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Federaal Kenniscentrum voor de Gezondheidszorg
Centre Fédéral d'Expertise des Soins de Santé
Belgian Health Care Knowledge Centre

ORGANISATION OF MATERNITY SERVICES IN BELGIUM

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- **The external experts were consulted about a (preliminary) version of the scientific report. Their comments were discussed during meetings. They did not co-author the scientific report and did not necessarily agree with its content.**
- **Subsequently, a (final) version was submitted to the validators. The validation of the report results from a consensus or a voting process between the validators. The validators did not co-author the scientific report and did not necessarily all three agree with its content.**
- **Finally, this report has been approved by common assent by the Executive Board.**
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LIST OF ABBREVIATIONS

ABBREVIATION	DEFINITION
ALOS	Average Length of Stay
AR	Labour room
APR-DRG	All Patient Refined-Diagnosis Related Group
BBC	Banker, Charnes and Cooper
BFM	Budget of Financial Means
CCR	Charnes, Cooper and Rhodes
CEpiP	Centre d’Epidémiologie Périnatale
CRS	Constant Returns to Scale
C-section	Caesarean delivery
DEA	Data Envelopment Analysis
DES	Discrete Event Simulation
DMU	Decision Making Unit
DRG	Diagnosis Related Group
DRS	Decreasing Returns to Scale
EEA	European Environment Agency
ECG	Electrocardiogram
EMPLODAY	Daily Registration of staff data
EMPLOPER	Periodical Registration of staff data
FOD – SPF	Federal Public Service Health, Food Chain Safety and Environment (‘Federale overheidsdienst Volksgezondheid, Veiligheid van de Voedselketen en Leefmilieu’/’Service public fédéral Santé publique, Sécurité de la Chaîne Alimentaire et Environnement’)
FPS	Federal Public Service
FTE	Full-Time Equivalent

GIS	Geographic Information System
HA	Harmony Effect
KCE	Belgian Healthcare Knowledge Centre
ICD-10-BE	International Classification of Diseases, Tenth Revision, Belgian modification
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
IRS	Increasing Returns to Scale
IQR	Interquartile Range
LE	Learning Effect
LOS	Length of Stay
LRAC	Long run average cost
MDC	Major Diagnostic Category
MIC	Maternal Intensive Care
MPSS	Most Productive Scale Size
MZG – RHM	Minimal Hospital Data (‘Minimale Ziekenhuis Gegevens’/’Résumé Hospitalier Minimum’)
NGI – IGN	National Geographical Institute (‘Nationaal Geografisch Instituut’/‘Institut Géographique National’)
NIC	Neonatal Intensive Care
OB	Delivery room
OCMW – CPAS	Public Centre for Social Welfare (‘Openbaar Centrum voor Maatschappelijk Welzijn’/‘Centre Public d’Action Sociale’)
PPF	Production Possibility Frontier
Q1	25th Percentile
Q2	Median
Q3	75th Percentile

QAT	Queueing Analytic Theory
RD	Royal Decree
RIZIV – INAMI	National Institute for Health and Disability Insurance (‘Rijksinstituut voor Ziekte- en Invaliditeitsverzekering’/’Institut National d’Assurance Maladie-Invalidité’)
ROM	Risk of Mortality
sd	Standard Deviation
SE	Scale Efficiency
SFA	Stochastic Frontier Analysis
SI	Size Effect
SPE	Studiecentrum Perinatale Epidemiologie
SOI	Severity of Illness
UK	United Kingdom
US	United States (of America)
VRS	Variable Returns to Scale

■ SCIENTIFIC REPORT

How to use this document?

This Scientific Report is not intended to be read as a stand-alone document, but as a complement to the Short Report of this study. It gives a detailed account of the methods and results of each of the scientific building blocks underpinning the messages rendered in the Short Report.

The discussion of the results, the conclusions and policy recommendations are to be found in the Short Report.

The Short Report is published as a separate document on our website. It can be accessed from the same referral page as the current document.

1 INTRODUCTION AND BACKGROUND

1.1 A rationalisation process of hospital services

In April 2015, the Federal minister of Social Affairs and Public Health (minister De Block) launched an 'Action Plan for a reform of the hospital payment system'[1] defining the 'healthcare landscape 2025' as a landscape with the following characteristics:

- Population needs should determine the hospital capacity planning (beds, equipment, care programmes, etc.).
- More collaboration initiatives between hospitals and between hospitals and other care settings are needed.
- Hospitals/hospital services (including expensive equipment and infrastructure) should be part of a network. Payments and the permission to perform certain activities should (increasingly) be granted to networks instead of to individual hospitals.
- More task division between hospitals is needed.

One of the objectives of the reform plans in the Action Plan is the long-term affordability of healthcare. An important spearhead to realise this objective is the rationalisation of hospital activities. Possible measures are a division of tasks between hospitals, a reduction in the number of hospital stays and a shorter length of stay or a reduction of capacity (beds, units). Loco-regional clinical networks are considered to be a vehicle for this rationalisation process. The basic principles of the Action Plan were given concrete shape in the Act of 28 February 2019,[2] amending some provisions of the Hospital Act of 10 July 2008 and entering into force no later than 1 January 2020 (see Box 1 for the definition of a loco-regional clinical network and of a care assignment in the Act of 28 February 2019).

Box 1 – Core elements of the Act of 28 February 2019 on hospital networks

Loco-regional clinical network

- A maximum of 25 loco-regional clinical hospital networks will be established for the country (with a maximum of 13 networks in het Flemish Region, 8 in the Walloon Region and 4 in the Brussels Capital Region).
- Each general hospital is obliged to join one and only one such network.
- Collaboration is within a contiguous geographic area (except in large cities) and hospitals in the network must offer care assignments that are complementary to each other.

Care assignments

- A distinction is made between loco-regional and supraregional care assignments. A care assignment includes all activities of hospitals related to a hospital service, a hospital function, a hospital department, a heavy medical device, a medical service, a medical-technical service or a care programme. Loco-regional care assignments must be provided within each loco-regional network while supraregional care assignments may not be offered within each loco-regional network.
- Regarding the activities that can be offered within each loco-regional network, the Act of 28 February 2019 makes a distinction between general and specialised care assignments. The difference between both types is that general care assignments can be provided in each hospital of the loco-regional network while specialised care assignments only in a limited number of hospitals within the network.
- Patients have free choice of provider.

Source: Act of 28 February 2019[2]

Although there is no exhaustive or commonly accepted list of criteria (or weights for these criteria) to classify hospital activities in terms of where they should be provided (close to the patient or more centralised), the following criteria emerge from the literature and practice abroad:[3]

- Interventions for time-critical conditions
- Capital intensity (expensive equipment or infrastructure)
- Size and composition of the target population
- Degree of specialisation/complexity
- Available workforce
- Frequency of the intervention (per patient).

The present report focuses on the organisation of maternity services in Belgium. In policy documents such as the Action Plan and other documents that operationalise the reform plans of the minister, maternity services are considered to be specialised care assignments.[4] In the Act of 28 February 2019 it is stipulated in Article 8 that the distinction between loco-regional and supraregional, and between general and specialised care assignments can be made by Royal Decree. At this moment (December 2019) no decision has been taken on the classification into general and specialised care assignments.

1.2 A high density of maternity services with a large variability in caseload and low occupancy rates

In 2017, KCE published a report (Report 289) on the required hospital capacity in 2025, at the macro level as well as for a selection of care assignments.[3] The report was commissioned by minister De Block and fits in the reform plans of the hospital sector – more specifically in the capacity planning and programming part of the reform.

KCE Report 289 (Chapter 8) includes a detailed description of the organisation, capacity and activity profile of maternity services in Belgium for the year 2014. A summary of the main results for general maternity services can be found in Box 2 (a detailed evaluation of 'maternal intensive care' departments (with MIC-beds) and specific care for high-risk pregnancies was out of scope).

Box 2 – Main results for the organisation of maternity services in KCE Report 289 (2017)

- A **high density of maternity services** but regional differences in size.
- A **larger share of maternity or M-beds in small hospitals**.
- A **large variability in caseload** between services. The median number of deliveries per hospital site was 897 which roughly corresponds to 2.5 deliveries per day. However, there was a large variability in caseload between hospital sites (from 212 deliveries/year or 0.6 deliveries/day to a maximum of 3 333 per year or 9.1 per day) and between regions (median of 2 236 deliveries per year in Brussels, 864.5 in Wallonia and 800 in Flanders).
- **Low occupancy rates**, except in Brussels. The national average occupancy level of the capacity of licensed M-beds was below 50%. The rate fluctuated between 39.9% and 58.3% over the course of a year, which is far below the normative occupancy rate of 70%. The annual average occupancy rate of maternity services in Brussels (69.33%) was much higher compared to Flanders (45.1%) and Wallonia (48.0%). Average occupancy rates did not only fluctuate between hospitals but also hide peaks in activity on specific days. In 2014, average occupancy rates ranged from nearly 0% to 150%. However, for most maternity services, the number of days with occupancy rates above 95% was limited. The situation in Brussels was different: 4 out of 11 sites had more than 30 peak days in 2014.
- **Reduction in length of stay will further decrease occupancy rates**. In KCE Report 289 the required hospital capacity for maternity services was assessed for 2014 and 2025. Taking account of a normative bed occupancy rate of 70%, overcapacity (in terms of the number of licensed beds) was estimated to be 631 beds (or almost 20% of the current 3 176 M-beds) in 2014 and 1 063 in 2025.

Source: Van de Voorde et al. (2017)[3]

1.3 An international trend of less and larger maternity services

As was shown in KCE Report 289, rationalisation efforts of maternity services abroad tried to balance the societal goals of efficiency (concentrating maternity care and closing small services) and accessibility for patients.

One of the main drivers of reforms abroad (selected countries in KCE Report 289 were England, France and Sweden) are economies of scale, which means that hospital costs are lower when the size, measured in terms of the number of deliveries, is larger (see also section 4.1.2). Although the literature on economies of scale for maternity services does not define a universal minimal number of deliveries per maternity service, when studies do report a minimum efficient scale (see section 4.4.2) it is set consistently above the Belgian median number of deliveries (i.e. 897 deliveries per year in 2014). This is not surprising given that maternity services have important fixed costs (e.g. 24h/7d availability of staff for the maternity service, for the labour & delivery room and the neonatal care department). Unless entire units or departments are closed, decreasing the number of maternity beds is likely insufficient to lead to budgetary savings. Moreover, larger staffing pools in larger maternity services can improve operational flexibility (e.g. midwifes allocated to the maternity unit can help in the delivery room at peak moments).

In the three selected countries in Report 289, efficiency arguments for closing maternity services are weighted against accessibility in terms of travel time. In the literature no clear indications are found for a relation between travel time to a maternity service and for example infant mortality, but in practice countries aim for a reasonable travel time or travel distance. In France and England a travel time of less than 30 minutes is aimed for but this threshold was not met in France for 22.7% of the deliveries (2012). In England 8% of the women of childbearing age have no obstetric unit within a 30 minute drive. In Sweden travel distance is much longer and can be up to more than 65 or even 100 km to reach the closest maternity service.[3]

1.4 Scope and aim of the current report

Recommendations of KCE Report 289

On the basis of the results for Belgium and evolutions abroad, it was recommended to adapt (periodically) programming standards for M-beds. However, as is the case in other countries, rationalisation efforts could go further than just reducing the number of M-beds and capacity reduction could also envisage a reduction in the number of maternity services, resulting in a larger number of deliveries per maternity service. Limiting the capacity reduction to only a reduction in the number of M-beds will not result in large budgetary gains for public authorities or hospitals. Instead, cost containment and efficiency gains are to be expected from closing maternity services with low activity levels. Therefore, in addition to the recommendation to adapt programming standards for M-beds, KCE Report 289 also recommended further research to evaluate the efficiency of Belgian maternity services: “Increasing the minimum standard of 400 deliveries per maternity service seems, based on literature and international practice, necessary to achieve economies of scale. To determine a specific threshold research into the relationship between the number of deliveries and (staff) costs should be set up.”

Aim and research questions of the report

The ultimate goal of the current report, which can be considered as a follow-up study to KCE Report 289 (Chapter 8), is to **provide recommendations on the organisation and capacity of maternity services in Belgian hospitals in terms of the number, size and geographical distribution**.

The general aim of the report can be detailed into the following **research questions**:

- Is the size of a maternity service, measured in terms of activity such as the number of deliveries, related to its efficiency?
- Which geographical distribution of maternity services across the Belgian territory guarantees access within a specified time limit?
- How many maternity beds are needed given the trade-off between an efficient use of scarce resources and the needed timely access to appropriate care?

We first update (some of) the analyses that were performed in KCE Report 289 on the organisation and activity levels in Belgian maternity services. This makes it possible to be coherent in the number of hospitals, beds, deliveries, etc. throughout this report. In Belgium there are two levels of maternity services: the general maternity services and the ‘maternal intensive care (MIC)’ departments (with MIC-beds). The terminology ‘maternal intensive care’ is, however, confusing since it does not concern ‘intensive care’ but the ‘intensive monitoring’ of high-risk pregnancies. Therefore, it would be better to use ‘maternal intermediate care’ instead. In this report the focus is on maternity services in general, the evaluation of MIC-beds and specific care for high-risk pregnancies are out of scope. Because in the efficiency analysis the scope is extended to neonatal care services, we also briefly describe the organisation and activity performed at these services.

1.5 Methods

The study applies several research methods. The main steps of the research are summarised in Table 1.

Table 1 – Research questions and methods

Research questions (what)	Method (how)	Chapter
What is the capacity of maternity services (2016)? Capacity is expressed as: • **the number of hospitals and hospital sites** • **the number of beds**	• Analysis of administrative database: Minimal Hospital Data (MZG – RHM)	Chapter 2
What is the activity level of maternity and neonatal care services (2016)?	• Analysis of administrative database: Minimal Hospital Data (MZG – RHM)	Chapter 3
Is the size of maternity services in Belgian hospitals, measured in terms of activity, such as the number of deliveries, related to their efficiency?	• Data Envelopment Analysis (DEA)	Chapter 4
Which geographical distribution of maternity services across the Belgian territory guarantees timely access?	• Spatial analysis based on Geographic Information Systems (GIS)	Chapter 5
How many beds are needed given the trade-off between an efficient use of scarce resources and the needed timely access to appropriate care?	• Simulation model based on queueing theory	Chapter 6
Scientific validation	• Review of this report by three independent scientific experts	/

Relation between the chapters

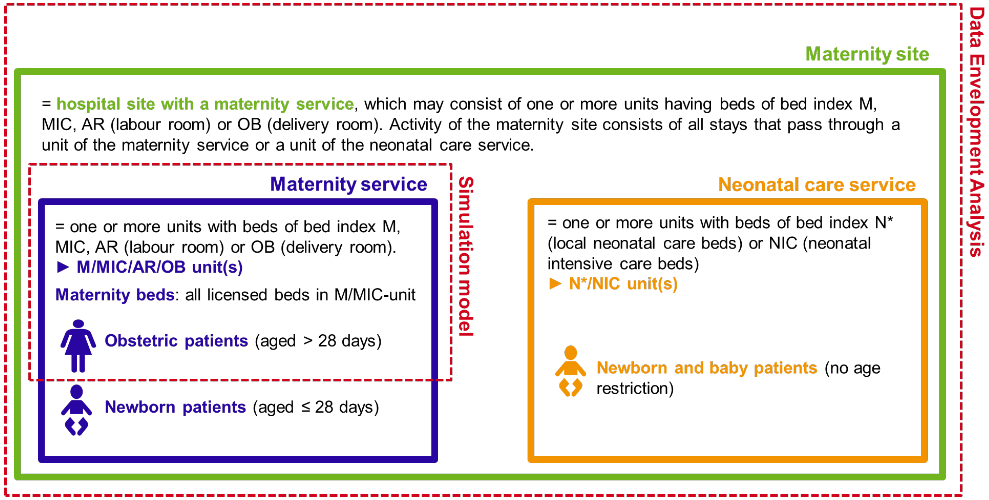
As was mentioned in section 1.3, one of the main drivers of maternity service reform and reconfiguration abroad are economies of scale. The current international trend goes towards a rationalisation and concentration of maternity care, and closing small maternity services. Indeed, larger units are often considered to have lower average costs and be more efficient than smaller units because of economies of scale. The findings of the efficiency analysis (DEA analysis) in Chapter 4 will provide insight to what extent the scale or size (measured in terms of activity, for example the number of deliveries) of Belgian maternity services has an impact on their efficiency.

If it is the case that maternity services with activity levels below some threshold size are less efficient than maternity services with a larger number of deliveries, efficiency could be increased by concentrating maternity care to a smaller number of hospital sites. However, the location of maternity services and the spatial distribution are key determinants to guarantee timely geographic access to these services. Geographic accessibility is calculated as the number of people in the target group (i.e. women of childbearing age) residing more than a specified number of minutes from an acute care hospital site with a maternity service. To this end, Geographic Information Systems (GIS) will be used that allow an in-depth analysis of the current situation and of improved resource allocation.

In the simulation model, based on queueing theory, two objectives of each healthcare system are combined, namely efficiency and accessibility. The model estimates the number of maternity beds that are needed to cope with variability in demand for care and to avoid waiting times. A second objective of the model is to assess the impact of the DEA and GIS analysis. More specifically, if a concentration of maternity services would lead to efficiency gains (DEA analysis) without affecting timely access (GIS analysis), the simulation model allows to assess whether the capacity in the remaining maternity services is sufficient to accommodate the additional activity.

In Figure 1 a schematic overview is given of the concepts as used in the respective chapters. Although in Chapter 2 the legal requirements of and interdependencies between maternity and neonatal care services are described, in the data used for the activity levels, the efficiency (DEA) analysis and the simulation model some choices had to be made to define for example a maternity or neonatal care service, and this is represented by the concepts in Figure 1.

Figure 1 – Definition of concepts



Data sources

The analyses in Chapters 2-4 and in Chapter 6 are based on the Minimal Hospital Data (MZG – RHM) (see Box 3) for 2016. Given the different selection of observations and variables in these chapters, a detailed description of the selection is provided in the respective chapters of this report. The spatial analysis in Chapter 5 is based on the results of the previous chapters and on population statistics of Statistics Belgium (Federal Public Service Economy).

The unit of analysis in this report is a hospital site with a maternity service. One hospital can have more than one site with a maternity service. Each maternity service consists of one or more units (‘verpleegeenheid’/ ’unité de soins’). However, no analyses will be performed at the unit level.

Box 3 – Minimal Hospital Data

Since 1991, all general hospitals have to submit twice a year a large set of data on all inpatient and day-care hospital stays and emergency room contacts. These data, called the Minimal Hospital Data (MZG – RHM), are transferred to the Federal Public Service (FPS) for Health, Food Chain Safety and Environment.

The MZG – RHM contains the following variables for each stay[a]: hospital information (identification of the hospital, identification of the site, number of beds per bed type in each unit), stay information (such as patient characteristics, length and type of stay, involved nursing units and time of admission in each unit); patient medical information (diagnoses and procedures coded in ICD-10-BE); and information on the patient pathology group (APR-DRG and severity of illness – see Box 5).

2 ORGANISATION OF MATERNITY AND NEONATAL CARE SERVICES IN BELGIUM

In KCE Report 289 (2017)[3] an extensive description can be found of the legislation and organisation of maternity services in Belgium. Since this legislation and organisation did not change between 2017 and 2019, we refer the interested reader to Chapter 8 in Report 289. In the current chapter we briefly repeat the main characteristics that are necessary to understand the updated tables and figures in Chapter 1 and the analyses in Chapters 4 and 6. Although an evaluation of MIC-beds and specific care for high-risk pregnancies is out of scope, we sometimes present results for maternity services with and without MIC-beds separately. Except stated otherwise M-beds refer globally to maternity services, that is both beds in the general maternity service and beds in the MIC-department (although in reality the general maternity service and MIC-department can be integrated). Beds in the delivery or labour room are not analysed.

In Chapter 4 an efficiency analysis is conducted, relating activity to the deployment of (nursing) staff. However, the number and working hours of staff cannot unambiguously be assigned to a maternity service versus a service for neonatal care for every hospital site (mainly because of differences in data registration between hospital sites). Therefore, the efficiency analysis includes the maternity service as well as neonatal care services, which are briefly described in the current chapter.

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a A detailed description including a list of datasets and variables is available from https://www.health.belgium.be/nl/gezondheid/organisatie-van-de-0gezondheidszorg/ziekenhuizen/registratiesystemen/mzg/https://www.health.belgium.be/fr/sante/organisation-des-soins-de-sante/hopitaux/systemes-denregistrement/rhm.

2.1 The system of perinatal hospital care in Belgium

Hospital care in general is organised in services, functions, departments and care programmes (see Box 4). Services, functions, departments and care programmes that are relevant for this study are listed in Table 2. There is no care programme specific to perinatal care. There is, however, a care programme for children, but newborns in a maternity service, a neonatal intensive care (NIC-) service or local neonatal care function (N*-) function are excluded. Table 2**Error! Reference source not found.** also includes the paediatric (E-) service. The organisation of the paediatric service as well as the care programme for children are, however, out of scope of the current report but will be studied in a future KCE Report to be published in 2020.

Box 4 – Organisation of hospital care activity

Hospital service: each hospital includes several services of care (maternity, surgery, paediatrics, etc.). Beds in these services are identified by an index (letter(s) possibly followed by a number).

The notion of **hospital department** (‘*afdeling*’ / ‘*section*’) is not properly defined in the law, but in general a department is part of a service.

A **hospital function** aims to provide transversal care across services and departments.

A **care programme** is designed as an organisational framework allowing to implement clinical pathways.

Source: Crommelynck et al. (2013)[5]

Table 2 – Hospital services, functions, departments and care programmes for perinatal care

Type	Name	Index	Programming standard	Minimum number of beds
Hospital service	Maternity	M	32 M-beds for 1 000 births[1]	
Hospital service	Neonatal intensive care	NIC (N)	6 NIC-beds for 1 000 births[1]	15[2]
Hospital service	Paediatric	E	37 E-beds for 1 000 births[1]	15[3]
Hospital department	Maternal intensive care	MIC		8[4]
Hospital function	Local neonatal care	N*		
Hospital function	Regional perinatal care	P*		
Programme of care	Programme of care for children			

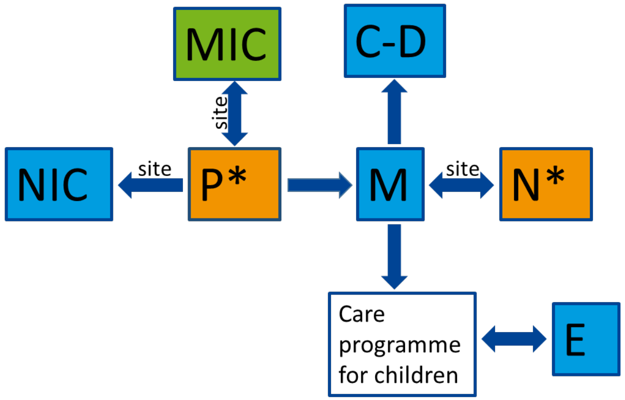
[1] Royal Decree (RD) of 21 March 1977[6]; [2] RD of 20 August 1996[7]; [3] RD of 21 January 1998[8]; [4] RD of 20 August 1996[9].

Interdependence between maternity and other services

The interdependence between maternity and other services, as visualized in Figure 2, is regulated in several Royal Decrees. In particular, the maternity service must belong to a hospital that includes:

- at least a service where surgery and internal medicine are practiced (services C and D) (RD of 21 January 1998, art. 3)[8]
- a licensed neonatal care function (N*-function) (RD of 20 August 1996, art. 1)[10]
- a licensed care programme for children (RD of 2 April 2014, art. 1)[11].

Figure 2 – Interdependencies between maternity and other services in Belgian law



Note: Hospital services are depicted in blue, hospital functions in orange and hospital departments in green. Each arrow stands for '… belongs to a hospital that also includes…'; for instance, a maternity service must belong to a hospital that also includes a surgery and internal medicine department. If the concerned services must be co-located on the same site, it is mentioned above the arrow. Except otherwise stated, the requirements are defined at the hospital level.
Although the N-function is required for each hospital with a maternity service, the N*-unit must be located within or adjacent to the maternity service, which explains the 'site' above the arrow (see section 2.2.3).*
The Royal Decree regulating the care programme for children was annulled in December 2016. Care for children is therefore organised by a previous RD (13 July 2006)[12]. Under this RD, each care programme for children must have at least 15 paediatric or E-beds, making the above link between paediatric service (E) and care programme for children bidirectional.
Source: art 2 of RD of 30 January 1989[13], art 1 and 20 of RD of 20 August 1996[10], art N5 and art N6 of RD of 23 October 1964[14] and RD of 20 August 1996[9]

Reference centres for high-risk pregnancies and neonatal care

The regional perinatal care function (P*-function, see Figure 2) consists of a licensed department for high-risk pregnancies (MIC-department) and a licensed service of neonatal intensive care (NIC-service), on the same hospital site (see also section 2.2). Hospitals with a P*-function act as a reference centre that has to make collaboration agreements with hospitals with an M/N*-function. Together, these hospitals must have at least 5 000 deliveries per year (RD of 20 August 1996, art 6).[9]

2.2 Legislation: programming and licensing standards

The services, functions and departments related to perinatal care are subject to programming standards (determined by the federal authorities) and licencing standards (since the 6th State reform determined by the federated authorities). In general, programming standards take the form of targets which are based on the size, age structure, and morbidity of the population as well as on the geographical dispersion. Licensing standards concern architectonic, functional and organisational (mainly related to staff) standards that hospitals, departments, functions, services, care programmes, etc. have to comply with to be licensed.

2.2.1 Programming standards

Programming standards apply to maternity services and neonatal intensive care (NIC-) services (see Table 2**Error! Reference source not found.**). There are no programming standards for maternal intensive care (MIC-) departments nor for the local neonatal care (N*-) function or regional perinatal care (P*-) function.

Maternity service

The national programming standard, as determined by the RD of 21 March 1977,[6] is 32 M-beds per 1 000 births.

Neonatal intensive care service

The national programming standard, also determined by the RD of 21 March 1997,[6] is 6 NIC[b]-beds per 1 000 births.

2.2.2 Minimum activity standards

Minimum activity requirements are defined for maternity services and for neonatal intensive care services. These requirements apply to each hospital site with a maternity service.[15]

Minimum activity at maternity services is set at 400 deliveries per year

The annual number of deliveries in a maternity service must be at least 400 on average during three consecutive years (RD of 30 January 1989, art. 17).[13] It is possible to deviate from these minimum standards in the following cases (RD of 30 January 1989, art. 18 and RD of 21 January 1998, art. 16):[8, 13]

- in the area where the service is established, the closest similar service is located at a distance of at least 25 km;
- the service is established in a municipality of at least 20 000 inhabitants where the closest similar service is located at a distance of at least 15 km;
- the closest maternity service in the same Community ('*Gemeenschap*' / '*Communauté*') is located at a distance of at least 50 km.

Activity standards for NIC-services

A NIC-service has to fulfil at least three of the following activity standards:[7]

- at least 50 newborns with a birthweight of less than 1 500 grams are admitted annually;
- at least 20% of the admissions per year relate to intra- or extra-uterine transfers;
- each year newborns who need intensive care from at least 5 000 deliveries are treated through collaboration agreements with M-services and N*- functions;
- each year at least 50% of the intra- or extra-uterine transferred NIC-patients are referred back to the referring institution.

2.2.3 Architectonic and functional licensing standards

Specific licencing standards relate to buildings, functioning and staff (see section 2.2.4 for staff-related licensing standards). These are defined in the RD of 23 October 1964 and further modifications for maternity services (article N5) and neonatal intensive care services (article N8).[14] Licensing standards for the regional perinatal care function or P*-function and MIC-department are defined in the RD of 20 August 1996.[9] Another RD of 20 August 1996 contains the licensing standards for the local neonatal care or N*-function.[10] The maternity service in university hospitals has to meet specific architectonic and functional licensing standards (see appendix 3 of the RD of 15 December 1978).[16]

Maternity service

Architectonic standards: Maternity services consist exclusively of one- or two-person bed rooms (no common rooms) and a sufficient number of one-person rooms must be available. A maternity service comprises at least one unit of care. Per unit of care (or for two contiguous units), the following premises must be available: a room for midwifes, a room for examination and treatment, a room for nurses, a room for doctors, a room for care material, a room for laundry, a room for storage, a kitchen (even if a central kitchen exists), a living room, a bathroom, a storage space for staff

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[b] In the RD of 21 March 1977 NIC-beds are called N-beds. The notation changed on 1 January 1997 by the RD of 20 August 1996.

belongings, separate toilets for staff and visitors, and a space dedicated to learning, group discussion and conversation.

In university hospitals a unit must have at least 20 beds.

Functional standards: A maternity service is part of a hospital with a licenced care programme for children and a licensed function for local neonatal care (N* function – see further).

The maternity service must have a milk kitchen (including two separate rooms, one for cleaning, and the other for preparation of baby bottles) and a delivery department. The latter consists of at least two delivery rooms, a labour room (where deliveries could take place in case of need) and several additional rooms for patients and staff. The area must be sufficiently equipped, according to the state of science, to guaranty the safety of the mother and her child.

Maternal intensive care department

A MIC-department is a department of a licensed maternity service for the intensive observation of high-risk pregnancies; for patients who require highly-specialised postpartum care; and for patients for whom there is strong suspicion that intensive neonatal care will be needed after delivery.

Architectonic standards: The MIC-department is integrated in a maternity service and has at least 8 beds.

Functional standards: No functional standards are defined.

Local neonatal care function and unit

Every hospital with a maternity service must also have an N*-function. Each N*-function is responsible for providing normal neonatal care in the room of the mother. Moreover, every N*-function must have an N*-unit, which is exclusively meant for the supervision, treatment and care of newborns with specific adjustment problems that require specialised, non-intensive, neonatal care.

Architectonic standards: The N*-unit is located within or adjacent to a licensed maternity service. There must be sufficient places (incubators and other facilities) also at peak times, with the necessary space around each place to allow parents and caregivers having direct contact with the newborn; and facilities necessary to apply hygiene rules.

Functional standards: These standards relate to the necessary equipment and guidelines for the treatment of and care for (premature) newborns in an N*-unit. For an exhaustive overview of the functional licensing standards, we refer to the RD of 20 August 1996 (Chapter IV, section 3).

Neonatal intensive care service

A NIC-service is exclusively intended for newborns who are in life-threatening or with special disease conditions. If the function of local neonatal care (N*-function) is integrated in the NIC-service, both must be clearly distinguishable from each other and intensive care must be reserved for the licensed NIC-beds.

Architectonic standards: A NIC-service must have at least 15 beds and contains the following premises, which as a whole are clearly distinguishable: facilities necessary to apply hygiene rules, one or more rooms intended for intensive care and a room with two insulation sections. Other, more technical premises that must be available are: a room for examination, a room for doctors, a room for the nursing staff, two laundry rooms and a milk kitchen. The milk kitchen has to fulfil the same conditions as the milk kitchen in the maternity service and can be shared with the maternity service. The technical premises can be located outside the NIC-service.

Functional standards: These standards relate to the necessary equipment for resuscitation, for administering parental nutrition or for performing minor surgery; to regulations concerning the patient’s medical file and perinatal registration; to transport by ambulance; and the organisation of follow-up of high-risk newborns. For an exhaustive overview of the functional licensing standards of a NIC-service, we refer to the RD of 23 October 1964 (article N8, III).

Function of regional perinatal care

A P*-function consists of a licensed MIC-department and a licensed NIC-service (at least four standards of article N8, point III of the RD of 23 October 1964 should be satisfied). A hospital with a MIC-department must have a P*-function. In addition, a P*-function can only be established in a hospital that has the following services or equipment: a genetic consult; a radiology service; a laboratory (24h/7d); a unit for prenatal monitoring and diagnosis (24h/7d for a list of investigations); a social service. The hospital must also have the following functions: cardiovascular diseases; pulmonology; nephrology; ophthalmology; pathological anatomy; neurology. Finally, the hospital or the hospital group to which the hospital belongs, must have an emergency department and an intensive care unit.

Architectonic standards: The NIC-service and the MIC-department are located at the same hospital site.

Functional standards: No functional standards are defined.

2.2.4 Licensing standards for staff numbers and qualifications

General licensing standards for nursing staff are defined in the RD of 23 October 1964 (article N1, III, 12°).[14] For all nursing units, the following general licensing standards for nursing staff are required:

- One nursing unit manager (or head nurse/head midwife) for each nursing unit: the nursing unit manager holds a bachelor degree in nursing or midwifery and received a supplementary management education in nursing, or a supplementary education at university level concerning the management of nurses, or a master of science in nursing and midwifery, a master of science in healthcare management, or a master of science in health education and health promotion.
- In order to assure continuity and quality of care, one nurse (diploma or bachelor in nursing or midwifery) on top of the nursing unit manager should be available at all times per nursing unit and per 30 patients.

Specific licencing standards for staff are defined in the RD of 23 October 1964 and further modifications for maternity services (article N5) and neonatal intensive care services (article N8);[14] in the RD of 20 August 1996 for the regional perinatal care function or P*-function and MIC-department;[9] and in another RD of 20 August 1996 for the local neonatal care or N*-function.[10] Specific licensing standards for staff in a maternity service in university hospitals are defined in appendix 3 of the RD of 15 December 1978.[16]

Maternity service

Medical staff: A licensed medical specialist in obstetrics and gynaecology, whose hospital work is exclusively in the hospital where (s)he is head of the service, is in charge of the maternity service. In Article N5, III 1.1 to 1.7 responsibilities and duties of the head of the service are defined. In addition, a gynaecologist-obstetrician, an anaesthesiologist and a paediatrician must be available on call at any time. In the delivery area a paediatrician must be available on a permanent basis.

Nursing and caring staff: Each nursing unit in the maternity service has a head midwife (or head nurse) as well as a sufficient number of midwives to ensure the required presence of midwives 24h/7d (this requirement also holds for the delivery area). In addition, a maternity service is staffed with the required number of qualified nurses and care assistants to meet the nursing and care needs. The nursing and caring staff should be experienced in the care of newborns.

In a university hospital a minimum of 0.6 nursing and caring staff (including the head nurse) are required per occupied bed, of which at least 2/3 are qualified (midwife, nurse, nursing assistant, certified nurse) and 1/3 child caretakers. One member of the senior management must be added for each nursing unit of 20 beds.

Maternity intensive care department

Medical staff: The head of the maternity service is also the head of the MIC-department. At least three medical specialists in obstetrics and gynaecology with experience in high-risk pregnancies must work full-time in the hospital. At least one of these medical specialists or a medical specialist in obstetrics and gynaecology in training with a least two years of specialisation (of which at least one year experience in high-risk pregnancies) supervised by a gynaecologist who is on call, has to be on site 24h/7d.

*Nursing st*aff: The MIC-department has its own staff of midwives. A 24h/7d presence must be guaranteed by at least the FTE of two midwives of which at least one midwife with one or more years of experience with high-risk pregnancies.

Local neonatal care function and unit

Medical staff: The head of the N*-function is a licensed medical specialist in paediatrics experienced in neonatology, and is responsible for the functioning and the medical scientific level of the N*-function. The head of the N*-function can be the head of the paediatrics service of the hospital, and has to work exclusively for the hospital of which (s)he is the head. At least 8/10 of his/her time is spent on hospitalised patients and on consultations in the hospital. Together with the head of the maternity service, the head of the N*-function defines procedures for the cooperation between both disciplines. A detailed description of the role and responsibilities of the head of the N*-function are described in articles 6 to 13 of the RD of 20 August 1996.

Nursing staff: The head nurse of the N*-function is a paediatric nurse or midwife (bachelor's degree) experienced in neonatology. It can be the same person who is head midwife at the maternity service or head nurse at the paediatrics service of the hospital. The head nurse is responsible for the nursing activities and the nursing scientific level of the N*-function. The specific roles and responsibilities of the head nurse are described in articles 15 and 16 of the RD of 20 August 1996.

The nursing staff for the N*-unit consists of at least the full-time equivalent of 6 graduated paediatric nurses and/or midwifes experienced in neonatology. This staff is assigned as a priority to the N*-unit for the care for and surveillance of newborns. The surveillance of newborns may not be combined with the surveillance of mothers in the delivery area or patients outside the maternity service.

Neonatal intensive care service

Medical staff: The head of the service is a licensed medical specialist in paediatrics experienced in neonatology, whose hospital work is exclusively for the hospital where (s)he is head of the service. He/she is responsible for the functioning and scientific level of the service and has to take all possible measures to guarantee the continuity of care for the newborn. A licensed medical specialist in paediatrics experienced in neonatology or a medical specialist in paediatrics in training with a least two years of post-graduate education, has to be on duty 24h/7d. In this last case, the concerned NIC-service must be part of the trainee's internship and (s)he must be familiar with the urgent treatment and resuscitation of the specialism. In addition, a medical specialist from the same discipline has to be on call 24h/7d. Per five licenced NIC-beds the NIC-service must dispose of a full-time equivalent medical specialist in paediatrics experienced in neonatology. The head of the service has to work full-time and exclusively in the concerned NIC-service. Other medical staff has to work at least 3/4 time and exclusively in the concerned NIC-service.

Nursing, caring and other staff: The head nurse is a graduated nurse (bachelor's degree), preferably a graduated paediatric nurse or midwife experienced in neonatology. The head nurse is responsible for the nursing activities of the NIC-service. The specific roles and responsibilities of the head nurse are described in Article N8, IV 2.2 to 2.5 of the RD of 23 October 1964. Per licensed NIC-bed the service must dispose of 2.5 full-time equivalent graduated, preferably paediatric nurses and/or midwives, of whom at least 60% experienced in neonatology. At least one full-time equivalent administrative worker has to be deployed in the service. A sufficient number of maintenance personnel must be available to allow a daily cleaning of the service, also during weekends and public holidays.

Function of regional perinatal care

Two medical specialists are in charge of the P*-function: the head of the maternity service and the head of the NIC-service. They coordinate the P*-function and define procedures for the optimal treatment of mother and child. More details can be found in articles 5 and 6 of the RD of 20 August 1996.

2.3 Hospital revenue sources

The Budget of Financial Means

The hospital budget, called the Budget of Financial Means (BFM), is a closed-end budget that is determined prospectively at the national level and is allocated to hospitals according to specific rules. The largest part of the BFM is the B2-part, mainly covering clinical services of nursing staff and healthcare assistants and most medical products. Each year, a closed-end budget for the B2-part is defined at the national level.

Justified beds

The national B2-budget is allocated to individual hospitals (mainly) on the basis of the national average length of stay per APR-DRG-SOI. The basic concept in this DRG-based budget allocation is called ‘justified activities’ where justified reflects average activity. The number of justified patient-days for a hospital is the result of multiplying the national average LOS per APR-DRG-SOI with the case-mix of the hospital. Per department or group of departments, the number of justified patient-days is multiplied by 365 and the ‘normative occupancy rate’ to calculate the number of justified beds. For maternity units this normative occupancy rate is 70%.

A point system to allocate resources to individual hospitals

The national B2-budget is allocated to individual hospitals by dividing it by the total number of B2-points ‘earned’ by all hospitals. This gives the monetary value of one B2-point.

Basic points are granted to finance nursing and caring staff. These points are based on the number of justified beds. The surgical unit is taken as reference with one point corresponding to one justified bed. For maternity units (including the delivery room) 1.46 points correspond to one justified bed; for MIC-units 3.75 points and for NIC-units 6.25 points correspond to one bed. Additional points are granted for the N*-function: 15 points for a maternity service with less than 1 000 deliveries per year, and for maternity services with more than 1 000 deliveries 17 points for the first 1 000 deliveries and 3 points for each additional 150 deliveries.[17]

The difference in the number of points per unit type corresponds to different ‘financing standards’ in the respective units. Financing standards are expressed as the number of FTE per number of beds. For example, the B2-part of the hospital budget finances 14 FTE per 24 justified beds for a maternity unit. For most units (surgery, internal medicine, maternity, etc.) one point corresponds with 0.4 FTE. Hence, 14 FTE/24 beds equals 0.58 FTE/bed. When we divide 0.58 by 0.4 we have 1.46 points per bed.

The following financing standards apply for MIC- and NIC-units: 1.5 FTE for a MIC-bed, and 2.5 FTE per NIC-bed.

The financing standards, which determine the basic financing for nursing and caring staff, should not be confused with the licensing standards described in section 2.2.4.

On top of the B2-part, hospitals receive additional budgets for extra staff, for example through collective labour agreements or for floating pools.

Physician fees

Most physicians working in a hospital are paid on a fee-for-service basis. Health insurance pays for medical and paramedical services based on a fee schedule, called ‘nomenclature’, which lists almost 9 000 unique covered services and their payment rates or tariffs.[18]

2.4 A high density of mainly small maternity services

The main conclusion of KCE Report 289 concerning the organisation of maternity services in 2014 was that the hospital landscape was characterised by a high density of mainly small maternity services. Table 3 provides more details for the year 2016 (December) on the number of hospitals and hospital sites with a maternity service, the geographic distribution of maternity services and the size of maternity services, measured by the number of beds.

In December 2016 there were 108 maternity services in Belgium (62 in Flanders, 35 in Wallonia and 11 in Brussels). At the hospital level, 96 out of 102 hospitals had at least one maternity service. Among these 96 hospitals, 18 also had a MIC-department (7 in Flanders, 5 in Wallonia and 6 in Brussels).

The 108 maternity services that were open in December 2016 represent 3 082 licensed beds, of which 192 are MIC-beds. This corresponds to 1.23 beds per 1 000 women aged 15-49 or 25.44 beds per 1 000 births, which is far below the programming standard of 32 M-beds (including MIC-beds) per 1 000 births which dates back to the 1970's.[6] At that time, the length of stay was much longer than it is today and hence more bed capacity was needed. The results of Brussels are different from those of Flanders and Wallonia: while the number of M/MIC-beds calculated in terms of women aged 15-49 is higher than in the two other regions, the number is lower when expressed in terms of births because of a higher number of births in Brussels. Also regarding the share of maternity services with MIC-beds, Brussels is differently organised than Flanders and Wallonia with more than half of the maternity services having MIC-beds.

Since every hospital with a maternity service must also have an N*-function, the distribution of the N*-function across regions is the same as for maternity services. Every maternity service with MIC-beds must also have NIC-beds[c]. There is no legal requirement for a hospital with NIC-beds to also have MIC-beds. In addition to the 'Universitair Kinderziekenhuis Koningin Fabiola'/ 'Hôpital Universitaire des Enfants Reine Fabiola' (see Footnote c), there is one hospital in Wallonia (Centre Hospitalier Universitaire de Charleroi, hospital site Hôpital Civil Marie Curie) with NIC-beds and no MIC-beds.

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[c] There is one hospital in Brussels that has MIC-beds but no NIC-beds (Centre Hospitalier Universitaire Brugmann (hospital site Victor Horta), working in close collaboration with the 'Universitair Kinderziekenhuis Koningin Fabiola'/ 'Hôpital Universitaire des Enfants Reine Fabiola' that has NIC-beds).

Table 3 – Hospitals and hospital sites with M/MIC-beds in Belgium, December 2016

	Brussels	Flemish region	Walloon region	Belgium
Hospitals with M-beds (total number of hospitals*)	10 (12)	54 (54)	33 (37)	96 (102)**
Hospital sites with M-beds (total number of hospital sites*)	11 (17)	62 (79)	35 (54)	108 (150)
Hospital sites with MIC-beds (total number of hospital sites with M-beds)	6 (11)	7 (62)	5 (35)	18 (108)
Number of M-beds (except MIC-beds)	346	1636	908	2890
Number of MIC-beds	72	70	50	192
Number of M/MIC-beds	418	1 706	958	3 082
Number of M/MIC-beds per 1 000 women aged 15-49	1.37	1.22	1.20	1.23
Number of M/MIC-beds per 1 000 births	23.32	25.85	25.72	25.44

** with at least one C, D, CD, E or M-bed.*
*** Centre Hospitalier Interrégional Edith Cavell is counted once in the Belgium column but has one maternity service in Brussels (site 1470 Clinique Ste-Anne St-Remi) and another in the Walloon region (site 1770 Braine-l'Alleud).*
Source for population midyear 2016 and births 2016: Statbel (Statistics Belgium). Source for hospitals and beds: Minimal Hospital Data (MZG – RHM).

Majority of maternity services in Flanders and Wallonia have less than 25 M/MIC-beds

The smallest maternity services (with less than 25 licensed M/MIC-beds) are concentrated in Flanders and Wallonia (see Table 4). The share of maternity services with less than 25 M/MIC-beds amounts to 65% in Flanders and 69% in Wallonia, while this share is only 18% in Brussels. The median number of beds for the country is 24 compared to 36 for Brussels. The biggest service had 105 beds.

Table 4 – Size of maternity services, December 2016

	Brussels	Flemish region	Walloon region	Belgium
Number of maternity services* with ≤ 15 M/MIC-beds	0	14	8	22
Number of maternity services* from 16 to 25 M/MIC-beds	2	26	16	44
Number of maternity services* with 26 to 40 M/MIC-beds	5	12	7	24
Number of maternity services* with > 40 M/MIC-beds	4	10	4	18
Median number of M/MIC-beds per maternity service*	36	22	22	24

**Hospital sites with M-beds.*
Source: Minimal Hospital Data (MZG – RHM)

3 ACTIVITY PROFILE OF MATERNITY AND NEONATAL CARE SERVICES IN BELGIUM

Chapter 3 describes the activity profile of Belgian maternity and neonatal care services based on the Minimal Hospital Data (MZG – RHM) for the year 2016. These activity data are used throughout the following chapters, to analyse the efficiency of Belgian maternity services (Chapter 4), to depict the geographic accessibility of maternity services (Chapter 5) as well as to simulate patient flows and determine capacity needs in the queueing system analysis (Chapter 6).

In Belgium, all newborns have their stays recorded in the MZG – RHM as soon as they are born (including stillborn babies) or are admitted to the hospital, even if they stay in the room of the mother. This allows to divide the activity into two distinctive groups of patients, mainly based on age: patients aged 28 days and below are defined as ’newborns‘ while all other patients are defined as ‘obstetric patients‘ (mainly women needing antepartum or postpartum care and labouring or delivering women). A detailed description of the included and excluded stays in both groups (such as ambulatory contacts) can be found in the Data Manual (available on request). The activity of both groups is described in the two following sections. The occupancy rate of maternity beds was calculated on obstetric patients only.

3.1 Obstetric patients in maternity services

3.1.1 Selection of stays

We selected all stays of patients aged above 28 days and discharged in 2016, who were at any time of their hospitalisation admitted in a maternity service, i.e. in any unit including a bed index M, MIC, AR (labour room) or OB (delivery room) in the MZG – RHM. The selection consists of pregnant women, labouring women, women having delivered and a few patients admitted for care unrelated to pregnancy or delivery. The total number of selected stays amounts to 211 787.

3.1.2 Patient clinical profile

Stays are classified according to their clinical profile using APR-DRG version 34.0 (see Box 5), readily available in the MZG – RHM. We use the hierarchical grouping of APR-DRGs into Major Diagnostic Categories (MDCs) to categorise the selected stays and describe the activity in maternity services.

For the purpose of the present study, we divide MDC 14 ‘Pregnancy, Childbirth and Puerperium’ into deliveries (henceforth called **MDC 14A**) and other APR-DRGs related to pregnancy and the puerperium (henceforth called **MDC 14B**) (see Box 6).

Box 5 – APR-DRG classification system

Belgium imported the 3M™ **APR-DRG** (All Patient Refined-Diagnosis Related Group) grouper to assign hospital stays an APR-DRG. The basic DRG structure is extended by adding two sets of subclasses to each APR-DRG, namely severity of illness (SOI) and risk of mortality (ROM).

Patients are allocated to an APR-DRG-SOI group by the 3M™ DRG software on the basis of principal diagnosis, secondary diagnoses and procedures (coded in ICD-10-BE in the MZG – RHM), age and sex of the patient, and for some APR-DRGs (e.g. burns) type of discharge or birthweight (for neonates).

Severity of illness is defined as the extent of physiologic decompensation or organ system loss of function and introduces four categories for SOI: 1=minor, 2=moderate, 3=major, 4=extreme. Hospital stays are classified into one of 318 APR-DRGs (version 34), each with 4 SOI-classes, and two 'residual' APR-DRGs grouping hospital stays whose medical record abstracts contain clinically atypical or invalid information, thus rendering SOI classification irrelevant (APR-DRG 955 – Invalid principal diagnosis and 956 – Ungroupable stay). Hence, the number of distinct groups amounts to 1 274.

Source: Devriese et al. (2016)[19], Averill, et al. (2016)[20]

Box 6 – Definition of selected MDCs and APR-DRGs

MDC 13 'Diseases and disorders of the female reproductive system'

MDC 14 'Pregnancy, Childbirth and Puerperium'

MDC 14A: Deliveries

APR-DRG 540 'Caesarean Delivery'

APR-DRG 541 'Vaginal Delivery with Sterilization and/or Dilatation and Curettage'

APR-DRG 542 'Vaginal Delivery with Complicating Procedure except Sterilisation and/or Dilatation and Curettage'

APR-DRG 560 'Vaginal Delivery'

MDC 14B: Other APR-DRGs related to pregnancy and the puerperium (APR-DRGs 544-546 and 561-566)

MDC 15 'Newborns & other neonates with conditions originating in the perinatal period'

Source: Averill, et al. (2016)[20]. The division of MDC 14 into MDC 14A and MDC 14B was made for this study only.

As it can be seen in Table 5, the vast majority of obstetric stays in maternity services are assigned an MDC 14 (68.6%), of which 121 180 deliveries (57.2%). In Chapter 8 in KCE Report 289, we calculated that only 0.71% of all hospital deliveries occurred in another service than the maternity service.[3] These deliveries are not included in the present selection. Only 0.7% of the deliveries in the maternity services occurred in a day-care setting. The most common MDC outside MDC 14 is the gynaecological MDC 13 'Diseases & disorders of the female reproductive system' (except for APR-DRG MMM which is specific to the Belgian situation – see below). The complete list of the number of obstetric stays per MDC can be found in Appendix 1.1.

Table 5 – Number (percentage) of stays in maternity services by type of stay and MDC, newborns excluded (2016)

Major Diagnostic Category		Number of stays (percentage)		
		Inpatient	Day care	Total
MDC 14A	Vaginal deliveries	94 818 (44.8%)	766 (0.4%)	**95 584 (45.1%)**
	Caesarean deliveries	25 515 (12.0%)	81 (<0.1%)	**25 596 (12.1%)**
	Subtotal deliveries	*120 333 (56.8%)*	*847 (0.4%)*	***121 180 (57.2%)***
MDC 14B	Pregnancy and puerperium	20 469 (9.7%)	3 557 (1.7%)	**24 026 (11.3%)**
Subtotal MDC 14	Pregnancy, childbirth and puerperium	140 802 (66.5%)	4 404 (2.1%)	**145 206 (68.6%)**
APR-DRG MMM	Former mini lump sums	-	48 621 (23.0%)	**48 621 (23.0%)**
MDC 13	Diseases and disorders of the female reproductive system	5 201 (2.5%)	1 400 (0.7%)	**6 601 (3.1%)**
Other MDCs	All stays outside MDC 13, MDC 14 and MMM	8 316 (3.9%)	3 043 (1.4%)	**11 359 (5.4%)**
Subtotal Other MDCs	All stays outside MDC 14	13 517 (6.4%)	53 064 (25.1%)	**66 581 (31.4%)**
Total	**All stays**	**154 319 (72.9%)**	**57 468 (27.1%)**	**211 787 (100.0%)**

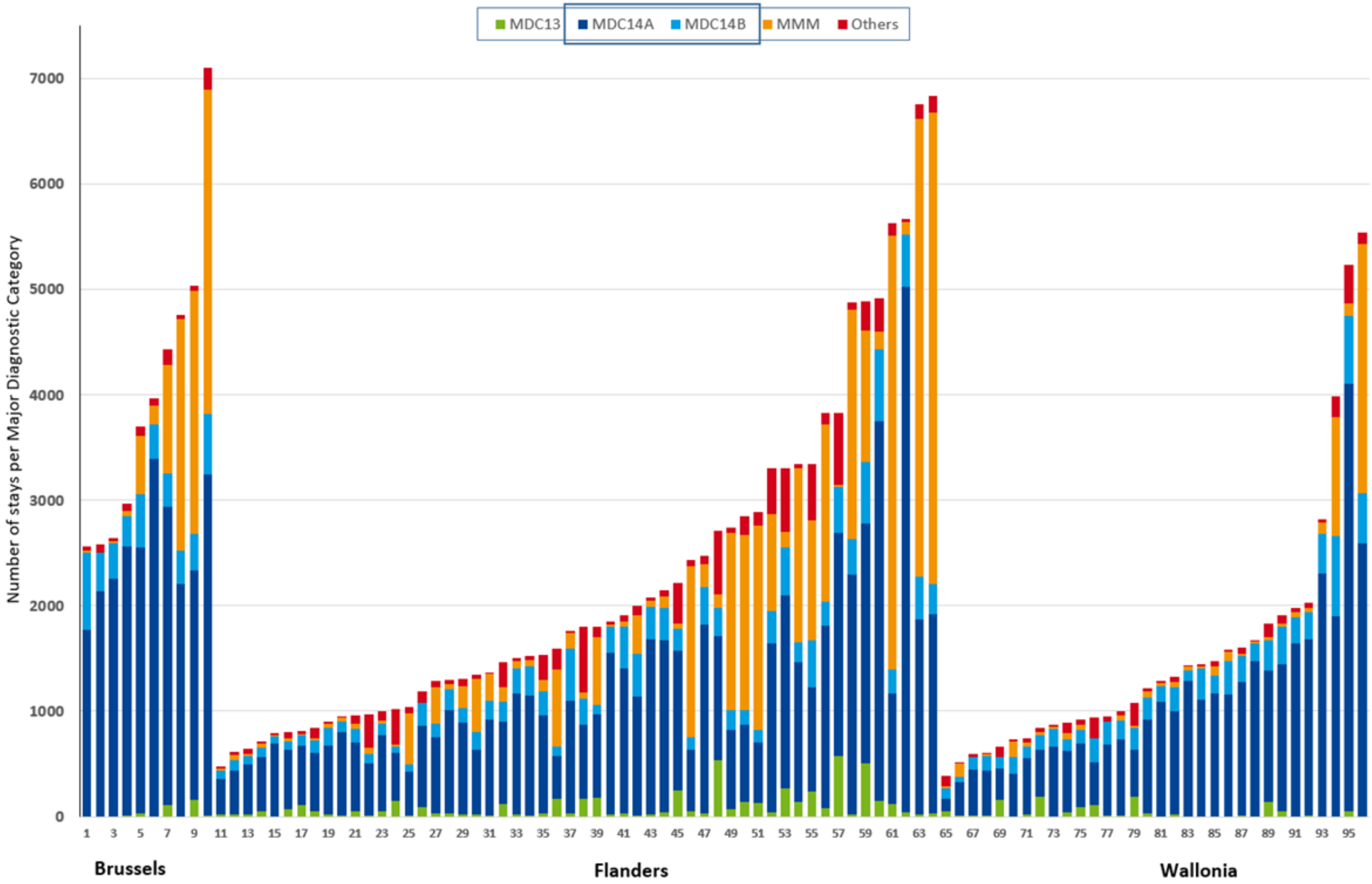
Source: Minimal Hospital Data (MZG – RHM)

APR-DRG MMM: a Belgian registration peculiarity

Twenty-seven percent of the obstetric stays in a maternity service are treated in a day-care setting. Almost 85% of these 57 468 day-care stays are assigned a so-called MMM APR-DRG. This APR-DRG is a Belgian addition to the original APR-DRG classification. Originally, this category was used for mini lump sums. Before 2014, hospitals received a lump sum amount for some interventions performed in day care. The corresponding RIZIV – INAMI billing codes were 761316 ('Ambulatory situation requiring urgent care in a hospital bed'), 761434 ('Ambulatory situation requiring an intravenous injection'), 761213 ('Urgent care or intravenous injection required') and 768375 ('Port catheter manipulation'). Since 1 January 2014, the financing of these interventions is transferred to the hospital budget, called Budget of Financial Means (BFM).[21] Although hospitals are not allowed anymore to charge the mini lump sums, they still have to record the aforementioned billing codes on the hospital bill with a € 0 amount. The reason is that private insurers otherwise consider these interventions as ambulatory care instead of day care and refuse to reimburse them, leading to a higher cost for (chronic) patients. In the hospital MZG – RHM registration, these patients should be assigned 'MMMMMM' as principal diagnosis and based on this principal diagnosis the FPS for Health, Food Chain Safety and Environment (FOD – SPF) assigns 'MMM' as APR-DRG. Note that secondary diagnoses or procedures are hardly recorded in that case and medical information is therefore lacking for these stays.

Figure 3 shows the number of stays, newborns excluded, in a maternity service per hospital. Hospitals are ranked by region and by ascending number of stays. The activity related to pregnancy, childbirth and puerperium is depicted in blue (marine for deliveries and cyan for pregnancy and puerperium). The share of MMM stays is highly variable between hospitals, ranging from 0% to 73.2% of all stays in a maternity service (newborns excluded). However, also the coding of the mini lump sum cases varies between hospitals. An exploratory analysis of the interventions billed during MMM stays and personal communications with hospital staff members, experts from the National Institute for Health and Disability Insurance (RIZIV – INAMI) and the FOD – SPF revealed that in some hospitals an MMMMMM principal diagnosis is coded in case of consultations by midwives at the maternity service. In other hospitals these consultations are organised in polyclinics, outside the maternity service. MMM cases are therefore a mix of day-care stays formerly covered by a mini lump sum and other activities such as ambulatory consultations. Due to their heterogeneous character, MMM cases are excluded from the activity in the efficiency analysis (Chapter 4).

Figure 3 – Activity related and unrelated to deliveries in maternity services by hospital, newborns excluded (2016)



MDC = Major Diagnostic Category. MDC 13 = Diseases and disorders of the female reproductive system; MDC 14A = Deliveries; MDC 14B = Pregnancy and puerperium Activity in hospitals with maternity services (inpatient and day-care settings). Source: Minimal Hospital Data (MZG – RHM). Location of primary site (Centre Hospitalier Interrégional Edith Cavell is classified in Brussels).

