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Scientific Disciplines of Geojunggi (the Traditional Crane) in Korean Science, Technology and History Class

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ABSTRACT
The purpose of this article is to provide applicable instructional strategy for teachers and researchers, which reflects the history of the exchange of science and technology between the West and the East. This research had as its foundation the mechanical drawings of Gigidoseol [Strange machines from the far West], Hwaseongseongyeoguigwe [A completion report for the Construction of Hwaseong Fortress]. This study provides science and technology teachers with a detailed instructional strategy to explain the traditional block-and-tackle and gear mechanisms. The examples of traditional mechanical drawings introduced in this paper will complement science and technology class materials. The core principle of traditional mechanical drawing based education is to utilize the traditional sciences as a medium that connects Science, Technology and History.

Keywords: Geojunggi, the mechanical drawings, science, technology, history

INTRODUCTION

Chong Yagyong, whose pen name was Tasan (茶山, Tea Mountain), is widely known as a great Korean writer who compiled the Silhak (practical studies) during the late Joseon Dynasty of Korea (Moon, 2013). But the capability that distinguished himself during the time period of his being in a public office was the field of engineering (Lee 2012, 53-54). Hwaseong Fortress is the wall surrounding the center of Suwon city, the provincial capital of Kyonggi-do, South Korea. The site was designated as a World Heritage site by the UNESCO in 1997. Chong Yagyong is an architectural construction engineer who designed the Hwaseong Fortress. And, at the same time, he is the mechanical engineer who developed the Geojunggi (擧重機, loader crane) and the Nongno (轆轤, jip crane).

Geojunggi is a device that symbolizes the Silhak of the late Joseon Dynasty which appears without missing any of the discussions related to the Hwaseong Fortress and Chong Yagyong (KAWAHARA 2008, 69). In a lot of the literatures, including the textbooks, Geojunggi has been described as a crane for building the castle walls.

In Korean history and science classes, many students ask how the Geojunggi operates and lifts stones. However, teachers cannot provide clear answers. In addition, the textbook does not explain exactly how to build a wall using a Geojunggi. Teachers' explanations are unclear, and they often embellish their answers with imaginative additions that are not factual. Korean schools claim that using the Geojunggi, the time required to construct the Hwaseong Fortress, which was planned to be 10 years, could be shortened to less than three years. However, this is not true.

In the existing literature, researchers have added their views and included traditional mechanical drawings. However, such studies rarely examine the specific process of developing machines. This paper provides

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State of the literature

- Throughout STS (Science, Technology and Society), STEM (Science, Technology, Engineering and Mathematics) & STEAM (STEM+Art), Korea has been steadily adopting scientific educational movements to grow the Competence of Convergent Human Resources.
- Although many educational researchers have been developing STEAM educational programs, there have been their limits, as a Humanities field was regarded as Art courses or excluded at all from the courses.
- In the existing literature, researchers have added their views and included traditional mechanical drawings. However, such studies rarely examine the specific process of developing machines.

Contribution of this paper to the literature

- This paper provides science and technology teachers with a detailed instructional strategy to explain the traditional block-and-tackle and gear mechanisms.
- The examples of traditional mechanical drawings introduced in this paper will complement science and technology class materials.
- The educational program that combines History and Science and Technology provides supports for teachers & researchers to discover and develop effective, applicable STEAM education contents.

science and technology teachers with a detailed instructional strategy to explain the block-and-tackle and gear mechanisms.

The purpose of this article is to feasibly infer the specific method of using the Geojunggi based on the literature referred to during the process of the development of the Geojunggi on the part of Chong Yagyong and the mechanical drawings he left behind. For this, first, the Gigidoseol (器機圖說, Strange machines from the far West) by Wang Zheng (1571-1644) & Joannes Terrenz Schreck (Chinese name is Deng Yuhan 鄧玉函, 1576-1630), which Chong Yagyong referred to was analyzed (Chong 2007, 99). Based on this, the Tasansimunjip (茶山詩文集, Collection of Tasan Chong yakyong's poetry and prose), which gathered the writings left behind by Chong Yagyong and the Hwaseongseongyeoguigwe (華城城役儀軌, A completion report for the Construction of Hwaseong Fortress), which is the national white paper, were comparatively analyzed (King Sunjo, 1801).

THE HANDLING METHOD FOR GEOJUNGGI AS MENTIONED IN THE LITERATURE

Hwaseongseongyeoguigwe was the 10-volume White Paper on Hwaseong Fortress Construction. The book was a decisive source of information for Hwaseong Fortress Construction. The first volume contains an architectural plan accompanied by drawings of details. Although the whole and the part drawings of Geojunggi are introduced in the first volume among the Hwaseongseongyeoguigwe's. However, there were no mentions on the use at all (**Figure 1**).

Regarding the use of the Geojunggi, it is mentioned that the reason why the machines that lift the heavy things and the Yuhyeonggeo (carts) were used was that it was a system with which the carriage is convenient in the Hwaseonggijeokbi (火城記蹟碑, a memorial stone for the Construction of Hwaseong Fortress) among the Hwaseongseongyeoguigwe's (King Sunjo, 1801). Although, regarding this construction monument, Kim Chongsu (1728-1799) wrote the draft following the order by King Jeongjo (1776-1800) in 1797, due to King Jeongjo's sudden death in 1800, it could not be erected and it has existed as the words within the Hwaseongseongyeoguigwe. In December 1991, in the Suwon City, a monument was made in the Changan Park and the contents written in the Hwaseongseongyeoguigwe were engraved on the tombstone just the way they were. The part that mentioned the purpose of making the Geojunggi and the cart has been engraved on the right side of the lower part of the backside of the tombstone.

Until now, the specific use of the Geojunggi could not receive the attention because it is simply mentioned in the writing on the monument. However, in the Hwaseongseongyeoguigwe, which is the most authoritative source on the construction of the Hwaseong Fortress, it is clearly and distinctly stated that the Geojunggi had been used as a transportation system that was used to convey the construction materials. If the monument was erected

