NEIGHBOR-PARK MANAGEMENT METHOD TO BOTH SMOOTHEN LONG-RUN BUDGET AND TO PRECAUTION EARLY-DETERIORATION OF PLAYGROUND-EQUIPMENTS

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***ABSTRACT*:** In recent years, the old city parks are increasing in number, and some accident may occur from carelessness and the deterioration of playground equipment. The manager of a city park is tackling check the condition and repair the part of playground equipments installed around the city area, but they have the problem that the budget to maintain them is insufficient. In order to maintain the equipments safely on the basis of budget constraint, the policy is needed where it is compatible in accident precaution and long-life use as possible as one can. The paper develops the neighbor-park management method which can smoothen the long-run budget for equipment‘s every year expenses under the lower risk of material hazard due to the events concerning early-deterioration of playground equipments. Actually, it applies to the one of neighbor parks at a city on Kanto region in Japan, and checks the usefulness of this method and it comments some policy implications of the neighbor-park management.

KEYWORDS: neighbor-park management, lifecycle cost-smoothing, early-deterioration risk

1. SAFETY, BUDGET OF CITY PARK

1.1 Material hazard and accidents precaution

National safety guide of park equipment has classified into the “risk” that children can judge, avoid accidents and the “hazard” leading to accidents when children can not judge it. Of course the playing is worth adventuring and challenging for growth of children. If children recognize its danger, the playing is one of challenges to that risk. Concerning without the value of playing, a certain danger that children does not fully recognize whether its accident would happen is the hazard.

The hazard of park equipment is separated with “human hazard” and “material hazard”. The former human hazard is related with users’ unsuitable action and their clothes. On the other hand the latter material hazard is based on the deficiency of design of the park equipments or its construction or its maintenance. **Figure-1** shows the key map of the material hazard of park equipment. For example the design and the construction of equipments are the “Product Liability” problem for the manufacturers indicating JPFA-S2008 that adjusts national safety guide of park equipments. The inadequate maintenance of equipments is included with the arrangement of them, the structure of crevice or projection, the unevenness of ground, the exposure of foundation work, the neglect of corrosion or abrasion or screw slack.

After installation of park equipments, the material hazard generated in the stage of maintenance is a “Management Liability” problem for the city park administrator’s responsibility. It is important for the park administrator to find the material hazard at actualized early stage of maintenance and also

exclude it. So they can provide safe opportunities for users to play existing park equipments. This paper highlights the material hazard from a viewpoint of long-life use of park equipments as one can possible.

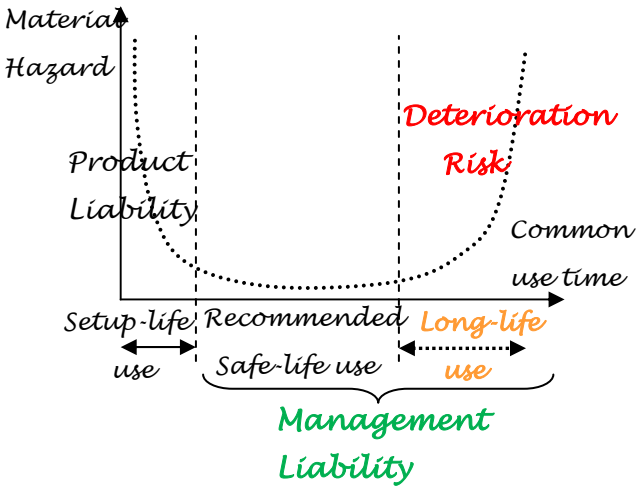

Figure- 1 Key map for material hazard of park equipments

In Japan almost park administrators recognized the importance of maintenance action for accident precaution. 1997, an newspaper publisher and some citizens surveyed the city park management towards 1,200 park administrators of cities and towns when there are 499 answers and the recovery rate is 42 percent. Regarding with the safety check list of park equipments, 40 percent of local governments were included. Among them, there were only two percent of the governments which stipulated the safety check standard. The key measure against accident prevention of park equipments were concluded with the maintenance of equipments when 75 percent administrators answered, understanding and cooperation of residents when 40 percent ones answered, safety standards when 31 percent ones answered, users' safety education when 11 percent ones answered.

1.2 Management budget shortage, long-life use

A survey of city park management for local self-government body reported that there are a few problems to be difficult against accident prevention of park equipments such as budget shortage answered by 60 percent and labor shortage by 30 percent. When it has a problem of budget shortage, it is difficult to update all existing equipments at once. It needs to check the state of equipments and also pay attention to users' safety and furthermore to carry out repair or renewal them.

As usual, use of park equipments is free. The local self-governing body pays the repair or renewal budget by tax revenues. It has a fixed restriction for source of revenue to invest the park maintenance. Under the constraint it needs to plan a budget at medium-to-long term for repairing and updating equipments as long as users can use them. A long-life use of park equipments is to equalize the administrative expenses every year without being pressed finances and also to prolong the lifetime of park equipments at safe level. Such a kind of research, incorporating the coexistence between accident precaution and long-life use, is not found as far as the author gets to know.

This paper focuses on the scene to decide upon the medium-to-long term budget planning which equalize the future administrative expenses, while incorporating an early deterioration risk. Then it proposes the management technique to assign the optimized combination of repair periods when it holds a safe level as much as possible, that is, the deterioration risk is minimized and when it is possible to equalize administrative expenses every year as long as one can. Actually it applies to park equipments and it comments some further themes.