Regional differences in type of activity

Due to the heterogeneity of these MMM stays, they should be excluded when comparing activity among hospitals or among regions (MMM stays represent 28.1% and 23.8% of the obstetric stays in Flanders and Brussels against only 9.7% in Wallonia). When MMM stays are excluded, **deliveries**, **pregnancy and puerperium care**, and **gynaecology** (MDC 14A, MDC 14B and MDC 13) represent respectively **74.3%**, **14.7%** and **4%** of all obstetric stays, leaving 7% in other MDCs (see Table 6). The percentage of deliveries is particularly high in Brussels (82.7%) compared to Flanders (70.5%) and Wallonia (75.9%). The share of MDC 14B is similar (13.5% in Brussels, 14.2% in Flanders and 16.4% in Wallonia). Flanders treats more stays outside MDC 14 in its maternity services: 5.8% in MDC 13 and 9.4% in other MDCs versus 1.1% and 2.7% in Brussels and 2.6% and 5% in Wallonia, respectively.

The high number of births in Brussels is not only due to a higher fertility rate in that region (1.82 children per woman in 2016 versus 1.66 in the two other regions)[22] but also to the high concentration of MIC-beds and university hospitals. In Brussels, only 74.7% of the women giving birth live in the region, 18.1% come from Flanders, 6.8% from Wallonia and 0.4% from abroad. In comparison, 92.9% of the women delivering in Flanders and 93.9% in Wallonia live in the same region.

Table 6 – Number (percentage) of stays in maternity services by region and MDC, without APR-DRG MMM and newborns (2016)

Major Diagnostic Category		Number of stays (Percentage) Brussels	Flanders	Wallonia	Belgium
MDC 14A	Vaginal deliveries	19 966 (65.9%)	48 842 (55.7%)	26 776 (59.3%)	**95 584 (58.6%)**
	Caesarean deliveries	5 089 (16.8%)	13 005 (14.8%)	7 502 (16.6%)	**25 596 (15.7%)**
	Subtotal deliveries	*25 055 (82.7%)*	61 847 *(70.5%)*	34 278 *(75.9%)*	***121 180 (74.3%)***
MDC 14B	Pregnancy and puerperium	4 100 (13.5%)	12 495 (14.2%)	7 431 (16.4%)	**24 026 (14.7%)**
MDC 14	**Pregnancy, childbirth and puerperium**	29 155 (96.3%)	74 342 (84.8%)	41 709 (92.3%)	**145 206 (89.0%)**
MDC 13	Diseases and disorders of the female reproductive system	329 (1.1%)	5 076 (5.8%)	1 196 (2.6%)	**6 601 (4.0%)**
Others	All stays outside MDC 13 and MDC 14	803 (2.7%)	8 286 (9.4%)	2 270 (5.0%)	**11 359 (7.0%)**
Other MDCs	**All stays outside MDC 14**	1 132 (3.7%)	13 362 (15.2%)	3 466 (7.7%)	**17 960 (11.0%)**
Total	**All stays, MMMs excluded**	30 287 (100%)	87 704 (100%)	45 175 (100%)	**163 166 (100%)**

Source: Minimal Hospital Data (MZG – RHM)

Caesarean deliveries present a more severe case mix than vaginal deliveries and stays related to pregnancy and puerperium

To compare the case mix of different types of delivery in MDC 14 and MDC 14B Pregnancy and puerperium, we use two methods. First, we weight each inpatient stay by the national average length of stay per APR-DRG-SOI and each day-care stay by 0.81 (which is the length of stay used in the payment system for surgical day-care stays). Second, we weight stays calculating a ‘case-mix index’ based on the relative weight per APR-DRG-SOI developed by 3M.[23] Whatever the method, caesarean deliveries present the most severe case mix followed by the vaginal deliveries and the stays related to pregnancy and puerperium. Using average length of stay, the means are 5.2 days (sd: 1.4) for caesarean deliveries, 3.4 (0.6) for vaginal deliveries and 2.8 (1.5) for MDC 14B. Using the case-mix index as weight, the respective average weights are 0.6 (sd: 0.2), 0.4 (sd: 0.1) and 0.4 (sd: 0.2). Hence, a vaginal delivery may have a longer length of stay than a stay in MDC 14B but does not necessarily require more resources.

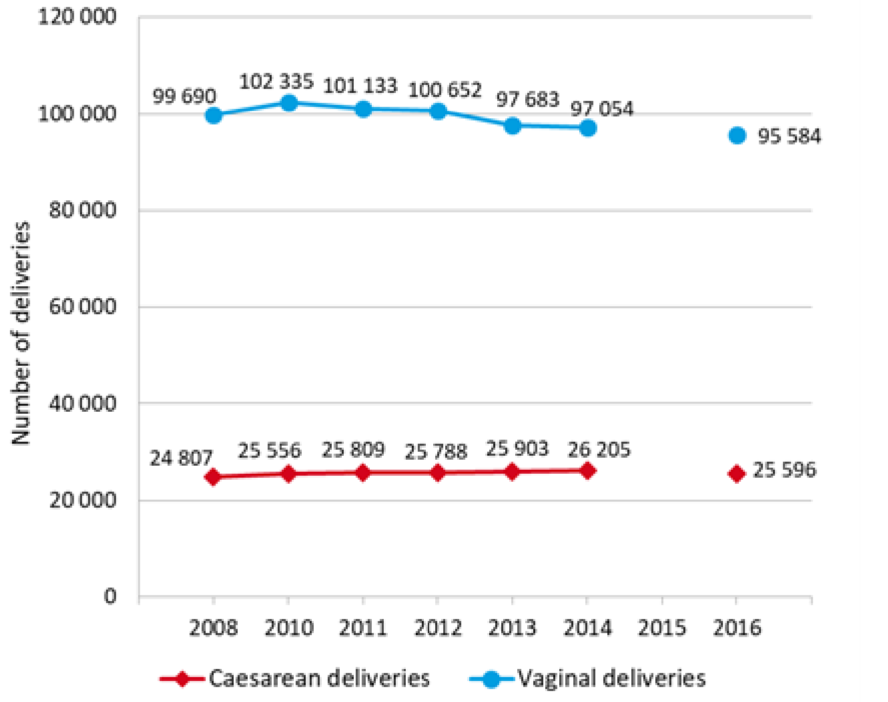
3.1.3 Deliveries in Belgian maternity services

3.1.3.1 Number of deliveries

The number of deliveries in Belgian maternity services is stable over time

In total 121 180 deliveries took place in 2016 in the Belgian maternity services, which is hardly less than the 122 380 deliveries in 2014 in KCE Report 289 (see Figure 4; no data are available for 2015 as this was a transitional year from ICD-9-CM to ICD-10-BE diagnostic and procedure codes registration in the MZG – RHM data).[3] The patterns and trends are similar to the results calculated then. For example, the percentage of vaginal deliveries versus caesareans continues to slowly decrease (78.7% versus 78.9% in 2014). Flanders has the highest share of deliveries (51% = 61 847 / 121 180, see Table 6). The slightly higher rate of caesarean deliveries observed in 2014 in the Walloon region is also confirmed in 2016 (21.9% versus 21% in the Flemish region and 20.3% in the Brussels region).

Figure 4 – Number of deliveries by delivery type in Belgium (2008-2016)



Source: Minimal Hospital Data (MZG – RHM)

The number of deliveries per maternity service remains highly variable

Among the 110[d] maternity services open in 2016 in Belgium, the median number of deliveries per site was 876, varying from 119 to 3 519 deliveries between sites. These two extremes are located in Wallonia (see Figure 5). The median number of deliveries of the 11 maternity services in Brussels is much higher than in the two other regions: 2 172 deliveries against 790 for the 63 Flemish services and 785.5 for the 36 Walloon services. The ‘smallest’ service in Brussels had not less than 1 118 deliveries in 2016.

Eight maternity services have less than 400 deliveries (see section 2.2.2 for the licensing standards) in 2016 (see Figure 5): five in Wallonia and three in Flanders. Note that one of the five Walloon sites was closed during 2016 and transferred its M-beds to another site. Although the minimum activity level stated in the law is defined as an average over three consecutive years, the annual data give us a good approximation of the number of services that do (not) reach the threshold. More details on the location and accessibility of maternity sites can be found in Chapter 5.

Note that some maternity services located near the borders receive a relatively high number of the women coming from abroad who represent 0.8% of all women giving birth in Belgium (0.4% from France and 0.3% from the Netherlands). Unfortunately, we do not have the reverse information on the Belgian residents delivering abroad, and more in particular on the number of women living near the borders who travel across these borders to give birth.

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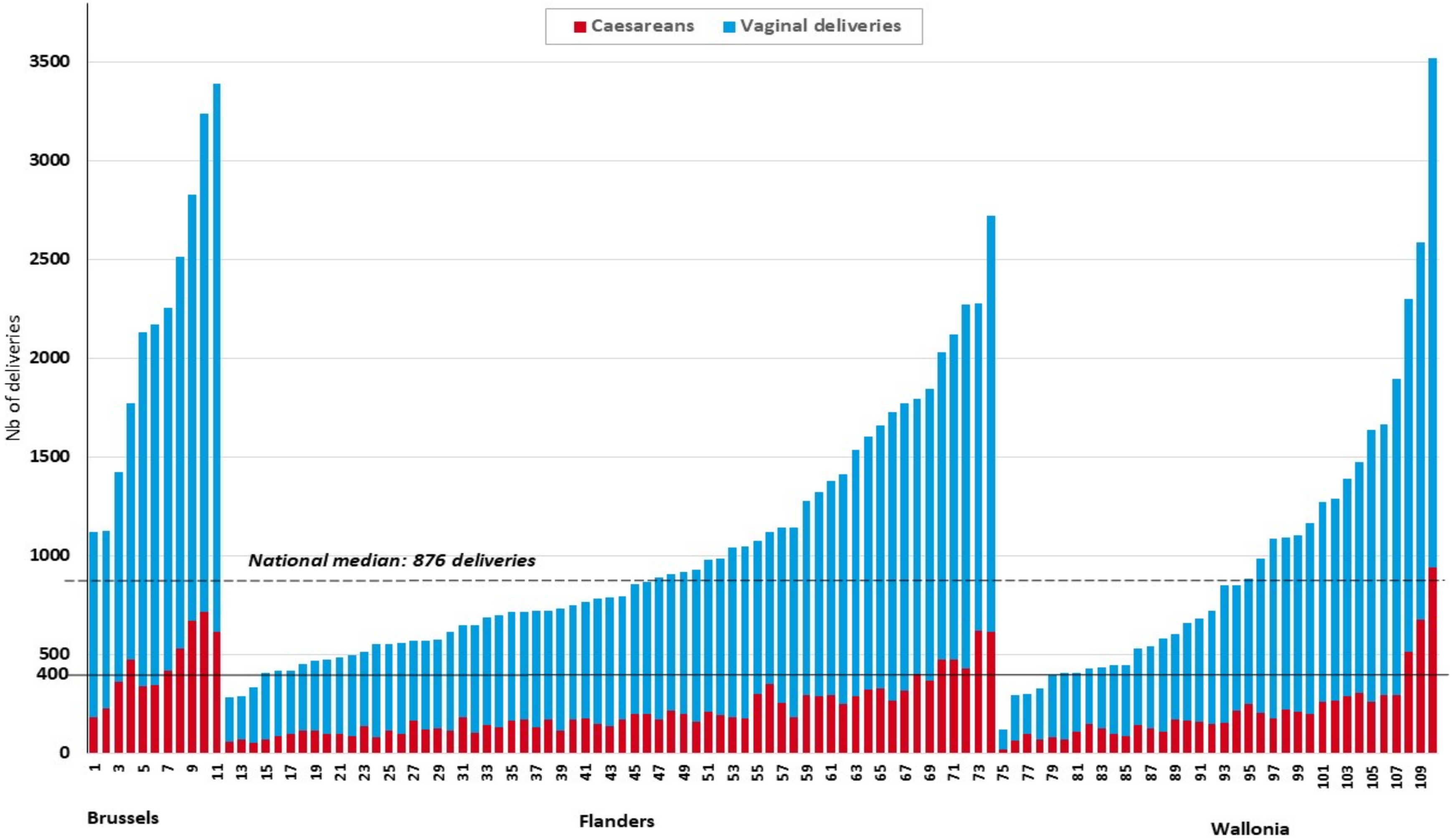
d In December 2016, there were 108 hospital sites with a maternity service (see Table 3). However, in the course of 2016 two more hospital sites had a maternity service which gives a total of 110 maternity services.

Figure 5 – Number of deliveries per maternity service by region in Belgium (2016)

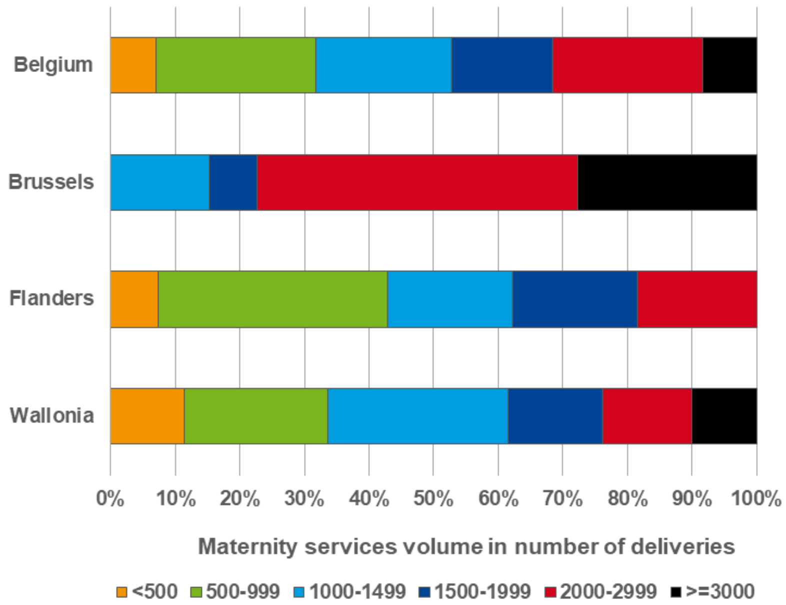


Deliveries in maternity services (inpatient and day-care settings). Source: Minimal Hospital Data (MZG – RHM).

The majority of deliveries are performed in large maternity services but there are large regional differences

In 2016, 68% of the deliveries occurred in a maternity service with at least 1 000 deliveries yearly, and almost half of them (47.2%) in a service performing more than 1 500 deliveries (see Figure 6). In Flanders 42.9% of the deliveries occur in a service with less than 1 000 deliveries versus 33.6% in Wallonia. In Brussels no delivery occurs in a service of this size. On the contrary, none of the deliveries in Flanders occur in a service with more than 3 000 deliveries per year while such services host respectively 9.9% and 27.7% of the deliveries in Wallonia and Brussels.

Figure 6 – Distribution of deliveries by maternity service volume, by region and in Belgium (2016)



Deliveries in maternity services (inpatient and day-care settings). Source: Minimal Hospital Data (MZG – RHM).

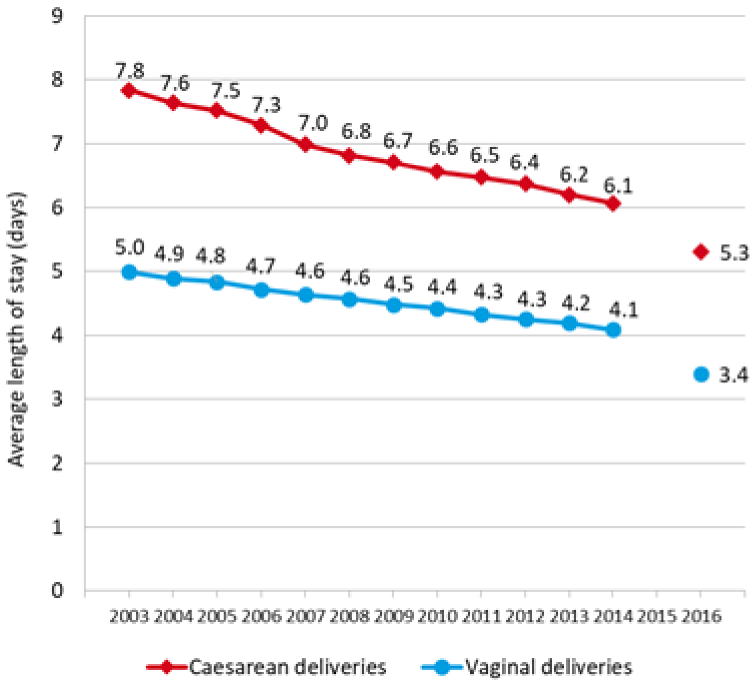
3.1.3.2 Length of stay

An accelerated reduction in the average length of stay in recent years

The length of stay for a delivery is a key factor when optimizing the number of maternity beds as a reduced length of stay may allow for bed capacity adjustments. The average length of stay in Belgium was 3.4 days for a vaginal delivery and 5.3 days for a C-section in 2016. Figure 7 shows the decreasing trend of the average length of stay between 2003 and 2016, which is in line with international observations.[24] In ten years, the average length of stay for a vaginal delivery was shortened by 1.3 days (-27.7%) and by 2 days in case of a C-section (-27.4%). The trend was most likely accelerated by the announcement and the launch of seven two-year pilot projects by the minister of Social Affairs and Public Health. With these pilot-projects, the minister wants to optimise the organisation of care before, during and after delivery at the hospital stay.[25] Variations between regions observed in 2016 are smaller for vaginal deliveries than for C-sections (see Table 7).

The length of stay is positively correlated with the severity of illness and is generally longer for vaginal deliveries when a procedure is performed, which is the case in only 4.4% of all inpatient vaginal deliveries. The majority of vaginal deliveries with procedure have a moderate level of severity (SOI=2 in 54.7% of those with sterilization and/or dilatation and curettage or APR-DRG 541, and 57.7% of those with another complicating procedure or APR-DRG 542), unlike vaginal deliveries without procedure that predominantly have a minor level of severity (SOI=1 in 65.8% of stays). Respectively 61% and 30.5% of the caesareans had a severity of illness 1 and 2. Figure 8 shows the distribution of length of stay per level of severity for inpatient vaginal deliveries respectively without (a) and with procedure (b) and caesarean deliveries (c). The majority of the stays for vaginal deliveries have a length of stay of three days or less. This holds for SOI 1 and 2 when no procedure is performed and only for SOI 1 in case of a procedure. For C-sections, the majority of stays last five days or less for SOI 1 and 2. For all types of deliveries, the distribution of length of stays is way more scattered for SOI 3 and 4.

Figure 7 – Evolution of the average length of stay (in days) for a delivery in Belgium (2003-2016)



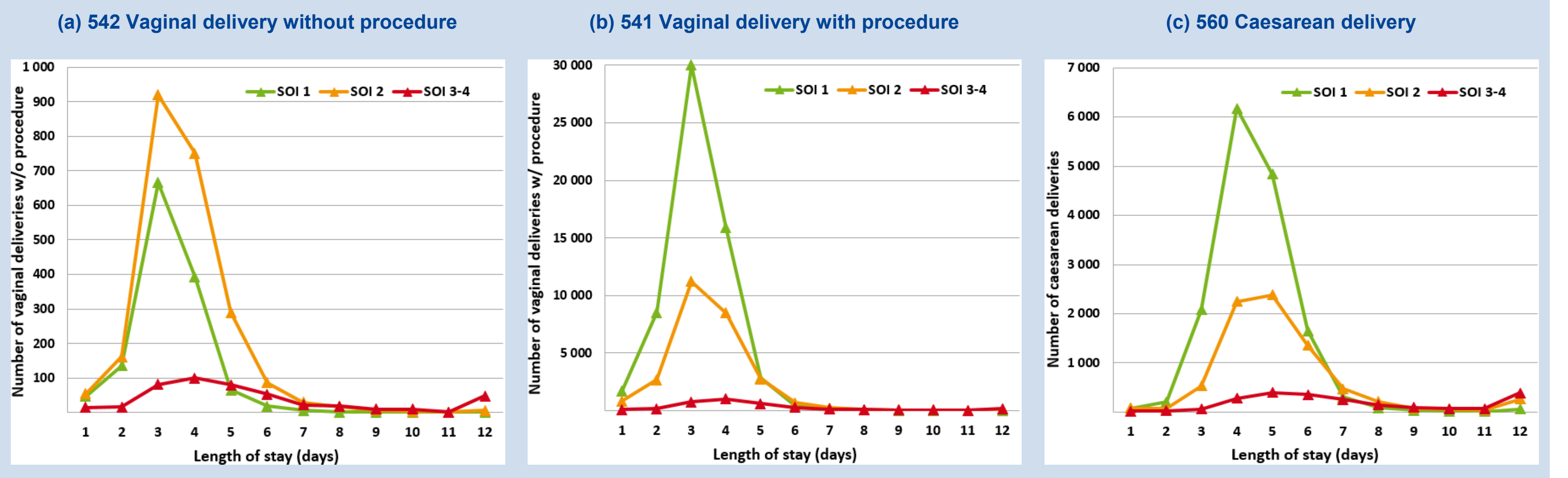
Deliveries in maternity services (inpatient setting). Source: Minimal Hospital Data (MZG – RHM).

Table 7 – Average length of stay (in days) for an inpatient delivery by region (2016)

	Caesarean delivery	Vaginal delivery
Brussels	5.3	3.4
Flanders	5.5	3.5
Wallonia	4.8	3.4

Deliveries in maternity services (inpatient setting). Source: Minimal Hospital Data (MZG – RHM).

Figure 8 – Distribution of length of stay (in days) for deliveries by APR-DRG and level of severity in Belgium (2016)



Deliveries in maternity services (inpatient setting). Source: Minimal Hospital Data (MZG – RHM).

Instead of using the commonly accepted and widely used length of stay (hospital discharge date minus hospital admission date), the MZG – RHM allows to calculate more accurately the time spent in the maternity service based on the admission time (date, hour and minute) in each unit as well as the discharge time. This time is used to model patient flows and bed capacity needs in Chapter 6 (see section 6.2.3.4 and Data Manual (available on request)). In 88.6% of the deliveries, the time can even be separated into a time before delivery and a time after delivery. On average, 0.6 day (sd: 1.3, median: 0.4) is spent in the maternity service before a vaginal delivery occurs (or 16.9% of the total time spent in the maternity service) versus 0.9 day (sd: 3.3, median: 0.3) before a caesarean is performed (corresponding to 17.6% of the total time spent in the maternity service). The distinction between times before and after the delivery is taken into account in the queueing system analysis described in Chapter 6.

3.1.4 Occupancy rate in Belgian maternity services

3.1.4.1 Bed occupancy rate

The daily occupancy rate is defined as the time, in days, spent in a maternity service by all inpatients present in the service on a particular day divided by the number of licensed beds available in the service that same day. This ratio is expressed as a percentage. When exceeding 100% it indicates that more patients are treated in the maternity service than there are licensed beds.

The numerator of this percentage concerns all obstetric inpatient activity in maternity services, including stays with another MDC than MDC 14 (pregnancy, childbirth and puerperium), knowing that MDC 14 and more specifically deliveries represent respectively 91.2%% and 78.0% of the inpatient stays in maternity services. On the other hand, the denominator includes all licensed beds of the service, irrespective of the bed index. Note that the number of licensed beds can be larger than the number of beds actually used in the maternity service (operational beds). However, no data on the number of operational beds are available. The MZG – RHM database allows to determine the time spent by a patient in a specific unit, but not to identify the specific bed index in which the patient was staying in units that contain different bed indices. Some maternity units only have M-beds, others only MIC-beds and some have M- as well as MIC-beds. Therefore, it was not possible to isolate the activity in MIC-beds as subpart of the activity in all maternity beds. Moreover, a few units also have other bed indices. On 31 December 2016, the number of beds of maternity services amounted to 3 082 maternity beds (2 891 M-beds and 191 MIC-beds) and 48 other beds (44 C-beds (surgery) and 4 N*-beds).

The definition and calculation of time spent in a maternity service is the same as for the simulation model (see section 6.2.3.4), including corrections for time in non-maternity units (operating room, intensive care unit) in case of caesareans to account for maternity bed blocking while a patient undergoes a caesarean. Similarly, time spent outside the maternity service by a patient transferred to a non-maternity unit is included if lower than 24h (e.g. for an examination). More details can be found in the Data Manual (available on request).

The average national occupancy rate is below 50%

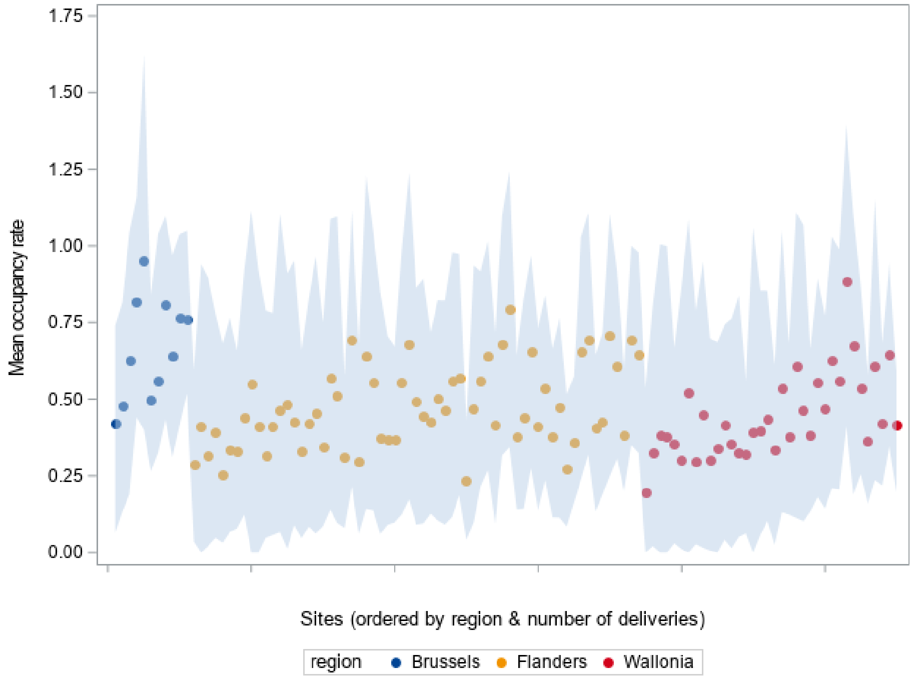
The average of the daily occupancy rates in 2016 of all maternity services together is 49.2%, the median is 48.9%, the minimum 38.8% and the maximum 60.2%.

The average occupancy rate per maternity service varies between 20% and 95% with manifest higher occupancy rates in Brussels

The national occupancy rate hides a high variability among maternity services. Figure 9 shows the annual occupancy rate of each maternity service in Belgium, ranked by region and number of deliveries. The dots give the average rates while the light blue band width spans from the minima to the maxima reached by maternity services in the course of 2016. Maternity services in Brussels have a higher average occupancy rate (on average 66.6%) than in the other regions (47.1% on average for maternity services in Flanders, 44.3% in Wallonia and 48.2% for Belgium). In Wallonia, the lowest annual occupancy rate is 19.6% while the highest is 88.4%, the median is 40.6%. Annual occupancy rates per maternity service in Flanders range from 23.3% to 79.3% with a median of 44.2%. In Brussels, however, the lowest occupancy rate is not lower than 42.0% while the highest reaches 95.2% and the median is 64.2%. These figures give averages over the year, and activity peaks can be observed on some days of the year. The lowest and highest activity peaks of each maternity service are depicted in Figure 9 by the blue band which fluctuates between 0% (days with no patient in the service) and 162.6%, which is the maximum observed in a Brussels maternity service on its busiest day.

As maternity services in Figure 9 are ranked according to the number of deliveries a weak association between the number of deliveries and occupancy rates can be observed in Flanders and Wallonia: the higher the number of deliveries, the higher the average occupancy rate. The pattern is less clear in Brussels.

Figure 9 – Average annual occupancy rate for each maternity service in Belgium (2016)



Activity in maternity services (inpatient setting). Source: Minimal Hospital Data (MZG – RHM).

The results are in line with the findings of our previous report on hospital capacity, which was based on data for 2014.[3] Similarly, we found that the occupancy rate does not seem to be influenced by the size of the maternity service in terms of number of beds but by the presence of MIC-beds. On average the annual occupancy rate of maternity services with MIC-beds reaches 66.4% versus 44.6% for the other services.

3.1.4.2 Activity unrelated to deliveries

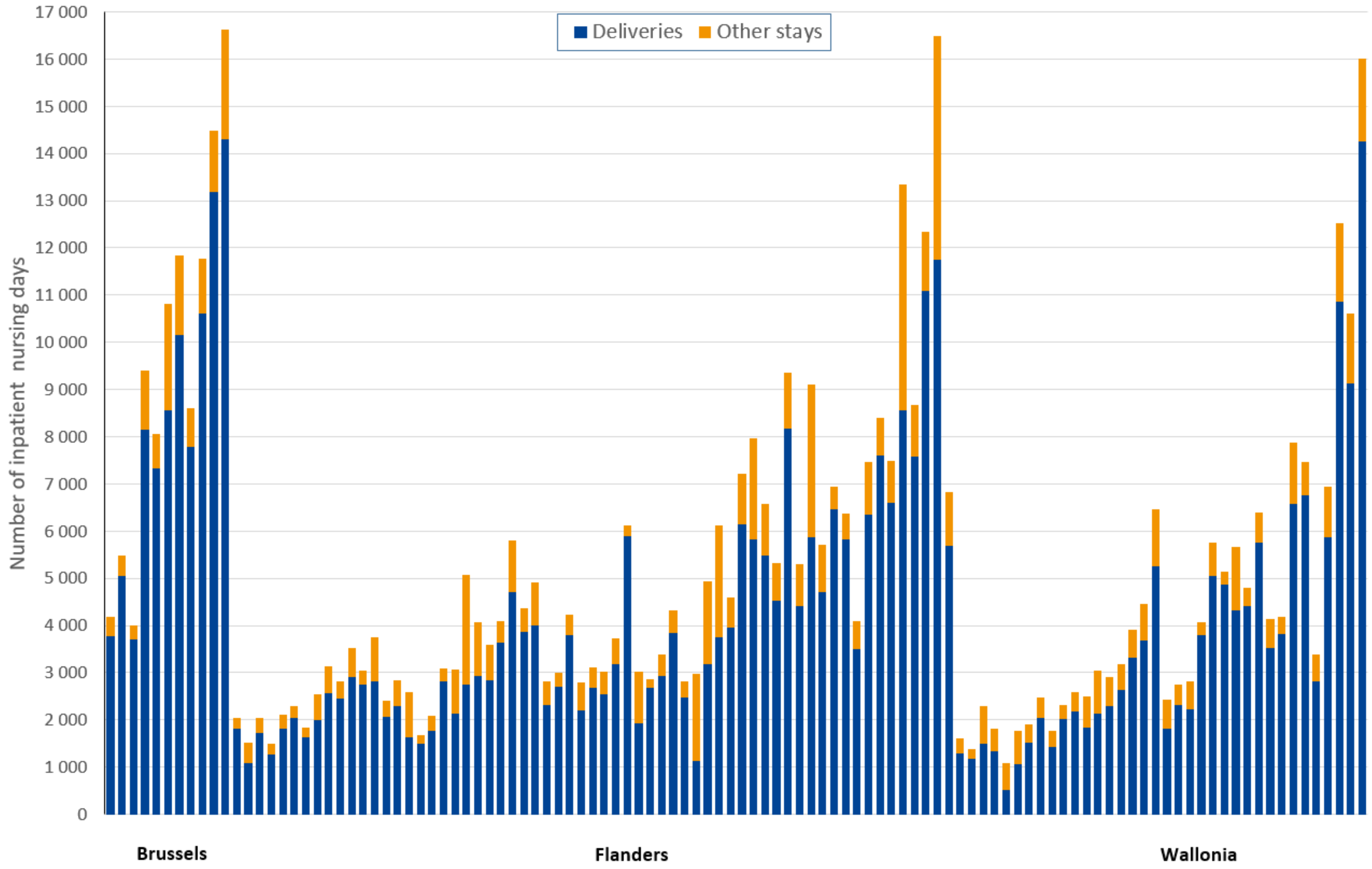
When studying bed occupancy rates, it is important to take into account that deliveries are not the sole activity in maternity services, even if they represent the largest share of the activity excluding newborn activity. The remaining part of the obstetric inpatient nursing days were dedicated to pregnancy and the puerperium (MDC 14B; 11.2%), to gynaecology (MDC 13; 2.6%) and to other MDCs (3.1%). Figure 10 presents the percentage of nursing days dedicated to deliveries and to the remaining activity by maternity service, ranked by region and number of deliveries. Table 8 presents the distribution of the percentage of nursing days dedicated to deliveries in maternity services per region. The share of the remaining activity beyond deliveries in nursing days is highly variable between maternity services, ranging from 3.4% to 61.7% (mean: 17.8%, median: 15.3%). The proportion of nursing days dedicated to other activity than deliveries is smaller in Brussels maternity services than in the two other regions.

Table 8 – Percentage of inpatient nursing days dedicated to deliveries in maternity services in Belgium, newborns excluded (2016)

Region	N services	Mean	Std	Min	Q1	Median	Q2	Max
Brussels	11	88.7%	4.0%	79.2%	86.0%	90.4%	91.1%	92.8%
Flanders	63	81.5%	10.6%	38.3%*	78.8%	84.9%	88.5%	96.6%
Wallonia	36	81.3%	9.5%	47.5%	78.7%	83.3%	86.7%	94.7%
Belgium	**110**	**82.2%**	**10.0%**	**38.3%**	**79.2%**	**84.7%**	**88.9%**	**96.6%**

Activity (except newborns) in maternity services (inpatient setting).: This maternity service dedicated 22.1% of its inpatient nursing days to MDC 09 'Diseases and disorders of the skin, subcutaneous tissue and breast' (mainly breast procedures) and another 21.8% to MDC 13 (mainly uterine and adnexa procedures). The maternity service does not exist anymore, it merged with another maternity service. Source: Minimal Hospital Data (MZG – RHM).*

Figure 10 – Activity related and unrelated to deliveries in maternity services in Belgium, newborns excluded (2016)



Activity in maternity services (inpatient setting). Source: Minimal Hospital Data (MZG – RHM).

3.2 Newborns in maternity and neonatal care services

3.2.1 Selection of stays

We selected all stays of patients aged 28 days or less discharged in 2016 who were at any time of their hospitalisation admitted in a maternity service and all patients admitted in an N*- or a NIC-unit, i.e. in any unit including either a bed index M, MIC, AR (labour room) or OB (delivery room), a local neonatal care bed (bed index N*) or a neonatal intensive care bed (bed index NIC) in the MZG – RHM. The reason to include units with N*- and NIC-beds was that in many hospital sites there is no clear distinction between the staff dedicated to the maternity services and the staff dedicated to the neonatal care services (see section 4.3.1). The selection consists of patients born or admitted to the hospital before the age of 29 days as well as the whole population staying in N*- or NIC-beds. The total number of selected stays amounts to 126 994.

3.2.2 Patient clinical profile

Similar to what was done for the obstetric population, the stays of newborns with an APR-DRG MMM were discarded from the original selection. Newborns with such an APR-DRG were far less numerous (n=203 stays corresponding to 0.2% versus 23% of the obstetric stays). Appendix 1.2 shows the MDCs of the newborns, per type of hospitalisation.

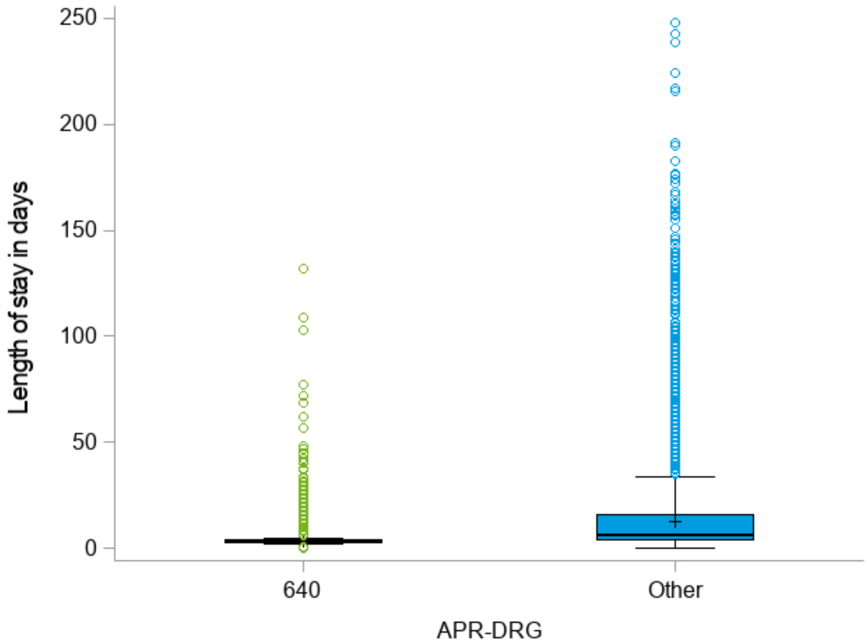
Almost all newborns were assigned an MDC 15 'Newborns & other neonates with conditions originating in the perinatal period', whatever the region of the hospital (98.5%, see Table 9). Among MDC 15, the majority of newborns (86.3%) were assigned an APR-DRG 640 'Neonate Birthweight >2 499g, Normal Newborn Or Neonate With Other Problem', which is the APR-DRG assigned at birth when the newborn does not suffer from any major health issue. Newborns with this APR-DRG have a shorter length of stay than the other newborns as shown in Figure 11. Only 1.2% of the newborns (excluding APR-DRG MMM) were admitted in day-care setting. In 98.8% of the cases, the stay started with the birth at the hospital, rather than following an actual admission of a newborn.

Table 9 – Number (percentage) of newborn stays by region and MDC, without APR-DRG MMM (2016)

Major Diagnostic Category		Number of stays (Percentage)			
		Brussels	Flanders	Wallonia	Belgium
MDC 15	Newborns & other neonates with conditions originating in the perinatal period	25 682 (99.4%)	63 960 (98.1)	35 241 (98.6%)	**124 898 (98.5%)**
Others	All stays outside MDC 15	165 (0.6%)	1 239 (1.9%)	504 (1.4%)	**1 908 (1.5%)**
Total	**All stays, MMMs excluded**	25 847 (100%)	65 199 (100%)	35 745 (100%)	**126 791 (100%)**

Source: Minimal Hospital Data (MZG – RHM)

Figure 11 – Length of stay of newborns, with or without APR-DRG 640 Neonate Birthweight >2 499g, Normal Newborn Or Neonate With Other Problem (2016)



Newborns at the maternity and neonatal care services (inpatient setting). Skeletal boxplots: boxes are drawn from Q1 to Q3 with Q2 as inside line, whiskers are drawn until first observation > Q1-1.5 IQR and last observation < Q3 + 1.5 IQR, + is the mean. Source: Minimal Hospital Data (MZG – RHM).

3.2.3 Newborn activity according to bed index

Because the profile of patients depends on the bed type (M/MIC-bed, N*-bed or NIC-bed), also the activity that is performed differs between these bed types. We compare three groups of newborns following the bed index they stayed in. The first group ('newborns in maternity beds') consists of newborns who stayed only in a maternity bed but not in an N*-bed or NIC-bed. Newborns who stayed in an N*-bed (and M/MIC-bed) but not in a NIC-bed represent the second group ('Newborns in M- or N*-beds') and newborns who stayed in a NIC-bed are the third group. Although we considered all stays in N*- and NIC-beds as newborns, in reality some babies staying in these beds were admitted to the hospital above 28 days of age. The highest admission ages were 1 year (n=2) and 2 years (n=2) respectively in the N*-group and the NIC-group (see Appendix 1.2 for more details on age at admission in each group).

Logically, the percentage of babies born at the hospital[e] is the highest in the maternity group (99.5%) followed by the N*-group (91.3%) and the NIC-group (78.3%). The 0.5% of newborns born outside the hospital and admitted in an M/MIC-bed can be explained by an admission of the mother.

Figure 12 shows the case mix comparison according to two methods. In panel (a), each inpatient stay is weighted by the national average length of stay per APR-DRG-SOI and each day-care stay by 0.81 (which is the length of stay used in the payment system for surgical day-care stays). In panel (b), each stay is weighted by the APR-DRG-SOI relative weight developed by 3M. Both methods were used because different patient groups may have the same average length of stay but require a different input of resources, and conversely. The case mix is more severe and patients stay longer in NIC-beds. The difference between M/MIC-stays only and N*-stays is more pronounced when using length of stay as a weight compared to the relative weight. In other words, although presenting a similar case-mix index, patients staying in N*-beds stay longer than those staying in M/MIC-beds only.

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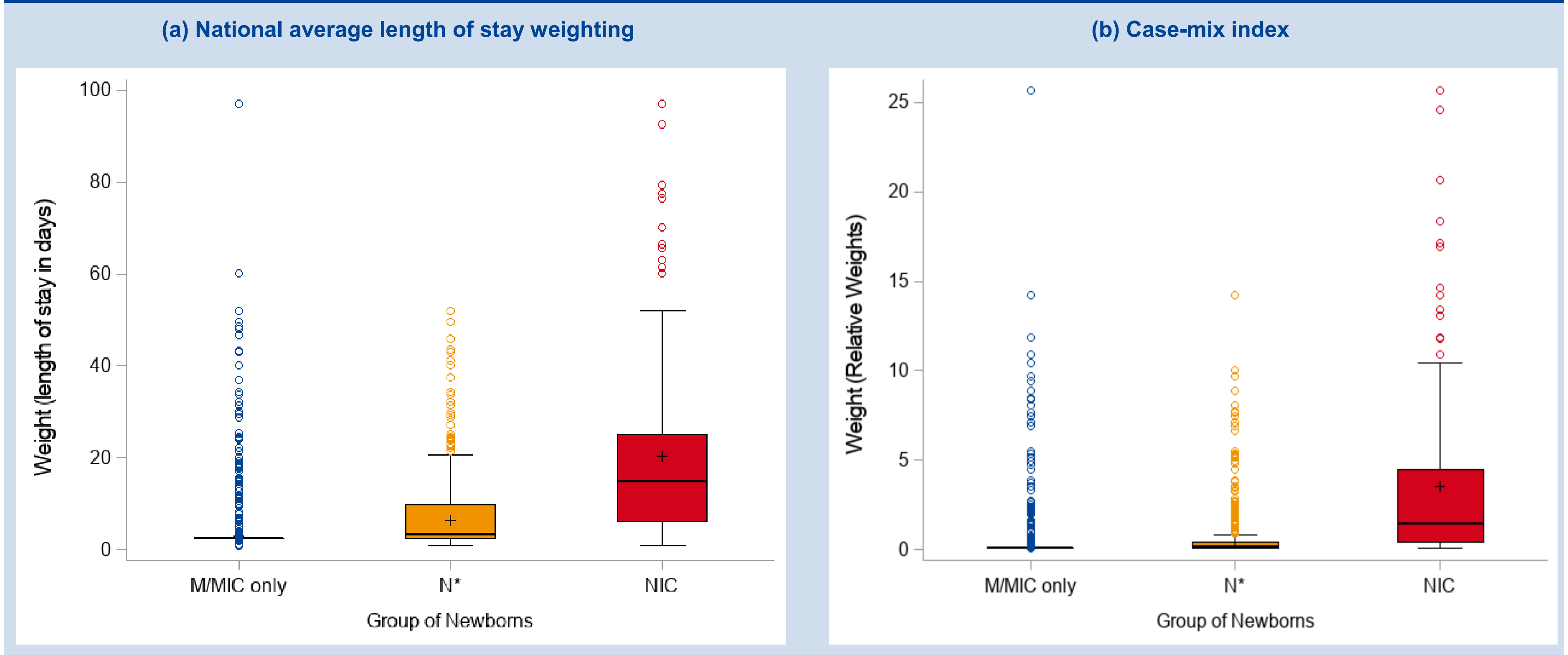
[e] Babies born on the way to the hospital are also recorded as born on site.

Figure 12 – Weight of stays by group of newborns, using national average length of stay (a) and case-mix index (b) (2016)



Newborns at the maternity and neonatal care services (inpatient and day-care settings). Skeletal boxplots: boxes are drawn from Q1 to Q3 with Q2 as inside line, whiskers are drawn until first observation > Q1-1.5 IQR and last observation < Q3 + 1.5 IQR, + is the mean. Only newborns aged 28 days or less at admission were retained (corresponding to 96.9% and 97.2% respectively of the stays in N- and NIC- beds) to compare the case mix of each group and the proportion of the three groups in each hospital. Source: Minimal Hospital Data (MZG – RHM).*

Hospitals differ in the way newborns are admitted or recorded

To study the inter-hospital variability of N* admission policy, the number of newborns in each bed index group is represented per hospital in Figure 13, ranking hospitals by region and total number of newborn stays. The proportion of newborns admitted to N* varies from 0% to 100% between hospitals. Three hospitals (almost)[f] never register newborns in M/MIC-beds where only the stay of the mother is recorded in case of delivery. We observed that these hospitals have the same ratio newborns/deliveries and the same percentage of newborns recorded as born on site as the other hospitals. We can therefore conclude that every baby born in these hospitals is recorded as staying in an N*-bed (or NIC-bed for those having NIC-beds). On the contrary, five other hospitals (almost)[g] never register newborns in N*-beds. The median percentage of newborns admitted in an N*-bed (and not in a NIC-bed) reaches 5% in hospitals with NIC-beds and 14.6% in hospitals without NIC-beds, without any notable regional difference.

The variability in N* or NIC admission policy can also be found in the annual reports of the regional perinatal epidemiology centres (Brussels[26], Flanders[27] and Wallonia[28]). The data in the annual reports are based on birth statistics. An admission in an N*-unit occurred in respectively 5.8%, 11.3% and 6.1% of live births in Brussels, Flanders and Wallonia (2016)[h]. For an admission in a NIC-service, these percentages were respectively 5.5%, 4.1% and 3.5%. More detailed data for Flanders on the reason for admission to an N*-unit or NIC-service show that a caesarean delivery often results in such admission.

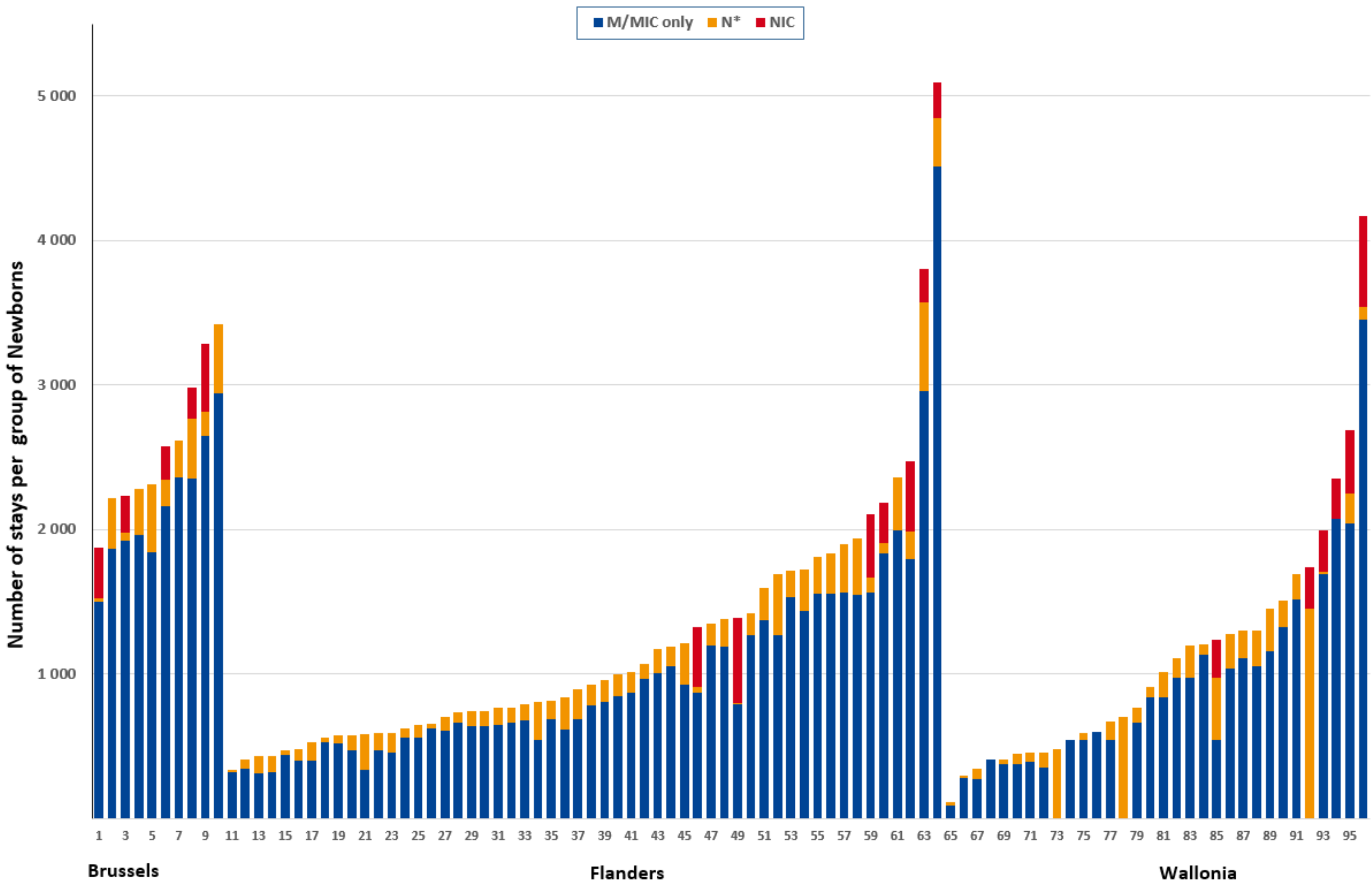
The inter-hospital variability in admission policy of newborns and staff registration motivated the inclusion of neonatal care services in the efficiency analysis detailed in Chapter 4.

f Hospital 92 and 73 in Figure 13 respectively admitted 8 and 1 newborns only in M/MIC-beds.

g Hospital 49 in Figure 13 admitted 3 newborns only in N*-beds.

h In Brussels and Wallonia only admissions in an N*-unit or NIC-service in the first 12 hours of life are taken into account, while in Flanders admissions until 7 days after birth (day 0) are registered.

Figure 13 – Number of newborn stays per hospital, by bed index group (2016)



Newborns at the maternity and neonatal care services (inpatient and day-care settings). Newborn stays spent only in a maternity bed (neither in an N-bed nor a NIC-bed) are depicted in blue, stays in an N*-bed (and M/MIC-bed) in orange and stays in a NIC-bed (and in an N*-bed and/or M/MIC bed) are represented in red. Source: Minimal Hospital Data (MZG – RHM).*

3.3 Key points

Obstetric patients

- **The number of deliveries is stable over time (about 121 200 deliveries in 2016) but there has been an accelerated reduction in the length of stay in recent years. In 2016, the average length of stay was 3.4 days for a vaginal delivery and 5.3 days for a caesarean delivery.**
- **The number of deliveries per maternity services ranges from 120 to 3 500 per service. Eight maternity services had less than 400 deliveries in 2016. The number also varies between regions: the median number of deliveries per maternity service is 2 172 in Brussels against 790 in Flanders and 786 in Wallonia.**
- **Also the activity unrelated to childbirth, pregnancy and puerperium varies widely between maternity services and regions: 15.2% of stays in maternity services in Flanders versus 7.7% in Wallonia and 3.7% in Brussels.**
- **The average occupancy rate per maternity service is 48.2%, ranging from 20% to 95%. The highest rates are found in Brussels: on average 66.6% versus 47.1% in Flanders and 44.3% in Wallonia.**

Newborn patients

- **Newborns represent almost 127 000 stays in maternity services or neonatal care services.**
- **The admission and registration policy of newborns in the maternity services and the neonatal (local and intensive) care services differs between hospitals.**

4 AN EFFICIENCY ANALYSIS OF BELGIAN MATERNITY SERVICES

4.1 Introduction

4.1.1 *Rationale for an efficiency analysis*

Chapters 2 and 1 have shown that the results of KCE Report 289 on the organisation and activity levels of Belgian maternity services in 2014[3] were still valid in 2016. The results can be summarised as a landscape with a high density of small maternity services with, on average, low occupancy rates of maternity beds and a large variability in caseload between maternity services.

The current international trend is a concentration of maternity care,[3] and a closing of small maternity services because larger units are often assumed to be more efficient than smaller ones. The explanation for being more efficient is that the costs of minimum staff and equipment requirements (see section 2.2) are fixed, also for the large number of maternity services with low activity levels. Hence, smaller services have a large average cost per delivery.

The central question in this chapter is: **Is the size of maternity services related to their efficiency?** To answer this question, we analyse the relation between the size of a maternity service, with size measured in terms of activity, and the input of staff and beds.

4.1.2 *Scope and concepts*

The efficiency of Belgian maternity services is **analysed at the level of a maternity service at a hospital site** (see Figure 1). A detailed description of the data selection criteria can be found in section 4.3.

In this section we introduce some concepts which will be used throughout this chapter.

Economies of scale

One potential source of inefficiency is related to the scale of hospitals or services. A hospital or a service experiences economies of scale when the average costs decline as the volume of activity increases.[i] Economies of scale are expected to be present when fixed costs are high relative to variable costs. The average cost per unit of output (for example a delivery) depends on how much the hospital service (in this case the maternity service) produces. As the scale increases, the fixed costs are spread over a larger volume. Economies of scale can provide information on the cost structure of a hospital or hospital service; they show the effect of an increased output level on unit costs.

We may expect economies of scale to be present for hospitals or services with small scale. It might be relevant to enlarge the scale of such a hospital or service to make better use of available staff, infrastructure and equipment. When the optimal scale is reached, no gain can be made by expanding the scale further. At some point, when the scale is too large, diseconomies of scale can appear: expanding the scale further increases the average costs.

Although there is an extensive empirical literature examining economies of scale in hospitals, only few studies have investigated the existence of economies of scale in maternity services (see Box 7).

Box 7 – Economies of scale for maternity services: previous studies

“Extensive literature on [the question of economies of scale] has been developed at the hospital level.[18, 29] In early studies, differences in case mix were not controlled for, which makes interpretation difficult (larger hospitals may attract more costly cases so that their average cost may be higher even if economies of scale are present). But most recent studies better control for case-mix differences, and use a wide range of statistical methods. These studies consistently report constant or increasing average costs for acute hospitals (i.e. absence of economies of scales or even presence of diseconomies of scale). If economies of scale are present, they appear for low level of capacity (around 100-200 beds). Diseconomies of scale seem to appear above 300-600 beds.

It must be noted that most of these studies are performed in the UK or in the US.[29] It is difficult to assess if the results would fit in another context. An important element is the definition of what constitutes minimum staff and equipment requirements. This definition may vary importantly in different countries. Where requirements are stronger, unexploited economies of scale are more likely. Indeed, the costs of minimum staff and equipment requirements are fixed even if the hospital does not utilize these inputs at full capacity. As the activity volume increases above the level that can be performed by the minimum staff and equipment, additional staff and equipment inputs become variable costs.

Even fewer studies have specifically examined maternity services. While references to economies of scale in maternity services were found back in the 1940s[30], our focus concerns more recent studies. The reader must be aware that, in this context also, research is biased towards Anglo-Saxon hospitals. Therefore the above remark regarding cautious interpretation applies. In Scotland, a national study looked at the impact of volume on the ratio of actual to expected costs, where expected costs are the ones that would prevail if the unit cost was the same as the average unit cost for a peer group.[31] A decreasing relationship was found

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[i] The interested reader is referred to Van de Voorde et al. (2014)[18], Chapter 13.

between the annual number of births and this cost ratio. In England, Frontier Economics (2012) found substantial economies of scale in maternity services.[32] The minimum efficient scale (lowest point on the long run average cost curve) was found to be at least 8 000 births per year for consultant-led units and 3 500 births per year for midwives-led units. In the same context, Monitor (2014) only found a slightly decreasing relation between scale and costs.[33] The difference between both results is likely to lie in the data used for computing the costs. While Monitor (2014) uses (reference) costs that are observed in practice, Frontier Economics (2012) uses theoretical costs based on best practice guidelines. As best practices are more and more adopted, economies of scale may therefore emerge.[33] Jones (2013) formulates doubts about the quality of reference costs submitted by hospitals.[30] Nevertheless, using these costs, he found that hospitals performing 3 000- 5 000 deliveries per year have lower costs than the national average due to economies of scale. Average cost is found to be £ 1 450 (€ 1 750) for a maternity service with 10 000 deliveries while it is £ 2 150 (€ 2 590) when 1 000 deliveries are performed. Another study found that an increase in size of a typical maternity unit from £ 5 million to £ 10 million would imply a reduction in the reference cost index of more than 15%.[34] Sandall et al. (2014) found no economies of scale in the cost of a delivery only but economies of scale appeared across the total maternity episode (i.e. including antenatal and postnatal care).[35] Costs are lower when the size, measured as the number of deliveries, is larger."

Source: Van de Voorde et al. (2017)[3]

Returns to scale

A concept that is related to economies of scale is returns to scale. While economies of scale measure the relationship between costs and outputs, returns to scale refer to the relation between inputs and outputs. More specifically, returns to scale tell us how outputs change in response to an increase in all inputs in the long run.

The relation between both economic concepts, economies of scale and returns to scale, is described in Box 8.

Box 8 – Relation between returns to scale and economies of scale

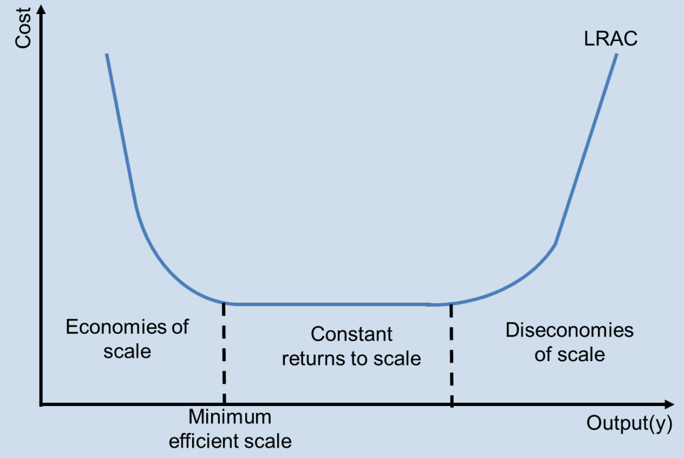
Suppose a firm is producing one output y with two inputs K and L, according to the production function $y=F(K,L)$.

