CRITICAL NEWBORN TRANSPORT IN VENETO REGION: MODELS AND SIMULATION

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ABSTRACT
The paper studies the problems connected with the transport of critical newborns from their birth centre towards specialized assistance centres, where they can undergo suitable intensive cares. The scope is to analyze whether the employed resources are sufficient for a correct service course; in fact on one side the transport requires apt means and specifically trained personnel, on the other side the structures where critical newborns can be admitted and may receive intensive neonatal cares are few, shall be equipped with special instrumentation and require specialized staffs. Here a simulation model describing critical newborns transport in Veneto Region has been built up and has elaborated data collected in all birth centres. Simulation results revealed that resources of centres with neonatal intensive care units are often insufficient to satisfy all admission requests. The model, implemented in language MicroSaint, is easily extendable to other Italian or foreign regions presenting analogous situations.

Keywords: critical newborn, transportation, neonatal intensive care unit

1. INTRODUCTION

The paper is a part of an extended study, operated by Veneto Region in Italy, about the characters of pregnancy and birth course. The critical newborn transport is an integral component of this study.

Newborn transport is necessary whenever a critical newborn, which has been born in a non specialized birth centre, is in a severe condition and shall be urgently transferred in a centre which is able to supply high level cares.

An accurate bibliographic research pointed out that many papers have been written about the matter, see Cornette (2004), Das and Leuthner (2004), Fenton, Lesile and Skeoch (2004), Fowlie, Booth and Skeoch (2004), Lupton and Pendray (2004), Nicholson, Burr and Powell (2005), Rashid, Bhuta and Berry (1999), Wright (2000), but none of them have developed a model describing the critical newborn transport phoenomenon.

In this paper such a phoenomenon has been studied with simulation techniques. By the implemented model every request for a newborn transport, coming from a non specialized birth centre, is assigned to the nearest third level centre (able to supply neonatal intensive cares) which has resources at disposition. Obviously if the birth took place in a third level centre, then the admission request is assigned to the centre itself, if resources are at disposition. Model data have been obtained from regional data bases, in particular from "birth assistance papers" (CEDAP) and "hospital discharge papers" (SDO), related to newborn transfer requests and to births in third level centres. From model runs we were able to determine whether resources employed for critical newborn transport and admissions in third level centres are sufficient to satisfy all requests; we observed that third level centres have not sufficient resources at disposition to satisfy all admission requests.

The model was utilized related to Veneto Region situation in a given time interval, but it can be easily employed for other both Italian and foreign regions presenting similar problems.

The paper is organized as follows. First pregnancy-birth course is analyzed to evidence the causes of critical newborn birth. Then the newborn transport problem is treated in detail. Model data sources are considered and discussed. The model and its implementation is presented and accurately described. Eventually model results, related both to current situation and to possible changed situations to obtain a better service are examined.

2. PREGNANCY AND BIRTH COURSE

Pregnancy is the state of a woman who carries the product of conception; during pregnancy woman's organism undergoes many variations which are useful to assure the best condition for embryo installation, nutrition and growing. We may distinguish two types of pregnancy: physiological, which follows a natural course without complications, and pathological, with complications both for the mother and for the embryo (e.g., diabetes, malformations, infections, …). For what concerns birth, we may distinguish birth without complications, birth with expected complications (e.g.,

foetal-pelvic disproportion, placental deformity, etc.) and finally birth with non expected complications (e.g., foetal distress, haemorrage, premature birth, etc.).

On the basis of complications encountered during pregnancy and at the birth, newborns may be classified in three levels: first level concerns normal newborns, which need to get neonatal generic assistance; second level concerns newborns presenting light pathologies or mild prematureness, which need to get neonatal pathology assistance (incubator); third level concerns newborns requiring neonatal intensive care (ventilated incubator) by a specialized neonatal intensive care unit. Every birth centre is characterized by the assistance levels it can give: in most centres we have only the first level, in some specialized centres we have first and second level, in few highly specialized centres (called third level centres) we have all three levels.

Every pregnant woman is generally admitted to a birth centre where the assistance level is appropriate to the expected birth complications. Anyway sometimes newborn conditions may appear more severe than expected, so that the resources at disposition in the birth centre are not sufficient and an urgent transfer to a higher level centre is required.

