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BAHÇEŞEHIR UNIVERSITY

STATISTICAL ANALYSIS AND CAPACITY PLANNING OF A THIRD LEVEL NEONATAL UNIT

M.S. Thesis

Elif ANILGAN

ISTANBUL, 2011

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THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
INDUSTRIAL ENGINEERING PROGRAM

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Acting Director

This is to certify that we have read this thesis and that we find it fully adequate in scope, quality and content, as a thesis for the degree of Master of Science.

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ABSTRACT

STATISTICAL ANALYSIS AND
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Anılgan, Elif

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This master thesis is based on observations at to a third degree neonatal unit which is a university hospital in Istanbul. Infant mortality rate is a major indicator for a country's development index and it is an economical factor. Because, it affects the characteristics of population like as old population or young population. This property is significant in terms of country development policies. Therefore, investment to health sector plays important roles for the future policies and current conditions. To develop the current situation in terms of baby rejections and equipment utilizations some basic statistical tests are made and some of them used in simulation model. In this study simulation is preferred for capacity planning because of the complexity of problem. In simulation model some performance criteria are determined according to neonatal unit's scarce resources. Moreover, some statistical data analyses are made for three years. Four solution suggestions are generated for current condition to minimize the number of rejections and waiting time. On the other hand it is aimed to maximize number of baby acceptance and equipment utilizations.

Key words: Capacity planning, Neonatal unit, Neonatal, Simulation, Statistical Analysis.

ÖZET

BİR 3.DERECE YENİDOĞAN ÜNİTESİNİN İSTATİSTİKSEL ANALİZİ VE KAPASİTE PLANLAMASI

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Bu yüksek lisans tezi İstanbul'da bulunan bir üniversite hastanesinin üçüncü derece yenidoğan ünitesi baz alınarak hazırlanmıştır. Bebek ölüm hızı bir ülkenin gelişmişlik endeks için önemli bir göstergesi ve ekonomik bir faktördür. Çünkü, gelecekteki nüfusun genç nüfus yada yaşlı nüfus olma özelliklerini belirleyen faktörlerden biridir. Bu durum ülkenin gelecekteki kalkınma politikalarını etkilemektedir. Bu yüzden, sağlık hizmetlerine yapılan yatırımlar aslında ülkelerin mevcut durum ve gelecekteki kalkınma politikaları açısından önemli rol oynamaktadır. Mevcut durumu, bebek reddetme oranları ve kaynak verimliliği açısından geliştirmek için bazı temel istatistiksel analizler yapılmış ve bunlardan bazıları simülasyon modellemesinde kullanılmıştır. Problemin karmaşıklığından dolayı kapasite planlama çalışması için simülasyon modeli tercih edilmiştir. Simülasyon modelinde mevcut durumun sınırlı kaynakları düşünülerek bazı performans kriterleri belirlenmiştir. Buna ek olarak, bazı istatistiksel veri analizleri yapılmıştır. Mevcut durumda bekleme süresini ve reddedilen bebek sayısını minimum yapmak amacıyla dört tane çözüm önerisi geliştirilmiştir. Diğer taraftan, sisteme kabul edilen bebek sayısı ve kaynak verimliliğini optimize etmek hedeflenmiştir.

Anahtar sözcükler: Kapasite Planlama, Yenidoğan Ünitesi, Yenidoğan, Simulasyon, İstatistiksel Analiz.

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ABBREVIATIONS

Buffer Zone	: BZ
Healthy/Exitus/Transfer	: HET
Human Development Index	: HDI
Intensive Care Unit	: ICU
Special Care Unit	: SCU
Tunnel phototherapy	: TPT
Turkey Population and Health Research	: TPHR

SYMBOLS

Average of incubator utilizations	:	$\overline{x}$
Beginning replication number	:	M
Critical value	:	C.V
Expected cumulative frequencies	:	F_e
Expected frequency	:	e_i
Index for expected and observed frequencies	:	i
Observed cumulative frequencies	:	F_0
Observed frequency	:	o_i
Occupancy ratio	:	OR
Ratio of error	:	ε
Rejection ratio	:	RR
Replication number	:	N
Standard deviation	:	$S(m)$
Table value	:	t
The largest absolute difference between the observed and the expected cumulative frequencies	:	D
Treatment ratio	:	TR
Waiting time	:	WT

1. INTRODUCTION

The rate of deaths in babyhood and childhood indicates the social economic situation in a country and standard of living in a population. Child mortality rates and especially infant mortality rates are frequently used for social development indicators or health condition of society indicators. In this respect, child and infant mortality rate indicators direct the health programs. (Dursoy, 2007)

Baby is called "neonatal" in the first 28 days after birth**. Neonatal mortality rate** indicates the number of deaths during the first month of a healthy born baby among 1000 neonatal. Infant period is called as an interval time between after 28th day and first age of the baby. **Infant mortality rate** indicates the number of deaths during this period. Child period is during five years after first age. In addition, **child mortality rate** is the number of deaths between first birthday and fifth birthday. In Turkey, infant mortality rate decreases speedily for the last 5 years. But, it is still inadequate when it is compared with other developed countries. According to the TPHR-2008 results; Table 1.1 shows neonatal, infant and child mortality rates between 1998 and 2008 in Turkey. In five years period, the neonatal mortality rate 13 indicates the number of neonatal death in every thousand alive birth. Other rates can also be explained similarly. Moreover, there is a 48 percent decrease in five years period for infant mortality rates between 2003- 2008 and 1998-2003 years.

Table 1.1 : Infant and child mortality rate

Years	**Neonatal mortality rate‰**	**Infant mortality rate‰**	**Child mortality rate‰**
2003-2008	13	4	6
1998-2003	17	16	9
1993-1998	21	23	10

The main causes for baby and child deaths are;

- Inadequate number of neonatal services,
- Insufficient number of specialist, nurse and hospital personnel,
- Limited equipment like incubator, ventilator,
- Underinvestment for health services.

Because of main causes, governments must give the needed importance to health sector. In Turkey, neonatal mortality rates and fertility rate can change among regions. In cities mortality rates are lower than rural regions while fertility rates are higher in rural regions because of the health investments and low level of education. But, according to the explanation of ministry of health, in recent years neonatal mortality rates are on the decline. In Table 1.2, study of TNSA covering 10 years before 2008 and infant mortality rate is found to be 17 and it is supposed to decrease fewer than nine in 2025. They aim to decrease neonatal and other mortality rates to digit numbers. However, when the neonatal mortality rates decline, it is more difficult to reduce later on. Since, firstly, solvable problems are removed then, the remaining problems need more time, more equipment and more knowledge. In parallel with this point, there is a bottleneck in the number of neonatal specialist. This issue can be solved by investing in education department.

Table 1.2 : The distribution of mortality rates according to different regions in a period of 10 years before 2008.

Settlement (Turkey)	**Neonatal mortality rate‰**	**Infant mortality rate‰**	**Child mortality rate‰**
City	13	9	7
Rural	20	14	10
Region			
West	9	7	10
South	17	13	6
Medium	12	9	1
North	16	8	3
East	24	15	11
Selected Regions	**Neonatal mortality rate‰**	**Infant mortality rate‰**	**Child mortality rate‰**
ISTANBUL	2	6	14
South East Anatolia	20	13	12

Due to the above mentioned reasons, regions must be good analyzed so that neonatal units can be positioned in essential places.

New born period is first 4 weeks after birth. Normally, babies are born after completing the 38-42 weeks period. 85 percent of the all new born babies are healthy while 15 percent of the all new born babies need special care. Premature baby refers to the birth of a baby of less than 37 weeks gestational age. Moreover, they are defined in three different degrees according to the birth weeks and birth weights.

- Advanced degree preterm: 24-31 weeks of gestational age.
- Medium grade preterm: 32-36 weeks of gestational age.
- Limit the preterm: 37 weeks of gestational age.

Neonatal units are also divided in three different levels according to the babies' required care. There are some differences in available treatments among the levels.

1.1 STEPS OF THE STUDY

There are some stages to reach the aim of the study.

1) Determination of the neonatal intensive care unit where the study will be applied.

2) Searching the literature review.

3) Definition of the problem.

4) Gathering the necessary data.

5) Performing the statistical analyses and hypothesis tests for baby arrivals, treatment times and baby exits.

6) Generating the scenarios and policies.

7) Simulation modeling of the current situation and the solution suggestions.

8) Evaluating the solutions and results according to the utilizable for the neonatal unit.

1.2 ORGANIZATION OF THE STUDY

The next parts of the study will continue with the following chapters;

1) In the second chapter literature review takes place. Literature review which includes past studies about capacity planning especially in health sector and neonatal units.

2) Problem definition takes place in the third chapter of the study. In this chapter, the scope of the study, assumptions and the neonatal current working conditions are mentioned.

3) In chapter four, some statistical analyses are made for ICU and SCU department. Moreover, some cases are examined that yearly baby attributes, hypothesis test results of different statistics between 2008 and 2010. Additionally, there are some compartments about girl and boy babies in this section.

4) Model and solution proposals are referred in chapter five. This chapter also includes some scenarios about solution offers. Simulation is used as solver method. Simulation analyses and their important result comparisons also take place in this section.

5) Conclusion chapter is in the last part of the study. General interpretation of the thesis is performed in this chapter.

2. LITERATURE REVIEW

Generally, capacity planning problems and simulation application in health sector are searched in past studies. Especially health sector is preferred intensively to catch some ideas about solution methodologies. In literature, capacity planning problems usually center on the ratio of bed occupancies and number of health staff. Therefore, the following past studies illuminate this thesis in terms of the solution methods and solution proposals.

2.1 SUMMARIES OF LITERATURE REVIEWS

Dursoy repose on the importance of capacity planning in neonatal care units (2007). Particularly, in health sector, the significance of time has vital values. Because of scarce time and inadequate equipment number, health centers can meet undesirable situations. Heading away from that, they optimize equipment requirements in newborn units at health centers; related to admission rates, capacity usages and waiting times. By planning capacity of neonatal care units, rate of patient rejections and rate of mortality will decrease. By this way Human Development Index (HDI) of the country will increase.

First aim of this study is modelling the uncertainty in patient demand accurately and managing this stochastic process in a robust way. Correct modeling of demand supplies the correct needed number of equipments. They choose Çukurova University Research Hospital as an application place. Patients can be directed to three different neonatal care unit levels according to their health conditions. Moreover if a patient's situation changes positively or negatively, baby can be transfered among the treatment levels or can be discharged from the hospital.

Hospital government keeps accounts for patient names, ages, weights, arrivals, discharges and departures with their causes. However, rejected patient accounts aren't kept therefore they prepare a new file which is rejection patient form and record this form during 3 months in the hospital. The following data are collected about newborn intensive care unit: Patient arrival and departure dates, patient's direction among the levels, probability of transitions among the levels and probability of discharging, rejected patient's dates, capacity values of levels in terms of equipments

Patient arrivals are tested by using chi-square or Kolmogrov-Smirnov tests and statistically the most suitable distrubution is determined. They decide that baby arrivals and baby rejections in each level conforms to Poisson process.

There are three intensive care levels for babies. The first level has two beds, the second level has eight incubators and three beds, lastly the third level has ten incubators, three beds and ten ventilators. High degree premature babies are treated in third level intensive care unit.Third level intensive care units serve all kinds of baby levels. In addition to this, source sharing and baby tranmissions can be occured among the levels according to babies' health problems. Thus, they determine two different strategies which have same equipment properties except transition policies.

Strategy 1; Includes existing work flow which indicates that, when a baby's treatment finishes in the first accepted level then doctors decide whether to continue treatment in another level or to discharge. In this case, interlevel transfers have precedences. In other words, if a baby waits for idle equipment in the next level to continue his cure, external baby arrivals are rejected for the same place. When all equipments are busy in the next level, then the baby proceeds his treatment in the current level until capacity is available in the next level. But, this waiting time is subtracted from the next level treatment time. If the neonatal is unable for the next level, then patient is discharged or transfered to another hospital.

Strategy 2; is different from strategy 1 since it has intermediate regions among the levels. Every level has its own transitional zone which has some equipments like homelevel. After controlling next treatment level and if it has not idle equipments for the baby, the patient is canalized to its transitional zone where he continues his treatment until the main level has an idle equipment. Nevertheless, like in strategy 1, the waiting time in the transitional zones is subtracted from the treatment time and the baby can be served during this remaining time in next level.

To solve queuing problems and to minimize waiting times in the system, they prefer simulation method where they decide 365 days for simulation length and 100 replications. Occupancy rate, waiting times, accepted demand ratio and patient arrivals are determined as performance criteria. It is conducted with experimental design to get the mathematical functions from regression which includes occupancy rate, waiting times, accepted demand ratio and patient arrivals. They suggest three models for strategy 1 and one model for strategy 2.

Model 1 handles how many equipments there should be in each level to decrease waiting times. Model 2 handles how many equipments there should be in each level so that the occupancy rate will be good (85 percent of occupancy rate). Model 3 handles how they should distribute equipments among the levels, so that total waiting times will be minimum. Model 4 handles how many equipments there should be found in each level and each intermediate region so that, waiting times will decrease or patient occupancy rate will be within limits. In conclusion, applied methodology is suitable for capacity planning problems, in parallel the required equipment numbers are found by using mathematical models. (Dursoy, 2007)

On the other hand, Kim (1999) try to decrease the number of patients who are scheduled for an elective surgery but then, are rejected because of inadequate bed capacity in intensive care units. They handle a multi-diciplinary intensive care unit (ICU) that receives patients from five sources: ward; accidents and emergency (A&E), operating theater emergency (OT-emer), operating theater elective surgery (OT-elec) and other hospitals. In addition to this, they suggest two bed assignment models. In Flexible Bed

Allocation (FBA) model; while existing state has intensive care unit, one or more beds are assigned for patients scheduled for an elective surgery. In Dependency Intensive Care Unit (DICU) model; every department has their own intensive care unit and every unit assigns one or more beds for scheduled patients.

Patients are accepted to the system according to FIFO (first-come, first served) method. DICU and FBA models have some performance strategies which are tested by simulation method. System performance is evaluated through the seven criteria that most concern the ICU physicians, the surgeons, and the ICU administrator. These are bed utilization, average number of patients waiting in the queue, average time spent waiting in the queue and the system cancelled surgeries, and the number of patients treated and rejected.

In Strategy 1, there are 13 beds and no reserved bed for any group; OT-elective patients often receive lower priority. In Strategy 2, 3,4,5 beds are located in other place for OT-elective patients only. In Strategy 3, reserved beds are used exclusively by OT-elective patients. In Strategy 4, reserved beds are open to use by A&E patients on Fridays and Saturdays. In Strategy 5, reserved beds are open to use by all patients on Fridays and Saturdays. In Strategy 6, reserved beds are shared with OT-emergency patients throughout the week. A general result shows that FBA model is most suitable for resolving the cancelled-surgery problem (Kim, 1999).

Moreover, Kokangül (2008) optimizes the required bed capacity by using the number of admissions per day, service level and occupancy level in hospital. One important thing is, how many beds each unit in the hospital should have to satisfy the target service level and occupancy level. The service level is the percentage of patients who arrive at the unit and can be admitted. Another important point is to advise a combination of deterministic and stochastic approximations. The developed approximation is applied to pediatric intensive care unit (PICU) to determine the size required bed capacity and break-even point of the size of the required additional bed capacity. Additional bed capacity is established according to some parameters about the patients. These parameters are daily accepted, rejected, or transferred arrivals and departures and length of stay (LOS) in the unit, are observed in a patient flow diagram for a few years then decided their distributions. Collected data shows that the accepted arrivals and rejected or transferred patients are distrubuted as a poisson process, and the LOS is distrubuted as log-normal.

Simulation model is used for analysing the number of patients in unit, determining the maximum size of required bed capacity and preventing rejections or transfers. Hereby, control parameters can be assigned for any given bed capacity. Simulation model was started from empty and idle state to estimate the steady-state. The model was run 365 days. They use two hundred replication. Linear models are applied to the obtained simulation results to get simple mathematical relationships. After that, the optimum size of the bed capacity with the target level of the control parameters can be denoted using the acquired mathematical relationships as objective functions or constraints in nonlinear mathematical models. Regression analysis and ANOVA analysis test the simulation results which show that there are nonlinear mathematical relationships between the control parameters and the bed capacity. The efficiency of the all control parameters are approximately more than 99.50 percent which shows that match is quite good (Kokangül, 2008).

In another study, Kokangül (2009) studies on some statistical analyses made for the number of arrivals, rejections or transfers due to lack of capacity and length of stays (LOS) in neonatal intensive care unit of a university hospital. They categorize the arrival patients according to the levels based on the required nurse: patient ratio and gestation age. Additionaly arrivals, transfers, gender and length of stays are analyzed.

There are three levels in the unit according to baby’s health conditions. Level 1 patients need close observation, but not necessarily the continuous presence of a nurse at the bedside, has two open beds. Level 2 patients have same properties with level 1 patients, but it differs by equipment size. Level 2 has three open beds and eight incubators. Level 3 patients need a nurse at the bedside continuously for 24 h/day, it has three open beds, ten incubators and ten ventilators.

Some probability distributions are performed for accepted, transferred or rejected arrivals and LOS for each gestation age and level in the NICU. Moreover, arrival sources, transfer reasons, gender of arrivals and transmitting rate among levels are statically analyzed. Statistical software package such as Statistica 6.0 and MathLab were used to analyze and test the patient characteristics statistically.

A priority rule is used for inside patients who transfer from a level to another by giving higher precedence then the patient coming from outside the NICU. To control the suitability with the Poisson process, hypothes tests are applied and analyzed with chi-square test. As a result, the arrivals show seasonal variations (Kokangul, 2009).

Additionaly, Nyguyen (2004) tries to optimize bed capacity in a hospital. A new method is developed and applied to two internal medicine departments and one urological surgery department. This method which is constructed with three parameters is based on a score comparison with ratio method. Parameters refer to number of transfers due to lack of space, number of days with no possibility for unscheduled admissions and number of days with at least a threshold of unoccupied beds.