The firm exhibits **constant returns to scale** (CRS) if $F(aK,aL)=aF(K,L)$ for any $a>0$: if both inputs are multiplied by a positive factor a, the output is multiplied by the same factor a. In a perfectly competitive input market, CRS imply that the long run average cost is constant.

The firm exhibits **increasing returns to scale** (IRS) if $F(aK,aL)>aF(K,L)$ for any $a>0$: if both inputs are multiplied by a positive factor a, the output is multiplied by more than a. In a perfectly competitive input market, IRS imply that the long run average cost is decreasing (**economies of scale**).

The firm exhibits **decreasing returns to scale** (DRS) if $F(aK,aL)<aF(K,L)$ for any $a>0$: if both inputs are multiplied by a positive factor a, the output is multiplied by less than a. In a perfectly competitive input market, DRS imply that the long run average cost is increasing (**diseconomies of scale**).

The **minimum efficient scale** (or **most productive scale size, MPSS**) is the lowest output that minimises the long run average cost; that is the level of output where returns to scale become constant.



LRAC = Long run average cost

When looking at the effect of volume on the average cost, it is important to distinguish between the cost-volume link within a same facility, and the comparison of costs between two facilities of different sizes.[29] For a hospital or a service of a given capacity and staff, increasing volume generally decreases average cost (until the capacity ceiling is reached). We are, however, interested in the second effect: are average costs in smaller hospitals higher than in larger ones, even if both are operating at full capacity?

In this context, the ability to measure **scale efficiency** and identify the **minimum efficient scale** of maternity services is crucial. In efficiency literature, the unit of which the scale efficiency is analysed (such as a maternity service), is called the 'decision making unit (DMU)'. A recent review of existing research on scale efficiency and optimal size in the hospital sector identified that most of the studies use non-parametric techniques such as Data Envelopment Analysis (DEA), and to a smaller extent parametric techniques such as Stochastic Frontier Analysis (SFA).[36] Both types of methods build a frontier of efficient production or a production possibility frontier (PPF): that is the frontier that the units should be able to reach by eliminating their inefficiency. The PPF shows the maximum outputs combinations of goods or services that can be achieved by fully using all available resources efficiently. Hence, the (unobservable) PPF represents the best practice function or the set of best attainable positions. It is a function bounding or enveloping the data for all DMUs in the sample. It benchmarks the actual performance of a DMU by comparing it with its own maximum potential performance or with the best-practice efficient DMUs in the sample.

Parametric methods, such as SFA, rely on specifying a functional form which relates the outputs to the inputs and then estimate the parameters of this function using the data. Non-parametric approaches such as DEA, on the other hand, do not explicitly state a functional form, but estimate the complete frontier using the data.

In what follows, we use a DEA approach to measure scale efficiency of maternity services in Belgium and estimate the minimum efficient scale in this context. The minimum efficient scale is expressed as a (yearly) minimum number of deliveries.

4.2 Data envelopment analysis (DEA)

In section 4.2 we describe the DEA method and related terminology (for example, different types of efficiency) in economic language. However, in section 4.2.8, the economic language will be 'translated' to the context of this study, being the efficiency measurement of Belgian maternity services.

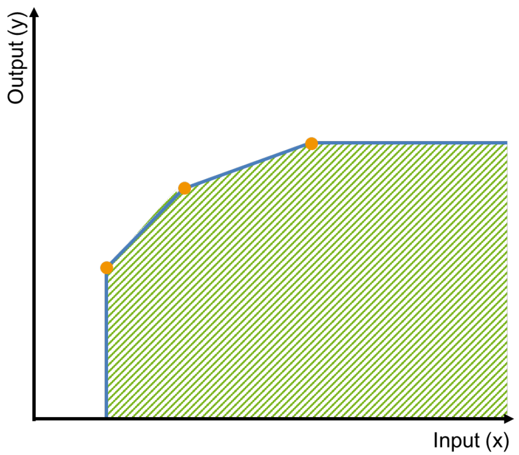
4.2.1 Method and interpretation

Data envelopment analysis (DEA) is a non-parametric approach that estimates efficiency scores from sample data by using linear programming techniques.[36] The method constructs a production possibility frontier using the efficient DMUs and measures how close other DMUs are to the frontier. Hence, a DEA model estimates the **relative efficiency** of DMUs and not absolute efficiency. Theoretical foundations of the method were firstly developed in Charles et al. (1978). Since then, DEA has been used widely to assess efficiency in different sectors including healthcare.[37]

The background of DEA literature is production theory: firms use inputs to produce outputs. In our context, we consider several maternity services that transform inputs (i.e. resources, such as staff) into outputs (i.e. activity, such as deliveries). The underlying assumption is that all firms have a common technology that allows them to transform inputs into outputs. While this assumption can be challenged in several contexts, we found no evidence of differences in technology between Belgian maternity services.

Our approach therefore consists of first estimating the technology from observed data. The technology set is a set of inputs-outputs combinations that are assumed to be feasible, such as the shaded area depicted in Figure 14 in a single input and single output case. Next, we use the estimated technology function to calculate the efficiency score for each maternity service. In a third step we assess potential gains from structural changes (such as a transfer of the activity of one maternity service to another nearby).

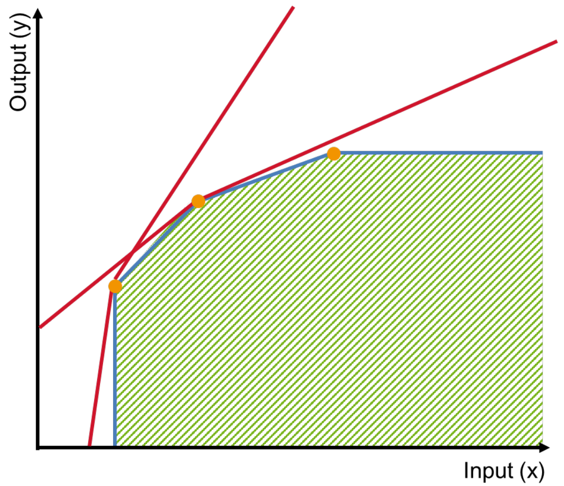
Figure 14 – Technology set



4.2.1.1 Minimal extrapolation

In DEA, the estimate of the technology set is constructed according to the '**minimal extrapolation principle'**. It means that the estimated technology set is the smallest set that contains the observed data and fulfils some assumptions (see section 4.2.2). For instance, in Figure 15, two possible sets are illustrated (below the red lines) that respect an assumption of convexity. Many other sets contain the observed data and respect this assumption of convexity. If one takes the intersection of all possible sets, one gets the shaded area. It is the smallest set that contains the observed data and fulfils the assumption of convexity.

Figure 15 – Minimal extrapolation principle

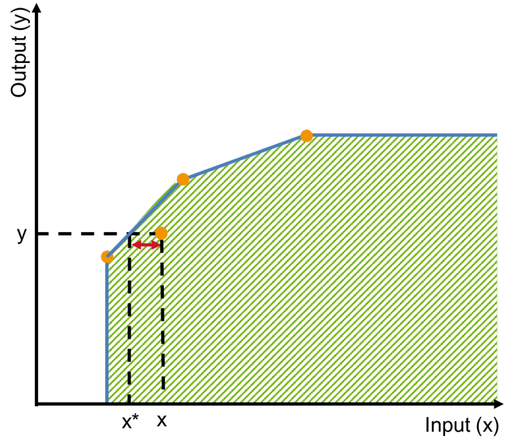


4.2.1.2 Farrell efficiency

In the production economics literature, the **efficient subset** of the technology set are the inputs-outputs combinations that cannot be improved: it is not possible to produce more outputs with the same inputs, neither to produce the same outputs using less inputs. The approach we use to measure the degree of efficiency is the one suggested by Farrell (1957),[38] known as Farrell efficiency. The input–based Farrell efficiency (or simply **input efficiency**) is a measure of how much the firm could decrease its inputs, keeping its outputs constant. For a given level of outputs *y*, it is the maximal proportional contraction of all inputs that allows the firm to produce *y*. The output–based Farrell efficiency (or **output efficiency**) is the maximal proportional expansion of all outputs that is feasible with the given inputs *x*. It measures how much the firm could increase its outputs, keeping its inputs constant.

Given the particular setting of our study, our analysis will focus on input efficiency, the idea being to measure how much the input costs could be contracted, to reach the same level of activity (i.e. number of deliveries). Input efficiency is illustrated in a single input and single output case in Figure 16. In that figure, the technology set is represented by the dashed area. One may see that input *x* can be reduced to *x** without decreasing the output. Input efficiency is given by $E=x^*/x$. Therefore, if $E=0.8$ for instance, it indicates that 20% of input could be saved while still producing the same output. When $E=1$, the firm is efficient, meaning that the level of output it produces cannot be obtained with less input.

Figure 16 – Input efficiency



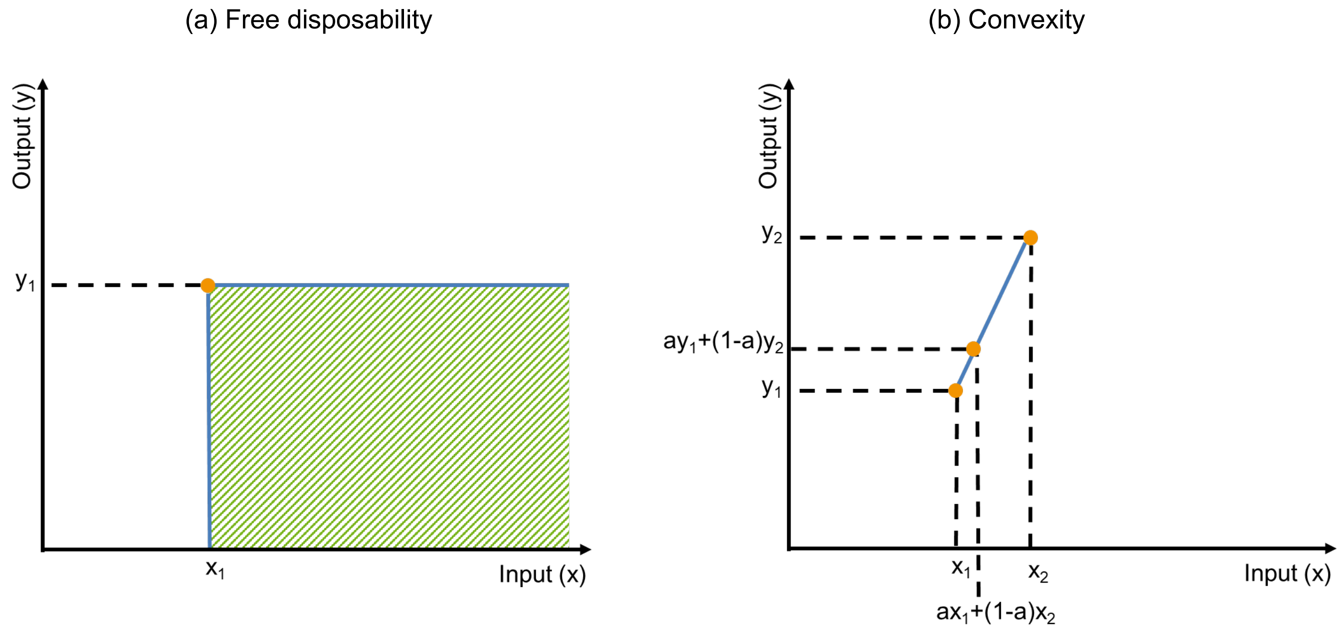
4.2.2 Assumptions about the technology

The different types of DEA models mainly differ in the assumptions they make about the technology. In what follows, we suppose the technology satisfies assumptions of free disposability and convexity. In addition, we consider technologies with constant as well as variable returns to scale.

Free disposability means that if the firm can produce a certain quantity of outputs with a given quantity of inputs, then it can also produce the same quantity of outputs with more inputs (it can freely dispose of surplus inputs). In the same way, the firm can also use the same inputs to produce less outputs (it can freely dispose of surplus outputs). Graphically (in a single input and single output context, see Figure 17), it means that when the firm can produce y_1 using x_1, then all the input-output combinations below and to the right of this data point are also feasible.

Convexity means that if two inputs-outputs combinations are feasible, then a weighted average of them is also feasible. Graphically (in a single input and single output context, see Figure 17), if the firm can produce y_1 using x_1, and y_2 using x_2 then all the input-output combinations located on a straight line between these data points are also feasible.

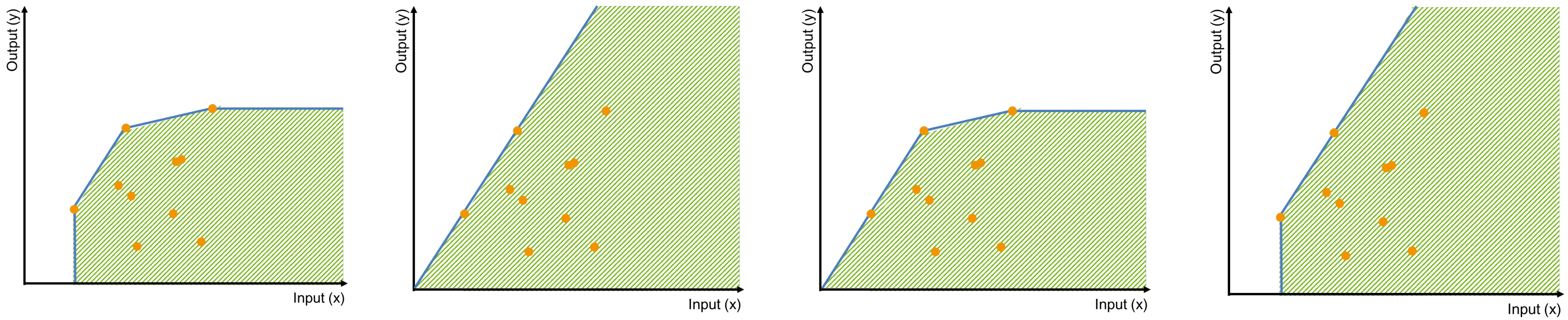
Figure 17 – Assumptions about the technology



The **returns to scale assumption** concerns feasible rescaling. If producing y_1 using x_1 is feasible, then we can also slightly decrease inputs to produce slightly decreased outputs and slightly increased inputs to produce slightly increased outputs. The **variable returns to scale** assumption supposes that no rescaling is possible. The **constant returns to scale** assumption on the other hand implies that any feasible inputs-outputs combination can arbitrarily be scaled up or down. In between, the **decreasing returns to scale** assumption means that the outputs tend to increase less than the inputs and the **increasing returns to scale** assumption means that the outputs tend to increase faster than the inputs. Under decreasing returns to scale it is therefore feasible to scale down but not up, and under increasing returns to scale it is therefore feasible to scale up but not down. Figure 18 depicts technology sets that satisfy free disposability and convexity, using different assumptions regarding the returns to scale.

Figure 18 – Returns to scale assumptions

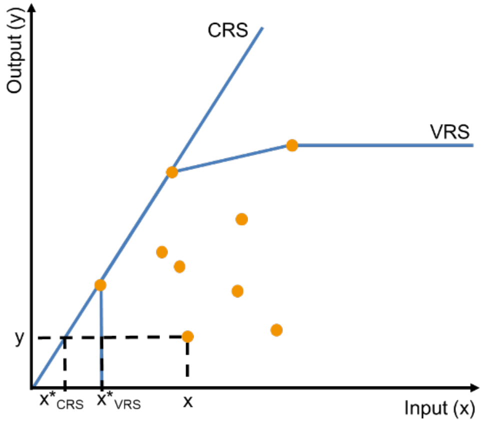
(a) Variable returns to scale (VRS) (b) Constant returns to scale (CRS) (c) Decreasing returns to scale (DRS) (d) Increasing returns to scale (IRS)



In our analysis, we use the two extreme assumptions: constant and variable returns to scale. A variable returns to scale model includes both decreasing and increasing returns to scale. In the DEA literature, the constant returns to scale (CRS) model is often called the CCR model, for Charnes, Cooper and Rhodes due to their seminal papers.[39, 40] The variable returns to scale (VRS) model is often called the BBC model for Banker, Charnes and Cooper.[41] Nevertheless, in what follows, we use the abbreviations CRS and VRS to make the reference to returns to scale easier.

The choice of returns to scale has an impact on the Farrell input efficiency score defined above (see section 4.2.1.2). It may be seen from Figure 18 that the technology set is always larger in the CRS model than in the VRS model (DRS and IRS lying in between). Therefore, the CRS model is more optimistic in the sense that the possibility of improvement for the firms is larger. On the other hand, it means that the firms look less efficient in the CRS model. For any given observed inputs-outputs combination (i.e. for any observed firm), the efficiency score in the CRS model is smaller than or equal to the efficiency score in the VRS model. One may for instance see on Figure 19 that x^*_{CRS}/x is smaller than x^*_{VRS}/x. In the same way, less firms are considered fully efficient (*E=1*) in the CRS than in the VRS model. On Figure 19, three of the observed firms (represented by the orange dots) have a score of one in the VRS model, but only two in the CRS model.

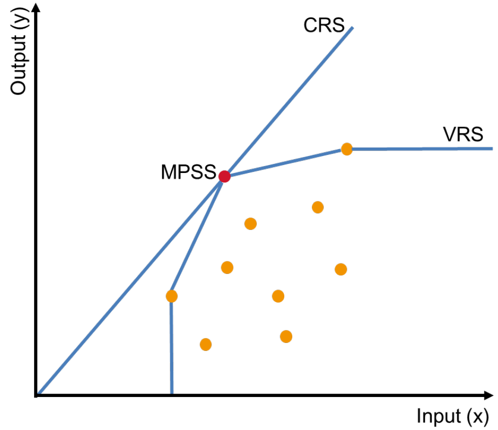
Figure 19 – Input efficiency under CRS and VRS



4.2.3 Overall, technical and scale efficiency

In the CRS model, the returns to scale are fixed by assumption, which is not the case in the VRS model. In a graphical representation of a single input and single output case, one may see that the returns to scale are increasing for small quantities of inputs, then they are constant and finally they are decreasing for large quantities of inputs. Indeed, if one draws a line from the origin to a point on the frontier of the VRS model, the slope of this line first increases, then stalls and finally decreases as we move along from smaller to larger inputs. From an economic perspective, it means that the average product (the quantity of output produced per unit of input) first increases, then is constant and finally decreases. The level of inputs for which the average product is maximum, that is the point where the returns to scale are locally constant, is called the **most productive scale size** (MPSS), as illustrated in Figure 20. This concept has first been suggested by Banker (1984).[41]

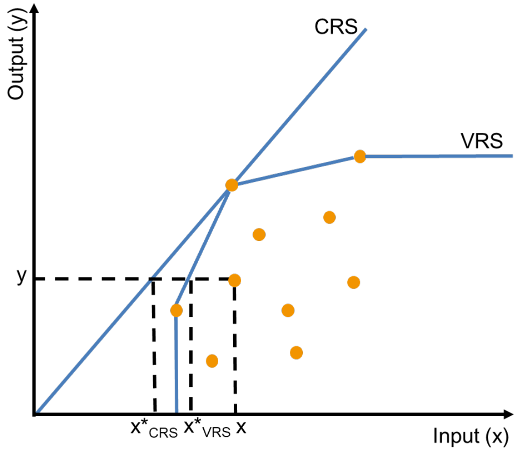
Figure 20 – Most productive scale size



Scale efficiency (SE) measures how close a firm is to operating at the most productive scale size. It is given by the ratio of input efficiency in a CRS model to the one in the VRS model: $SE=E_{CRS}/E_{VRS}$. This ratio ranges between zero and one, and is precisely one when the CRS and VRS technologies coincide, that is when the firm is operating at the most productive scale size.

Therefore, the efficiency score from the CRS model (or **overall efficiency** score) can be decomposed in two elements: **technical efficiency** (ability to use best practices, i.e. to use a small quantity of inputs to produce a given level of output) and **scale efficiency** (ability to operate where the average product is maximal). This is illustrated Figure 21 where *SE* is measured by the ratio between x^*_{CRS}/x and x^*_{VRS}/x.

Figure 21 – Scale efficiency



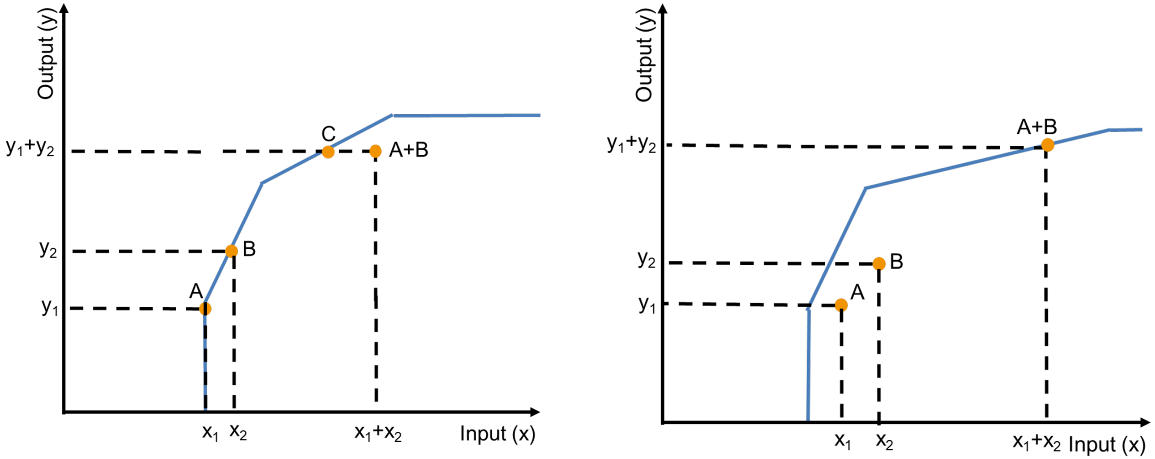
Measuring scale efficiency gives an indication of the structural efficiency of the sector (see section 4.2.4), i.e. to what extent the sector has the right number of firms of the right size.

4.2.4 Structural efficiency

Structural efficiency concerns efficiency at the sector level. In particular, it analyses the potential gains from horizontal integration of two similar firms (or services). For instance, consider two firms, producing respectively y_1 and y_2 using x_1 and x_2 as inputs. First, consider the case where the two firms integrate but continue to operate as separate entities: they will produce together y_1+y_2 using x_1+x_2. The efficiency of this inputs-outputs combination can be evaluated, following the method described before. Even if the two firms were technically efficient before integrating, it does not mean the integrated structure will also be efficient.

On the other hand, two inefficient firms can integrate into an efficient one. These two cases are illustrated in Figure 22. On the left panel, firms A and B are technically efficient, however the integrated structure A+B is not. On the right panel firms A and B are not technically efficient, but A+B is. Obviously the integration can concern more than two firms. The above reasoning can be generalised to direct pooling of the inputs and outputs of several firms.

Figure 22 – Structural efficiency



In reality, integrated firms will not simply pool their inputs and outputs (i.e. continue to operate as separate entities) but will use new synergies to improve their efficiency. For instance, on the left panel of Figure 22, the integrated entity would be able to produce y_1+y_2 using less inputs than x_1+x_2 (see point C in the figure). This possibility for improvement can be summarised using Farrell input efficiency by comparing the horizontal length between A+B and C. Formally, **the potential overall gain from integrating** H firms (denoted E^H) is the maximal proportional reduction in the aggregated inputs that allows the production of the aggregated outputs. If $E^H<1$, the integration produces savings, while if $E^H>1$, the integration is costly. For instance $E^H=0.8$ suggests that 20% of the inputs could be saved by integrating the H firms.

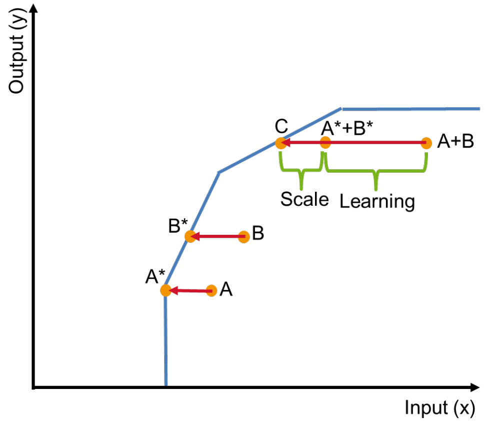
While calculating the overall potential gain is useful, this measure can be refined. Indeed, if the initial firms are not efficient, the assumption that the integrated structure could be efficient can be questioned. Therefore measuring the overall potential gain from integrating leads to overoptimistic conclusions. In addition, some gains could possibly be obtained without integration. To take this into account, one may decompose the overall potential gain measure into several effects:

- **Learning** (or technical efficiency) **effect** is related to the ability to adjust to best practices. If the original firms are not technically efficient, potential gains are available to them, independently of the integration process. In Figure 23, firms A and B are technically inefficient. They have a potential for improvement (moving to A* and B*) even without integration. Therefore, part of the potential improvement of the integrated structure A+B is not associated with the integration (i.e. moving to A*+B*).
- **Scope** (or harmony) **effect** is related to the mix of inputs and the mix of outputs. In a multiple inputs-multiple outputs context, the firms can reallocate the inputs and outputs among themselves. This effect cannot

be shown on a single input-single output illustration such as in Figure 23.

- **Size effect** is associated with economies of scale. When economies of scale are present, it is interesting for firms to become larger, since they can produce at lower average costs. In Figure 23, the remaining part of the potential improvement from integration is due to the size effect (i.e. moving from A*+B* to C).

Figure 23 – Decomposition of potential gain from integrating



These effects can be mathematically decomposed. Denote LE^H (with $LE^H \leq 1$) the learning measure that captures the gains from making the H individual firms technically efficient. Denote HA^H, the harmony measure that captures the scope effect. Denote SI^H, the size measure that captures the gains from operating at full scale. The rescaling is advantageous if $SI^H<1$ and disadvantageous if $SI^H>1$. Summarizing, the potential overall gain from integrating can be decomposed as follows: $E^H=LE^H.HA^H.SI^H$. Ignoring the potential gains from learning, that could be acquired without pooling, the potential gain from pooling is $E^*=HA^H.SI^H$.

4.2.5 Second stage analysis

One may be interested in analysing how some contextual factors may be associated with higher or lower efficiencies, that is analysing whether there are differences between the efficiencies of two types of firms (for instance between university hospitals and non-university hospitals, or between maternity services with and without MIC-beds, etc.). Contextual (or environmental) factors are variables that are beyond the influence of the firm.

To that purpose, we perform univariate analyses that study the impact of maternity services characteristics on efficiency scores, one characteristic at a time. In addition, we perform a multivariate analysis, that also shows how the considered variables are associated with higher or lower efficiencies, but adjust for confounding factors. Although the central question of these analyses concerns scale efficiency, we also present results regarding technical and overall efficiencies for completeness.

There has been an active debate about how to incorporate contextual factors into a DEA model.[42] One possibility is to include these variables directly in the DEA model, as inputs or outputs. However, this would imply that one needs to decide a priori whether the contextual variable is favourable or detrimental to production, which may not always be feasible in practice (see Ray (2004)[43] for the algebra underlying this statement). Another possibility is to estimate the model without contextual variables, and to incorporate them only in a second stage analysis, that uses efficiency scores from the DEA model as the dependent variable. This could raise issues as the dependent variable will comprise a set of serially correlated values.[44] Nevertheless, it has been shown that this two-step procedure yields consistent estimators for the contextual variables. In particular, this two-stage procedure significantly outperforms parametric methods.[45]

The most common approach used to perform the multivariate second stage analysis is the Tobit regression (see Box 9). Indeed, the dependent variable (the efficiency score) is censored, i.e. we only observe values ranging from 0 to 1.

Box 9 – Tobit regression

The Tobit model is a censored regression model that refers to a class of regression models in which the observed dependent variable is subject to an upper and/or lower limit. It generally applies when the variable to be explained is partly continuous but has positive probability mass at one or more points. This occurs mainly for two reasons: either the dependent variable is not observable for part of the population (i.e. the dependent variable is censored above or below some value); or the dependent variable describes an observable choice or outcome for an economic agent that can result in a corner solution.

The Tobit model can be written as:

$$y^* = x\boldsymbol{\beta} + u \qquad u|x \sim \text{Normal}(0, \sigma^2)$$

$$y = \begin{cases} y^* \text{ if } y_L < y^* < y_U \\ y_L \text{ if } y^* \leq y_L \\ y_U \text{ if } y^* \geq y_U \end{cases}$$

where y^* is the latent variable that is censored from above and below, y is the observed dependent variable, y_L and y_U are the censoring values, x is a vector of explanatory variables, β is a vector of parameters and u is the error term.

Partial effects of the explanatory variable x_j can be simplified to:

$$\frac{\partial E(y|x)}{\partial x_j} = \boldsymbol{\Phi}\left(\frac{x\boldsymbol{\beta}}{\sigma}\right)\beta_j$$

where $\boldsymbol{\Phi}$ is the standard normal cumulative distribution function. Although this partial effect is not entirely determined by β_j (there is an adjustment factor multiplying β_j), one may show that the sign of β_j is the same as the sign of the partial effect of x_j.

The interested reader is referred to Wooldridge (2002), Chapter 16.[46]

4.2.6 Sensitivity analysis

One may suspect results from the analysis to be dependent on the assumptions made, in particular concerning the variables chosen to measure inputs and outputs. To check the robustness of the results against different assumptions, we first develop a base model, then define alternative specifications. Three types of alternative models are built. First, we use different variables to define inputs. Second, we use alternative variables for the outputs. Third, we restrict the model to a subset of maternity services, excluding services with given characteristics that may affect the results.

4.2.7 Additional robustness checks

One could also wonder if potential measurement errors in the underlying data affect the results. The bootstrapping method is used to deal with this issue. It consists in sampling observations from the data set to create several new datasets that are considered as ‘random’. Using these datasets, we can calculate the efficiency scores, called replicates. This process is repeated to create a sample of replicates. Based on this sample, we can draw conclusions about the distribution of the efficiency scores.

In a same way, measurement errors may create outliers (decision making units that differ to a large extent from the others). The presence of outliers does not necessarily imply measurement errors, but may simply represent atypical observations. In any case, it could be that these outliers are poorly captured by the model or have a too large impact on the results and it is advisable to check the robustness of the results to the removal of outliers. To that aim, we identified outliers using the ‘data cloud method’ and run alternative DEA models where the identified outliers are removed.[47-49]

4.2.8 DEA analysis for maternity services

The previous parts of section 4.2 explain the DEA method in a non-technical way. However, since DEA is grounded in the economic theory of production, a lot of economic jargon is used. In Table 10 the economic jargon used for the main concepts is translated into a non-economic reader-friendly language, applied to an efficiency measurement of Belgian maternity services.

Table 10 – DEA concepts applied to maternity services

Economic language	Applied to maternity service
Decision making unit (DMU) or firm	Maternity service at a hospital site
Inputs	Resources (staff and beds)
Outputs	Clinical activity (deliveries and other activity)

4.3 Data

This analysis uses two types of data available in the Minimal Hospital Data (MZG – RHM, see Box 3): on the one hand clinical activity by All Patient Refined-Diagnosis Related Group (APR-DRG) and severity of illness (SOI) (see Box 5).and, on the other hand, staff related data. The main variables used in the analysis are presented hereafter. A more elaborate discussion of the data and manipulations of the data can be found in the Data Manual (which is available upon request).

4.3.1 Units of interest

The analyses in this chapter are performed at the level of a hospital site with a maternity service (further called *maternity site*), which may consist of one or more units including maternity beds (bed index M, MIC, AR (labour room) or OB (delivery room) in the MZG – RHM) (see Figure 1).

Selection of clinical activity and staff related data consists of all activity and working time taking place in the M/MIC/AR/OB-units but also in the N*- and NIC-units, all taken together. The main reason for not distinguishing between M/MIC/AR/OB-units and N*- and NIC-units are the observed inconsistencies in staff data registrations (see also Figure 24). In particular, staff from the N*-unit is sometimes recorded in the N*-unit, but sometimes in the M/MIC/AR/OB-unit or in the NIC-unit (for instance because N*- and NIC-units are located at the same place in the hospital). It is therefore impossible to precisely distinguish staff working in the M/MIC/AR/OB-units from staff working in N*- or NIC-units. In addition, as shown in Figure 13, some hospital sites (almost) never register newborns in M/MIC/AR/OB-units or in N*-units. Newborns who are not recorded in M/MIC/AR/OB-units are likely to be recorded in N*-units or in NIC-units, and newborns who are not recorded in N*-units are likely to be recorded in NIC-units or in M/MIC/AR/OB-units. It is therefore impossible to precisely distinguish newborns hospitalised in the M/MIC/AR/OB-units from newborns hospitalised in N*-units and NIC-units.

4.3.2 Period of analysis and number of maternity sites

Although clinical activity data are available for all maternity sites, for each day of the year, this is not the case for staff related data. The analysis is therefore restricted to the hospital sites and time periods for which all information is available. In particular, daily staff data (see section 4.3.3) are recorded during four registration periods in 2016: from 1 to 15 March 2016 (Period 1), from 1 to 15 June 2016 (Period 2), from 1 to 15 September 2016 (Period 3) and from 1 to 15 December 2016 (Period 4). The analysis focuses therefore on these four periods of time.

In Period 1, there were 109 hospital sites with maternity beds. Between Period 1 and Period 2, maternity beds from one of these sites have been transferred to another site that had no maternity beds, so that the number of hospital sites with maternity beds is still 109 in Periods 2 and 3, although one site has been replaced by another. Between Period 3 and Period 4, maternity beds from one of these sites have been transferred to another site (that already had maternity beds), so that the number of hospital sites with maternity beds in Period 4 is 108.

One of the hospital sites did not complete the daily staff registration for the maternity service, for none of the four periods, and is therefore excluded from the analysis. In addition, three sites did not provide daily staff registration for one of the periods (Period 2, 3 and 4 respectively), and one site did not provide daily staff registration for two periods (Periods 2 and 3).

4.3.3 Staff related data

Staff data are collected in two separate files: a periodical registration (‘*EMPLOPER*’) and a daily registration (‘*EMPLODAY*’). These data are not collected continuously through the year. Periodic staff data, that include the number of persons, the number of full-time equivalents (FTEs) and the number of FTEs converted into a 38-hour week, are collected four times a year: at the beginning of March, June, September and December. Any staff member under contract with the institution on the day of registration that has worked at least one working day during that month, is counted. Therefore, to be registered the staff member does not have to have worked on the first day of the month (e.g. in case of sick leave), but he/she must have worked at least one working day during this month. This information is therefore difficult to link to the variability of clinical activity. Daily staff data, that include the number of hours and minutes worked, are collected during four periods each year: the first fifteen days of March, June, September and December. Since 2017, the registration of periodical as well as daily staff data is not mandatory anymore.

The analysis uses daily staff registration data from the four registration periods of 2016. Data are aggregated by registration period. Worked hours and minutes for staff members who actually provide nursing care or support are recorded. If a staff member is absent for a period of more than half a day (e.g. for training), his/her hours of work are not recorded. An absence of less than half a day (e.g. for a meeting) is recorded as working time. Hours worked by nurses and caregivers in floating teams are also registered when this staff replaces or reinforces the nursing team of the care unit (i.e. not if they only perform punctual acts such as sample collection, ECG or social services). Working times are recoded by categories. Descriptive statistics are provided in Table 11. The variation between periods of observation is limited, except for students (CAT6): less hours are recorded for students in September (when the academic year has not started yet) and in June (during the exam session) than during periods 1 and 4.

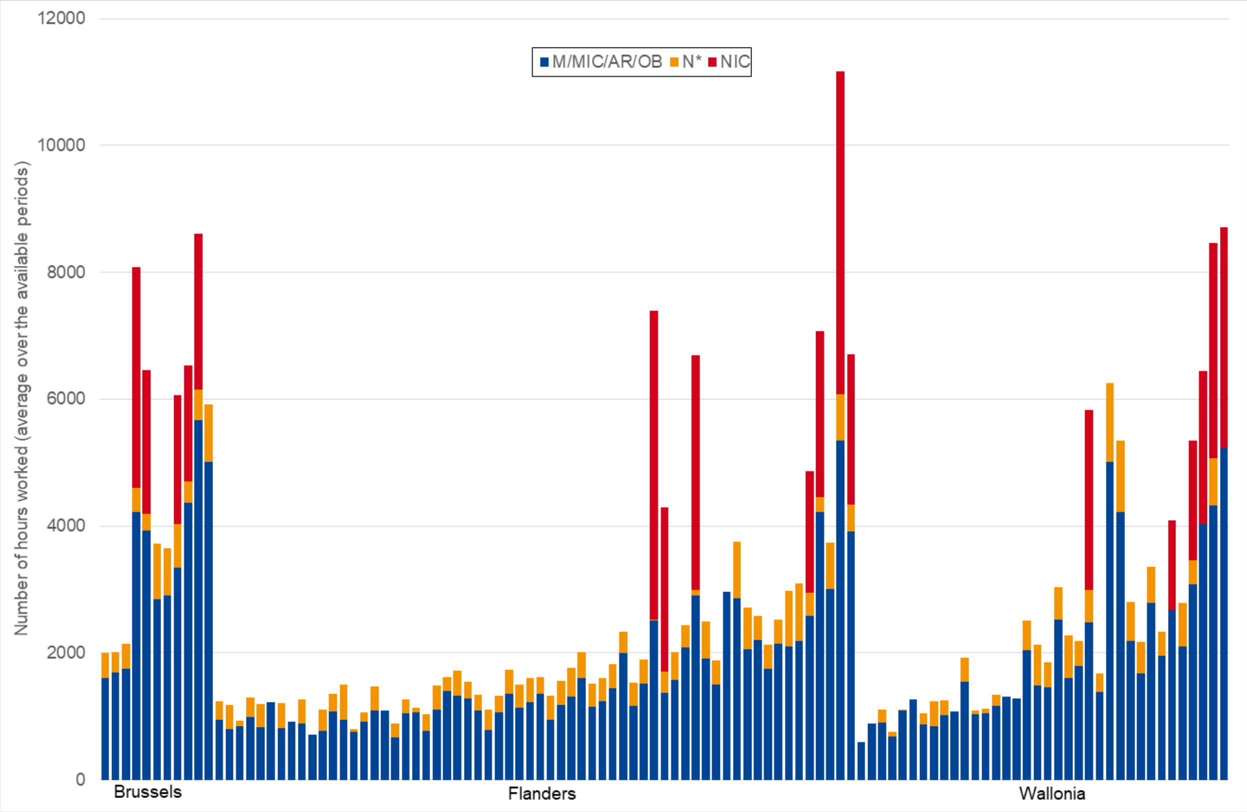
Table 11 – Daily staff registration: summary statistics for 4 periods (2016)

Mean (sd)	Period 1	Period 2	Period 3	Period 4	Average**
Number of hours worked over the period (15 days)					
CAT1: Nurse or midwife with university degree	46.93 (91.9)	47.4 (84.8)	45.8 (92.8)	48.2 (91.3)	46.3 (86.4)
CAT2: Nurse or midwife with higher education degree	2 478.0 (1 978.9)	2 442.0 (1 996.3)	2 455.4 (1 950.8)	2 396.8 (1 894.2)	2 464.1 (1 943.4)
CAT3: Nurse with secondary education degree	32.0 (68.3)	31.0 (65.9)	30.3 (62.5)	28.3 (53.0)	29.9 (59.6)
CAT4: Caregiver staff	61.1 (99.3)	54.1 (95.3)	55.9 (86.8)	53.3 (84.4)	55.1 (87.7)
CAT5: Support staff	108.2 (168.6)	102.6 (170.6)	98.5 (153.3)	98.0 (152.7)	106.3 (165.0)
CAT6: Students	242.8 (310.9)	134.6 (209.3)	56.0 (93.4)	221.9 (313.5)	162.5 (194.6)
N (number of maternity sites*)	108	106	106	106	109

*Period 1: from 1 to 15 March 2016, Period 2: from 1 to 15 June 2016, Period 3: from 1 to 15 September 2016, Period 4: from 1 to 15 December 2016. * The number of maternity sites (109 in periods 1, 2 and 3; 108 in period 4) is reduced because daily staff registration for the maternity service is not available for 1 site in period 1, 3 sites in period 2, 3 sites in period 3 and 2 sites in period 4. ** Average over the available periods.*

Figure 24 shows the distribution of daily staff registration by type of unit. As already stated, some inconsistencies are observed. For several maternity sites, no worked hours are recorded in the N*-unit, but these hours are likely to be recorded the M/MIC/AR/OB-unit or in the NIC-unit. It is therefore impossible to precisely distinguish hours worked in the M/MIC/AR/OB-units from hours worked in N*- or NIC-units. This is the main reason for not distinguishing between M/MIC/AR/OB-units and N*- and NIC-units in the analysis.

Figure 24 – Daily staff registration by type of unit



Number of hours worked by staff in categories CAT1, CAT2, CAT3, CAT4 and CAT5, per maternity site, averaged over the available periods (2016). For most of the maternity sites, data are available for 4 periods. In some cases, less periods are available because the maternity site either closed or opened in 2016, or did not provide daily staff records for some periods. Maternity sites are ranked by region and annual number of deliveries (2016).

4.3.4 Clinical activity data

To measure activity in the different maternity sites, we use data from the 2016 Minimal Hospital Data (MZG – RHM). These data are available on a daily basis, but we focus on the four periods of registration of daily staff data. Daily activity data within each of the periods are aggregated over the period.

Clinical activity in maternity sites can be divided into activity related to newborns on the one hand and activity related to obstetric patients on the other hand. Activity related to obstetric patients can be further divided between (see Box 5):

- Deliveries (MDC 14A). These can be further divided between caesarean and vaginal deliveries.
- Other activity related to pregnancy (MDC 14B).
- Other activity not related to pregnancy (related to gynaecology (MDC 13) or not).

Activity is measured by the number of stays[j] (over each period of interest) for each of the above categories. Stays are recorded both for inpatient stays and day-care activities. Descriptive statistics are provided in Table 12.

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[j] For each period, stays that start within the period as well as stays starting before the period with part of the stay occurring during the period are included.

Table 12 – Clinical activity: summary statistics (2016)

Mean (sd)	Period 1	Period 2	Period 3	Period 4	Average***
Number of stays (inpatient and day-care*) over the period (15 days):					
Vaginal deliveries (APR-DRG 541, 542 and 560)	43.6 (28.5)	44.3 (31.6)	46.6 (30.7)	43.3 (31.4)	44.3 (29.6)
Caesarean deliveries (APR-DRG 540)	12.3 (9.1)	12.6 (9.6)	13.4 (10.6)	12.7 (9.7)	12.7 (9.1)
MDC 14 except deliveries (MDC 14B)	9.9 (7.4)	9.4 (7.0)	9.0 (6.9)	8.9 (6.3)	9.3 (6.1)
MDC 13	3.2 (5.5)	2.4 (4.6)	3.0 (5.4)	2.3 (4.5)	2.9 (4.7)
Other MDCs (except newborns)	5.2 (6.6)	4.2 (6.4)	3.6 (5.9)	5.7 (8.8)	4.7 (5.9)
Newborns	60.8 (41.3)	62.3 (44.8)	64.1 (43.5)	61.2 (43.9)	61.8 (42.3)
Number of inpatient stays over the period (15 days)	130.0 (82.3)	131.5 (89.8)	136.0 (87.1)	130.0 (86.7)	131.5 (84.5)
Number of day-care* stays over the period (15 days)	5.0 (6.2)	3.7 (4.5)	3.6 (4.3)	4.6 (5.6)	4.3 (4.2)
N (number of maternity sites)**	108	106	106	106	109

*Period 1: from 1 to 15 March 2016, Period 2: from 1 to 15 June 2016, Period 3: from 1 to 15 September 2016, Period 4: from 1 to 15 December 2016. MDC = Major Diagnostic Category. * Excluding APR-DRG MMM (see section 3.1). ** The number of maternity sites (109 in periods 1, 2 and 3; 108 in period 4) is reduced because daily staff registration for the maternity service is not available for 1 site in period 1, 3 sites in period 2, 3 sites in period 3 and 2 sites in period 4. *** Average over the available periods.*

Clinical activity is weighted to capture case-mix differences between maternity sites

As stays cannot be directly summed-up (for instance some are more severe than others and/or require more care than others), we adjust them by the average length of stay per APR-DRG-SOI in all Belgian hospitals in 2016, available from the National financial feedback by pathology published by the Technical Cell on its website.[k] This average length of stay is not specific to the M/MIC/AR/OB, N* or NIC units but is calculated for the entire hospital stay. Concretely, in our analysis, a stay that only partially takes place in the maternity service is weighted the same way as a stay with the same APR-DRG-SOI that takes place entirely in the maternity service. For day-care stays, a length of stay of 0.81 day is used (which is the length of stay used in the payment system for surgical day-care stays).

In a sensitivity analysis, we also adjust stays by the relative weight per APR-DRG-SOI developed by 3M: a relative average value assigned to each APR-DRG-SOI that indicates the amount of resources required to treat patients in the group, as compared to all other APR-DRGs within the system. Here also, no specific adjustment is made for stays that only partially take place in the maternity or neonatal care services. More details on these adjustment can be found in sections 3.1.2 and 3.2.3.

4.3.5 Capital input

Capital input is approximated by the number of licensed M-beds (maternity beds including MIC-beds) available in the maternity service during the period of interest (see section 1.4 for the meaning of MIC-beds). Note that the number of licensed M-beds can be larger than the number of beds actually used in the maternity service (operational beds).

Table 13 – Licensed M-beds: summary statistics (2016)

Mean (sd)	Period 1	Period 2	Period 3	Period 4	Average**
Number of licensed M-beds (including MIC-beds)	28.6 (16.1)	28.6 (16.2)	28.3 (16.1)	28.6 (16.4)	28.6 (16.1)
N (number of maternity sites*)	108	106	106	106	109

*Period 1: from 1 to 15 March 2016, Period 2: from 1 to 15 June 2016, Period 3: from 1 to 15 September 2016, Period 4: from 1 to 15 December 2016. * The number of maternity sites (109 in periods 1, 2 and 3; 108 in period 4) is reduced because daily staff registration for the maternity service is not available for 1 site in period 1, 3 sites in period 2, 3 sites in period 3 and 2 sites in period 4. ** Average over the available periods.*

[k] https://tct.fgov.be

4.4 Results

4.4.1 Base model

Number of hours worked and staff categories

The base model relates the daily staff records and the number of maternity beds to the clinical activity of the maternity site (including stays in a maternity or neonatal care bed). To calculate the number of hours worked over the four periods, no distinction is made according to the category (qualification) of the staff member. Hence, CAT1 to CAT5 (see Table 11) are taken as one group in the analysis but hours worked by students (CAT6) are excluded. The reason for not distinguishing between CAT1 to CAT5 is because the available data do not allow to assess whether different staff categories contribute differently to clinical activity. Hence, although we can assume that logistics or administrative assistants (CAT5), caregivers (CAT4) and to a smaller extent nurses with secondary education degree (CAT3) do not contribute directly, or less directly to clinical activity than midwives or nurses in CAT1 and CAT2, their number of hours worked cannot be linked directly to their 'outputs'. However, nurses and midwives with a higher education degree (CAT2) represent by far the largest group of staff within maternity services and therefore the input of this group will dominate the results of the analysis. To take the impact of CAT3 to CAT5 into account, we also run alternative models that excludes these categories of staff (see section 4.4.4). Hours worked by students are not included in the base model. Indeed, although students contribute to clinical activity, their presence also consumes resources (for teaching/monitoring) that is not translated into larger clinical activity. It is therefore difficult to assess, a priori, if hours worked by students could be included in the model as an input, or rather as an output.

Number of hours worked and type of unit

The number of hours worked in the selected periods is also considered independently of the type of unit (M/MIC/AR/OB, N* or NIC) where they have been registered. Indeed, although clinical activity in M/MIC-beds should be related to staff work registered in the M/MIC/AR/OB-units, we have noted inconsistencies in the way hours are registered. In particular, hours worked in an N*-unit are sometimes recorded in the N*-unit, but sometimes in the M/MIC/AR/OB-unit or NIC-unit (for instance because N*- and NIC-units are located at the same place in the hospital). It is therefore impossible to precisely distinguish hours worked in the M/MIC/AR/OB-units from hours worked in N*- or NIC-units. For that reason, hours recorded in the three types of units are counted together.

Clinical activity

Clinical activity is restricted to deliveries (with a distinction between vaginal deliveries and caesareans), related activities (MDC 14B) and activities related to newborns (mainly MDC 15). Stays are adjusted by the average length of stay per APR-DRG-SOI in all Belgian hospitals in 2016. Although the aim of the analysis is not to assess which type of care should take place in the maternity service, we exclude activity (except for newborns) that is outside MDC 14 (more details can be found in section 3.1.2). Indeed, the magnitude and composition of this activity is very heterogeneous among maternity services and is likely to depend on organisational choices within the hospitals. It is not clear whether these activities require the same type and quantity of resources as activities related to pregnancy or newborns. Including these extra activities in the base model could lead to underestimating (technical) efficiency scores for maternity sites that focus their activities on pregnancy, delivery and care of the newborn. Nevertheless, we verify the impact of omitting this part of the activity in a subsequent model (see section 4.4.4).

Average measure for inputs and outputs

For each maternity site, information for each of the periods for daily staff records, number of maternity beds and clinical activity is averaged over the available periods (four for most of the maternity sites, less for maternity sites that either closed or opened in 2016, or did not provide daily staff records for some periods) in order to avoid seasonal effects. Table 14 shows summary statistics (over the 109 maternity sites) of the variables used in the base model.

Table 14 – Variables in the base DEA model

Average over the available periods*	By maternity site (N=109)			
	Mean	Standard deviation	Minimum	Maximum
Number of hours worked over the period (CAT1, CAT2, CAT3, CAT4 and CAT5)	2 701.7	2 187.6	591.5	11 166.1
Number of licensed M-beds (including MIC-beds)	28.6	16.1	10.0	105.0
Number of vaginal deliveries (APR-DRG 541, 542 and 560) (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI	151.8	103.8	15.6	509.2
Number of caesarean deliveries (APR-DRG 540) (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI	67.7	53.2	4.8	272.4
Number of stays in MDC 14B (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI	26.5	18.0	2.9	92.7
Number of newborn stays (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI	370.0	449.0	24.0	2 218.0

** For most of the maternity sites, data are available for 4 periods. In some cases, less periods are available because the maternity site either closed or opened in 2016, or did not provide daily staff records for some periods.*

Efficiency scores

Table 15 shows the results regarding scale, technical and overall efficiency scores of the base DEA model. The results for structural efficiency are reported in Chapter 5. The mean value of the technical efficiency score equals 0.88. This means that, on average, 12% of the resources could be saved (1-0.88=0.12). Hence, technical inefficiency is observed in Belgian maternity sites. However, about a third of the sample (36/109) is technically efficient. This does not mean that these maternity sites are overall efficient, as under- and over-sized services are not scale efficient.

Indeed, on average, resources could be reduced by 23% to reach overall efficiency, as shown by the mean overall efficiency score (1-0.77=0.23). The mean scale inefficiency level is 13% (1-0.87=0.13). However, 12 maternity sites experience constant return to scale (scale efficiency score equal to 1) and are considered as scale efficient. Actually most sites are close to the constant returns to scale frontier (median of scale efficiency score is 0.89, third quartile is 0.97, not far from 1), but some are further from this frontier (minimum scale efficiency score is 0.44).

Table 15 – Results of the base DEA model

	Overall efficiency score (E_{CRS})	Technical efficiency score (E_{VRS})	Scale efficiency score ($SE=E_{CRS}/E_{VRS}$)
Mean	0.77	0.88	0.87
Standard deviation	0.16	0.12	0.13
Minimum	0.37	0.46	0.44
Q1	0.66	0.79	0.81
Median	0.79	0.91	0.89
Q3	0.87	1	0.97
Maximum	1	1	1
Number of efficient units (score=1)	12	36	12

N=109.

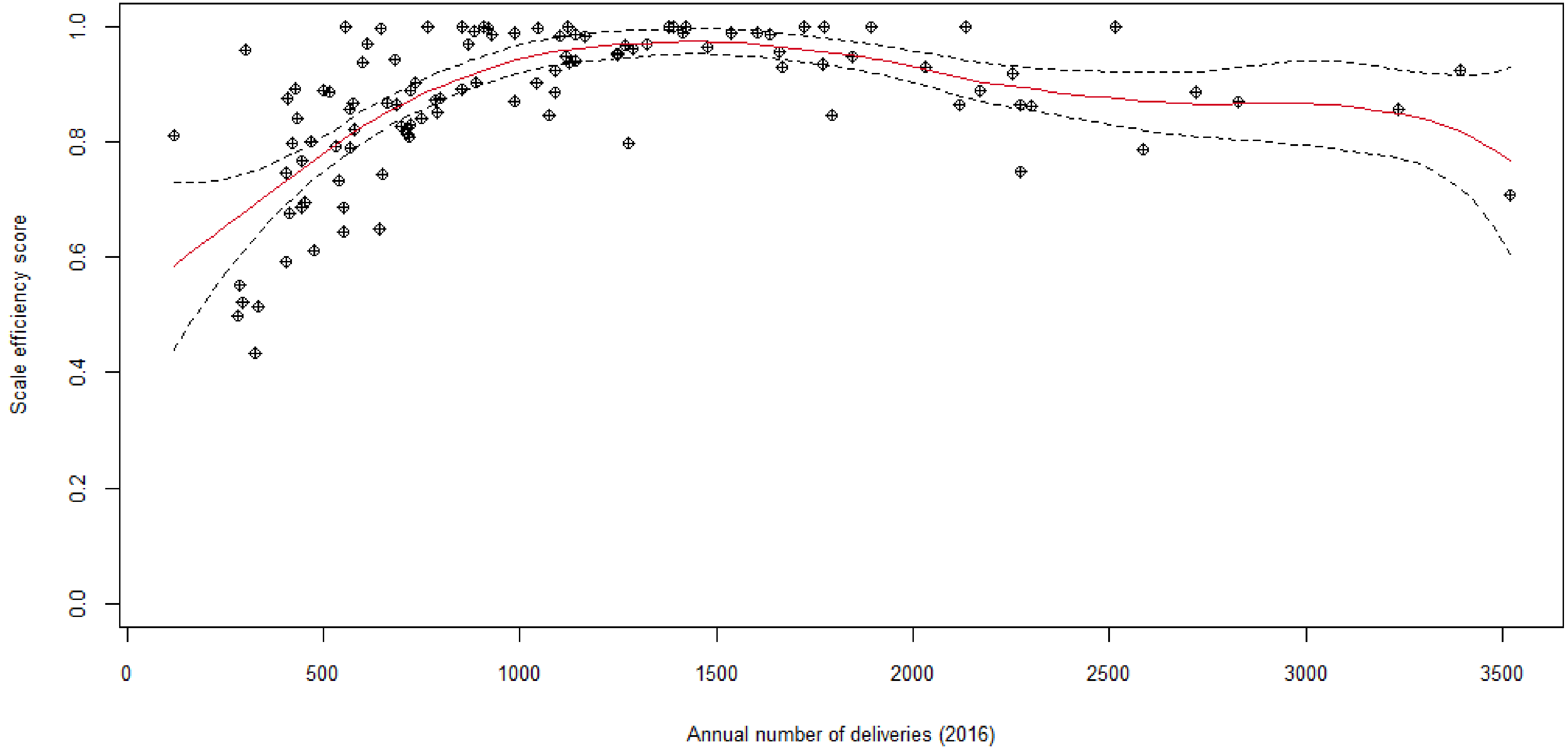
4.4.2 Minimum efficient scale

Figure 25 shows the scale efficiency score of each maternity site with maternity sites ranked from the smallest to largest, in terms of annual number of deliveries.

As expected, Figure 25 presents an inverse U-shape, indicating that returns to scale are increasing for small services, are constant for middle-sized services, and are decreasing for the largest services. This implies that – if services operate technically efficient – the average cost is decreasing for small services, constant for middle-sized services, and increasing for the largest services. The conclusions related to the latter group should be interpreted with caution as very few maternity services operate at such large scale, so that the confidence interval illustrated in **Error! Reference source not found.** is particularly large for this group of maternity sites.

The smallest (in terms of number of deliveries) maternity site which operates in the output range where constant returns to scale are observed (i.e. the smallest maternity site for which the scale efficiency score is equal to 1) had 557 deliveries in 2016 (see Table 16). This corresponds to the minimum efficient scale or the minimum number of deliveries for a maternity site to be scale efficient. Amongst the 25 maternity sites with less than 557 deliveries in 2016, the average scale efficiency score is 0.72, while it is 0.92 on average for maternity sites with 557 or more deliveries in 2016.

Figure 25 – Base DEA model: scale efficiency scores



Each dot represents an observation (a maternity site). The red line represents a Gaussian Kernel smoothing, that is the weighted average of neighbouring observed data $f(x) = \sum_{i=1}^{n} W_{hi} y_i$ *where the weight is* $W_{hi} = K(\frac{x-x_i}{h}) / \sum_{i=1}^{n} K(\frac{x-x_i}{h})$*, where K(.) is the standard Gaussian density and h is a bandwidth equal to 1 000 annual deliveries. The black dashed lines represent the upper and lower bound of a 95% confidence interval.*

Table 16 – Base DEA model: minimum efficient scale

Minimum efficiency scale and score measures	
Minimum efficient scale (annual number of deliveries)	557
Number of maternity sites with scale efficiency score < 1	97
Number of maternity sites smaller than the minimum efficient scale (in terms of annual number of deliveries)	25
Average scale efficiency score for maternity sites smaller than the minimum efficient scale	0.72
Average scale efficiency score for maternity sites larger than or equal to the minimum efficient scale	0.92

N=109

Table 17 presents summary statistics for the scale efficiency scores for groups of maternity sites with increasing number of annual deliveries (ranges of 500 deliveries). It shows how scale efficiency scores evolve when the annual number of deliveries increases. The average scale efficiency score increases as we move to groups of larger maternity sites, up to the group of maternity sites with 900-1 400 deliveries per year, then stabilises around 0.95. At the same time, variability (coefficient of variation) in scale efficiency scores decreases sharply for groups of small maternity sites, then stabilises from the group of maternity sites with 900-1 400 deliveries per year. This is also illustrated by Figure 26.

