CHAPTER 7

Cost

Contents

7.1 Cost Overview

7.1.1 Overview

This Chapter discusses the project construction cost for GLC and a preliminary estimate of its operating cost. The estimated construction cost, presented here, includes all of the costs for fabrication, assembly and installation of accelerator components and for the construction of conventional facilities associated with them. However, it does not include the cost for the detector facility, which is most likely to be built by an international collaboration, separated from the construction team for the accelerator complex.[1]

The estimates quoted here should be considered as "version one" numbers, based on the first round of cost analysis efforts made by the GLC group. The numbers are subject to continuous reviews and revisions in the future, through attempts to improve their accuracy as well as further cost optimizations. The ambiguities associated with the present cost estimate are considered to be of the order of $10 \sim 20\%$.

7.1.2 Assumptions for the Estimates

The present cost analysis was made under a set of assumptions that are summarized below.

As of 2003, important points to note in the standard cost accounting rules at Japanese national laboratories are as follows:

1. Contingencies and escalations are *not* to be separately quoted in formal Japanese budget request documents. They are, if judged necessary, implicitly included in individual entries of the cost breakup sheet. The present GLC cost estimates follow this practice.
2. Salaries of the staff members at national institutes are *not* to be included in a project budget in the Japanese accounting system. In practice, a budget request for a project is often accompanied by requests for new staff positions related to the project in question. However, at funding agencies their assessment is done as separate matters. Consequently, the present GLC cost estimate does not include salaries of the laboratory staff. However, all other personnel expenses, for instance, those for contract workers, are included in the cost estimate.

In addition, the following points should be noted:

- The hardware configuration and layout of the accelerator complex follow the design discussed in Chapter 4.

[1] The cost for the detector facility is considered to be approximately $30 \sim 40$ Billion Yen.

- The baseline design of GLC assumes the linac tunnels to be long enough ($\sim$ 33 km) to allow a straightforward extension of the main linacs for Stage II operation at $E_{CM} \gtrsim 1$ TeV, as discussed in Chapter 5. The baseline GLC cost estimate for the conventional facilities assumes that such long tunnels are to be prepared from the initial construction. However, as for the RF components, the cost estimate considers only the main linac hardware that is required to support the Stage I operation at $E_{CM} = 500$ GeV. The cost for the linac upgrade from Stage I towards Stage II is not included.
- This cost estimate assumes construction of only one experiment hall, and the final focus beamlines and beam dump sections associated with it. Although it is possible to introduce another experiment hall at additional cost, this is not included in the present cost estimate.
- Cost reduction of mass-produced components is, whenever considered adequate, taken into account. The rate of cost reduction depends on the individual component types. The assessment is based on the past experience and record that have been accumulated at KEK, and are considered to be reasonably accurate.

7.2 Accelerator

The subsystem items that are included in the cost estimate for the accelerator are summarized here. Fig. 7.1 illustrates the definitions of the subsystem names that are used for cost analysis purposes. It should be noted that the definitions of these subsystems are not exactly the same as those that appear in Chapter 4.

For each subsystem, the costs are included for the RF components, magnets, beam instrumentation, vacuum systems, power supplies, low-level control hardware, racks and cables. Their procurement, assembly, installation and system check-out are all accounted for.