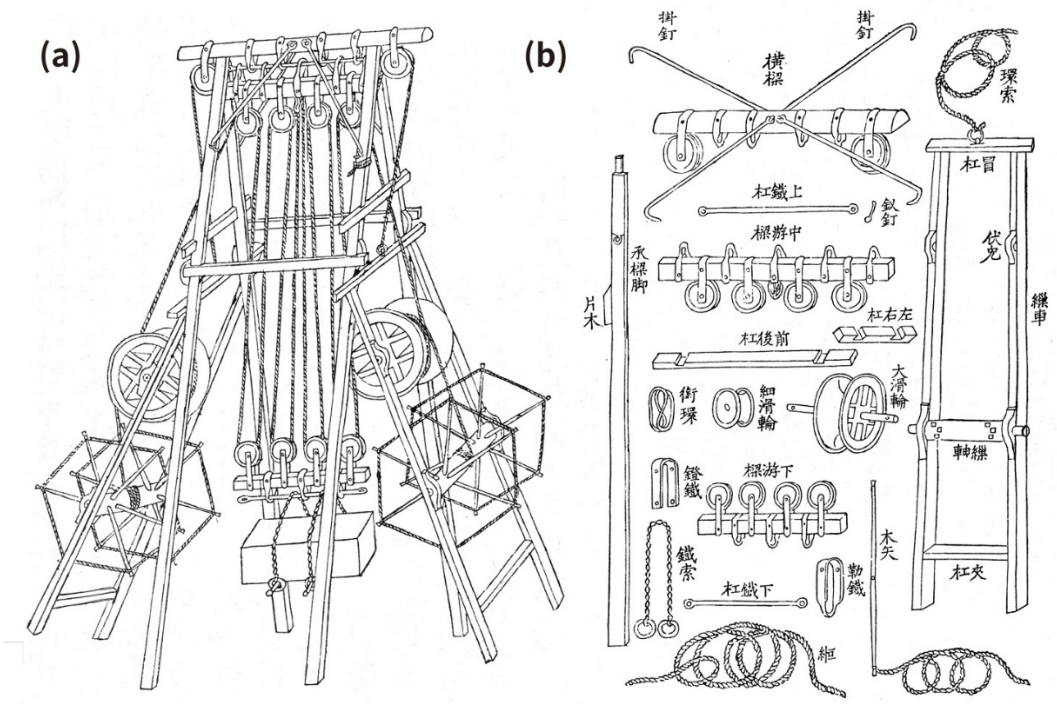

Figure 1. The Whole drawings of Geojunggi (a) and the part drawings of Geojunggi (b) Geojunggi was used in the construction of Hwaseong Fortress walls. (Reprinted, with permission of Seoul National University Kyujanggak Institute for Korean Studies.)

right after the completion of the Hwaseong Fortress Construction, the accurate use of the Geojunggi would have been conveyed widely.

THE CONSTRUCTION METHOD FOR THE CASTLE WALLS OF THE HWASEONG FORTRESS

Seongseol (城說) is the master plan on the construction of the Hwaseong Fortress, which was written by Chong Yagyong (Chong, 1792). It is organized with a total of 8 construction strategies, including 1 on the size, 1 on the materials, 4 on the engineering methods, and 2 on the transportation strategies. By examining the strong points and the weak points of the existing Joseon castles system and, also, by researching the castles system of China, a castle suitable for the Hwaseong Fortress was designed (Noh 2007, 150). It was in the winter of the year 1792, more than 1 year before the construction of the Hwaseong Fortress, that Chong Yagyong presented the Seongseol to The King Jeongjo. The King Jeongjo announced the plans for a new construction that was Eojeseonghwajuryak (御製城華籌略).

The best method for building the castle walls is the in & out stone-filling construction method, which piles up the stones both on the inside and on the outside. Although Chong Yagyong said, “Regarding the castles, building them on the inside and the outside simultaneously is originally the best thing”, this was not reflected with the Hwaseong Fortress (Chong, 1792). Although the engineering method of building both the inside and the outside has the strong point of building the strong castle walls, a lot of the costs are needed (Kim 2012, 66). As such, the construction becomes difficult. After the castle walls have been built, a construction that does away with the soil slope ways must be carried out additionally.

In order to shorten the construction duration period in an in & out stone-filling construction method, there are the limitations when using the soil slope method (Song, 2009). Instead, a lot of the jib cranes must be

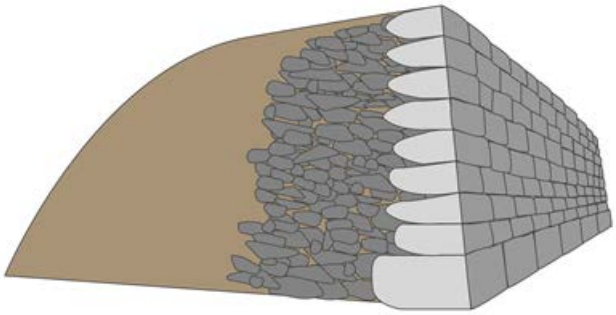

Figure 2. Cross section of fortress wall built in a Soil-in & Stone-out construction method. (Created by the author)

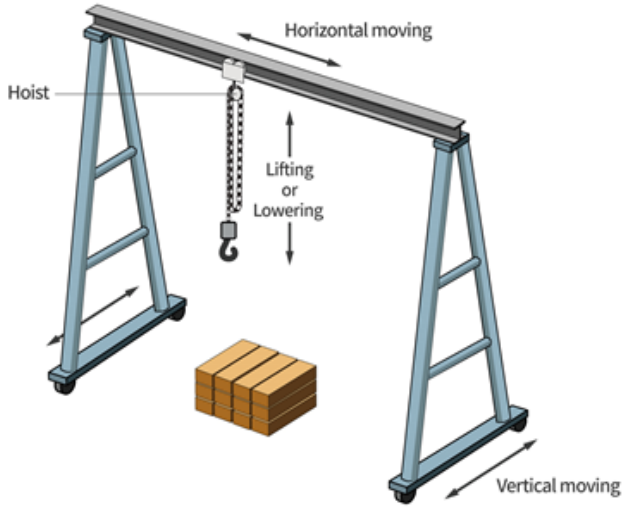

Figure 3. The degree of freedom (DOF) of a mechanical system is the number of independent parameters that define its configuration. Hoist Gantry Crane is the three-degree-of-freedom control system. (Created by the author)

simultaneously mobilized to build while lifting the stones. Because, at the Hwaseong Fortress construction site, two units of the Nongno and one unit of the Geojunggi were used, it cannot be considered that the cranes were used for the task of building the castle walls.

According to the Seongseol, regarding the Hwaseong Fortress walls, the outside was piled up with the stones and the inside was built with the construction method of tramping and putting in the small stones and the soil (Chong, 1792). The soil-in & stone-out construction method built the castle walls in the method of pulling and carrying the stones after the slopes were made and hardened by using the soil that came out after digging the moats (**Figure 2**). As a result, the cranes like Nongno and Geojunggi are not needed. Also, as the soil slope ways used for carrying the stones are utilized by hardening them just the way they are, there is no need to remove the soil slope ways after finishing the construction.

MACHINE STRUCTURE OF GEOJUNGGI

The form of the Geojunggi is similar to the modern overhead crane which is equipped with the hoist on the gantry. But Geojunggi is the one degree of freedom (DOF) control system (**Figure 3**). Only the lifting or the lowering are possible and the vertical moving is not possible. And, with regard to the point that the horizontal moving is not possible after lifting up, there are no big differences in terms of the functions. For the vertical moving

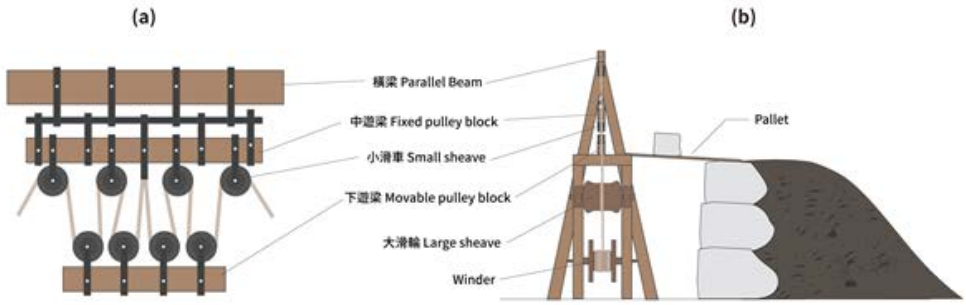

Figure 4. Pulley System of Geojunggi (a) and the construction of fortress walls utilizing Kojunggi (b). (Created by the author)

to be possible, there must be the wheels on the legs of the gantry. And, in order for the horizontal moving to be possible, the hoist must move on the running rail as Hoist Gantry Crane.