2. NEIGHBOR-PARK EQUIPMENT MANAGEMENT METHOD

2.1 Equipment accidents, safety management

(1) Focusing on primary park-equipments

In Japan city park equipments are installed at 129

thousands of places, reported by the Ministry of Land, Infrastructure, Transport, city and regional development bureau, park green division, 2009. They includes with “neighbor parks” by the rate of 80 percent. This paper highlights the neighbor parks when there are a lot of parks in Japan. The neighbor parks have five highest ranks of equipments such as the sandbox, the swing that is wooden board type, the slide, the iron bar, the spring equipment. At the periods which renewal demand concentrates, the park administrator's finances must be pressed, regarding with the equipments which have a lot of quantity at each parks and whose unit price is high.

The accident case survey 1997 due to the equipment of the city parks reported 34 cases with some fatality accidents and more than 30 days medical treatments. They includes in the order of number of cases, such as the athletics, the slide, swing that is wooden board type and box type, the combination equipment with Tarzan rope and suspension bridge. There were 4 to 14 serious injury accidents from 1998 to 2004. Although the accidents were going to decrease reported to the serious injury, but the slight injury accident is latent without national reports. The risk of accidents due to park equipments is not always canceled completely. This paper focuses on the primary equipments of neighbor parks that are much installed and serious accidents often occurred comparatively. The concrete equipments are typical three ones installed at neighbor parks such as the swing that is wooden board type, the slide, the athletics.

(2) Setup scenarios for long-life use

In order to long-life use park equipments there are several scenarios such as 1) preventive maintenance type where viewing or condition monitoring is possible, 2) time-based maintenance type where condition monitoring is difficult, 3) posterior maintenance type whose response is quickly after breakdown is discovered. This paper set up some maintenance scenarios in accordance with the time-based maintenance type contributed to accident precaution. The periods of year for repairing or renewal are based on the Standard usable years by the standards of Japanese park association or some maker's reference usable life.

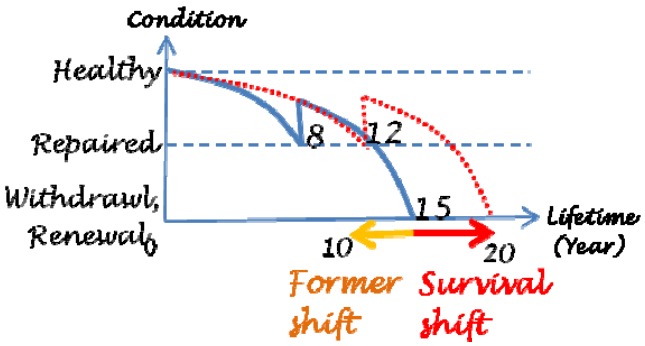

Figure- 2 Swing-repairing scenario

Notes) Updating main part is the steel beam. Repairing subpart is hanging metallic ornaments and wooden board.

Figure- 2 shows a scenario of wooden board type swing to repair and renewal. The horizontal axis is the management level of the swing. The vertical axis is the lifetime of swing by the unit of years. The solid line is an accident prevention type scenario where the eighth year is repairing period for the subpart of swing and where 15th year is updating period for the main part of swing. Three year former shift of repairing or updating is permitted. The dotted line is a long-life use type scenario where the 12th years is repairing year for the subpart of one and where 20th years is updating period for the main part of swing. Also the scenario of the athletics equipment is the same as that of swing. But updating main part of the athletics is steel support and repairing subpart is nets and wooden frame.

Figure- 3 shows the updating scenario of slide. At the accident prevention type, the tenth year is updating main part of slide. Three year former shift updating is permitted. At the long-life use type, the 14th year is updating main part of slider.

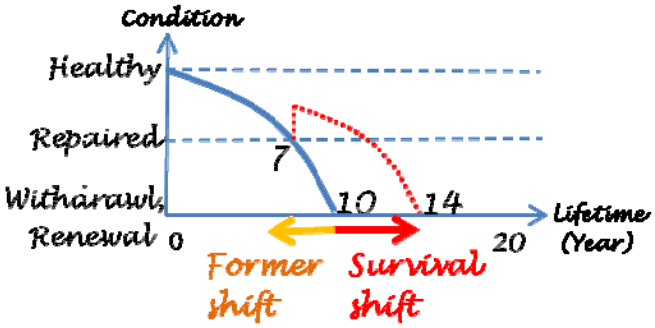

Figure- 3 Slide-repairing scenario

Notes) Updating main part is pillar, stairs, landing.

2.2 Early-deterioration risk profiling

(1) Definition of early-deterioration risk

The scene where an accident happens is classified into the initial stage that equipments are installed and the maintenance stage in use. An accident risk of an initial stage depends on the responsibility of the contractor whether there is any poor construction work. This paper pays attention to the risk of park equipment accident which occurs in the maintenance stage with much responsibility of an administrator. If park equipments are repaired or updated within the standard usable year on the safe side which makers recommend, then it could minimize the risk of maintenance stage, although it is not zero. When it is time of standard usable year, if any remarkable deterioration is not recognized, then the use of equipment might be continued with condition monitoring. Here, at the risky maintenance stage when the lifetime of equipment is exceeded over the standard usable year, the risk event could happen where it deteriorates earlier than the administrator's prospect. In this paper such a risky event is defined by the "early-deterioration risk". Below is the risk profile of early-deterioration, it is specified by the severity due to park equipment accident and the frequency of risky maintenance events. It is assumed that each risk of equipments is occurred independently and identically. The risk of early-deterioration is structured with the severity of equipment accident $L_{i,t}^{k}$ and the frequency $F_{i,t}^{k}$. Setting a year t at a city park $i \in \{1,2,...,N\}$, let us assume that equipment $k \in \{1,2,...,K\}$ has a risk of early-deterioration. Its risk is specified as follows.

$$R_{i,t}^{k} = L_{i,t}^{k} \cdot F_{i,t}^{k}, t \in \{m, m+1, m+2, ..., m+M\} \quad (1)$$

Here m stands for the standard usable year on the safe side which makers recommend. The formula (1) means that it is exposed to the risk of early-deterioration under the excess M years in long life use.