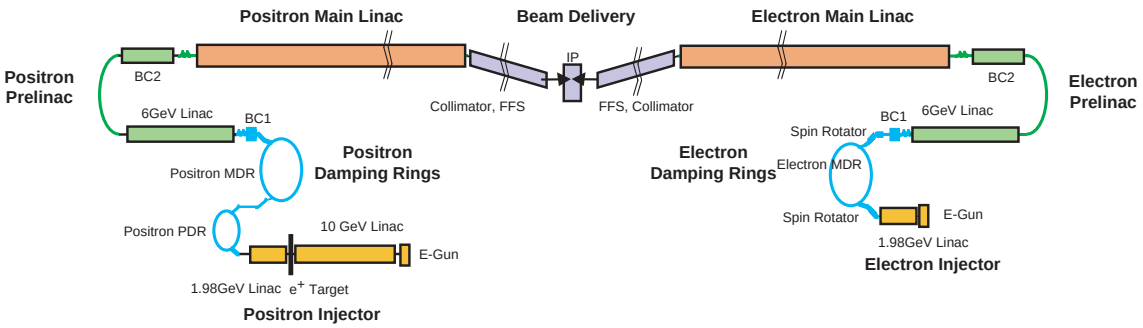

Figure 7.1: *Definitions of the subsystem names that are used for cost analysis purposes. It should be noted that the definitions of these subsystems are not exactly the same as those that appear in Chapter 4.*

7.2.1 Injectors

Sources

The cost estimate for the electron and positron sources include the following items: the electron gun, a 2 GeV electron injector linac, a 10 GeV electron drive linac for positron production, a positron target system, and a 2 GeV positron injector linac. The electron gun system includes an 80 MeV electron gun and an 80 MeV polarized electron gun. An 80 MeV electron gun for the 10 GeV electron drive linac for positron production is also included.

In this analysis, the known costs for the 1.54 GeV ATF linac and the 8 GeV KEK injector linac for KEKB and light sources have been used for cross-checking purposes.

Damping Rings

Two 1.98 GeV main damping rings (one for the electron, the other for the positron) and one 1.98 GeV positron pre-damping ring are included. All of the transport lines related to the damping rings, including the first bunch compressor (BC1), are also accounted for.

For the positron part, an injection line from the positron 2 GeV linac to the pre-damping ring, a transport line from the positron pre-damping ring (PDR) to the positron main damping ring (MDR), an extraction line from the positron main damping ring, and the first-stage positron bunch compressor (BC1) are included.

For the electron part, an injection line from the electron linac to the electron MDR, an extraction line from the electron MDR and the electron BC1 are included.

The known construction cost for the ATF damping ring has been used as a reference for evaluating the cost for the PDR and MDRs. Whenever possible, the analysis is based on integration of estimated cost for individual beamline components. Otherwise, the cost is estimated based on scaling from existing, similar beamlines.

Prelinacs

For both the electron and positron sides, this part includes the cost for 6.25 GeV S-band prelinacs, the second-stage bunch compressor (BC2) arcs, the BC2 cavities and associated beamline components.

In this analysis, the known costs for the 1.54 GeV ATF linac and the 8 GeV KEK injector linac for KEKB and light sources have been used for cross-checking purposes.

7.2.2 Main Linacs

The cost for the RF power source elements has been estimated based on an accounting of all the required components. The cost reduction expected in mass production is taken into account. The experience from past R&D for GLC and other RF equipment is taken into this analysis.

The cost estimation for accelerator structures is based on evaluations of the required production infrastructure and their operation cost in addition to the cost for the raw material. The costs for installing the beamline components are included.

The cost for the vacuum system has been evaluated based on scaling from existing, similar beamlines.

7.2.3 Beam Delivery

The costs for the beam delivery, including the collimation, final focus, interaction region and beam dump lines, have been estimated based on individual accounting of the required components, except for the vacuum system. The cost for the vacuum system has been deduced based on scaling from existing, similar beam transport lines. It is noted that the cost for this area is subject to changes, depending on the progress of the detailed designs of the required components.

7.2.4 Control System

The cost for the hardware in the control system has been estimated based on individual accounting of the required components.

The cost for the software in the control system has been estimated by scaling from past experience in developing the software infrastructure for the existing accelerator systems at KEK.

7.3 Conventional Facilities

The cost for conventional facilities include the expenses for civil engineering construction of underground tunnels and surface buildings, power conversion facilities, air conditioning and temperature control, and cooling water distribution and drainage. As stated earlier, the labor costs for the contractors are implicitly included in individual items. It should be noted that the cost estimate here is based on a "model" site as discussed in Chapter 5. The cost estimate, therefore, is subject to changes depending on the selection of the actual construction site.