Although the height of the Geojunggi is approximately 4.4m, when considering the special, structural characteristics, the maximum height of the lifting up of the stones is merely around 3m. This is because, in the space below the Parallel Beam (横梁), a space for fixed pulley block (中遊梁) and Movable pulley block (下遊梁) to meet is needed. As Chong Yagyong designed the height of the castle walls to be approximately two jang (丈) five cheok (尺) (about 7.75m), the Geojunggi cannot be used for building the castle walls that are higher than 3m (Chong, 1792).

As, regarding the method of the construction of a castle utilizing the Geojunggi, it is not mentioned in any literature, in order to prove that the castle walls were built, the feasible method of lifting the stones and then relocating the stones to the castle walls must be presented. Ordinarily, regarding the pallets, the case of conjecturing that the upper part of the Geojunggi and the castle walls are connected and the stones are relocated is general (**Figure 4**).

But, in this case, the more the stones are lifted, the center of the gravity height (the center of the weight) of the Geojunggi moves to the above. And, if the stones are moved in the condition in which the center of the gravity height has moved to the above, there is the big possibility that the Geojunggi will be overturned.

Moving around the Hwaseong Fortress construction site, which reaches 188,048 m², and using only one unit of the Geojunggi is inefficient. This is because the Geojunggi is not a machine that was designed by considering the movability. In the Whole and the Part Drawings of Geojunggi by Hwaseongseongyeoguigwe, there are no components with regard to which the movabilities, like the wheels, were considered at all. Although it can be seen that the reason behind the presentation of the part drawings is for the disassembly and the assembly, when considering the complicated assembly process in which a lot of the sheaves must be connected to the lines, dismantling and assembling frequently is inefficient.

BLOCK-AND-TACKLE MECHANISM

Pulley System is a combination of sheaves and ropes often used for lifting. The block-and-tackle mechanism is a phenomenon that has been discovered here and there in the East and the West simultaneously over many generations. Already, from the days of ancient Greece and Rome, the cities had been constructed by mobilizing the large-sized cranes. During the long time from the ancient times to the modern times, the many people in each of the countries in the world developed the Geojunggi. Although, in Korea, it is known that Chong Yagyong invented the Geojunggi, it was not an invention of a new thing that did not exist before, but, it was the improvement of a previously existent thing so that it fits our actual circumstances. Da Vinci (Leonardo di ser Piero da Vinci, 1452-1519), designed a crane utilizing the block-and-tackle mechanism around 300 years before the Chong Yagyong (**Figure 5**).

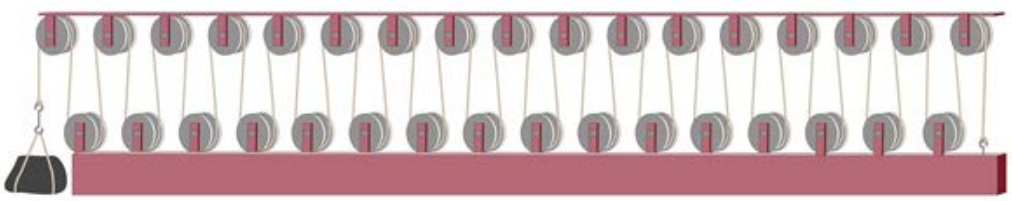

Figure 5. The Design of Crane that Davinci left as a sketch. Davinci's crane was organized with 16 movable pulleys and 17 fixed pulleys. (Created by the author)

Figure 6. Newly designed wheeled cart, Yuhyeonggeo (遊衡車). (Created by the author)

Chong Yagyong recorded, in detail, the process of developing the Geojunggi in the Gijunggadoseol (起重架圖說, Technical drawing of prototype) together with the pictures (Chong, 1983). Chong Yagyong's Geojunggi is a block-and-tackle mechanism which uses 8 pulleys. The block-and-tackle mechanism that Chong Yagyong and Davinci designed has the same mechanical principles. There is only the difference in terms of the method of rolling up.

Although, in Davinci's drawing, there is the rolling up only on one side, the Geojunggi by Chong Yagyong was designed so that there are the rolling ups on both sides. As Davinci's sketch expressed only the principle of the machine, it has been restored to the diverse methods today. But, as the components organizing the device of the Geojunggi by Chong Yagyong were systematically arranged, they can be restored to their appearances at the time of the late Joseon period.

While giving the Gigidoseol by Wang Zheng & Joannes Terrenze Schreck to Chong Yagyong, The King Chong Cho gave the instruction that both the Hoist (起重器) and the Winch (引重器) get developed. The Gigidoseol by Terrenz, which was published in 1627, is a book that organized the drawings of the diverse machines together with the simple explanations (Wang, Z. & Schreck, J. T., 1627). It is an introduction of the machines that were improved by comprehensively analyzing the machines that have been passed on, including the ancient construction equipments. In the Gigidoseol, 11 mechanical drawings of the hoists (起重圖) and 4 mechanical drawings of the winches (引重圖) were presented. The hoist rolls up the string in the direction that is opposite the gravity. And the winch rolls up the string in the direction that is parallel to the gravity.

Chong Yagyong did not develop the winch that pertains to the winch and concentrated on the development of the winch (Chong, 1783). It looks as though the reason is that, as the efforts and the costs for producing the winch are formidable, it was judged that the method of using the carts is more efficient (**Figure 6**). In fact, even though The King Jeongjo did not instruct it, Chong Yagyong developed the Yuhyeonggeo (遊衡車, a cart that shakes like the scale).

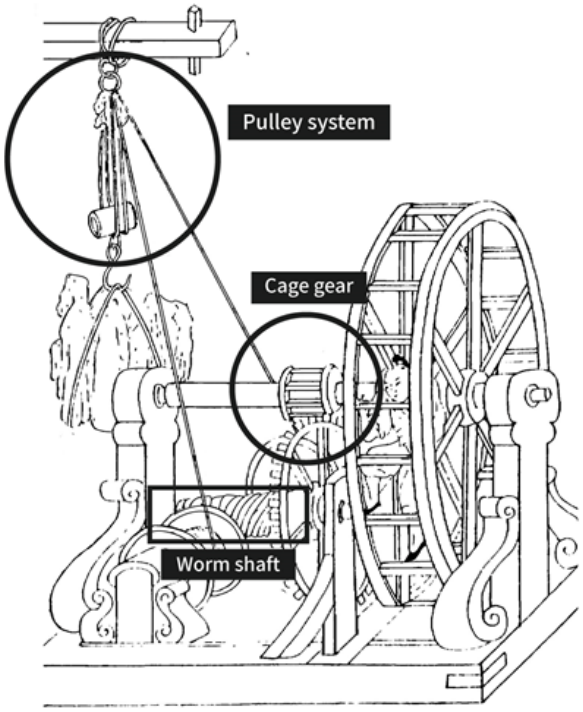

Figure 7. The 10th mechanical drawing of hoist. (起重第十圖)
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Among the mechanical drawings by Gigidoseol, Chong Yagyong evaluated the 10th mechanical drawing of the hoist as the most precise and mysterious machine (**Figure 7**). The 10th mechanical drawing of the hoist expresses the mechanism in which, if a person goes into a large-sized wheel and rotates the wheel like a squirrel rotating a treadwheel, a gear connected to the wheel rolls up the string connected to the block-and-tackle. As such, the method in which a person goes into a wheel hub and rotates the wheel and creates the power of the wheel was not first proposed in the Gigidoseol by Terrenz, but it is a method that had already been widely used with regard to the Roman treadwheel crane (Wang, Z. & Schreck, J. T., 1627).