(2) Severity of park-equipment accidents

What is called "city park" stands for the park or the green build by administrative divisions or municipalities such as cities, towns and villages, at the city park law under article 2, established in 1956. In addition, they are various, the nursery school over which the Ministry of Health, Labor and Welfare has jurisdiction, the kindergarten over which the Ministry of Education and Science has jurisdiction, the residential housing which the association of a community manages. In Japan, the Ministry of Land, Infrastructure and Transport has jurisdiction over park-equipment makers. From 2003 to 2008, the Japan Park Facilities Association (JPFA) has reformed the safety standards of park-equipments, their member are included by its makers. Still now, park equipments of each domestic park or green are checked at the safety standards.

The JPFA provides the product-liability-insurance system for park equipment makers after installation among two years. But the statistics of equipment accidents are not exhibited. From a maker's web information, the insurance maximum payments are three billion yen for medical accidents and ten million yen for real accidents. In order to specify the degree of influence of park equipment accident, it must be based on their present statistics. However, the sufficient statistics are not released, which recorded the park equipment accidents on the complete coverage in all Japan. So, the author must use the limited existing data which is the fragmentary records which each organization arranged.

From 1996 to 2004 up to nine years, 122 affairs of serious injury or death accident are reported to the country from the administrators. The annual average is 13.6 affairs every year. The park equipments which the accident occurred are combination equipments at 51.6 percent, swing at 22.1 percent, slide at 9 percent, and so forth. However, these

values are the extreme statistics limited to the serious injury accidents and the death accidents. These are only one corner of an iceberg.

Table- 1 Examples of accidents and compensations for park equipments

2003 Oct., Hyogo prefecture Amagasaki city park
Accident ; ・Combinations with jungle gym, net, iron bar. ・Infants are taken into the park by four childcare workers. ・An infant at age 4 fell down on iron bar, and blew her belly heavily, so become dead. Compensation, lawsuit ; ・The park administrator, the nursery school was accused of the homicide through negligence in carrying out their duty. ・The lawsuit of infant's damages responsibility.
2008 Aug., Osaka pref. Habikino city park
Accident ; ・When a child at age 11 rid on swing and stood it, the wooden sheet has come off. ・The child fell down and had a slight injury to his finger. They did not tighten up a piece of screw. Compensation, lawsuit ; ・Police investigation whether the past inspection at a month before were defective.
2009 May, Tochigi pref. Utsunomiya city park
Accident ; ・At sailing boat type equipment, an infant at age 3 fell down from the suspension bridge, so her leg fractured. ・Due to overlooking the unsuitable height over the safety standard while inspecting them. Compensation, lawsuit ; ・A reconciliation has been effected between the two with a pay of one million yen.

From 1996 to 2000, the Ministry of Health, Labor and Welfare investigated the accidents which occurred with the park equipments installed at nursery schools, handicapped-child institutions, etc. In nursery schools 2,319 affairs of equipment accidents occurred among the number of nine million users. Its annual average is 463.8 affairs every year. The contents of the accidents in nursery schools are included below, such as fall down at 56.6 percent, fall beside at 13.2 percent, collision at 12.8 percent, jumping off at 10.4 percent and insert at 3.5 percent. Children's unreasonable action might be taken exceeding physical strength by his/her adventurous spirit. Since the children at the age until five are not fully learning the danger of any accidents, it needs the suitable instruction to play for children by childcare workers. And it also needs managers' responsibility for duty of childcare or homicide through negligence.

Table- 1 shows the example of park equipment accidents and the contents of compensations and lawsuits. Summarily, the degree of influence to the administrator for a park equipment accident is included with 1) the labor for response such as investigation and reconciliation, 2) the court costs for lawsuit, 3) the payment for users' damages and 4) the trust loss by lost lawsuit. The administrator's expense paid directly and indirectly cannot generally be set up. The complete records of the statistics of the compensatory claim payment are not official announced. So this paper sets up the degree of influence of park equipment accidents, referring the maximum payment of product liability insurance by JPFA.

Table- 2 Risk stages of equipment accident and administrator's response

Risk stage	Administrator's response
Order I	0) Without measure
Order II	1) Signboard notice (nudge) 2) Temporary measure
Order III	3) Repair, 4) Improvement
Order IV	5) Use stop, 6) Withdrawal 7) Remove, 8) Renewal

(3) Estimating frequency of risk events

In order to prevent some park equipment accidents, express the response which an administrator performs as $a \in \{1, 2, ..., E\}$ against the risk events of accidents. Concretely its response are included with 0) Without measure, 1) Signboard notice

(nudge), 2) Temporary measure, 3) Repair, 4) Improvement, 5) Use stop, 6) Withdrawal, 7) Remove, 8) Renewal. Regarding with the risk of park equipment accidents, these responses are ranked into four orders as follows **Table- 2**.

