The location and routing models applicable to the transport of persons with disabilities

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The location and routing models applicable to the transport of persons with disabilities – Case study Valenciennes, France

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Abstract. The public transport attempts to provide a service to every citizen on the same level of approachability. Even when the budget allows investments to upgrade the transport facilities accessibility, it would be necessary to deal with the time and transport organization. The research problem that has been treated here is the variant of the possible models applicable to the transport of persons with disabilities on the existing transport network by providing independence in their displacement . The literature recognizes several optimization models that could assist in delivering better transport services to persons with disabilities, such as transport on demand (also knows as dial-a-ride model), and another category is the model that proposes the shortest path on the network. In this paper, the conditions of the public transport network in Valenciennes (France) are analyzed within the transport flows and explained the best fitting with the optimization and location models.

Keywords: location and routing models, public transport, persons with disabilities.

Introduction

In the recent past, public transport systems have faced more and more diversified users with increasing numbers of themselves. This diversity is spread up, especially in the case of persons with disabilities (PWD). Besides, the increasing numbers of general users of public transport, these numbers are increasing as well in the demands of transportation of PWD. World health organization reported one billion PDW, which presents 15% of the total population (World Health Organization, 2011). Also, the number of this kind of transport will increase, as well, because of the growth in the demographic population (Darbéra, Westerlund, & Cazemier, 2012; United Nations, 2006). In addition, French demographic trends are characterized by a rapid increase in the number of people who have difficulty getting around. The forecast indicates 17 million people aged 60 and over, and four million people aged 80 and over after 2020. From 2010, the French population over 60 is more numerous than those under 20 (EgisFrance Villes & Transport).

The public transport has to meet the regulations that are becoming more and more demanding in order to integrate PWD. Nevertheless, the design of transportation systems has not fundamentally changed. Still, the focus is on general users. The number of users and the diversity of their needs make transportation planning particularly complex. This complexity especially increases when the specific needs of PWD have to be met. Since several types of disability may be distinguished (physical, intellectual, motor, and visual), it is necessary to define the specific needs of each group. This paper treats only the user's PWD in a wheelchair. Beyond the number of participants, the transport PWD is also limited by particular constraints (for example, the characteristics of a network, journeys, and vehicles).

The literature recognizes several optimization models that could deliver better transport services to persons with disabilities. One such model is transport on demand model (also known as dial-a-ride model)(Archetti, Speranza, & Weyland, 2018; Cordeau & Laporte, 2007; Molenbruch, Braekers, & Caris, 2017). The other category is the model that considers the shortest paths on the network (Bast et al., 2016; Pallottino & Scutella, 1998; Turner, 2011). However, we aim to make the public network closer to PWD. The first model, transport on demand, is created to provide the service, that is PWD could move from point A to point B, without using the public network. The second model, the shortest path, is used on the public network, its meaning when PWD has already reached it. We could say that these two models are compatible relative to the network.

In general, the problem is recognized in part from the point of the origin (where PWD leaves the house) to reach the first point on the public network (Meyer & Miller, 2001). The model that could help in this situation is location problems, in this case, p-hub location problem (Alumur & Kara, 2008; Gelareh & Nickel, 2011). The possible fitting of the hub-location model is analyzed in the situation of the city Valenciennes, positioned in the north of France. In fact, the public transport network, transport flow and the position of the existing hubs in Valenciennes are analysed for the matching the p-hub location problem. Since, to our best knowledge, the literature doesn't treat location problems to the transport of persons with disabilities.

This paper is structured as follows: Section 1 describes the location and routing models. Section 2 presents the public transport network in Valenciennes, while section 3 is dedicated to the discussion of the improvement of public transport in Valenciennes. Finally, Section 4 presents the conclusion and discussion for future research.

1 Location and routing models

Location problems are divided into several classes, and one of them consists of network location problems (Labbé, 1998). In this paper, the location problems are considered in order to further improve the accessibility of PWD to the public transport network. One part of the solution is to determine the locations of hubs with accessibility. The hubs present the facilities that assist as an exchange, transit, or point of exit in two-way distribution systems (Labbé, 1998).

In our case, PWD access hubs either directly or they are transferred by shuttle. Once they arrive at the hub, they can use the existing network and be transferred to another hub. Upon arriving at certain hubs, they may leave the network by going to their destination, either directly or by shuttle. Therefore, we believe such an approach, which combines location and routing models, may represent a viable solution for public transport services. As the objective in location and routing models, one may consider the maximization of the direct access to hubs within a given budget for installing hubs, minimization of total traveling time, minimization of the number of used shuttles etc. among others.