3. CRITICAL NEWBORN TRANSPORT GENERAL CHARACTERISTICS

Initial cares supplied to a newborn represent one of the key factors which determine its survival; critical newborn transport is an integral part of such cares. The procedure starts when the birth hospital identifies the newborn emergency situation; the reasons which bring to decide the transport may be many, as follows (Fowlie, Booth and Skeoch 2004): unsuitable structures, insufficient medical staff, lack of places (full neonatal intensive care unit or specific care unit), unexpected birth far from home, transfer towards local structures. Obviously the structure where birth took place shall be able to supply at least base cares and a first stabilization while waiting for the transport team. Alerted transport team moves from its base towards the birth centre, carrying all transport equipment; once arrived at the birth centre it devotes a time interval, which may be up to one or two hours, to newborn stabilization, so to make it able to survive to the trip; then the transport takes place towards the nearest third level centre with admission resources at disposition; during the trip assistance is continuous; once arrived at the admission centre, the newborn is delivered to the centre team. If all places of arrival centre are busy at the arrival instant, the critical newborn is admitted in another department of the same hospital.

We may have two types of transport supply: "dedicated" and "on demand"; the dedicated service is made up of a specialized team using specialized means, whose only job is neonatal transport, with the advantages of timely response and continuous improvement of supplied cares; the on demand service is carried out by people usually engaged in other jobs and available for emergencies.

The transport team includes specially prepared personnel, trained to supply neonatal intensive cares under stress in difficult conditions, generally formed of medical doctors and nurses (of specialized nurses only in Canada and U.S.A.); the transport means may be different according to the distance and to the conditions of the place: the ambulance is generally apt for a maximum trip duration of 1.5 hours, the aircraft for long distances, over 350 km, and the helicopter for medium distances (with the advantage of overcoming obstacles and the disadvantage of reduced working space); the main transport equipment is an incubator with forced ventilation, provided of independent electrical supply, of all measurement sets and of all necessary gases, liquids and drugs. The transport shall generally be preceded by a suitable stabilization, operated by the transport team.

In Veneto Region births are about 45,000 per year, and take place in 41 birth centres, of which 8 are of third level: Padova with 10 places, Verona with 8, Treviso with 6, Vicenza, Camposanpiero and Rovigo with 4 places each, Mestre and Belluno with 2 places each. Two critical newborn transport services are working, in Padova and in Verona, each one serving a well defined part of the region. Every transport centre works on demand, and the team resources include: a special ambulance, with two serving persons, a complete incubator, a specialized neonatal doctor and a specialized nurse.

Every birth centre is equipped to supply assistance to the mother (gynaecologic-obstetric unit) and to the newborn (neonatology-paediatric unit), at one of three distinct assistance levels, corresponding to newborn possible pathologies, as seen above; every pregnant woman is generally admitted to a birth centre where the assistance level is appropriate to the expected birth complications, therefore the majority of critical newborns are born where they can be suitably assisted; anyway the 2-2.5% of newborns require a transport towards another centre because of: unforeseen risks, scarcity of places, necessity of special exams or of special treatments; a special transport is the return to the original birth centre once the acute phase is over (back transport).

4. DATA SOURCES

The Epidemiology and Community Medicine Unit manages a large amount of national and regional data concerning population health and health assistance.

The most interesting data for our work are contained in two papers, the CEDAP (birth assistance paper) and the SDO (hospital discharge paper). The CEDAP reports information about the parents, the pregnancy, the birth and the newborn. The SDO reports information about the patient, the hospital, the admission, the admission department (or departments), the disease and the cares supplied; it is emitted also for newborns. By use of suitable filters we have obtained: the number and the length of stay of third level newborns who have been born in the third level birth centres and have been