This paper formulizes a method to estimate the frequency which the order of risk events occurred due to park equipment accident. Now denote the response for the risk of a park equipment i as $a_i \ (i = 1,...,N)$. The threshold response level, it stands for r, which exceeds the rank of order where the risk events would actualize. Define the "Safe condition S "comparatively safer than the rank of risk order under the threshold response level. It is expressed as follows.

$$S \ \text{ if } \ a_i \in \{0,1,2,...,r-1\} \tag{7}$$

Next define the "Dangerous condition D " which exceeds the rank of risk order over the threshold response level and actualizes the deterioration risk. It is expressed below.

$$D \ \text{ if } \ a_i \in \{r, r+1, r+2,..., E\} \tag{8}$$

The condition at risk stage of the park equipment is included to one of conditions.

$$\Pr(D) = 1 - \Pr(S) \tag{9}$$

In order to set up the early deterioration risk at the stage of the risk ranking concerned, it needs to estimate the occurrence probability of a dangerous condition $\Pr(D)$. Below is modeling phenomena which condition of the park equipment is included in either of two conditions that exceeds over the threshold response level or does not. Concretely, using the two-grouped poisson model, it omits "2GP", the paper proposes a method to estimate the occurrence probability which exceeds the risk order with threshold response level.

Now, see a park-equipment managed by an administrator, whose attribute denoted by z_i. The administrator has a preventive response a_i against accidents at the park equipment i. It expresses the probability generating the comparatively safe condition under the threshold response level as a following formula.

$$p_i^S(z_i) = \Pr(a_i \in S \mid z_i) = \sum_{a_i \in S} f(a_i \mid z_i) \tag{10}$$

Assume that densities of responses are independently and identically Poisson distributed below.

$$f(a \mid z_i) = \frac{\exp(-\lambda_i)(\lambda_i)^a}{a!}, a = 0,1,2,...,E \tag{11}$$

Here, the mean of Poisson distribution is taken into consideration with the attribute of park-equipment. It specifies as follows.

$$\lambda_i = \exp(z_i'\beta) \tag{12}$$

Here, $z_i' = (z_{i1},...,z_{il})$ is the number of l elements of the park equipment characteristic vector. And $\beta' = (\beta_1,...,\beta_l)$ is the number of l elements of characteristic parameter vector. Then the likelihood function of 2GP can be formulized below.

$$L^{2GP} = \prod_{i=1}^{N} p_i^S(z_i)^{d_S} \left[1 - p_i^S(z_i)\right]^{(1-d_S)} \tag{13}$$

Here, d_S denotes the membership function contained in the safe condition under threshold response level. If the administrator's response against an equipment is included in the safe condition under the threshold response level, it becomes that $d_S = 1$. Else if it is exceeded over the threshold level in the dangerous condition, it becomes that $d_S = 0$.

Furthermore, the logarithm likelihood function of 2GP is expressed with the following formula.

$$\log L^{2GP} = \sum_{i=1}^{N} d_S \log p_i^S(z_i) + \sum_{i=1}^{N} (1 - d_S) \log\left[1 - p_i^S(z_i)\right] \tag{14}$$

Here, the occurrence probability of the safer condition under the threshold response level is expressed as follows.

$$p_i^S(z_i) = \sum_{a=0}^{r-1} \frac{\exp(-\lambda_i)(\lambda_i)^a}{a!} \tag{15}$$

In order to estimate park equipment characteristic parameters $(\beta_1,...,\beta_l)$ possible to maximize the log-likelihood function of 2GP, it can calculate a numerical computation using the quasi-Newton's method.

It can use the estimated values of park equipment characteristic parameters to calculate the occurrence

probability in the dangerous condition. The occurrence probability at the stage of a risk order exceeded over a threshold response level is calculated below.

$$p_i^D(z_i;\beta_1,...,\beta_l) = \Pr(a_i \in D \mid z_i)$$

$$= 1 - p_i^S(z_i;\beta_1,...,\beta_l) \qquad (16)$$

(4) Risk attributes of park-equipments

The early deterioration risk of park equipment is different from the kinds of equipment, such as swing, slide and athletics. Regarding the mean of the Poisson distribution (12) of the preventive response against park equipment accidents, it specifies next.

$$\lambda_i = \exp(\lambda_0 + d_i'\beta) \qquad (17)$$

Here, λ_0 is a constant parameter. And d_i' denotes the dummy variables of the kind of park equipment.

$$d_i' = (d_i^1,...,d_i^K) \qquad (18)$$

Here, d_i^k stands follows, if the park equipment i is the kind k, it becomes $d_i^k = 1$, else if it is another kind of equipment, it becomes $d_i^k = 0$.

2.3 Budget smoothing and risk minimizing

(1) Minimizing excess budget, degradation risk

Denote a equipment in a neighbor park as a unit $k \in K$, its unit belongs to the set of equipments. Denote the lifetime of an equipment within the planning periods by years as the year $t \in T$, its lifetime belongs to the set of years. The paper deals with the problem which minimizes the sum of repairing cost excess over the guide budget and early deterioration risk, for the administrator to manage equipments of neighbor parks. This problem is formulized in the next program.

○Variable $y_t^k \in R_+ \quad k \in K$

: Repairing cost for an unit $k \in K$ at the lifetime $t \in T$. Here R_+ stands for real number above zero.

$r_t^k \in R_+ \quad k \in K$

: Early deterioration risk of unit $k \in K$ recognized at the lifetime $t \in T$.