Nyguyen (2004) handles main scarce hospital resources and evaluate some solver methods and approaches up to that time. In this way, they want to have a diffent method that is as simple to use as the ratio methods while minimizing their biased approaches. There are three criteria which are; the number of unoccupied beds (productivity), the number of patients transferred since of full bed occupancy (security), one or more beds availability for unscheduled patients (accessibility).

Optimization model is based on the minimization of both the standard deviation and the mean score for each number of beds in the model. In addition to this, the solution is only consist in the statistical properties of the model. Thus, no hypothesis concerning the distribution of stays or the the admission or target bed occupancy is needed. In conclusion, they obtain highly realistic optimal bed numbers for each department by using score method (Nguyen, 2004).

In this study BOMPS (Bed Occupancy Management and Planning Software) is implemented in a hospital curing geriatric patients, to determine the effects on bed usage and occupancy rates by Garcia and Navarro (2001). There are three different stages of patients which are; acute, rehabilitative and long-stay care groups. While geriatric patients can make transitions between stages, they can also leave from the system by discharging or by dying. These movements form the patient flow in the hospital.

Data collected includes some informations about the patients that are; age admissions, gender, dates of admission and discharge, and reason for discharge. All these informations are evaluated to analyse data by using BOMPS. According to the results, the proportion of patients receiving acute care increases with time, on the otherhand there is a decrease in the proportion of patients receiving long-stay care. Therefore, average bed occupancy decreases in last parts of the study period. One of the most important properties in this study is: it is the first study to document the effects of introducing rehabilitative care into a chronic sick hospital (Garcia-Navarro, 2001).

Ridge (1998) handles a simulation model for bed capacity planning in Intensive Care. Patient acceptance is occurred by two ways: Firstly emergency patients arrive at random and must be admitted with a minimum delay. The free beds.have a priority. Moreover, planned (elective) patient admissions are admitted only when care unit has free bed but, if they have no available capacity for patients, they keep patients waiting or transfer to another hospital.

For two patient groups which are emergency and planned patients that are seperated in three types in theirself. Then some analyses are made on these types by using mean length of stays (LOS), LOS percentage point, mean annual admissions and daily arrival rates. Queuing model is used to find the suitable ‘warm up’ and ‘run times’ in simulation model. According to this, warm up time is decided 5 years and run time is decided 100 simulated years.

The following simulation model parameters are chosen to observe:The relationship between emergency transfers and number of beds occupied, the relationship between emergency and planned patient transfers or planned patient deferral time, the relationship between emergency, planned and all patient transfers or number of reserved beds, the relationship between number of free beds at midnigth or day of the week.

As a result, the model shows that there is a non linear relationship between number of beds, mean occupancy level and the number patients. Increasing the numbers of beds make lower occupancy level and lower patient transfer rate. However, the random arrival of the emergency patients makes more expensive to guarantee a free bed all the time. Therefore, there is always a small probability of lack of space or bed (Ridge, 1998).

Darzi (1998) uses queueing system to remove blockage on the flow of patients in geriatric departments. There are three kinds of departments in the system which are acute, rehabilitative and long-stay care. Patients are initially admitted to acute care where patients are discharged within a few days or through death. Medium-stay patients can stay for a few months. If they move on to a long-stay care unit, they could stay until they die. The target of this survey is to evaluate the benefits of the model which determines the effect of bed blockage, occupancy and emptiness on patient flow in a geriatric inpatient unit. A flow modelling is performed to assist in the planning and decision making process of geriatric departments. But, it can not answer bed blocking, bed allocation and occupancy. Therefore they develop discrete event simulation model which includes three basic components: Entities referring to patients, activities referring to three depatments and queues and system state referring to number of available beds, the waiting time in a queue, etc.

In the model, the queueing system has some servers which are beds, and the patients are customers. First in first out (FIFO) dicipline is implemented in the system. The results show that, the flow model and unconstrained simulation are equally consistent to measure bed occupancy in the geriatric department. There is a small increase in the queueing variables and a small decrease in the emptiness of the compartments. They try to have some opinions in all three compartments about the percentage of the rejected patients, average emptiness, the percentage of patients in queues, maximum queue length between the compartments (El-Darzi, 1998).

Akçali (2006) developes a network formulation to solve the problems when demand increases and resources are diminished in hospital bed capacity. This network flow model also determines the facility performance and budget constraints for hospital. In this paper, they focus on aggregate hospital bed capacity planning decisions. The developed model aims to simultaneously determine the timing and magnitude of changes in bed capacity which minimizes capacity cost while maintaining a desired level of facility performance.

In this model, there are three types of decision variables: number of beds in period t, the amount of increase in bed capacity at the beginning of period t, the amount of decrease in bed capacity at the beginning of period t. It is formulated as bed capacity planning (BCP) problem as a nonlinear integer programming. The objective function minimizes the total cost of patient waiting, changing the bed capacity, and operating the existing bed capacity. Apart from that there are five constraints more: The first constraint imposes a maximum allowable limit on the expected patient waiting. The second constraint sets the initial bed capacity. The third constraint is a flow balance equation stating that the number of beds available in a period. The fourth constraint is the budget constraint which limits the amount of the funds allocated to changing capacity. Lastly, the fifth constraint ensures that number of beds and changes in bed capacity are integer valued. On the other hand, six scenarios are formed about respectively base scenario, increased rate of demand, higher demand variability, higher service variability, higher cost of waiting per patient and smaller maximum expected delay per patient.

As a conclusion, the model involves the reasonable concerns associated with determining hospital bed size, an upper bound on the average waiting time before a patient is admitted to a hospital bed, and a budget constraint that limits the amount of money which can be separated to changing bed capacity (Akcali, 2006).

This study underlines bed capacity planning problems. Tutuncu (2009) applies some models in two time buckets: annual bed capacity and monthly bed capacity. The annual capacity problem includes three techniques: Integer programming model minimizing the total waiting cost and total cost. M/M/s Queue Model in which the beds are referred to servers and Genetic algorithm. On the other hand, monthly time buckets are defined as shortest path problems and monthly bed capacity problems are solved by using Dijkstra Algorithm. To make improvement for the number of bed capacity, they determine the key parameters which affect the optimum size of the required bed capacity that are occupancy levels, the number of admissions per day, service level and incurred staff cost to service demand. Bed capacity is evaluated according to bed types which are common beds and private beds.

According to the monthly results, the hospital needs an additional 7 private beds and a common bed. Some beds must be reclassified during the summer because of seasonal change. For annual bed capacity problem, the results are not similar for integer programming model and M/M/s queue model. Shortly, bed capacity can be increased and by avoiding exceed budget. Thus, service quality can be increased and expected waiting time of patients can be decreased (Tutuncu, 2009).

2.2 CONSIDERATION OF LITERATURE REVIEWS

Past studies are usually scrutinized carefully capacity planning in different areas. Generally studies include service sector and production sector. When service sector is analyzed, broadly simulation, mathematical models, generic algorithms, queuing models, Markov chain, and network models are preferred by researchers. Health is a fairly complicate department since of its process design. Therefore, simulation method is available for this kind of systems. Generally, simulation models go on with waiting times, rate of occupancy, numbers of rejected patients, rates of acceptances that are used as performance criteria. The main aim is to optimize the systems which support these criteria. Correspondingly, some strategies and scenarios are improved according to the solution offers.

Neonatal capacity planning is not common in the literature. However (Dursoy, 2007) a master thesis about the equipment optimization for newborn department in 2007 is an informative guidance for this thesis.

3. PROBLEM DEFINITION

3.1 GENERAL INFORMATION ABOUT PRETERM'S AND NEONATAL UNITS

Preterm birth refers to the birth of a baby of less than 37 weeks gestational age. They are called pre-term or premature babies because they have not completed their full-term of 38-42 weeks in their mother's womb. Babies born before the end of the 37th week of pregnancy are considered pre-term. Generally, all low-weight babies were thought to be pre-term. But now it is known that it is not the weight but the time in the womb that defines a pre-term. Some pre-term babies weigh as light as small wool pillow. Some full-term babies' weight as little as small wool pillow, but they are physically mature enough to breathe and suck normally shortly after birth, whereas pre-term babies often are not. Since they are born too soon, many of their biological systems, such as those involving the lungs and liver, are not developed enough to work properly on their own. This can result in jaundice or breathing difficulties after they are born. Therefore, different levels of neonatal units are available according to preterm babies' treatments.

First Level Unit: This care unit generally covers healthy babies. Basic health controls are performed and high risk babies that must be transported to upper up levels are identified.

Second level unit: medium risk babies are treated in this unit. Generally, phototherapy needs are provided to babies in this level and additionally, babies having single organ lackings are cared in this unit. Basic equipments are incubator, open bed, phototherapy machine, and ventilator.

Third level unit: High risk babies are treated in this unit. Usually, it services babies who are not in complete growing process and have multi organs lacking. These care units have incubators, open bed, phototherapy machine, ventilators and more complex treatment machines.

In neonatal units, the most important equipments are incubator, open bed, phototherapy machine, ventilator and cooling machine. Their usage purposes are given below.

Incubator; preterm babies generally can't adjust their body temperature and incubator helps them in that way. Also, incubator is used for premature babies or problematic babies to keep them away from infectious illnesses.

Open bed; is used for babies in emergency situations for direct interventions. At the same time it is used for during surgical operations.

Phototherapy machine; is a form of medical treatment in which some form of light is used to address a medical issue and helps the body convert the bilirubin into a form which can be urinated or excreted, allowing the baby's skin to return to a more usual color. Phototherapy for babies is usually conducted in a hospital immediately after birth, with staff keeping an eye on the baby to make sure that he or she is not struggling with other medical problems.

Ventilator; is a machine that supports breathing. These machines mainly are used in hospitals and neonatal units.

- Get oxygen into the lungs.
- Remove carbon dioxide from the body
- Help babies breathe easier.
- Breathe for babies who have lost all ability to breathe on their own

Cooling machine; is a kind of ventilator machine helps breathing for asphyxiated babies.

3.2 THE REFERENCED NEONATAL UNIT

Data are taken from a training and research hospital in Istanbul. The neonatal unit in hand is a third level unit. The unit can service all kinds of baby levels like advanced degree preterm, medium- grade preterm and limit the preterm or mother side. In this unit, advanced degree preterm babies are serviced in intensive care unit, on the other hand, medium-grade preterm babies are serviced in special care units. Mainly, these two levels are using hardly.

Special care neonatal unit has ten incubators, two expert nurses. Intensive care unit has; nine incubators, ten ventilators and three expert nurse. In addition to this, there are some resources which are using in common between two units, like eight phototherapy machines, one doctor, one transport incubator, one open bed, nine monitors and one cooling machine and ten nurses.

Except common resources, other resources are not being shared among the levels. Every incubator should be used for only one baby. While in special care unit, one nurse can care at most five babies, in intensive care unit, one nurse care at most three babies. Babies can be directed to another care levels according to their health conditions. If the condition of a baby in the intensive care unit improves then he/she is either discharged or transferred to the special care unit. According to the given information, 90 percent of intensive care unit (ICU) babies continue their treatment in special care unit (SCU). ICU is used for advanced degree preterm babies or in other words third level babies. On the other hand 10 percent of SCU babies continue their treatment in ICU when their health conditions become worse. SCU is used for medium grade preterm babies or second level babies. Daily resource usage is almost full capacity. If a baby cannot find empty resources in the other transfer level, then the baby waits in the same treatment level until resources available in the other transfer level. If essential conditions are not provided, then babies are transferred to another hospital due to their health conditions. Therefore, sometimes babies are rejected because of resource shortage. To avoid these situations, hospital management controls their capacity when high-risk pregnancies come. If their capacity is not available for premature baby then, firstly they transfer the high-risk pregnancy patient to another hospital. The main resource shortage comes from through lack of expert nurse because the number of incubators used depends on the number of expert nurses. So, critical resources are expert nurse and incubator. Daily birth number is ten and nearly three of these births are included by ICU or SCU.

The following figure shows the percentages of internal transfers between SCU and ICU. According to Figure 3.1, 90 percent of intensive care unit (ICU) babies continue their treatment in special care unit (SCU) and 10 percent of SCU babies continue their treatment in ICU when their health conditions become worse. 90 percent of SCU arrivals leaves as healthy, death or transfers to another hospital. Similarly, 10 percent of ICU arrivals leaves as healthy, death or transfers to another hospital.

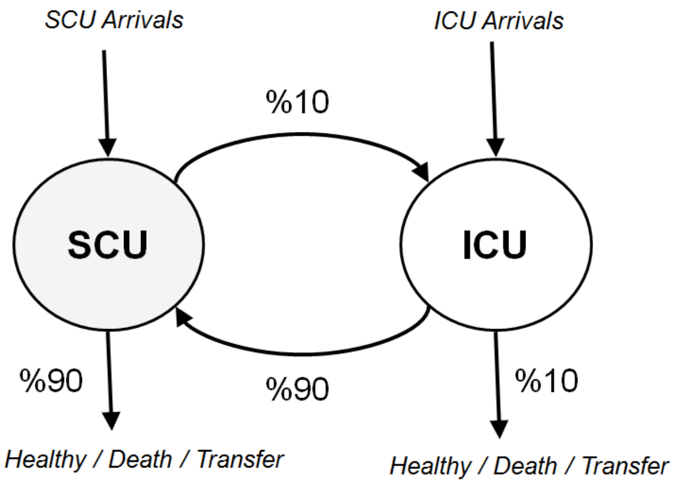

Figure 3.1 : The percentages of internal transfers between SCU and ICU

The referenced neonatal unit is not using any computer program for keeping baby records. They keep a book for daily records manually. Therefore it is difficult to gather the data for three years. Nevertheless, babies' weight, arrival time, leaving time, arrival level, types of departure, gender and phototherapy machine usage of each arrivals are entered to excel program. Level system has been used since 2008, therefore data between 2008 and 2010 are entered to the excel program. Table 3.1 is an example of the entries belonging to a few arrivals in 2008.

Table 3.1 : The example of data file in excel

Gram	Arrival Date	Departure Date	Treatment Time	Entrance Level	TFT	Departure Type	Gender
3450	07.10.2008	15.10.2008	8	ICU	not used	Healthy	girl
1690	10.10.2008	25.10.2008	15	ICU	not used	Transfer	boy
3300	13.10.2008	14.10.2008	1	ICU	used	Healthy	boy
2780	14.10.2008	21.10.2008	7	SCU	not used	Healthy	girl
1940	16.10.2008	27.10.2008	11	ICU	not used	Healthy	boy
3440	16.10.2008	20.10.2008	4	ICU	not used	Healthy	boy
940	18.10.2008	22.11.2008	35	ICU	not used	EX	boy
1620	20.10.2008	31.10.2008	11	ICU	not used	Healthy	boy
3750	20.10.2008	27.10.2008	7	SCU	used	Healthy	girl
3370	28.10.2008	03.11.2008	6	ICU	not used	Healthy	boy
1400	02.11.2008	26.11.2008	24	ICU	not used	Transfer	girl
2970	14.01.2008	17.01.2008	3	SCU	not used	Healthy	boy
1330	15.01.2008	25.01.2008	10	SCU	used	Transfer	girl
1980	04.11.2008	06.11.2008	2	ICU	not used	Healthy	boy
1380	15.01.2008	28.01.2008	13	SCU	not used	EX	girl
2180	04.11.2008	10.11.2008	6	ICU	not used	Transfer	girl
2620	17.01.2008	20.01.2008	3	SCU	used	Healthy	boy
780	07.11.2008	24.11.2008	17	ICU	not used	EX	girl
2400	07.11.2008	09.11.2008	2	ICU	not used	Healthy	girl
2780	07.11.2008	18.11.2008	11	ICU	not used	Healthy	boy
2400	08.11.2008	16.11.2008	8	ICU	not used	Healthy	boy
3150	17.01.2008	18.01.2008	1	SCU	used	Healthy	boy
2300	09.11.2008	13.11.2008	4	ICU	not used	Healthy	boy
820	14.11.2008	11.12.2008	27	ICU	not used	EX	boy
790	19.11.2008	22.12.2008	33	ICU	not used	Transfer	girl

3.3 AIMS, SCOPE AND ASSUMPTIONS OF THE STUDY

3.3.1 Aims

- Determination of the bottleneck resources while acceptance and treatment processes are being executed to the third level intensive care babies and special care babies.

- Development of methodological solutions to handle the critical resource problems.

- Determination of performance criteria for resource assignment

- Development of alternative solution proposals to improve performance criteria

3.3.2 Scope

As a capacity planning of neonatal unit, bottleneck resources are specified and baby rejections will be minimized.

1) Problem Definition: Premature babies' treatments are realized in three different level. First level is baby room which is used for generally baby health controls and canalizing is performed here. Second level is SCU and third level is ICU. Babies' treatments have some variations according to their health conditions. But, in this study only SCU and ICU departments will be examined. Basic neonatal equipments are incubator, ventilator, phototherapy machine, open bed and nurse.
2) Statistical Analysis: some statistical tests are made by using data about the neonatal unit.
3) Determination of scenarios for alternative solution suggestions: to handle the bottleneck resources and resource optimizations, some scenarios will be developed to improve performance criteria.
4) Simulation Model: According to the specified solution suggestions and current model situation, simulation models will be constructed. To get this simulation model, the research hospital neonatal unit data will be analyzed by using statistical methods. Babies' arrivals and treatment times will be characterized and in parallel with, the performance criteria will be examined.