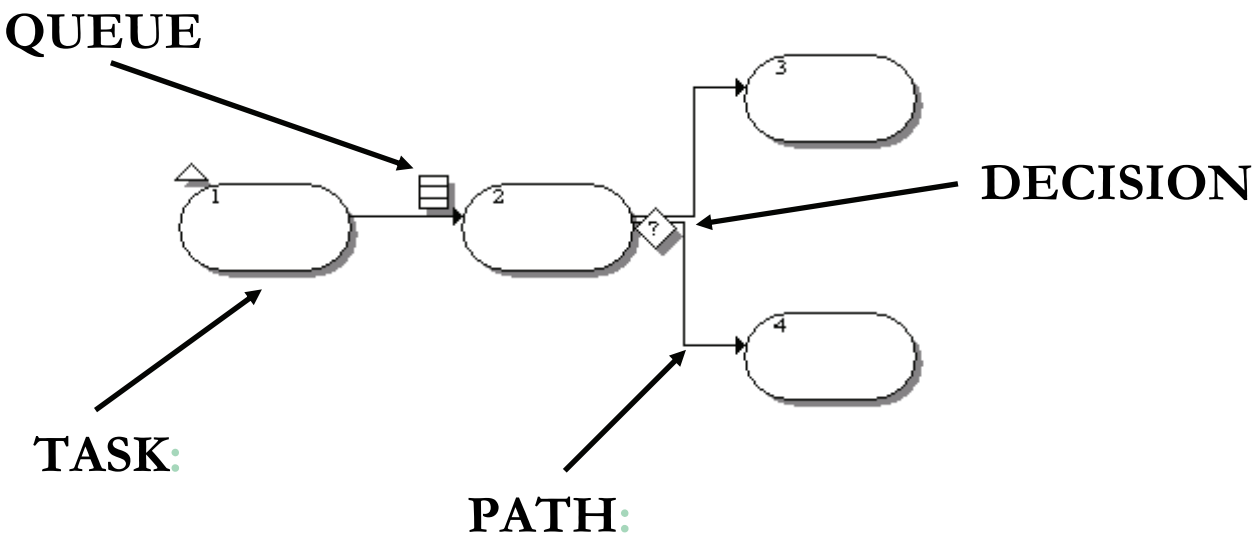

Fig. 1: Essential elements of graphic model representation by MicroSaint

admitted in the neonatal intensive care unit of the same centre; the number and the length of stay of newborns which have been transferred from other birth centres to third level centres (for which the day of discharge from the first centre is equal to the day of admission in the second centre). All above data are used to compute patient flows for transport and admissions.

From other orderly sources we could accurately compute motor car run times: between the two transport service bases and all birth centres; between all birth centres and all third level assistance centres; between all third level assistance centres and the transport service bases. Such run times are used to compute transportation times in the model.

5. THE MODEL

The model is devoted to analyse whether resources at disposition are sufficient for what concerns newborn transport and newborn admissions in the region. Therefore the model includes two main interacting parts: the first one concerns newborn transfers and the second one concerns newborn admissions. Newborn transfer considers the following actions: critical newborn generation in one of the birth centres of first or second level, wait for the transport team set up and trip, newborn stabilization in the birth centre, trip towards the closest third level centre with places at disposition, newborn admission in the third level centre and team return to the operation place. Newborn admissions in the third level centres considers the following actions: entry, both for local births and for arrivals after transport, stay and discharge: all these arrival-discharge pairs determine disposition of places for further admissions.

For model implementation we used the software package Micro Saint 3.2, a powerful and flexible instrument, which can be used both by simulation's experts and programmers and by less qualified users. Model implementation uses a graphic model representation where essential elements, shown in Fig. 1, are: ellipses ("tasks") representing activities (time running and/or variable computing), directed arcs ("paths") representing activity sequences, rhombs ("decisions") representing (multiple, probabilistic or deterministic) decisions and striped rectangles ("queues") representing queues.