7.3.1 Civil Construction

This includes the cost for underground facilities, such as the accelerator tunnels, klystron tunnels, injector tunnels, an experiment hall. In addition, the costs for the access tunnels and utility tunnels, whose lengths are assumed to be 500 m, are included.

The cost that is associated with preparation of surface access routes from existing roads to the tunnel access points is not included. This item should be studied when the list of site candidates is narrowed down in the near future.

The costs have accounted for surface facilities, such as the central power station and all of the technical, support and research buildings for the laboratory. However, the extent of research buildings and the accommodation facilities, which are not considered to be essential for the initial operation of the accelerator and detector, is limited to minimal levels.

7.3.2 Power Distribution

This covers almost all of the items related to electric power conversion and distribution for the entire accelerator complex and the laboratory campus. As discussed in Chapter 5, the power handling capacity of the system considered here is such that operation at $E_{CM} = 1$ TeV can be supported, although approximately only half of the RF components will be installed for initial operation at $E_{CM} = 500$ GeV. The telephone, broadcasting, radio communication as well as safety systems are included.

Items not accounted here are: installation of high-voltage power cables onto the laboratory site, static var compensator system and harmonic filter systems, which may be determined necessary in future studies.

7.3.3 Air Conditioning and Cooling

All of the costs related to the air conditioning and cooling water, together with the pumping and drainage equipment, for underground facilities are included. As discussed in Chapter 5, the capacity of the system considered here is such that operation at $E_{CM} = 1$ TeV can be supported, although approximately only half of the RF components will be installed for initial operation at $E_{CM} =$ 500 GeV.

The air conditioning and water facilities for surface buildings are listed under "civil construction".

7.4 Cost Summary

The total construction cost for GLC, as described above, is estimated to be 495.1 Billion Yen (4951 Oku Yen).[2] Fig. 7.2(A) illustrates the cost breakup.

For reference purposes, cost estimates have also been made for cases, where a shorter tunnel infrastructure is build in such a way that operation only up to $E_{CM} = 300$ GeV or $E_{CM} = 500$ GeV is to be supported. In this case, an upgrade for operation at $E_{CM} = 1$ TeV will incur a large amount of additional civil construction work. However, the project cost limited to lower energy operation can be reduced.

7.5 Human Resources during Construction

As pointed out earlier, all of the expenses related to the human resources associated with the contractors to work during construction are indirectly accounted for in our analysis. However, the amount of human resources that are required as the laboratory staff (accelerator physicists and senior engineers) to supervise the construction needs to be counted separately.

As a reference, Table 7.1 summarizes the absolute minimum staff count that is considered necessary during the construction of GLC. In this case, a primary job of these staff members is to supervise the work to be done by a large number of contract workers. Naturally, this estimate is subject to changes, depending on the exact work-sharing model between the laboratory staff and the contractors. Additional participation by visitors and seconded personnel from collaborating institutes are highly desirable. It should also be noted that Table 7.1 does not include members in the administrative and secretarial groups within the laboratory.

[2] 1 Oku Yen means 100,000,000 Yen.