3.3.3 Assumptions

There are some assumptions about the neonatal unit in hand.

i. The neonatal unit will be divided in two different departments as an intensive care unit and special care unit. Because these two units have critic resources and have baby population.

ii. High-risk pregnancies will be admitted in a controlled manner when the capacity is full.

iii. Basic resources will be incubator, ventilator, phototherapy machine and nurse.

iv. Premature babies can be transferred to another care level according to their health conditions.

v. If the capacity is not available for the baby when it is transferred to another level, then baby starts to wait in the same care unit until another level will be available.

vi. If capacity is not available, then babies are rarely transferred to another hospital for their treatments.

vii. Each resource is used by only one baby, except every nurse can service at most 3 babies in the ICU while one nurse can service at most 5 babies in the SCU.

viii. The baby arrivals and baby treatment times are independence from each other. Each baby is unique in itself.

ix. Reasons for baby rejections come from lacking of nurse and incubator. Therefore these two resources are included in the model.

x. The new length of stay is calculated according to the distribution of next level in transitional forms

4. STATISTICAL DATA ANALYSES

4.1 ANALYSIS OF BABY ARRIVALS AND DEPARTURES

To determine the behaviors of premature babies in neonatal unit, 1148 records are evaluated for three years between January 2008 and December 2010. According to the data of three years; baby arrivals are seen in Figure 4.1. When the data are evaluated for three years, the most baby acceptance is seen at the 2008. On the other hand data of 2009 and 2010 are almost the same with regard to acceptance number. Nevertheless, 2008 baby acceptance is not so different from the 2009 and 2010 acceptance numbers.

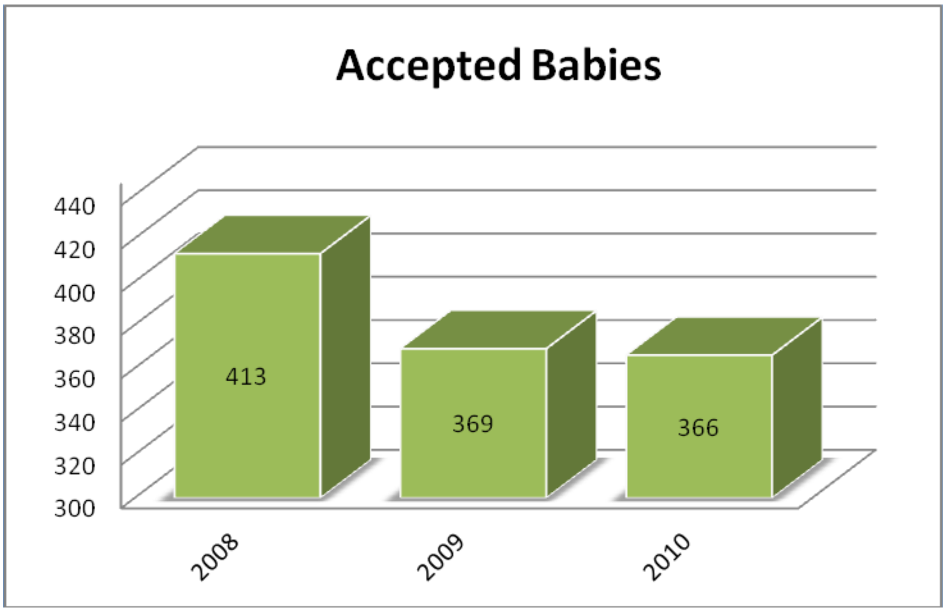

Figure 4.1 : Number of yearly accepted babies to the neonatal unit between 2008 and 2011

In addition to this, the acceptance babies can be separated according to their gender. Figure 4.2 displays the number of baby boys and baby girls for each three years. According to this, numbers of baby boys are more than number of baby girls for all three years. Therefore, an argument can be done about these data; baby boys need more postnatal care than baby girls.

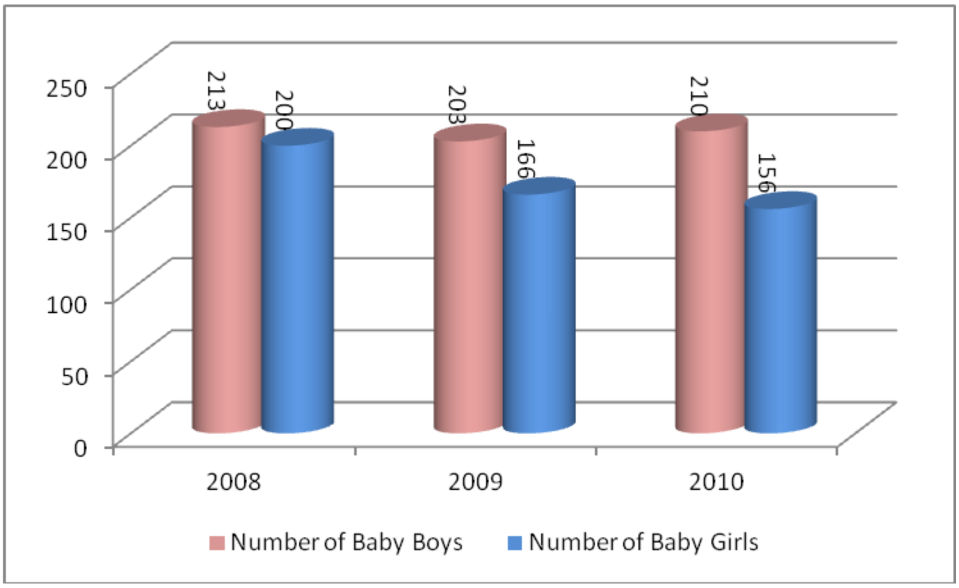

Figure 4.2 : The yearly indication of number of boys and girls between 2008 and 2011

After health controls are made, babies are either placed in ICU or SCU department according to their care necessities if the required resources are available in the unit. The following Table 4.1 shows the baby movements after entrance. Moreover, it indicates the average treatment times and average weights for baby boys and baby girls. According to Table 4.1; ICU babies' treatment time is more than SCU babies'. There is almost an average of 3 days of difference. However the treatment time always depends on babies' treatment necessities. On the other hand, the weights of ICU babies are lower than SCU babies. The weight factor is also another determinant on the length of stay in ICU and SCU departments. Generally the lower weight babies stay more in the ICU. In parallel with this, ICU babies spend more time in the system than SCU babies.

Table 4.1 : Baby attributes for three years after entrance

Enrance Level	Number	average time spent (day) in the system	AVG Gram	Girl			Boy		
				Number	Treatment Time	KG	Number	Time	Gram
SCU	472	6.96	2883	218	7.27	2748	256	6.69	2998
ICU	676	9.63	2037	307	9.55	1884	371	9.70	2163

Baby acceptances are fairly changeable in the system with respect to months. Babies are accepted to SCU or ICU can either leave the unit as healthy, death or transfer to another hospital; or internal transfer to the other unit in the hospital, ie. to ICU if it is currently in SCU. Figure 4.3 shows the trend in the number of each type of departures in three years. The less number of arrivals and consequently healthy baby departures and transfers are between July and August in every year. Other types of departures have changeable characteristics.

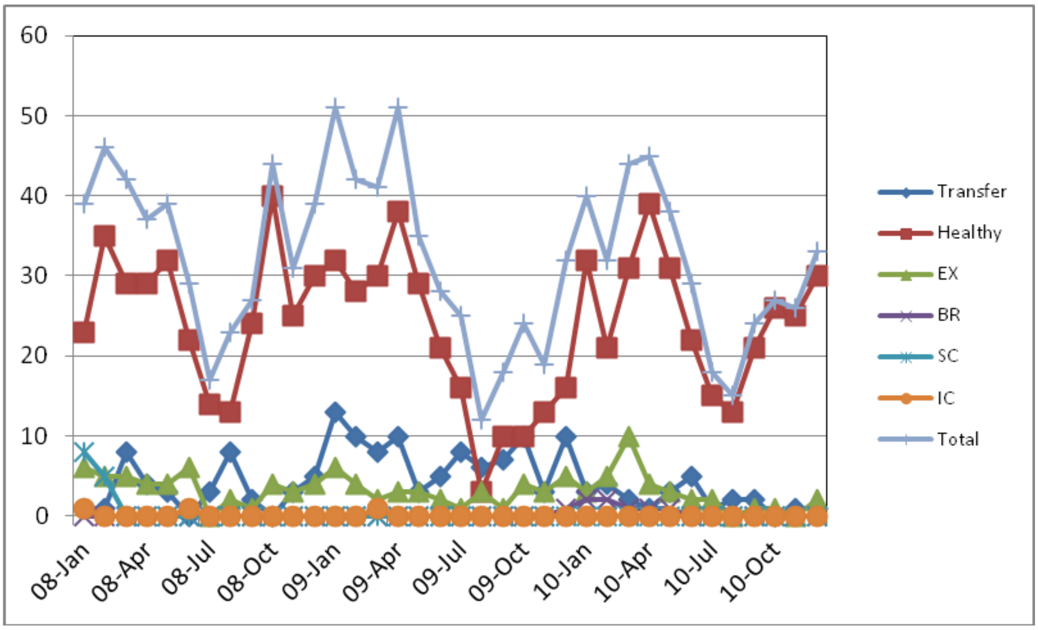

Figure 4.3 : Monthly baby departures from the system between 2008 and 2011

Table 4.2 and Figure 4.4 are other types of indication for baby departures which are arranged in months. It can be seen that the most number of transfers are in January, February, April, October and December for 2009. It can be commented that in these months the usage of resources are almost full capacity.

In Figure 4.5, number of healthy baby departures is seen intensively. In each year, this number starts to decrease in May and continues to decrease until September. So we can say that arrivals and hence healthy departures have a cyclic pattern. When general situation is evaluated, the neonatal unit service is in good performance however the number of ex babies and transfers should be minimized to get better performance and for babies' health.

Table 4.2 : Indication of baby departures from hospital according to the months

Type Of leavings	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08
Transfer	1	1	8	4	3	0	3	8	2	0	3	5
Healthy	23	35	29	29	32	22	14	13	24	40	25	30
EX	6	5	5	4	4	6	0	2	1	4	3	4
SC	8	5	0	0	0	0	0	0	0	0	0	0
IC	1	0	0	0	0	1	0	0	0	0	0	0
Total	39	46	42	37	39	29	17	23	27	44	31	39

Type Of leavings	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09
Transfer	13	10	8	10	3	5	8	6	7	10	3	10
Healthy	32	28	30	38	29	21	16	3	10	10	13	16
EX	6	4	2	3	3	2	1	3	1	4	3	5
SC	0	0	0	0	0	0	0	0	0	0	0	0
IC	0	0	1	0	0	0	0	0	0	0	0	0
Total	51	42	41	51	35	28	25	12	18	24	19	31

Type Of leavings	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10
Transfer	3	4	2	1	3	5	1	2	2	0	1	1
Healthy	32	21	31	39	31	22	15	13	21	26	25	30
EX	3	5	10	4	3	2	2	0	1	1	0	2
SC	0	0	0	0	0	0	0	0	0	0	0	0
IC	0	0	0	0	0	0	0	0	0	0	0	0
Total	38	30	43	44	37	29	18	15	24	27	26	33

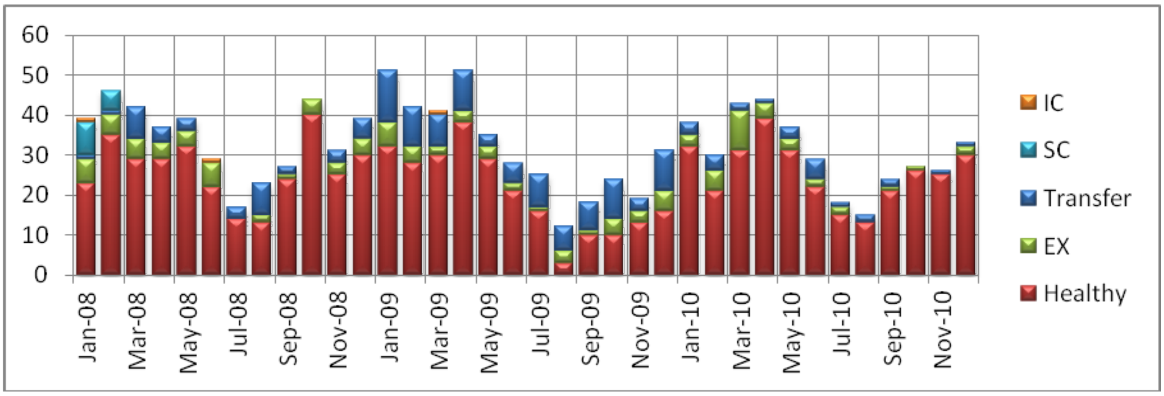

Figure 4.4 : Types of departures

On the other hand, Figure 4.6 shows the baby acceptances to levels during three years. Babies are accepted as SCU or ICU. Figure 4.6 shows all kinds of levels and genders for babies.

When baby arrival densities are examined, it is clearly seen that baby acceptances have variable movements among the months. Towards the end of year, number of baby arrivals is increasing while it is decreasing in the middle of the year.

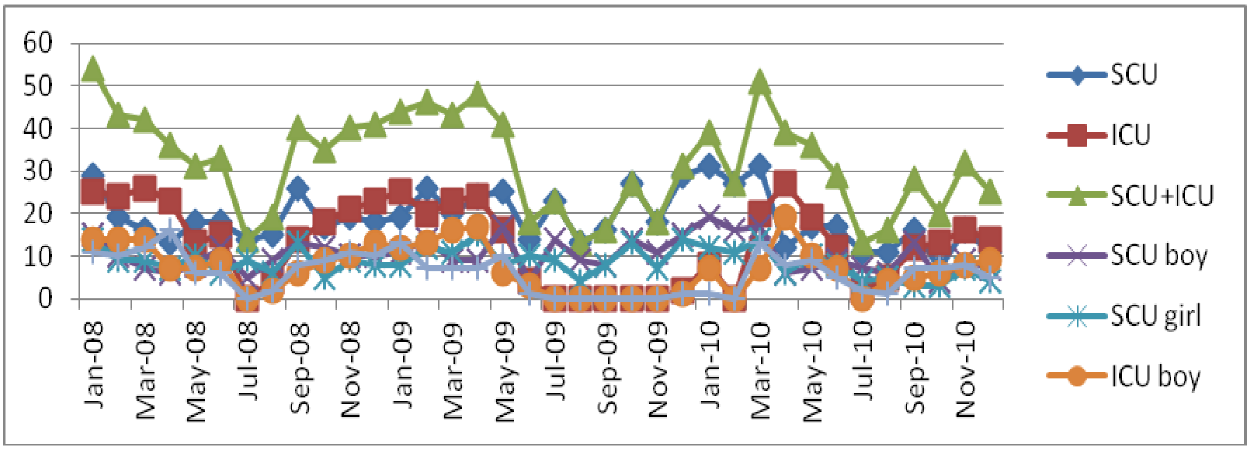

Figure 4.5 : Baby acceptances to ICU and SCU

Figure 4.7 shows the comparison of SCU and ICU levels in the same graphic. This can be interpreted as the monthly number of ICU arrivals generally between 10 and 20 days while SCU baby density is showing variable character among the months. According to the three years data; analyses denote that maximum 31 ICU baby and 27 SCU baby arrivals are recorded for one month. At the sum, it can be said that 54 baby number is the maximum baby acceptance number for one month in these three years. On the other hand minimum baby acceptance number is 13 during one month. If gender types are examined, it can be seen that generally density of baby boys are more than density of baby girls for both treatment levels.

The following Figure 4.8 and Figure 4.9 show baby movements according to their gender and treatment departments. In some months, the attribution of baby arrivals and baby departures shows similar movements. This situation occurs because, the usage of all equpments are full in these months. Especially, bottleneck equipments has an important role in this circle.

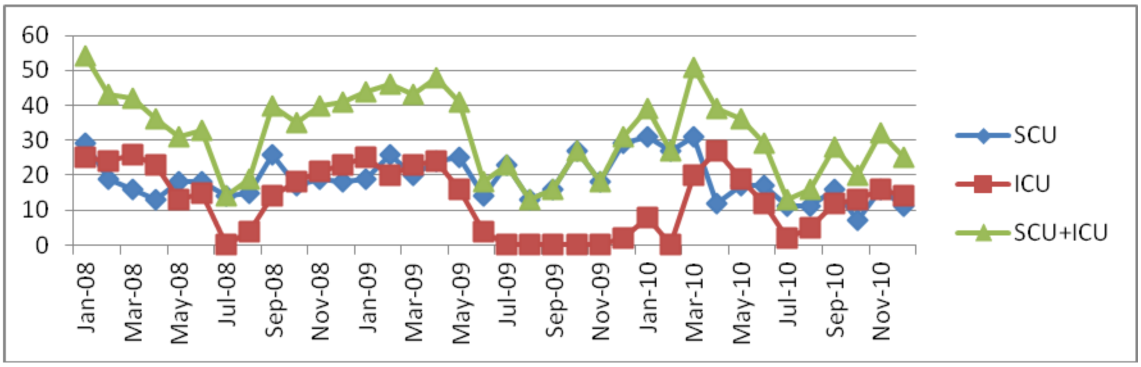

Figure 4.6 : The presentation of the acceptances to SCU and ICU and matching with sum of the SCU and ICU.

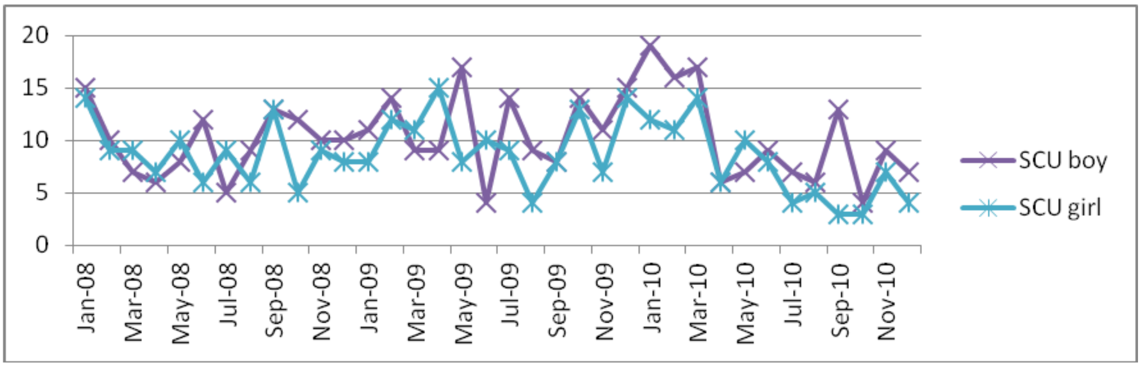

Figure 4.7 : SCU department is shown according to baby genders.