$p_t \in R_+ \quad t \in T$

: Upper value of excess cost over the guide budget at the lifetime $t \in T$. That is a middle slack variable.

$u_t \in R_+ \quad t \in T$

: Upper value of early deterioration risk recognized at the lifetime $t \in T$. That is also a middle slack variable.

○Constant b : Guide budget every year within the planning periods.

C : Penalty weight against the sum of repairing excess cost over the guide budget.

○Minimize $C \cdot \sum_{t \in T} p_t + \sum_{t \in T} u_t \qquad (19)$

: Sum of weighted cost overrun and early deterioration risk within the planning periods.

○Constraint

$$(y_1^k,\cdots,y_t^k,\cdots,y_T^k) \in G^k \quad k \in K \qquad (20)$$

: Repairing costs of unit k every period are included with the feasible set to shift former or to survival.

$$p_t \geq \sum_k y_t^k - b \quad t \in T \qquad (21)$$

: Sum of repairing cost on all unit k never excess the guide budget every period.

$$u_t \geq \sum_k r_t^k \quad t \in T \qquad (22)$$

: Sum of the early deterioration risk of all unit at the lifetime $t \in T$ is less than or equal to the upper slack value.

At the formula (19) penalty weight is ranged on integer above zero. If the early deterioration risk changes in term of money, the scale of its risk often becomes larger than that of repairing cost. The weight C unifies the both scale of cost and risk in order to adjust the trade-off of administrative repairing expense and early deterioration risk.

At the equation (20) the repair time of unit permits flexibility among eight years. Regarding the primary equipments such as swing, slide and athletics, the

standard usable years ranges from ten to fifteen years. If it breaks down a repairing scenario on a large scale, it becomes its huge waste of administrative expenses and its marked actualization of deterioration risk for equipments. Of course it has to avoid that situation. Therefore below is the one feasible set that the three year former shift of repair time is enabled from the standard usable year of equipments. Furthermore it is another feasible set that the four years long life use is taken possible from the standard usable year.

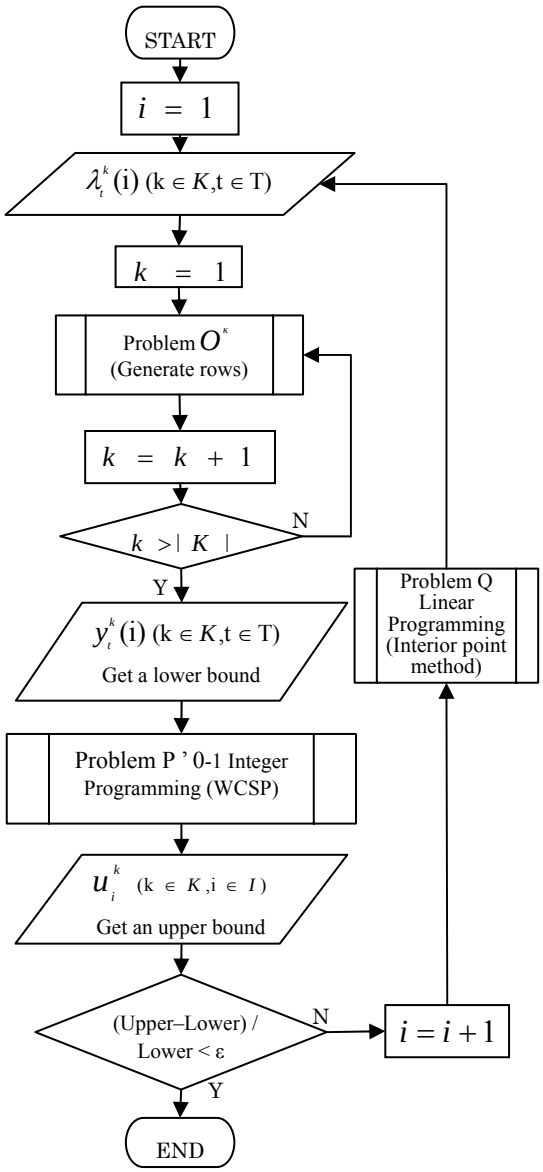

Figure- 4 Calculation flow of Lagrange relaxation method

(2) Algorithm to minimize repairing cost overrun and deterioration risk

The primary problem is structured by formula (19) to formula (22) where it assigns the repairing cost and early deterioration risk is recognized in each year. Although it becomes a large-scale discrete programming, it is solved using the Lagrange relaxation method. At first the primary problem P is relaxed to minimization problem P', it acquires the upper bound of approximate solutions. On the other hand, the maximization problem Q which is dual problem of the relaxed minimization problem P', it gets the lower bound of approximate solutions. Next it searches any row where it generates from the feasible set based on a repairing scenario, which it invests administrative expenses and when it repairs or updates equipments. It repeats to improve both approximate solutions of the upper bound and the lower bound. And it brings close to the optimal solution of the primary problem.

Figure-4 shows a flow of numerical computation using the Lagrange relaxation method. These consist of three part of search program connected mutually, such as firstly the row generation where each repairing cost is feasible, secondly how to solve the lower bound using the interior point method from the linear programming that is Lagrange relaxed and thirdly how to solve the upper bound using the 0-1 integer programming that is Lagrange dual problem. It repeats to solve the three parts of programming to improve the feasible repairing cost at each year, upper bound from a relaxed problem and lower bound from dual problem. The mark of convergence is whether the each step's difference between the upper bound and lower bound becomes sufficiently small to a limited range.