The principle of the 10th mechanical drawing of the hoist is very similar with the Roman treadwheel crane with regard to the point that it uses the block-and-tackle mechanism and the treadwheel (**Figure 8**). But, it developed more than the Roman treadwheel crane with regard to the point that the size of the treadwheel was reduced by improving so that the power is efficiently delivered by utilizing the worm gear and the cage gear. We can find out that, according to the Gijunggadoseol, Chong Yagyong had a deep interest in the 10th mechanical drawing of the hoist.

When Chong Yagyong took a look at the methods for pulling up the heavy things on the Gigidoseol which was handed down by the King, there were 11 in general. But, all of them were not precise. Except, the drawings number 8, number 10, and number 11 were precise and mysterious. However, the drawing number 10 had to have a copper spiral sheave. As such, as I think of it now, even if the engineer is the best in the country, he will not be able to make it. What is more, making a sawtooth on a copper wheel must be difficult (Gijunggadoseol, 1792).

In Institute for the Translation of Korean Classics, in the process of translating the Gijunggadoseol, recorded with Chinese characters, the 銅鐵螺絲轉 was expressed as the copper spiral sheave. But, as Chong Yagyong expresses the sheave as Hwalcha (滑車) or Hwallyun (滑輪), if one considers the context at the front and at the back, it is correct to translate it as the copper spiral shaft.

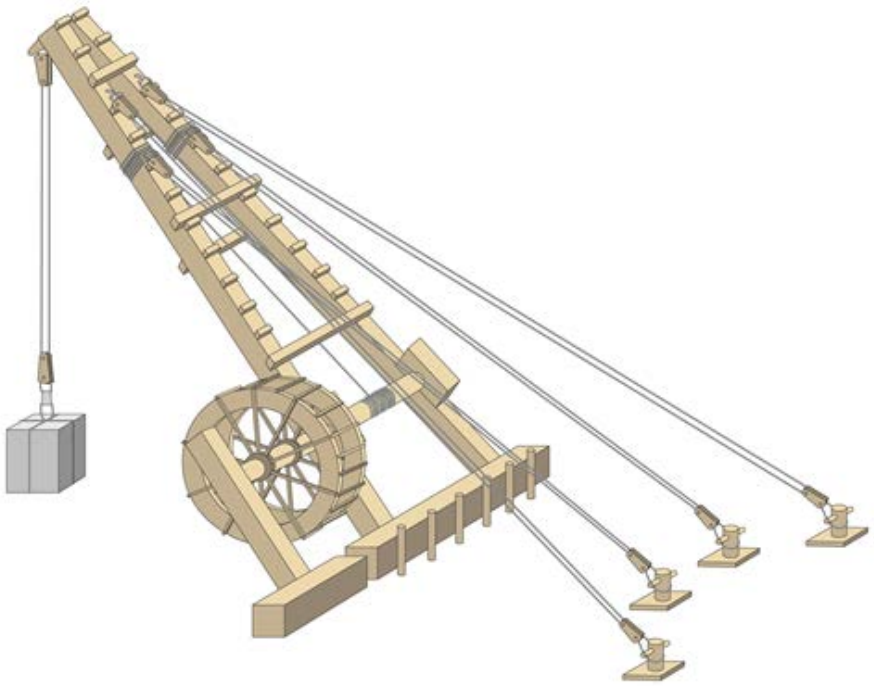

Figure 8. Roman treadwheel crane is a wooden, human powered, hoisting and lowering device. (Created by the author)

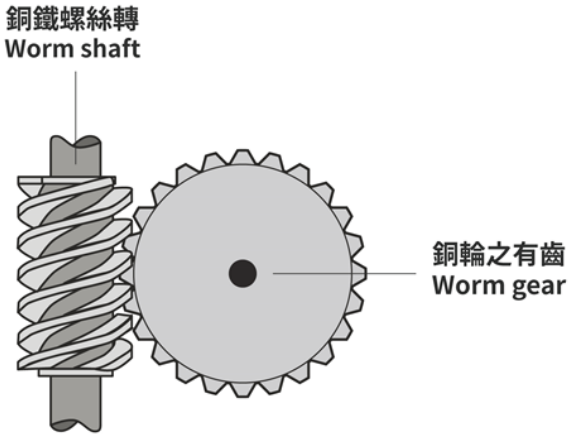

Figure 9. Worms and worm gears are gear sets that offer high gear reduction and torque multiplication with a small footprint. (Created by the author)

Today, the copper spiral shaft pertains to a worm shaft (**Figure 9**). Chong Yagyong judged that making the copper spiral shaft and the copper worm gear used in the 10th mechanical drawing of the hoist will be impossible. The reason why Chong Yagyong made such a negative conclusion was that Terrenz did not draw, in detail, and communicate the part that the worm shaft contacts the worm gear. The worm gear has a long history, but its application has been limited due to its difficulty of manufacturing.

The mechanism of 10th mechanical drawing of hoist is as follows: when one men tread in the large wheel, they cause it to turn together with cage gear. Since the cage gear engages with its rundles the teeth of wheel, it

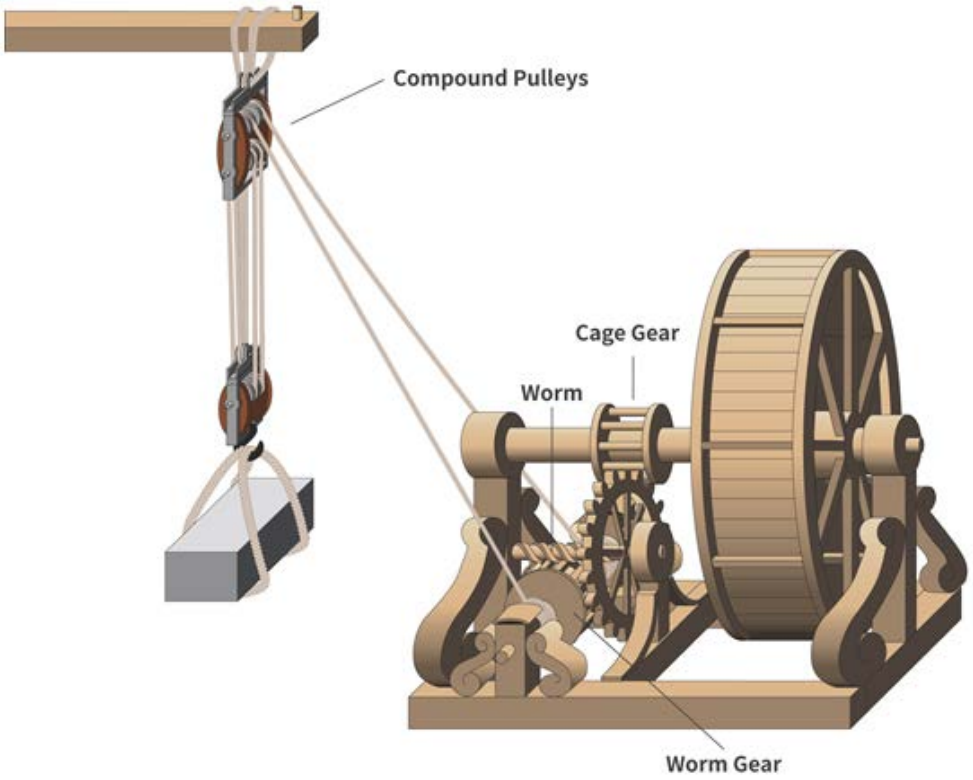

Figure 10. Gear and Pulley System in 10th mechanical drawing of hoist. (Created by the author)

likewise causes this wheel to turn, together with the worm and worm gears causes it to turn with these movements, together with the two drums set on either side of its shaft. These drums wind around themselves the two ends of the rope that passes through the Compound Pulleys (**Figure 10**).