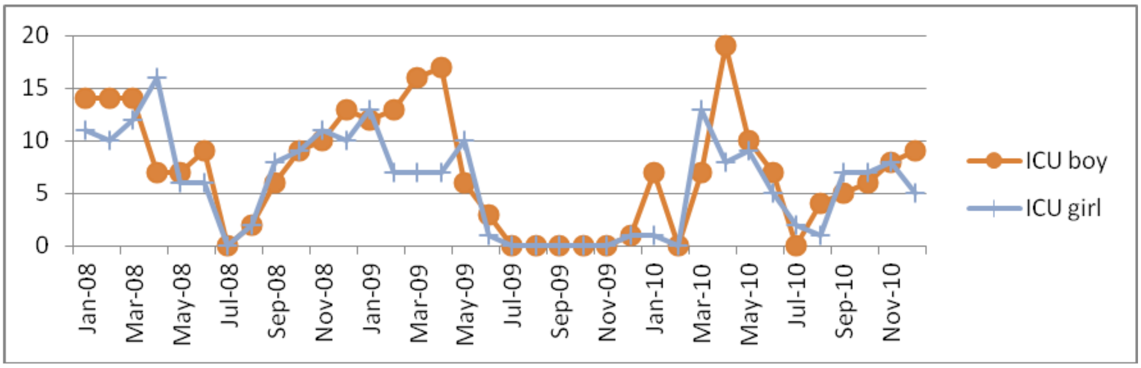

Figure 4.8 : ICU department is shown according to baby genders.

Additionally, Figure 4.10 indicates the percentage of baby departures in the system between 2008 and 2010. As far as the data, 75.2 percent of babies leave healthfully. Moreover, 13.5 percent of the departures are transfers since there are some scarce resources. Percentage of death babies comes thirdly after transfers. Departures to ICU or SCU units are less than the others because data about internal transfers among SCU and

ICU units were generally not recorded by the neonatal unit authorized people. Because of the missing information, the internal transfers are asked to the expert nurses and doctors, and according to them 90 percent of ICU babies continue their treatment in the SCU department because of their improving health condition. On the other hand, 10 percent of SCU babies continue their treatment in the ICU department, when their health condition is worse.

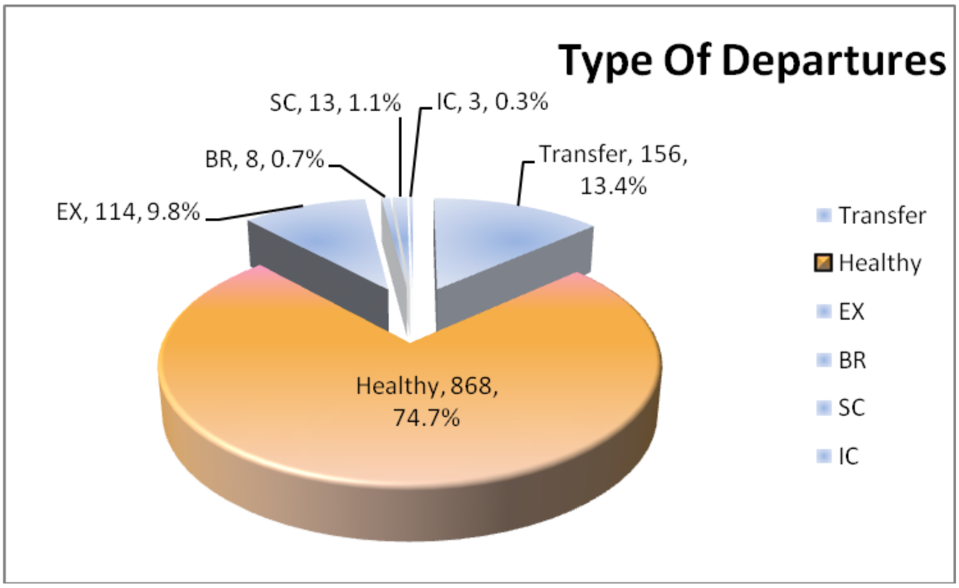

Figure 4.9 : The percentage of baby departures in the system for three years

Table 4.3 is a summary of the data collected in the neonatal unit. For instance, in 2008 413 babies are accepted to the system. This number decreases in 2009 to 369 and in 2010 to 366. All information are also evaluated according to the babies' gender. The acceptances of babies to SCU and to ICU are also given in the Table 4.3. According to the data, 251 babies are cared in ICU in 2009. 116 of these babies are girl, whereas 135 of them are boy. Other data can be commented similarly. The number of babies who use TFT is also shown in the table. TFT is a ray treatment for yellowness after birth. It is separated in ICU and SCU. Firstly, the general TFT usage is shown then by, ICU TFT usage and SCU TFT usage are given in the following rows.

Table 4.3 : The general acceptance information about the data for three years

	YEAR	2008	2009	2010
Arrivals	Number of Babies	413	369	366
	Number of Girls	200	166	156
	Number of Boys	213	203	210
SCU	Total	203	117	151
	SCU Girl	100	49	68
	SCU Boy	103	68	83
ICU	Total	210	251	208
	ICU Girl	100	116	86
	ICU Boy	110	135	122
Departure Healthy	Total	316	240	302
	Healthy SCU Healthy SCU Girl Healthy SCU Boy	185	103	142
	Healthy ICU Healthy ICU Girl Healthy ICU Boy	131	137	153
	Healthy Girl	153	110	127
	Healthy Boy	163	130	175
Departure EX	Total	44	34	32
	EX Girl	21	18	14
	EX Boy	23	16	18
	EX SCU	3	0	1
	EX ICU	41	34	31
	EX SCU Boy	2	0	0
	EX SCU Girl	1	0	1
	EX ICUBoy	21	16	18
	EX ICU Girl	20	18	13
TFT	Total	147	68	113
	TFT Girl	74	27	55
	TFT Boy	73	41	58
SCU TFT	Total	130	63	90
	SCU TFT Girl	64	27	47
	SCU TFT Boy	66	36	43
ICU TFT	Total	17	5	23
	ICU TFT Girl	10	0	8
	ICU TFT Boy	7	5	15

In Table 4.4, the treatment times, average weights and departure numbers are given about babies. When it is divided as girl and boy, there are some differences for variables. For example, girls generally have low weights but their ex numbers and transfer numbers are also lower than boys. As whole boys need more time for treatment than girls while their weights are higher than girl weights. In these three years, 858 babies leave from the neonatal unit healthily; 156 of babies are transferred to another hospitals and the average treatment time for the transferred babies is 0.49 day while average weight is 1971 gram. Moreover, 110 of babies can't survive their lives. Other supplement inputs can be understudied similarly. Additionally, BR symbol in the table refers to baby room where some first basic controls are performed.

Table 4.4 : Some information about the departure types for three years

Types of departures	Number	average time(day) spent in the system	AVG Gram	Girl			Boy		
				Number	Treatment Time	KG	Number	Time	Gram
Transfer	156	0,49	1971	68	0.69	1918	88	0,33	2011
Healthy	858	9,38	2601	390	9.85	2424	468	8,98	2748
EX	110	12,82	1315	52	9.57	1396	58	15,73	1243
BR	8	2,75	2921	3	3.00	2823	5	2,60	2980
SCU	13	9,31	1991	8	7.25	1787	5	12,60	2318
ICU	3	6,67	3937	0	0	0	3	6,67	3937

4.2 STATISTICAL INFERENCES OF THE REFERENCED NEONATAL UNIT

In the last part of this chapter, some statistical hypothesis tests are performed based on the collected data from the referenced neonatal unit. Two types of hypothesis tests are conducted: One compares two different types of statistics in each year. For instance, healthy girl ratio among all girls is compared with the healthy boy ratio among all boys in years 2008, 2009 and 2010. Overall comparisons are also performed. Table 4.5 gives the results of these hypotheses. The other one compares the same statistic in different pair wise years. For instance, healthy girl ratio among all girls in 2008 is compared with the healthy girl ratio among all girls in 2009. Table 4.6 gives the results of these second type hypotheses. In both hypothesis test types, two-sided two sample t-test is performed. In the tables, second column gives the p-values of the hypothesis tests. Significance level is taken as 0.05. "P-value>0.05" indicates that there is no significant difference; hence the equality hypothesis is failed to reject and the conclusion is represented as "Equal". On the other hand, "p-value≤0.05" indicates that there exists significant difference; hence the conclusion is represented as either "greater" or "less" depending on the values of the first and second statistics. For instance, number of healthy SCU / SCU Total is compared with the number of healthy ICU /ICU Total in Table 4.5. As a result, the p-values are determined to be zero in each year. So, it can be deduced that the ratio of healthy departures from the SCU department is significantly greater than the ratio of healthy departures from the ICU department in years 2008, 2009 and 2010.

Table 4.5 : Hypothesis test results of different statistics between 2008 and 2010

1	Healthy girl/Number of Girls = Healthy boys/Number of boys	Conclusion
2008	0.995	Equal
2009	0.655	Equal
2010	0.634	Equal
Overall	0.985	Equal
2	SCU Healthy Girl /SCU girl = SCU Healthy Boy/ SCU boy	Conclusion
2008	0.754	Equal
2009	0.007	less
2010	0.073	Equal
Overall	0.011	less
3	ICU Healthy Girl /ICU girl = ICU Healthy Boy/ ICU boy	Conclusion
2008	0.12	Equal
2009	0	less
2010	0	less
Overall	0	less
4	Healthy SCU / SCU Total= Healthy ICU /ICU Total	Conclusion
2008	0	greater
2009	0	greater
2010	0	greater
Overall	0	greater
5	TFT girl/number of girls=TFT boys/number of boys	Conclusion
2008	0.563	Equal
2009	0.328	Equal
2010	0.12	Equal
Overall	0.369	Equal
6	SCU TFT Total/SCU Total =ICU TFT Total/ICU Total	Conclusion
2008	0	greater
2009	0	greater

2010	0	greater
Overall	0	greater
7	SCU TFT girl/SCU girl =SCU TFT boy/SCU boy	Conclusion
2008	0.991	Equal
2009	0.817	Equal
2010	0.027	greater
Overall	0.149	Equal
8	ICU TFT girl/ICU girl =ICU TFT boy/ICU boy	Conclusion
2008	0.338	Equal
2009	0.023	less
2010	0.488	Equal
Overall	0.469	Equal
9	Healthy Girl avg weight = Healthy boy avg weight	Conclusion
2008	0	less
2009	0.001	less
2010	0.028	less
10	ICU Girl avg weight = ICU Boy avg weight	Conclusion
2008	0.012	less
2009	0.016	less
2010	0.003	less
11	SCU Girl avg weight = SCU Boy avg weight	Conclusion
2008	0	less
2009	0.07	Equal
2010	0.489	Equal
12	SCU treatment time = ICU treatment time	Conclusion
2008	0	less
2009	0.021	less
2010	0	less
13	SCU Girl treatment time = SCU Boy treatment time	Conclusion
2008	0,006	less
2009	0,436	Equal
2010	0,248	Equal
14	ICU Girl treatment time = ICU Boy treatment time	Conclusion
2008	0	less
2009	0,021	less
2010	0,335	Equal
15	EX Girl treatment time = EX Boy treatment time	Conclusion
2008	0.141	Equal
2009	0.082	Equal
2010	0.365	Equal
16	EX Girl weights = EX Boy weights	Conclusion
2008	0.612	Equal
2009	0.902	Equal
2010	0.454	Equal

Comments for the hypothesis test results of different statistics:

According to Table 4.5, the following statistical inferences can be made:

- There exists no significant difference between healthy girl departure ratio among all girls and healthy boy departure ratio among all boys in all years.
- Healthy girl departure ratio of babies accepted by SCU is significantly less than healthy boy departure ratio of babies accepted by SCU
- Healthy departure ratio of babies accepted by SCU is significantly greater than healthy departure ratio of babies accepted by ICU in all years.
- There exists no significant difference between TFT usage of girls and boys in all years.
- TFT usage ratio of the babies entering SCU is significantly greater than TFT usage ratio of the babies entering ICU in all years.
- There is no significant difference between TFT usage ratio of the girls entering SCU and TFT usage ratio of the boys entering SCU in years 2008 and 2009. However TFT usage ratio of the girls entering SCU is greater than TFT usage ratio of the boys entering SCU in 2010. Nevetheless, overall comparison results of this test gives no significant difference between boys and girls.
- There is no significant difference between TFT usage ratio of the girls entering ICU and TFT usage ratio of the boys entering ICU in years 2008 and 2010. However TFT usage ratio of the girls entering ICU is less than TFT usage ratio of the boys entering SCU in 2009. Nevetheless, overall comparison results of this test gives no significant difference between boys and girls.
- Average initial weight of the healthy departures of girls is significantly less than the average initial weight of the healthy departures of boys in all years.
- Average initial weight of ICU-entered girls is significantly less than the average initial weight of ICU-entered boys in all years.
- Average initial weight of SCU-entered girls is significantly less than the average initial weight of SCU-entered boys in 2008. Nevertheless, there exists no significant difference between the initial weights of the girls and boys entering SCU.

- As for the treatment times, mean treatment time spent in SCU is significantly less than the mean treatment spent in ICU in all years.
- Mean treatment time spent in SCU for girls and the mean treatment spent in SCU for boys has similar values.
- Mean treatment time spent in ICU for girls is significantly less than the mean treatment spent in ICU for boys.
- As for the EX-departures, there exists no significant difference between the mean treatment time of EX-departed girls and the mean treatment time of EX-departed boys.
- There exists no significant difference between the mean weight of EX-departed girls and the mean weight of EX-departed boys.

Table 4.6 : Hypothesis test results of pairwise comparison of the same statistics among years.

1	Number of girls / Number of babies (arrival ratio)	Conclusion
2008-2009	0.335	Equal
2008-2010	0.104	Equal
2009-2010	0.518	Equal
2	SCU total / Number of babies	Conclusion
2008-2009	0	greater
2008-2010	0.027	greater
2009-2010	0.007	less
3	Number of Healthy departure / Number of Babies	Conclusion
2008-2009	0	greater
2008-2010	0.037	less
2009-2010	0	less
4	Number of Healthy girl / Number of girls	Conclusion
2008-2009	0.031	greater
2008-2010	0.256	Equal
2009-2010	0.002	less
5	Number of Healthy boy / Number of boys	Conclusion
2008-2009	0.005	greater
2008-2010	0.079	Equal
2009-2010	0	less
6	Number of SCU healthy baby / Number of SCU total	Conclusion
2008-2009	0.39	Equal
2008-2010	0.295	Equal
2009-2010	0.092	Equal

7	Number of ICU healthy baby / Number of ICU total	Conclusion
2008-2009	0.089	Equal
2008-2010	0.014	less
2009-2010	0	less
8	Number of SCU healthy baby / Number of healthy departures	Conclusion
2008-2009	0	greater
2008-2010	0.004	greater
2009-2010	0.340	greater
9	TFT total / Number of babies	Conclusion
2008-2009	0	greater
2008-2010	0.162	Equal
2009-2010	0	less
10	TFT girls / Number of girls	Conclusion
2008-2009	0	greater
2008-2010	0.734	Equal
2009-2010	0	less
11	TFT boys / Number of boys	Conclusion
2008-2009	0.001	greater
2008-2010	0.138	Equal
2009-2010	0.076	Equal
12	SCU TFT total / SCU total	Conclusion
2008-2009	0.074	Equal
2008-2010	0.396	Equal
2009-2010	0.345	Equal
13	ICU TFT total / ICU total	Conclusion
2008-2009	0.003	greater
2008-2010	0.303	Equal
2009-2010	0	less
14	Number of TFT girl / Number of TFT total	Conclusion
2008-2009	0.141	Equal
2008-2010	0.79	Equal
2009-2010	0.236	Equal
15	Number of SCU TFT / Number of TFT total	Conclusion
2008-2009	0.307	Equal
2008-2010	0.057	Equal
2009-2010	0.008	greater

Comments for the hypothesis test results of the same statistics:

According to Table 4.6, the following statistical inferences can be made:

- Girls' ratio among all arrivals is not significantly different in any one of the three years.
- SCU arrivals' ratio among all arrivals is significantly different in all three years. Namely, it is significantly lowest in 2009 whereas in 2010 it is significantly higher, but in 2008 it is the highest. This means that ICU arrivals's ratio is highest in 2009 and this may be the most probable reason of the high ratio of low ratio of the healthy departures in 2009.
- Healthy departures' ratio among all arrivals is significantly different in all three years. Namely, it is significantly lowest in 2009 whereas in 2008 it is significantly higher, but in 2010 it is the highest which shows that there exists improvements in the conditions of the neonatal unit.
- Healthy departures' ratio among all girls is significantly lowest in 2009 like the case of healthy departures' ratio among all arrivals whereas there exists no significant difference in this statistic between 2008 and 2010. Healthy departures' ratio among all boys has also the same inferences.
- Healthy departures' ratio among all SCU-entered babies is not significantly different in all three years. Healthy departures' ratio among all ICU-entered babies is not significantly different in 2008 and 2009. However it is significantly the highest in 2010. This may be because of the improvements performed by the hospital and the government for the ICU department.
- SCU-entered healthy babies'ratio among all healthy departures is significantly highest in 2008. This is because SCU arrivals' ratio among all arrivals is significantly highest in 2008.
- TFT usage ratio is significantly low in 2009 when compared with 2008 and 2010. This result is also consistent with the gender, meaning that TFT usage

ratio of girls and also boys are also significantly low in 2009 when compared with 2008 and 2010. Paralel with this result, TFT usage ratio of the babies entering ICU is significantly low in 2009 when compared with 2008 and 2010. However, there is no evidence to say that TFT usage ratio of the babies entering SCU is significantly different in any of the three years.

- Girls’ ratio among the ones using TFT is not significantly different in any one of the three years. SCU entered babies’ ratio among the ones using TFT is highest in 2009, and there exists a significant decrease in this ratio in 2010.