The whole model graphic representation is reported in Fig. 2. There task 1 gives the start to the whole simulation and activates task 2 (birth activator), task 19 (transport requests to Padova service activator) and task 42 (transport request to Verona service activator). On its own task 19 activates twenty transport request generators (tasks 20 to 39), each one corresponding to a (first or second level) birth centre which is served by Padova service; as can be seen in Fig. 2 and 3, every generated request is processed by tasks 89 (call to Padova service), 40 (activation of Padova team), 41 (trip of Padova team from Padova to the birth centre), 58 (newborn stabilization), 67 (newborn transport) 60 to 66 plus 69 (newborn admission in one of the third level centre) and eventually 92 to 99 (come back to Padova); if all places in the arrival third level centre are busy, the newborn is admitted in another department of the same hospital (task 87). Correspondingly task 42 activates thirteen transport request generators (tasks 43 to 55), each one corresponding to a (first or second level) birth centre which is served by Verona service; as can be seen in Fig. 2 and 3, every generated request is processed by tasks 91 (call to Verona service), 56 (activation of Verona team), 57 (trip of Verona team from Verona to the birth centre), 59 (newborn stabilization), 68 (newborn transport) 60 to 66 plus 69 (newborn admission in one of the third level centre) and eventually 92 to 99 (come back to Verona); if all places in the arrival third level centre are busy, the newborn is admitted in another department of the same hospital (task 88). As can be seen in Fig. 2 and Fig. 4, on its own