Figure 1 presents one example of possible positions of the hub centers on the public transport network. In the figure, the dashed red line represents the shuttle service, i.e., the DARP model is considered. The green lines represent direct access of PWD to the network. In this situation, PWD have access to the sidewalks from the point of the origin (leave the house/job) to the public network and opposite when PWD leave the network. As will be explain in the section 2, the public network in Valenciennes already have nodes "*pole d'échange*" which correspond as main elements of the hub location models. Furthermore, the organization of the transport on demand will be presented in details to enrich the elements of the hub location models.

2 Public transport in Valenciennes

Valenciennes is a town in the north of France, with a population of 370.000 habitants in 2016 (L'Institut national de la statistique et des études économiques France, 2016).

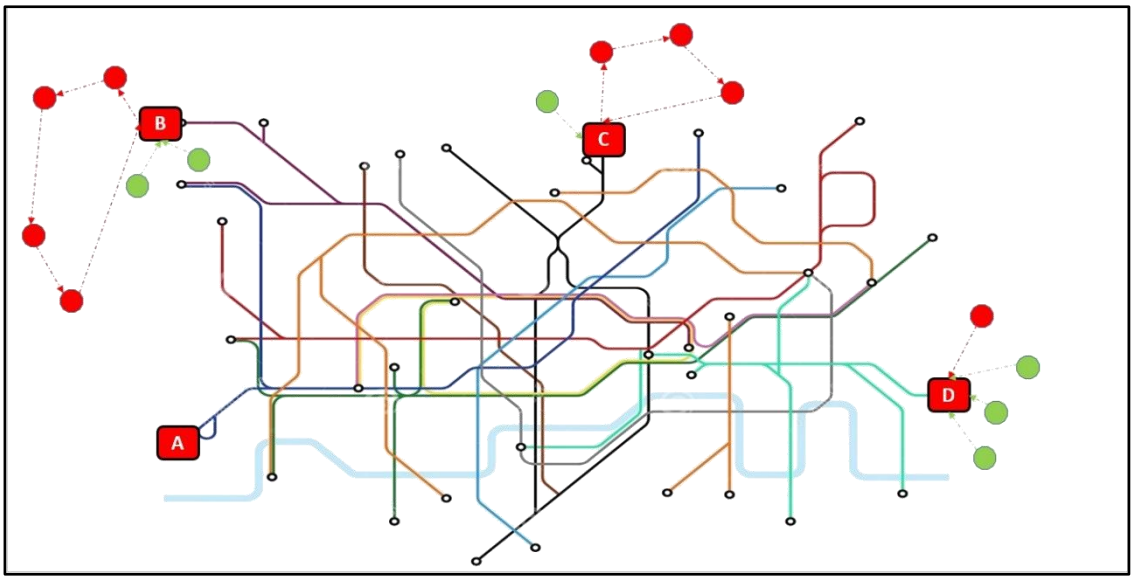

Figure 1. Hub position example

Circulation of public transport on the territory of Valenciennes depends on several communities, and each of them organizes it independently:

- Urban transport belongs to the Transvilles network (https://www.transvilles.com), which is under the responsibility of SIMOUV, Transvilles is also a part of the "Autonomous Parisian Transportation Administration" (*Régie Autonome des Transports Parisiens* – RATP). RATP is a state-owned public transport operator and maintainer;
- Interurban road transport is managed by the Department of the North;
- TER intercity rail transport (Regional Express Train) and regional interurban lines depend on the Hauts-de-France Region.

The network includes 1570 stop/stations, two tramway lines, 37 bus lines, four zones of transport on demand (Taxival), 300 school tours, three shuttle buses, one service for PWD (*Sésame*), three agencies commercial and five parking relais. The network covers 9 500 000 km of lines and five nodes "*poles d'échanges*" (Station Anzin-Hôtel de Ville; Station Denain-Espace Villars; Station-Famars Université; Station Gare; Station Saint Waast). Three of them (Station Anzin-Hôtel de Ville; Station Gare; Station Saint Waast) are positioned in the core of the town with very small radius, and the nodes Station Denain-Espace Villars and Station-Famars Université is positioned on the outskirts of the town.