5. MODEL AND SOLUTION PROPOSALS

Generally, the main causes of high neonatal mortality rates come from scarce capacity and/or inadequate capacity assignment problems. The major goal of this master thesis is to analyze capacity problems in a neonatal unit and develop solution proposals for these. Therefore, the basic equipments in the neonatal unit like incubator, expert nurse, doctor, monitor, ventilator, open bed, phototherapy machine and cooling machine are investigated to be planned efficiently to achieve better utilization. First stage of the aim is to determine the bottleneck resources in a third level neonatal unit which is the unit in hand for the thesis. Then, following stage is to offer some solutions about the current condition.

All of the data are gathered from a university medical faculty hospital in Istanbul. Real data usage provides real solutions and real results in terms of usability of the study. The neonatal unit in hand is a third level unit. The unit is able to give service to various treatment requirements. It has two different levels of unit for baby care which are Special Care Unit (SCU) and Intensive Care Unit (ICU).When premature baby comes to the unit, first controls are made in the baby room and then directed to the related care unit by doctors. The “level” system has been used since 2008. Hence, three years of data are collected. Babies can change their current levels according to their health conditions, in case they progress or deteriorate. Information related with the babies are always recorded by the hospital authorities but, because of some problems in the recording process and missing information, the percentage of transmissions between levels are stated by specialist doctors.

Baby records include the weight, gender, arrival time, departure time, entrance level, departure type and TFT usage requirement for each baby arriving to the unit. These data are used mainly for determining the treatment route, capacity of levels, transmission rates between levels. Data are analyzed statistically in ARENA program and results are given in Table 5.1. Results show that arrivals to both SCU and ICU are pursuant to Poisson distribution with 95 percent of confidence level. Moreover, baby treatment times comply with gamma distribution in both ICU and SCU departments. Baby arrival and treatment distributions are determined by using Kolmogorov-Smirnov test and chi square test respectively. Table 5.1 is a summary distribution table for SCU and ICU departments. These tests help to find the most suitable statistical distribution for the study. While Kolmogorov-Smirnov test is used for baby arrivals to ICU and SCU, chi-square test is applied for treatment time. According to the Kolmogorov Smirnov (K.S) test and Chi-square test, both of the department arrivals conform to Poisson distribution while treatment times show the feature of gamma distribution.

Table 5.1 : Baby arrival and treatment time distribution for SCU and ICU departments

	Arrivals / Treatment time Distribution	**Test statistics**	**critical value (α=0.05)**
SCU Arrivals	Poisson λ=0.42335766	K.S. Test D=0.046797959	0.565
ICU Arrivals	Poisson λ =0.61116194	K.S. Test D=0.052888522	0.486
SCU Treatment time	Gamma $\alpha = 3.04$, $\beta = 2.4$ x-bar = 6.81, s = 5.06	Chi-square Test X^2=9.89 *(p-value=0.701)*	22.36
ICU Treatment time	Gamma $\alpha = 10.8$, $\beta = 1.09$ x-bar = 11.2, s = 12.2	Chi-square Test X^2=20.3 *(p-value=0.676)*	36.42

Chi-square test generally controls if there is a significant difference among two or more data set. In this method, the observed values are compared with the expected values. The null and alternative hypotheses in testing for goodness of fit are as follows:

$H_0 : o_i = e_i$; $i = 1, 2, ..., r, ...$ $(o_1 = e_1, o_2 = e_2, ..., o_r = e_r)$ (Observed frequencies conform to expected frequencies)

$H_1 : o_i \neq e_i$ (Observed frequencies do not conform to expected frequencies, difference is important)

Equation 5.1 gives the chi square test statistic. This value is compared with the critical value C.V is the significance level and it is taken as 0.05 where n is the number of class intervals.

$$C.V = x^2_{\alpha, n-2}\alpha \qquad (5.1)$$

If $x^2 > C.V$ then the observed frequencies do not conform to expected frequencies at the significance level of α. Else if $x^2 \leq$ C.V, then it is failed to reject that the observed frequencies do not conform to the expected frequencies.

$$x^2 = \sum_{i=1}^{r} \frac{(o_i - e_i)^2}{e_i} \qquad (5.2)$$

Kolmogorov- Smirnov test is an alternative test for chi-square tests. In chi square test, data set has big input volume to reach the required limitations. However Kolmogorov-Smirnov test has not limitations for expected frequencies. Test statistic is shown as D which is the largest absolute difference between the observed and the expected cumulative frequencies.

$$\text{D} = \max\left|F_0 - F_e\right| \qquad (5.3)$$

F_0 = observed cumulative frequencies

F_e = expected cumulative frequencies

$$C.V = D\alpha;n \tag{5.4}$$

In deciding process there is Equation 5.4; where α refers to the level of significance. If D > C.V then the observed frequencies do not conform to expected frequencies at the significance level of α. Else if D ≤ C.V, th en it is failed to reject that the observed frequencies do not conform to the expected frequencies.

5.1 SIMULATION MODELS

The neonatal unit in hand is third level unit and it has two main departments for the needs of baby care. Therefore the system has two independent acceptances as SCU and ICU. Usually they try not to reject premature babies so, if equipment capacity is not available for high risk pregnancies then they are directed to another hospital for birth. When all equipments are using with full capacity then, babies continue their care process in the same treatment level until the other treatment level equipments are available. After waiting for another care level, if baby can be transferred to the next level, the waiting time is reduced from new level treatment time. Because the causes of rejections are scarce expert nurses and incubators, they are included to simulation model. All incubators and nurses are identical to each others.

SCU and ICU departments have different equipments in terms of baby care. For example, SCU has ten incubators and two nurses. Each nurse is responsible from five babies. On the other hand ICU has nine incubators and three nurses. Each nurse is responsible from three babies. In addition, ICU has 10 ventilators as distinct from SCU. One incubator can be used for only one baby. Transfers between SCU and ICU have important roles in babies' health conditions. The main aim should be minimized waiting times when transfers occur. Therefore in addition to the current situation, four strategies are developed as proposed solutions for level transfers. Firstly, the current situation will be described with its simulation flow chart then, improved strategies will be continued with flow charts.

5.1.1 Current Situation

Babies' first acceptance is determined according to the capacity sufficiency of the current level. If capacity is not available then the baby is rejected. After the baby's treatment is completed in the first acceptance level, if doctors decide to continue baby's treatment in another level then baby is directed to the next level. But, if the number of equipments is inadequate in the next level then, the baby waits in the current level with the same care equipments until capacity is available in the next level. When capacity is available, the baby is transferred to the next level but, his waiting time is reduced from the next level treatment time. Figure 5.1 shows the movements of baby arrivals to levels and intermediate transfers between levels. In Figure 5.2 and Figure 5.3, flow charts of the simulation models are given as ICU and SCU for the current situation.

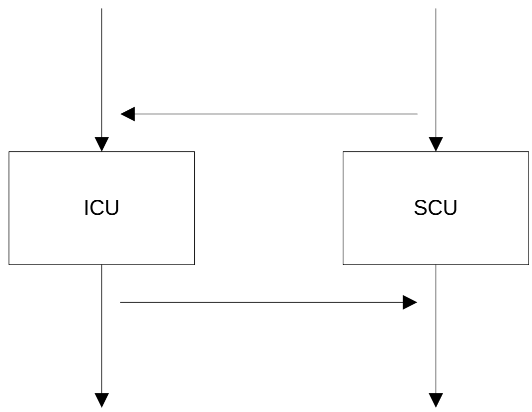

Figure 5.1 : The indication of movements between levels in current situation

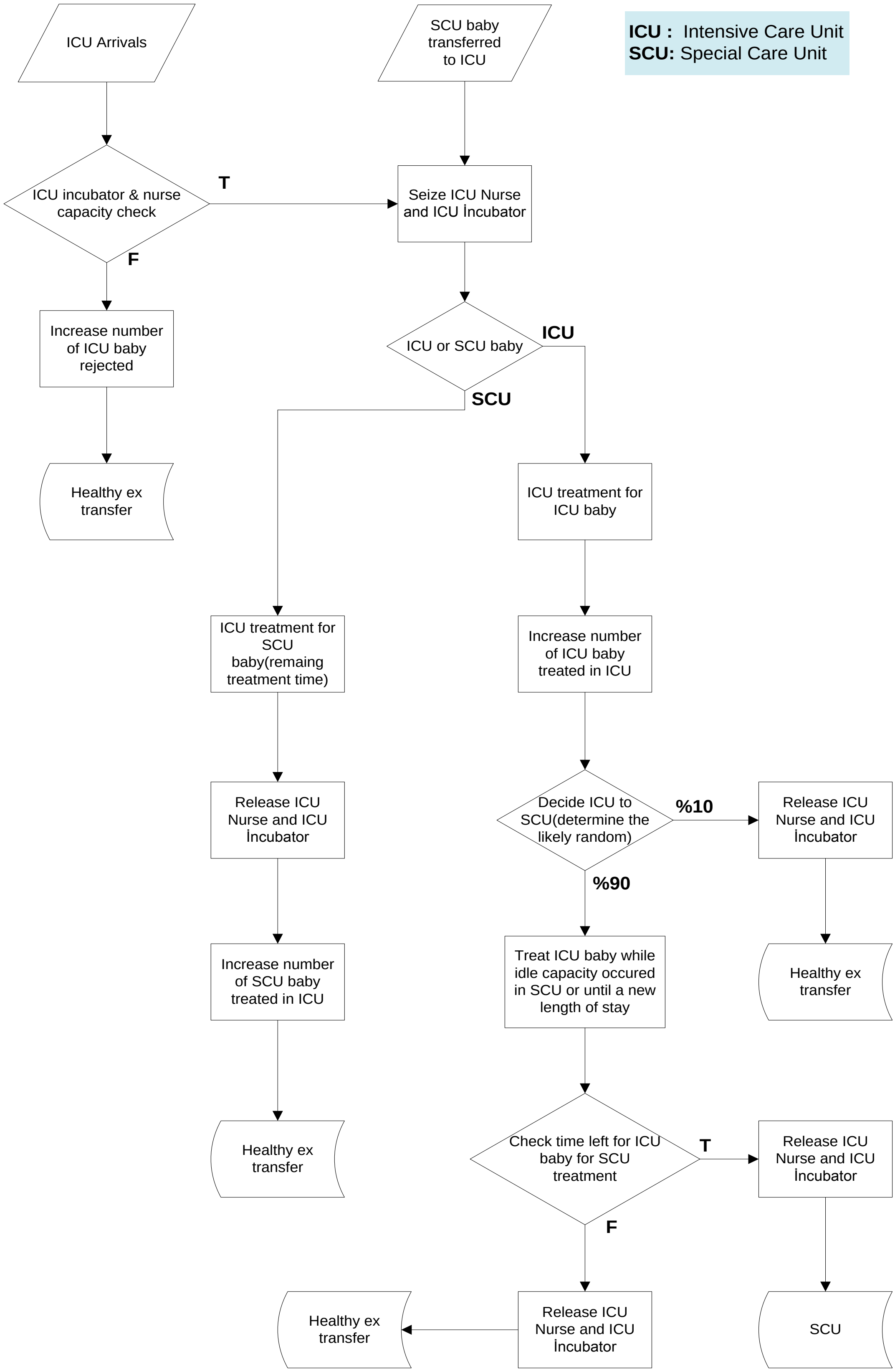

Figure 5.2 : Flowchart of ICU department for Current Situation

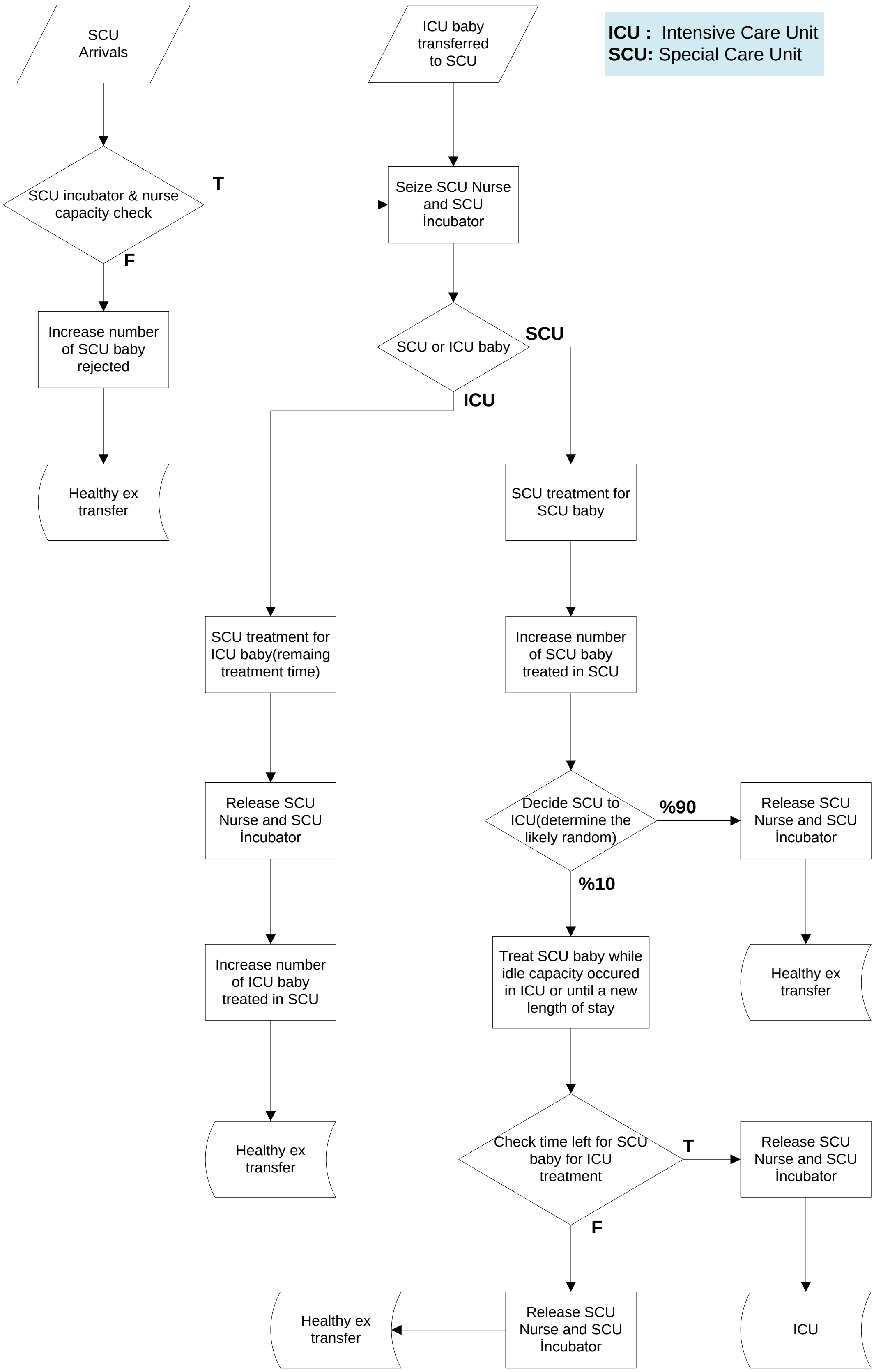

Figure 5.3 : Flowchart of SCU department for Current Situation

5.1.2 Strategy I

In this solution alternative, one buffer zone is created between SCU and ICU departments because; the number of rejected babies who are not even treated is high and the equipment utilizations for each department are low. So, the number of rejected and untreated babies is high. The resources of buffer department are supplied from SCU department. There is one incubator in the buffer zone and the nurse is supplied from SCU department.

When a baby comes to SCU or ICU, the equipment capacity is controlled in the unit as in the current situation. If capacity is not available then baby is directed to the buffer unit. If buffer unit capacity is not available then the baby is transferred to another neonatal unit. In addition to this, the similar conditions are validated for transition process between SCU and ICU departments. When a baby is transferred to a next level and if capacity is not available in that unit then he is directed to the buffer unit. If buffer unit capacity is also not available then the baby waits in the current care unit until capacity is available in next unit or buffer department. When buffer unit or next unit capacity is available, then the baby spends remaining care time in these units. Waiting times are reduced from the next level treatment times. If the waiting time equals to the next unit's treatment time then the baby leaves from the system.

The aim of this strategy is canalizing rejected babies and intermediate transfer babies to the buffer zone to make better equipment utilizations in SCU and ICU departments. In this way, untreated baby number is hoped to decrease. BZ refers to the buffer zone. Figure 5.4 summaries the baby movements among departments. In Figure 5.5 and Figure 5.6, flow charts of the simulation models are given as ICU and SCU for the strategy 1.