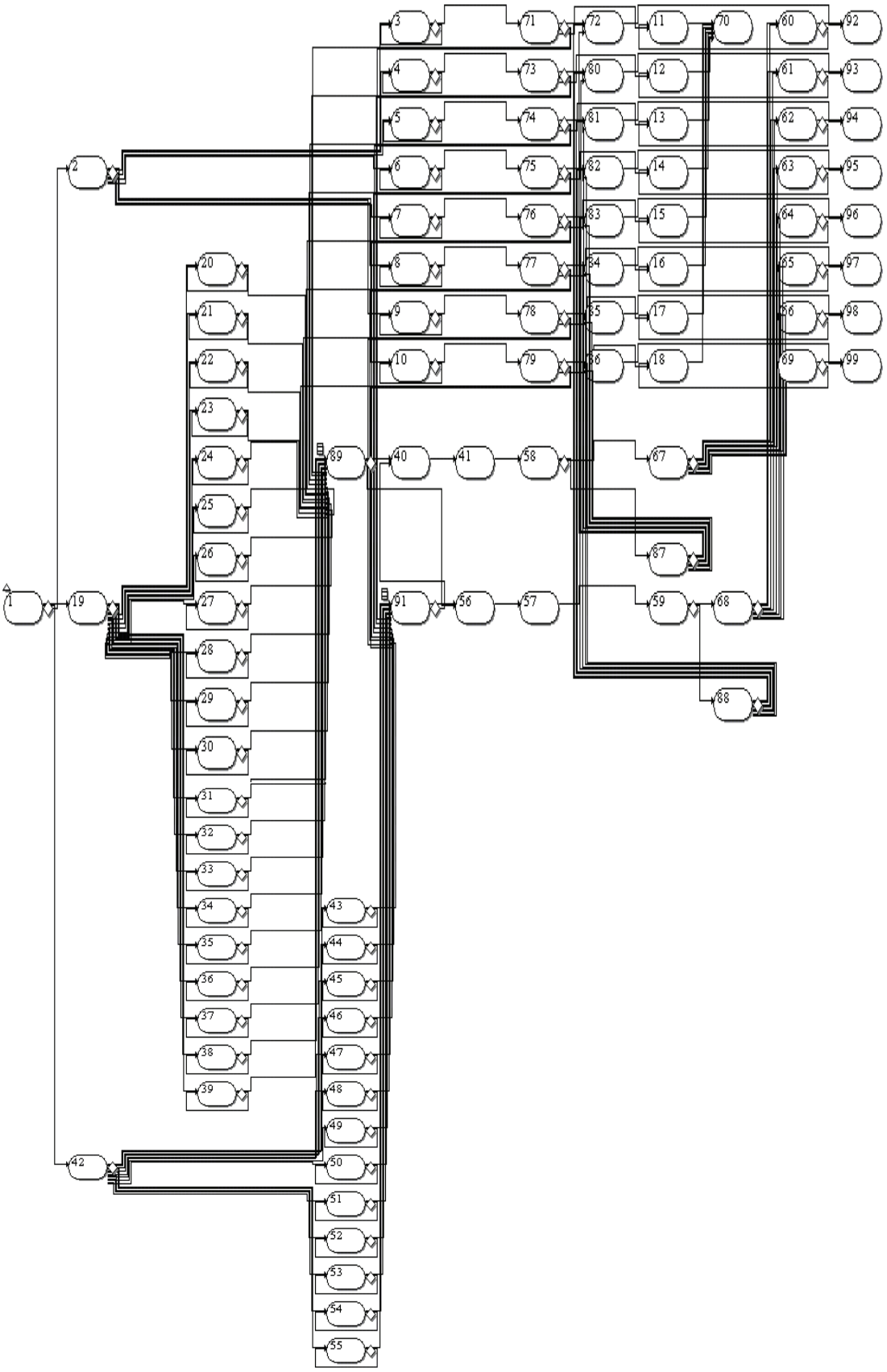

Fig.2 Whole model graphic representation

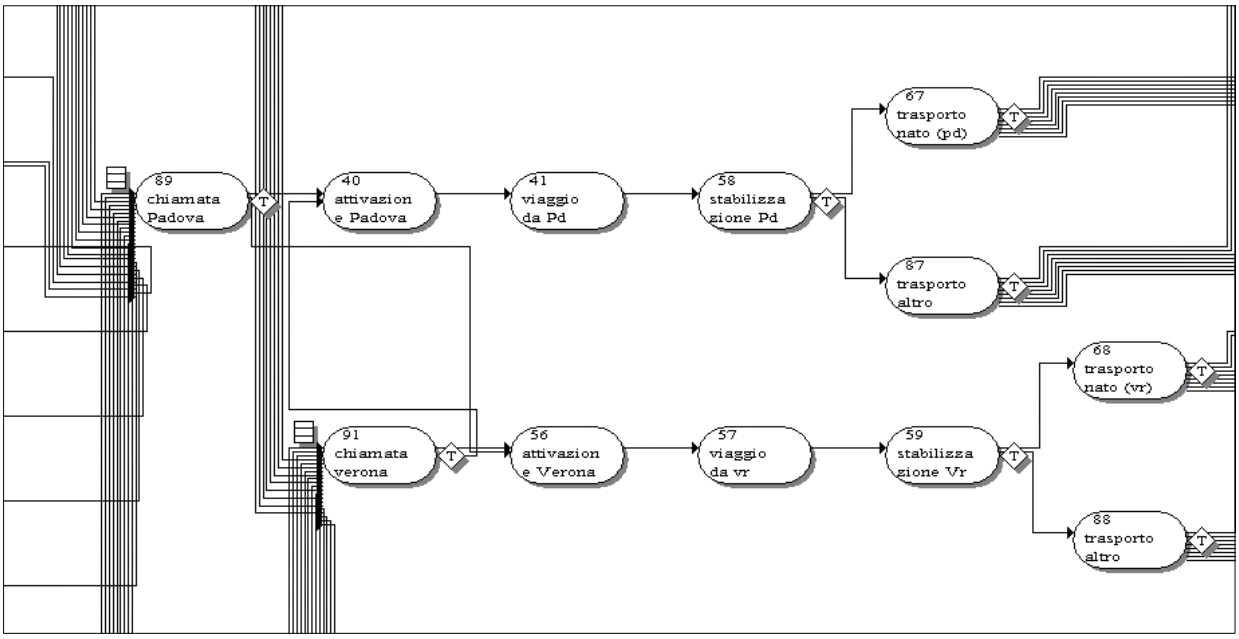

Fig.2: Graphic representation of critical newborn transport functions.