In fact, with regard to the Gigidoseol, the thing that is not any less important than the gear is the block-and-tackle mechanism. Pulleys grouped together in a single frame make up what is called a pulley block. In the block-and-tackle mechanism, the pulley blocks have been in the pairs. Regarding the pulley blocks, there is the parallel combination method and there is the tandem combination method (**Figure 11**).

The double parallel pulley block is made of 2 parallel sheaves assembled on a frame. The double tandem pulley block is made of 2 tandem sheaves on a frame. In case the mechanical advantages are the same, there is the strong point that, compared to the tandem pulley block, the space captured by the parallel pulley block is small. Or, in other words, the efficiency of the parallel pulleys method is more extraordinary than the tandem pulleys method, of which the sizes and the weights of the blocks can only increase.

As the parallel pulleys method can make the distance between the pulleys on the fixed blocks of the upper part and the pulleys on the movable blocks in the lower part long, it has the strong point that it can be applied to the jip cranes that pull up the things to the high places. But, there is the weak point that the work of connecting a string to a pulley is somewhat cumbersome.

Terrenz accurately understood and diversely applied the block-and-tackle mechanism (Wang, Z. & Schreck, J. T., 1627). In the case in which, because the copper wires that pull up the things are simple, the strings do not get entangled, the flexibility was exercised in which the pulleys on the fixed blocks were substituted with the steel rings and the pulleys on the movable blocks were substituted with the cylinders. The 10th mechanical drawing of the hoist, referred to by Chong Yagyong, is a pulley system that substituted the pulley blocks with the steel rings and the cylinders for each (**Figure 12**).

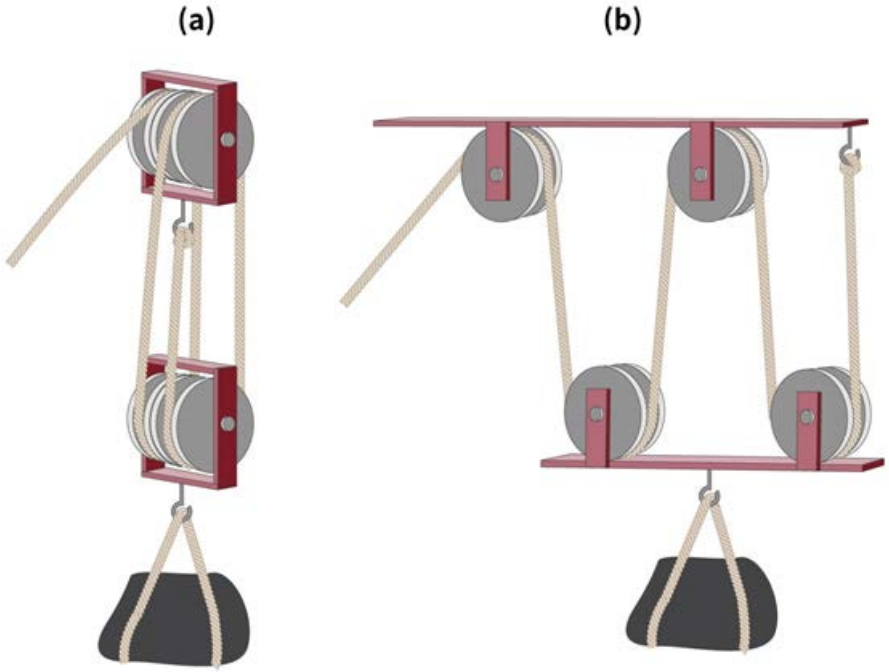

Figure 11. Parallel Pulleys (a) vs Tandem Pulleys (b). (Created by the author)

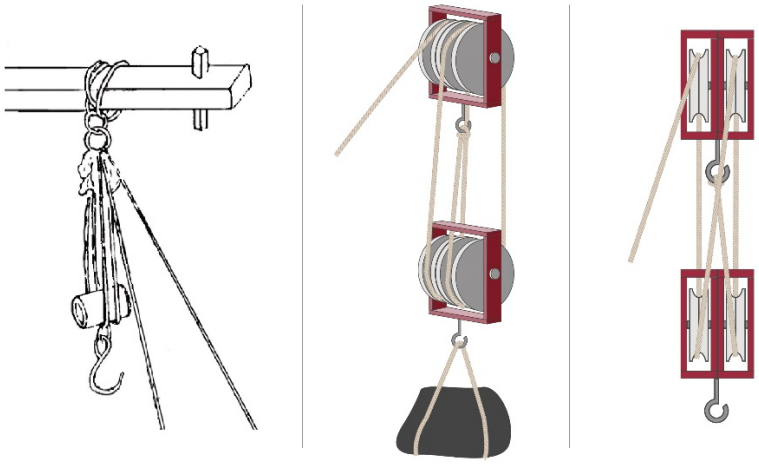

Figure 12. The Pulley System in the 10th mechanical drawing of hoist. (Created by the author)

In this way, the core technology of the block-and-tackle mechanism is the minimization of the space captured by the blocks that combined the pulleys. The 3rd mechanical drawing of the hoist introduced the informal equipment that replaced the pulleys with the steel rings in the so-called "gun tackle method", organized with the fixed pulleys and the movable pulleys, one for each (**Figure 13**).

It seems that Chong Yagyong did not consider the point that the sizes of the spaces captured by the pulleys must be reduced by using the parallel pulleys method. The reason is related with the fact that the castle walls of the Hwaseong Fortress were built through the soil-in & stone-out construction method. At the Hwaseong Fortress construction site, the jip cranes that pull up the heavy stones to the high places were not needed, but, the loader