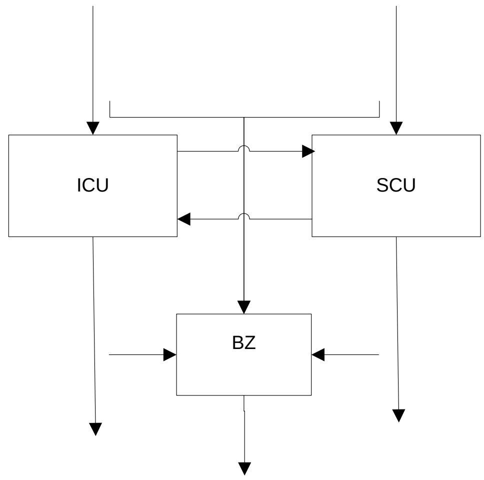

Figure 5.4 : The indication of movements between levels in strategy I

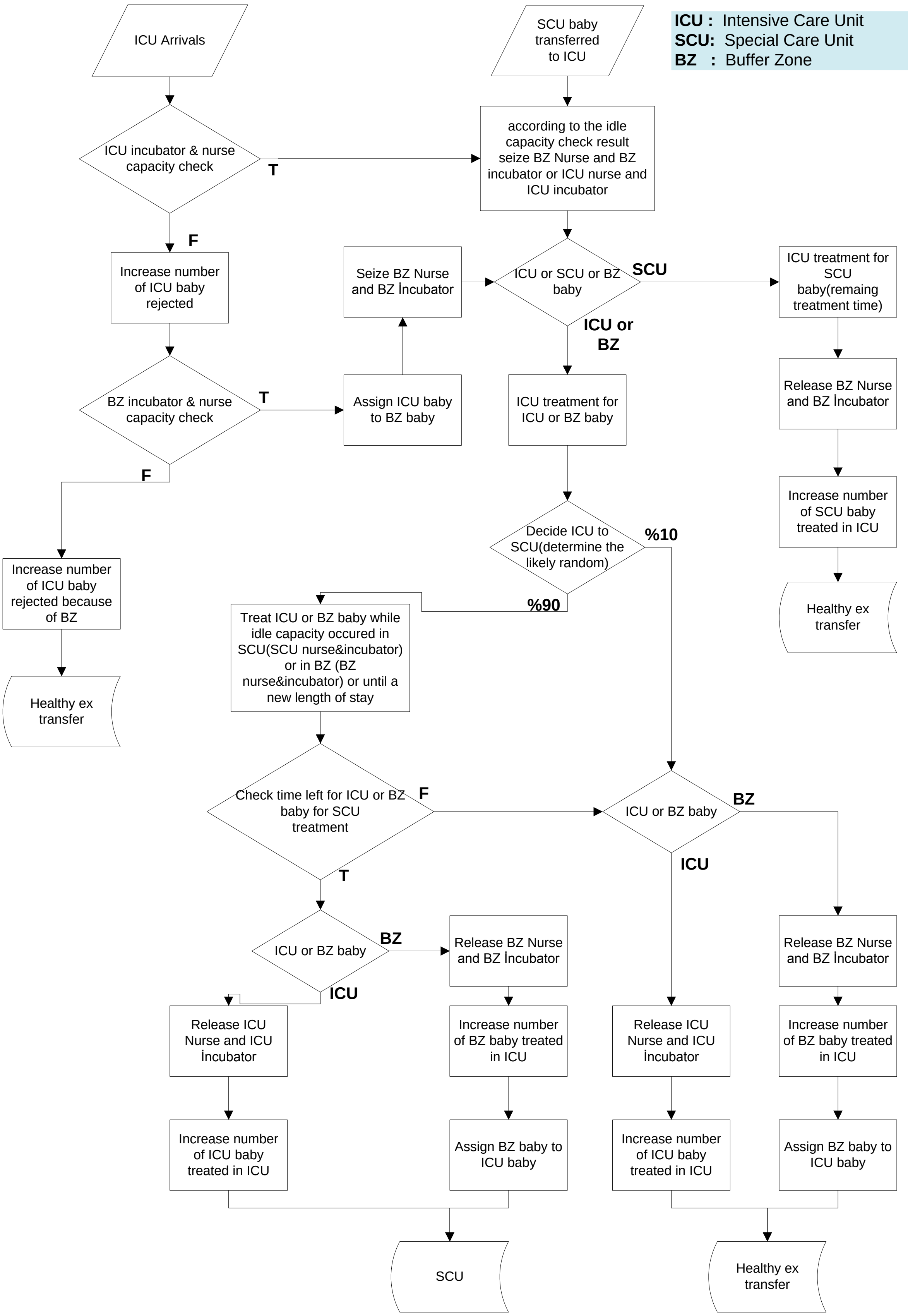

Figure 5.5 : Flowchart of ICU department for Strategy I

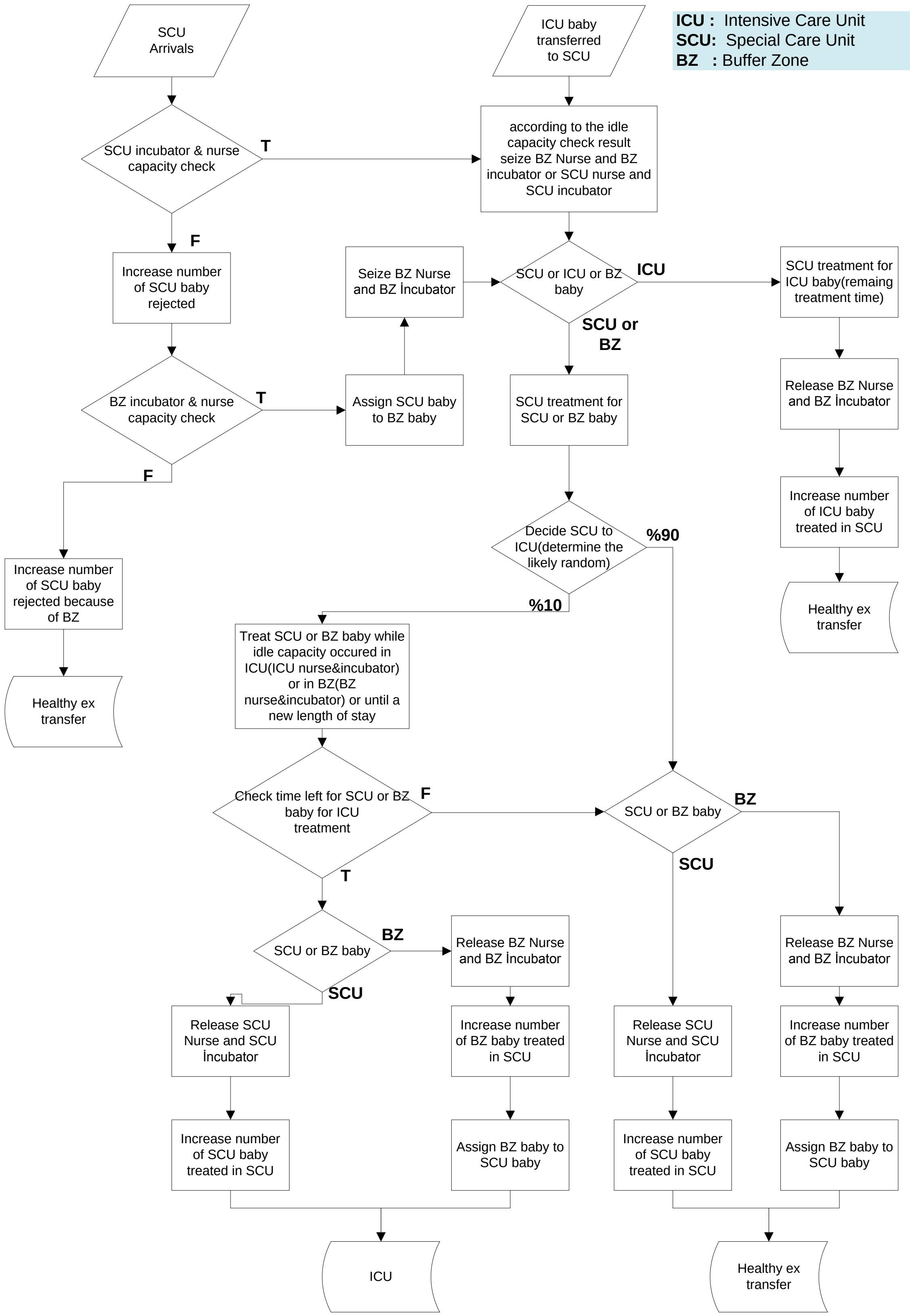

Figure 5.6 : Flowchart of SCU department for Strategy I

5.1.3 Strategy II

This strategy is very similar to strategy I in terms of the functioning of processes but a small detail makes it different. In strategy I, intermediate transfers can be directed from SCU and ICU to buffer department. But, in strategy II, buffer department can only accept external rejected babies. Other working procedures are the same as strategy one.

The equipment utilizations and the number of rejected and untreated babies are aimed to make better than the current strategy. Therefore only external and untreated babies are accepted to buffer zone in this strategy. In Figure 5.7 the difference between strategy one and strategy two can be seen more clearly. In Figure 5.8 and Figure 5.9, flow charts of the simulation models are given as ICU and SCU for the strategy 2.

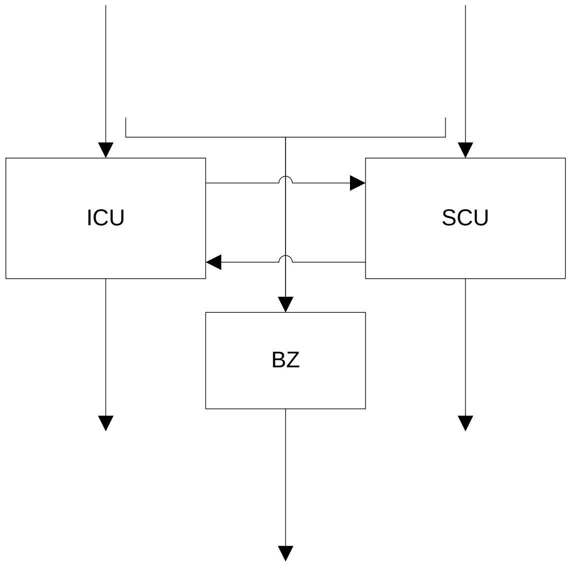

Figure 5.7 : The indication of movements between levels in strategy II

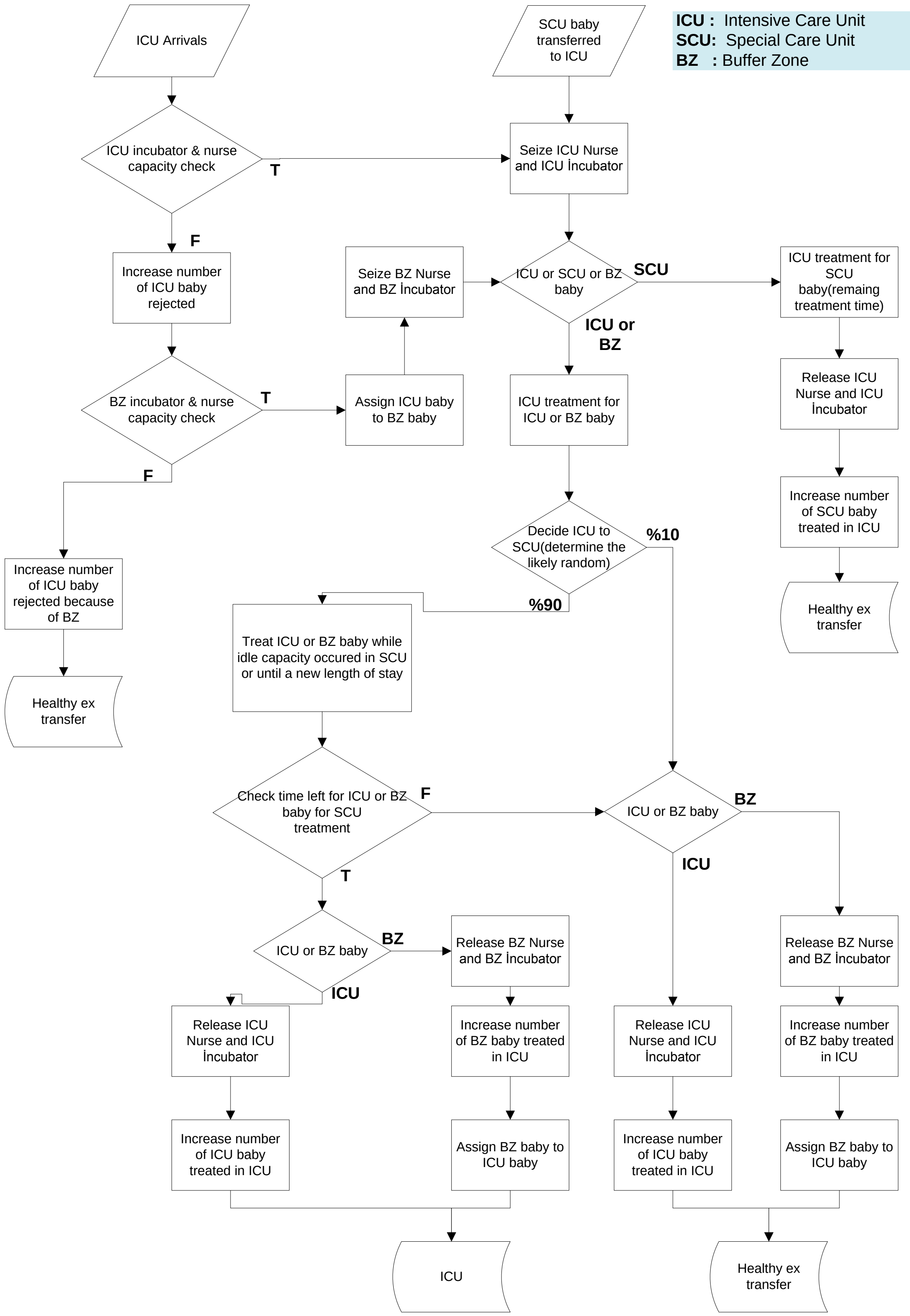

Figure 5.8 : Flowchart of ICU department for Strategy II

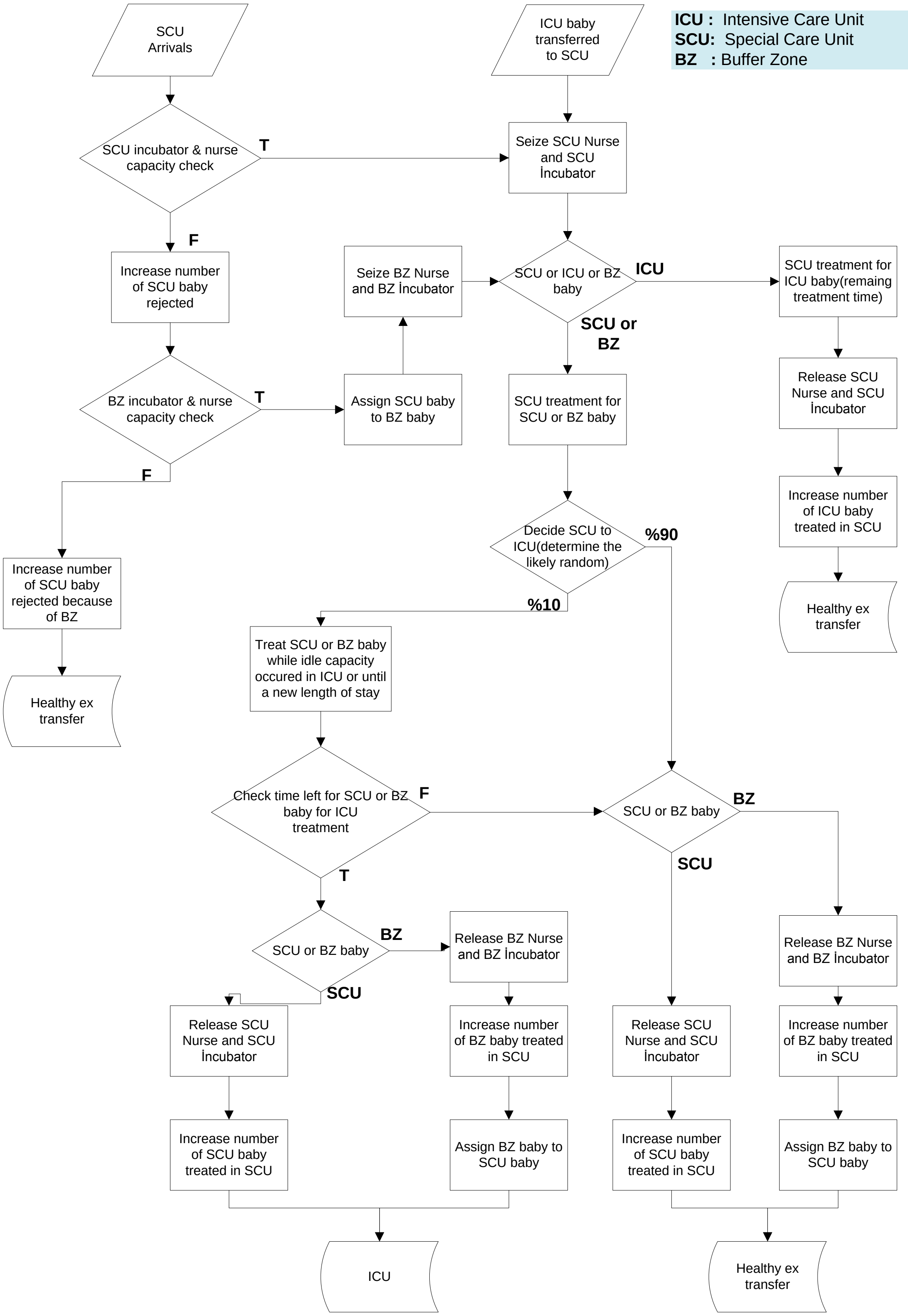

Figure 5.9 : Flowchart of SCU department for Strategy II

5.1.4 Strategy III

Due to high intermediate transitions between SCU and ICU departments, a buffer zone is created for only transitions between SCU and ICU when the next department is not available. Other untreated babies are not accepted to the buffer in this model. On the other hand all other working procedures and equipment conditions are the same as strategy I.

This strategy is interested in the waiting time when a baby is transferred to the next level. Thus, it can be a good solution to decrease waiting times between SCU and ICU departments. Figure 5.10 shows the flow of baby transitions among the levels. In Figure 5.11 and Figure 5.12, flow charts of the simulation models are given as ICU and SCU for the strategy 3.