The percentage of maternity sites with a high scale efficiency score (above 0.80, 0.90 or 0.95) also increases as the range of annual deliveries increases. In the group of maternity sites with 400 to 900 deliveries per year, only 15% (resp. 23% and 69%) have a scale efficiency score above 0.95 (resp. 0.90 and 0.80). This proportion is 64% (resp. 84% and 96%) for the group of maternity sites performing 900 to 1 400 deliveries per year. Figure 27 shows that the proportion of maternity sites with a scale efficiency score above 0.80 starts stabilising in the range of 700-1 200 deliveries per year. The percentage of maternity sites with a scale efficiency score above 0.9 starts stabilising in the range of 1 100-1 600 deliveries per year. The maximum proportion of maternity sites with a scale efficiency score above 0.95 is found in maternity sites with 1 200-1 700 deliveries per year.

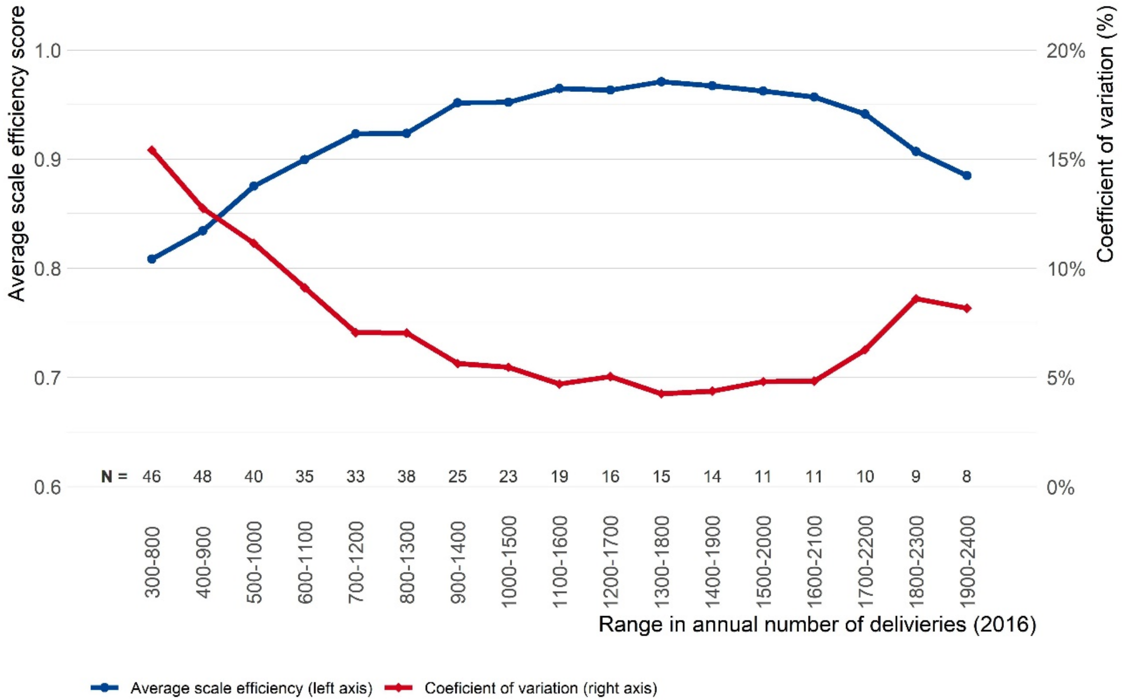
Therefore, although the minimum efficient scale is 557 in the base model, maternity sites may still benefit from economies of scale by increasing their scale above this threshold, at least up to 900-1 000 deliveries per year.

Table 17 – Summary statistics for scale efficiency scores of groups of maternity sites according to the annual number of deliveries

Annual deliveries	Number of maternity sites	Mean SE	Standard deviation SE	Sites with SE>0.8	Sites with SE>0.9	Sites with SE>0.95
200-700	38	0.47	0.51	15.79%	10.53%	2.63%
300-800	46	0.81	0.12	63.04%	17.39%	10.87%
400-900	48	0.83	0.11	68.75%	22.92%	14.58%
500-1 000	40	0.88	0.10	82.50%	37.50%	27.50%
600-1 100	35	0.90	0.08	94.29%	48.57%	31.43%
700-1 200	33	0.92	0.07	100.00%	60.61%	39.39%
800-1 300	38	0.92	0.07	97.37%	63.16%	44.74%
900-1 400	25	0.95	0.05	96.00%	84.00%	64.00%
1 000-1 500	23	0.95	0.05	95.65%	86.96%	65.22%
1 100-1 600	19	0.96	0.05	94.74%	94.74%	78.95%
1 200-1 700	16	0.96	0.05	93.75%	93.75%	87.50%
1 300-1 800	15	0.97	0.04	100.00%	93.33%	80.00%
1 400-1 900	14	0.97	0.04	100.00%	92.86%	71.43%
1 500-2 000	11	0.96	0.05	100.00%	90.91%	63.64%
1 600-2 100	11	0.96	0.05	100.00%	90.91%	54.55%
1 700-2 200	10	0.94	0.06	100.00%	70.00%	40.00%
1 800-2 300	9	0.91	0.08	88.89%	55.56%	22.22%
1 900-2 400	8	0.88	0.07	87.50%	37.50%	12.50%
2 000-2 500	8	0.88	0.07	87.50%	37.50%	12.50%

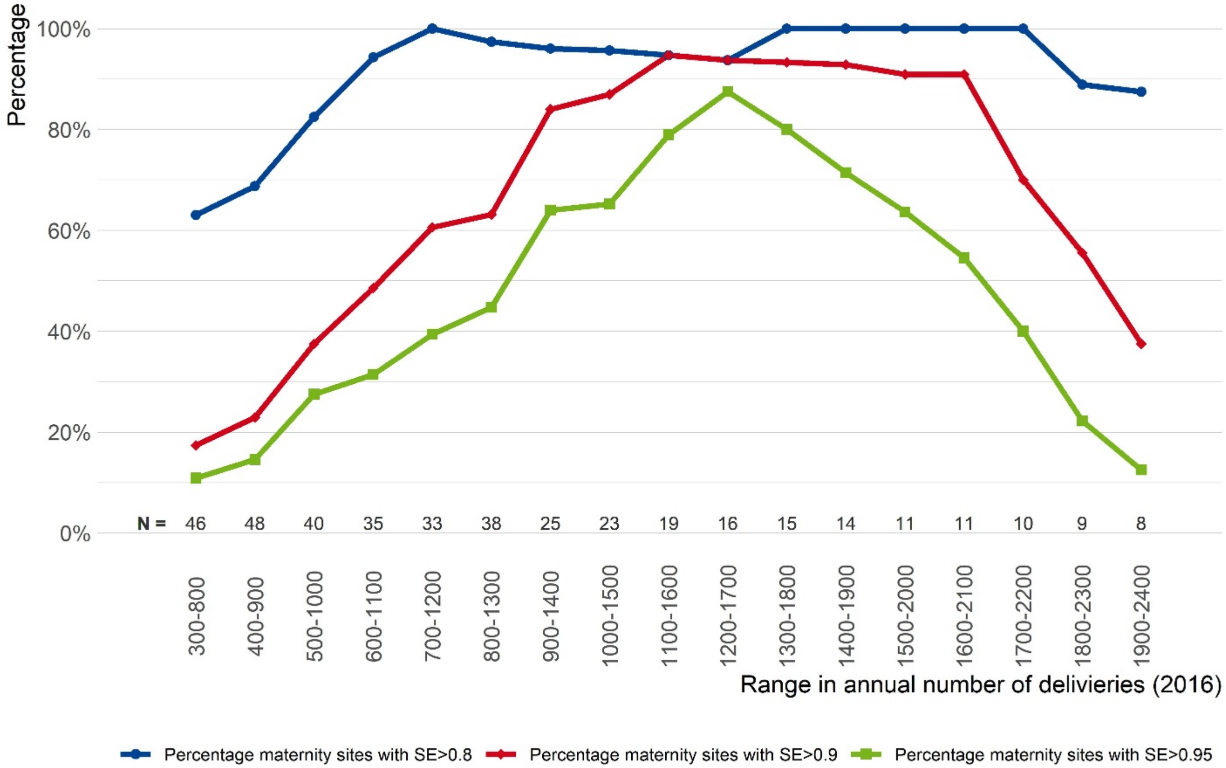
SE= scale efficiency score.

Figure 26 – Scale efficiency score: average and coefficient of variation for groups of maternity sites according to the annual number of deliveries



Coefficient of variation for the scale efficiency score is defined as the ratio between standard deviation and mean.

Figure 27 – Percentage of maternity sites with high scale efficiency scores for groups of maternity sites according to the annual number of deliveries



SE= scale efficiency score.

4.4.3 Second stage analysis

4.4.3.1 Univariate analyses

University hospitals

University hospitals have, on average, higher technical (and overall) efficiency scores than other hospitals (see Table 18). A possible explanation is that university hospitals employ more students and that this staff category (which is not accounted for in the resources in the base model) contributes to clinical activity. Another possible explanation lies in the more severe case mix of these hospitals. Indeed, in the base model, stays are weighted by the average length of stay per APR-DRG-SOI at the national level. However, this average length of stay may not be representative of the intensity of resources required. In particular, for long stays, it is possible that our measure overestimates the clinical activity of the service. Finally, university hospitals have to meet different licensing standards and may be able to organise their (staff) resources differently.

There is no such large difference in scale efficiency. Nevertheless, university hospitals tend to be larger (in terms of annual number of deliveries) and are therefore more likely to operate where returns to scale are constant (i.e. are more likely to operate above the minimum efficient scale).

These results regarding university hospitals must be interpreted with caution due to the small number of observations (seven university hospitals).

MIC-beds

Maternity sites with MIC-beds also have, on average, higher technical (and overall) efficiency scores than other maternity sites. A similar explanation, lying in the overestimation of the clinical activity for maternity sites with severe case mix (because the average length of stay overestimates the required resources for long stays) may apply. No difference in scale efficiency score is observed between maternity sites with and without MIC-beds.

Socioeconomic context

Because of low socioeconomic status (that translates into a more extensive use of the social services of the hospital and a longer length of stay because of lack of support at home), some patients require a higher use of resources that is not accounted for in the APR-DRG system. Maternity sites where a large share of the patients generate such extra work could appear as technically inefficient in the DEA analysis. To take this into account, we use data from the hospital budget for patients with a low socioeconomic status. Since 2002, part of the hospital budget (B8) is a specific budget for these patients. A score is calculated for each hospital based on the proportion of patients entitled to the social maximum billing; the proportion of patients entitled to the income maximum billing and single; and the proportion of homeless persons whose hospital costs are reimbursed by the Federal Public Planning Service for Social Integration, anti-Poverty Policy, Social Economy to the public centre for social welfare (OCMW – CPAS).[l] Hospitals with a score above the median receive payments from the B8-budget for patients with a low socioeconomic status.

According to Table 18, maternity sites belonging to a hospital whose score is above the median show, on average, slightly lower efficiency scores (overall, technical and scale efficiency).

The B8 part of the hospital budget also distributes a closed budget to take account of specific language problems or cultural characteristics of patients. Maternity sites belonging to such a hospital have, on average, similar technical efficiency scores as other maternity sites.

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[l] For more details on the B8 budget, the reader is referred to Van de Voorde et al. (2014)[18] Chapter 5.

Of course, it is possible that the socioeconomic status of patients for the hospital as a whole diverges from the socioeconomic patient profile of the maternity service in particular. In that case, the above proxies do not capture the specific socioeconomic profile and corresponding input of resources of the maternity service. There is, however, no other measure available in routinely registered data.

Breastfeeding counselling activities

As breastfeeding counselling during the postpartum period is an activity that may be time consuming for the midwives, maternity sites that put more effort in this activity (that is not registered per se in the clinical activity as we measured it here) may appear to be less (technically) efficient. No reliable data are available on the breastfeeding rate by maternity site, but since 2008, maternity services can receive a label 'Baby Friendly Hospital Initiative' if their breastfeeding encouragement policy fulfils certain conditions.[50] We can use this label as a proxy to measure the efforts and resources a maternity site dedicates to encourage breastfeeding.

Table 18 shows no large differences in efficiency scores for these maternity sites. If anything, maternity sites that have received the 'Baby Friendly Hospital Initiative' label have, on average, slightly higher efficiency scores (overall, technical and scale efficiency) than other maternity sites. An explanation might be that all maternity services are now involved in breastfeeding policy encouragement and the label is not a distinguishing measure to assess the additional resources required by these policies.

Vaginal deliveries without epidural injections

In the measure we use for (vaginal) delivery, no distinction is made between deliveries with or without epidural injection. However, it may be argued that providing care during labour and delivery to a woman who did not receive an epidural injection is more time consuming for the midwives and nurses. On the other hand, postpartum care is likely to require more resources when the delivery has taken place under epidural anaesthesia. If the former effect dominates, maternity sites where a larger proportion of deliveries take place without epidural injection may appear less (technically) efficient. If the latter effect dominates, the technical efficiency scores would be overestimated for these maternity sites.

To identify epidural injections, we use billing data coupled with the MZG – RHM. These data are available at the hospital level only (not at the hospital site level) and are not available for every delivery (i.e. not all data are coupled). These data allow us to calculate the ratio of vaginal deliveries for which an epidural anaesthesia is billed[m]. On average, this ratio amounts to 70.2% for maternity services in Wallonia, 68.7% in Brussels and 63.5% in Flanders. As comparison, CEpiP reports that the percentage of epidural anaesthesia among vaginal deliveries as recorded on birth certificates is 75.7% in Wallonia and 69.2% in Brussels.[26, 28] In Flanders, SPE reports 75.4% for nulliparous women and 55.1% for multiparous ones.[27]

As results in Table 18 indicate, maternity sites where a large part of the vaginal deliveries occur without epidural injection appear to be, on average, more technically efficient than the others, likely because postpartum care consumes less resources when no epidural injection is performed. On the other hand, these maternity sites have, on average, lower scale efficiency scores (see also Figure 33).

[m] Nomenclature codes used to identify epidural anaesthesia are the following: 202016-202020; 202090-202101; 202193-202204.

Table 18 – Group differences

	Overall efficiency score (E_{CRS}) Mean (sd)	Technical efficiency score (E_{VRS}) Mean (sd)	Scale efficiency score ($SE=E_{CRS}/E_{VRS}$) Mean (sd)
University hospitals			
University hospitals (N=7)	0.91 (0.10)	0.98 (0.06)	0.93 (0.10)
University-like general hospitals (N=20)	0.76 (0.16)	0.88 (0.13)	0.86 (0.11)
General hospitals (N=82)	0.76 (0.16)	0.87 (0.12)	0.87 (0.13)
MIC-beds			
Maternity site without MIC-beds (N=91)	0.75 (0.16)	0.87 (0.12)	0.87 (0.13)
Maternity site with MIC-beds (N=18)	0.83 (0.11)	0.93 (0.10)	0.89 (0.09)
Maternity site belonging to a hospital with score for B8-budget for patients with a low socioeconomic status			
lower than or equal to the median (N=56)*	0.80 (0.15)	0.90 (0.10)	0.89 (0.13)
above the median (N=51)*	0.74 (0.16)	0.86 (0.13)	0.86 (0.13)
Maternity site belonging to a hospital with B8-budget for intercultural mediation and communication			
no (N=77)*	0.76 (0.16)	0.88 (0.11)	0.86 (0.13)
yes (N=30)*	0.78 (0.16)	0.87 (0.15)	0.90 (0.11)
Maternity service with Baby Friendly Hospital label			
no (N=85)	0.75 (0.17)	0.87 (0.13)	0.86 (0.14)
yes (N=24)	0.81 (0.12)	0.90 (0.10)	0.90 (0.09)
Maternity site with percentage of vaginal deliveries with epidural injection			
in]60%-90%) (N=79)	0.77 (0.16)	0.88 (0.13)	0.88 (0.12)
in]50%-60%) (N=19)	0.75 (0.17)	0.87 (0.12)	0.86 (0.13)
in (15%-50%) (N=11)	0.76 (0.16)	0.93 (0.08)	0.82 (0.18)

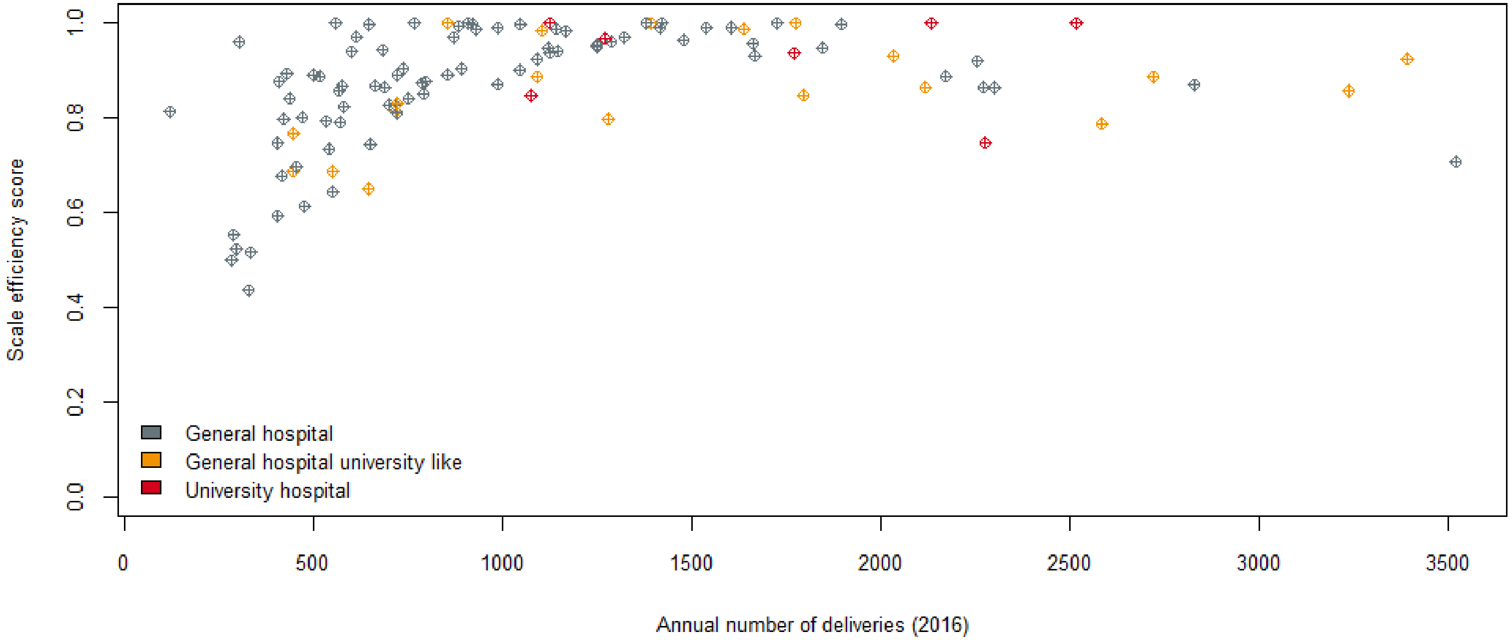
*N=109. *N=107 (missing data for 2 maternity sites)*

4.4.3.2 *Impact of contextual factors on scale efficiency scores*

University hospitals

In Figure 28 maternity sites of university and university-like hospitals (these are general hospitals without a medical school that are allocated a number of university beds) are identified respectively in orange and red. Maternity sites in these hospitals are not concentrated neither amongst the least nor amongst the most scale efficient maternity sites. Most maternity sites in university hospitals operate in the activity range where returns to scale are constant. Most (but not all) of these maternity sites show scale efficiency scores close to one.

Figure 28 – Scale efficiency scores of university and non-university hospitals

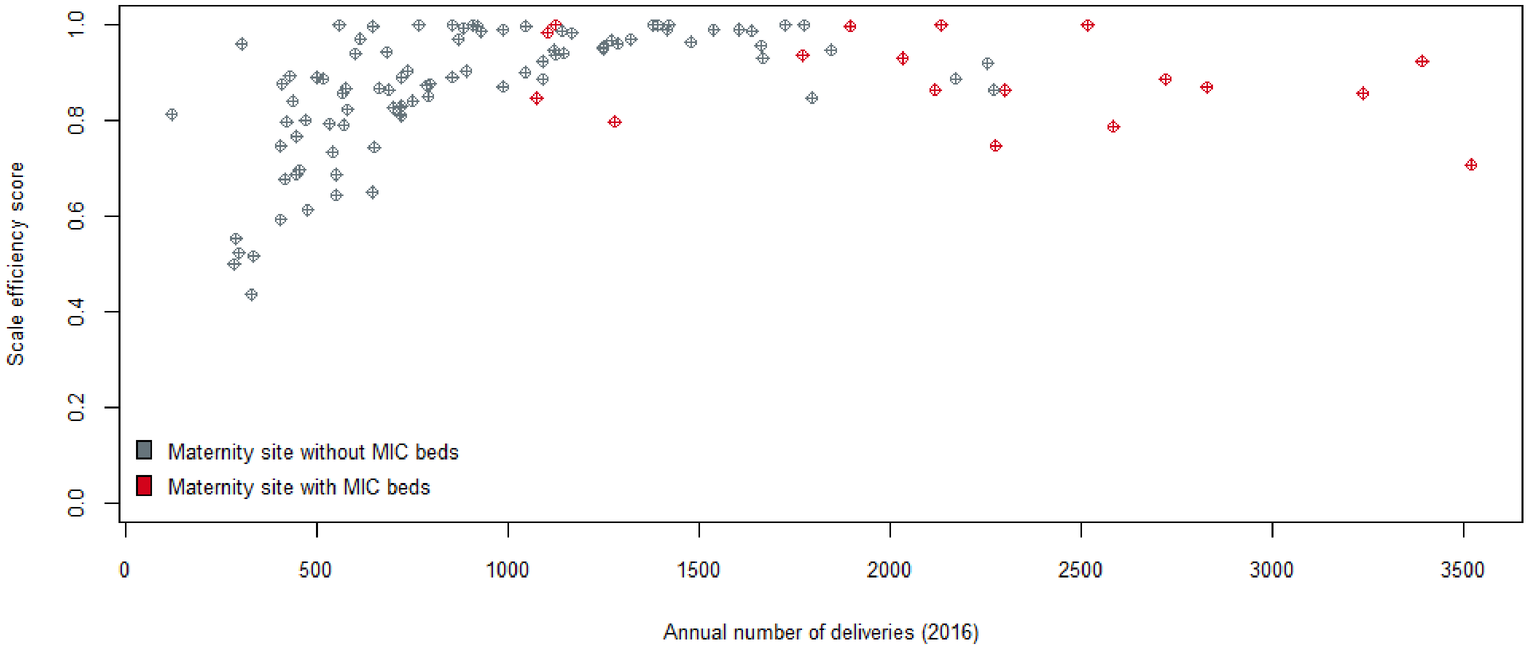


MIC-beds

In Figure 29 maternity sites with MIC-beds are identified in red. These maternity sites are concentrated amongst the largest ones (in terms of number of deliveries), and therefore are larger than the minimum efficient scale. It is also worth noting that some of these units are located in the part of the figure where returns to scale are decreasing. Actually, all maternity sites at this right part of the figure have MIC-beds. Nevertheless, as there are very few maternity sites performing more than 2 000 deliveries per year it is difficult to draw reliable conclusions for this group (the confidence interval illustrated in Figure 25 is particularly large for this group of maternity sites).

Although, on average, the group of maternity sites with MIC-beds is not more scale efficient than the group of other maternity sites (see Table 18), a major distinction can be made. The group of maternity sites without MIC-beds is composed of maternity sites operating at the efficient scale and of maternity sites operating below the minimum efficient scale (i.e. experiencing increasing returns to scale), while the group of maternity sites with MIC-beds is composed of maternity sites operating at the efficient scale and of maternity sites experiencing decreasing returns to scale.

Figure 29 – Scale efficiency scores: presence of MIC-beds

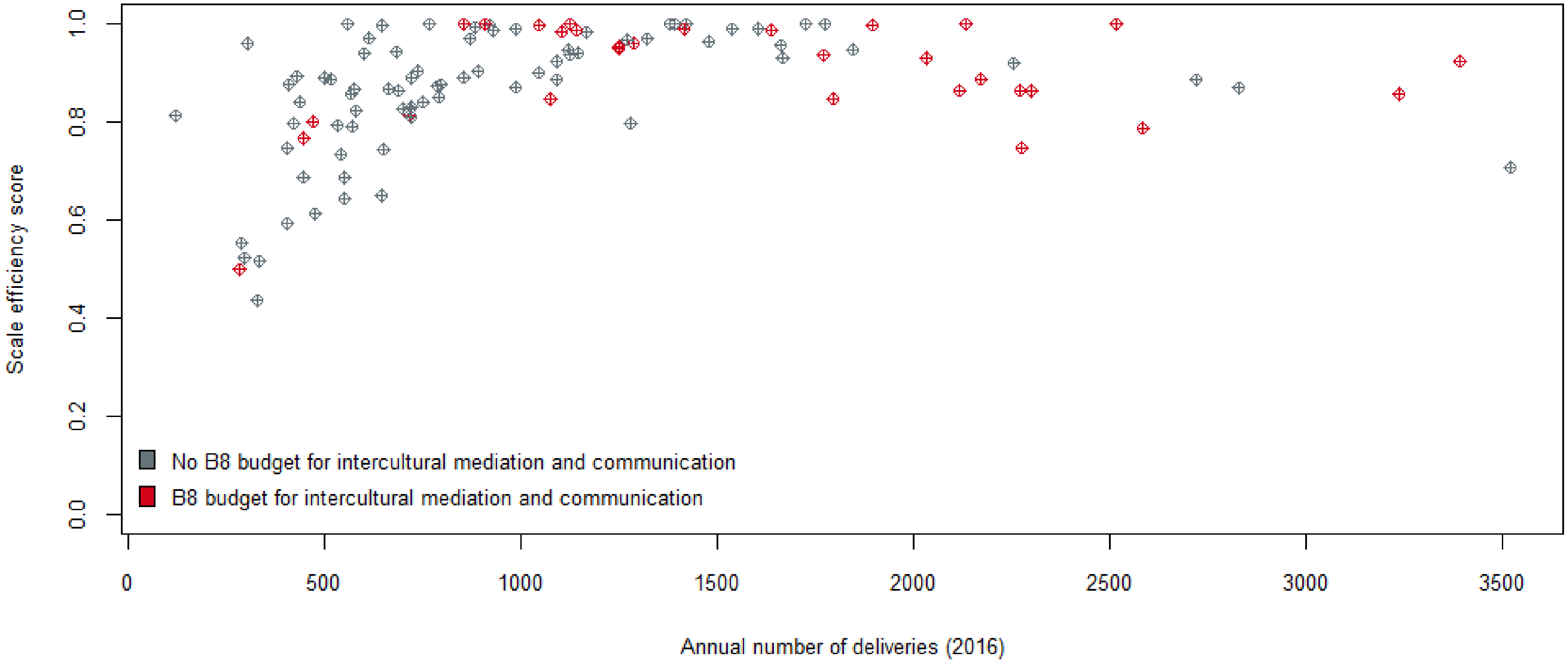


Socioeconomic context

In Figure 30, maternity sites belonging to a hospital whose score for the proportion of patients with low socioeconomic status is above the median are identified in red. These maternity sites do not seem to be concentrated among the least nor among the most scale efficient ones. Maternity sites belonging to a hospital entitled to a B8 budget to take account of specific language problems or cultural characteristics of patients are identified in red in Figure 31. These maternity sites are not concentrated among the least nor among the most scale efficient ones.

Figure 30 – Scale efficiency scores: B8-budget for patients with a low socioeconomic status

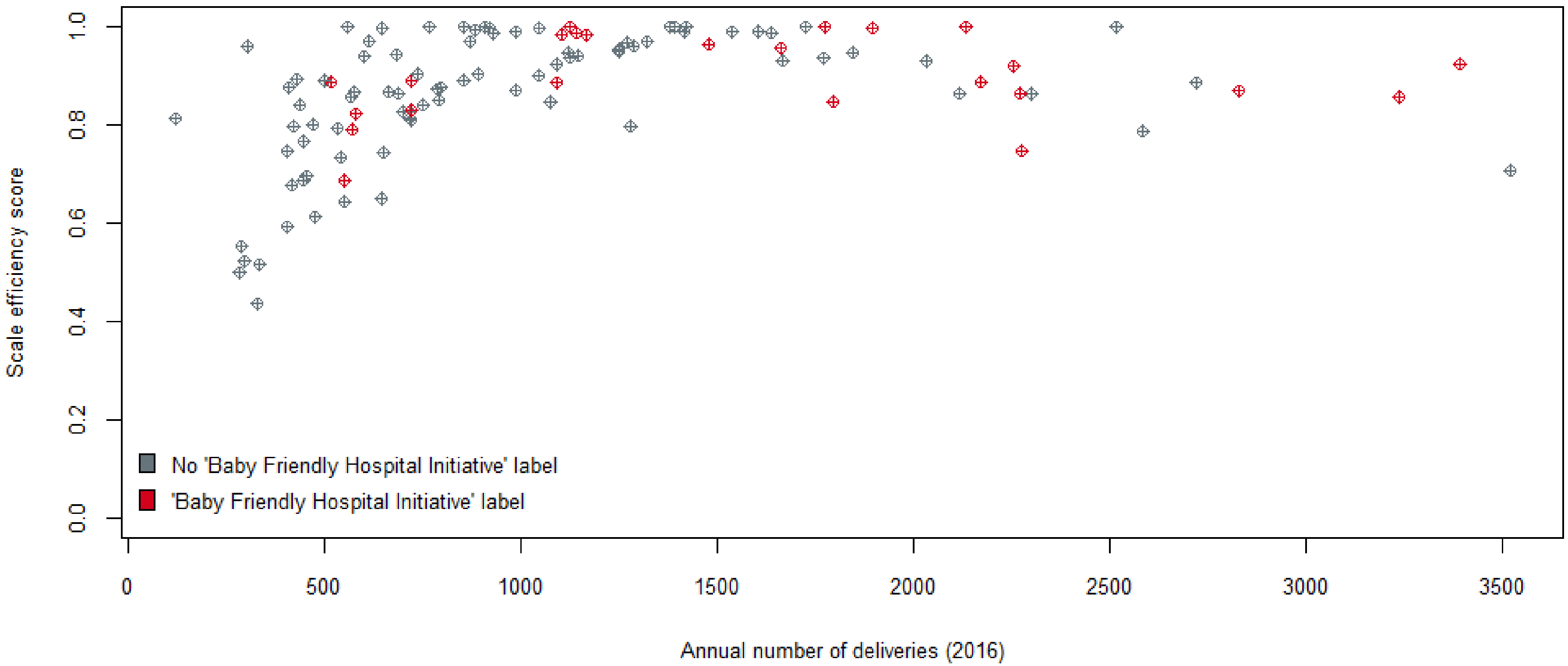
Figure 31 – Scale efficiency scores: B8-budget for intercultural mediation and communication



Breastfeeding counselling activities

In Figure 32, maternity sites that have received the 'Baby Friendly Hospital Initiative' label are identified in red. These maternity sites are not concentrated among the least nor among the most scale efficient ones.

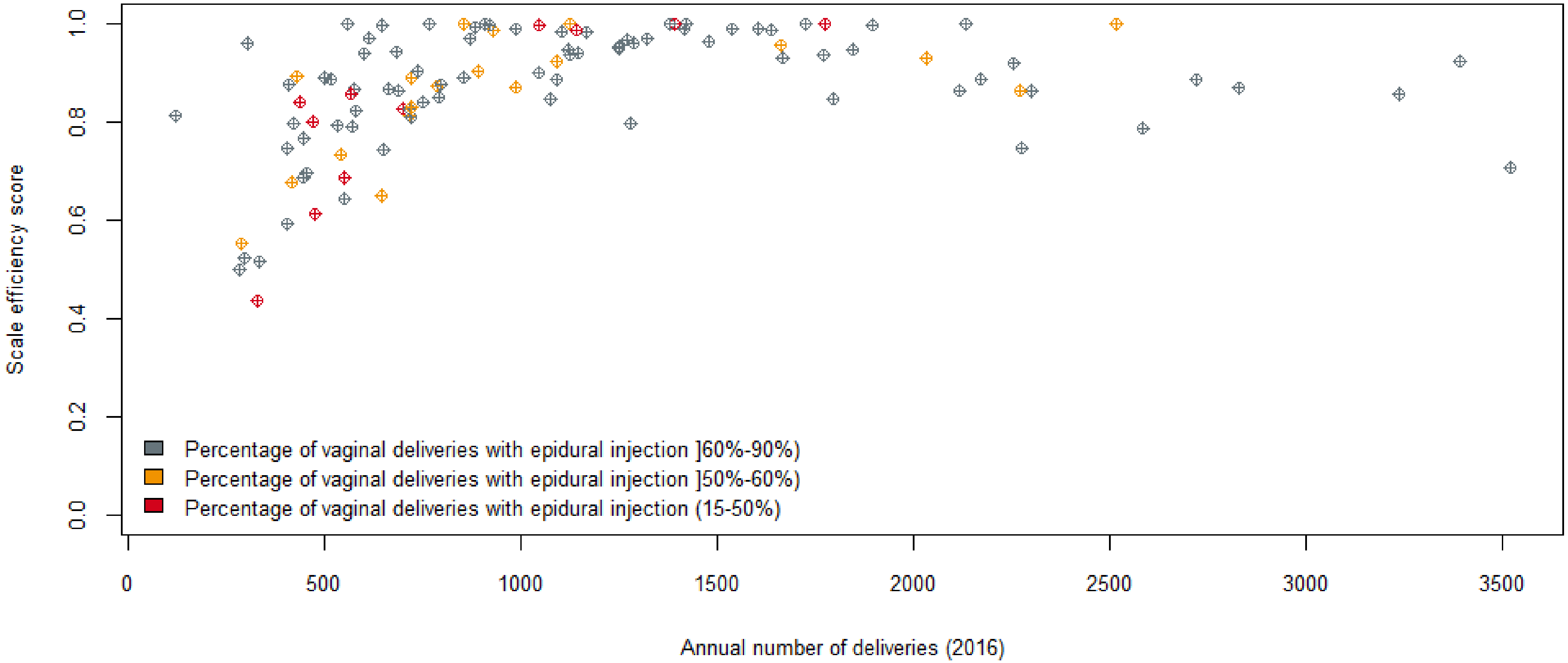
Figure 32 – Scale efficiency scores: 'Baby Friendly Hospital Initiative' label



Vaginal deliveries without epidural injections

In Figure 33, maternity sites where less than 60% or 50% of the vaginal deliveries occur with an epidural injection are identified in orange and red respectively. It appears that maternity sites where the percentage of epidural injections is below 50% tend to be concentrated amongst the smallest (in terms of annual number of deliveries), therefore least scale efficient ones.

Figure 33 – Scale efficiency scores: vaginal deliveries with epidural injection



4.4.3.3 Tobit model

Explanatory variables for the Tobit model analysis are described in Table 19 The first two variables are binary variables describing the particular context of the maternity site (university hospital or not; providing maternal intermediate care or not). The two following variables describe the socioeconomic context of the hospital. The score for B8-budget for patients with a low socioeconomic status is a continuous variable, while the B8-budget for intercultural mediation and communication is a binary variable equal to one if the maternity site belongs to a hospital benefiting from such a budget. The 'Baby Friendly Hospital Initiative' binary variable is equal to one if the maternity service has received such a label. The percentage of vaginal deliveries with epidural injection is based on billing data coupled with the MZG – RHM.

Table 19 – Second stage analysis: explanatory variables in the Tobit model

Explanatory variables	
University hospital (N)	7
Presence of MIC-beds (%)	18
Score (x100) for B8-budget for patients with a low socioeconomic status* (mean (sd))	9.6 (3.0)
B8-budget for intercultural mediation and communication* (N)	30
'Baby Friendly Hospital Initiative' label (N)	24
Percentage of vaginal deliveries with epidural injection (mean (sd)	66.2 (12.7)

*N=109. *N=107 (missing data for 2 maternity sites)*

Results from the Tobit regression are presented in Table 20. In a first model (1), we only the type of hospital (university or not[n]) and the presence of MIC-beds. These variables are used as explanatory variables in a Tobit model where the dependent variable is the efficiency score (overall efficiency score E_{CRS}, technical efficiency score E_{VRS} or scale efficiency score SE) obtained from the base DEA model. Although the results must be interpreted with caution due to the small number of observations, university hospitals tend to have a larger technical (and overall) efficiency score than the other hospitals but are not different regarding scale efficiency. Maternity sites with MIC-beds on the other hand do not present differences with other maternity sites for the overall efficiency score.

In a second model (2), we add variables related to the socioeconomic patient profile of the hospital. Maternity sites belonging to a hospital that receives a B8-budget for intercultural mediation and communication have a significantly lower technical efficiency score, although the effect is not strong enough to significantly reduce overall efficiency. Socioeconomic context, as measured here, does not have a significant impact on the scale efficiency score.

In model (3), variables related to clinical activity that is not measured by the APR-DRG classification are added. One may expect the 'Baby Friendly Hospital Initiative' label to have a negative impact on efficiency scores, as breastfeeding counselling takes time, but the results show no impact. An explanation might be that all maternity services are now involved in breastfeeding policy encouragement and the label is not a distinguishing measure to assess the additional resources required by these policies.

As in the univariate analysis, a higher percentage of epidural injections has a negative impact on the technical efficiency score. However, this impact is not strong enough to translate into a significantly different overall efficiency score.

[n] As the univariate analysis (see Table 18 and Figure 28) shows no difference between general hospitals and university-like general hospitals, these two groups are taken together in the multivariate analysis.

None of the explanatory variables taken into account in the second stage of the DEA analysis has a significant impact on the scale efficiency score. From this we can conclude that the scale efficiency scores calculated in the base model are not over- or under-estimated for a particular group of maternity sites. The inverse U-shape relationship observed between scale efficiency score and size (measured by the annual number of deliveries) is not affected by the external factors included in the second stage.

Table 20 – Second stage analysis: results from the Tobit model

	Overall efficiency score (E_{CRS})			Technical efficiency score (E_{VRS})			Scale efficiency score ($SE=E_{CRS}/E_{VRS}$)		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
University hospital	0.172**	0.178**	0.176**	0.209**	0.224**	0.226**	0.098	0.079	0.077
	(0.079)	(0.081)	(0.080)	(0.098)	(0.092)	(0.091)	(0.065)	(0.065)	(0.065)
MIC-beds	0.032	0.036	0.047	0.066	0.095*	0.131**	0.001	-0.020	-0.032
	(0.050)	(0.055)	(0.056)	(0.051)	(0.054)	(0.053)	(0.041)	(0.045)	(0.046)
B8 score (socioeconomic)		0.138	0.011		0.796	0.808		-0.324	-0.419
		(0.592)	(0.596)		(0.652)	(0.639)		(0.480)	(0.485)
B8 budget (intercultural)		-0.020	-0.021		-0.084**	-0.079**		0.049	0.046
		(0.044)	(0.043)		(0.042)	(0.040)		(0.036)	(0.035)
'Baby Friendly' label			0.030			-0.031			0.039
			(0.042)			(0.039)			(0.034)
Epidural injections			-0.192			-0.413***			0.068
			(0.135)			(0.129)			(0.110)
Constant	0.759***	0.753***	0.885***	0.895***	0.834***	1.107***	0.872***	0.898***	0.856***
	(0.018)	(0.057)	(0.106)	(0.018)	(0.061)	(0.104)	(0.015)	(0.046)	(0.086)
Observations	109	107	107	109	107	107	109	107	107
Log Likelihood	21.822	21.668	23.210	-0.253	3.071	8.124	42.647	43.384	44.098

*Note: *p<0.1; **p<0.05; ***p<0.01. Standard errors are presented between parentheses.*

4.4.4 Sensitivity analysis

4.4.4.1 Variables to measure resources

In the base model, two types of resources are taken into account: staff (measured by the number of hours worked) and capital (measured by the number of licensed maternity beds). In what follows, we show how changes in the variables used to measure resources affect the results.

In a first sensitivity check (model 1 hereafter), we exclude the number of maternity beds. Indeed, the number of beds included in the base model are licensed beds and do not necessarily correspond to operational beds. In addition, they are only a proxy for capital input. In the base model, the number of hours worked by staff are taken as a whole, independently of the category of the staff member, although students are excluded. In models 2 and 3 hereafter, more categories of staff are excluded (model 2 only takes into account nurses and midwives with a university or a higher education degree, while model 3 also includes nurses and midwives with a secondary education degree ('certified' staff members)). Descriptive statistics for the variables used in these models are provided in Table 21.

Table 21 – Sensitivity analysis: variables to measure resources

Variables used in the model	Average over the available periods* (Mean (sd))		
	Model 1	Model 2	Model 3
Number of hours worked over the period **(CAT1, CAT2, CAT3, CAT4 and CAT5)**	2 701.7 (2 187.6)		
Number of hours worked over the period **(CAT1 and CAT2)**		2 510.4 (1 990.6)	
Number of hours worked over the period **(CAT1, CAT2 and CAT3)**			2 540.3 (2 018.7)
Number of **licensed M-beds** (including MIC-beds)		28.7 (16.1)	28.7 (16.1)
Number of **vaginal deliveries** (APR-DRG 541, 542 and 560) (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI	151.8 (103.8)	151.8 (103.8)	151.8 (103.8)
Number of **caesarean deliveries** (APR-DRG 540) (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI	67.7 (53.1)	67.7 (53.1)	67.7 (53.1)
Number of **stays in MDC 14 except deliveries** (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI	26.5 (18.0)	26.5 (18.0)	26.5 (18.0)
Number of **newborn stays** (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI	370.0 (449.0)	370.0 (449.0)	370.0 (449.0)

*N=109. * For most of the maternity sites, data are available for 4 periods. In some cases, less periods are available because the maternity site either closed or opened in 2016, or did not provide daily staff records for some periods.*

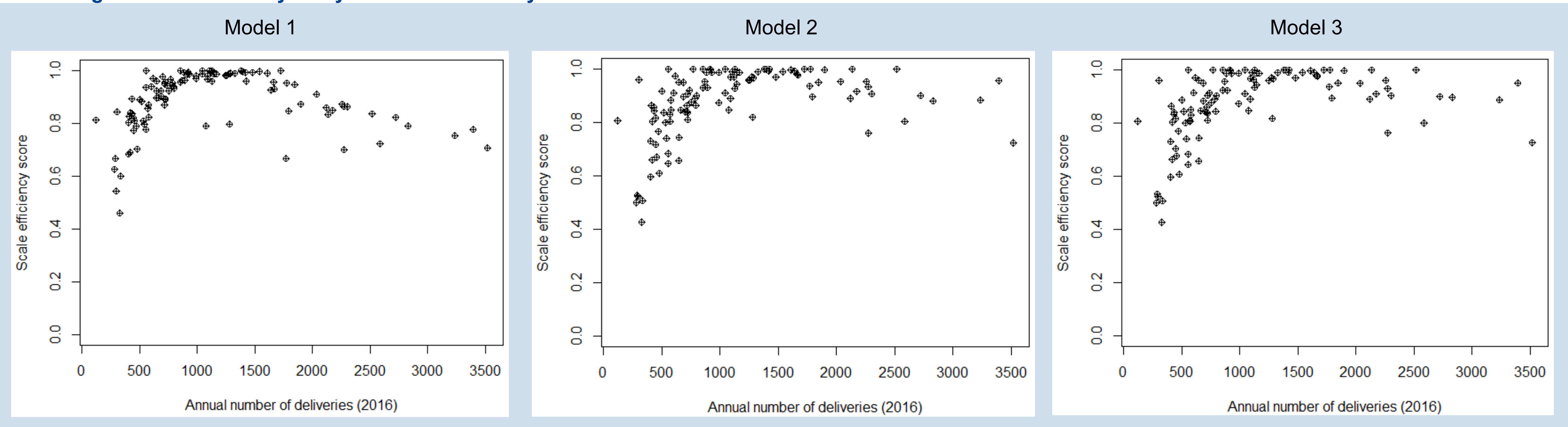
Results from models 1 to 3 are presented in Table 22 and Figure 34. The results of the base model are quite robust to changes in the variables related to resources. In particular, the minimum efficient scale is 557 deliveries per year in models 1, 2, and 3, as in the base model.

Table 22 – Sensitivity analysis: results from DEA models with other variables used to measure resources

Results of the model	Base model	Model 1	Model 2	Model 3
Overall efficiency score (E_{CRS}) (mean (sd))	0.77 (0.16)	0.70 (0.17)	0.78 (0.16)	0.78 (0.16)
Technical efficiency score (E_{VRS}) (mean (sd))	0.88 (0.12)	0.80 (0.16)	0.89 (0.12)	0.89 (0.12)
Scale efficiency score ($SE=E_{CRS}/E_{VRS}$) (mean (sd))	0.87 (0.13)	0.89 (0.11)	0.88 (0.13)	0.88 (0.13)
Number of scale efficient units (SE=1)	12	5	12	12
Minimum efficient scale (annual number of deliveries)	557	557	557	557
Number of maternity sites smaller than the minimum efficient scale (in terms of annual number of deliveries)	25	25	25	25

N=109.

Figure 34 – Sensitivity analysis: scale efficiency scores from DEA models with other variables used to measure resources



4.4.4.2 Variables to measure clinical activity

In what follows, we show how changes in the variables used to measure clinical activity affect the results. In the base model, clinical activity is defined by deliveries (with a distinction between vaginal deliveries and caesareans), other activities related to pregnancy (MDC 14B) and activities related to newborns. In alternative model 4, we restrict clinical activity to inpatient stays only. In model 5 and 6 clinical activity is extended to stays (inpatient and day-care) unrelated to pregnancy (outside MDC 14): model 5 includes stays in MDC 13 and model 6 includes stays in all MDCs.

In the base model, stays (inpatient and day-care) are adjusted by the average length of stay per APR-DRG-SOI in all Belgian general hospitals in 2016 (for day-care stays, a length of stay of 0.81 days is used). Model 7 uses an alternative weight: in that model stays are adjusted by the case-mix index developed by 3M, which is a relative average value assigned to each APR-DRG-SOI that indicates the amount of resources required to treat patients in the group, as compared to all the other DRGs within the system. In model 8, no adjustment is made (i.e. stays are unweighted).

Descriptive statistics for the variables used in these models are provided in Table 23.

Table 23 – Sensitivity analysis: variables to measure clinical activity

Variables used in the model	Average over the available periods* (Mean (sd))				
	Model 4	Model 5	Model 6	Model 7	Model 8
Number of **hours worked** over the period (CAT1, CAT2, CAT3, CAT4 and CAT5)	2 701.7 (2 187.6)	2 701.7 (2 187.6)	2 701.7 (2 187.6)	2 701.7 (2 187.6)	2 701.7 (2 187.6)
Number of **licensed M-beds** (including MIC-beds)	28.7 (16.1)	28.7 (16.1)	28.7 (16.1)	28.7 (16.1)	28.7 (16.1)
Number of **vaginal deliveries** (APR-DRG 541, 542 and 560) **(inpatient only)** over the period, weighted by average length of stay per APR-DRG-SOI	151.5 (103.7)				
Number of **caesarean deliveries** (APR-DRG 540) **(inpatient only)** over the period, weighted by average length of stay per APR-DRG-SOI	67.6 (53.1)				
Number of **stays in MDC 14 except deliveries (inpatient only)** over the period, weighted by average length of stay per APR-DRG-SOI	25.4 (17.3)				
Number of **newborn stays (inpatient only)** over the period, weighted by average length of stay per APR-DRG-SOI	369.6 (449.0)				
Number of **vaginal deliveries** (APR-DRG 541, 542 and 560) (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI		151.8 (103.8)	151.8 (103.8)		
Number of **caesarean deliveries** (APR-DRG 540) (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI		67.7 (53.1)	67.7 (53.1)		
Number of **stays in MDC 13 and MDC 14 except deliveries** (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI		34.0 (24.6)			
Number of **stays (all MDCs) except deliveries and newborns** (inpatient and day-care, except mini lump sums) over the period, weighted by average length of stay per APR-DRG-SOI			47.4 (38.9)		
Number of **newborn stays** (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI		370.0 (449.0)	370.0 (449.0)		
Number of **vaginal deliveries** (APR-DRG 541, 542 and 560) (inpatient and day-care) over the period, **weighted by case-mix index** per APR-DRG-SOI				15.5 (10.6)	
Number of **caesarean deliveries** (APR-DRG 540) (inpatient and day-care) over the period, **weighted by case-mix index** per APR-DRG-SOI				7.9 (6.1)	

Number of **stays in MDC 14 except deliveries** (inpatient and day-care) over the period, **weighted by case-mix index** per APR-DRG-SOI	3.3 (2.4)
Number of **newborn stays** (inpatient and day-care) over the period, **weighted by case-mix index** per APR-DRG-SOI	43.1 (81.1)
Number of **vaginal deliveries** (APR-DRG 541, 542 and 560) (inpatient and day-care) over the period, **unweighted**	44.3 (29.6)
Number of **caesarean deliveries** (APR-DRG 540) (inpatient and day-care) over the period, **unweighted**	12.7 (9.1)
Number of **stays in MDC 14 except deliveries** (inpatient and day-care) over the period, **unweighted**	9.3 (6.1)
Number of **newborn stays** (inpatient only) over the period, **unweighted**	61.8 (42.3)

*N=109. * For most of the maternity sites, data are available for 4 periods. In some cases, less periods are available because the maternity site either closed or opened in 2016, or did not provide daily staff records for some periods.*

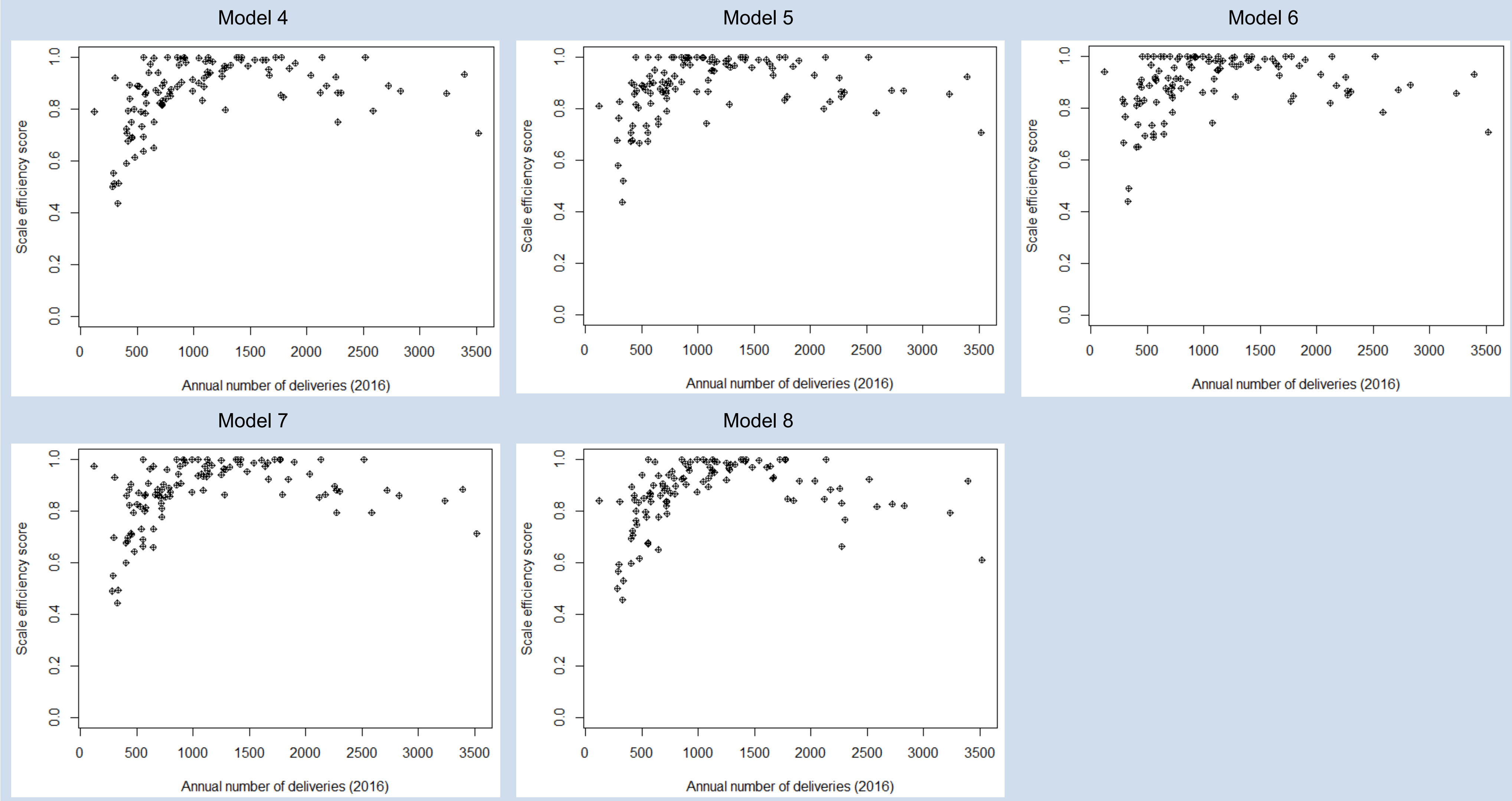
Results from models 4 to 8 are presented in Table 24 and Figure 35. The results of the base model are quite robust to changes in the weight used to adjust stays (models 7 and 8). In particular the minimum efficient scale (557 deliveries per year) is not affected by these changes. It is also not affected by the exclusion of day-care activity (model 4). However, the minimum efficient scale is smaller (446 or 453 deliveries per year) when the activity unrelated to pregnancy and newborn is taken into account (models 5 and 6). For maternity sites that have a large part of their activity outside MDC 14 and newborns, it is likely that part of the resources accounted for in the base model are dedicated to activity that is not accounted for in the base model. Including this extra activity in the alternative models increases the scale efficiency score for some small maternity sites. Hence the smallest maternity site to be scale efficient is situated at the left of the one of the base model.

Table 24 – Sensitivity analysis: results from DEA models with other variables used to measure clinical activity

Results of the model	Base model	Model 4	Model 5	Model 6	Model 7	Model 8
Overall efficiency score (E_{CRS}) (mean (sd))	0.77 (0.16)	0.77 (0.16)	0.79 (0.15)	0.79 (0.15)	0.77 (0.16)	0.76 (0.16)
Technical efficiency score (E_{VRS}) (mean (sd))	0.88 (0.12)	0.88 (0.12)	0.89 (0.12)	0.88 (0.12)	0.89 (0.12)	0.87 (0.13)
Scale efficiency score ($SE=E_{CRS}/E_{VRS}$) (mean (sd))	0.87 (0.13)	0.86 (0.13)	0.89 (0.11)	0.89 (0.11)	0.89 (0.12)	0.87 (0.12)
Number of scale efficient units (SE=1)	12	12	18	17	13	11
Minimum efficient scale (annual number of deliveries)	557	557	446	453	557	557
Number of maternity sites smaller than the minimum efficient scale (in terms of annual number of deliveries)	25	25	15	16	25	25

N=109.

Figure 35 – Sensitivity analysis: scale efficiency scores from DEA models with other variables used to measure clinical activity



4.4.4.3 Subsets of maternity sites or services

Because it is not possible in the data to distinguish with certainty activity and/or staff related to M/MIC/AR/OB-, N*- and NIC-units, in the base model, clinical activity and worked hours are considered as a whole, as taking place in the maternity site. In model 9 hereafter, we restrict our measures of clinical activity and staff worked hours to the ones recorded in the M/MIC/AR/OB-units. For consistency, we also excluded newborn stays from the clinical activity measures.

In the base model, all 109 maternity sites for which clinical activity and daily staff data were available for at least one registration period in 2016 are included. As already stated, some of these maternity sites have particular characteristics that could bias the estimation of the efficiency score. As a robustness check, we run the base model on a subset of maternity sites, excluding those with specific characteristics. In model 10, maternity sites with MIC-beds or NIC-beds are excluded. In model 11, we exclude maternity sites that can be considered as outliers regarding the share of activity unrelated to pregnancy and newborns. These maternity sites are defined as the ones with a proportion of (weighted) stays (except newborns) outside MDC 14 above 36.76% (=Q3+1.5*IQR). Descriptive statistics for the variables used in these models are provided in Table 25.

Table 25 – Sensitivity analysis: subsets of maternity sites or services

Variables used in the model	Average over the available periods* (Mean (sd))		
	Model 9 (N=109)	Model 10 (N=90)	Model 11 (N=101)
Number of **hours worked** over the period (CAT1, CAT2, CAT3, CAT4 and CAT5)	1 881.6 (1 198.9)	1841.8 (960.7)	2 805.1 (2 235.7)
Number of **licensed M-beds** (including MIC-beds)	28.7 (16.1)	24.7 (12.1)	29.4 (16.3)
Number of **vaginal deliveries** (APR-DRG 541, 542 and 560) (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI	151.8 (103.8)	119.3 (66.9)	158.3 (104.5)
Number of **caesarean deliveries** (APR-DRG 540) (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI	67.7 (53.1)	48.9 (26.2)	70.9 (53.8)
Number of **stays in MDC 14 except deliveries** (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI	26.5 (18.0)	20.4 (11.3)	27.4 (18.2)
Number of **newborn stays** (inpatient and day-care) over the period, weighted by average length of stay per APR-DRG-SOI		184.1 (104.7)	390.6 (460.0)

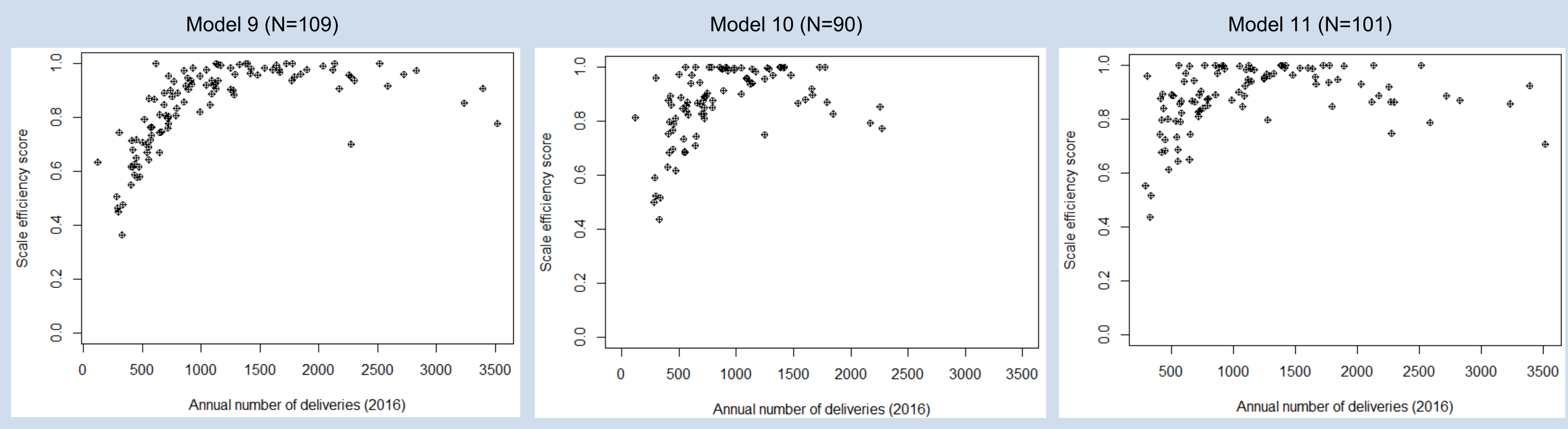
*N=109. * For most of the maternity sites, data are available for 4 periods. In some cases, less periods are available because the maternity site either closed or opened in 2016, or did not provide daily staff records for some periods.*

Results from models 9 to 11 are presented in Table 26 and Figure 36. Again, the results of the base model are quite robust. In particular, excluding maternity sites with MIC-beds (model 10) does not affect the minimum efficient scale (557 deliveries per year). It is worth noting that when the DEA model is run on the subset of maternity sites with no extreme clinical activity outside MDC 14, the minimum efficient scale is 557 deliveries per year, as in the base model. This indicates that results of model 5 and 6 (lower minimum efficient scale) are driven by a few outliers that may not be representative of other maternity sites in Belgium. When the DEA model is restricted to maternity care (excluding neonatal care), the minimum efficient scale is larger (612 deliveries per year, instead of 557 in the base model) but one must keep in mind that inconsistencies in the staff and clinical activity data may bias the results.