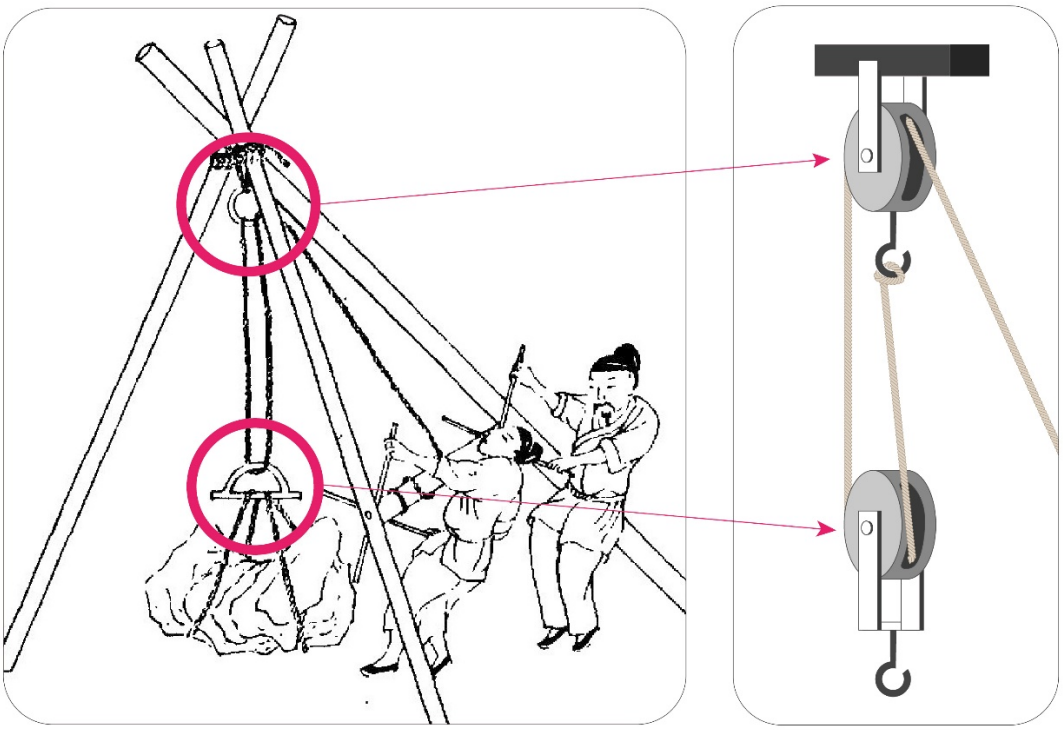

Figure 13. The 3rd mechanical drawing of hoist. (起重第三圖)
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cranes that pull up the heavy stones to the carts were needed. If the in & out stone-filling construction method, which must pull up the stones to the high places, was selected, the parallel pulleys method would have been opted for rather than the tandem pulleys method.

Chong Yagyong referred a lot to the 11th mechanical drawing of the hoist. Instead of not using the block-and-tackle mechanism, this mechanical drawing used the double cage gear. This mechanism is a structure in which the people rotate clockwise, wind the winder, delivers the force through the cage gear connected to the winder, and pulls up the things handing on the fixed pulleys installed on the high places. The cage gears used at this time not only save the force but, also, play the role of a device that prevents the slipperiness (**Figure 14**).

The cage gear is a technology that was used for the Jagyeongnu (自擊漏, water clock), too, by Chang Yeongsil in the beginning of the Joseon period. At the time, it could produce sufficiently with the technologies of the late Joseon period. Despite this, Chong Yagyong did not reflect the double cage gear in the Geojunggi, which he designed himself. This proves that the use of the Geojunggi is not the jip crane that lifts the things to the high places but is the loader crane.

In order to realize the worm gear described in 10th mechanical drawings of a crane, Chong Yagyong called forth a painter and endeavored by drawing in large size. However, eventually, he made the conclusion that it is impossible and abandoned the method of using the worm gear. Instead, it is assumed that the body of the Geojunggi was designed by referring to the 3rd and 6th mechanical drawings of the hoist in the Gigidoseol which pulls up the heavy things by winding the winder (**Figure 15**).

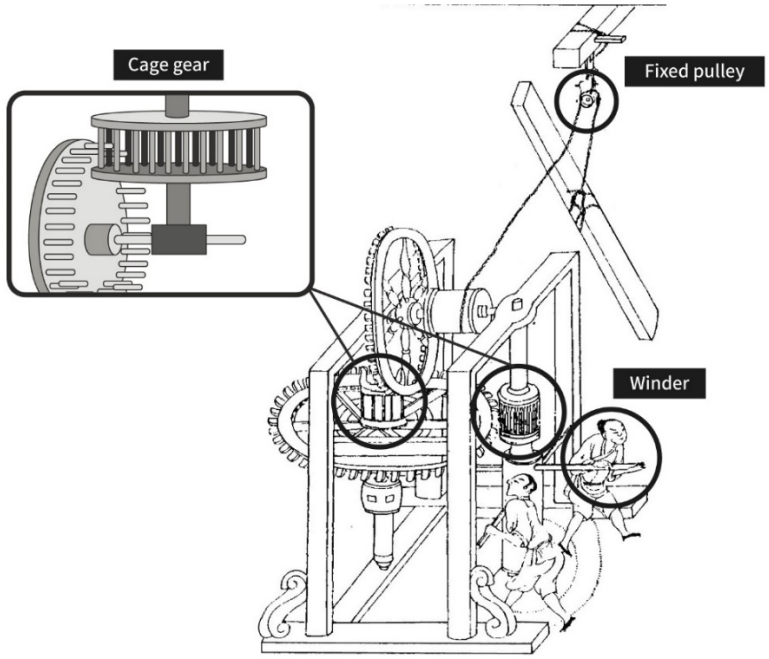

Figure 14. The 11th mechanical drawing of hoist. (起重第十一圖)
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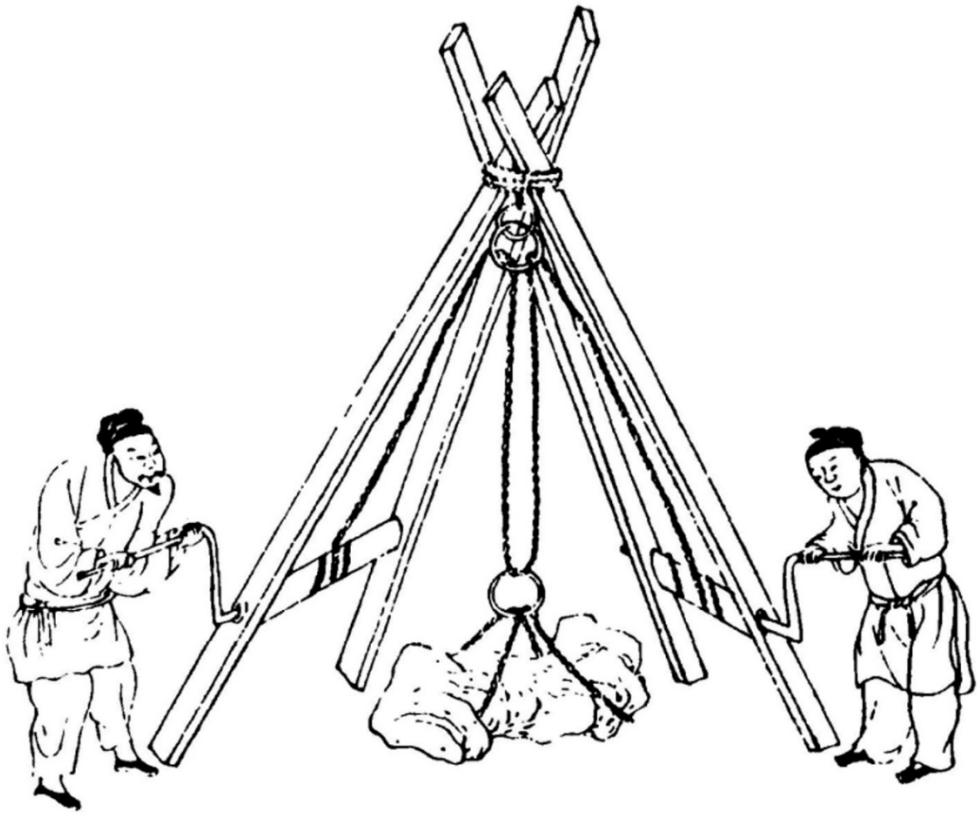

Figure 15. The 6th mechanical drawing of hoist. (起重第六圖)
(Reprinted, with permission of Seoul National University Kyujanggak Institute for Korean Studies.)