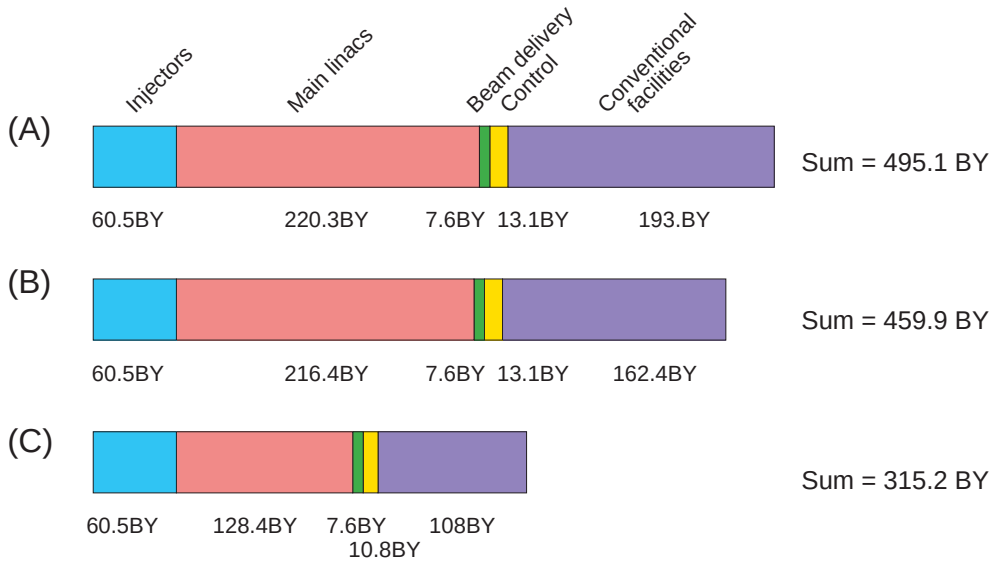

Figure 7.2: *Break-up of the construction cost for GLC into injectors, main linacs, beam delivery, controls and conventional facilities. The numbers shown are in the unit of Billion Yen (10 Oku Yen). (A) Baseline case, where the main linacs to support operation at $E_{CM} = 500$ GeV are built within long tunnels which can eventually support $E_{CM} = 1$ TeV operation. (B) Reference case, where the main linacs to support only up to $E_{CM} = 500$ GeV are built within short tunnels. which cannot be extended for $E_{CM} = 1$ TeV operation unless additional civil construction work is done. (C) Another reference case, where the main linacs to support operation only up to $E_{CM} = 300$ GeV are built within even shorter tunnels.*

Area	Number of staff		
Beamline design	5		
Injectors	25		
		Sources	5
		Linacs	10
		Damping rings	10
Linac RF	30		
		RF sources	20
		Structures	10
Magnet	15		
Vacuum	15		
Instrumentation	15		
Control	15		
Alignment	10		
Safety	15		
Conventional Facilities	20		
Total	**165**		

Table 7.1: *Estimated total human resources required as the laboratory staff during construction of GLC. The quoted numbers should be considered as minimum requirements for supervising the work to be done by contract workers. Members of secretarial and administrative staff are not included.*

7.6 Operating Costs

The annual electric power bill for operating an accelerator facility in Japan can be estimated by using the following empirical formula:

$$C[\text{Oku yen}] = 0.5 \times P_{AC}[\text{MW}], \tag{7.1}$$

where the estimated annual power bill, C, is in units of "Oku yen" (100 MYen), and P_{AC} the site power in units of MW. This is equivalent to assuming the annual operation time to be on average 5000 hours, and the electric power cost 10 yen/kWh.

Other operating expenses associated with maintenance, repair and hardware updates are difficult to accurately estimate in the case of GLC. Experience with past and existing accelerators at KEK suggests that the amount of the annual maintenance and repair budget will be roughly the same as the annual electric power bill. In addition, for operation of a variety of power conversion, air conditioning, cooling and other equipment, approximately 100 contract workers are estimated to be required.

The total amount of site power that is required for Stage-I operation ($E_{CM} = 500$ GeV) is estimated to be 233 MW. The annual power bill is thus estimated to be 11.7 billion yen (117 Oku yen) by using Eq. 7.1. Thus, the total operating cost is estimated to be 23.3 billion yen (233 Oku yen) per year.

In Stage-II operation ($E_{CM} = 1$ TeV), the total site power consumption would be 300 MW. In this case, the annual operating cost could be 30 billion yen (300 Oku yen), including both the electric power bill and other operating expenses.

If GLC is built with a tunnel infrastructure limited in length so as to accommodate the main linacs supporting operation only up to $E_{CM} = 300$ GeV, the site power requirement could be 155 MW. In this case, the annual operating cost would be 15.5 billion yen (155 Oku yen), including both the electric power bill and other operating expenses.