Table 26 – Sensitivity analysis: results from DEA models on subsets of maternity sites or services

Results of the model	Base model (N=109)	Model 9 (N=109)	Model 10 (N=90)	Model 11 (N=101)
Overall efficiency score (E_{CRS}) (mean (sd))	0.77 (0.16)	0.71 (0.17)	0.78 (0.16)	0.78 (0.15)
Technical efficiency score (E_{VRS}) (mean (sd))	0.88 (0.12)	0.85 (0.13)	0.89 (0.12)	0.89 (0.12)
Scale efficiency score ($SE=E_{CRS}/E_{VRS}$) (mean (sd))	0.87 (0.13)	0.84 (0.15)	0.87 (0.13)	0.88 (0.12)
Number of scale efficient units (SE=1)	12	8	11	12
Minimum efficient scale (annual number of deliveries)	557	612	557	557
Number of maternity sites smaller than the minimum efficient scale (in terms of annual number of deliveries)	25	31	25	25

Figure 36 – Sensitivity analysis: scale efficiency scores from DEA models on subsets of maternity sites or services



4.4.5 Additional robustness checks

As additional robustness check, we use the bootstrapping method to draw a sample of replicates of the efficiency scores of the base model. Results (presented in Appendix 2.1) show that the estimation of the minimum efficient scale of the base model (557 deliveries per year) is quite robust.

We also identify two groups of potential outliers using the data cloud method.[47-49] Removing these outliers does not affect the results regarding minimum efficient scale, as shown in Appendix 1.1.

4.5 Key points

- **When maternity services are ranked according to the annual number of deliveries, we observe that returns to scale are first increasing, then constant and finally decreasing. The scale efficiency score presents a clear inverse U-shape, being increasing for small maternity services, close to one for middle-sized maternity services, and decreasing for larger maternity services although the results for this latter group must be interpreted with caution due to the small number of observations.**
- **The minimum efficient scale is estimated at 557 deliveries per year in the base model. It represents the smallest number of deliveries for which returns to scale are constant. This number is robust to several sensitivity checks.**
- **In 2016, 25 maternity services had a smaller scale than the minimum efficient scale: for these maternity services, potential efficiency improvement exists, as they can benefit from economies of scale.**
- **Also beyond the minimum efficient scale of 557 deliveries per year, the average scale efficiency score increases, indicating that efficiency gains can be achieved by extending the scale above this threshold, at least up to 900-1 000 deliveries per year.**
- **The scale efficiency score is not affected by the contextual factors we consider. Therefore, our model does not over- or under-estimate scale efficiency for a particular group of maternity services.**
- **The ability to obtain maximal activity from a given set of resources is however affected by external factors. Technical efficiency scores are significantly higher for:**
    - **maternity services from university hospitals;**
    - **maternity services with MIC-beds;**
    - **maternity services where a lot of vaginal deliveries are performed with epidural injection;**
    - **maternity services from hospitals without a special budget for intercultural mediation and communication.**

5 GEOGRAPHIC ACCESSIBILITY OF MATERNITY SERVICES

5.1 Introduction

As is clear from the previous chapters, Belgium has a diverse landscape of maternity services, spread across the country. But to what extent can Belgian women of child-bearing age reach one or more maternity services in a timely fashion? In the following sections we address the research question on the reachability of maternity services in Belgium (see section 1.4). Additionally, we combine the possibility to reach a service within time with the results of the previous chapter that shows that activity levels of a number of maternity services in Belgium are too low and that to be scale efficient a maternity service should have at least 557 deliveries per year. One possible policy measure that could be taken in response to these results, is that maternity services with a number of deliveries under the efficiency threshold transfer their activity to one or more neighbouring maternity services and close. Although the landscape of maternity services is dense in most areas in Belgium, it should however be avoided that with the closure of maternity services travel time or travel distance becomes too long. Therefore, the efficiency analysis in the previous chapter has to be complemented with an analysis of the possibility to reach a maternity service within time. For this part, we collaborated with the National Geographical Institute (NGI – IGN), who provided us with key elements for this analysis (see method section below).

Geographic access can be measured in either distance or travel time. Given the dense road network in Belgium, mainly but not only in large cities, a measure in terms of travel time was preferred. The accessibility analysis of maternity services as conducted in this study is comparable with and inspired by research on the accessibility of emergency hospital care in the Netherlands.[51]

5.2 Geographic Information System to measure access to maternity services within a specified time limit

The possibility to reach a maternity service within time is defined as the possibility for a woman between 15 and 49 years old to reach one or more maternity services within a specified time limit (e.g. 30 minutes). We analysed this question with a Geographic Information System (GIS) in several steps:

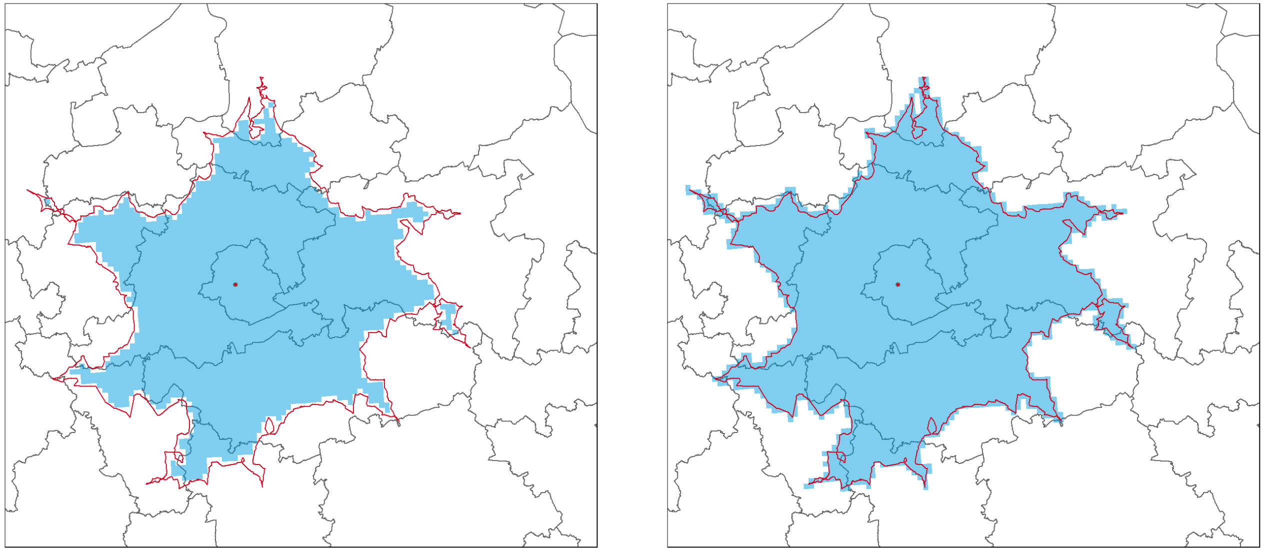
- We determined the geographical location of each maternity service, based on the official address of the maternity service as provided by the FOD – SPF in April 2019. A total of 104 different maternity services were then geocoded to the latitude and longitude of the official site address.
- For each maternity service, the NGI – IGN calculated the area within an isochrone using the Network Analysis module of ArcGIS.[52] The area within an isochrone comprises all streets or street segments around a maternity service that can reach the maternity service within a specified time limit, taking into account traffic on the chosen time reference point. In ArcGIS, isochrones are constructed with a propriety solver, the network service area solver, based on an extension of Dijkstra's algorithm for finding shortest paths.[53] The NGI – IGN had access to TomTom historical traffic data speed profiles, representing the normal traffic situation in Belgium on an average weekday: times represent average travel time by car for a specific street segment for the last two years, taking into account possible distorting factors like outlier driver behaviour, exceptional weather conditions, road works or traffic accidents.[54]
- From Statbel, the NGI – IGN received the number of Belgian women between 15 and 49 years old in 2016, per European Environment Agency (EEA) reference grid cell.[55] The EEA reference grid subdivides Belgium geographically in cells with a resolution of 1km². For each of these grid cells, we determined per maternity service if they fell within the isochrone. For cells falling partly in and partly out of the isochrone, we defined two scenarios:

- Within area: the cell needs to be contained *entirely* within the area to count. In this definition, the number of women that can reach a maternity service within the time limit can be underestimated because grid cells that fall partially outside of the isochrone are not counted. At the same time, this definition creates artificial areas of unreachability at the borders when these coincide with the isochrones ().
- Intersects area: the cell needs to be contained *entirely or partially* within the area to count. In this definition, the number of women that can reach a maternity service within the time limit can be overestimated because grid cells that fall partially outside of the isochrone are counted as well.

An example of the difference between the two is shown in Figure 37.

Figure 37 – Example of the 'within area' and 'intersects area' definitions

within area **intersects area**



red line = isochrone, blue squares = grid cells

In the sections that follow, we show results from the 'intersects area' definition because it does not create artificial areas of unreachability unlike the within area definition. The intersects area definition has an additional 0.4% of the women between 15 and 49 years old that fall within the isochrones compared to the within area definition. For completeness, the same results using the within area definition are available in Appendix 3.

- For each EEA grid cell, we calculated the number of areas within an isochrone containing the cell. We used the following categories:
  - No women between 15 and 49 years old and not contained in any of the areas within an isochrone.
  - No women between 15 and 49 years old but contained in at least one area within an isochrone.
  - A population of women between 15 and 49 years old but not contained in any of the areas within an isochrone.
  - A population of women between 15 and 49 years old and contained in *x* areas within an isochrone (with x ≥ 1).
- For each of these categories, we calculated the proportion of the population of women between 15 and 49 years old that fall into the category.

We used 30 minutes as time limit. Although no firm conclusions can be drawn from the literature about the association between travel time and patient outcomes (such as perinatal mortality), travel times should be kept reasonable. There is, however, no existing guidance that states what a reasonable distance or travel time is. Therefore, a coverage of maternity services in terms of (road) travel time within 30 minutes places to a certain extent an arbitrary limit on proximity. It is, however, in accordance with the travel time in studies for other countries, such as France and England.[3]

For context, we also looked at 15 minutes as an illustrative approximation for heavy traffic because we had no access to traffic data on specific time points during the day (e.g. during rush-hour) and also at 45 minutes as this limit is often used in other studies[56] or for emergency services.[57] The results for 15 and 45 minutes are available in Appendix 3. In addition, we identified maternity services that are the only service reachable within a specified time limit for at least a part of the women between 15 and 49 years old living in the area within the isochrone of the maternity service. In geospatial terms, these maternity services are services with EAA grid cells that are contained only in the area of the isochrone of this maternity service and not in any other. We defined 'a part of the women' in two ways:

- Strict: one grid cell (even with only one woman between 15 and 49 years old) that can reach only this maternity service.
- Threshold: one or more grid cells with a summed population of at least 21 women between 15 and 49 years old that can reach only this maternity service. We calculated '21' as the ratio of women between 15 and 49 years old and the number of deliveries in 2016, estimating the average number of women for at least one delivery.

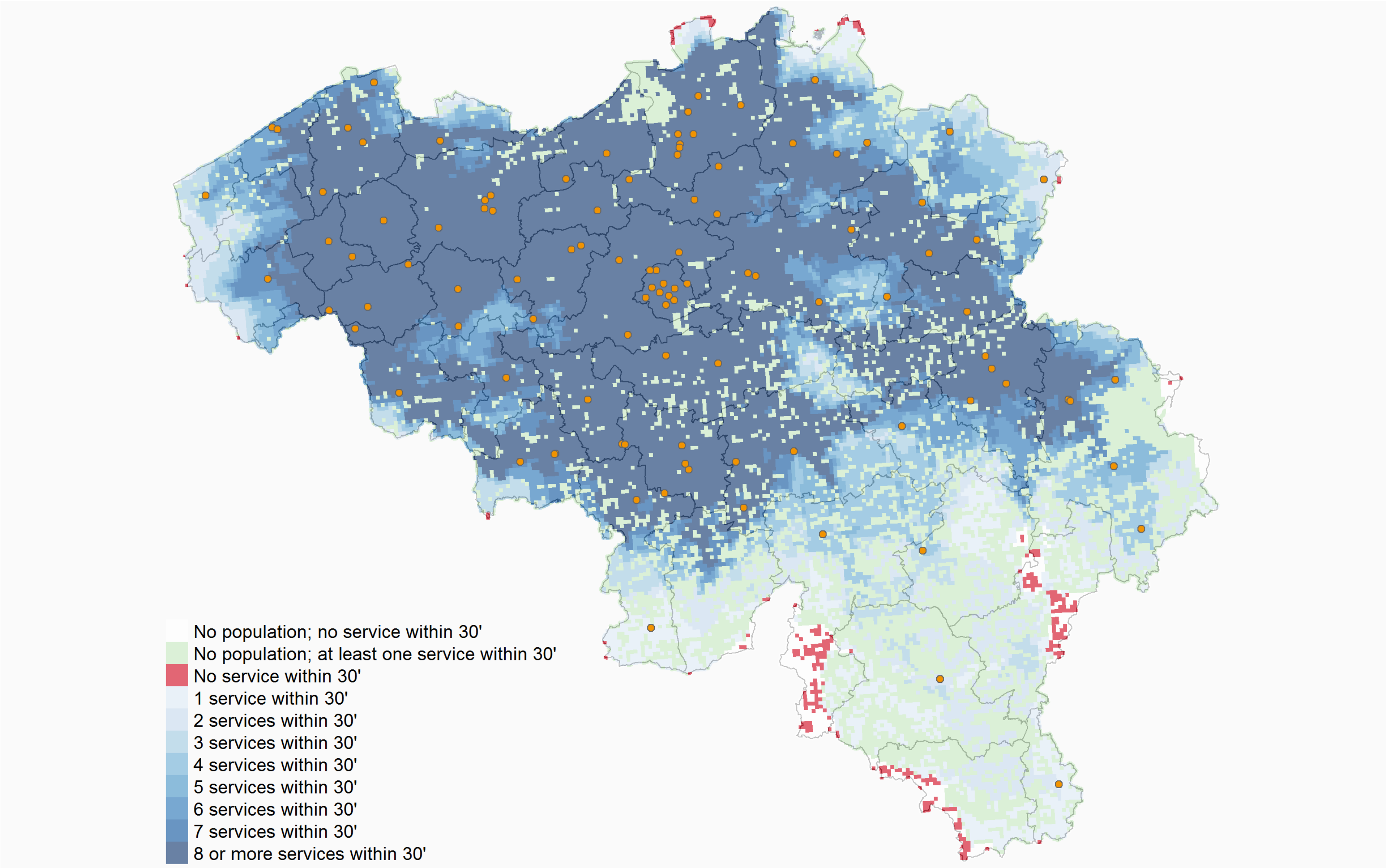
The strict definition makes some maternity services the only service reachable within 30 minutes for a very small number of women (e.g. one woman). To make our results less prone to small population fluctuations over the years, we show the results for the threshold definition. Determining this threshold is a policy decision as there is no hard criterion to guide such a choice.

5.3 Results

5.3.1 *Current possibility to reach a maternity service within 30 minutes*

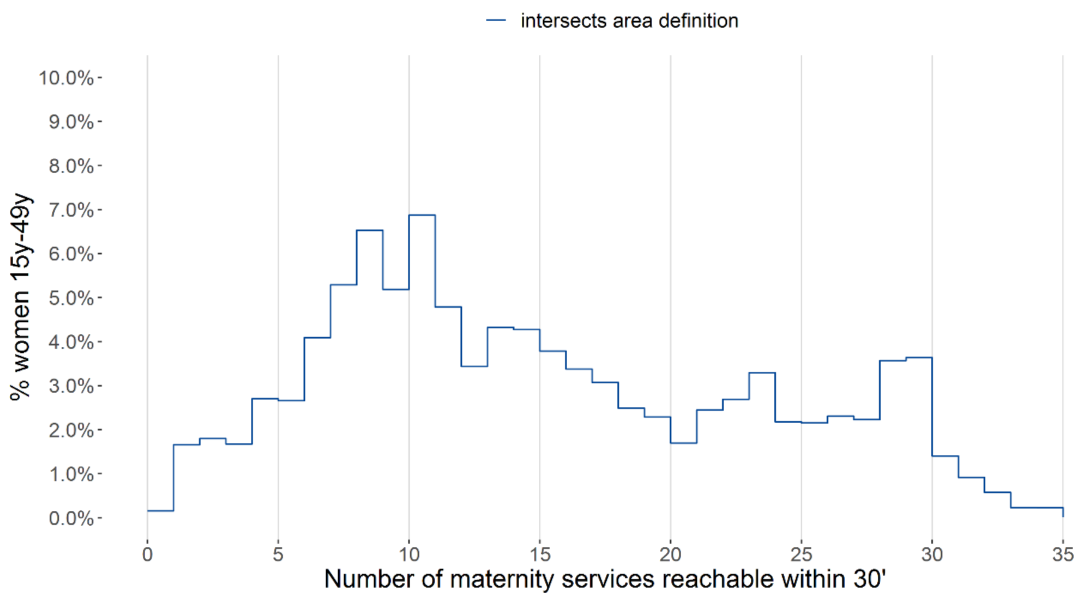
Based on the 2016 population, 99.8% of women between 15 and 49 years old can reach one or more maternity services within 30 minutes, given normal traffic conditions (see Figure 38). The other 0.2% of women between 15 and 49 years live mostly near the border and in the south of the country (no information is available on women living in these areas actually traveling across the borders to deliver). A large part of Flanders, Brussels and the northern part of Wallonia have access to eight or more maternity services within 30 minutes, given normal traffic conditions (see also Figure 39).

Figure 38 – Maternity services reachable within 30 minutes



Intersects area definition; orange dots represent maternity services April 2019

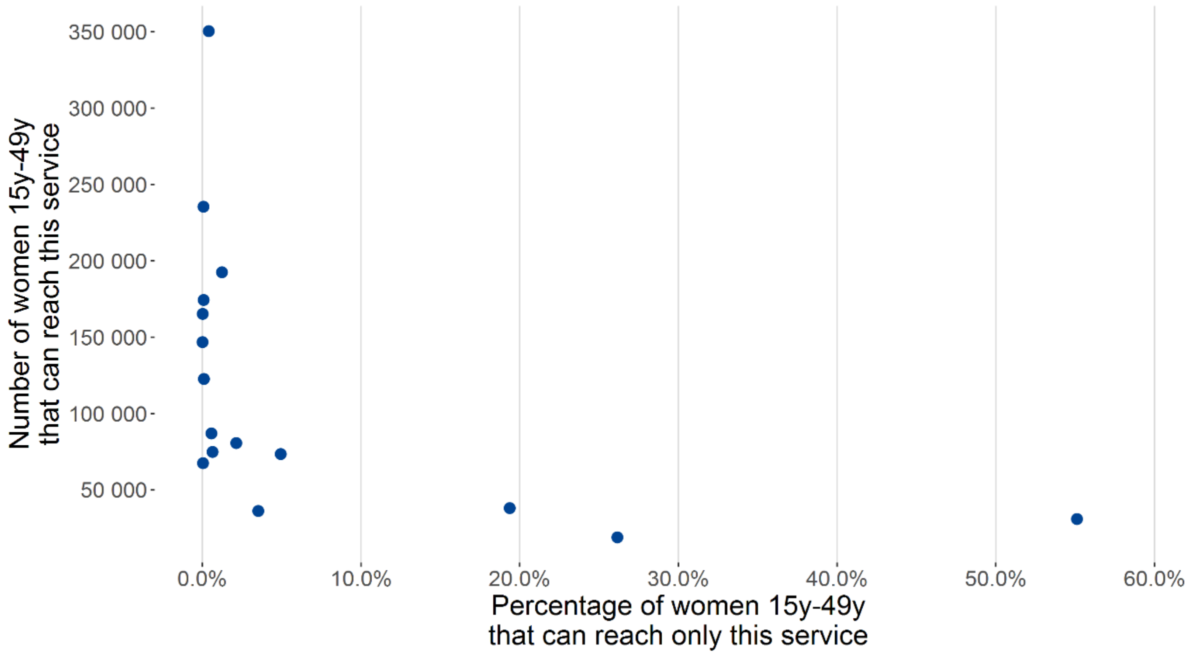
Figure 39 – Percentage of women 15-49 year old by number of maternity services reachable within 30 minutes



We found 16 (15.4%) maternity services that are the only service reachable within 30 minutes for at least 21 of the women between 15 and 49 years old living in the area of the isochrone of the maternity service ("1 service within 30'" in Figure 38). In total, 1.7% of the women between 15 and 49 years old live in the areas where only one maternity service can be reached. Per maternity service, the proportion of women that can reach this service only versus all women that can reach this and other services, ranges from 0.02% to 55.11% with most services having a proportion below 10% (see Figure 40).

As mentioned in section 5.2, the 30 minutes represent a normal traffic situation on a weekday. Although we did not have access to more detailed travel times, we tried to assess the current reachability in heavy traffic by considering the 15 minutes isochrone average weekday traffic as a stand-in for a hypothesized 30 minutes isochrone heavy traffic. In other words, we assume that the distances reachable within 15 minutes in normal weekday traffic, take 30 minutes in heavy traffic. Because heavy traffic is mostly problematic in large cities, we looked at Brussels, Liège and Antwerp which have structural heavy traffic during rush hours. The detailed analysis can be found in Appendix 1.1.1. In summary, we found that one third (Antwerp) to almost half (Liège and Brussels) of the women between 15 and 49 years old, can reach the same number of maternity services in simulated heavy traffic as in normal traffic. The remaining group of women have access to less maternity services. For Liège and Antwerp, a very small number of women (respectively 0.1% and <0.01%) no longer have access to a maternity service within the simulated 30 minutes in heavy traffic.

Figure 40 – Proportion of women that can reach only this service versus all women that can reach this service



5.3.2 Possibility to reach a maternity service within 30 minutes following scale efficiency

5.3.2.1 Scale efficiency taking changes 2016 -2019 into account

The efficiency analysis presented in Chapter 4 relies on hospital data for the year 2016. It concludes that, in 2016, 25 maternity sites were below the minimum efficient scale of 557 deliveries per year. Since then, three of these 25 maternity sites, as well as one larger maternity site, have been closed (data April 2019). In two cases, the closure resulted from a site merger. Table 27 shows the results of an exercise of organisational restructuring that replicates these two cases of site mergers. Further details on the methodology used can be found in section 4.2.4.

For these two pairs of sites, potential savings from integration is 38% ($1-E^H$). A non-negligible part of these savings, namely 22% or 13% ($1-LE^H$), is coming from learning potentials, which could be acquired without merging. Indeed, the learning (or technical efficiency) effect is related to the ability to adjust to best practices. If the original sites are not technically efficient, potential gains are available to them, independently of the integration process. Nevertheless, even if we ignore the learning effect, the savings from grouping are still 20% and 29% (1-E*). The harmony effect (generating savings thanks to a better allocation of the inputs and outputs) is small (4% or 0%, $1-HA^H$). Most of the potential gain is coming from the size effect (16% or 28%, $1-SI^H$) and both pairs generate substantial savings by benefiting from economies of scale. This is the case because the neighbouring site that is grouped with the small site is not too large, so that the resulting group operates at a size where constant returns to scale are possible.

Table 27 – Organisational restructuring

Pair of sites	Annual number of deliveries on 1st site	Annual number of deliveries on 2nd site	Total annual number of deliveries for the group	Learning effect LE^H	Harmony effect HA^H	Size effect SI^H	Gain from integration $E^H=LE^H.HA^H.SI^H$	$E^*=HA^H.SI^H$
A	282	1 046	1 328	0.78	0.96	0.84	0.62	0.80
B	453	551	1 004	0.87	1.00	0.72	0.62	0.71

As shown in Table 27, both site mergers that occurred between 2017 and 2019 contribute to an increase in structural efficiency. The first merger (pair of sites A), grouped a maternity site that operated below the minimum efficient scale with a larger one. Obviously, the new structure operates above the minimum efficient scale. The second case (pair of sites B) consists in the merger of two maternity sites that operated below the minimum efficient scale. However, their combined number of deliveries is above the minimum efficient scale.

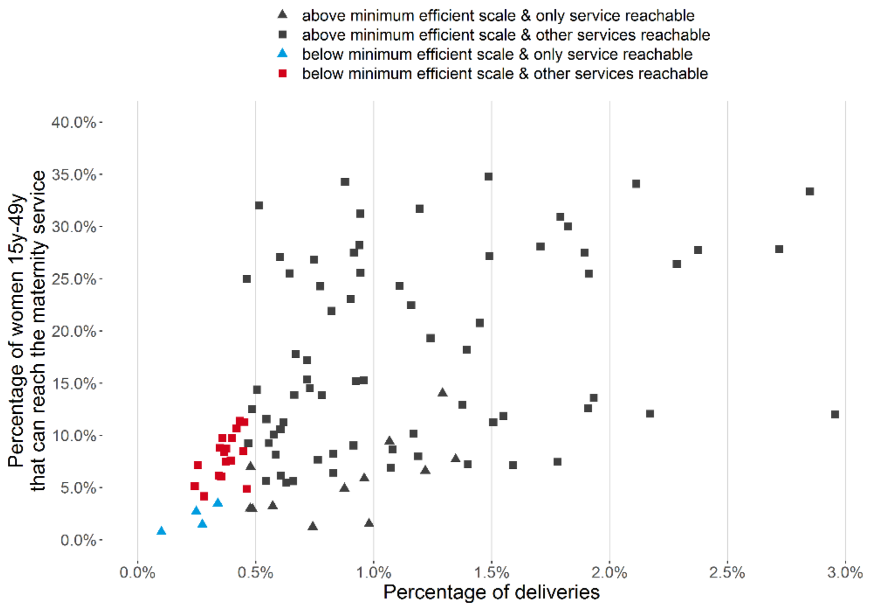
Therefore, from the 25 maternity sites that operated below the minimum efficient scale in 2016, three were closed, and one is likely to operate above the minimum efficient scale in 2019, thanks to the transfer of activity of one of the closed sites. For that reason, we consider that 21 maternity sites operate below the minimum efficient scale in April 2019.

5.3.2.2 Possibility to reach a maternity service within 30 minutes

We simulated the impact of transferring activity of maternity services that fall below the minimum efficient scale, to other services, on the possibility to reach a maternity service within 30 minutes, taking into account the changes detailed in the previous section. We know that for 16 maternity services (see Figure 40 in section 5.3.1) this would lead to at least a part of the women between 15 and 49 years old to no longer have access within 30 minutes to a maternity service. In this simulation, we therefore chose to transfer activity of maternity services below minimum efficient scale except if they are also one of the aforementioned 16 maternity services.

A total of 17 (16.3%) maternity services are below minimal efficient scale *and* are *not* a service in the current situation that is the only service reachable within 30 minutes for at least a part of the women between 15 and 49 years old (red squares in Figure 41 and Figure 43).

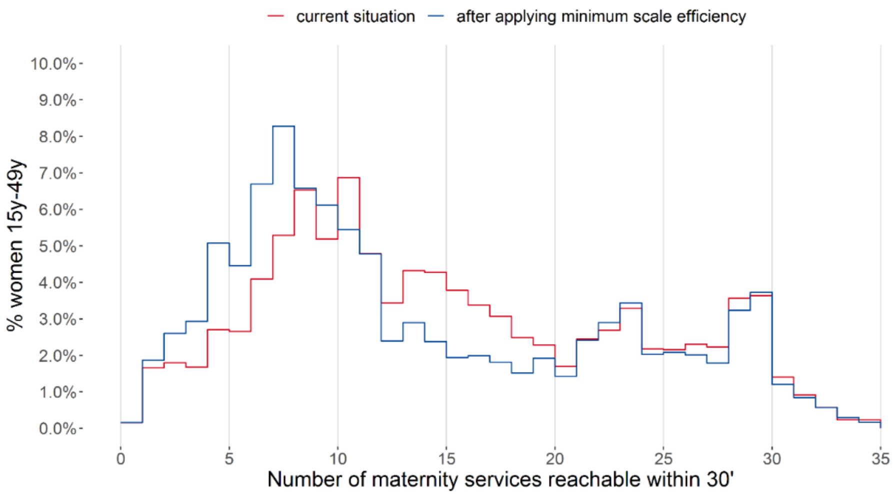
Figure 41 – Percent of deliveries and population that can reach a maternity service within 30 minutes by minimum efficient scale



Intersects area definition

For these 17 maternity services, we simulated transfer of activity to other services and the impact on reachability within 30 minutes is shown in Figure 43 To what other services this activity could be transferred is treated in Chapter 6. For about half of the women between 15 and 49 years old (52.6%), nothing changes: they can reach the same maternity services as before (see also Table 28). 47.2% of women between 15 and 49 years old have access to less maternity services than before the transfer of activity (see Figure 42). A very small number of women (<0.01%) can no longer reach a maternity service within 30 minutes. Despite excluding maternity services that were already the only services reachable within 30 minutes for a part of the population, the transfer of activity resulted for a few women in no longer being able to reach these services, while previously they were able to reach two maternity services within 30 minutes.

Figure 42 – Percentage of women between 15 and 49 years old by number of maternity services accessible within 30 minutes, current situation versus after applying minimum scale efficiency



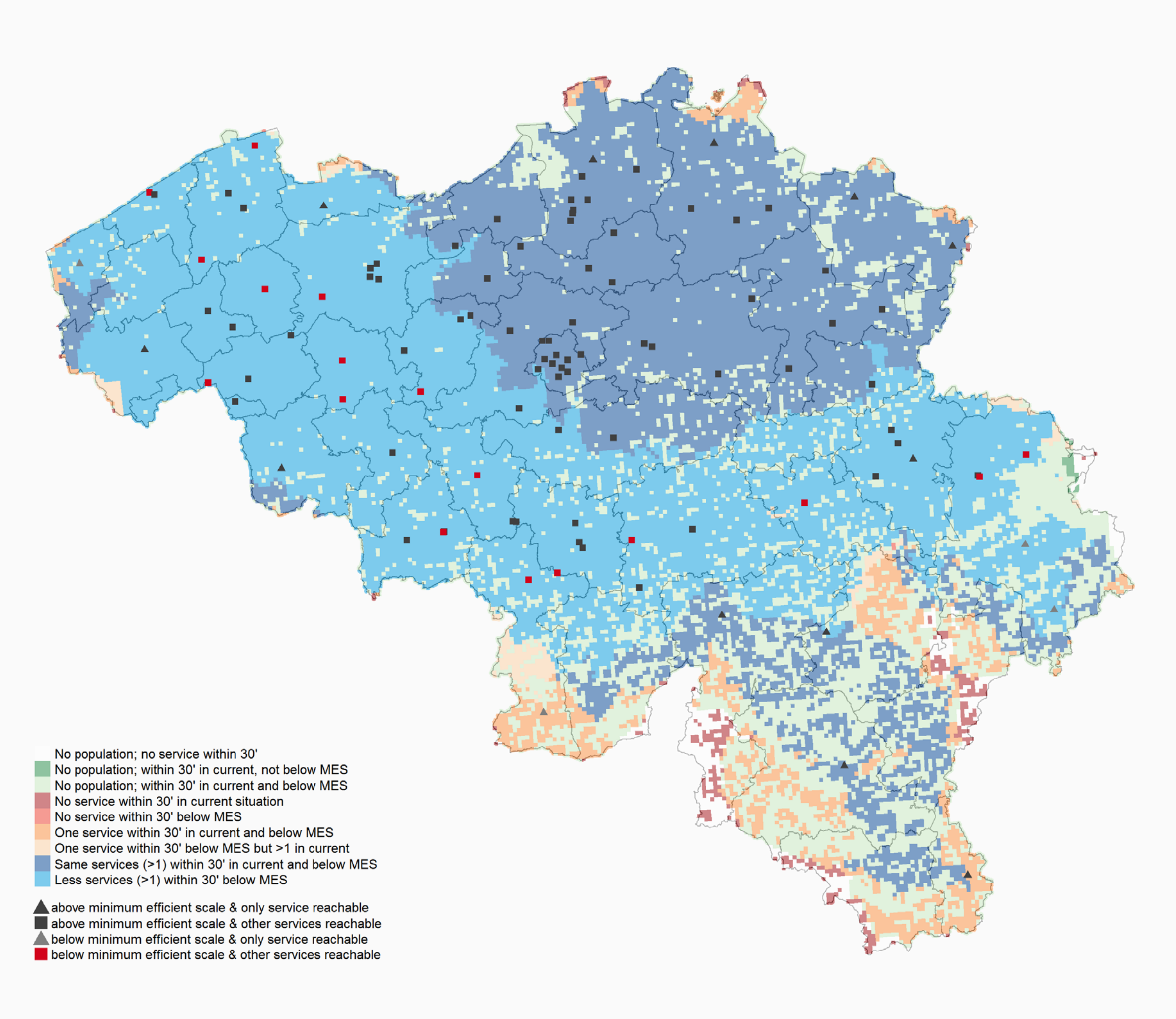
Intersects area definition

For the 47.2% of women between 15 and 49 years old that can reach less services within 30 minutes, almost all (99.66% or 47% of the population) can still reach two or more maternity services after transfer of activity. However, 0.44% (or 0.2% of the population) can now reach only one maternity service within 30 minutes.

Table 28 – Descriptive statistics on number of women between 15 and 49 years old following scale efficiency

	Women between 15 and 49 years old	
	Number	%
No maternity service reachable within 30 minutes prior to transfer of activity (current situation)	3 935	0.16%
No maternity service reachable within 30 minutes after transfer of activity	18	<0.01%
One maternity service reachable within 30 minutes both in current situation and after transfer of activity	41 407	1.66%
One maternity service reachable within 30 minutes after transfer of activity but more than one in current situation	5 221	0.21%
The same number of maternity services (>1) reachable within 30 minutes both in current situation and after transfer of activity	1 273 283	50.97%
Less maternity services (but >1) after transfer of activity	1 174 230	47.01%

Figure 43 – Maternity services reachable within 30 minutes following scale efficiency



Intersects area definition; there is a transfer of activity following scale efficiency only for the red squares

5.4 Key points

- **Between January 2017 and April 2019, three of the 25 maternity sites operating below minimum efficient scale have been closed. In two cases, the closure resulted from a site merger. A replication exercise shows that these mergers increased structural efficiency (efficiency at the sector level).**
- **In Belgium, almost all (99.8%) women between 15 and 49 years old can reach one or more maternity services within 30 minutes, given normal traffic conditions.**
- **1.7% of the women between 15 and 49 years old live in areas where only one maternity service can be reached within 30 minutes, given normal traffic conditions.**
- **16 maternity services (out of 104 in April 2019) are the only service reachable within 30 minutes for at least 21 women between 15 and 49 years old, this number being an approximation corresponding to one delivery.**
- **Once the aforementioned maternity services that are the only service reachable within 30 minutes are excluded, there are 17 maternity services for which activity is below the minimal efficient scale of 557 deliveries per year.**
- **Transferring activity from these 17 maternity services changes nothing for about half of the women between 15 and 49 years old (52.6%): they can reach the same maternity services as before. 47.2% of women between 15 and 49 years old have access to less maternity services. Only a very small number of women (<0.01%) can no longer reach a maternity service within 30 minutes.**

6 MODELLING PATIENT FLOW AND BED CAPACITY NEEDS

6.1 Introduction

6.1.1 Context

Healthcare systems are challenged to provide quality care using scarce resources, such as hospital beds, staff and equipment in an efficient way. In this setting, it is imperative to identify excess inpatient bed capacity. There are, however, different judgements and methodologies to quantify excess or shortage in capacity. The focus in this chapter is on the evaluation of capacity needs for maternity beds and not on capacity needs for other resources. While other resources, such as operating theatres, delivery beds, operating theatres or staff, may act as a bottleneck and effectively hinder timely access to care[58], there is insufficient information to evaluate them in a reliable way.

Traditional capacity planning

Hospital capacity decisions traditionally have been made based on target occupancy levels, which were introduced in the 1970s to easily calculate the necessary bed capacity with the aim to control accelerating health care costs. Target occupancy levels were calibrated by service type to avoid ‘unacceptable’ delays in a ‘typical’ hospital.[59-61] The target occupancy rate applied in the calculation of the hospital budget for maternity services is 70%.[3] Maternity services with an occupancy rate below [above] the target level have excess [insufficient] capacity based on this criterion.[o] The average national occupancy rate for maternity services in 2016 amounted to 49.3%, ranging from an annual occupancy rate of 19.6% to 95.2% at the level of an individual maternity service (see calculations in section 3.1.4.1).

o As discussed in Chapter 1, we do not have information on operational beds in hospitals and use licensed beds to calculate occupancy rates. The number of operational beds can be higher or lower than the number of licensed beds.

Only 9 of the 110 maternity services had an annual occupancy rate of 70% or more, suggesting an important excess capacity.

Following the traditional approach, the excess capacity of M-beds was calculated for 2014 in KCE report 289 and valued at 432 beds, based on the target occupancy rate of 70%. Moreover, the excess capacity was projected to increase to 1 063 M-beds by 2025, mainly because of a further reduction in average length of stay, while admissions were projected to increase slightly by 2025.[3]

Timely access

Low occupancy rates are considered to be indicative of operational inefficiency and viewed as undesirable.[62] While reducing excess capacity makes sense in terms of increasing efficiency and eliminating waste, it needs to be done in an appropriate and thoughtful way. Even though there is an important share of care in maternity services that is scheduled and can be planned in advance (in 2017, 11.5%, 9.8% and 10.5% of all deliveries were planned caesarean deliveries and 24.6%, 28.6% and 31.6% of all deliveries were induced in hospitals in Flanders[p], Brussels[p] and Wallonia, respectively)[63-65], the majority of the patients using maternity services are unscheduled. They are generally classified as 'emergent' and requiring immediate treatment.[61, 66] The inflow of unscheduled patients cannot be controlled which results in a disparity between the variable demand of care and the available capacity, which is generally fixed over a long period of time.[58, 60] Insufficient bed capacity is undesirable as it can lead to congestion and delay, earlier discharge of patients than desired, placement of postpartum mothers into less appropriate service units, all of which might be associated with adverse patient outcomes and dissatisfaction of patient and staff.[59, 60, 67, 68]. Also from a financial point of view, waiting time can lead to a longer length of stay and higher costs which are not fully compensated in the hospital financing system.[67]

Hence, other criteria can be important to identify the appropriate bed capacity. In this respect, the Institute of Medicine stated that next to efficiency, timeliness – defined as limiting waiting time and potentially harmful delays for both those who receive and those who give care – is considered a key aim of a healthcare system having a major impact on capacity.[62, 69] If the ability to place obstetric patients in appropriate beds in a timely fashion is considered a core element of service quality, then the traditional capacity planning approach using target occupancy rates is not suited to guide capacity decisions for maternity beds. Target occupancy levels do not vary by the activity level (number of admissions and inpatient days) of a hospital service, and only rudimentary account for the variability in demand over time and the variability in service time (length of stay); all essential determinants to guarantee timely access to a bed.[59, 70]

Capacity planning using queueing systems

An alternative approach to capacity planning using queueing systems, can be found in the field of operational research. Queueing theory is the mathematical theory of waiting lines, or queues. A queueing system is an abstract model that allows to analyse the functioning of a system that provides a service and faces random demands.[71] An extensive body of literature exists in which this methodology is applied in various settings, including the healthcare sector to analyse the patient flow through a healthcare service, i.e. the ability of a healthcare service to serve patients timely, reliably and efficiently as they move through the different stages of care.[67, 72]

It makes explicit the trade-off between an efficient allocation and use of resources (bed, staff, and/or equipment) and the timely access to these resources.[73] Timely access is evaluated in terms of having a delay to access a resource or the waiting time experienced by patients. Queueing theory provides a methodology to calculate the necessary capacity and corresponding occupancy rate satisfying a chosen performance indicator for timely access. Queueing systems can be solved using mathematical formulas or computer simulation models.

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p Results for Flanders and Brussels both include information from UZ Brussels.

Modelling method

We use a discrete event simulation (DES) model to recreate the patient flow of obstetric patients and model their use of inpatient services in each of the Belgian maternity services and solve the corresponding queueing system. The simulation model is used to verify and analyse the above-mentioned trade-off between timely access and high occupancy rates and to assess the impact on bed capacity needs in Belgian maternities. Our methodology and assumptions will be discussed throughout this chapter. Data from the year 2016 are used to calibrate the model.

6.1.2 Research questions

Simulation of patient flows can be used to assess changes in activity, capacity or policies for which the effects on resource requirements, efficiency and timely access can generally not be easily learned through real life experiments. The discrete event simulation model developed in this project aims to answer the following research questions:

1. What is the need for maternity beds in Belgium given the trade-off between an efficient use of scarce resources and the needed timely access to appropriate care for obstetric patients?
2. If a reduction in the number of maternity services currently operating would be pursued to increase the efficiency (see Chapter 4) without affecting geographical accessibility (see Chapter 5), would it be possible to accommodate the activity in the remaining maternity services?

6.1.3 Scope and concepts

Bed capacity needs are **evaluated at the level of a maternity service in a hospital site**. The maternity service consists of all units with at least one bed for labour (AR), delivery (OB) or maternity care (M, MIC) and with activity recorded in 2016 (see Figure 1). In this chapter, we consider the 108 maternity services that were open in December 2016 (see section 2.3). Two of the 108 maternity services have had an increase in capacity during 2016 directly related to a closure and transfer in capacity and activity of another maternity service within the same hospital. The activity and capacity of the closed and remaining maternity service in the year 2016 are taken together and the combined activity and bed capacity is used in the analysis.

All inpatient activity of obstetric patients that (partly) passes through the maternity service is used to calibrate the model; newborn patients, day-care and ambulatory activity are excluded. While day care and ambulatory care constitute 4.2% and 23.0% of all stays, respectively (see Table 5), their direct impact on bed use is difficult to quantify, but appears to be minimal.[q] The studied activity includes deliveries, but also other activity in MDC 14 and in other MDCs (see Table 6). A first reason to include all inpatient activity is that no assessment was done of the type of activity that should be or should not be performed within a maternity service. Hence, no specific care types are excluded a priori. Second, all inpatient stays have taken up bed capacity and should be accounted for when assessing bed needs and potential delays. It is assumed that ambulatory care and day care do not contribute to bed blocking and delay.

Activity that is not accounted for in the model is the so called ‘coupled care’, i.e. the stay of the mother (or both parents) at the hospital when a fragile newborn is hospitalised in neonatal care (N*-unit) or neonatal intensive care (NIC) with the purpose to promote physical parent–infant closeness, but without the need for acute care for the mother (or parents). In certain hospitals, the mother occupies in this case a bed in the maternity service.

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[q] The impact of ambulatory care on maternity bed use is unclear, as consultations do not necessarily require a (maternity) bed and generally have a short duration. When day care is assumed to have a length of stay of 0.81 days (which equals the length of stay used in the payment system for surgical day-care stays), they represent only 1.2% of all nursing days.

We do not account for this type of stay for two reasons. First, because it is not registered and no data exist to properly quantify this activity. Second, since no care is given to the mother (or parents) it is not clear whether this activity should take place in beds licensed for care. This issue is further studied in an ongoing KCE study.

Bed capacity is expressed in terms of **maternity beds, i.e. all recorded, licensed beds in M/MIC-units** with activity in 2016 (see Figure 3). Generally, these are M- or MIC-beds, but occasionally also other, unrelated, licensed bed-types that are located in M/MIC-units (in 2016 C (surgical), D (internal medicine) or N* (neonatal care) beds were found). The number of maternity beds is the starting point in the simulation model and is used as benchmark to evaluate a potential increase or reduction of bed capacity. If a reduction or increase in maternity beds has taken place during the year 2016, a weighted[r] average of the bed capacity has been used as reference value. The considered maternity services totalized 3 141 maternity beds in 2016.

Bed capacity is also related to the **need for other resources**, such as physicians, midwives, operating theatres, various types of equipment and non-licensed beds for labour and delivery (AR/ OB-beds). An evaluation of these other resources is not performed in this study. The capacity need for labour and delivery beds or operating theatres has not been studied mainly because they are not reliably registered. An important number of maternity services do not even record labour or delivery units separately from maternity units, so that no information is available on time spent in the different stages of the delivery. An evaluation of the required staff to guarantee access to care, necessitates an assessment of the needed care time for each patient group at the different stages of a hospital stay (e.g. admission, labour, delivery, post-partum, discharge etc.). Such an assessment was out-of-scope for the current study.

6.1.4 Overview chapter

The remainder of this chapter is organised as follows. Section 6.2 provides more background on queueing systems, the available data, the set-up of the simulation model and the methodological choices and assumptions. More detail is provided on how timely access is evaluated. Section 6.3 presents the results of the model. First, we verify the validity of the model in simulating the situation as is, next simulation results are discussed to answer the two research questions. Section 1.1 summarizes the key points.

6.2 Queueing systems, data and methodology

6.2.1 Background on queueing systems

6.2.1.1 Literature

Relevance of queueing theory for capacity planning of maternity services

Queueing theory is the mathematical theory of waiting lines, or queues. It was developed in the early 1900s by Agner Krarup Erlang who studied the capacity requirements for the Danish telephone system. More generally, queueing theory is a mathematical analysis of systems that provide services and face random variability in the demand for services and in the duration of the service process. A queueing system is an abstract representation of a system’s main features that relate to its ability to meet random demand. The objective of the queueing system is to optimise the use of scarce resources while dealing with delays in service that result from the mismatch between demand and capacity, i.e.to analyse the trade-off between timely access and efficiency, and to identify the most influential factors contributing to potential delay.

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[r] Weighted by the number of days that a particular bed capacity was recorded.

Queueing theory has been applied in various industrial settings and service industries. Also in healthcare services it has been used extensively – although predominantly for hospital care –, and proven to be particularly useful to model patient flow. Randolph Hall introduced the term 'patient flow modelling'. It represents the ability of a healthcare service to serve patients timely, reliably and efficiently as they move through the different stages of care.[67, 72] Patient flow models are used to identify appropriate levels of staff, beds, rooms and equipment as well as guide decisions on resource allocations in existing and new healthcare services. Given that healthcare services are faced with delays and waiting lists, increasing demand over time and constrained resources, it is generally recognised that the analysis of queues and patient flows can produce improvements in medical performance, patient satisfaction and cost efficiency in healthcare delivery.[60, 67] Readers interested in the many healthcare applications can find leads in, amongst others, the books of Hall (2013) and Denton (2013) or literature reviews by Günal and Pidd (2010) and Lakshmi and Sivakumar (2013).[68, 74-76]

A number of original papers specifically study patient flow in maternity services. They analyse capacity planning of beds, staff, delivery rooms or operating theatres; map out different care trajectories through the maternity services; or analyse the impact on capacity needs in various scenarios such as (i) a change in demand, (ii) a reduction in length of stay, (iii) a change in the proportion of C-sections, (iv) a shift in care policy, such as one-to-one care during labour (each obstetric patient is assigned her own midwife).[58, 59, 66 , 70, 77-84] Nearly all research is focused on the modelling and analysis of one specific hospital. The paper closest to our research objective – Green and Liu (2015) –, however, takes a public health perspective and studies the need for beds in maternity services across New York City in relation to timely access.[59] Timely access is operationalised as the percentage of patients who encounter a delay (irrespective of the waiting time). Timely access is considered to be guaranteed if this percentage does not exceed 5% on an annual basis. The minimum number of beds that ensures timely access is defined as the bed capacity need. Significant excess capacity is found, but with important variation between hospitals, some of which even had insufficient capacity to achieve timely access. They conclude that a large number of maternity services can likely reduce their bed capacity while still achieving timely access to care.

Building blocks of a queueing system

All queueing systems follow the same process (see Figure 44). In the terminology of queueing theory, it can be formulated as follows (see also Table 29): *customers* arrive (to request a service), wait (in the *queue* if necessary) for a *server* to become available to provide the required service, and then leave.[71] The *customer* is the person or thing that waits for a service; in our setting it is an obstetric patient admitted in the maternity service. The *server* is the person or the thing providing the service; in our setting the server is a maternity bed (and the care received while occupying the bed). The *queue* is the group of customers waiting to be served; in our setting these are obstetric patients in the maternity service for whom no bed is available at the time of admission.

Figure 44 – Queueing system applied to maternity setting

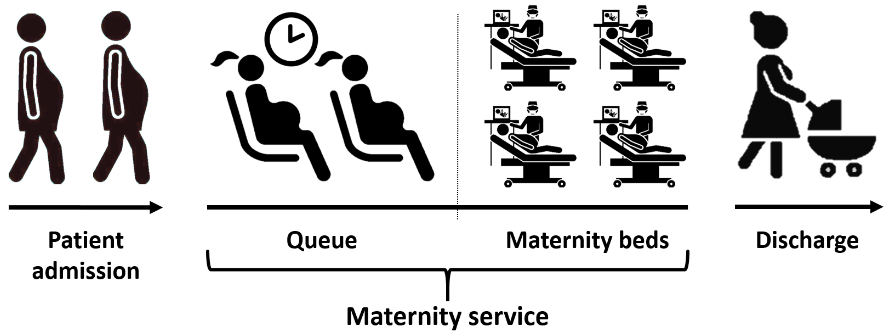

Table 29 – Queueing concepts applied to maternity services

Economic language	Applied to maternity service
Customers	Patients
Queue	Waiting room
Service	Care in the maternity service
Server	Maternity bed
Service time	Length of stay
Utilisation rate	Occupancy rate

The essence of the queueing system can be captured in three components:

1. the stochastic (that is, probabilistic or variable) nature of the demand, which is captured by the variability in the arrival process and in the service process;
2. the system's configuration, which is defined by the number and arrangement of the servers;
3. the queue discipline, which determines in what order customers are served and how the queue is organised.

More detailed information on queueing systems can be found in Box 10.

Box 10 – General features of a queueing system applied to the patient flow in a health service

All queueing systems consist of the same building blocks. However, they can be applied to different situations and different choices can be made to customise a system to the specificities of the situation. Below, we describe the general features and most common choices to be made. We assume that the system is a hospital service, its customers are patients and the servers are the hospital beds in the service. The three main components of the queueing system are:

1. the stochastic (that is, probabilistic or variable) nature of the demand, which is captured by the variability in the admission process and in the service process, i.e. the length of stay. The queueing system has two major sides, the input or patient side and the service side. Both sides are assumed to experience variability.

   Input process: the input process represents the timing and the number of patients arriving at the hospital service. If all patient admissions were scheduled in advance, a queue can be avoided and there would be no need for a queueing system analysis. In a hospital setting, there are generally both scheduled and unscheduled admissions. Hence only part of the input process can be controlled and another part will experience variability and randomness. Therefore, the input process is generally described using random variables which can represent either the number of admissions during a time-interval or the time-interval between successive admissions.

   The input process may vary profoundly. Differences relate to whether (i) patients arrive independently from each other, i.e. the occurrence of one admission is not related to another (dependency can arise e.g. in case of an epidemic outbreak); (ii) patients arrive in groups; (iii) patients arrive at constant rate or the admissions vary in time (e.g. weekday vs weekend, peak hours); (iv) patients prefer not to join the queue if there is one – referred to as balking –, or leave the queue before being served if they have to wait too long – referred to as reneging. Reneging and balking are often difficult to incorporate in a queueing system as patients who did not receive care are generally not recorded in hospital data.

   Service process: the service process represents the time taken to provide care to patients while they stay in a hospital bed, also referred to as service time or length of stay in a hospital setting. Generally this varies between patients. Length of stay might depend on the type of pathology, patient characteristics or the time of admission. The length of stay is generally determined using random variables.
2. the **system's configuration**, which is defined by the number and arrangement of the servers. There can be a fixed number of beds or it can be adjusted flexibly during the year, e.g. to cope with seasonal

variation in demand. Hospital beds can work in parallel and perform identical tasks, i.e. each can accommodate the same type of activity, or in sequence, e.g. first pre-operation bed, next operation and recovery bed followed by post-operation bed. In the latter case, the rules to determine the transition from one bed to the other have to be defined.

3. the **queue discipline**, which determines in what order customers are served and how the queue is organised. The first important feature of the queue concerns its organisation. There can be one single queue that feeds all beds, or there can be a separate queue for each bed or something in between. What is the maximum number of patients that can wait at the same time? There can be a specific maximum, but if the queue can be large, it is generally assumed that for all practical purposes, it is infinite.

   The second feature is the order in which the patients in the queue are served. This can be done e.g. on a first-come, first-served basis, on a last-come, first-served basis, or on a random selection for service. It might be that patients in specific (time-sensitive) conditions have a different priority for being served, e.g. in the emergency department, and if so criteria have to be established to assign priority. Priority queues can either be pre-emptive (and interrupt care for a patient with low priority when a higher priority patient enters the queue), or non-pre-emptive where the higher priority patient waits until a bed is free.

Source: Cooper (1981)[85], Cooper (2000)[71], Green (2013)[60], Hall (1991)[86], Hall (2013)[74]

A number of **key lessons** can be drawn from the literature on patient flow. First, there is an important association between capacity, e.g. number of beds, occupancy rate and the probability of delay for a resource. Hospital units with smaller capacity need to work at a lower occupancy rate compared to units with a larger capacity while attaining the same levels of delay in order to cope with the inherent variability in demand (see Box 11 for an example). There are economies of scale in the use of resources and applying one occupancy rate irrespective of the bed capacity can lead to undesirable levels of access for patients.[60, 70] Second, a larger variability in demand, i.e. in the number of patients that can arrive on a given day and their length of stay, necessitates more capacity to achieve the same level of timely access.[61] Third, at 'high' occupancy rates even small increases in demand can disturb the normal functioning of a hospital service and lead to important delays. The notion 'high' depends on the bed capacity of the hospital unit, as mentioned in the first argument.[61]

Box 11 – Basic relation between bed capacity, occupancy rate and timely access

The input process can be summarised in terms of the average number of obstetric patients per day and the variability thereof. If we assume that the admissions of obstetric patients are unscheduled, it has been shown that the input process (see Box 10) can be approximated by a Poisson process (see also section 6.2.3.3).[60, 87, 88]. In this case, the probability of having ***P*** patients on a given day is given by the equation:

$$\text{Probability } (\boldsymbol{P} \text{ patients}) = \frac{e^{-\mu}\mu^{P}}{\mu!}$$

where ***μ*** is the average number of obstetric patients per day.

Using this equation, it can be calculated that a maternity service with a daily average of 4 obstetric patients can expect that there is only 1% probability that the number of patients arriving on any one day will exceed 9. Similarly, a maternity service with 8 expected obstetric patients per day may anticipate that there is a 1% probability that on a given day, the number of arriving patients will exceed 15. In a large unit with 12 obstetric patients expected on average per day, this threshold increases to 21 arriving patients. Hence, in order to operate at the same probability of having insufficient capacity, the combination of two smaller units requires more capacity than the larger one. The smaller maternities need to plan for a joint capacity of 24 arriving obstetric patients per day, 3 more than the larger one. Hence smaller units need to plan for a higher buffer capacity which leads to lower occupancy rates.

Source: Barra et al. (2015)[87], Kirkwood and Sterne (2003)[89]

6.2.1.2 Queueing analytic approach versus discrete event simulation

Discrete event simulation (DES) and queueing analytic theory (QAT) are the most widely applied methods to evaluate queueing systems. Both methods allow to balance timely access and efficiency and have their strengths and weaknesses.

Queueing analytic theory applies a set of analytic techniques to define closed form mathematical expressions to describe the properties of the queueing system.[60, 90] A vital assumption is that the queueing system has a steady state, i.e. when the system operates for a sufficiently long time with the same properties – admission rates, length of stay, capacity – the main performance measures reach a certain level which is independent of time.[60] These performance measures include amongst other the probability of having a delay at admission, the average waiting time experienced or the average utilisation rate, and can be calculated using a formula.

In order to derive mathematical expressions, the queueing system needs to be simplified to its essential components. Mathematical expressions have been derived for over 40 different specifications of queueing systems.[s][91] A major strength is that with little data – bed capacity, average number of admissions and average length of stay can be sufficient – and the application of an existing formula, an evaluation can be made in little time. This provides a broad understanding of the system and generalizable insights.[66 , 70, 84]

However, there are limits on the complexity that can be captured through mathematical formulas. QAT is ill-suited to deal with more complex system features, such as time-dependent admission rates – for example peak hours during the day, differences between weekday and weekend, or seasonal effects –, multiple patient groups with different characteristics – for example different length of stay or admission rates by patient type –, or non-random, e.g. scheduled, admissions.[81, 90]

A **discrete event simulation model** is a computer model that mimics the dynamic behaviour of the processes in the queueing system over time.[90] Performance measures in terms of delay, waiting time or utilisation rates, can be easily computed from the simulation outcome. Normally, multiple simulation replications are made to capture the system's variability. This allows to calculate also other statistics such as the standard error or a confidence interval of the results.[68, 91]

Unlike QAT, DES models are not a priori restricted by specific assumptions or the limits of analytic tractability. DES is more commonly applied to model patient flow as it can incorporate much more details and address complex problems in a flexible way.[81, 90, 92] This is a major strength. DES models are able to cope, amongst others, with time-dependent variability, various patient groups with different care trajectories or length of stay, scheduled and non-scheduled patients, and context-specific features. The increased complexity in system features and processes, also allows to test more complex scenarios and specify more complex performance measures, e.g. instead of the average waiting time, one can quantify the maximum waiting time of a specific patient group over a specific period. The drawback of the added complexity is that the data requirements to fit the model are more demanding.[68]

The main disadvantages are that it takes more time to develop and validate a complex realistic simulation model than apply QAT formula, and second, that there is a risk of overfitting the model to a specific situation so that results are situation specific and less generalisable.[90]

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[s] Mathematical formula exist for example to analyse queueing systems with limited waiting room, patients leaving after waiting for an amount of time (e.g. overcrowding in the emergency department), patients with different priority levels, etc.