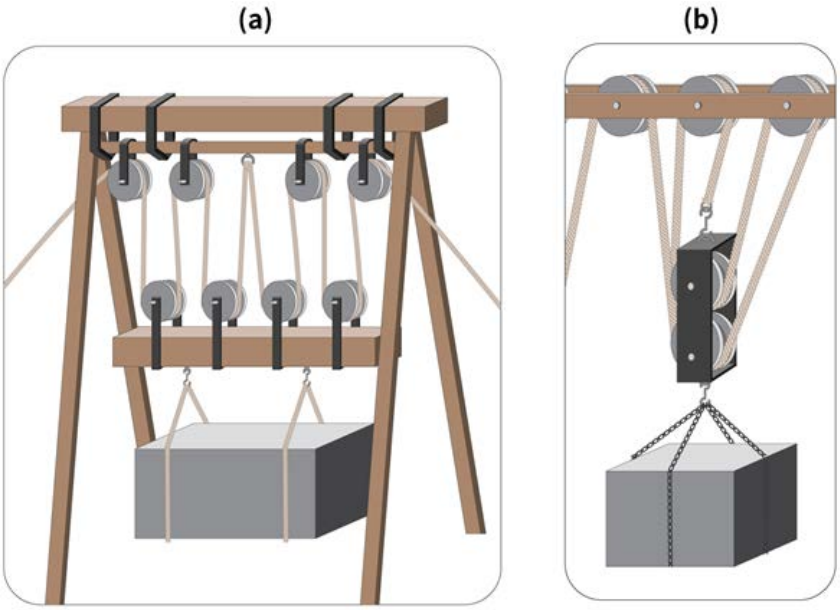

Figure 16. Chong Yagyong's Pulley System (a) vs Terrenz's Pulley System (b). (Created by the author)

Joannes Terrenz Schreck's Pulley System consists of vertical and horizontal tandem block (**Figure 16**). In comparison, Chong Yagyong's Pulley System consists of two horizontal tandem pulley blocks. One is fixed block (中游樑), the other is movable block (下游樑). As, regarding the horizontal tandem pulleys method, the breadths of the pulley blocks could only be wide, in order to support these, the legs of the supper fixtures, too, increased from three to four.

In this way, Chong Yagyong boldly abandoned the worm gear mechanism and the parallel pulleys method, of which the productions were judged to be not possible with the technologies at the time, by referring to the Gigidoseol. Instead, he adopted the tandem pulleys method as the block-and-tackle mechanism.

THE METHOD OF COMBINING THE SLABS OF THE STONES

Differently from the Gigidoseol by Terrenz and the sketches by Davinci, the Geojunggi by Chong Yagyong subdivided the components so that the disassemblies and the assemblies are easy and simple. And by attaching the names to the components, it produced a manual explaining the role. Especially, regarding the core components, which are difficult to be assembled, they were bundled into one module, thereby heightening the practicality. The movable pulley blocks were modulized by designing so that the small sheaves and the stirrups metals are bundled into one block and so that they are connected to the under steel bars through the rib-pieces (**Figure 17**).

The excellence of the Geojunggi is the point that it made the method of combining the movable pulley blocks and the stones and dismantling them easy. The method of connecting the stones to the movable pulley blocks is to install the support timbers on the ground, move the stones, and stick the steel bars through the spaces between the timbers. Next, by using the rings to connect the linking chains to the under steel bars and the steel bars, it was made to be easy to combine and dismantle.

Through the method of combining the movable pulley blocks and the stones, too, we can confirm that the Geojunggi is not a construction crane but is an equipment for putting on the stones on the carts. The reason why the chain rings and the steel bars can be easily combined and dismantled is that the stones are put on top of the support timbers. In the case of putting the stones on the stones, it becomes difficult to remove the steel bars under the stones. If we were to organize the method of the use of the Geojunggi in a pictorial manual with the 7 phases based on the above discussions, it is as shown in **Figure 18**.

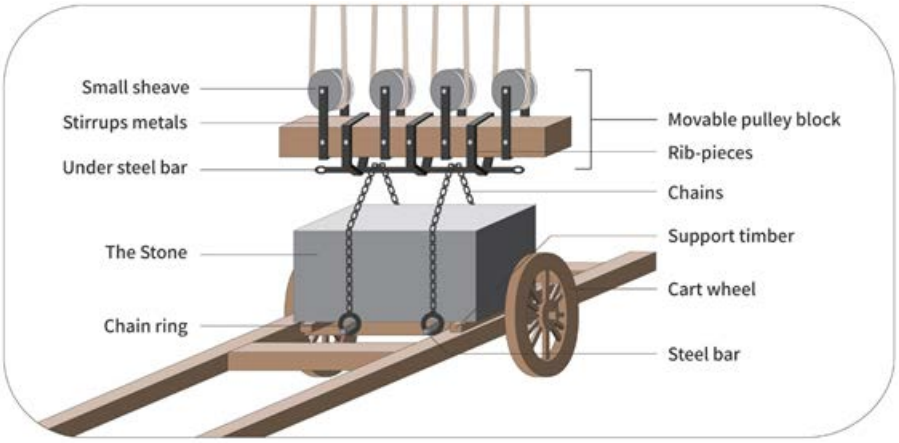

Figure 17. The composition of parts of low pulley block module. (Created by the author)