3. APPLIED RESULTS

3.1 Setup an illustrating condition

(1) Illustrating neighbor-park equipments

Applied example is 205 neighbor parks of one of city on Kanto region in Japan. They are managed by the local self-governing body on a scale of 300 thousand people. This repairing plan starts 2010. It calculates future 30 years after administrative expenses to repair the park equipments.

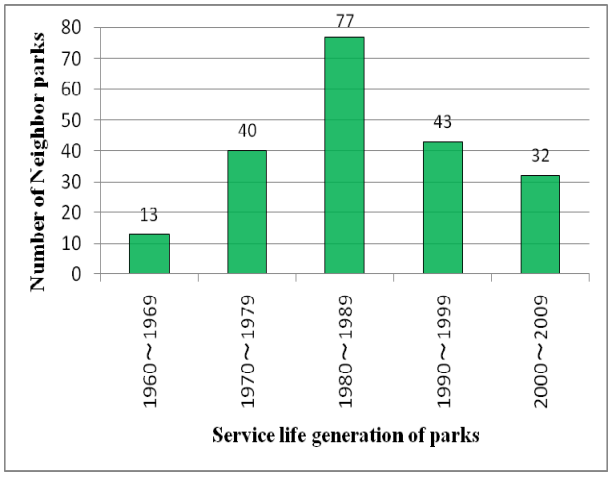

Figure-5 Example of the service lifetime of neighbor parks

Figure-5 shows the generation of concerned neighbor parks, that is service start year. That average value is 23.7 years old by past years from the start to 2009. There are 130 neighbor parks, they are 60 percent of all, where it passed 20 years from 1989 to 2009, exposed the higher risk of accident due to early deterioration. The total quantity of equipments to manage them is 307 installed in the neighbor park of this example. Their equipments includes with 149 swings of wooden board type, 121 slides and 37 athletics.

Due to data restrictions, their equipments are standardized as homogeneous type and scale in each neighbor park. Concretely, it standardizes the swing as large-sized for two persons including a safe fence. And it standardizes the slide as medium size. Furthermore it standardizes the athletics as steel pillar with a net.

Table-3 shows the unit price of primary equipments to repair and update, based on the catalogs of local makers at the study area. Below is to set up the repairing or renewal cost.

Table- 3 Setup unit prices to repair, renewal

(one thousand yen)

Park equipment	The contents of repair, renewal	Unit price
Swing (Stretcher board type)	Component-repair of Metallic chain, board	105
	Main part renewal of Beam, stem pipe, fence	310
Slide	Component-repair of Slide side	115
	Main part renewal of Pillar, stair, landing	285
Athletics	Component-repair of Net, wooden frame	145
	Main part renewal of Steel pillar	290

When its lifetime has passed already the standard usable year, their old equipments should be updated as soon as possible. In this case it assumes that their old equipments are updated within ten years from the start of this management plan. It is possible that updating period is given as the random number ranged from one year to ten year.

(2) Illustrating risk due to early-degradation

Figure-6 shows the assumption of loss by park equipment due to deterioration. The zero-year stands for the standard usable year. Even if it is supposed that they repair the usable years by safe side of maker recommendation, an early deterioration risk is not zero. It is assumed that the longer life use of equipments, the more loss of accidents increases. At the deterioration stage of inferior condition of park

equipments, it is assumed that it does not use long life more than five year. It is assumed that the maximum probable loss happens when it passes five year from standard usable year. The maximum probable loss is set up to three billion yen, it is reference about the maximum of the medical compensation frame of JPFA.

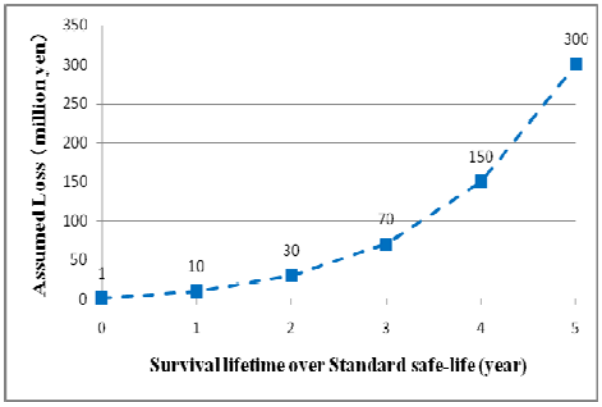

Figure- 6 An assumed losses due to equipment deteriorations at the long-life periods

Figure-7 shows the point estimates and the approximated curve of excess probability at the stage of preventive responses against the deterioration risk event of accidents. It approximates well their curves using power function. It is in the tendency for the excess probability of concerned swing and athletics to be larger than the slide.

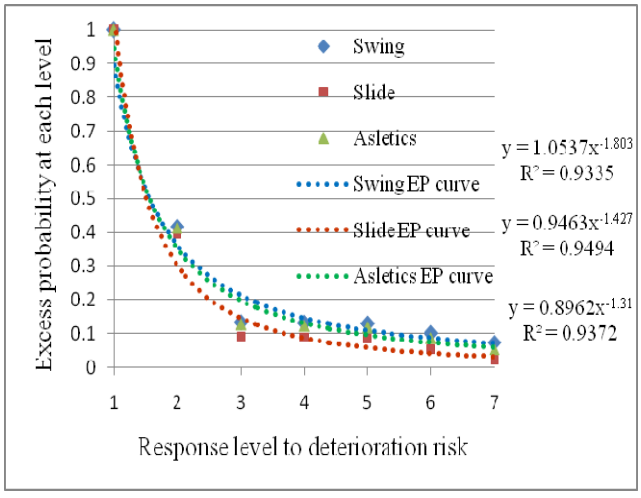

Figure- 7 Excess probability at risk stage

Table-4 Estimated results of the occurrence probabilities of deterioration risk events