QAT and DES can be complementary. The accuracy of many QAT formulations have been investigated using simulation modelling. Moreover, both methods have been used jointly, with part of the queueing system solved using DES and another part using QAT. However, generally, only one approach is chosen.

Choice for discrete event simulation

With the objective to answer the research questions above (see section 6.1.2), DES was preferred above QAT. It was considered essential to incorporate specific complexities of the patient flow in maternity services into the model to make it more realistic. These specificities include that (i) part of the admissions are scheduled, (ii) the admission rate varies over time, which is at least partly related to these scheduled admissions (see section 6.2.3.3), (iii) there are differences in admission rates and length of stay by type of care, hence a subdivision by patient group seems appropriate. The flexibility of simulation modelling allows to account for these three features, while QAT cannot. In this case, a simulation model is expected to be more accurate.[59] Finally, the more extensive data requirements do not impede the use of DES, as most data are available in the hospital records (see section 6.2.2).

6.2.2 Data

Data from the Minimal Hospital Data (see Box 3) for 2016 are used both for the calibration and the validation of the model. A separate simulation model is constructed for each maternity service. Information from all obstetric inpatient stays (irrespective of APR-DRG) that pass through the maternity service is used (see Figure 10). This selection consists of pregnant women, labouring women, women having delivered and patients admitted for care unrelated to pregnancy or delivery. A more elaborate discussion of the data and manipulations of the data can be found in the Data Manual (which is available upon request).

6.2.2.1 Data for the calibration of the model

In order to calibrate the simulation model (more information on the simulation model is given in section 6.2.3), information is needed on the patient flow for each maternity service, more specifically on patient groups, admission patterns, length of stay, bed capacity and discharge patterns.

Patient groups

Using the APR-DRG classification (see Box 5), we subdivide the clinical activity of inpatient obstetric patients into three groups: caesarean deliveries, vaginal deliveries and all other activity.

Time spent in the maternity service

The admission time is defined as the moment when the patient enters the maternity service for the first time. Time registration has a precision of one minute. The admission time is used as a proxy for scheduled deliveries (planned caesarean deliveries and induced deliveries). Another variable (A2_CODE_ADM) that provides more information on the type of admission, including the option that the admission was planned, was not used. The information in this variable is questionable as an important number of planned deliveries occur in the weekends and outside the typical hours for planned admissions.

The length of stay is defined as all time spent in the maternity service. The length of stay in the maternity service is extended in two cases. First, for caesarean deliveries, all time spent in the operating theatre and recovery room is added to the length of stay. Second, if an obstetric patient leaves the maternity service for another service and returns within 24 hours to the maternity service, it is assumed that her bed remains reserved within the maternity service and hence the time in the other services is added to the length of stay. When applying these rules to determine length of stay in the maternity service, we find that the total length of stay equals the length of stay in the maternity service for over 96% of all deliveries[t] and 75% of all other activity. It is clear that stays unrelated to deliveries often only partially take place in the maternity service, while the overwhelming majority of obstetric patients admitted for a delivery remain the entire hospital stay in the maternity service.

For deliveries, the length of stay can be further subdivided in a pre-delivery time and post-delivery time (see also section 3.1.3.2). This is only possible for maternity services that separately record the pre-delivery units (AR/OB-units for labour and delivery). Seven maternity services do not record an AR-unit or an OB-unit. To create the subdivision, the moment of delivery was fixed using a set of rules. For vaginal deliveries at the time of exit of the last AR/OB-unit of the stay. For caesarean deliveries according to the following order of priority: time of exit of the first operating theatre during the stay; time of exit of the last AR/OB-unit of the stay; time of entry of the first recovery unit of the stay. The subdivision in pre- and post-delivery time could be made for 90.1% of all caesarean deliveries and 87.4% of all vaginal deliveries.

For simplicity of the model and given the close match between total length of stay and length of stay in the maternity service, we assume that length of stay is uninterrupted and hence the discharge time equals the admission time plus the length of stay in the maternity service.

Bed capacity

The bed capacity equals the maternity beds, i.e. all licensed beds in M/MIC-units as recorded in UNITINDX. If a reduction or increase in maternity beds has taken place during the year 2016, a weighted[u] average of the bed capacity has been used as reference value.

6.2.2.2 Data for the validation of the model

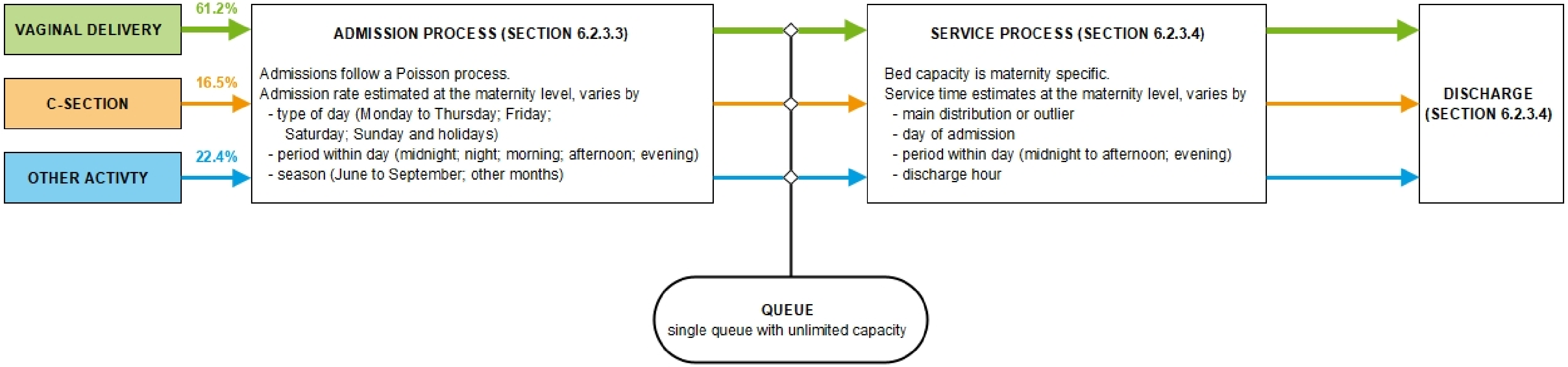
In order to validate the model, the distribution of the simulation outcomes is compared to the observed distribution for 2016 of:

- Daily occupancy rates. The daily occupancy rate in a maternity service is computed as the total time spent (expressed in days) by all patients in a maternity service on a given day, divided by the number of available maternity beds;
- Midnight census. The midnight census is a count of the number of inpatient obstetric patients present in the maternity service at midnight;
- Length of stay;
- Number of daily admissions in the maternity service, in total as well as subdivided by patient group.

[t] We ignore time spent of less than 30 minutes in the emergency department which is assumed to be related to the inscription of the obstetric patient in the hospital.

[u] Weighted by the number of days that a particular bed capacity was recorded.

Figure 45 – Main structure of the discrete event simulation (DES) model



6.2.3 *Methodology*

6.2.3.1 *Overview of the model*

The simulation model aims to recreate the patient flow and model the use of inpatient services in each of the Belgian maternity services. It is specified at the level of an individual maternity service. The access to care in each maternity service is evaluated based on a target maximum percentage of patients who may experience a delay in obtaining a bed at admission (see section 6.2.3.2). The model is built in R 3.6.0, using the package 'simmer' version 4.2.2.

The maternity service has a specific and well-defined patient population. Although there is complex interaction between the different units within the maternity service (labour, delivery, postpartum, neonatal care etc.), the interaction with other hospital services is very limited (for over 96% of all deliveries in 2016, the total length of stay in the hospital equals the length of stay in the maternity service). Hence it can be (safely) assumed that a maternity service operates and sets its bed capacity independently of the rest of the hospital.

To limit the risk of overfitting, the structure of the model is the same for each maternity service; it is based on the major trends and features that are observed in the hospital data at the national level. Figure 45 provides an overview of the main structure; a detailed description follows in the sections below. Whenever modelling choices or assumptions had to be made, we have **favoured conservative choices, i.e. choices that bias the estimated bed capacity needs upwards rather than downwards.**

As presented in Figure 45, the model assumes that there are three types of care: vaginal delivery (61.2% of all admissions), caesarean delivery (16.2% of all admissions) and all other activity (22.4% of all admissions). Admissions for each patient group in the maternity service occur according to a time-dependent Poisson process. The variability in time has three dimensions: differences between days, differences within a day and seasonal differences. In the baseline scenario, each patient is assigned a maternity bed at admission, whereas in the alternative scenario obstetric patients admitted for a delivery are assigned a maternity bed at delivery. If no bed is available, the patient has to wait in a single queue with an infinite capacity until one is available. A bed is provided to patients in the queue based on the first-come first-served principle without priority between patient types (see also Box 10 on the general features of a queueing system). Each patient occupies a maternity bed and receives care for a certain length of stay, which is drawn from a distribution. Finally, the patient is discharged and the hospital bed is again available for other patients.

The structure of the model provides a framework wherein maternity specific differences can exist. Nearly all parameters that specify the admission process or length of stay are fitted at the level of the individual maternity service. It does, however, not impose those differences to be present nor important (see Box 12 for an example).

Box 12 – How the structure of the DES model accommodates maternity specific complexities

The DES model provides a flexible way to model patient flow. Although the main structure of the model is the same for all maternity services, maternity-specific differences can be accounted for. As will be detailed in section 6.2.3.3, the model allows for time-varying admission rates. It is, for example, observed in the data that an important number of maternity services have a peak in admissions for induced vaginal deliveries just past midnight (between 0h and 1h) on weekdays. In the structure of the model, it is specified that the admission rate may be different on weekdays and weekend days, and may vary within the day. Admission rates are allowed to be different in the period between 0h and 1h compared to e.g. the period between 1h and 6h. The simulation model, however, does not impose the admission rates to be different over these two periods. How (dis)similar they are, depends on the calculations based on the hospital data. For maternity services that do not organise induced deliveries at midnight, the admission rates in the two periods are likely to be similar. For maternities that do schedule induced deliveries at midnight, the admission rates in the two periods are likely to have quite different values.

6.2.3.2 *Objective of timely access*

Hospital bed capacity decisions traditionally have been made based on target occupancy levels, with the assumption that higher occupancy rates are indicative of more efficiency. As discussed in the introduction (section 6.1), target occupancy levels might not be the best criterion to guide capacity decisions as they do not vary by the activity level (number of admissions and inpatient days) of a hospital service, and only rudimentary account for the variability in demand over time and the variability in service time. Queueing system analysis starts from a different premise, i.e. that high occupancy rates should not impede timely access to care. The underlying philosophy is that an appropriate bed capacity level for a maternity service implies that there are sufficient beds to assure timely access.

There are various definitions as to what constitutes timely access. In this study, **timely access is defined in terms of encountering a delay to access a maternity bed**. More specifically, it is measured as the fraction of patients for whom no maternity bed is available at the time of admission (also referred to as the **probability of delay** in accessing a bed). Alternative definitions of timely access refer to (i) the fraction of patients that cannot be secured a bed within a certain amount of time after admission, (ii) the average waiting time, (iii) the average number of patients in the queue.

What constitutes an acceptable probability of delay? Surprisingly, not much evidence can be found in the literature. No official or operational standard value could be found for capacity planning in maternity services.[70] Arguably, the acceptable delay is likely to be context specific.[60, 70] Obstetric patients are considered ‘emergent’ and require immediate treatment, hence the tolerance for bed unavailability cannot be set too high.[61] In the literature on capacity planning in maternities, target values of 1%, 5% and 10% have been used.[59, 61, 70, 79, 82, 93] We propose using the same target values and give a corresponding range of bed capacity needs.

Evaluation of bed capacity

Bed capacity needs are evaluated based on the chosen objective of timely access. It is determined as the minimum number of beds that ensures that in each maternity service no more than 1%/5%/10% of the patients experience a delay in accessing a bed on an annual basis. The resulting occupancy rate is not a target in itself, but a by-product of the analysis. The bed capacity need changes substantially depending upon the probability of delay that is deemed acceptable.

For each maternity service, a double calculation of the probability of delay is performed, once over the entire year and once limited to the summer months (June to September). As discussed in section 6.2.3.3, the summer is a period of sustained higher activity in maternity services at the national level, which can affect occupancy rates, waiting time and probability of delay in an important way. The more stringent of both – i.e. the highest level of probability of delay – is used in the evaluation of the necessary bed capacity. This capacity level will ensure timely access both throughout the year and in the potentially busier summer period.

Baseline scenario – bed reserved at admission

It is important to remark that the probability of delay refers to the unavailability of maternity beds, i.e. the recorded, licensed beds in the M/MIC-unit(s) of the maternity service (see Figure 1 and section 6.1.3), and does not include beds in the labour, delivery or operating units. The latter are not accounted for, as their use and availability are not well recorded in the hospital data. In the baseline scenario of the simulation model, it is assumed that at admission, a maternity bed is reserved for each new patient, whether or not the patient immediately requires one. Indeed, more than three quarters of patients in the maternity services are admitted for a delivery and do not immediately require a postpartum bed. This is a conservative approach, as a longer length of stay in maternity beds is assumed in the model than in reality observed, which translates in a more important bed need and an increased probability of delay. The results of this scenario can be considered as an upper bound on the bed capacity needs. It is important to keep this in mind when interpreting the results.

Alternative scenario – bed reserved postpartum

In the alternative scenario of the simulation model, it is no longer assumed that a maternity bed is automatically reserved for a patient upon arrival. Patients admitted for a delivery are assumed to first spend time in a labour or delivery unit and only require a maternity bed post-delivery. The time spent in labour and delivery is modelled as a fraction of the length of stay in the maternity service. The fraction is drawn from a lognormal distribution and is specified by patient group and number of intermediary days. It is not estimated at the maternity level as we do not have information for all maternity services. The fraction is capped at 80% of the length of stay to avoid outlier values. The alternative scenario serves two purposes. First, an alternative probability of delay can be calculated related to the bed capacity needs as evaluated in the baseline scenario. Second, alternative bed capacity needs can be quantified using the alternative scenario. As the time spent in a licensed maternity bed is reduced to a minimum, the corresponding bed capacity needs should be interpreted as a lower bound on the bed capacity needs.

6.2.3.3 Admission pattern

A distinction is made between three obstetric patient groups: caesarean deliveries, vaginal deliveries and all other activity. We are interested in different patient profiles for three reasons. First, the admission pattern differs by patient type; not only the number of admissions per day, but also the variation over days of the week and the intraday variation. Second, the length of stay can be quite different (see section 6.2.3.4). Third, the fraction of scheduled admissions differs by method of delivery (in 2017, 55.0%, 49.7% and 48.2% of all caesarean deliveries were planned and 27.8%, 31.7% and 35.3% of all deliveries excluding the planned caesarean deliveries were induced in hospitals in Flanders[p], Brussels[p] and Wallonia, respectively).[63-65] Therefore, the three patient groups make different use of the available capacity and have a different impact on bed needs.

Admissions follow a Poisson process

In line with other patient flow models in maternity services, it is assumed in the DES model that the probabilistic nature of the admission process follows a Poisson process (see Box 13 for more information on the Poisson process). This is a standard assumption that is mathematically convenient as it is characterised by only one parameter, the average admission rate. Each of the three patient groups has its own admission process.

A main assumption underlying the Poisson process is that the probability of an admission is independent of time. It has been shown that this assumption is reasonable for unscheduled admissions in the maternity service, after adjusting for seasonal effects.[60, 87, 88] Even though the majority of admissions are unscheduled, a non-negligible part of the activity consists of scheduled admissions (in 2017, 36.1%, 38.4% and 42.1% of all deliveries were either planned caesarean deliveries or induced deliveries in hospitals in Flanders[p], Brussels[p] and Wallonia, respectively).[63-65] The standard Poisson process of random arrivals is not suited to deal with scheduled arrivals.

A solution is the use of a Poisson process with time-dependent admission rates. Instead of simulating the admission process with one average daily admission rate, time is subdivided in timeslots in which the admission rates can be different. The timeslots are used to separately model periods with higher and lower activity. Differential admission rates by day of the week and period within the day are used to accommodate scheduled admissions which generally occur on weekdays and either at midnight or in the morning (see below). This approach allows to account for time varying circumstances in the assessment of bed capacity needs.

Box 13 – Poisson process

In a Poisson process, the number of admissions that occur in a time period has a Poisson distribution, or alternatively, the time intervals between admissions are exponentially distributed. An important feature is that the time of the next admission is independent of when the last admission occurred. Therefore a Poisson process is sometimes called 'memoryless', and considered as the most random input process. It is the most prevalent distribution to describe the input process in queueing systems.

There are three main assumptions underlying the Poisson process:

1. Patients arrive one at the time.
2. The probability that a patient is admitted at any time is independent of when other patients were admitted.
3. The probability that a patient is admitted at any time is independent of time itself.

Assumptions 1 and 2 seem reasonable assumptions for maternity care, and in fact for most other types of care. A violation of assumption 1 could be a (major) accident that leads to multiple simultaneous arrivals. A violation of assumption 2 could be an epidemic outbreak, where the contamination process is responsible for generating multiple related admissions over a time period.

Assumption 3 is difficult to substantiate. The admission rate in maternities varies over time. Admission rates are higher on weekdays than on weekends and peak periods exist within weekdays. Both effects are predominantly the result of scheduled admissions. Moreover, there is an increased number of deliveries in the summer months (June to September). However, a time-dependent Poisson process is able to reconcile the variation in admission rates over time and assumption 3. In a time-dependent Poisson process, time is subdivided in timeslots. Assumption 3 applies in this case to a timeslot, which means that average admission rates should be the same within a timeslot, but are allowed to differ between timeslots. As such, it is possible to adjust admission rates to reflect peak hours, variation in days of the week or seasonal variation.

Source: Green (2013)[60], Kolker (2010)[90]

Variation in admissions over time

The use of maternity services is not uniform across the year, the week or even the day. Figure 46 to Figure 48 present the observed differences in admissions by day of the week, by period within the day and by season. The time-dependent admission process that we implement reflects this variation.

In Figure 46, the **distribution of the daily admission rate** is given by patient group for each day of the week. School holidays[v] and public holidays[w] are typically periods of lower activity and are presented as separate categories. The following observations can be made. The highest daily admissions are recorded from Monday to Thursday. On Friday and weekdays during school holidays, the admission rate is somewhat lower. Given that scheduled admissions are generally not planned in weekends and public holidays, these days are characterised by much lower admission rates. A slightly higher number of admissions is recorded on Sunday and public holidays, compared to Saturdays. These findings apply to all patient groups. Chi-square tests indicate significant differences between four groups of days: Monday to Thursday (group 1); Friday and weekdays in school holidays (group 2); Saturday (group 3); Sunday and public holidays (group 4).

In the simulation model, separate admission rates are estimated (by maternity service) for each group of days. The average admission rate observed in group 1 is used to simulate admissions on Monday, Tuesday, Wednesday and Thursday; the average admission rate observed in group 2, group 3 and group 4 are used to simulate admissions on Friday, Saturday and Sunday, respectively. In the model, the normal structure of a week is repeated over time for an entire year (i.e. 366 days in 2016). Hence, school holidays or public holidays are not simulated, but are replaced by 'normal' week- or weekend days. This replacement most likely contributes to higher simulated activity levels and conservative – upward biased – estimates of bed capacity needs, as the simulated activity on a 'normal' week- or weekend day generally surpasses the observed activity on holidays.

We are aware that the conclusions drawn at the national level might not apply to a specific maternity service, i.e. a maternity service can choose to plan all scheduled admissions on Tuesday and Thursday and therefore the admission rates can be quite different between Monday and Wednesday on the one hand and Tuesday and Thursday on the other hand, the four days in group 1. While there may be organizational or other reasons for this hospital policy, it is not necessarily optimal from a public health policy perspective, and hence, we have decided not to accommodate these differences, and adjust the model structure only to differences in admission patterns discernible at the national level.

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[v] School holidays do not include the summer holiday, which lasts two months, because it is considered unrealistic to significantly alter the activity level through hospital policy for such an extensive period.

[w] Public holidays include legal holidays and bridge days of the federal government as well as the days of Flemish, French and German communities.

Figure 46 – Distribution of daily admission rate at the national level by day

The **intraday variation in the average admission rate** is depicted in Figure 47 for each patient group and group of days. From the differences in hourly admission rates, three conclusions are drawn. First, peak periods occur on weekdays, but not on weekend days, indicating that the peak in activity is caused by scheduled admissions. Second, there are two peak moments, in the morning (from 6h up to 10h) and at midnight (from 0h up to 1h). The morning peak applies to all patient groups, whereas the midnight peak is especially pronounced for vaginal deliveries and to a lesser extent for caesarean deliveries. A significant number of maternities plan the admission for deliveries with induced labour at midnight to optimise the length of stay for the mother. The smaller peak in caesarean deliveries can be explained by a fraction of the induced deliveries that result in caesarean deliveries. Third, there is a drop in admissions for vaginal deliveries in the afternoon (10h up to 18h), after the morning peak.

Based on these findings, we subdivide a day in the following five periods: midnight [0h-1h); night [1h-6h); morning [6h-10h); afternoon [10h-18h); evening [18h-0h). However, it seems unnecessary to estimate period-specific admission rates for each group of days and patient group. For example, the admission rate for caesarean deliveries on a Saturday hardly varies over the day, hence no difference is made between the different periods when estimating the admission rate. The timeslots for which a different admission rate is calculated and simulated are indicated by different colours in Figure 47. The colour scheme should be interpreted independently for each group of days and patient group. It can be seen in Figure 47 that the hourly admission rates on a Saturday (group 3) for caesarean delivery all have the same colour, indicating that they are quite similar and only one admission rate will be estimated over the entire day. For vaginal deliveries on a Friday (group 2), on the other hand, four colours are used to depict four different periods (from midnight to 1h; from 6h to 10h; from 10h to 18h; and a combined period from 1h to 6h and from 18h to midnight). For each of these four intraday periods a separate maternity-specific admission rate will be estimated.

Figure 47 – Admissions per hour by activity type and type of day

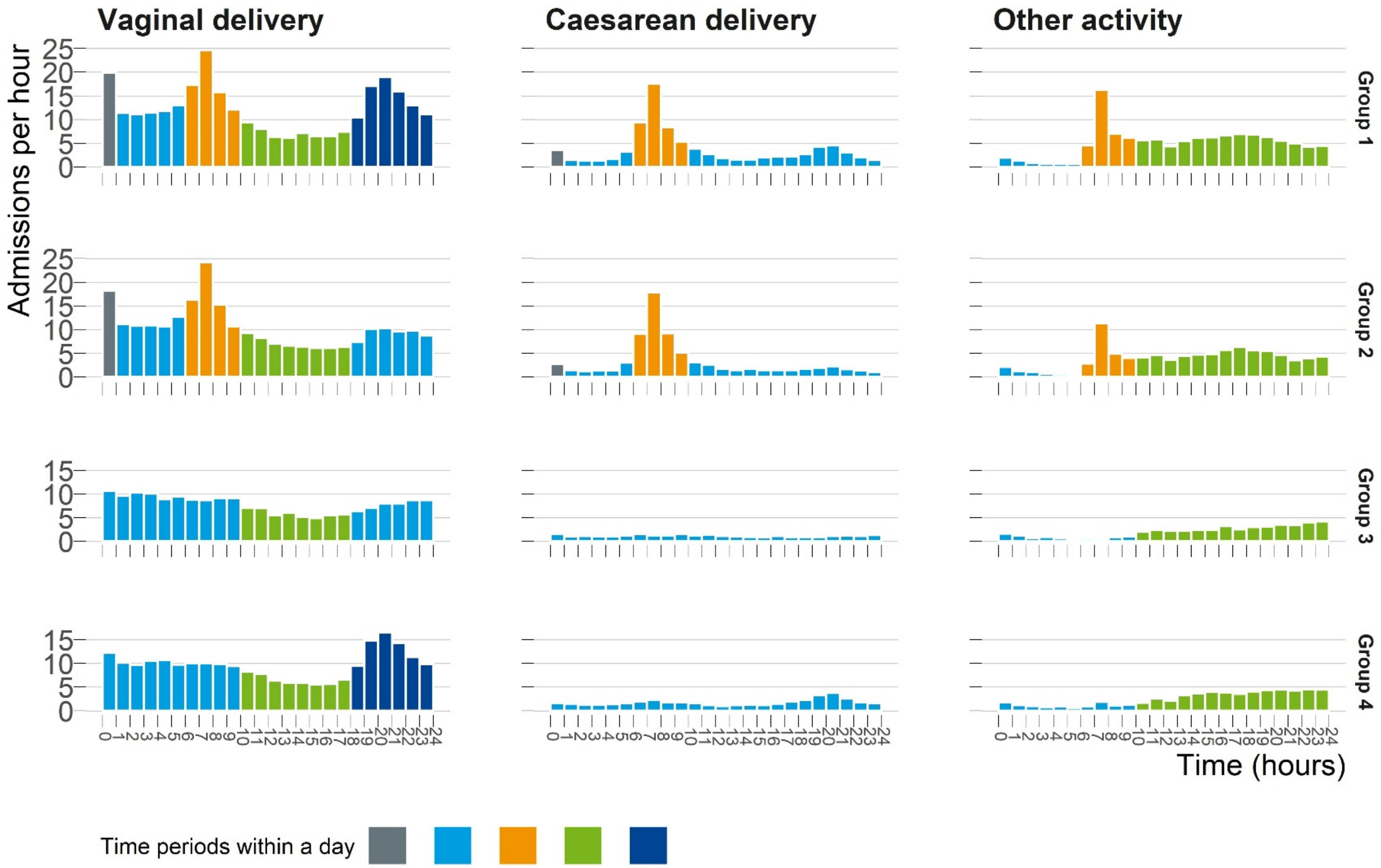
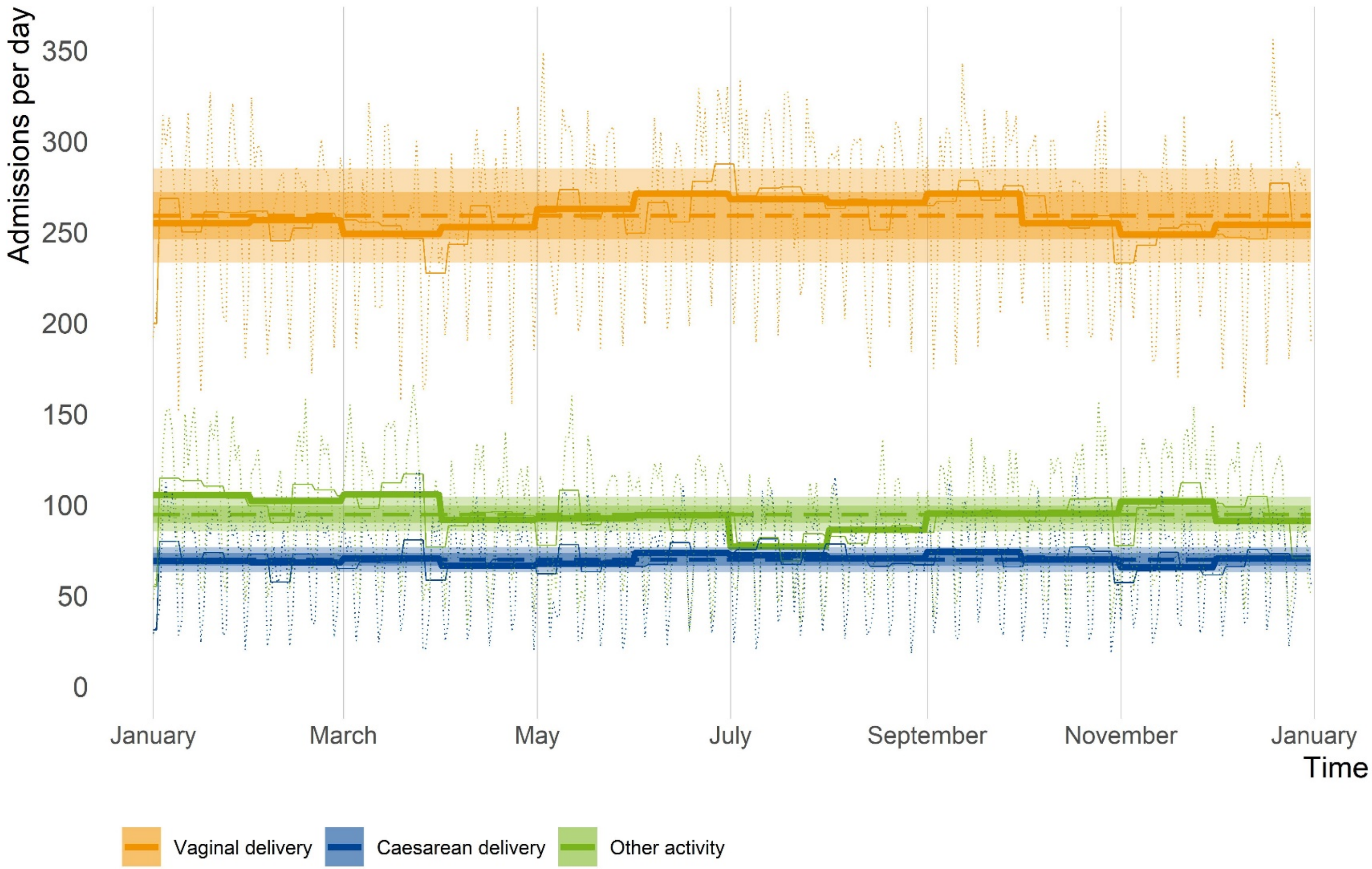


Figure 48 – Seasonal variation by patient group over time



Note: Annual average admissions per day = long-dashed line; 10% deviation around annual average = light coloured band; 5% deviation around annual average = dark coloured band; monthly average admissions per day = thick solid line; weekly average admissions per day = thin solid line; daily average admissions per day = dotted line.

Seasonal effects in the daily admission rate are represented in Figure 48. The long dashed line represents the annual average of the number of daily admissions for the year 2016. The light and dark coloured bands show, respectively, the 10% and 5% deviation around the year average. The thick solid line, the thin solid line and the dotted line show the variation over time and represent, respectively the monthly, weekly and daily variation.

Monthly variation in daily admission rates is limited and the deviation around the mean is generally less than 10% (except for other activity in July). There is, however, a sustained period of an increased number of deliveries in the summer months (June to September). This seasonal pattern is not specific to the year 2016 and is also observed in other countries.[59, 61, 87] Although the deviation is limited in magnitude at the national level, it might be important at the maternity level and, as discussed in section 6.2.1.1, even small changes in activity level can have a pronounced effect on the experienced delay when operating at high occupancy levels.

Therefore, the admission rates are estimated and simulated separately for the summer months and the other months. Moreover, the probability of delay criterion is evaluated separately during the summer months in addition to the evaluation on an annual basis. The more stringent of both is used to determine the bed capacity need (see section 6.2.3.2). This is a conservative approach to make sure that also in months with higher activity levels, timely access is achieved.

6.2.3.4 Length of stay and discharge

After the patient is admitted and assigned a bed, the service process starts. It represents the time that the patient occupies or reserves a maternity bed and the maternity bed is unavailable to other patients. In the baseline scenario, the service time equals the length of stay (LOS) of a patient throughout the maternity service. In the alternative scenario, it is assumed that patients who are admitted for a delivery, first spend some time in the labour and delivery unit or operating theatre and the service time equals the postpartum part of the LOS. Nothing changes for patients admitted for other care. Given that in the baseline scenario a bed is assigned at admission while a maternity bed is not yet needed for a patient admitted for delivery, we do not additionally account for the bed turnover time, i.e. the time that is needed to make a bed available for the next patient after discharge. We assume that the bed turnover can be realized between admission and delivery.

For simplicity, it is assumed that length of stay in the maternity is uninterrupted. This is a reasonable assumption as the total length of stay in the hospital equals the length of stay in the maternity service for over 96% of the obstetric patients admitted for a delivery and 75% of the obstetric patients admitted for other care. Moreover, in two specific circumstances, time spent in other units is added to the LOS in the maternity service (see section 6.2.2.1). This is a conservative approach as a longer LOS contributes to a higher capacity need.

LOS decomposed

In its most simplified conceptualisation, LOS is the time between admission (in the maternity service) and discharge (from the maternity service). The time of admission is determined by the admission process (see section 6.2.3.3). The discharge is not random, but is largely determined by hospital policy. The majority of maternity services have a peak in discharges at one particular (or a limited number of) hour(s) in the day. Moreover, there is no significant correlation between the hour of admission and the hour of discharge. Both events appear to be driven independently from each other. Therefore, we suggest to decompose the LOS in three parts: (i) LOS on the day of admission (from the time of admission to midnight); (ii) LOS on the day of discharge (from midnight to the hour of discharge); and (iii) the days between admission and discharge (in what follows denominated ‘intermediary days’). The total LOS is the sum of the three components. Remark that this implies that a discharge from the maternity service cannot take place on the same day as the admission to the maternity service. Given that the scope is limited to inpatient care, this is rarely observed in the data (it occurs in 0.3% of the caesarean deliveries, in 0.0% of the vaginal deliveries, and in 2.4% of stays for other activity).[x]

A major advantage of this approach is that it makes LOS more accurate and bed occupancy more in accordance with the observed activity. A discrete probability distribution is used to simulate the discharge hour. Each discrete value, i.e. each of the 24 hours in a day, has a particular probability of occurrence, which together form a probability distribution. Using a uniform random number between 0 and 1, and the cumulative probability as cut-off values, a nearly perfect fit can be obtained between simulated and observed discharge hours. Similarly, the number of intermediary days can be simulated with a very good fit from a discrete probability distribution. If, alternatively, the complete LOS was drawn from a continuous distribution, it might be possible to have a good fit for total LOS, but it will be impossible to achieve the observed peak in discharges without additional (stringent) conditions. To give an example, a patient is admitted for a delivery at 23h21, a LOS is drawn from a distribution and equals 3 days, 2 hours and 5 minutes, which implies a discharge at 1h26, 4 days later. This is clearly not a time at which discharges typically occur.

Estimation of LOS

Differences in length of stay have a profound impact on the capacity assessment. To improve the accuracy of the model's predictions, LOS is estimated and simulated at a very detailed level. In practice, this concerns only the middle part of the LOS, i.e. the intermediary days. The admission time is fixed during the admission process and the first part does not need to be estimated, whereas the discharge hour is simulated at the maternity level without further subdivisions. Variability in LOS in the following five dimensions is taken up in the model.

First, differences in LOS by patient group are accounted for. Caesarean deliveries have on average a longer length of stay than vaginal delivery (5.3 days versus 3.5 days at the national level). Patients admitted for other care have the shortest stays (2.8 days). It is more common that these patients are in the maternity service for only part of their stay.

Second, a maternity-specific LOS is used, as LOS can reflect, amongst others, differences in case-mix that are justified and important to incorporate in the model.[y] For example, women with high-risk pregnancies are generally treated in maternity services with a MIC-unit, leading to admissions with longer LOS.

Third, the distribution of intermediary days is skewed to the right for all three patient groups (see Figure 49), meaning that there is a small group of patients with a long length of stay that form a long right tail in the distribution. The group in the tail is too small at the maternity level to make reasonable probabilistic predictions. Therefore, the distribution is split in the main distribution and the tail distribution (coloured green and red in Figure 49, respectively). For each patient group, the main distribution is delineated as

[x] This can occur if only part of the hospital stay takes place in the maternity services, which is more frequently the case for other activity than for deliveries.

[y] Differences in LOS in maternity services can also reflect differences in efficiency, in practice, in the availability of outpatient care, or in early discharges due to lack of capacity. From a public health policy perspective not all differences in LOS are justifiable and need to be accounted for. However, it is impossible to attribute differences in LOS to a specific cause based on the available hospital data.

the LOS below the mean augmented with two times the standard deviation.[z] The main distribution ranges from 0 days to 5, 8 and 7 days, for vaginal deliveries, caesarean deliveries and other activity, and comprises 98.2%, 96.3% and 96.5% of the stays, respectively. The main distribution is fitted using a discrete probability distribution. The tail distribution is estimated using a negative binomial distribution. The tail distribution is estimated separately for each patient group, but is not further detailed, e.g. not maternity-specific.

Fourth, the main distribution of intermediary days is different in function of the day of admission. The reason is that there are fewer discharges in the weekend, especially on Sunday, and this has an effect on the LOS. As a result, a day-specific probability distribution is applied in the model. Figure 50 illustrates the issue. It shows the main distribution for deliveries with vaginal delivery specified by day of arrival. When looking at the distribution of Thursday, it can be seen that the probability of having two intermediary days is smaller than average while the probability of having three intermediary days is higher than average. This corresponds to a day of discharge on Sunday and Monday, respectively. The longer LOS for patients admitted on Thursday is compensated by a shorter stay of patients admitted on Friday, who have a higher probability of staying two intermediary days, i.e. discharge on Monday.

Fifth, the main distribution of intermediary days varies in function of the intraday period in which the obstetric patient is admitted. The difference is especially apparent for patients admitted for a delivery in the evening hours (18h to midnight). As illustrated in Figure 51, these patients are more likely to have an additional intermediary day, compared to patients admitted during the day (0h-18h). Consequently, the main distribution is split into an evening distribution and a day distribution for both types of delivery (not for other activity).

[z] The mean ± 2 times the standard deviation captures around 95% of the observations in case of a normal distribution, a level generally used to establish statistical significance. The remaining 5% can be considered as divergent from the mean. The criterion used here, mean + 2 times the standard deviation will capture an even higher share of the observations.

Figure 49 – Distribution of intermediary days by activity type

Note: Stays with more than 40 intermediary days are not represented in the figure (n = 25 or 0.03% for Vaginal delivery, n= 49 or 0.19% for Caesarean deliveries and n = 62 or 0.18% for Other activity)

Figure 50 – Main distribution of intermediary days for deliveries with vaginal delivery, specified by day of admission

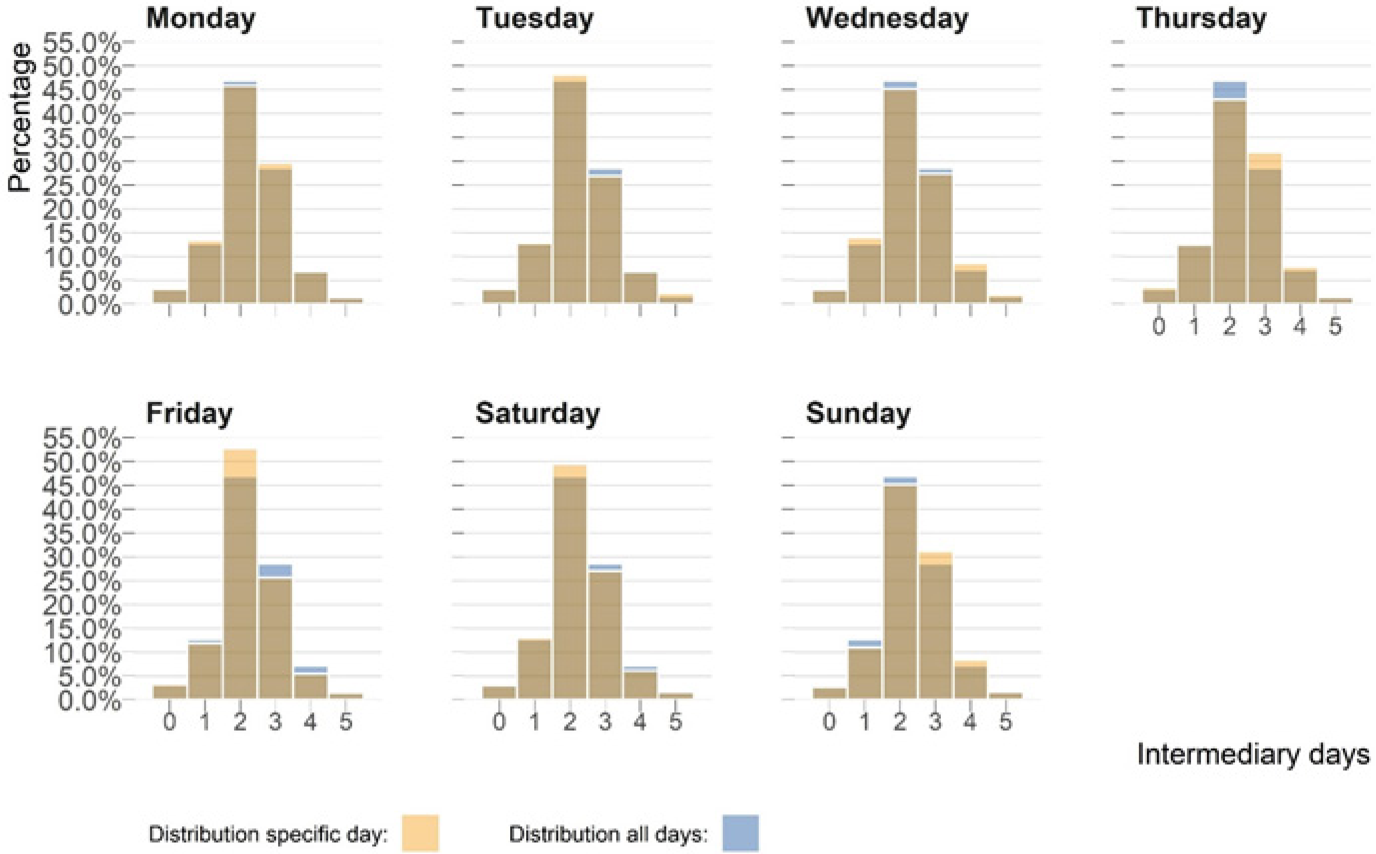
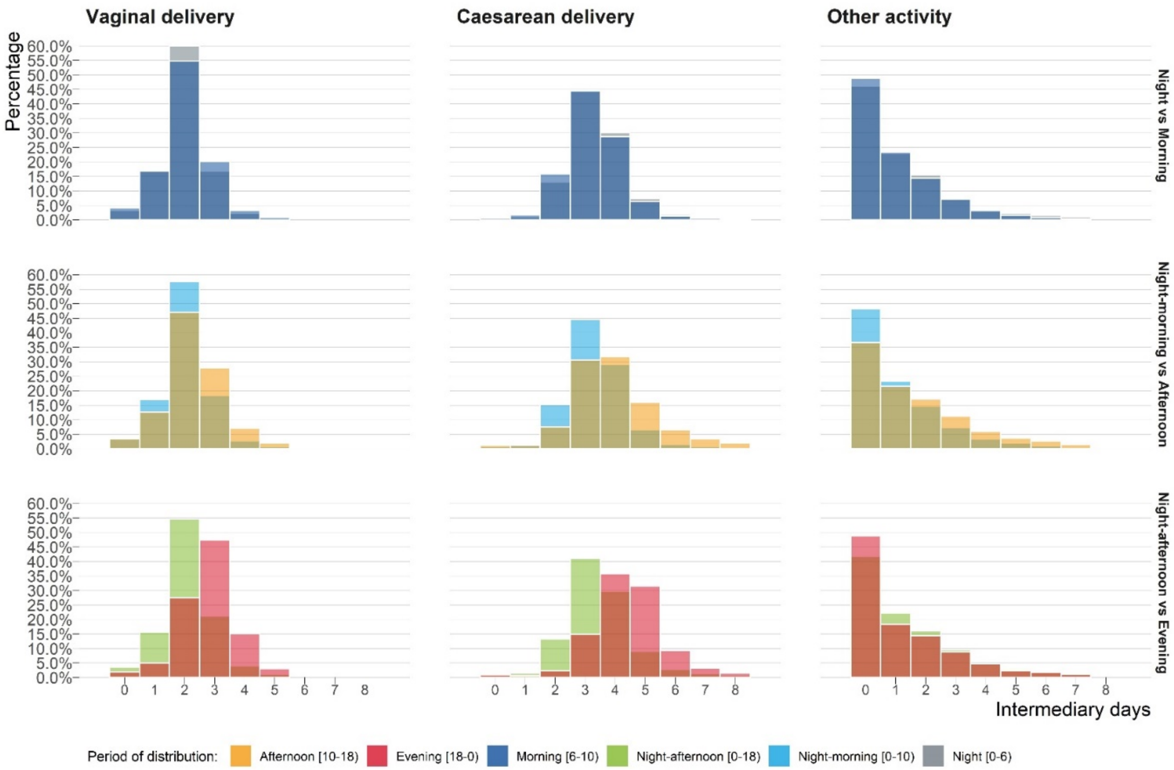


Figure 51 – Main distribution of intermediary days, specified by patient group and period of admission



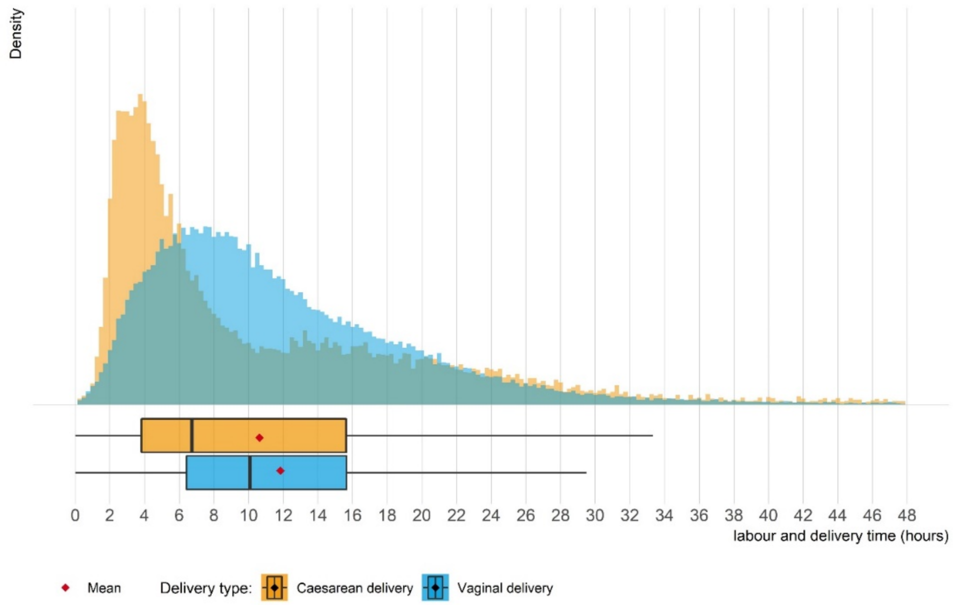
Pre-delivery time

In the baseline scenario of the simulation model, all obstetric patients are assigned a maternity bed at the time of admission and need to wait if no bed is available at that time. Obstetric patients admitted for delivery, however, do not yet require a maternity bed at admission, as they first spend time in the labour and delivery units or the operating theatre. This is a conservative approach in the estimation of the needed capacity of maternity beds.

Therefore, an alternative scenario is simulated as well in which obstetric patients admitted for a delivery are only assigned a maternity bed at the time of delivery. Hence, in the alternative scenario, time spent in a maternity bed is shorter as no maternity bed is occupied before the delivery and the necessary bed capacity will be lower.

The time spent before the delivery can only be computed for a subset of maternities (see section 6.2.2). Nonetheless its distribution can be indicative of the time a maternity bed is reserved, but not used in the baseline scenario. It can be compared to the waiting time recorded in the simulation model and allows to contextualise the significance of a target probability of delay. Figure 52 visualises the distribution of time before the delivery for caesarean deliveries and vaginal deliveries. When excluding patients with pre-delivery time exceeding 48 hours, we find that women spend, on average about 10 hours and 38 minutes in labour and delivery for a caesarean delivery, although the median is less than 7 hours (6h44m). The distribution is skewed, implying that an important fraction of caesarean deliveries remain only a short time in labour and delivery units or operating theatres, whereas other caesarean deliveries take more time. They might start as a vaginal delivery and the mode of delivery is switched in the process. Vaginal deliveries have a median (mean) time of about 10 hours and 4 minutes (11h50m) in labour and delivery.

Figure 52 – Distributions of time spent before delivery for vaginal delivery and Caesarean delivery



Note: Time of delivery is determined using a set of rules (see section 6.2.2). Stays with time before delivery of more than 48h are removed (n = 2 516 or 2.4%). Boxplot rectangle is drawn from Q1 to Q3 with median as inside line, whiskers are drawn until first observation > Q1-1.5 IQR and last observation < Q3 + 1.5 times IQR, red diamond indicates the mean.

6.3 Results

6.3.1 Running the model

One model run generates results for one maternity service operating at a specific capacity for one year, i.e. 366 days to be able to compare the simulation results with the observations in 2016. For each capacity level, 50 replications are made, using a different set of random numbers. In order to ensure replicability of the simulation results, predefined seeds are used to initialize the pseudorandom number generator.

The use of replications limits the risk that some simulations are particularly good or bad with respect to timely access and bias the results. An inspection of the results showed that 50 replications are sufficient to generate robust, steady state averages of the main variables of interest – total number of arrivals, daily admission rates and LOS by patient group; daily occupancy rates; probability of delay (annual and summer); and waiting time – as well as tight confidence intervals.

To generate meaningful results, the analysis should not start with an empty system, but from a maternity service with a realistic number of patients in – or waiting to be in – a maternity bed and receiving care. As a result, a warm-up period of 20 weeks is set to train the model and to ensure that the maternity operates at a normal activity level.

6.3.2 Validation

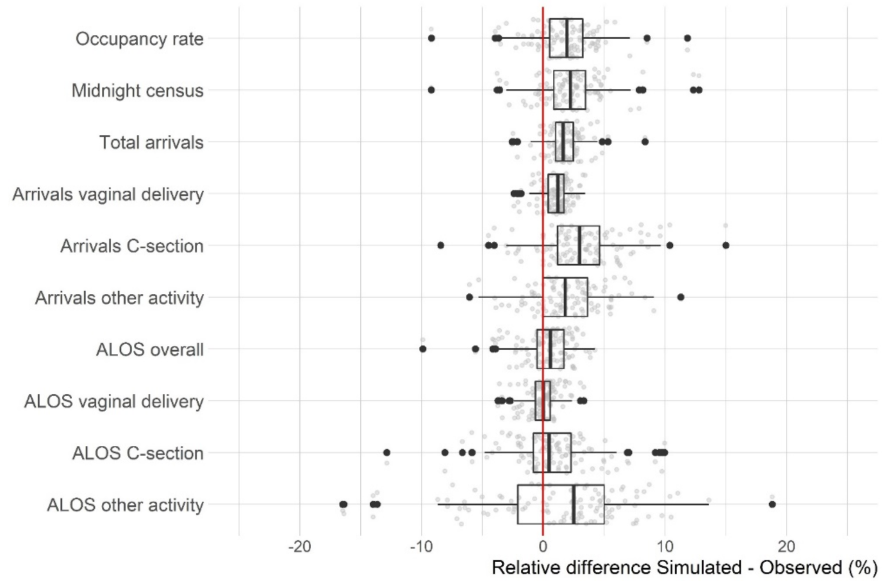
Objective

A validation is performed to evaluate the functioning of the model and assess whether or not the DES model is able to generate simulation results that closely match the observed data. This is a necessary first step, before the model can be used to answer the research questions.

Method

For each maternity service, the baseline model is run with the current capacity of maternity beds. As explained in section 6.2.3, the admission rates, LOS and discharge policy are calibrated at the maternity level using the observed activity in 2016. The simulation outcomes are validated through comparison of the average daily occupancy rate, the total number of arrivals by patient group, the average LOS by patient group and the average midnight census with actual observations and through comparison of simulated and observed distributions of the number of arrivals per day, the daily occupancy rate, the daily midnight census, the intermediary days and the discharge hour (see also section 6.2.2.2).

Figure 53 – Relative divergence between simulated results and the observed situation in 2016



Note: ALOS = average length of stay; red line = simulated value equals observed value; grey dot = validation result of 1 maternity service; Boxplot rectangle is drawn from Q1 to Q3 with median value as inside line, whiskers are drawn until first observation > Q1-1.5 IQR and last observation < Q3 + 1.5 times IQR; black dots = outlier results.

Results

A large overlap of the different simulated and observed distributions listed above is found when visually inspecting the validation results at the level of a maternity service. To assess the match between real-life values and simulated results for the annual averages and annual totals, their relative difference is calculated. The results are presented in Figure 53. A positive difference indicates that the simulated value is higher than the observed value. For each variable of interest a boxplot summarises the distribution of the relative differences and the value of each individual maternity service is given by a grey dot. We conclude that for all variables of interest, the relative difference is below 5% in absolute value for the majority of maternity services. Second, the simulated number of admissions, the midnight census and the occupancy rate are on average and for the majority of maternity services above the observed activity levels. This can be explained by the conservative choices that are made in the structure of the model, which introduce an upward bias in the number of admissions. The length of stay is simulated with high accuracy, especially for obstetric patients admitted for a delivery.

In Figure 53, a number of outliers are observed. Further investigation shows that there are three causes of outlier values. First, certain maternity services have a high fraction of patients with LOS in the tail distribution. The tail is estimated at the national level, due to the small sample size, and might therefore not be a perfect fit at the maternity service level. This causes discrepancies for LOS, but also for the occupancy rate and the midnight census. Second, certain maternity services have low activity levels, i.e. low occupancy rate and/or low number of admissions, which implies that relatively small absolute differences translate in larger relative differences and sometimes outlier values. This causes outlier values for occupancy rates and admissions. Third, a number of maternity services operate at very high occupancy rates (see section 3.1.4.1). At high occupancy rates, even small variations in activity can profoundly impact the probability of delay and waiting time. Patients who are waiting, but not yet in treatment are counted for the midnight census, leading to important divergences.

Overall we conclude that the validation of the model is satisfactory and that the DES model is able to simulate the activity in the Belgian maternity services.

6.3.3 Research question 1: Bed capacity needs

6.3.3.1 Setup

Objective

An assessment is made of the number of maternity beds needed in Belgium to achieve timely access. All Belgian maternity services operational in December 2016 are included in the evaluation. It is assumed that all maternity services remain operational at their observed activity level. Three target values for probability of delay are used (1%, 5%, and 10%) and the target has to be achieved in every maternity service.

Method

For each maternity service, the simulation model is run multiple times with different bed capacities using both the baseline scenario and the alternative scenario. As explained in section 6.2.3, the admission rates, LOS and discharge policy are calibrated at the maternity service level using the observed activity in 2016. For each maternity service and capacity level, the annual and summer probability of delay are calculated. The more stringent of both – i.e. the highest probability of delay – is used to evaluate timely access and compute the bed capacity need in the maternity service. Moreover, we compute the occupancy rate and the distribution of the waiting time experienced. For each maternity service, simulation results are generated for all capacity levels between a low level (associated with a probability of delay >10%) and a high level (associated with a probability of delay <1%).

The bed capacity level for which the probability of delay is closest to the target value in absolute terms, is identified as the bed capacity need for that maternity service. The sum of all maternity-specific bed capacity needs gives the overall bed capacity need and can be compared with the current number of licensed maternity beds.

The baseline and alternative scenario apply the same method but differ with respect to the moment that a maternity bed is assigned to a patient. For the baseline model, this is at the time of admission for all obstetric patients, whereas in the alternative model, patients admitted for a delivery are assigned a maternity bed after the delivery took place.

6.3.3.2 Results

Association bed capacity, occupancy rate and probability of delay

One of the key lessons of the literature on patient flow is that there is an important association between bed capacity, occupancy rate and probability of delay (see section 6.2.1.1). This association invalidates the use of target occupancy rates to determine bed capacity needs and is at the centre of our evaluation strategy. When a target value for timely access is used as main criterion to determine bed capacity needs, one needs to accept differences in occupancy rates which are a function of the number of beds. Larger maternity services can cope more efficiently with variability in demand than smaller ones and can therefore operate at higher occupancy rates.

The association is visualised in Figure 54 for both the baseline scenario and the alternative scenario. Figure 54 shows the occupancy rate on the vertical axis, the bed capacity on the horizontal axis and contour lines that have a constant probability of delay. The grey dots indicate for each maternity service the currently observed capacity – occupancy rate combination. The figure can be read in different ways. When moving upwards along the vertical axis, the occupancy rate increases while keeping bed capacity fixed. This leads to a higher probability of delay level. Moreover, as occupancy rates increase the distance between the contour lines decreases, implying that the probability of delay grows non-linearly. When reading the figure horizontally, keeping the occupancy rate fixed, it can be seen that larger maternities can ensure higher standards for timely access than smaller maternities. If the target occupancy rate of 70% was effectively reached by all maternities, the smaller units would operate at higher risk of delay. However, one can immediately see that few maternities (only 9 out of 108) had an occupancy rate of 70% or above in 2016. From the perspective of timely access, it might be in fact preferable not to operate at a 70% occupancy rate. If for example both a target occupancy rate of at least 70% and a probability of delay of maximum 5% are combined, this would imply that the bed capacity should be at least 34 maternity beds in the baseline scenario (corresponding to about 2 000 deliveries per year[aa]) and 20 maternity beds in the alternative scenario (corresponding to about 1 000 deliveries per year[aa]). When starting from a contour line, the maternity services situated below [above] the contour line operate at a lower [higher] probability of delay. The contour line moves upwards, indicating that larger maternity services can achieve higher occupancy rates than smaller units while ensuring the same risk of delay.

Given our definition of daily occupancy rates – all time in the maternity service expressed in days divided by the number of maternity beds (see section 6.2.2.2) –, occupancy rates are the same in the baseline and alternative scenario. However as bed use is different, timely access at a given capacity level has changed. This explains the different association between bed capacity, occupancy rate and probability of delay in the baseline and alternative scenario. It can be seen in Figure 54 that a given target of timely access can be reached in the alternative scenario at lower bed capacity level or put differently, the probability of delay is lower at a given capacity level.

[aa] The number of deliveries is determined by exploring the association between number of deliveries, occupancy rate and probability of delay in a similar way as was done for bed capacity, occupancy rate and probability of delay.