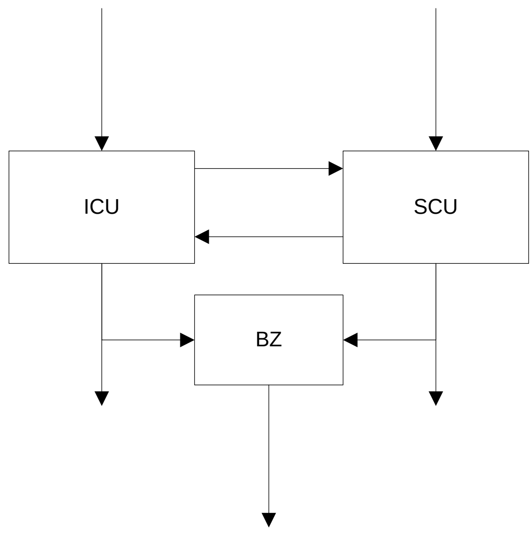

Figure 5.10 : The indication of movements between levels in Strategy III

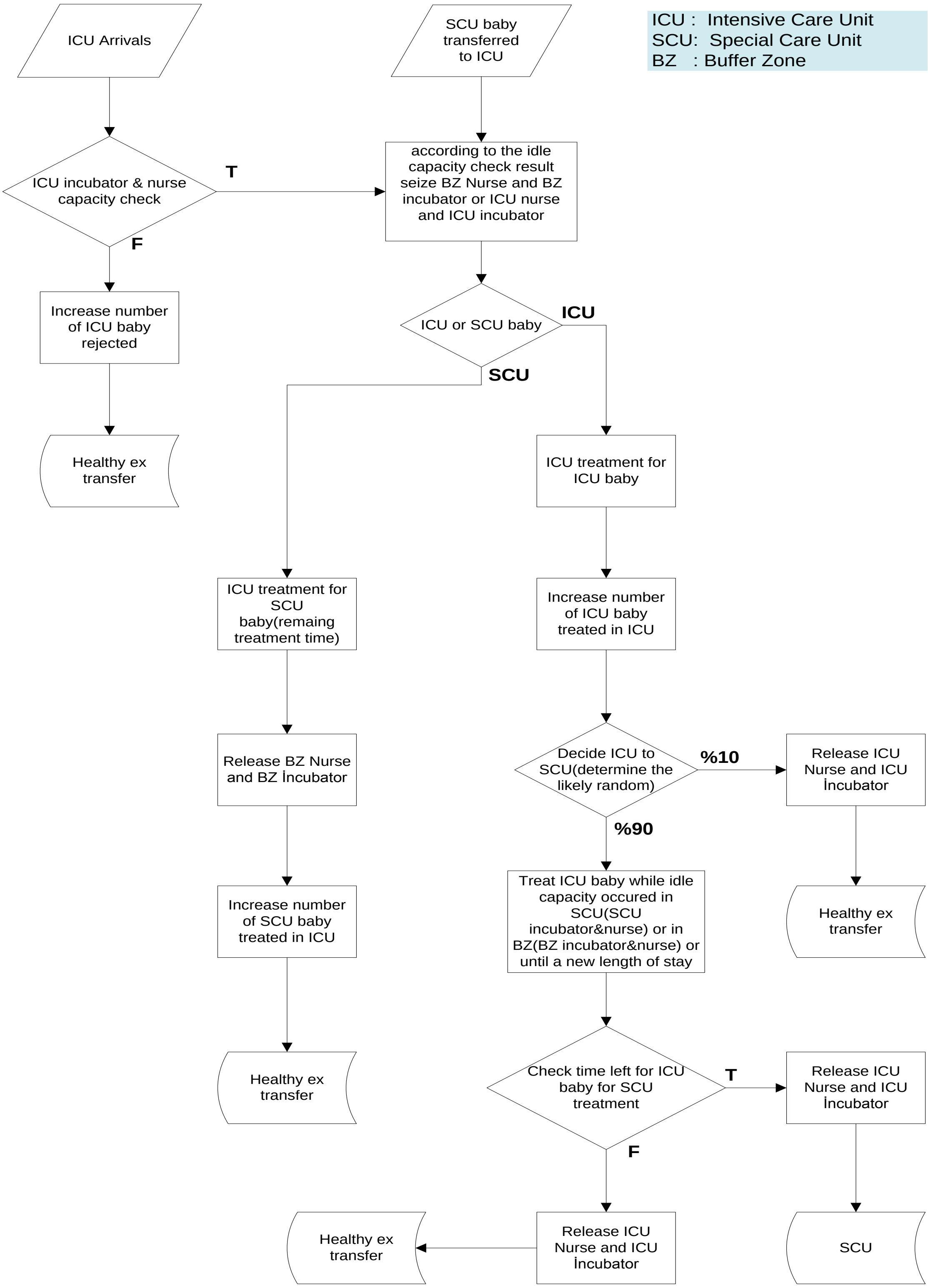

Figure 5.11 : Flowchart of ICU department for Strategy III

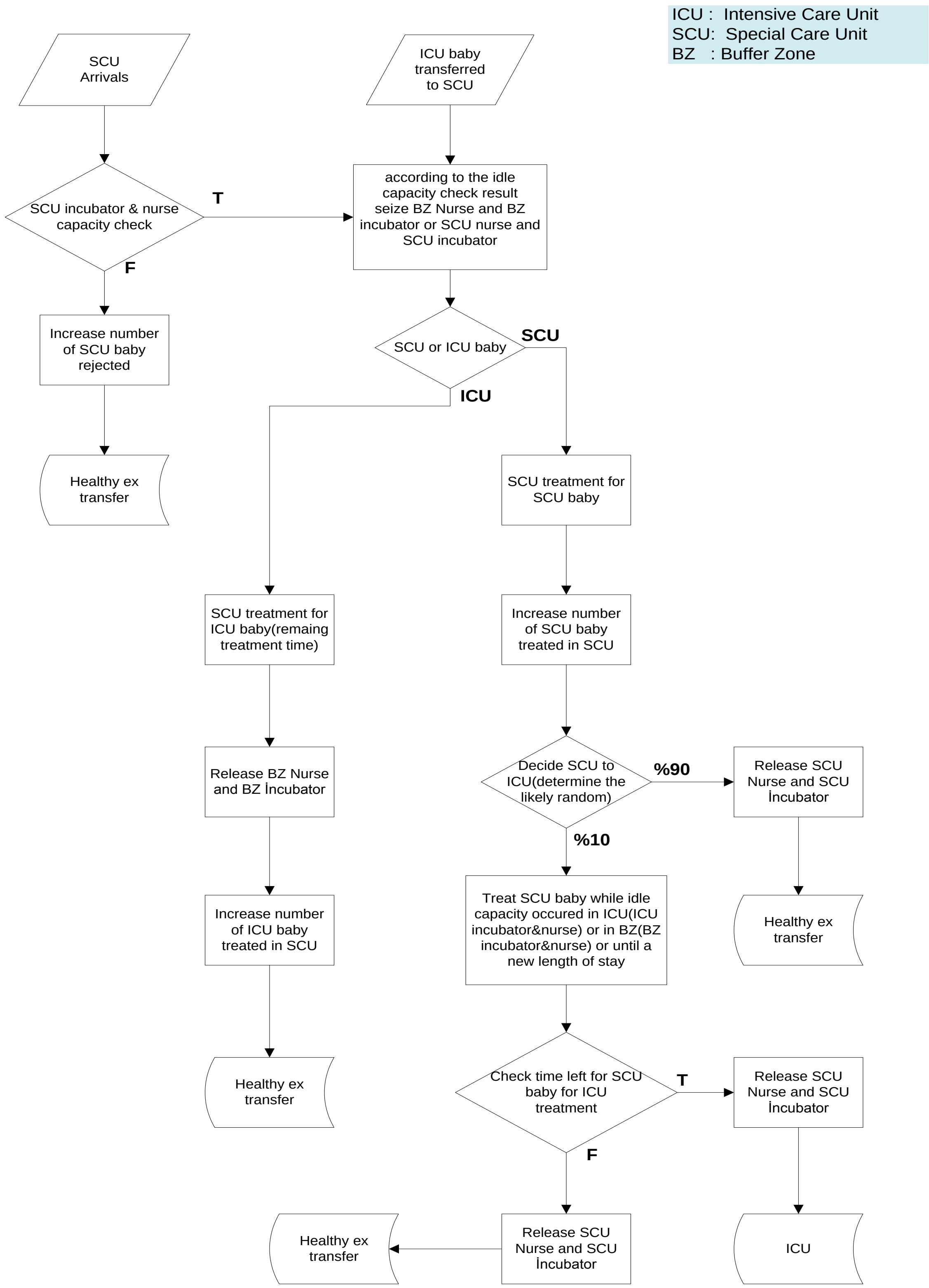

Figure 5.12 : Flowchart of ICU department for Strategy III

5.1.5 Strategy IV

Due to the significance of transitions between levels and the high number of baby transfers between departments, two buffer units are generated between care units. One of the buffer departments belongs to SCU, the other one is generated for ICU. Buffer department has the same equipments as ICU or SCU departments. It changes according to the care unit which the buffer unit is under ICU or SCU. But the equipment numbers are smaller than main departments. One incubator is taken from SCU department, other incubator is supplied from ICU. Nurse source is used with the main departments. Shortly, the model totally has two buffer zones for intermediate transfer babies when the next department is not sufficient. Other all working principles like waiting procedures, transition rules and treatment conditions are the same as the current situation. The external rejected baby acceptance by the buffer departments and transitions between buffer zones are excluded from model not allowed in this strategy. Figure 5.13 shows the flow of baby transitions among the levels. In Figure 5.14 and Figure 5.15, flow charts of the simulation models are given as ICU and SCU for the strategy 4

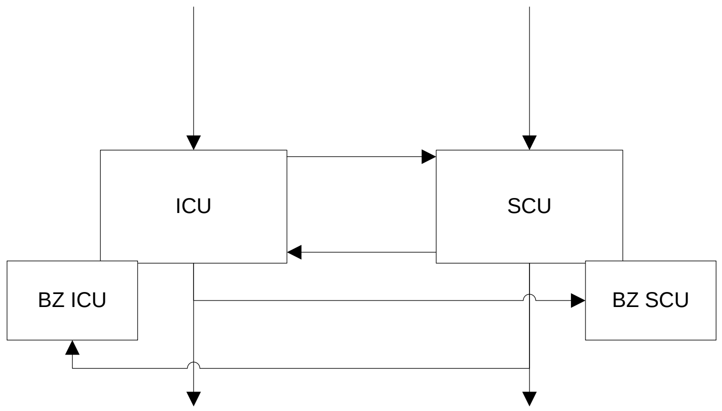

Figure 5.13 : The indication of movements between levels in strategy IV

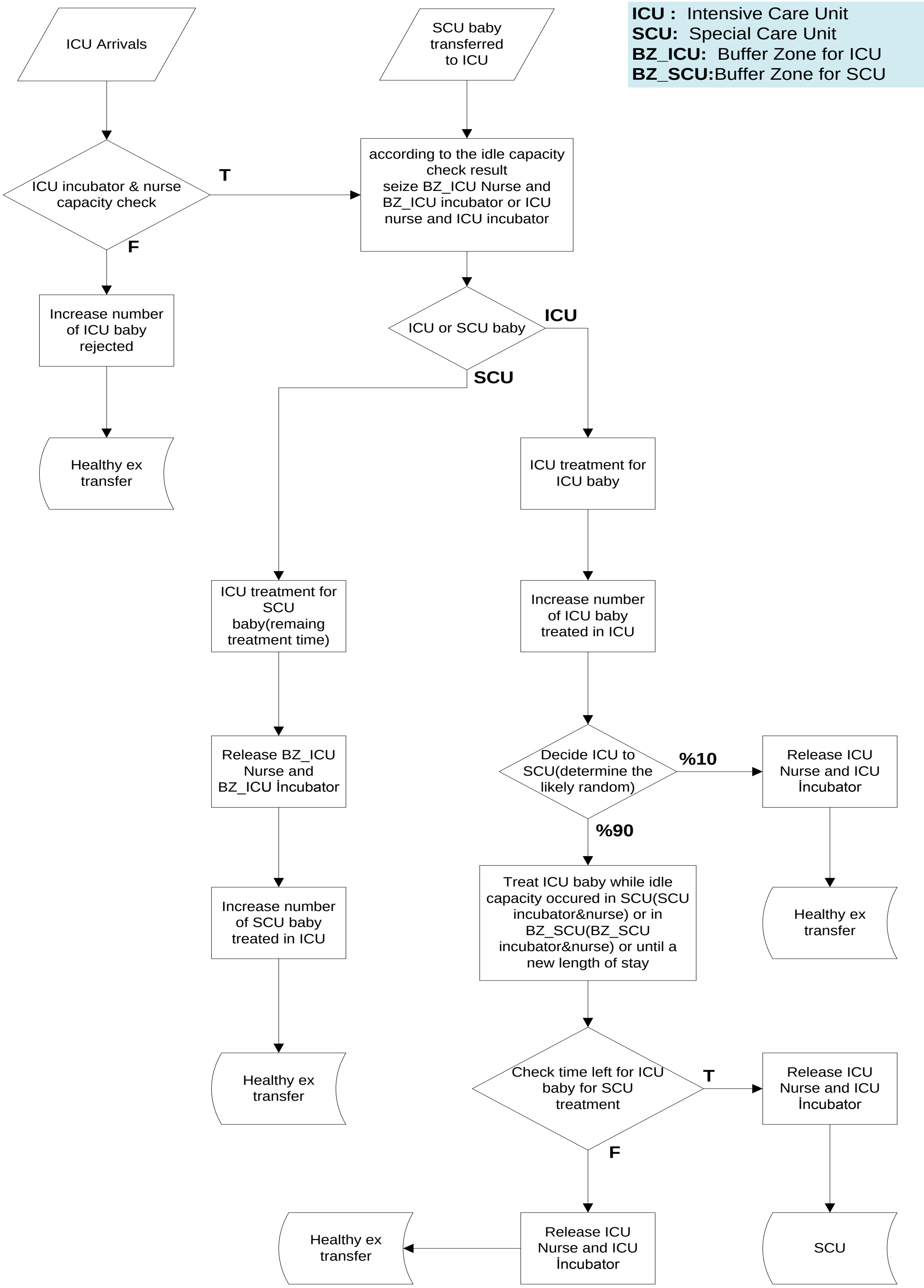

Figure 5.14 : Flowchart of ICU department for Strategy IV

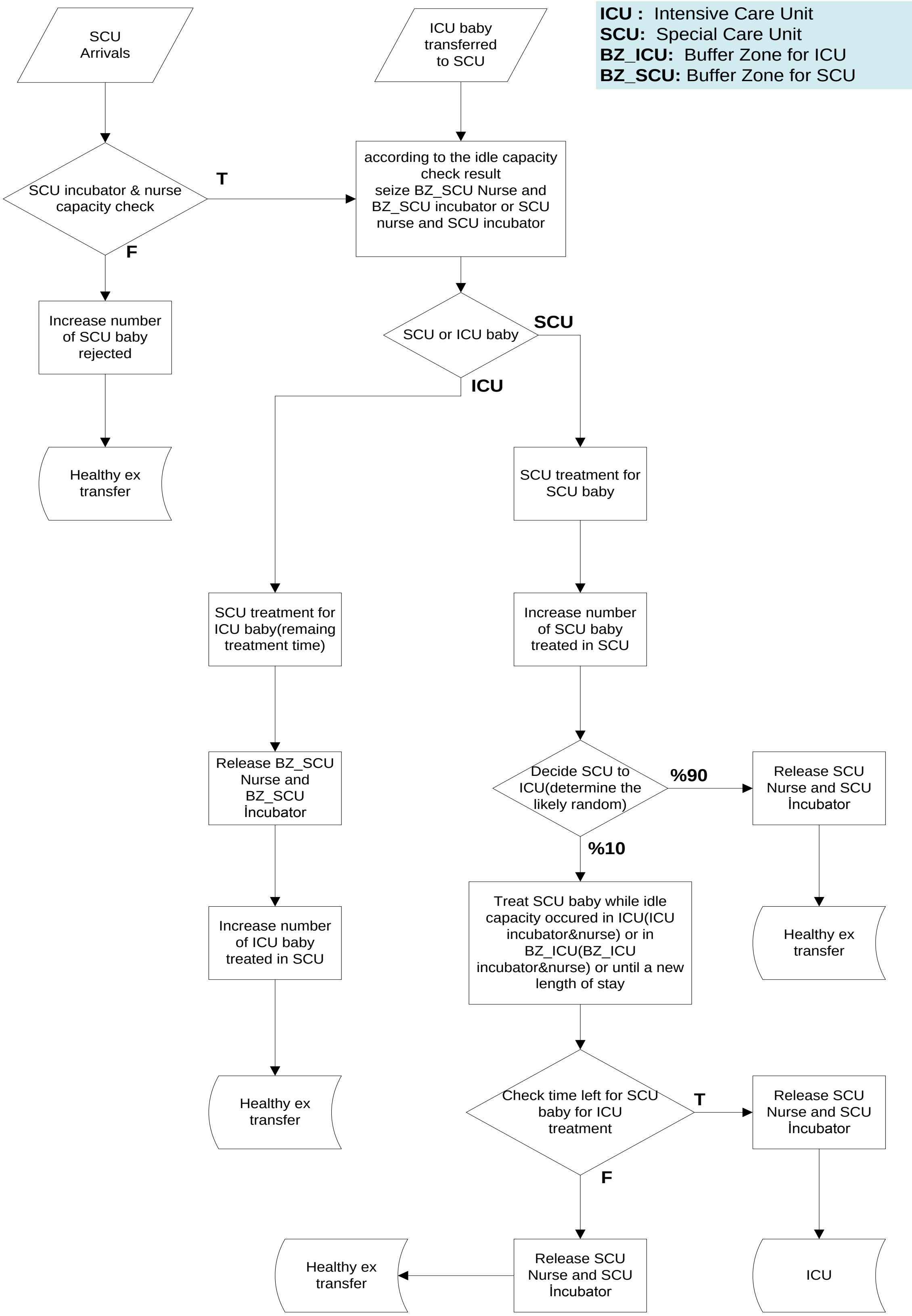

Figure 5.15 : Flowchart of ICU department for Strategy IV

5.2 SIMULATION PARAMETERS AND PERFORMANCE CRITERIA

Simulation method has large area of usage. Generally it is used in real systems. Real life problems can be more complicate for other solver methods and normally simulation is available for these kinds of problems. Neonatal units have various rules and applications in working process. The queuing system is not used in these units because of the baby care procedures. In terms of complexity of model simulation method is preferred in this study.