	Excess risk-event threshold		
Explanately variables	r=1	r=3	r=5
Constant λ_0	-1.9944 [.00***]	0.1731 [.00***]	0.6994 [.00***]
Swing dummy β_1	0.0389 [.27]	0.0383 [.01***]	-0.0731 [.00***]
Slide dummy β_2	-0.3669 [.00***]	-0.149 [.00***]	-0.2527 [.00***]
Iterations to convergence	5	6	6
Number of observation	141,158	141,158	141,158
Log likelihood	-49192.4	-47803.1	-20161.7

Denote) *** : p<0.01(1% significant), ** : p<0.05(5%), * : p<0.10(10%) .

Table-4 shows the estimated results of the frequency model for deterioration risk event generating in a threshold level. It uses statistics data of the preventive responses against equipment accidents which the park administrator carried out in Japan, the Ministry of Land, Infrastructure and Transport, 2007. According to the kind of park equipments such as swing, slide and athletics, it can be interpreted that the frequency of deterioration risk event is different significantly.

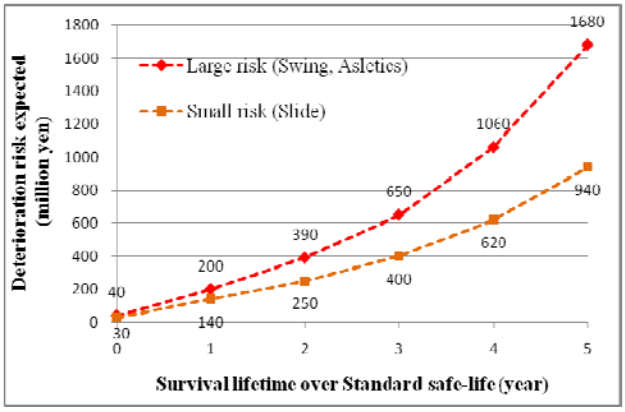

Figure- 8 Setup the expected risk due to early-deterioration of park equipments

Figure-8 shows the setup of the early degradation risk of equipments, using the point estimate of the frequency for deterioration risk events and the losses assumed when accidents probably happens. The early degradation risks are divided into the large risk equipments such as swing, athletics and the small risk equipment of slide. It sets up that the longer life it uses passed over standard usable year, the more deterioration risk increases.

3.2 Applied Results

(1) Distribution of repairing cost and risk due to early-deterioration

Figure-9 shows the histograms of the repairing cost of park equipments with different penalty weights against excess over the guide budget. It tends to concentrate on 8.8 million yen when it penalizes repairing cost overrun strongly. On the other hand, when it permits the smaller penalty weight to cost overrun, it happens as the repairing cost from 12 million yen to 16 million yen.

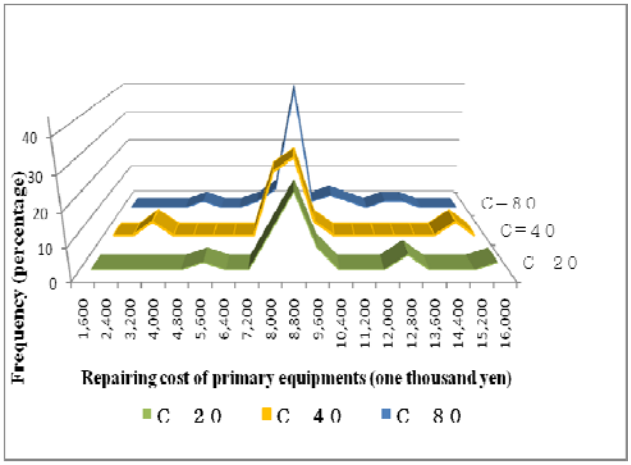

Figure-9 Histogram of repairing cost

Figure-10 shows the histograms of the early deterioration risk of equipments with different penalty weights against excess over the guide budget. When it does not allow repairing cost overrun strongly, it frequently generates the year which remarkable degradation risks actualize. When cost overrun can be permitted, penalty weight is small, whose budget is comparatively abundant, the early deterioration risk can be controlled small relatively.

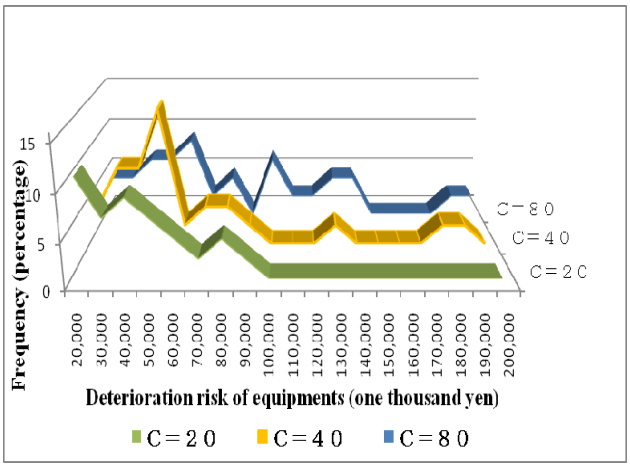

Figure-10 Histogram of expected risk due to deterioration of primary equipments

(2) Trade-off of repairing cost and risk of early-deterioration

Figure-11 shows the yearly average value of the repairing cost and the early degradation risk, when it inputs of the several penalty weight of excess cost over the guide budget. The guide budget is eight million yen. It makes the approximated curve when each point is connected. The dotted curve is optimized positions where an administrator can try to control as lower as possible repairing cost and early degradation risk.