Figure 54 – Relation between occupancy rate and bed capacity of maternity units specified by probability of delay

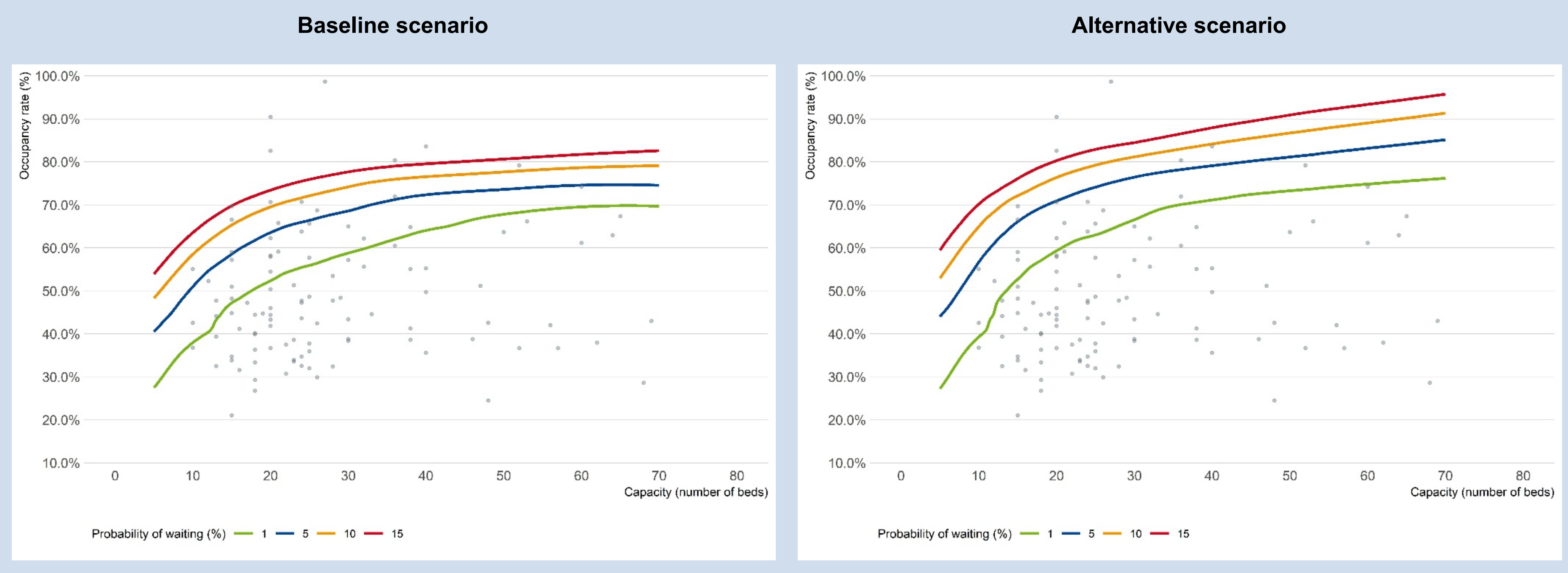
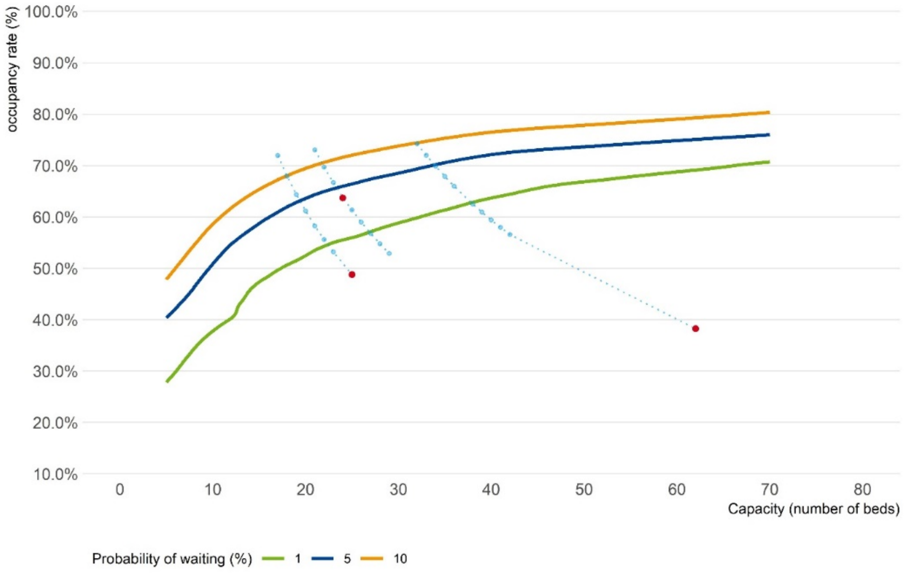


Figure 55 – Relation between occupancy rate, bed capacity and probability of delay for three selected maternities in the baseline scenario



Bed capacity need in the baseline scenario

If one wants to assess bed capacity needs related to a target probability of delay, the capacity level closest to the contour line needs to be identified. For each maternity service a range of capacity levels is evaluated in the simulation model, leading to different combinations of occupancy rate, bed capacity and probability of delay. Figure 55 provides an example for three randomly chosen maternity services. The red dot indicates the starting position, i.e. the observed capacity – occupancy rate combination. The light blue dots indicate the simulated baseline values using different capacity levels, and different values for the same maternity service are connected by a dotted line. A reduction [increase] in bed capacity leads to an increase [decrease] in both the occupancy rate and the probability of delay. If the red dot is below [above] the target contour line, there is excess [insufficient] capacity. Excess capacity means that the number of beds can be reduced while still achieving the target probability of delay, whereas capacity shortage implies that more bed capacity is necessary to achieve the target probability. The simulated levels can be used to quantify the excess [shortage]. The net excess or shortage in capacity at the national level is the combination of all individual values.

Table 30 provides information on the number of maternity services with excess or insufficient capacity in the baseline scenario evaluated at each of the three target probabilities of delay. The majority of maternity services has excess capacity in licensed beds, i.e. 69, 90 and 99 maternity services on a total of 108, respectively, at the 1%, 5% and 10% target probability level. As the target probability is raised, the buffer capacity to cope with the variability in demand can be reduced, excess bed capacity increases and it is possible to operate at higher occupancy rates. **Overall, the simulation results of the baseline scenario indicate a net excess of 390, 736 and 899 licensed maternity beds in 2016 evaluated at the 1%, 5% and 10% level, respectively, on a total of 3 141 licensed beds in maternities**. As comparison, the excess capacity of M-beds was calculated for 2014 in KCE report 289 and valued at 432 beds, applying the traditional approach at a target occupancy rate of 70%.[3] The excess capacity is likely to persist given that the length of stay of patients admitted for delivery decreases over time.

The excess capacity is concentrated at the larger maternity services, 63% of the excess in licensed beds at the 1% delay target is located in maternity services with over 40 maternity beds, the fraction remains high at 45% and 41% at the 5% and 10% target, respectively. This can be explained by the ability of the larger maternity services to better cope with the variability in demand and operate at higher occupancy rates. At a target probability of delay of 5%, maternity services with over 40 maternity beds in 2016 can attain on average an occupancy rate of 70% if excess capacity is cut back without impeding timely access. At a target level of 10%, also maternity services with over 25 maternity beds in 2016 can reach an occupancy rate of 70% or more if excess capacity is cut back.

In order to assess **the appropriateness of a 1%, 5% or 10% probability of delay and the corresponding bed capacity levels**, we can look at the probability of delay for the proposed bed capacity level in the alternative scenario and have a more detailed analysis of the distribution of waiting times. As can be seen in Table 30, the average **probability of delay when running the alternative scenario** at the proposed bed capacity levels of the baseline scenario is 0.3%, 1.9% and 4.2%, which is significantly below the 1%, 5% and 10% targets, respectively. This implies that by changing the time at which a bed is assigned from admission to delivery for obstetric patients admitted for delivery, greatly impacts the number of patients who experience a delay.

Second, it is important to analyse **the distribution of waiting times**. Is there a risk of excessive waiting times? Table 30 suggests that the average waiting time is small, 4 minutes, 27 minutes and 65 minutes at the 1%, 5% and 10% level, respectively. This value comprises the large majority of patients who do not experience any waiting time. When considering only the subgroup of obstetric patients who experience a delay, the mean [median] waiting time amounts to 6h54m [4h50m], 9h10m [6h18m], and 10h58m [7h32m] at 1%, 5% and 10%, respectively. In the baseline, a maternity bed is reserved at admission for every obstetric patient admitted for a delivery, even though the bed is not necessarily used before the delivery takes place. Therefore, it makes sense to compare the waiting time experienced before a maternity bed is available with the time in the maternity service before the moment of delivery. The distribution of time before delivery is given in Figure 52. The mean [median] time before delivery amounts to 10h38m [6h44m] for caesarean deliveries and 11h50m [10h04m] for vaginal deliveries. This is well above the mean and median waiting time for target values 1% and 5% and in line with the waiting time for the 10% target. This suggests that the chosen probability levels and associated waiting time do not impede timely access to a maternity bed.

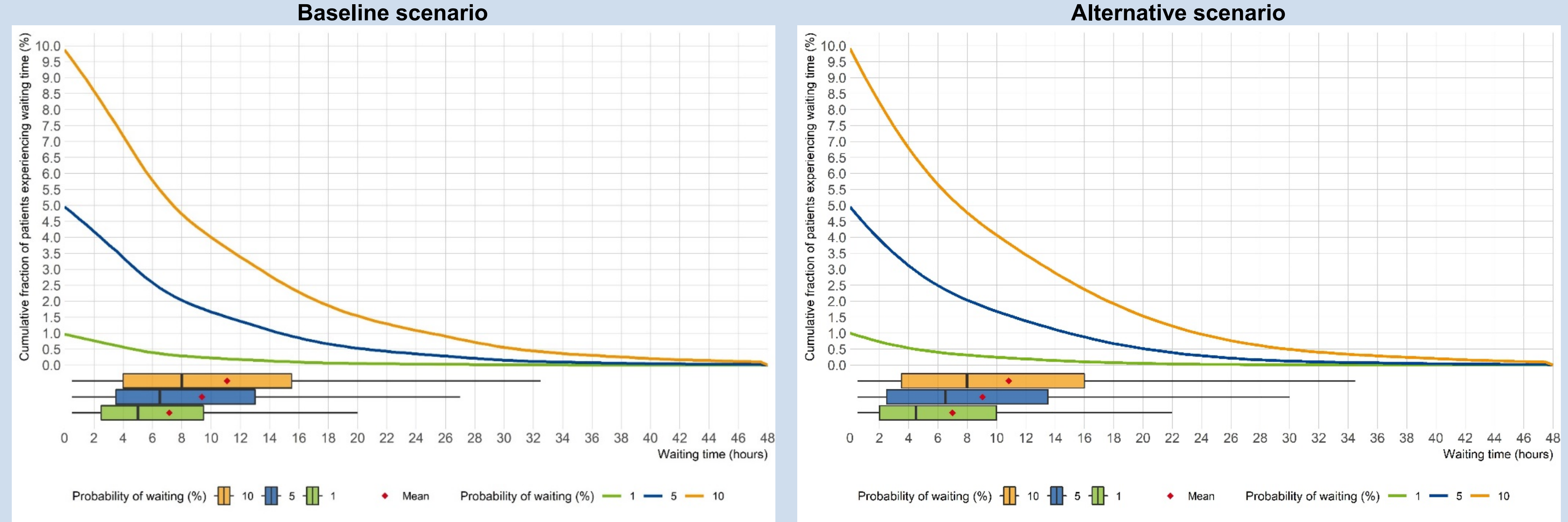
Both for the waiting time and the time before delivery, the mean exceeds the median, implying that a small group of patients experience long waiting times and time in labour or delivery. An inverse cumulative distribution of waiting time by target probability of delay is given in Figure 56. The coloured lines indicate the fraction of patients (in percentage on the vertical axis) that experience a waiting time that exceeds the corresponding value on the horizontal axis (the waiting time expressed in hours). For example, the green line (1% target) indicates that 1% of the patients experience a waiting time of more than 0h (this corresponds to the target value by definition), or that 0.56% of the patients experience a waiting time of 4 hours or more. The boxplots at the bottom of the figure summarise the distribution of waiting time (when waiting) for the different target values. In addition, Table 30 indicates the fraction of patients who experience a delay when waiting time exceeds a specific threshold time (from 4h to 16h). The results show that this fraction becomes very small, certainly with a 1% and 5% probability of delay.

Table 30– Overview bed capacity needs and timely access in the baseline scenario specified by target probability of delay (N=108)

	1% Probability of delay	5% Probability of delay	10% Probability of delay
Bed capacity needs			
Maternity services with excess capacity	69	90	99
Maternity services with excess capacity by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds – N = 18 / 45 / 27 / 18)	6 / 30 / 17 / 16	12 / 39 / 22 / 17	16 / 41 / 24 / 18
Maternity services with >20% excess capacity	35	59	68
Mean excess bed capacity	7.5	8.7	9.3
Median excess bed capacity	5.0	6.0	7.0
Total excess bed capacity	517	779	922
Maternity services with insufficient capacity	30	10	7
Maternity services with insufficient capacity by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds – N = 18 / 45 / 27 / 18)	10 / 11 / 7 / 2	2 / 4 / 3 / 1	1 / 3 / 3 / 0
Maternity services with >20% insufficient capacity	9	3	2
Mean bed capacity shortage	4.2	4.3	3.3
Median bed capacity shortage	3.0	3.5	3.0
Total bed capacity shortage	127	43	23
Total net bed excess	**390**	**736**	**899**
Total net bed excess by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds – N = 244 / 950 / 885 / 1062)	-6 / 82 / 70 / 244	34 / 207 / 166 / 329	54 / 262 / 213 / 370
Average daily occupancy rate	53.60%	61.89%	66.80%
Average daily occupancy rate by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds)	44.6 / 50.8 / 58.0 / 63.2	53.2 / 59.4 / 65.9 / 70.8	58.9 / 64.3 / 70.7 / 75.1
Timely access			
Average waiting time	4 minutes	27 minutes	65 minutes
Average waiting time when waiting	6 hours 54 minutes	9 hours 10 minutes	10 hours 58 minutes
Median waiting time when waiting	4 hours 50 minutes	6 hours 18 minutes	7 hours 32 minutes
Probability of delay > 4h	0.56%	3.36%	7.17%

Probability of delay > 8h	0.28%	2.03%	4.73%
Probability of delay > 12h	0.17%	1.37%	3.38%
Probability of delay > 16h	0.09%	0.85%	2.28%
Probability of delay alternative scenario	**0.28%**	**1.90%**	**4.24%**

Figure 56 – Inverse cumulative distribution of waiting time specified by probability of delay



Note: Boxplot rectangle is drawn from Q1 to Q3 with median value as inside line, whiskers are drawn until first observation > Q1-1.5 IQR and last observation < Q3 + 1.5 times IQR, red diamond indicates the mean.

Bed capacity needs in the alternative scenario

The simulation outcomes of the alternative scenario are summarized in Table 31. As the time spent in a maternity bed is shorter in the alternative scenario than in the baseline scenario, it comes as no surprise that the required bed capacity is below the baseline bed needs at every target probability of delay. The results show that more maternity services have excess capacity, i.e. 85, 99 and 103 maternity services at the 1%, 5% and 10% target, respectively, leading to an excess of 632, 951 and 1 107 maternity beds at the national level. As before, the excess in beds is predominantly concentrated at larger maternities, which can operate at higher occupancy rates than smaller maternities while ensuring the same level of timely access. If we would run the baseline scenario using the capacity levels that result from the alternative scenario at the 1%, 5% and 10% target probability of delay, then we get a probability of delay in the baseline scenario of 2.99%, 11.62% and 21.23%, respectively. This underlines that the alternative scenario serves as a lower bound on capacity needs and the baseline scenario as an upper bound.

In the baseline scenario, all patients were assigned a bed at admission, even though patients admitted for a delivery did not immediately require such a bed as they first pass through the labour and delivery unit or operating theatre. Therefore, even if those patients experience a delay in bed availability for a short period of time, this would not necessarily disrupt the patient flow or care process. In the alternative scenario, waiting time is not cushioned by time spent in another unit as patients are assigned a bed at the moment they effectively require one. Hence, delay and waiting time have a more disruptive effect on the patient flow and care process. The waiting time is slightly lower than simulated in the baseline scenario, with a mean [median] waiting time for patients who experience a delay that amounts to 6h44m [4h25m], 8h49m [6h03m], and 10h42m [7h32m] at 1%, 5% and 10%, respectively. The close similarity in the distribution of waiting time in the baseline scenario and alternative scenario can be seen by comparing both panels in Figure 56.

Table 31 – Overview bed capacity needs and timely access in the alternative scenario specified by target probability of delay (N=108)

	1% Probability of delay	5% Probability of delay	10% Probability of delay
Bed capacity needs			
Maternity services with excess capacity	85	99	103
Maternity services with excess capacity by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds – N = 18 / 45 / 27 / 18)	11 / 36 / 21 / 17	15 / 42 / 24 / 18	17 / 42 / 26 / 18
Maternity services with >20% excess capacity	47	70	85
Mean excess bed capacity	8.2	9.8	10.8
Median excess bed capacity	6.0	8.0	9.0
Total excess bed capacity	694	970	1116

Maternity services with insufficient capacity	17	6	3
Maternity services with insufficient capacity by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds – N = 18 / 45 / 27 / 18)	6 / 6 / 4 / 1	1 / 3 / 2 / 0	0 / 2 / 1 / 0
Maternity services with >20% insufficient capacity	5	2	0
Mean bed capacity shortage	3.6	3.2	3.0
Median bed capacity shortage	3.0	2.5	3.0
Total bed capacity shortage	62	19	9
Total net bed excess	**632**	**951**	**1107**
Total net bed excess by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds – N = 244 / 950 / 885 / 1062)	16 / 155 / 139 / 322	52 / 268 / 233 / 398	69 / 329 / 274 / 435
Average daily occupancy rate	58.72	67.90	73.60
Average daily occupancy rate by level (≤15 beds / 16-25 beds / 26-40 beds />40 beds)	48.9 / 55.4 / 63.3 / 70.0	58.1 / 64.7 / 72.7 / 78.3	63.9 / 71.2 / 77.7 / 83.1
Timely access			
Average waiting time	4 minutes	26 minutes	64 minutes
Average waiting time when waiting	6 hours 44 minutes	8 hours 49 minutes	10 hours 42 minutes
Median waiting time when waiting	4 hours 25 minutes	6 hours 3 minutes	7 hours 32 minutes
Probability of delay > 4h	0.53%	3.11%	6.79%
Probability of delay > 8h	0.31%	2.03%	4.77%
Probability of delay > 12h	0.19%	1.38%	3.45%
Probability of delay > 16h	0.10%	0.88%	2.37%
Probability of delay baseline scenario	**2.99**	**11.62**	**21.23**

6.3.4 Research question 2: Change in bed capacity needs when the number of maternity services is reduced due to efficiency and geographical considerations

6.3.4.1 Setup

Objective

A scenario is developed for a reduction in the number of maternity services in Belgium that were operational in December 2016, based on the efficiency analysis (see Chapter 4) and the analysis of geographical accessibility (see Chapter 5). In this scenario, maternity services with an activity level in 2016 below the minimum efficient scale (see section 4.4.2) and whose closure does not affect the number of women who can reach at least one maternity service within 30 minutes (see section 5.3.2.2), are closed. The activity in the closed maternity services is transferred to other services. It is assessed whether or not the number of maternity beds in the remaining maternity services is sufficient to achieve timely access while absorbing the activity from the maternity services that are simulated to close. Moreover, we assess whether the closure of maternity services with activity levels below the minimum efficient scale allows for a further reduction in the required bed capacity while ensuring timely access, compared to the baseline scenario (see section 6.3.3). Three target values for probability of delay are used (1%, 5%, and 10%) and the target has to be achieved in every remaining maternity service.

Method

The analysis is performed in two steps. First, the 2016 baseline scenario is updated to take into account closures and reorganisations of maternity services that occurred between January 2017 and April 2019 (see section 5.3.2.1). Then, starting from the updated 2019 baseline, we simulate the closure of remaining maternity services according to the above criteria, i.e. services with an activity level below the minimum efficient scale and whose closure does not affect the number of women who can reach at least one maternity service within 30 minutes using the threshold definition (see section 5.2).

Between January 2017 and April 2019, two maternity services were closed without transfer of maternity beds to another service. **In a first step we update the baseline scenario to the 2019 situation**, by closing these maternity services and transferring all the activity in these services to other services. We apply an algorithm based on the observed patient flow for care in maternity services to transfer the activity in the closed maternity services to other services (detailed in Box 14). For each of the maternity services that are predicted to have an increase in activity, new admission rates are calculated by patient group. The new admission rates equal the old admission rates scaled up proportionally by the percentage increase in activity by patient group.

Moreover, in this period, there were two mergers of nearby maternity services of the same hospital. In these mergers there was a transfer of maternity beds and the number of licensed M-beds was preserved. Given the limited distance between the merged sites, we assume that the activity in the merged sites equals the sum of the activity in the separate sites. Thus, new admission rates for the merged sites were computed as the sum of admission rates of the separate sites. The same assumption was made in the structural efficiency analysis.

The simulation model is run using the same methodology as for the baseline scenario (see sections 6.2.3.1 and 6.3.3.1), but with the new admission rates. A comparison is made for the subset of impacted maternity services – 2 closed services, 4 services merged into 2, 15 services with increased activity – between the simulation results of the 2016 baseline scenario and the 2019 situation.[bb] No new information is taken into account for maternity

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[bb] For the merged maternity services, the baseline benchmark is the combination of the baseline simulation results of the separate services, i.e. the sum of the required bed capacities and the weighted mean of the occupancy rate (weighted by required bed capacity).

services which are not impacted by the changes between 2017 and 2019 – i.e. 87 maternity services – and hence the simulation outcomes of the baseline scenario remain valid for this subgroup.

In a **second step**, the situation in 2019 is considered as the new benchmark. Among the 104 maternity services in April 2019, we identified 17 services with an activity level below the minimum efficient scale in 2016 (see section 4.4.2), whose closure does not affect the number of women who can reach at least one maternity service within 30 minutes. In a scenario analysis, these maternity services are closed and all the activity performed in these services is transferred to other maternity services using an algorithm based on the observed patient flow for care in maternity services (detailed in Box 14). It can be argued that the patient flow will change as a consequence of the closures as hospitals or loco-regional networks might attempt to hold on to the activity in the closed maternity service(s). Hence other criteria could be used to (partially) reallocate the activity, such as transfer of (part of the) activity to the closest maternity service, to the closest maternity services within the same loco-regional network or the closest maternity service within the same hospital. However, each criterion imposes an assumption on the future patient flow which is yet unclear and subject to patient preferences and various policy choices and trade-offs to be made at the hospital and network level. The different criteria can lead to different reallocations (see Box 15) and the choice for one or the other criterion would be arbitrary. Therefore, it was decided to reallocate the activity based on the patient flow observed in 2016.

As for the update to the 2019 situation, new admission rates are calculated by patient group for each of the maternity services that are predicted to have an increase in activity. The new admission rates equal the old admission rates scaled up proportionally by the percentage increase in activity by patient group. The simulation model is run using the same methodology as for the baseline scenario (see sections 6.2.3 and 6.3.3.1), but with the new admission rates. A comparison is made for the subset of maternity services between the simulation results of the scenario and the 2019 situation.

Box 14 – Patient flow algorithm

When maternity services close, the demand for maternity care services will not be altered in an important way and needs to be absorbed by other maternity services. In order to evaluate the ability of other services to accommodate more patients using the simulation model, assumptions need to be made on the reallocation of the activity in the closed maternity services to other services. This will be done using a patient flow algorithm.

The objective of the patient flow algorithm is to generate a data-driven proposal for the reallocation of the activity in the closed maternity services to other maternity services. This is done using data for 2016 on all inpatient stays of obstetric patients in maternity services.

Building distributions of admissions

Each inpatient stay is assigned to a patient group (caesarean delivery, vaginal delivery, other activity), a municipality (based on the zip code of the patient) and a maternity service. In less than 1% of the stays (N=1 429), the zip code of the patient was unknown and the zip code of the maternity service was used instead to assign the municipality.

A distribution by patient group is made for each municipality, showing the number and fraction of admissions in the municipality that can be attributed to a particular maternity service. In the same way, for each maternity service, a distribution by patient group is made showing the number and fraction of admissions in the maternity service that can be attributed to a particular municipality.

Adjusting distributions of admissions

It is possible that a combination of maternity service and municipality is infrequent. This can be due to coincidence (e.g. being on holiday far from the home municipality) or special care needs (e.g. treatment in a maternity service with MIC-beds or a university hospital far from the home municipality). In order to limit the dispersion of activity over the entire country, two thresholds are imposed to the observed admissions and fractions: one to be included in the municipality distribution (minimum of 5 admissions or a fraction of 2.5%) and one to be included in the maternity service distribution (minimum of 10 admissions or a fraction of 5%). If the threshold is not met, the combination of municipality – maternity service is removed (set to 0). The fraction of admissions in the municipality and in the maternity service are scaled up proportionally so that the relevant sum equals 100%, resulting in the adjusted fractions in the Table below.

To clarify the algorithm, an example is used to illustrate the different steps. We consider the calculations for a municipality (Muni A) and a maternity service (MS 1) for vaginal deliveries. MS 1 is a maternity service whose activity falls below the minimum efficient scale and which is prone to closure based on the efficiency and geographic criteria. The Table below shows the observed and adjusted distributions. After excluding infrequent observations, the fraction of admissions in the municipality and in the maternity service are scaled up proportionally so that the relevant sum equals 100%, resulting in the adjusted fractions in the Table. Next, for each maternity service, the adjusted number of admissions is calculated using the adjusted fractions. For maternity service 1, the adjusted number of admissions coming from municipality A is therefore 11.9 (3.6% * 330).

Municipality A (Muni A) with 34 vaginal deliveries					Maternity service 1 (MS 1) with 330 vaginal deliveries				
Maternity service (MS)	Observed admissions	Observed fraction of admissions	Adjusted fraction of admissions		Municipality (Muni)	Observed admissions	Observed fraction of admissions	Adjusted fraction of admissions	Adjusted number of admissions
MS 1	11	32.4%	33.3%		Muni A	11	3.3%	3.6%	11.9
MS 2	8	23.5%	24.2%		Muni B	9	2.7%	0%*	0
MS 3	8	23.5%	24.2%		Muni C	7	2.1%	0%*	0
MS 4	3	8.8%	9.1%		Muni D	106	32.1%	34.6%	114.3
MS 5	3	8.8%	9.1%		Muni E	44	13.3%	14.4%	47.5
MS 6	1	2.9%	0%*		Muni F	9	2.7%	0%*	0
					Muni G	145	43.9%	47.4%	156.4

** Adjusted fraction of admissions is set to 0% because the observed number of admission and/or the observed fraction of admission is below the defined threshold.*

Adapting distributions of admissions to closures of maternity services

In order to generate the patient flow that results from closing maternity services, three additional steps are taken. The results of these manipulations are shown in the next Table.

1. For each maternity service which is simulated to close, the adjusted number of admissions has to be reallocated to other maternity services in the municipalities in which it is active. For MS 1, this means a transfer of 11.9 admissions in Municipality A, 114.3 admissions in Municipality D etc.

2. For each municipality, the maternity services that are simulated to close are removed from the distribution (set to 0) and the adjusted fraction is updated to reflect the new situation. In the example, MS 1 and MS 4 are closed.

3. The activity to be reallocated within a municipality equals the sum of the admissions to be transferred from each of the services to be closed (the result from step 1). The reallocation is made using the newly adjusted fraction as a key, resulting in the 'newly allocated admissions'. In the example there are 15.9 admissions to be transferred (11.9 from MS 1 and 4 from MS 4). 42.1% of these admissions are allocated to MS 2, resulting in 6.7 additional vaginal deliveries in this maternity service.

Municipality A (Muni A) with 34 vaginal deliveries					
Maternity service (MS)	Observed fraction of admissions	Adjusted fraction of admissions	Newly adjusted fraction of admissions	Admissions to be transferred	Newly allocated admissions
MS 1	32.4%	33.3%	0%**	11.9	-
MS 2	23.5%	24.2%	42.1%	-	6.7
MS 3	23.5%	24.2%	42.1%	-	6.7
MS 4	8.8%	9.1%	0%**	4	-
MS 5	8.8%	9.1%	15.8%	-	2,5
MS 6	2.9%	0%*	0%*	-	0

** Adjusted fraction of admissions is set to 0% because the observed number of admission and/or the observed fraction of admission is below the defined threshold.*

*** Adjusted fraction of admissions is set to 0% because the maternity service is in the subset of services to be closed.*

The proposal for the reallocation of the activity based on the patient flow can now be computed by summing up the newly allocated activity for each maternity service that is projected to experience an increase in activity. In our example, this is MS 2, MS 3 and MS 5.

Box 15 – Criteria for reallocation of activity

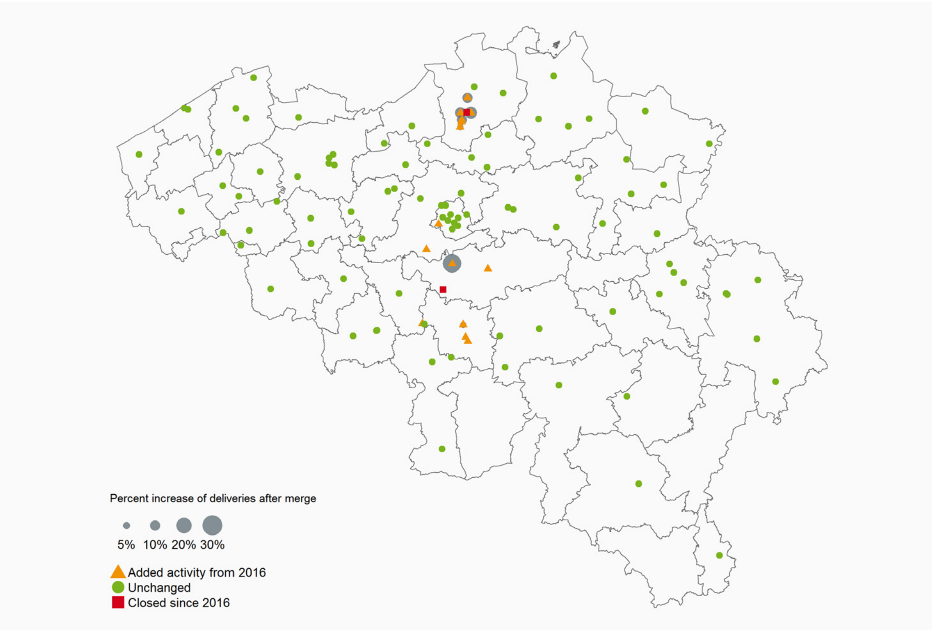
There are different criteria to reallocate activity from one maternity service to another within the simulation model. The criterion followed in the simulation exercise is a reallocation based on observed patient flow of obstetric patients (see Box 14).

However, alternative criteria could be used to (partially) reallocate the activity, such as transfer of (part of the) activity to the closest maternity service, to the closest maternity services within the same loco-regional network or the closest maternity service within the same hospital. Each of these alternative criteria can be defended and has merit. It is, however, clear that each alternative criterion corresponds to specific choices on the future patient flow, choices which are part of future hospital and loco-regional network policies and trade-offs (notwithstanding patient freedom of choice). Moreover, it appears ill-suited to apply one particular alternative criterion to all situations as the situations can be quite different. We give two examples.

Example 1. Maternity service MS1 has an activity level below the minimum threshold and is included in the subset of maternity services simulated to close. It is located at about 1 kilometre of another maternity service which is the closest alternative maternity service and belongs to the same loco-regional network. However, another maternity service from the same hospital as MS1 is located at about 30 kilometres. Would MS1 close, it is possible that some of its staff (midwives and doctors) would be transferred to this more distant service and some of the patients would follow suit. The future patient flow can be heavily influenced by network and hospital policies. Therefore it is difficult to impose either the criterion of closest maternity service in the loco-regional network or the closest maternity service within the same hospital.

Example 2. Maternity service MS2 has an activity level below the minimum threshold and is included in the subset of maternity services simulated to close. There are several maternity services in the vicinity. There is a maternity service at about 17 minutes but located at the other side of the linguistic frontier, and another at about 15 minutes in the same linguistic community. Both services belong to a different loco-regional network than MS2. The closest maternity service within the same loco-regional network is at about 21 minutes. The closest maternity service within the same hospital is at about 30 minutes. Again the future patient flow might depend on various aspects of hospital and network policies and it is difficult if not impossible to arbitrarily transfer part of the activity based on one of the alternative criteria.

Figure 57 – Transfer in deliveries (based on patient flow algorithm) related to the closure of two maternity services between 2017 and 2019



6.3.4.2 *Results*

Change in bed capacity needs related to the updated 2019 baseline scenario

A reassessment of the bed capacity needs in the baseline scenario is made, accounting for the reorganisations that took place between January 2017 and April 2019: two mergers and two closures (see section 6.3.4.1). The expected effects of the mergers and closures on bed capacity needs goes in opposite direction.

To assess the effects of the mergers, the required bed capacity is simulated for the merged service and compared to the required bed capacity of the separate services. The activity level of the merged maternity service equals the sum in the separate services. Figure 54 and section 6.2.1.1 demonstrate and discuss the presence of economies of scale in the use of capacity. One maternity service with a large activity can use its bed capacity more efficiently to deal with the variability in demand and ensure timely access than two smaller maternity services that jointly have the same activity level. Therefore, we expect an increase in excess beds from the mergers compared to the 2016 baseline situation.

The closure of two maternity services has led to a transfer of activity to the surrounding maternity services. The reallocation is visualised in Figure 57. Based on the patient flow algorithm (see Box 15), 15 maternity services are projected to have an increase in activity, with an important surge in activity in the maternity services closest to the closed services. On the one hand, the maternity beds in the closed services lead to a direct reduction in required bed capacity. As these beds are no longer used to provide maternity care, they can be considered as excess capacity. On the other hand, the additional activity requires more beds to accommodate the additional activity and a reduction in excess beds or an increase in shortage of beds is expected, compared to the 2016 situation.

The simulation outcomes are summarised in Table 32 and provide information on the impact of the reorganisation on bed capacity. The 2016 baseline simulation outcomes are given for the subset of impacted maternity services at the 1%, 5% and 10% target level for probability of delay. The changes that result from the reorganisation are given between square brackets. Overall the simulation outcomes indicate that the reorganisation between 2017 and 2019 allows for a further reduction in maternity beds. **The net excess increases by 24, 16 and 11 maternity beds evaluated at the 1%, 5% and 10% level, respectively.** This is the combined result of different effects: at the 1%, 5% and 10% target level, the net excess increases due to the closures of the two sites by 28, 24 and 21 beds, respectively, and due to the mergers by 12, 8 and 7 beds, respectively. On the other hand, net excess decreases due to the absorption of the additional activity in other maternity services by a reduction in excess beds of 10, 9 and 10 beds, respectively and an increase in shortage of beds by 6, 7 and 7 beds, respectively. Hence, the net effect in terms of excess beds due to the closures and mergers that occurred between 2016 and 2019 is less than just closing the beds in the concerned maternity services.

A number of additional observations and conclusions can be made. First, the impact on bed capacity of the reorganisation differs by the target set for timely access. This is clearly visible for the direct reduction in required bed capacity of the two closed maternity services. The reason is that the required bed capacity in the two services, as simulated in the 2016 baseline, differs by the target level for probability of delay as a lower tolerance for delay necessitates a higher bed capacity. Therefore the possible bed reduction compared to these baseline simulation is more important the lower the target probability. As the target probability is raised, the required bed capacity to cope with the variability in demand as evaluated in the baseline simulation is lower (see section 6.3.3.2) leaving less room for further reductions in maternity beds.

Second, despite the increase in activity, the majority of maternity services are able to accommodate the additional activity while ensuring timely access. At the 1%, 5% and 10% target level, excess capacity is found for 10, 12 and 13 maternity services out of 17, only a minor reduction compared to the 2016 baseline results.

Third, among the impacted maternity services, there is an important number of services which are confronted with a shortage in maternity beds in the 2016 baseline simulation and which require additional bed capacity to ensure timely access. This problem is somewhat aggravated as a result of the reorganisation, with 0, 1 and 2 additional maternity services experiencing shortage at the 1%, 5% and 10% target level, respectively. However, there is no increase in maternity services experiencing more than 20% shortage in bed capacity, compared to the 2016 baseline.

Fourth, the increase in activity and required bed capacity in the impacted maternity services contributes to an improvement of the occupancy rate by 1.5 to 2 percentage points. Not only a more efficient usage of the available bed capacity is observed in the simulation results, but also positive effects with respect to timely access, with shorter mean and median waiting times. The improvement in timely access is especially pronounced at the 10% target level for probability of delay.

Table 32 – Overview bed capacity needs and timely access in update to situation 2019 for subset of impacted maternity services

	1% Probability of delay	5% Probability of delay	10% Probability of delay
Closure of maternity services (N=2)			
Excess in required bed capacity compared to 2016 baseline	28	24	21
Bed capacity needs – Baseline [Difference with 2016 baseline] (subset of impacted services – N=17; N=15 for closures and N=2 for mergers)			
Maternity services with excess capacity	11 **[-1]**	12 **[0]**	14 **[-1]**
Maternity services with excess capacity by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds – N = 0 / 6 / 7 / 4)	- / 3 **[-1]** / 4 **[0]** / 4 **[0]**	- / 4 **[0]** / 4 **[0]** / 4 **[0]**	- / 4 **[0]** / 6 **[-1]** / 4 **[0]**
Maternity services with >20% excess capacity	4 **[-1]**	8 **[-1]**	9 **[-1]**
Mean excess bed capacity	6.8 **[-0.9]**	10.2 **[-0.1]**	10.6 **[+0.5]**

Median excess bed capacity	4.0 **[0]**	8.5 **[-0.5]**	9.5 **[-0.5]**
Total excess bed capacity	75 **[+2]**	122 **[-1]**	147 **[-3]**
Maternity services with insufficient capacity	6 **[0]**	3 **[+1]**	2 **[+2]**
Maternity services with insufficient capacity by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds – N = 0 / 6 / 7 / 4)	- / 3 **[0]** / 3 **[0]** / 0 **[0]**	- / 2 **[0]** / 1 **[+1]** / 0 **[0]**	- / 1 **[+1]** / 1 **[+1]** / 0 **[0]**
Maternity services with >20% insufficient capacity	3 **[0]**	2 **[0]**	1 **[0]**
Mean bed capacity shortage	6.3 **[+1]**	5.3 **[+0.5]**	5.5 **[-1.5]**
Median bed capacity shortage	4.5 **[+2.5]**	5.0 **[-0.5]**	5.5 **[-2.5]**
Total bed capacity shortage	38 **[+6]**	16 **[+7]**	9 **[+7]**
Total net bed excess (comprising reduction in beds, change in excess capacity and capacity shortage)	**37 [+24]**	**106 [+16]**	**138 [+11]**
Average daily occupancy rate	57.52 **[+1.92]**	65.71 **[+1.63]**	70.38 **[+1.43]**
Average daily occupancy rate by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds)	- / 54.1 **[+1.3]** / 58.2 **[+2.1]** / 61.4 **[+2.6]**	- / 62.7 **[+0.6]** / 66.4 **[+1.8]** / 69.0 **[+2.9]**	- / 67.3 **[+0.9]** / 71.2 **[+1.4]** / 73.5 **[+2.3]**
Timely access – Baseline [Difference with 2016 baseline] (subset of impacted services – N=17; N=15 for closures and N=2 for mergers)			
Average waiting time	4 minutes **[0]**	26 minutes **[0]**	62 minutes **[-3 minutes]**
Average waiting time when waiting	6 hours 48 minutes **[-20 minutes]**	8 hours 57 minutes **[-17 minutes]**	10 hours 36 minutes **[-31 minutes]**
Median waiting time when waiting	4 hours 59 minutes **[-5 minutes]**	6 hours 17 minutes **[-8 minutes]**	7 hours 22 minutes **[-18 minutes]**
Probability of delay > 4h	0.57% **[+0.03]**	3.35% **[+0.09]**	7.23% **[-0.17]**
Probability of delay > 8h	0.27% **[+0.01]**	1.92% **[+0.01]**	4.59% **[-0.21]**
Probability of delay > 12h	0.16% **[0]**	1.28% **[-0.02]**	3.24% **[-0.22]**
Probability of delay > 16h	0.08% **[0]**	0.78% **[-0.03]**	2.14% **[-0.18]**

Change in bed capacity needs related to the scenario for closure of maternity services

In the closure scenario, the impact on bed capacity needs is evaluated when closing 17 out of 104 maternity services in 2019 as discussed in section 6.3.4.1. Based on the patient flow algorithm (see Box 15), 41 maternity services are projected to have an increase in activity. The reallocation is visualised in Figure 58. The left panel shows the expected additional number of deliveries, whereas the right panel shows the additional number of deliveries as a percentage of the number of deliveries already performed in the impacted maternity service. Figure 58 clearly shows that the closures as well as the reallocation of activity is concentrated in the provinces of West-Flanders, Hainaut, Liège and the south of East Flanders. The reallocation in activity is substantial, with an average increase in the expected number of deliveries by 16.7% and a peak in activity growth up to 70%.

Figure 58 – Transfer in deliveries (based on patient flow algorithm) related to the scenario for closure of maternity services

Activity increase **Percentage activity increase**

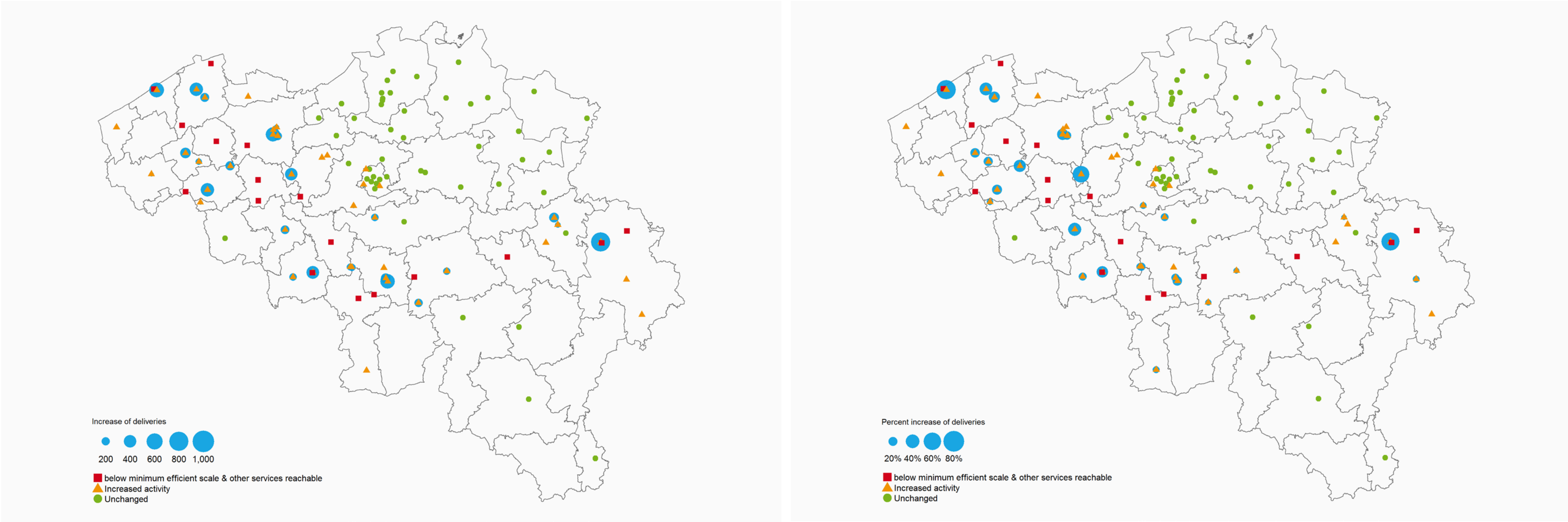


Table 33 summarises the simulation results of the closure scenario compared to the 2019 baseline. The table presents the 2019 baseline simulation outcomes for the subset of impacted maternity services at the 1%, 5% and 10% target level for probability of delay. The changes that result from the closure scenario are given between square brackets.

The simulation results show that, in comparison to the 2019 baseline simulation, further reductions in maternity beds are achievable when closing smaller maternity services while ensuring the same level of timely access in the remaining maternity services. **The net excess increases by 76, 44 and 36 maternity beds evaluated at the 1%, 5% and 10% level, respectively.** The net excess reflects two opposite effects. On the one hand, the excess of maternity beds in the closed services. The maternity beds in the maternity services that are simulated to close are no longer used to provide maternity care and are considered to be in excess. The bed capacity that was required in these services to ensure timely access to care (as simulated in the 2019 baseline scenario), amounts to 226, 189 and 172 beds at the 1%, 5% and 10% target level for probability of delay, respectively. On the other hand, the additional bed capacity required in the surrounding maternity services to accommodate the additional activity while ensuring timely access. The latter effect is observed both through a reduction in excess beds, amounting to 48, 81 and 81 additional beds at the 1%, 5% and 10% target level, respectively, and through an increase in the shortage of maternity beds, amounting to 102, 64 and 55 beds at the 1%, 5% and 10% target level, respectively.

At the 5% and 10% target level for probability of delay, the majority of maternity services has a bed capacity that is (more than) sufficient to absorb the transferred activity. There are 28 and 32 maternity services (out of 41) with excess capacity at the 5% and 10% target level, respectively, of which 15 and 20 with more than 20% bed capacity in excess. This is, as expected, a lower number compared to the baseline results. At a probability of delay of 1%, there are 19 maternity services with excess capacity, 2 services with a sufficient capacity and 20 services with a capacity shortage of which 9 with a capacity shortage above 20%. At the 5% and 10% target level, there are, respectively, 10 and 9 maternity services that experience a shortage in maternity beds, 4 of which have a shortage above 20%. At all target levels, the number of maternity services that are confronted with a shortage in maternity beds is doubled compared to the 2019 baseline results. This demonstrates that for a number of maternity services, there is currently not sufficient capacity to accommodate the increase in activity in the closure scenario. Other solutions will be needed (in addition), such as a redirection of the patient flow to other maternity services with excess capacity, a capacity expansion for a limited number maternity services, or an expansion of the activity in a number of smaller maternity services so that their activity level exceeds at least the minimum efficient scale.

The observations and conclusions that result from the simulation outcomes are similar to those made with respect to the update. First, the impact on bed capacity differs by the target set for timely access. As the target probability is raised, the required bed capacity to cope with the variability in demand as evaluated in the baseline simulation is lower (see section 6.3.3.2) leaving less room for further reductions in maternity beds.

Second, the increase in activity and required bed capacity in the impacted maternity services contributes to an improvement of the occupancy rate by 1.2 to 1.7 percentage points. Not only a more efficient usage of the available bed capacity is observed when closing smaller maternity services, but also positive effects with respect to timely access, with a reduction in mean waiting times by 30 to 40 minutes and median waiting times by about 20 minutes.

Table 33 – Overview bed capacity needs and timely access in scenario of closure of maternity services for subset of impacted maternity services

	1% Probability of delay	5% Probability of delay	10% Probability of delay
Closure of maternity services (N=17)			
Excess in required bed capacity compared to 2019 baseline	226	189	172
Bed capacity needs – Baseline [Difference with 2019 baseline] (subset of impacted services – N=41)			
Maternity services with excess capacity	26 **[-7]**	36 **[-8]**	37 **[-5]**
Maternity services with excess capacity by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds – N = 3 / 16 / 13 / 9)	2 **[0]** / 9 **[-3]** / 6 **[-2]** / 9 **[-2]**	3 **[0]** / 13 **[-3]** / 11 **[-4]** / 9 **[-1]**	3 **[0]** / 14 **[-2]** / 11 **[-3]** / 9 **[0]**
Maternity services with >20% excess capacity	12 **[-5]**	22 **[-7]**	24 **[-4]**
Mean excess bed capacity	8.0 **[-0.4]**	9.1 **[-0.9]**	10.4 **[-1.4]**
Median excess bed capacity	4.0 **[+2.0]**	6.0 **[-1.0]**	7.0 **[-1.0]**
Total excess bed capacity	193 **[-48]**	311 **[-81]**	368 **[-81]**
Maternity services with insufficient capacity	9 **[+11]**	4 **[+6]**	4 **[+5]**
Maternity services with insufficient capacity by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds – N = 3 / 16 / 13 / 9)	0 **[0]** / 5 **[+5]** / 4 **[+5]** / 0 **[+1]**	0 **[0]** / 2 **[+2]** / 2 **[+3]** / 0 **[+1]**	0 **[0]** / 2 **[+2]** / 2 **[+3]** / 0 **[0]**
Maternity services with >20% insufficient capacity	5 **[+4]**	2 **[+2]**	2 **[+2]**
Mean bed capacity shortage	6.0 **[+1.0]**	6.8 **[+0.7]**	4.5 **[+1.6]**
Median bed capacity shortage	3.0 **[+2.0]**	6.5 **[0]**	4.0 **[0]**
Total bed capacity shortage	38 **[+102]**	11 **[+64]**	0 **[+55]**
Total net bed excess (comprising reduction in beds, change in excess capacity and capacity shortage)	**155 [+76]**	**300 [+44]**	**368 [+36]**
Average daily occupancy rate	55.84 **[+1.73]**	64.096 **[+1.20]**	68.79 **[+1.19]**
Average daily occupancy rate by level (≤15 beds / 16-25 beds / 26-40 beds / >40 beds)	38.4 **[+2.0]** / 52.1 **[+1.9]** / 59.5 **[+1.6]** / 63.0 **[+1.5]**	47.6 **[-0.1]** / 60.5 **[+2.3]** / 67.8 **[+0.6]** / 70.5 **[+0.6]**	54.2 **[-0.8]** / 65.2 **[+1.8]** / 72.2 **[+1.0]** / 75.1 **[+1.0]**

Timely access – Baseline [Difference with 2019 baseline] (subset of impacted services – N=41)			
Average waiting time	4 minutes **[0]**	26 minutes **[-3 minutes]**	62 minutes **[-4 minutes]**
Average waiting time when waiting	6 hours 34 minutes **[-28 minutes]**	8 hours 39 minutes **[-31 minutes]**	10 hours 22 minutes **[-40 minutes]**
Median waiting time when waiting	4 hours 32 minutes **[-17 minutes]**	5 hours 53 minutes **[-18 minutes]**	7 hours 5 minutes **[-22 minutes]**
Probability of delay > 4h	0.54% **[-0.01]**	3.21% **[-0.16]**	7.03% **[-0.17]**
Probability of delay > 8h	0.27% **[-0.02]**	1.90% **[-0.15]**	4.55% **[-0.21]**
Probability of delay > 12h	0.16% **[-0.02]**	1.26% **[-0.12]**	3.20% **[-0.21]**
Probability of delay > 16h	0.08% **[-0.01]**	0.75% **[-0.10]**	2.09% **[-0.20]**

6.4 Key points

- **There is a strong association between bed capacity, occupancy rate and probability of delay. This association invalidates the use of uniform target occupancy rates unadjusted to the activity size of the maternity service to determine bed capacity needs. Instead, measures for timely access, such as the probability of delay, are used to assess bed capacity needs.**

What is the need for maternity beds in Belgium?