There are some simulation parameters which are used in when simulation program is set up. These parameters are specified to obtain healthy solutions. These are simulation length, warm up period, number of replication and lastly performance measures. Performance measures generally evaluated in simulation results to compare different conditions or strategies.

Due to statistical analysis applications, some arrival distributions and treatment time distributions are gained to use in simulation model. According to the result performance simulation length is determined as 365 days.

Replication number and warm up period has a strong relationship when their values are determined. In this study five time periods are tested in the model as warm up periods which are 0, 15, 30, 45 and 60. Table 10 shows the results of these tests for l=30, 45 and 60 where l refers to the warm up period. In the last column of the table the minimum required replication number is also calculated similarly in Ezzat (1999). In the tests, the Arena program is run for 20 times to get incubator utilization per each replication in ICU and SCU departments. Because incubator utilization is assigned as critic resource for performance criteria. Then, average and standard deviation numbers are specified for each treatment unit to use in formula of replication number. Equation 5.5 gives the replication number and calculation.

$$N(m) = \left[S(m) t_{m-1,(1-\alpha/2)} / (\overline{X}(m)\varepsilon) \right]^2 \tag{5.5}$$

In Equation 5.5; *m* is the beginning replication number for incubator utilization where $S(m)$ is standard-deviation, $\overline{X}$ is average of incubator utilizations for all replications, t is table value and ε is ratio of error which refers to 1 percent. Table 10 shows the values of 20 replications and relations between warm up period and replication number. According to Table 5.2, when Equation 5.5 is applied, it is found that the most suitable replication number is 144 or 131. Because in this condition, the average incubator utilization reach to stationary situation and warm up period shows 30 days. Although replication number is adequate for 144, it is assigned as 200 replication numbers. Warm up period is taken as 60 days to guarantee steady state conditions.

Table 5.2 : Indication of table which is used for determine warm up period and replication number

I=30	Instantaneous Utilization	REP 1	REP 2	REP 3	REP 4	REP 5	REP 6	REP 7	REP 8	REP 9	REP 10	REP 11	REP 12	REP 13	REP 14	REP 15	REP 16	REP 17	REP 18	REP 19	REP 20	AVG	Std. Dev.	SQRT(Rep.Num)	Rep.Num
	inc ICU	0,68	0,75	0,75	0,75	0,74	0,75	0,72	0,72	0,64	0,73	0,70	0,74	0,73	0,70	0,70	0,66	0,72	0,60	0,68	0,73	0,71	0,04	11,97	143,34
	inc SCU	0,54	0,58	0,58	0,59	0,58	0,57	0,62	0,61	0,57	0,58	0,61	0,58	0,61	0,55	0,64	0,66	0,61	0,57	0,55	0,54	0,59	0,03	11,46	131,28
I=45	Instantaneous Utilization	REP 1	REP 2	REP 3	REP 4	REP 5	REP 6	REP 7	REP 8	REP 9	REP 10	REP 11	REP 12	REP 13	REP 14	REP 15	REP 16	REP 17	REP 18	REP 19	REP 20	AVG	Std. Dev.	SQRT(Rep.Num)	Rep.Num
	inc ICU	0,68	0,75	0,73	0,75	0,74	0,76	0,73	0,72	0,65	0,72	0,70	0,74	0,73	0,70	0,72	0,68	0,72	0,60	0,68	0,74	0,71	0,04	11,39	129,71
	inc SCU	0,55	0,58	0,57	0,59	0,58	0,57	0,61	0,62	0,58	0,59	0,60	0,58	0,60	0,55	0,62	0,67	0,61	0,57	0,55	0,55	0,59	0,03	10,67	113,89
I=60	Instantaneous Utilization	REP 1	REP 2	REP 3	REP 4	REP 5	REP 6	REP 7	REP 8	REP 9	REP 10	REP 11	REP 12	REP 13	REP 14	REP 15	REP 16	REP 17	REP 18	REP 19	REP 20	AVG	Std. Dev.	SQRT(Rep.Num)	Rep.Num
	inc ICU	0,69	0,75	0,73	0,73	0,73	0,77	0,73	0,71	0,65	0,73	0,70	0,74	0,73	0,71	0,73	0,69	0,72	0,62	0,69	0,75	0,72	0,04	10,24	104,90
	inc SCU	0,56	0,58	0,57	0,60	0,58	0,58	0,61	0,62	0,59	0,59	0,60	0,59	0,62	0,54	0,63	0,67	0,61	0,58	0,55	0,54	0,59	0,03	11,24	126,26

Performance criteria are evaluated for utilization of incubator. Because nurse and other equipments depend on utilization of incubator. The following performance criteria are decided to be used during simulation analysis of the current situation and the proposed solutions:

- Occupancy ratio for incubator in ICU and SCU departments. **(OR)**
- Rejection ratio for incubator in ICU and SCU departments. **(RR)**

- Waiting time during intermediate transitions **(WT)**

- Treatment ratio for the intermediate transition **(TR)**

Treatment ratio is percentage of treatment time that baby can spend in next level. For example, when baby cannot be transferred and waits in buffer zone until transferred to next unit. Then, according to the system, waiting time in buffer zone subtracts from next unit treatment time. Remaining treatment time is spent in next unit. This ratio is called treatment ratio.

5.3 SIMULATION ANALYSES

Simulation model is implemented in study to reach the average steady state values in equipment utilizations, waiting time and rejections. Simulation models are get by using ARENA program and some results are obtained about treatment time, arrivals, rejections, waiting time and treatment ratio. There are three kinds of result tables for each strategy. First tables show treatment time, second tables show occupancy ratios and rejections for SCU and ICU departments. Third tables indicate the results of treatment ratio for ICU and SCU.

5.3.1 Arena Simulation Results for The Current Situation

Table 5.3 shows the neonatal stay of current situation for each department. According to the results, ICU baby spends more time than SCU baby in the system.

Table 5.3 : Indication of neonatal stays for ICU and SCU baby.

	Average	Min	Max
ICU baby	14,6034	0	113,2634
SCU baby	7,3454	0	90,3356

On the other hand, the occupancy ratio and rejection ratio are given in Table 5.4. In Table 5.4, OR refers to occupancy ratio. ICU occupancy ratio is higher than occupancy ratio of SCU department. Moreover, In ICU, the number of rejections and other parameters are in higher than SCU department.

Table 5.4 : Indication of occupancy ratio and rejection ratio for ICU and SCU departments.

	Arrivals	Rejections	RR	OR
ICU baby	258	36	0,1395	0,6947
SCU baby	179	11	0,0614	0,583
Total	437	47	0,1075	

In Table 5.5, the treatment durations in SCU and ICU and the ratio of treatments are given for inter transfer babies. When it is compared in terms of day unit, it is not so signal but, if it is evaluated in terms of hour unit, the difference is more sensible.

SCU->ICU means the babies who have initially arrived to SCU but should continue their treatment in ICU. ICU->SCU vice versa. WT (hours) is the waiting time (treatment time) in the current unit in terms of hours.

Table 5.5 : Indication of treatment time ratio for inter transfers baby

	SCU days	ICU days	WT(hours)	TR
SCU->ICU	0,1562	11,4105	3,7488	0,9865
ICU->SCU	6,7904	0,0318	0,7632	0,9953

5.3.2 Arena Simulation Results for Strategy I

This strategy aims to minimize the number of rejected babies and waiting time for next level treatment. The decision of incubator using for buffer zone is decided, according to the incubator utilizations in current situation. Therefore the buffer zone incubator is taken from SCU department. Due to the simulation analyses report, ICU baby rejections are also decrease about 19 percent. The number of total baby rejections decrease about 8 percent. On the other hand, the number of SCU baby rejections increase in proportion to 27 percent since buffer zone incubator is taken from SCU hence, equipment utilization of SCU increases in the ratio of 7 percent. Moreover, the waiting time in transfer process in ICU for ICU to SCU babies increases in proportion to 52 percent. This is because, the number of baby transfers from ICU to SCU is high, there exits one incubator shortness in SCU and the service of buffer zone includes both transfers and rejections. Nevertheless waiting time in SCU department for SCU to ICU babies decrease in proportion to 30 percent. This improvement is very important for the babies continuing their treatment in ICU. The buffer zone utilization is 0.54. Therefore, other strategies are made for increasing of usibility of buffer zone and decreasing the number of baby rejections. Table 5.6 , 5.7 and 5.8; treatment times for ICU and SCU baby, occupancy-rejection ratios and treatment durations are given for Strategy I, respectively.

Table 5.6 : Indication of treatment time for ICU and SCU baby

	Average	Min	Max
ICU baby	15,0615	0	115,07
SCU baby	7,1566	0	96,04

Table 5.7 : Indication of occupancy ratio and rejection ratio for ICU and SCU baby

	Arrivals	Rejections	RR	OR
ICU baby	258	29	0,1124	0,6983
SCU baby	178	14	0,0787	0,6251
Total	436	43	0,0986	

Table 5.8 : Indication of treatment time ratio for ICU and SCU baby

	SCU days	ICU days	WT(hours)	TR
SCU -> ICU	0,1084	11,6041	2,6016	0,9907
ICU -> SCU	6,7612	0,0484	1,1616	0,9929

5.3.3 Arena Simulation Results for Strategy II

With this strategy, it is intended to reduce the number of patients rejected. According to this strategy simulation report, because of using buffer zone, total rejected baby number is decreased by 21 percent. Also, because of the equipment taken from SCU department, SCU equipment utilization is increased by 10 percent. But due to reduction in the number of patients rejected, the number of patients treated in system is increased, so the waiting time of patients using other department for their treatments is increased more than 2 times. However, waiting time for SCU baby in transfer process for the next department is increasing by 12 percent. With this strategy, improvement ensured for the number of baby rejected, but the utilization of buffer zone equipment is 0.41, so for more efficient use of buffer zone and because of the number of baby transferred baby is more than rejected baby, it is decided to create. In Table 5.9, 5.10 and 5.11; treatment times for ICU and SCU baby, occupancy-rejection for ICU and SCU baby ratios and treatment durations are given for Strategy II, respectively.

Table 5.9 : Indication of treatment time for ICU and SCU baby

	Average	Min	Max
ICU baby	15,1649	0	105,9691
SCU baby	7,2547	0	94,4675

Table 5.10 : Indication of occupancy ratio and rejection ratio for ICU and SCU baby

	Arrivals	Rejections	RR	OR
ICU baby	258	25	0,0969	0,6904
SCU baby	179	12	0,067	0,643
Total	437	37	0,0847	

Table 5.11 : Indication of treatment time ratio for ICU and SCU baby

	SCU days	ICU days	WT(hours)	TR
SCU->ICU	0,1753	11,8494	4,2072	0,9854
ICU->SCU	6,7347	0,0728	1,7422	0,9893

5.3.4 Arena Simulation Results for Strategy III

The objective of this strategy is decreasing waiting time for next level and by this way, the rate of equipment utilizations will be decreased and the number of baby rejections will be decreased partially. According to the simulation results, because of buffer zone using waiting time for ICU transfers decrease in proportion to 76 percent and waiting time for SCU transfers decrease in proportion to 24 percent. In spite of that, in SCU department waiting time and number of baby rejections since of given one incubator to buffer zone. While equipment utilizations almost same for ICU, it increases in the ratio of 7 percent for SCU. The buffer zone utilization is determined as 0.18. However rate of equipment utilization is low in buffer zone so, other strategies are performed. In Table 5.12, 5.13 and 5.14 treatment times for ICU and SCU baby, occupancy-rejection for ICU and SCU baby ratios and treatment durations are given for Strategy III, respectively.

Table 5.12 : Indication of treatment time for ICU and SCU baby

	Average	Min	Max
ICU baby	14,5606	0	109,3751
SCU baby	7,0155	0	90,69

Table 5.13 : Indication of occupancy ratio and rejection ratio for ICU and SCU baby

	Arrivals	Rejections	RR	OR
ICU baby	260	37	0,1423	0,6914
SCU baby	178	16	0,0899	0,6245
Total	438	53	0,121	

Table 5.14 : Indication of treatment time ratio for ICU and SCU baby

	SCU days	ICU days	WT(hours)	TR
SCU->ICU	0,0367	11,6535	0,8808	0,9969
ICU->SCU	6,7772	0,0241	0,5784	0,9965

5.3.5 Arena Simulation Results for Strategy IV

With this strategy, using two different buffer zones, it is intended to decrease the waiting of transferred baby. According to the simulation report, the utilization of SCU equipment increases by 4 percent and ICU equipment increases by 5 percent. Despite the increase of utilization, the number of baby rejection increases by 36 percent. Also the waiting time of baby transferred decrease because of using two different buffer zones. But the utilization of buffer zones' equipment utilizations is too low, SCU buffer zone equipment utilization is 0.11 and ICU buffer zone equipment utilization is 0.07. So, according to the current situation there is no improvement, because of current utilization of buffer zones' equipment and the number of baby rejected. In Table 5.15, 5.16 and 5.17 treatment times for ICU and SCU baby, occupancy-rejection for ICU and SCU baby ratios and treatment durations are given for Strategy IV, respectively.

Table 5.15 : Indication of treatment time for ICU and SCU baby

	Average	Min	Max
ICU baby	13,6166	0	126,84
SCU baby	7,0568	0	88,28

Table 5.16 : Indication of occupancy ratio and rejection ratio for ICU and SCU baby

	Arrivals	Rejections	RR	OR
ICU baby	259	50	0,1931	0,729
SCU baby	180	14	0,0778	0,6105
Total	439	64	0,1458	

Table 5.17 : Indication of treatment time ratio for ICU and SCU baby

	SCU days	ICU days	WT(hours)	TR
SCU->ICU	0,0248	11,6618	0,5952	0,9979
ICU->SCU	6,8289	0,0162	0,3888	0,9976

5.3.6 Summary of Arena Simulation Results

Table 5.18 summarizes all simulation results of the developed strategies and the current situation. According to Table 5.18, Strategy I can be accepted as a good suggestion in terms of the ratio of treatment results. But Strategy II is also a good alternative solution. Because it has the best minimum result for the number of baby rejection among all strategies. If incubator and nurse are accepted as unlimited resource in current situation then, system needs 15 incubators for ICU and 16 incubators for SCU department.

As a result, necessary actions are performed then; Strategy I and Strategy II are decided as two available solutions for current situation.

Table 5.18 : Comparison table for all strategies and current situation

	Current situation	Strategy I	Strategy II	Strategy III	Strategy IV
Average days					
ICU baby	14,6034	15,0615	15,1649	14,5606	13,6166
SCU baby	7,3454	7,1566	7,2547	7,0155	7,0568
Arrivals					
ICU baby	258	258	258	260	259
SCU baby	179	178	179	178	180
Total	437	436	437	438	439
Rejections					
ICU baby	36	29	25	37	50
SCU baby	11	14	12	16	14
Total	47	43	37	53	64
RR					
ICU baby	0,1395	0,1124	0,0969	0,1423	0,1931
SCU baby	0,0614	0,0787	0,067	0,0899	0,0778
Total	0,1075	0,0986	0,0847	0,121	0,1458
OR					
ICU baby	0,6947	0,6983	0,6904	0,6914	0,729
SCU baby	0,583	0,6251	0,643	0,6245	0,6105
SCU days					
SCU->ICU	0,1562	0,1084	0,1753	0,0367	0,0248
ICU->SCU	6,7904	6,7612	6,7347	6,7772	6,8289
ICU days					
SCU->ICU	11,4105	11,6041	11,8494	11,6535	11,6618
ICU->SCU	0,0318	0,0484	0,0728	0,0241	0,0162
WT(hours)					
SCU->ICU	3,7488	2,6016	4,2072	0,8808	0,5952
ICU->SCU	0,7632	1,1616	1,7422	0,5784	0,3888
TR					
SCU->ICU	0,9865	0,9907	0,9854	0,9969	0,9979
ICU->SCU	0,9953	0,9929	0,9893	0,9965	0,9976

6. CONCLUSION

In this thesis, a capacity planning study is applied into a third level neonatal unit. Infant mortality rate has an importance in future of country economics. Because, it affects the characteristics of population like as old population or young population. This property is significant in terms of country development policies. Therefore, investment to health sector plays important roles for the future policies and current conditions. Generally, the main causes of high neonatal mortality rates come from scarce capacity and/or inadequate capacity assignment problems. The major goal of this master thesis is to analyze capacity problems in a neonatal unit and develop solution proposals for these. Therefore, the basic equipments in the neonatal unit like incubator, expert nurse, doctor, monitor, ventilator, open bed, phototherapy machine and cooling machine are investigated to be planned efficiently to achieve better utilization. To develop the current situation in terms of baby rejections and equipment utilizations some basic statistical tests are made and some of them used in simulation model. In solution method, simulation is preferred for capacity planning because of complexity of problem. In simulation model some performance criteria are determined according to neonatal unit's scarce resources. Moreover, some statistical data analyses are made by using three years data. These statistical hypothesis tests are performed based on the collected data from the referenced neonatal unit. Two types of hypothesis tests are conducted: One compares two different types of statistics in each year. For instance, healthy girl ratio among all girls is compared with the healthy boy ratio among all boys in years 2008, 2009 and 2010. The other one compares the same statistic in different pair wise years. For instance, healthy girl ratio among all girls in 2008 is compared with the healthy girl ratio among all girls in 2009. Additionally, in simulation model, four solution suggestions are improved for current condition to minimize the number of rejections and waiting time. At the same time, it is aimed to maximize number of baby acceptance and equipment utilizations in solution suggestions.

The improvements in the study, has its own advantages and disadvantages situations. For example, Strategy I and II has minimum number of rejections. But their treatment ratio is lower than Strategy III and Strategy IV. Moreover, waiting time is high in

Strategy I and II while it is low in Strategy III and Strategy IV. Because, the occupancy ratio is lower in Strategy III and Strategy IV than Strategy I and Strategy II. Therefore, these four solution strategies can be preferred by different hospital management. But, generally common approach among hospital managements is to minimize rejection ratio. Since, Strategy II and Strategy I can be preferred by hospital managements.

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