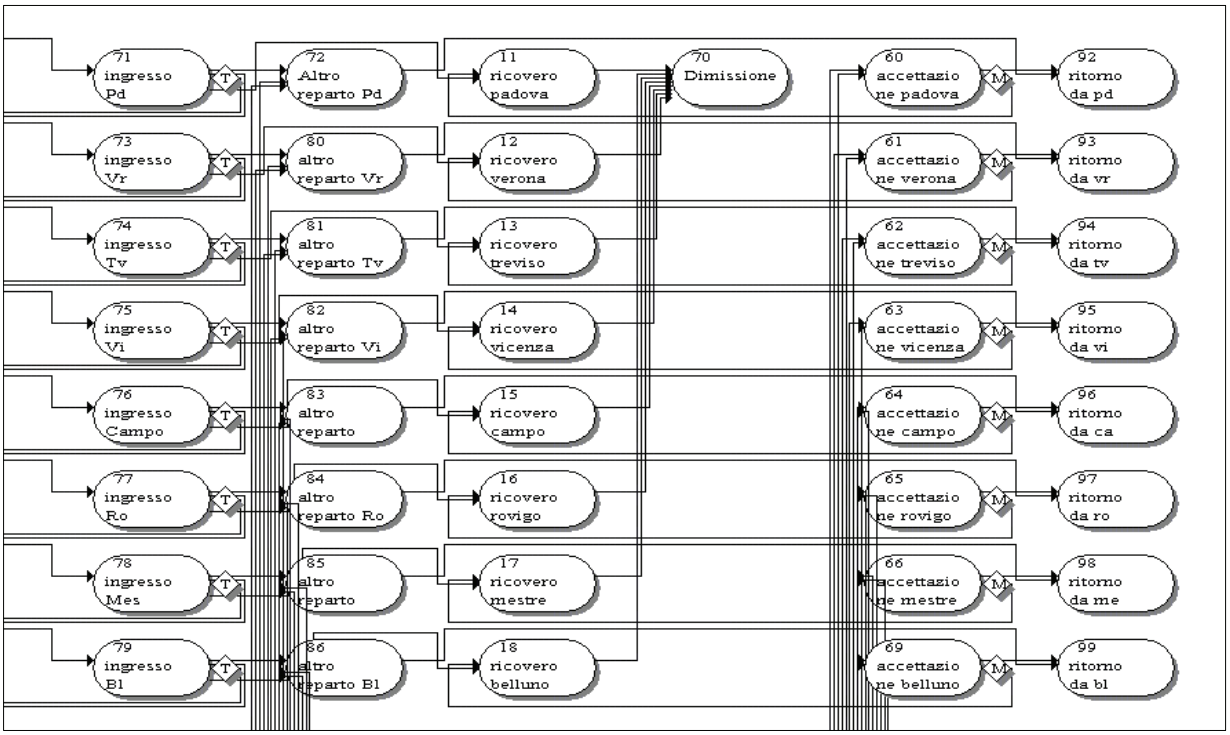

Fig. 3: Graphic representation of admission and discharge functions at the eight third level centres

task 2 activates all births which take place in the third level centres (tasks 3 to 10); such births are processed by tasks 71 plus 73 to 79 (entry in the corresponding third level centre) and 11 to 18 (admission in the centre); if all places are busy, they are admitted in another department of the same hospital (tasks 72 plus 80 to 86).

All times associated with tasks have been obtained from data sources considered in Section 4.

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6. ANALYSIS OF RESULTS

Main simulation results concern: mean transport teams utilization times, actual newborn transport time between call and admission in the third level arrival centre, queue analysis. Transport team utilization times vary between 4 and 5 hours for the Padova service and is about 6 hours for the Verona service, depending on the third level centre where the newborn is transferred; average actual newborn transport time is 4 and 5 hours respectively, where the difference is due to the fact that the city of Verona is comparatively less central in Veneto Region. For what concerns waiting times, a wait due to busy service is rare both for Padova and Verona, but it may rise up to 6 and 8 hours respectively.

An in-depth analysis about the two services results was carried out, and it concluded that they may be considered as satisfactory; what is not satisfactory is the amount of resources for critical newborn admissions. Two different modifications to be effected in the structures regarding critical newborns were suggested, and the respective consequences on the transport service examined by the model. The first suggestion was an increase in the number of neonatal intensive care places in three most required hospitals: the number of new places was 5, 2 in Padova, 1 in Verona and 2 in Vicenza, on a total of 40 current places in the whole region; the suggested place increase were obtained from the number of critical newborn admitted in hospital departments different from neonatal intensive care units; the modification result is a dramatic reduction of "irregular" admissions for all region third level centres; moreover we notice a soft reduction of actual transport time, and the cancellation of waiting times. The second suggestion was the institution of a second ambulance in Padova: for this case some light improvements were obtained in the reduction of waiting times.

7. CONCLUSIONS

A model of critical newborn transport in Veneto Region has been built up and implemented. The model was usefully employed to validate current service and to test the consequences of some possible structural modification; it may be employed to test new situation as for instance a sensible increase of the amount of critical newborns in next years; finally it may be employed to test different situations in different regions

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