission of Foreign Economic Relations, *Yuanwai Chengtao Xiangmu Jichu Ziliao Huibian [Basic Design Data on Foreign-Aid Projects in Tanzania]* (Beijing, Commission of Foreign Economic Relations, 1977).

However, the climate-driven design of China-aided projects was not evenly distributed between industrial and non-industrial spaces. For instance, the Friendship Textile Mill was initially planned with many welfare facilities, such as dormitories, canteens, schools and hospitals[73]. Due to the tight budget, the investment in workers' dormitories was cut to firstly ensure the climatic design and construction of industrial workshops. Only 500 multi-family collective dormitories were eventually built, with minimized private spaces, limited modern comfort, shared kitchens and bathrooms (figure 7). In contrast, covered by prefabricated concrete louvers, wind shields and lattice panels, the main workshop even had its own nursing unit, living quarter, café, shower room and dining room[74]. Other China-aided industrial projects in Africa, including the Conakry Tobacco Factory (1963) in Guinea, Segou Textile Factory (1967) and Djoliba Tobacco Factory (1968) in Mali, Zanzibar Tobacco Factory (1968) and Mahonda Sugar Factory (1972) in Tanzania, even did not have residential areas for workers[75]. For example, the initial proposal of Conakry Tobacco Factory, which equipped the public canteen with electric fans and verandahs, was rejected by the Party as an uneconomical design standard in non-industrial spaces[76], which contrasted sharply with the art clubs, sanitary facilities, private workspaces and loggias-corridors offered for the Soviet-built Tema Residential District (1962) in Ghana, or the 100-sqm high-standard rooms equipped with electric fans and fridges at the East German-built *Kikwajuni* Housing (1964) in Zanzibar[77].

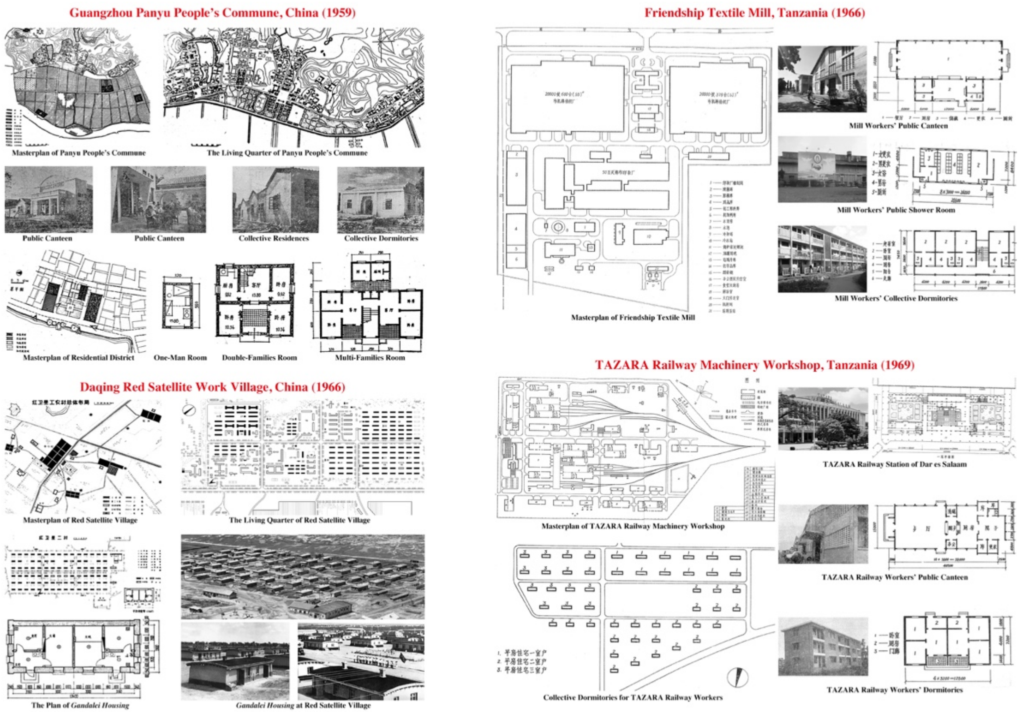


Figure 7: Four typical examples of the Chinese-built work-units in China and Tanzania, 1959-69.
Source: Compiled by the author based on South China Institute of Technology, *Renmin Gongshe Jianzhu Guihua Sheji [The Planning and Design of People's Communes]* (Guangzhou, South China Institute of Technology Press, 1959); China's Commission of Foreign Economic Relations, *Yuanwai Chengtao Xiangmu Jichu Ziliao Huibian [Basic Design Data on Foreign-Aid Projects in Tanzania]* (Beijing, Commission of Foreign Economic Relations, 1977); Hou Li, *Building for Oil: Daqing and the Formation of the Chinese Socialist State* (Cambridge, Harvard Asian Center, 2018).