- **Most maternity services have excess capacity in maternity beds: in the baseline simulation scenario 69 (resp. 90; 99) maternity services (out of 108) have capacity in excess to what is necessary to ensure a probability of delay below 1% (resp. 5%; 10%). These numbers are higher in the alternative scenario: 85 (resp. 99; 103) maternity services at the target 1% (resp. 5%; 10%) in probability of delay. In addition, 9 (resp. 8; 2) maternity services (out of 108) have sufficient capacity to ensure timely access at the target of 1% (resp. 5%; 10%) in the baseline scenario; and 3 (resp. 6; 2) maternity services in the alternative scenario. In the baseline scenario a maternity bed is available upon arrival, in the alternative scenario a bed is available post-delivery.**
- **The total net excess capacity is 390 (resp. 736; 891) beds (out of 3 141) estimated at the target of 1% (resp. 5%; 10%) in probability of delay in the baseline scenario. In the alternative scenario, the net excess capacity is estimated to 632 (resp. 951; 1 107) beds.**
- **The excess capacity is located predominantly in larger maternity services, which are better suited to cope with the variability in demand.**
- **If excess capacity is cut back, a 70% occupancy rate can be realised in large maternity services when applying the 5% delay target and medium to large maternity services when applying the 10% delay target. Small maternity services cannot ensure timely access and reach a 70% occupancy rate at the same time.**
- **The majority of patients experiencing a delay, have a waiting time below 8h (69%, 60% and 52% resp. at the 1%, 5% and 10% target). In the baseline scenario, a maternity bed is assigned at admission but not immediately required for obstetric patients admitted for a delivery. The waiting time for an obstetric patient who is experiencing a delay is on average smaller or of similar magnitude than the average time spent in delivery.**

Impact of the closure of maternity services with scale below minimum efficient scale and without impact on reachability of at least 1 service

- **A further reduction in bed capacity of 76 (resp. 44; 36) beds is achievable when closing smaller maternity services while ensuring a probability of delay below 1% (resp. 5%; 10%).**
- **Most maternity services are able to accommodate the additional activity that results from the closures: excess capacity is found for 19 (resp. 28; 32) maternity services and sufficient capacity for 2 (resp. 3; 0) maternity services (out of the 41 impacted maternity services) at the target 1% (resp. 5%; 10%) in probability of delay.**
- **The number of maternity services that are confronted with a shortage in maternity beds is doubled among the impacted services: 20 (resp. 10; 9) maternity services (out of 41) at the target 1% (resp. 5%; 10%) in probability of delay.**
- **Positive effects are found with respect to efficient use of bed capacity, i.e. an improvement of the occupancy rate by 1.2 to 1.7 percentage points, and with respect to timely access, i.e. a reduction in mean [median] waiting times by about 30 to 40 minutes [20 minutes].**

APPENDICES

APPENDIX 1. APPENDIX TO CHAPTER 3

Appendix 1.1. Obstetric patients

Table A.1 – Number of selected stays in maternity services, by Major Diagnostic Category and type of stay (2016)

Major Diagnostic Category	Number of stays Percentage Inpatient	 Day care	 Total
14 Pregnancy, childbirth & the puerperium	140 802 66.48	4 404 2.08	145 206 68.56
APR-DRG MMM (ex mini lump sums)	0 0.00	48 621 22.96	48 621 22.96
13 Diseases & disorders of the female reproductive system	5 201 2.46	1 400 0.66	6 601 3.12
09 Diseases & disorders of the skin, subcutaneous tissue and breast	2 136 1.01	433 0.20	2569 1.21
23 Rehabilitation, aftercare, other factors influencing health status and other health service contacts	992 0.47	1 163 0.55	2 155 1.02
03 Ear, nose, mouth & throat and craniofacial diseases and disorders	832 0.39	588 0.28	1 420 0.67
06 Diseases & disorders of the digestive system	805 0.38	129 0.06	934 0.44
00 Residual group	737 0.35	105 0.05	842 0.40

Major Diagnostic Category	Number of stays Percentage		
	Inpatient	Day care	Total
08 Diseases & disorders of the musculoskeletal system & connective tissues	612 0.29	203 0.10	815 0.38
11 Diseases & disorders of the kidney & urinary tract	433 0.20	84 0.04	517 0.24
21 Poisonings, toxic effects, other injuries and other complications of treatment	319 0.15	28 0.01	347 0.16
10 Endocrine, nutritional & metabolic diseases & disorders	270 0.13	6 0.00	276 0.13
07 Diseases & disorders of the hepatobiliary system & pancreas	263 0.12	9 0.00	272 0.13
05 Diseases & disorders of the circulatory system	142 0.07	101 0.05	243 0.11
01 Diseases & disorders of the nervous system	171 0.08	33 0.02	204 0.10
04 Diseases & disorders of the respiratory system	171 0.08	4 0.00	175 0.08
02 Diseases & disorders of the eye	81 0.04	49 0.02	130 0.06
18 Infectious & parasitic diseases, systemic or unspecified sites	105 0.05	3 0.00	108 0.05
16 Diseases & disorders of blood, blood forming organs and immunological disorders	65 0.03	32 0.02	97 0.05

Major Diagnostic Category	Number of stays Percentage		
	Inpatient	Day care	Total
19 Mental diseases & disorders	91 0.04	6 0.00	97 0.05
12 Diseases & disorders of the male reproductive system	14 0.01	62 0.03	76 0.04
17 Lymphatic, hematopoietic, other malignancies, chemotherapy and radiotherapy	66 0.03	4 0.00	70 0.03
20 Alcohol/drug use & alcohol/drug induced organic mental disorders	3 0.00	0 0.00	3 0.00
22 Burns	2 0.00	1 0.00	3 0.00
PP pre-MDC	3 0.00	0 0.00	3 0.00
25 Multiple significant trauma	2 0.00	0 0.00	2 0.00
24 HIV infections	1 0.00	0 0.00	1 0.00
TOTAL	**154 319** **72.87**	**57 468** **27.13**	**211 787** **100.00**

Source: Minimal Hospital Data (MZG – RHM)

Appendix 1.2. Newborns

Table A.2 – Number of selected stays in maternity services, by Major Diagnostic Category and type of stay (2016)

Major Diagnostic Category	Number of stays Percentage Inpatient	 Day care	 Total
15 Newborns & other neonates with conditions originating in the perinatal period	123 407 97.18	1 476 1.16	124 883 98.34
23 Rehabilitation, aftercare, other factors influencing health status and other health service contacts	1 219 0.96	8 0.01	1 227 0.97
APR-DRG MMM (ex mini lump sums)	0 0.00	203 0.16	203 0.16
10 Endocrine, nutritional & metabolic diseases & disorders	116 0.09	1 0.00	117 0.09
18 Infectious & parasitic diseases, systemic or unspecified sites	95 0.07	2 0.00	97 0.08
06 Diseases & disorders of the digestive system	89 0.07	1 0.00	90 0.07
04 Diseases & disorders of the respiratory system	75 0.06	0 0.00	75 0.06
01 Diseases & disorders of the nervous system	63 0.05	0 0.00	63 0.05
05 Diseases & disorders of the circulatory system	53 0.04	0 0.00	53 0.04

Major Diagnostic Category	Number of stays Percentage Inpatient	 Day care	 Total
00 Residual group	38 0.03	1 0.00	39 0.03
03 Ear, nose, mouth & throat and craniofacial diseases and disorders	30 0.02	0 0.00	30 0.02
02 Diseases & disorders of the eye	21 0.02	0 0.00	21 0.02
16 Diseases & disorders of blood, blood forming organs and immunological disorders	17 0.01	3 0.00	20 0.02
09 Diseases & disorders of the skin, subcutaneous tissue and breast	16 0.01	0 0.00	16 0.01
11 Diseases & disorders of the kidney & urinary tract	11 0.01	1 0.00	12 0.01
07 Diseases & disorders of the hepatobiliary system & pancreas	9 0.01	1 0.00	10 0.01
08 Diseases & disorders of the musculoskeletal system & connective tissues	8 0.01	0 0.00	8 0.01
19 Mental diseases & disorders	7 0.01	0 0.00	7 0.01
21 Poisonings, toxic effects, other injuries and other complications of treatment	6 0.00	0 0.00	6 0.00
12 Diseases & disorders of the male reproductive system	3 0.00	1 0.00	4 0.00

Major Diagnostic Category	Number of stays Percentage		
	Inpatient	Day care	Total
13 Diseases & disorders of the female reproductive system	4 0.00	0 0.00	4 0.00
20 Alcohol/drug use & alcohol/drug induced organic mental disorders	4 0.00	0 0.00	4 0.00
17 Lymphatic, hematopoietic, other malignancies, chemotherapy and radiotherapy	3 0.00	0 0.00	3 0.00
TOTAL	**125 296** **98.66**	**1 698** **1.34**	**126 994** **100.00**

Source: Minimal Hospital Data (MZG – RHM)

Table A.3 – Number (percentage) and age at admission of newborn stays by bed index group (2016)

Age at admission	Number of stays per group (Percentage)			
	Maternity	N*	NIC	ALL
Born at hospital	101 546 (99.5%)	16 043 (91.3%)	5 003 (78.3%)	**122 592** **(97.3%)**
Admitted between 0 and 7 days	382 (0.4%)	692 (3.9%)	1 150 (18.0%)	**2 224** **(1.8%)**
Admitted between 8 days and 14 days	105 (0.1%)	56 (3.2%)	127 (2.0%)	**797** **(0.6%)**
Admitted between 15 days and 28 days	36 (<0.1%)	277 (1.6%)	110 (1.7%)	**423** **(0.3%)**
Entering the case-mix comparison	**102 069** **(100%)**	**17 577** **(100%)**	**6 390** **(100%)**	126 036 (100%)
Excluded from the comparison	*.*	*569*	***186***	***755***

Source: Minimal Hospital Data (MZG – RHM)

APPENDIX 2. APPENDIX TO CHAPTER 4

Appendix 2.1. Bootstrapping

Table A.4 – Results of the bootstrapping DEA models: efficiency scores

	Overall efficiency score* (E_{CRS})	Technical efficiency score* (E_{VRS})	Scale efficiency score* ($SE=E_{CRS}/E_{VRS}$)
Nb of replicates = 1 000, sample size = 109, with replacement			
Mean	0.79	0.90	0.88
Minimum	0.39	0.48	0.45
Q1	0.71	0.82	0.85
Median	0.82	0.94	0.91
Q3	0.91	1	0.97
Maximum	1	1	1
Number of efficient units (score=1)	12	36	12
Nb of replicates = 1 000, sample size = 80, without replacement			
Mean	0.79	0.89	0.88
Minimum	0.38	0.47	0.44
Q1	0.70	0.81	0.84
Median	0.81	0.93	0.90
Q3	0.90	1	0.97
Maximum	1	1	1
Number of efficient units (score=1)	12	36	12
Nb of replicates = 1 000, sample size = 80, without replacement, 1 site excluded**			
Mean	0.78	0.89	0.88
Minimum	0.38	0.47	0.44
Q1	0.69	0.82	0.84
Median	0.80	0.93	0.90
Q3	0.89	1	0.97
Maximum	1	1	1
Number of efficient units (score=1)	11	35	11

** Average over the replicates. ** The specific maternity site that has 557 deliveries per year in 2016 is excluded.*

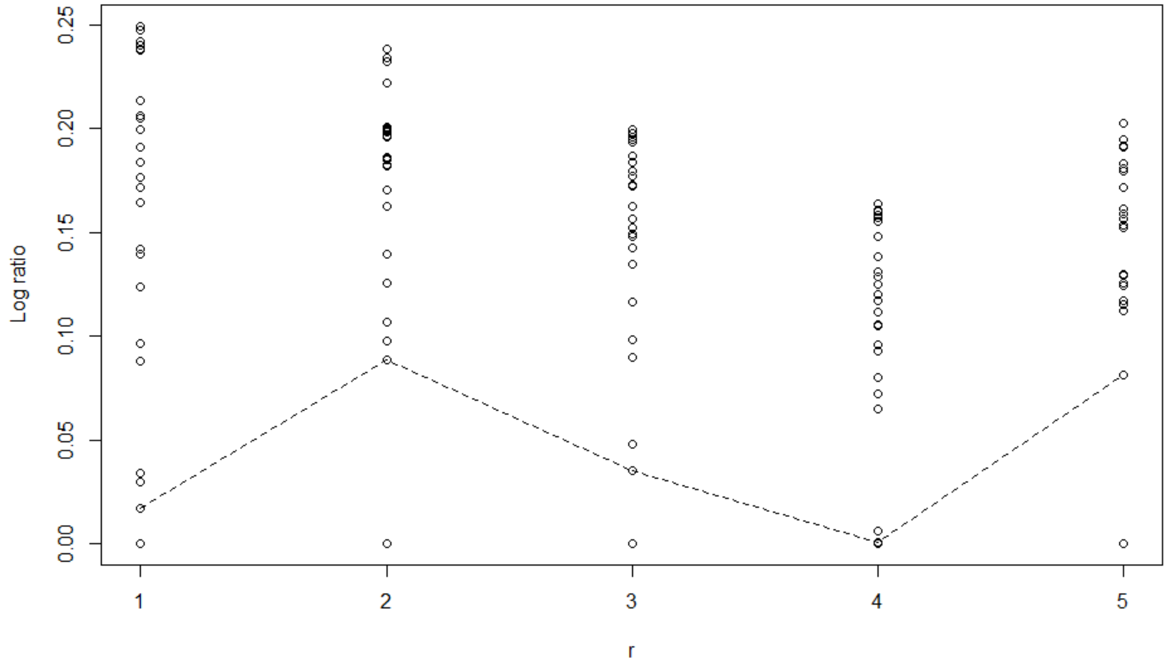
Table A.5 – Results of the bootstrapping DEA models: minimum efficient scale

	Q1	Median	Q3
Nb of replicates = 1 000, sample size = 109, with replacement			
Minimum efficiency scale	499	557	557
Nb of replicates = 1 000, sample size = 80, without replacement			
Minimum efficiency scale	557	557	557
Nb of replicates = 1 000, sample size = 80, without replacement, 1 site excluded*			
Minimum efficiency scale	612	646	766

** The specific maternity site that has 557 deliveries per year in 2016 is excluded.*

Appendix 2.2. Outliers

Figure A.1 – Log-ratio plot for identification of outliers using the data cloud method



r = number of maternity sites removed from the dataset (N=109). Log-ratio = log ($R^{(r)}$/ $R^{(r)}_{min}$) where $R^{(i)}=D^{(i)}/D$; $R^{(r)}_{min}$ is the minimum value of $R^{(r)}$; D is the determinant of the combined matrix that contains all the observations; and $D^{(i)}$ is the determinant after removing maternity site i.
Groups of outliers are identified where there is a gap between the points above 0 and the point at 0, i.e. where the dashed line is far above 0 (see Bogetoft and Otto (2010)[47] for more details).

Table A.6 – Removed observations corresponding to a minimum value of $R^{(r)}$

r	Removed observations					$R^{(r)}_{min}$
1	73					0.72
2	89	90				0.48
3	73	89	90			0.34
4	17	73	89	90		0.25
5	17	69	73	89	90	0.17

r = number of maternity sites removed from the dataset (N=109). $R^{(r)}_{min}$ is the minimum value of $R^{(r)}$ where $R^{(i)}=D^{(i)}/D$; D is the determinant of the combined matrix that contains all the observations; and $D^{(i)}$ is the determinant after removing maternity site i.

Table A.7 – Results of the DEA models after removal of identified outliers

	Overall efficiency score (E_{CRS})	Technical efficiency score (E_{VRS})	Scale efficiency score ($SE=E_{CRS}/E_{VRS}$)
2 outliers (ID 89 and 90) removed, N=107			
Mean	0.77	0.89	0.87
Minimum	0.37	0.62	0.43
Q1	0.67	0.80	0.81
Median	0.79	0.91	0.89
Q3	0.87	1	0.97
Maximum	1	1	1
Number of efficient units (score=1)	12	36	12
Minimum efficient scale			557
5 outliers (ID 17, 69, 73, 89 and 90) removed, N=104			
Mean	0.79	0.89	0.88
Minimum	0.37	0.63	0.43
Q1	0.68	0.81	0.83
Median	0.79	0.91	0.92
Q3	0.91	1	0.98
Maximum	1	1	1
Number of efficient units (score=1)	12	36	12
Minimum efficient scale			557

APPENDIX 3. APPENDIX TO CHAPTER 5

Appendix 3.1. Current possibility to reach a maternity service

Appendix 3.1.1. Within 30 minutes

Figure A.2 – Maternity services reachable within 30 minutes (within area definition; orange dots represent maternity services April 2019)

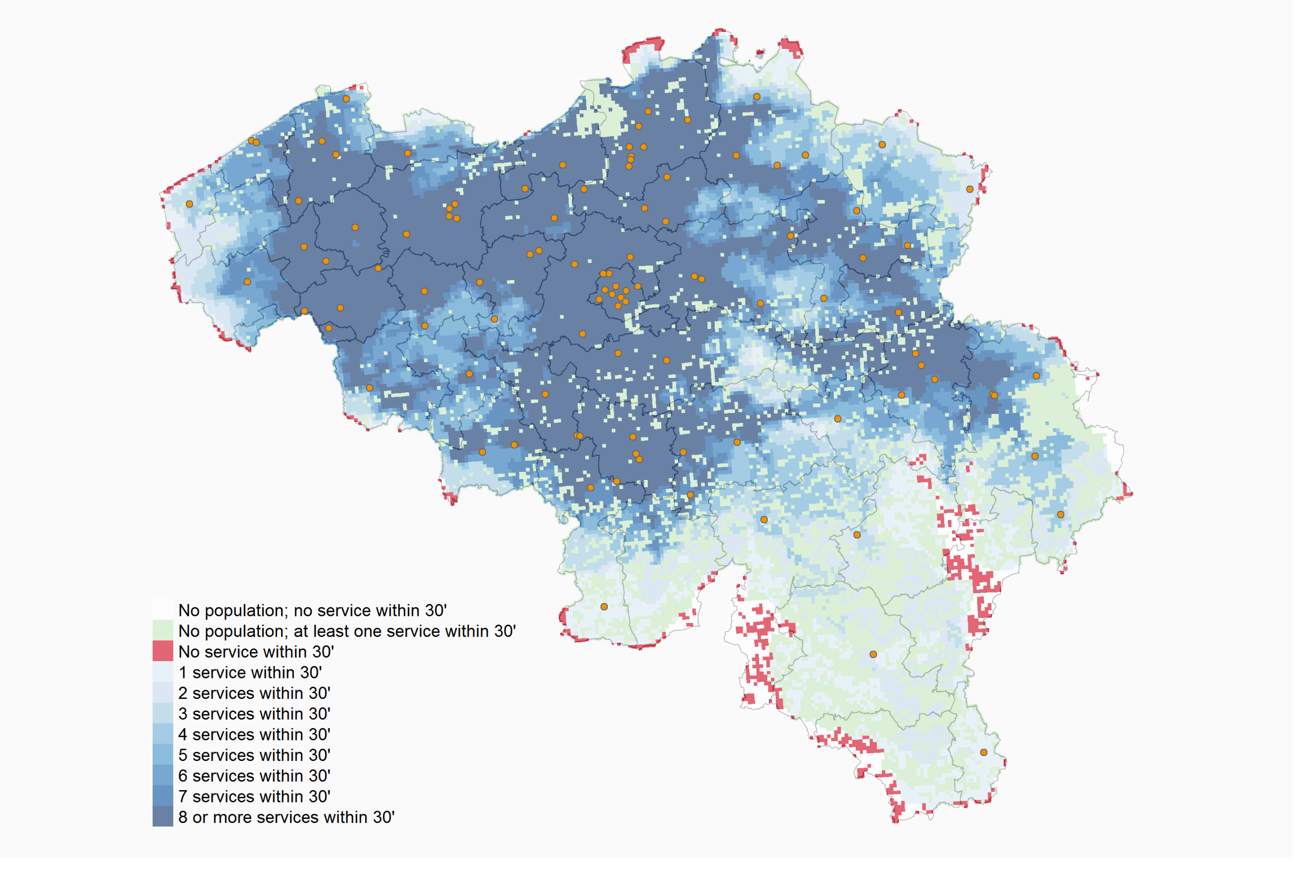
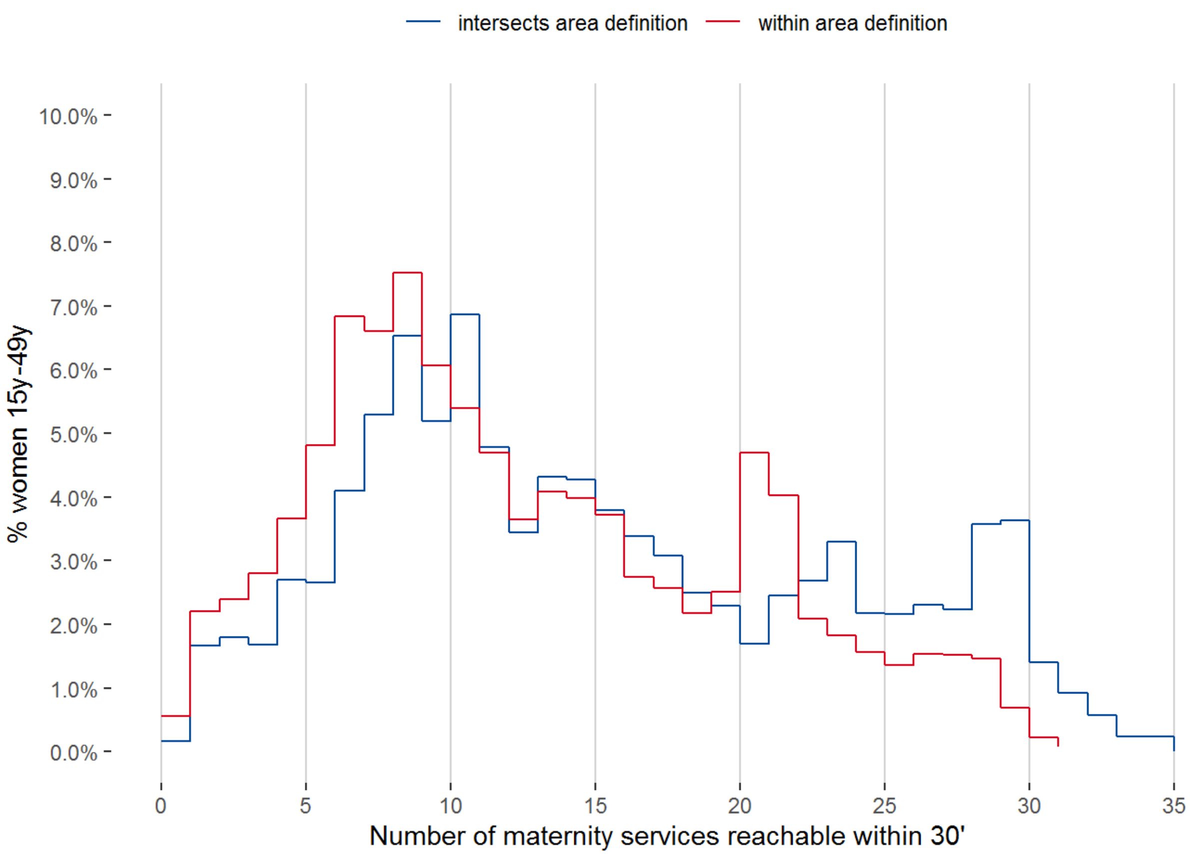


Figure A.3 – Percentage of women 15-49 year old by number of maternity services reachable within 30 minutes



Appendix 3.1.2. Within 15 minutes

Figure A.4 – Maternity services reachable within 15 minutes (intersects area definition; orange dots represent maternity services April 2019)

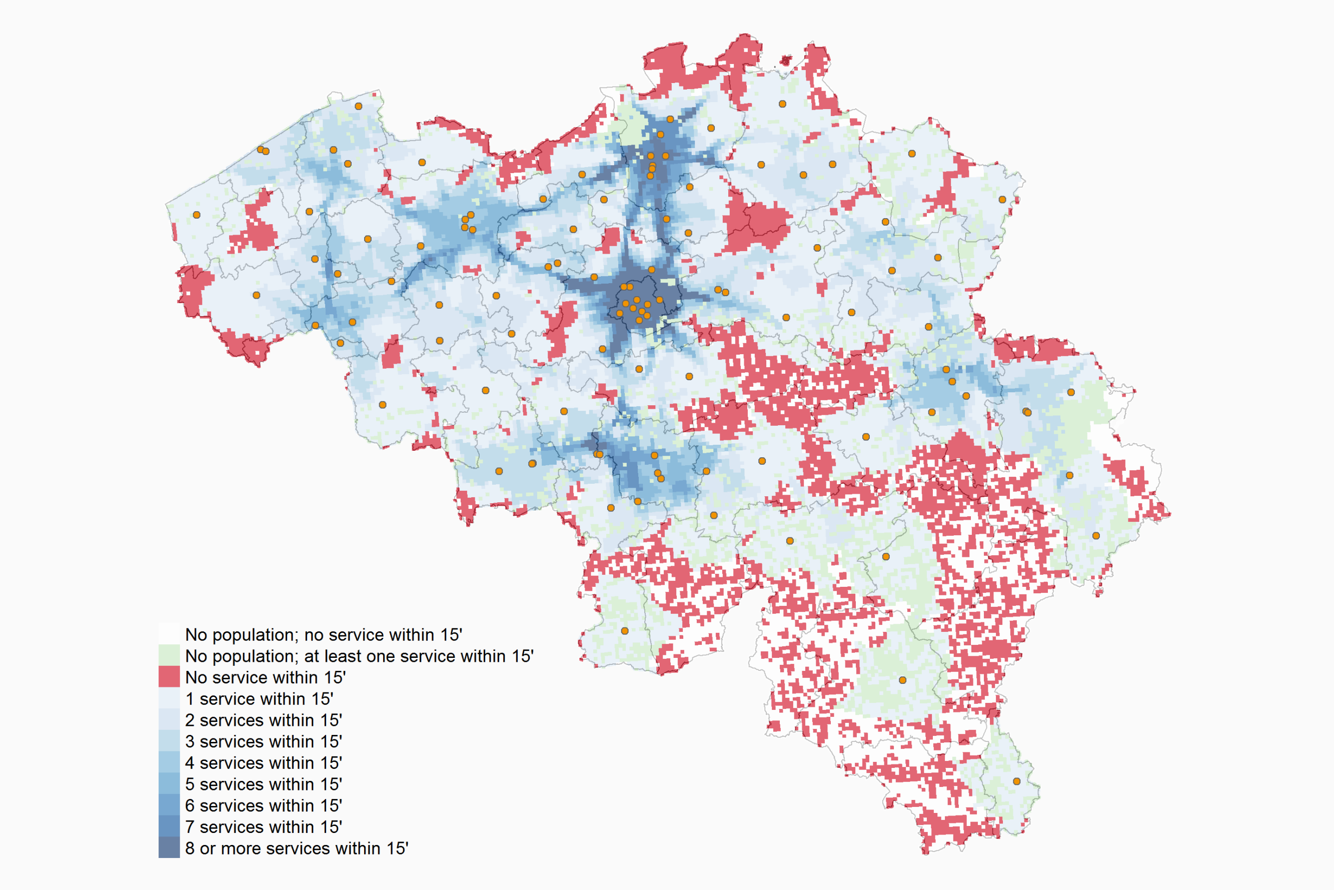


Figure A.5 – Maternity services reachable within 15 minutes (within area definition; orange dots represent maternity services April 2019)

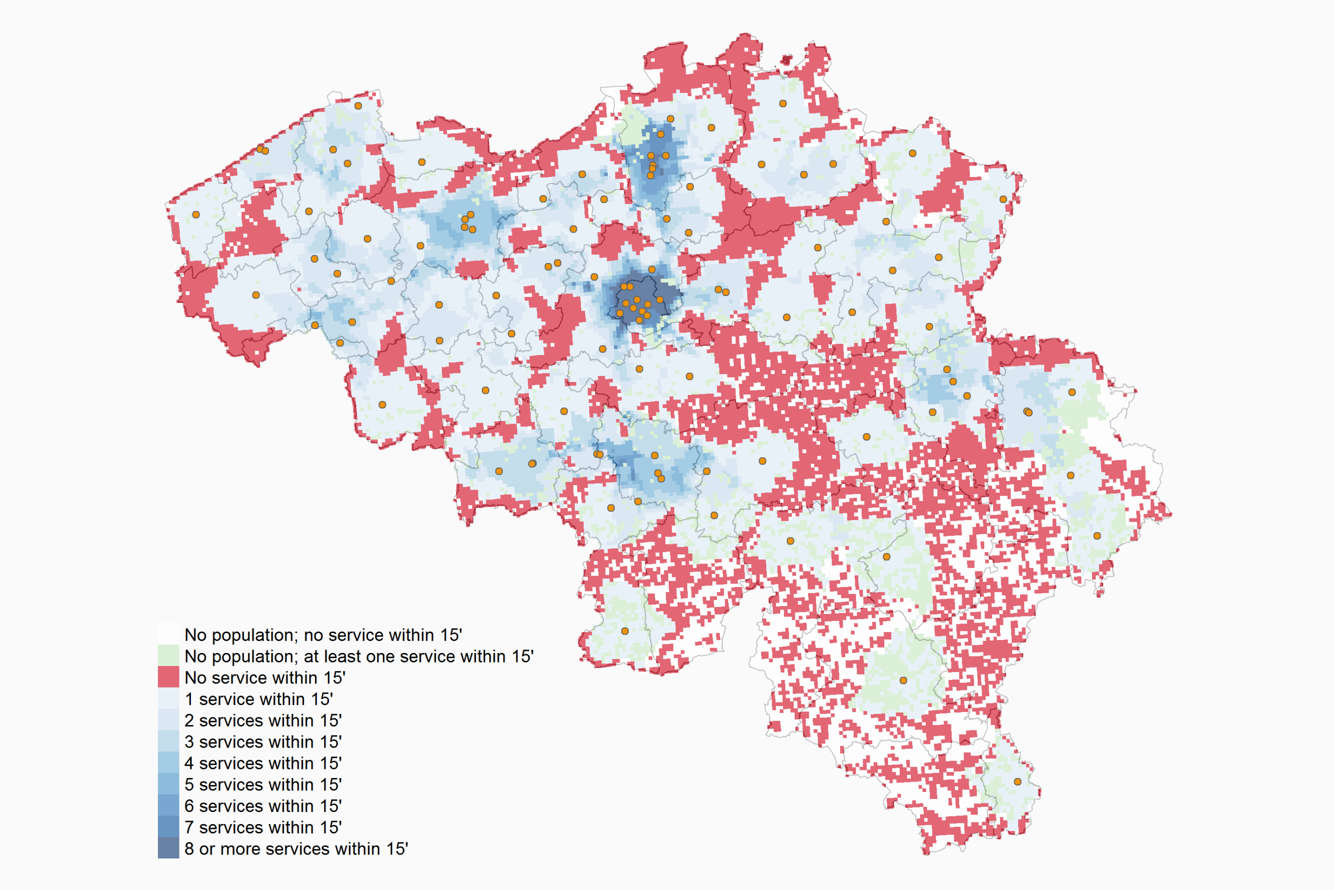
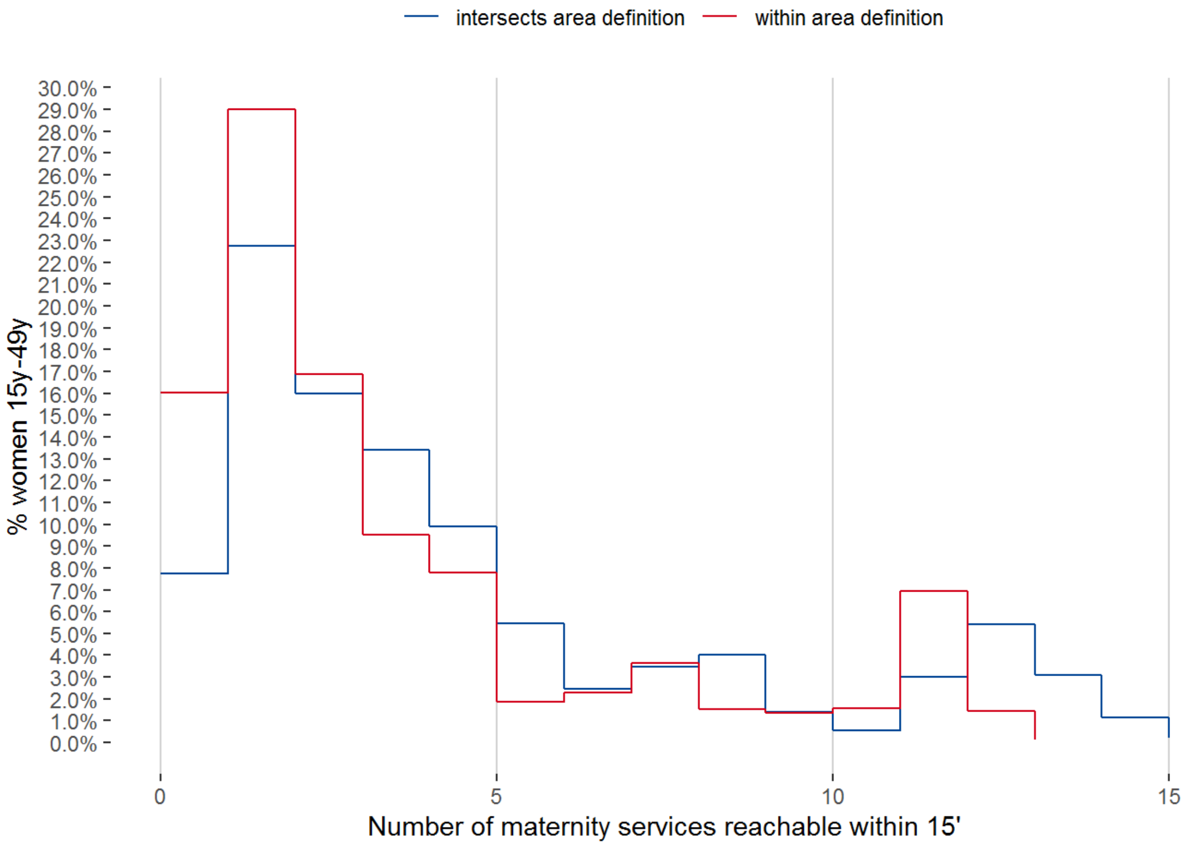


Figure A.6 – Percentage of women 15-49 year old by number of maternity services reachable within 15 minutes



Appendix 3.1.3. Within 45 minutes

Figure A.7 – Maternity services reachable within 45 minutes (intersects area definition; orange dots represent maternity services April 2019)

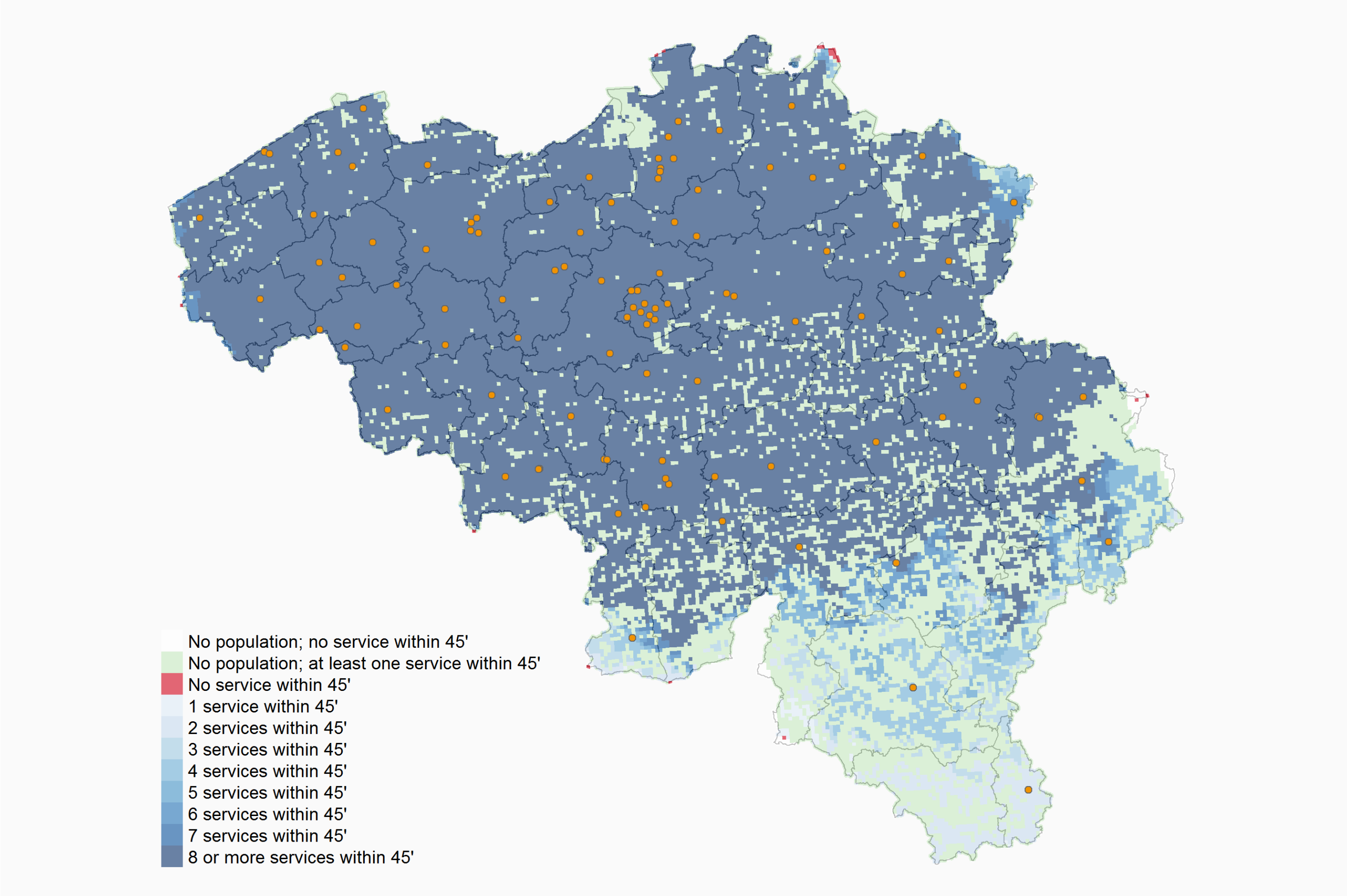


Figure A.8 – Maternity services reachable within 45 minutes (within area definition; orange dots represent maternity services April 2019)

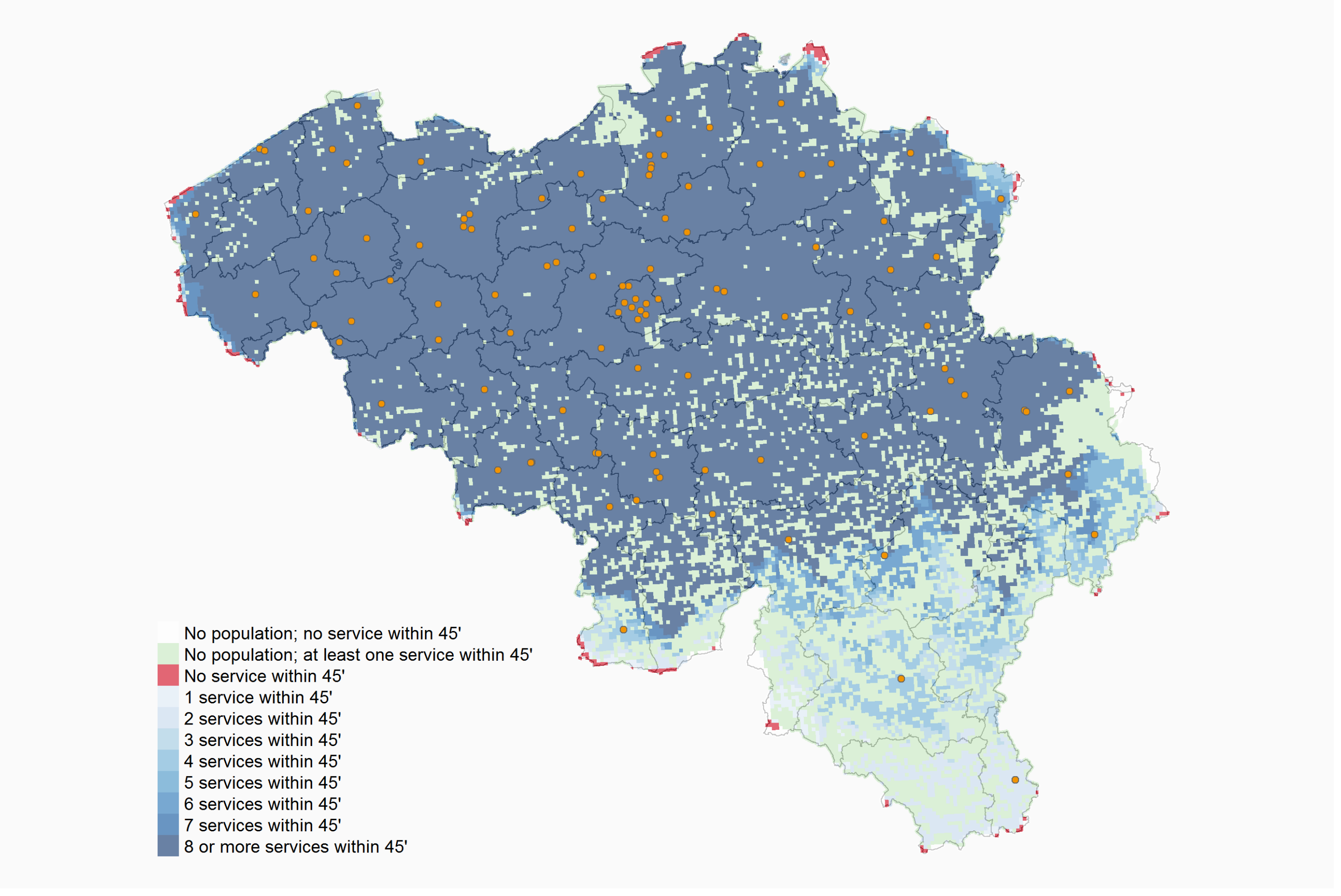
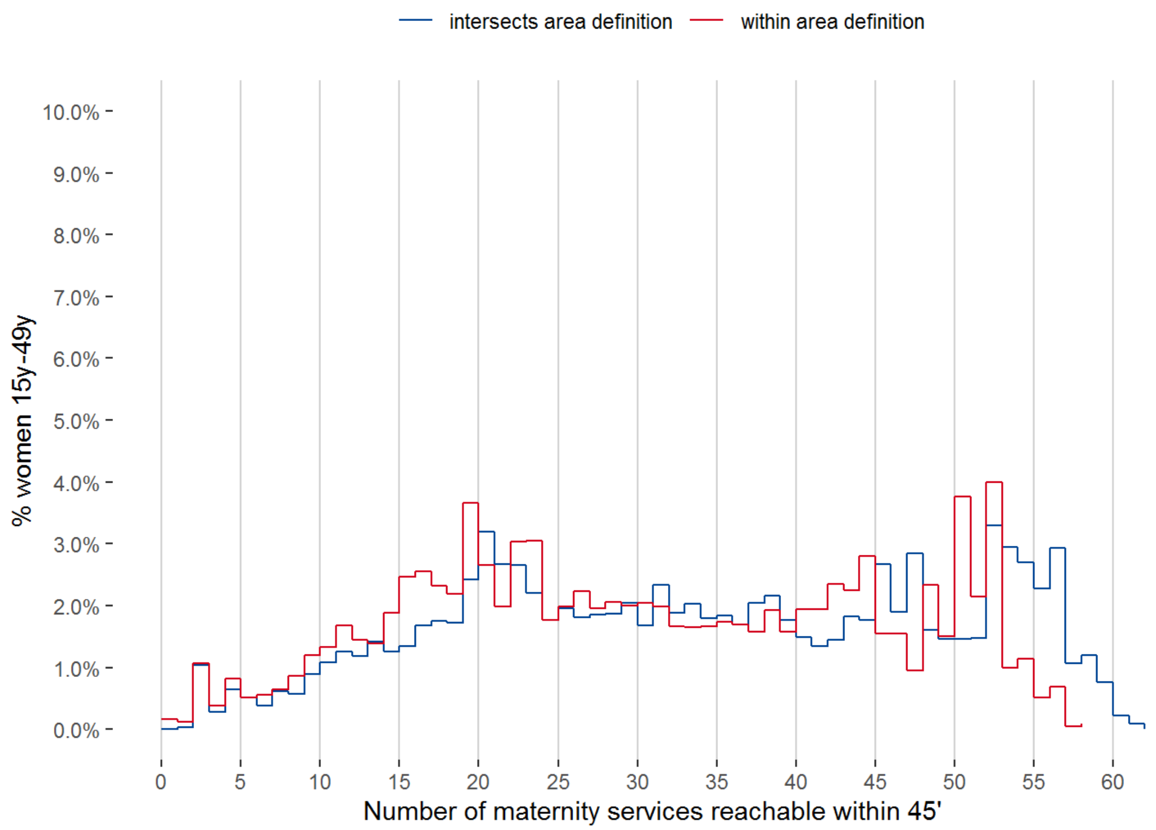


Figure A.9 – Percentage of women 15-49 year old by number of maternity services reachable within 45 minutes



Appendix 3.1.4. Simulation of heavy traffic around three cities

The 30' time limit within which women between 15 and 49 years old can reach a maternity service represents average traffic on a weekday. To simulate heavy traffic around larger cities, we use the 15 minutes isochrone average weekday traffic as a stand in for 30 minutes isochrone heavy traffic. In other words, we assume that the distances reachable within 15 minutes in normal weekday traffic, take 30 minutes in heavy traffic.

We selected Brussels, Liège and Antwerp because they show structural heavy traffic during rush hours. For each city, we identified the maternity services within official city limits:

- Brussels: all maternity services within the Brussels region.
- Liège: all maternity services within the communities officially part of Liège municipality (Liège, Angleur, Bressoux, Chênée, Glain, Grivegnée, Jupille-sur-Meuse, Rocourt, Wandre).
- Antwerp: all maternity services within the communities officially part of Antwerp municipality (Antwerpen, Berchem, Berendrecht-Zandvliet-Lillo, Borgerhout, Deurne, Ekeren, Hoboken, Merksem, Wilrijk).

For each grid cell that can reach a maternity service within 30' in normal weekday traffic in one of the chosen cities, we look at the change in number of maternity services the women between 15 and 49 years old can reach:

- Grid cells that fall both within the 30 minutes isochrone and within the 15 minutes isochrone for the maternity services in the chosen city: no changes in reachability.
- Grid cells that fall within the 30 minutes isochrone but not within the 15 minutes isochrone: we assume that because of heavy traffic, they can no longer reach the maternity services in the chosen city, but still other maternity services outside the chosen city: how many can they still reach excluding the maternity services in the chosen city?

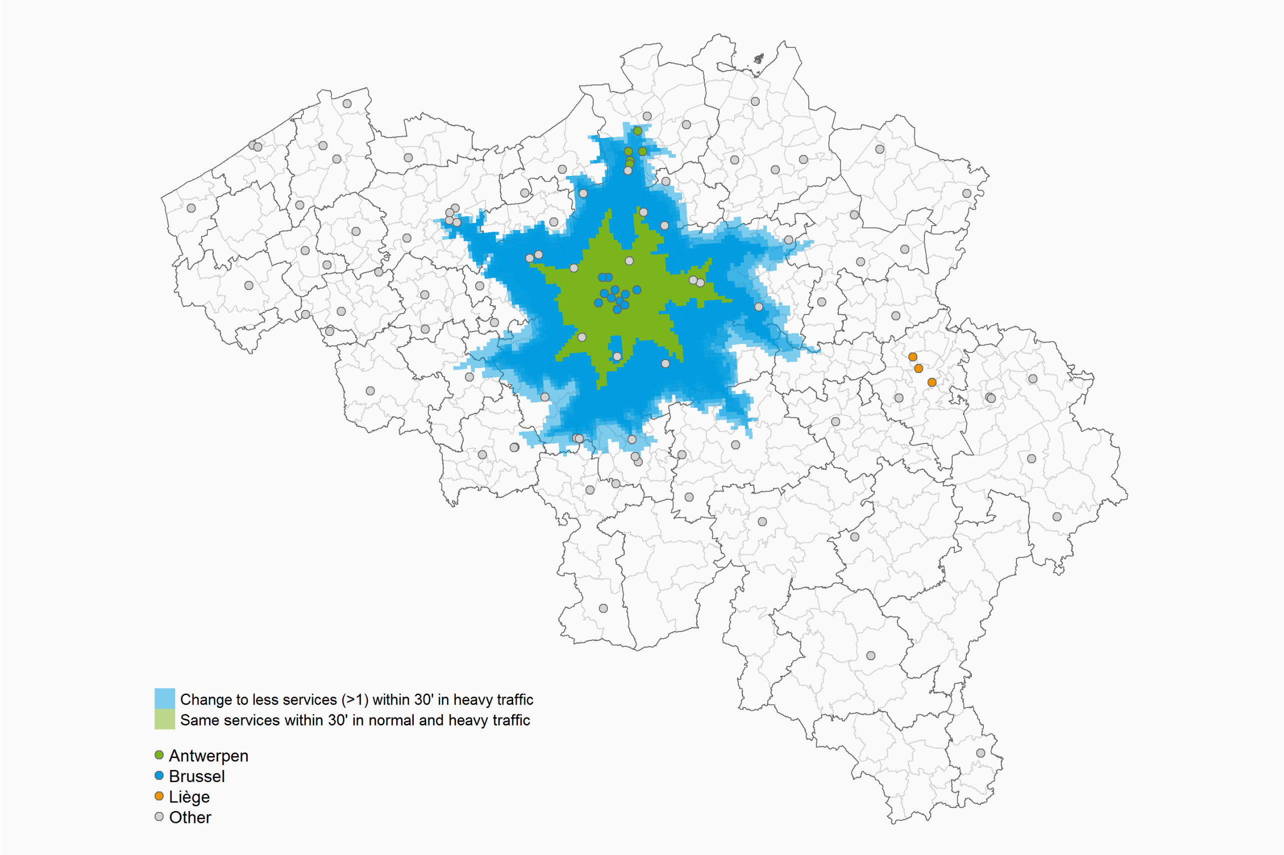
Figure A.10 and Table A.8 show the results for the three cities separately.

Table A.8 – Percentage of women between 15 and 49 years old in function of change in reachability in heavy traffic simulation per city

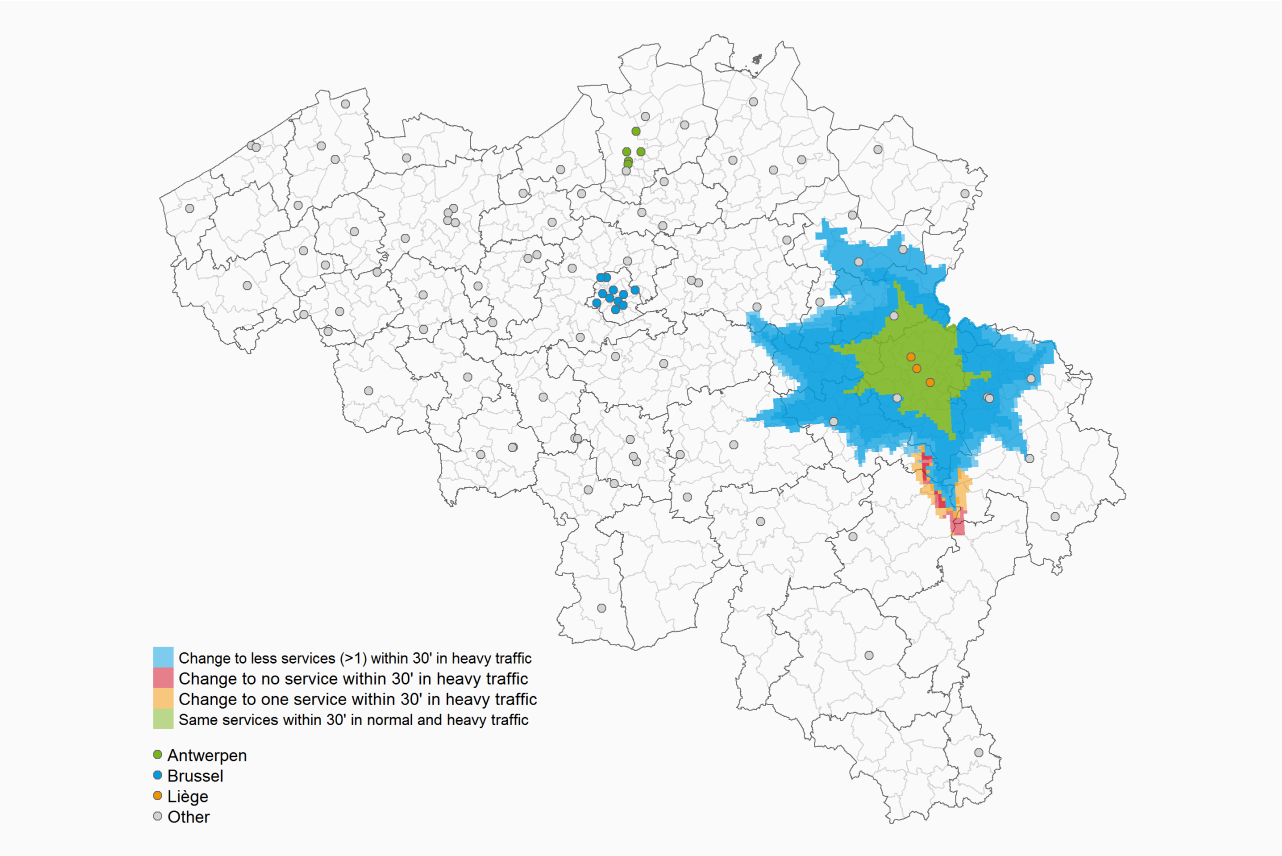
Change	Brussels	Liège	Antwerp
Change to no service within 30 minutes in heavy traffic		0.10%	<0.01%
Change to one service within 30 minutes in heavy traffic		0.25%	0.35%
Change to less services (>1) within 30 minutes in heavy traffic	51.70%	54.07%	66.77%
Same services within 30 minutes in normal and heavy traffic	48.30%	45.58%	32.88%

Figure A.10 – Changes because of heavy traffic simulation (intersects area definition)

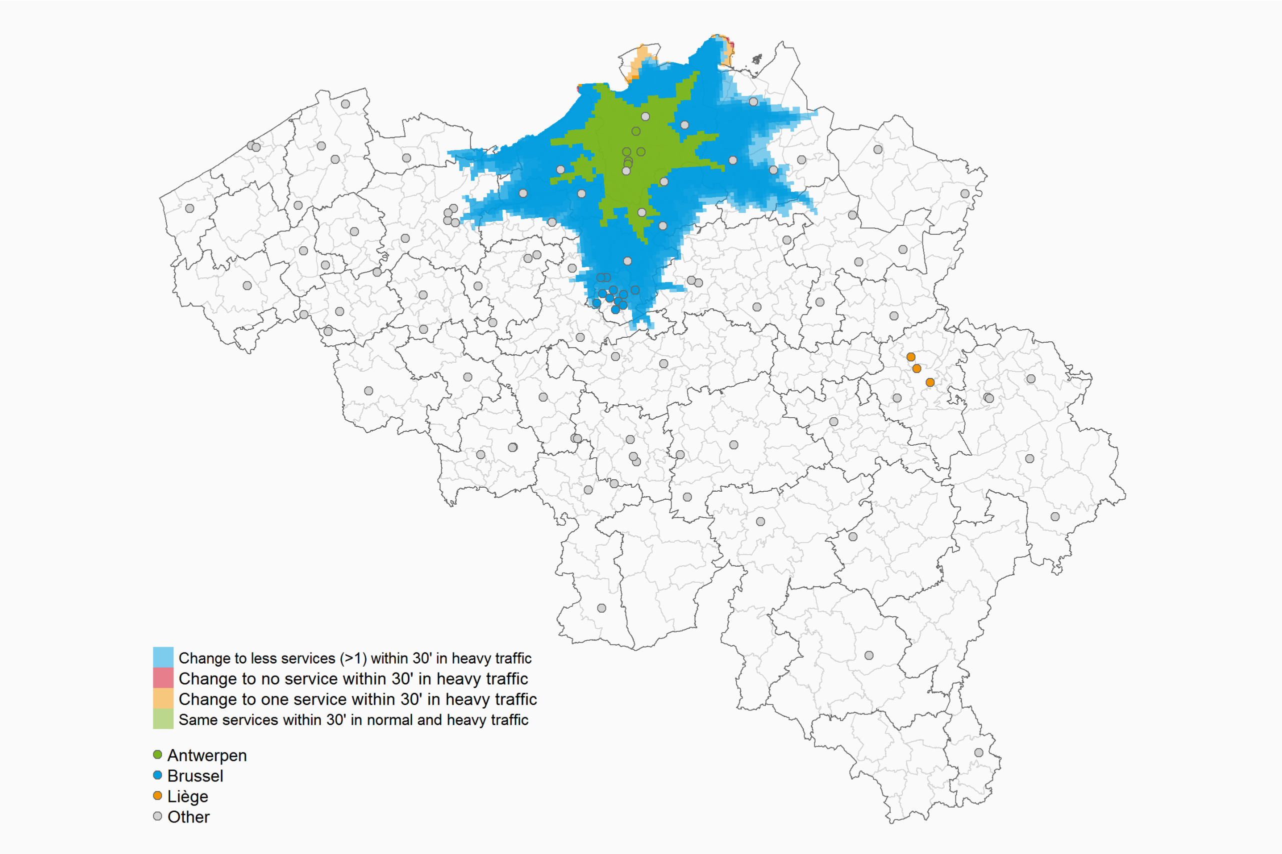
Brussels



Liège


Change to less services (>1) within 30' in heavy traffic
Change to no service within 30' in heavy traffic
Change to one service within 30' in heavy traffic
Same services within 30' in normal and heavy traffic
Antwerpen
Brussel
Liège
Other

Antwerp


Change to less services (>1) within 30' in heavy traffic
Change to no service within 30' in heavy traffic
Change to one service within 30' in heavy traffic
Same services within 30' in normal and heavy traffic
Antwerpen
Brussel
Liège
Other

Appendix 3.2. Possibility to reach a maternity service within 30 minutes following scale efficiency

Figure A.11 – Minimum efficient scale and reachable within 30 minutes of maternity services as the only service or not (within area definition)

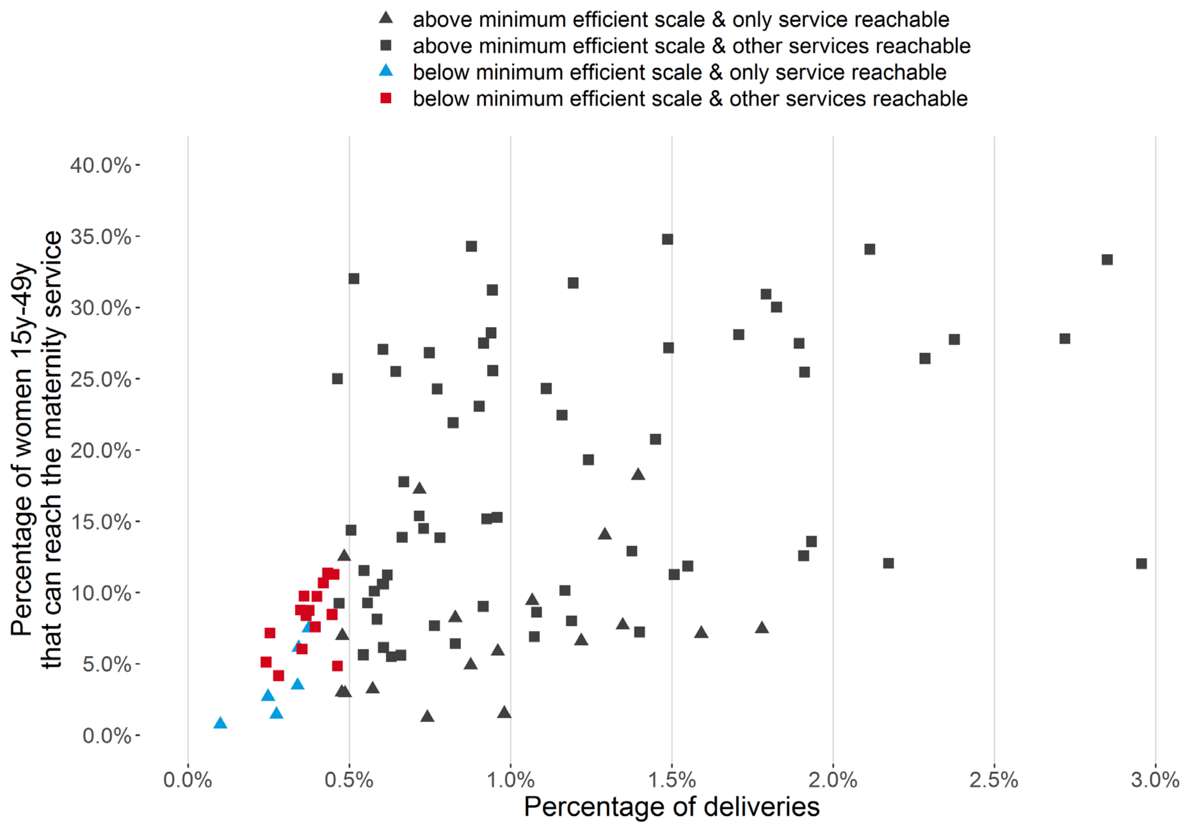
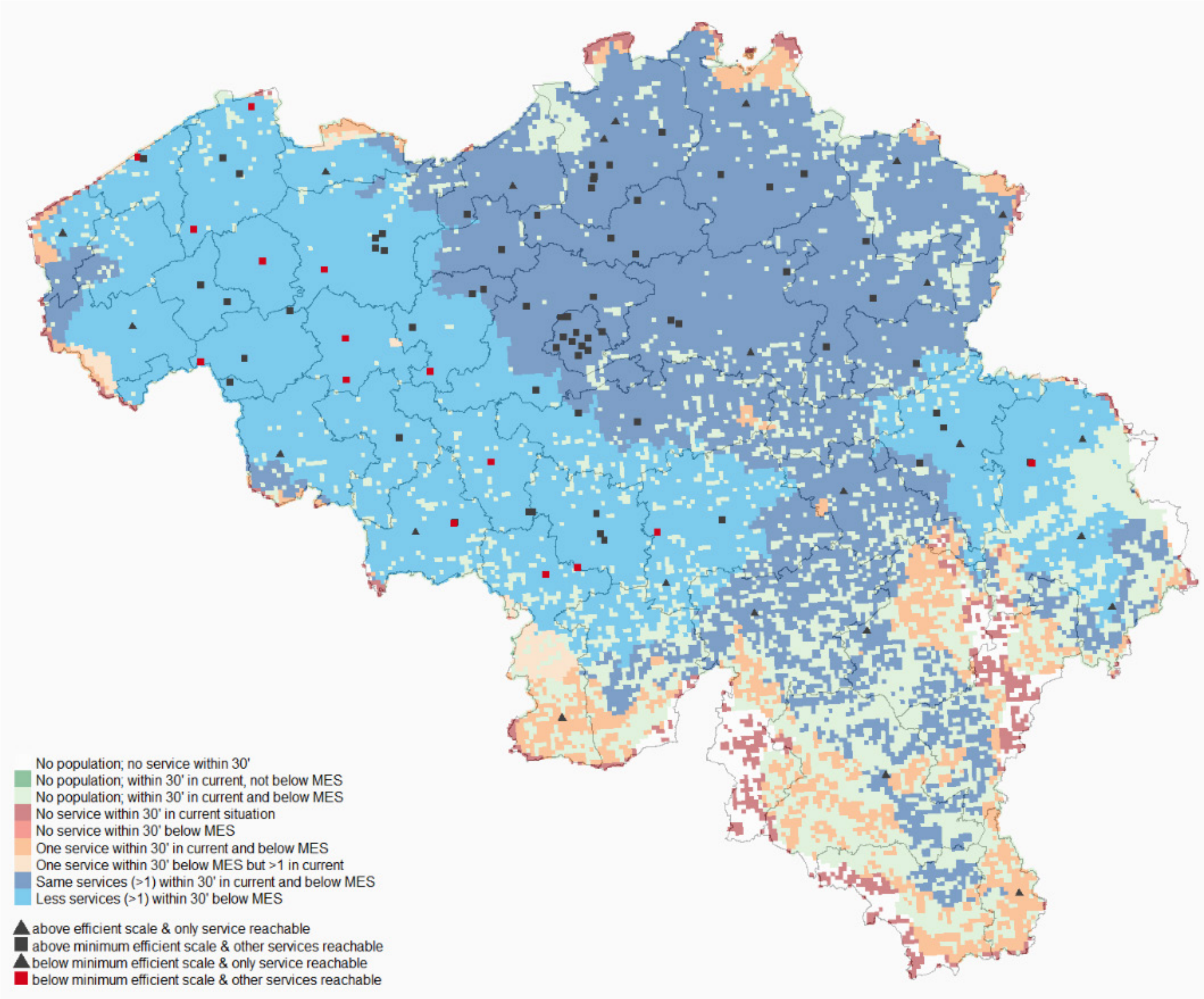


Figure A.12 – Maternity services reachable within 30 minutes following scale efficiency (within area definition)



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