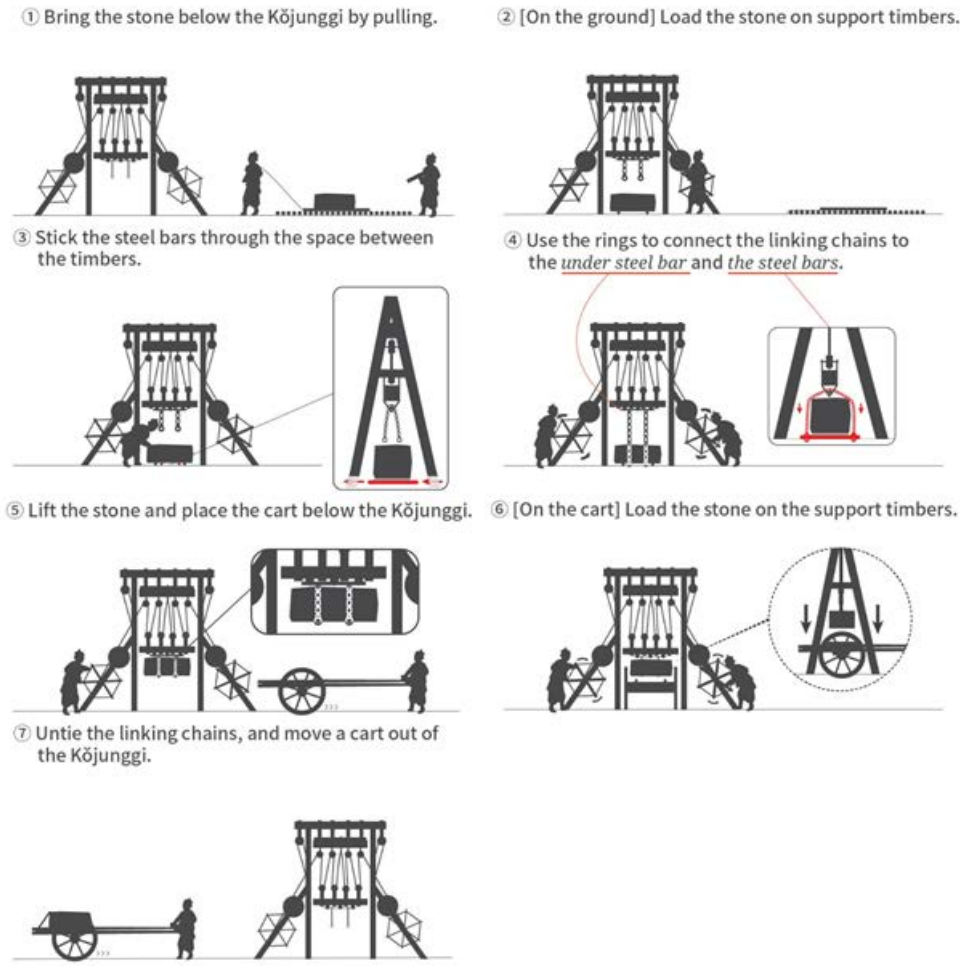

Figure 18. The Process of stone-loading utilizing Geojunggi. (Created by the author)

CONCLUSION

The reason why a lot of people said that the Geojunggi can improve the work efficiency by four times until now is related to the fact that the Hwaseong Fortress, regarding which 10 years were anticipated, actually ended in only two and a half years. Taking out the 6 months during which the construction had been suspended in the hot summer and the cold winter, the construction was finished within only 1/4 of the anticipated time period of the construction.

But, this word is a nonscientific inference and, at the same time, and it is different from the methods of calculating the work efficiencies today. According to the Hwaseongseongyeoguigwe, there was only one unit of the Geojunggi that was actually utilized on the construction site. There is a commonsensical problem with seeing that the time period of the large-sized construction of making the castle walls and the facilities that reach 5.4km was shortened to within 3 years with only one Geojunggi. Despite this, there has not been an example that raised an objection regarding a detail in a textbook and that attempted an analysis in earnest.

There is no accurate record that says that the construction duration period was shortened by using the Geojunggi. Except, there was only the introduction by Chong Yagyong that the construction cost of 40,000 nyang (兩) could be reduced by using a cable driving system with regard to the tombstone which he wrote by himself (Lee 2008, 142). Seeing that it was accurately mentioned that the sum amount of the money of the reduction of the budget was 40,000 nyang (兩, a traditional Korean monetary unit), there is the big possibility that this was the labor cost of the daily laborers who carried the stones. As the 40,000 nyang was merely 4.6% of the total construction cost of the Hwaseong Fortress which was approximately 870,000 nyang, the interpretation that the construction duration period could be shortened by using the Geojunggi is wrong. This is because the reduction of the costs and the reduction of the construction duration period are totally different issues. According to the Hwaseongseongyeoguigwe, the expenditures break down into 320,000 nyang spent on the purchase of construction material, 300,000 nyang for wages, 220,000 nyang for transportation of construction materials, and 90,000 nyang for other expenses (King Sunjo, 1801).

As the fact that the Geojunggi was used as a transportation system was clearly and definitely recorded in the Hwaseongseongyeoguigwe, the use of the cable driving system must be inferred by relating to the cart. When considering the structural limitation of the Geojunggi of having no other choice but to pull up the stones or put down the stones, Geojunggi was probably used mainly at the quarries. It is feasible to see that the Geojunggi is not a jib crane that lifts things and puts them on the high places like the Nongno, but, is a stationary loader crane used for loading the stones on the carts.

The reason why the young government official had the power to design a new city by referring to a Chinese book on strategy and the science and technology books of the West in such a short time is because of the engineering talents that had been fostered from the time he was little. The activities of the engineer Chong Yagyong were not the voluntary things but all of them were under the command of Jeongjo. Chong Yagyong prepared a strategy for carrying through a national project by reorganizing the engineering knowledge that had been obtained by studying intensively within a short period of time according to the King's command into a systematic logic. Eventually, Jeongjo's discerning eye of looking at the gifted engineers and his leadership had made Chong Yagyong for an engineering literacy. The engineering reasoning formed while being solidified became the core capability that can compile the Silhak (Realist School of Confucianism) while writing the books in the diverse fields during the time he had been on an exile.

A convergent human resources education needs to have a wide scope that encompasses the fields of science, technology, engineering, art, and mathematics and the fields of humanities. The traditional sciences include the elements of science, technology, and engineering, and, in view of the fact that it can be approached in a cultural context based on the historical literature and records, it naturally entails the elements of the humanities.

The examples of traditional mechanical drawings introduced in this paper will complement science and technology class materials. The core principle of traditional mechanical drawing based education is to utilize the traditional sciences as a medium that connects Science, Technology and History.

The block-and-tackle mechanism is a phenomenon found simultaneously in East and West. The compound pulley and gear mechanisms documented in western 16th century literature were introduced to China in the 17th century and then studied in Korea in the 18th century. The mechanical drawing of compound pulley and gears, which reflects the history of the exchange of science and technology between the West and the East, provides support for teachers and researchers to discover and develop an effective, applicable instructional strategy.

Drawings developed by The Roman treadwheel crane and Da Vincici's crane through Wang Zheng & Joannes Terrenze Schreck's crane through Chong Yagyong's Geojunggi can be useful in science class.

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APPENDIX: GLOSSARY

Cheok	尺	about 30.3cm
Jeongjo	正祖	The King Jeongjo
Chungyulyang	中遊梁	The Fixed pulley block
Eojeseonghwajuryak	御製城華籌略	The City Planning that was announced by the King Jeongjo
Geojunggi	擧重機	A traditional Korean Stationary Loader Crane
Gigidoseol	奇器圖說	Strange machines from the far West. The word Gigidoseol (奇器圖說) is the abbreviation for Wonseogigidoseollokchoe(遠西奇器圖說錄最)
Gijunggadoseol	起重架圖說	Technical drawing of prototype
Hangang	漢江	Han Liver
Hayulyang	下遊梁	Movable pulley block
Hoenglyang	橫梁	Parallel Beam
Hwalcha	滑車	a sheave
Hwallyun	滑輪	The Sheave wheel
Hwaseong	華城	Hwaseong Fortress
Hwaseonggijeokbi	火城記蹟碑	A memorial stone for the Construction of Hwaseong Fortress
Hwaseongseongyeoguigwe	華城城役儀軌	A completion report for the Construction of Hwaseong Fortress
Jagyeongnu	自擊漏	Water clock
Jang	丈	about 3m
Nongno	轆轤	Jip crane
Nyang	兩	A traditional Korean monetary unit
Seongseol	城說	The City Planning in Hwaseong Fortress
Silhak	實學	Practical studies
Tasansimunjip	茶山詩文集	Collection of Tasan(pen name) Chong Yagyong's poetry and prose
Yeoyudangjeonseo	與猶堂全書	Complete collection of Chong yakyong's works
Yuhyeonggeo	遊衡車	A cart that shakes like the scale