This spatial pattern was deeply influenced by the typology of *danwei* [work-unit], i.e. the basic unit of Maoist China's urbanization. Despite being influenced by Soviet micro-district and American neighborhood-unit, China's work-unit-based urbanism could be seen as an alternative to both of them. The urban built environment across Maoist China was mostly characterized a number of self-contained work-units with integrated workplace, residence and service facilities rather than the separation of land use[78]. Each work-unit, such as the Panyu People's Commune in Guangzhou (1959) or Red Satellite Village in Daqing (1966), was planned under the guideline of "privileging production over consumption" or "Production First, Livelihood Second[79]", which was promoted nationwide by the Party[80]. Due to the extreme scarcity of resources, the investment in the construction of non-industrial programs, such as housing and service facilities, was strictly curbed, while everything else, including laborers' quality of life, had to be temporally sacrificed to firstly ensure that of industrial projects. In the mid-1950s, under the state austerity, the housing standard was even adjusted to 4.5 square meters per capita, only half of the Soviet one. Many spaces like the kitchen, bathroom and dining room were extracted from the housing and replaced by collective welfare facilities in workshops to minimize the residential area[81].

The systematic body of tropical knowledge, thermal comfort norms, climatic design strategies and prefabricated environmental technologies from Lingnan played a crucial role in the adaptability of Maoist China's domestic work-unit typology and even its socialist development model to the climatic and socio-political conditions of Africa. As discussed before, since the Chinese understanding of thermal comfort took for granted the causality between interior microclimate, heat-balance of human body, workers' efficiency and industrial productivity, the doctrine of "Production First, Livelihood Second" was widely accepted. For China's tropical architecture, the thermal comfort of workers' laboring bodies in the industrial spaces was given priority to, and among the scarce building resources and professional workforce, over 71.7% were invested in ensuring the climatic design of workshops, while the pursuit of comfort in non-industrial spaces such as housing was seen as compromising the centrally-planned goal of industrialization[82]. According to China's tropical knowledge of heat-balance model, building-machine and human-machine, the "labor" was deprived of its socio-political meanings, and thus reduced to merely the calculation of heat input and output, or "a question of human energy", while the human body, whose energy was exploited by the sealed building machine, was seen as "a human motor" working towards the same goal of maximum efficiency[83]. Although this spatial pattern was legitimized by a systematic body techno-scientific knowledge, it did not result in a higher productivity. Workers' suffering in the terrible living quarters had largely diminished their working efficiency in industrial quarters. In the late-1970s, this paradigm of "production over consumption" was also criticized by the Party's newspaper, *People's Daily*, as "producing only for the sake of producing while largely downplaying the real needs of people", which triggered heated debates nationwide around the meaning of production and people's livelihood. As pointed out in the debates, in most work-units, people were perceived as merely the means to statist ends, rather than as the ends in their own right. The long-term interests and even the health and livelihood of workers were all sacrificed to seek the industrial victory only in form.

## Conclusion

The practice and knowledge production of Maoist China's internal and external tropical architecture were both concurrent and co-constitutive. Through the transnational techno-scientific network of experts, institutions, knowledge and things, China's thermal comfort standards, sanitary discourses, environmental technologies, work-unit typologies and even its socialist regulative norms and development model in Lingnan and the postcolonial tropics, were stabilized institutionalized as a systematic body of tropical knowledge, which could be circulated, translated and adapted to other climatic and socio-economic contexts outside China. Underpinned by its architectural technologies and urban typologies, China's systematic tropical knowledge has gradually reshaped the design strategies, planning system, building industry, labor regime, people's everyday practice and even their socio-cultural understanding of the body and comfort both in Lingnan and Africa. The technocratic centrally-planned schemes redistributed the heat and rendered people the universalized passive recipients of given thermal conditions. The people, to whom the state once promised to bring modernity, prosperity and development, now became merely the instrument for the industrialization[84].

In fact, the techno-political history of China's two tropical architecture is a history of the present, especially in the context of a global transition to more sustainable cooling technologies of the built environment. This article helps us understand why many problems of thermal comfort, environmental management and modern development are deeply rooted in the history.

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