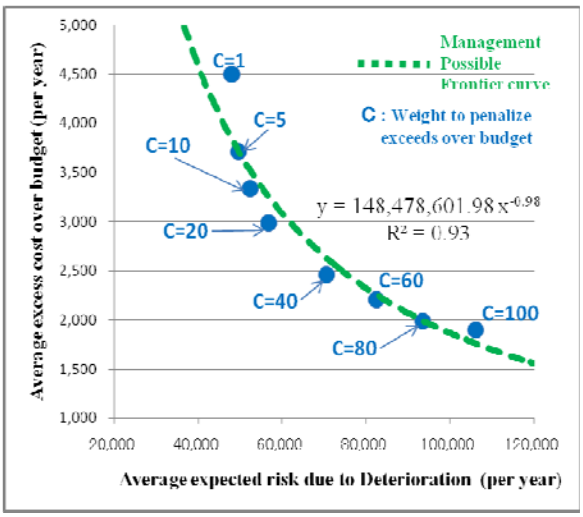

Figure-11 Trade-off between the repairing cost and the risk of equipment deterioration

This is called the “management possible frontier

curve". It is estimated by a power function below.

$$c_1^* = 148,478,601/(r_1^*)^{0.98}$$

$$R^2 = 0.93, C \in \{1,5,10,20,40,60,80,100\} \quad (23)$$

However this curve is not sufficient to fit all positions. So two curves are separated at the change point where the penalty weight is 20. They are estimated by power function as follows.

$$c_1^* = 146,108,202,120,971/(r_1^*)^{2.25}$$

$$R^2 = 0.89, C \in \{1,5,10,20\} \quad (24)$$

$$c_2^* = 9,233,371/(r_2^*)^{0.74}$$

$$R^2 = 0.99, C \in \{20,40,60,80,100\} \quad (25)$$

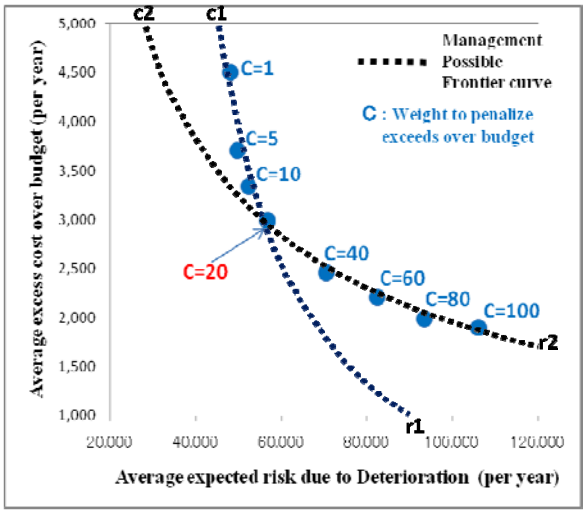

Figure-12 Two management possible frontier curves at the change point C=20

Figure-12 shows two separated management possible frontier curves. Among the cost over penalty weight range from C=1 to the change point C=20, early deterioration risk does not almost change. On the other hand at the weight range from C=20 to C=100, early deterioration risk increases remarkably. In short it proposes that C=20 is an optimized position as lower excess cost over guide budget as possible and it also can permits the small increasing deterioration risk.

4. CONCLUDING REMARKS

4.1 Concluding remarks

This paper focuses on the primary equipment in the neighbor at one of city parks. It developed the method to minimize the repairing cost overrun with the basis of feasible scenarios and the early degradation risk. Constrained on the set of feasible periods to repair or update them, it is supportable to decision the maintenance plan which adjusted the trade-off between the repairing expense and the deterioration risk. Actually it applies to a domestic neighbor parks and it checks the usefulness of this method. Especially it exist the change point as lower repairing cost as possible and it also can permits small increasing risk of early deterioration. It can create some optimized alternative plan where it adjusts the trade-off between one distribution of excess cost over the guide budget and another distribution of early deterioration risk for preventive response. It also can create the cost table containing with the year and the cost to repair or update equipments. It is utilizable as one of budgetary request data. Furthermore it creates the risk table where the early degradation risk is recognized at the stage of inferior equipments. It is utilizable as one of basic reference for preventive responses and the extraction for risky equipments.

4.2 Further developments

Although the paper focuses on the primary equipments, in addition to this other equipments remains to study them. It needs to raise the flexibility to set up the various conditions on which the administrators are put and also accumulate examples of management possible frontiers. Although the paper introduces the time based scenarios, in the future situation where inspection data are stored it sets up the deterioration prediction based scenarios. Especially when the guide budget is much reduced and it uses much longer life, it introduces preventive and breakdown maintenance scenarios, furthermore it needs to analyze the reliability of equipments and to predict the year to repair or update them. The paper proposes to estimate the occurrence probability of risky stage according to the kind of

equipments using the limited statistics. It needs to improve the accuracy to set up the early degradation risk. So it incorporates the heterogeneous attribute of park equipment such as frequency to use it, residential situation around the neighbor park. Furthermore it needs to improve the objective function incorporating the loss of former shift and the merit of long life use than the standard usable years. It is happy that this paper contributes to manage park equipments safely and to get the source of repairing budget timely in fewer children society.

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