The volume of the transport is about 17 000 000 passengers/year. Table 1 shows the number of passengers per year and the number of transport on demand. Figure 3 depicts the plan of public transport network run by Transvilles in Valenciennes.

Year	Passenger	Transport on demand
2014	17155033	
2015	16667534	10548
2016	16870412	11120
2017	15519879	10237
2018	13 220 479	9 793

Table 1. The volume of transport per year (Source: https://www.simouv.fr/)

The different modes of transport exist in Valenciennes, such as: Tramway, bus, and transport on demand. The volume of transport per kilometer and per mode is presented in Table 2.

Year	Tramway	Bus	Transport on demand Sésame Propres
2014	1724573	4513462	306622
2015	1770854	3976076	352375
2016	1756200	3890325	348493
2017	1509902	3531151	366016
2018	1369649	3598443	461083

Table 2. Evolution of kilometers by mode (Source: https://www.simouv.fr/)

The network connects the municipalities forming part of the urban community of Valenciennes Métropole, and those of the agglomeration community of the Porte du Hainaut between them by an extensive network of public transport.

The outline of the Urban Travel Zone in Valenciennes corresponds to the perimeter of Urban Transport (75 municipalities) and the seven municipalities of the CCRVS (Community of Rural Municipalities of the Scarpe Valley): in total 82 municipalities corresponding to the arrondissement.

There are divided into three zones of public establishment for inter-municipal cooperation (*Etablissement public de coopération intercommunale – EPCI)*:

- the Valenciennes Agglomeration Community (CAVM),
- The Porte du Hainaut Urban Community (CAPH)
- the Community of Rural Communes of the Scarpe Valley CCRVS.

Regarding the existing organization of PWD transport "*Sésame"* is that they have a fleet of 14 vehicles. The type of the vehicle is presented on the Figure 2. The depo of the vehicles is always in the base station of Transville that is located in Saint Saulve, which is not the node. Only one vehicle is park in node Station Denain-Espace Villars.The "*Sésame*" service is organized into circuits, whenever possible, in order to group people. These circuits are offered for work, internships, higher education as well as for leisure travel. This service works on the reservation in ahead two weeks within the confirmation 48 hours.

Besides the problem of the integration PWD to the public transport, here we can notice that we have a problem in the organization of the transport on demand inside the enterprise.

Figure 2. Type of vehicle using for transport on demand

3 Discussion

According to the report of the activities 2018 of SIMOUV (SIMOUV, 2018), we have the following portioning of transport: 16% - Tramway; 44% - Bus; 6% - Transport on demand (*Sésame Propres*); 27% - Shuttle bus (*Bus affrétés*); 1% - Transport on demand outsource (*Sésame sous-traités*); 2% - Taxival, 4% - Regional lines (*Lignes régionales sous convention SIMOUV*). Hence, the mode of transport that dominates the others is bus transport.

In table 1, we can notice that the number of regular users is decreased by year. However, for PWD in 2018, we have an increased number of users in transport on demand. Unfortunately, we do not have information about the participation of PWD users in total numbers by mode of transport, only for direct transport on demand.

Since that area of Valenciennes is more rural than urban, in fact, we have arisen of rural urbanization (*périurbanisation*). This increase brings to the adverse outcomes for the collective organization of travel and favors individual modes. In addition, one of the issues is that each community that organizes transport (SIMOUV, Department of North, or TER) has its own plans for the accessibility for PWD. It means that we have to find the adjustment of all documents and bring it collaboration on different levels of decisions.

The configuration of data shows that possible application to the p-hub location model, may bring more adequate dial-a-ride solutions, which may have a significant impact on organizations by buses. One of the constraints in transport organizations by buses is the number of vehicles with the accessibility for PWD. Besides the accessibility, another important parameter is the availability. The availability presents that the service is provided to places where PWD wants to go at times they want to travel.

In the urban area, the focus should be on locating the hub centers to satisfy the maximum distance that PWD could have to reach to the hub using the walk sides. In this regard, it will be necessary to make a comprehensive analysis of the geographical positions (the point of origin) of PWDs. As a hub location problem deals with locating facilities (hubs) and allocating points of demands (nodes) to facilities on a network, in order to provide a transshipment service, routed between origin-destination, we will do service on the border of the tramway network and chose the best position on the bus network. The objective should be to minimize the total transportation cost of moving flows from the origin nodes to the destination nodes via the hubs.

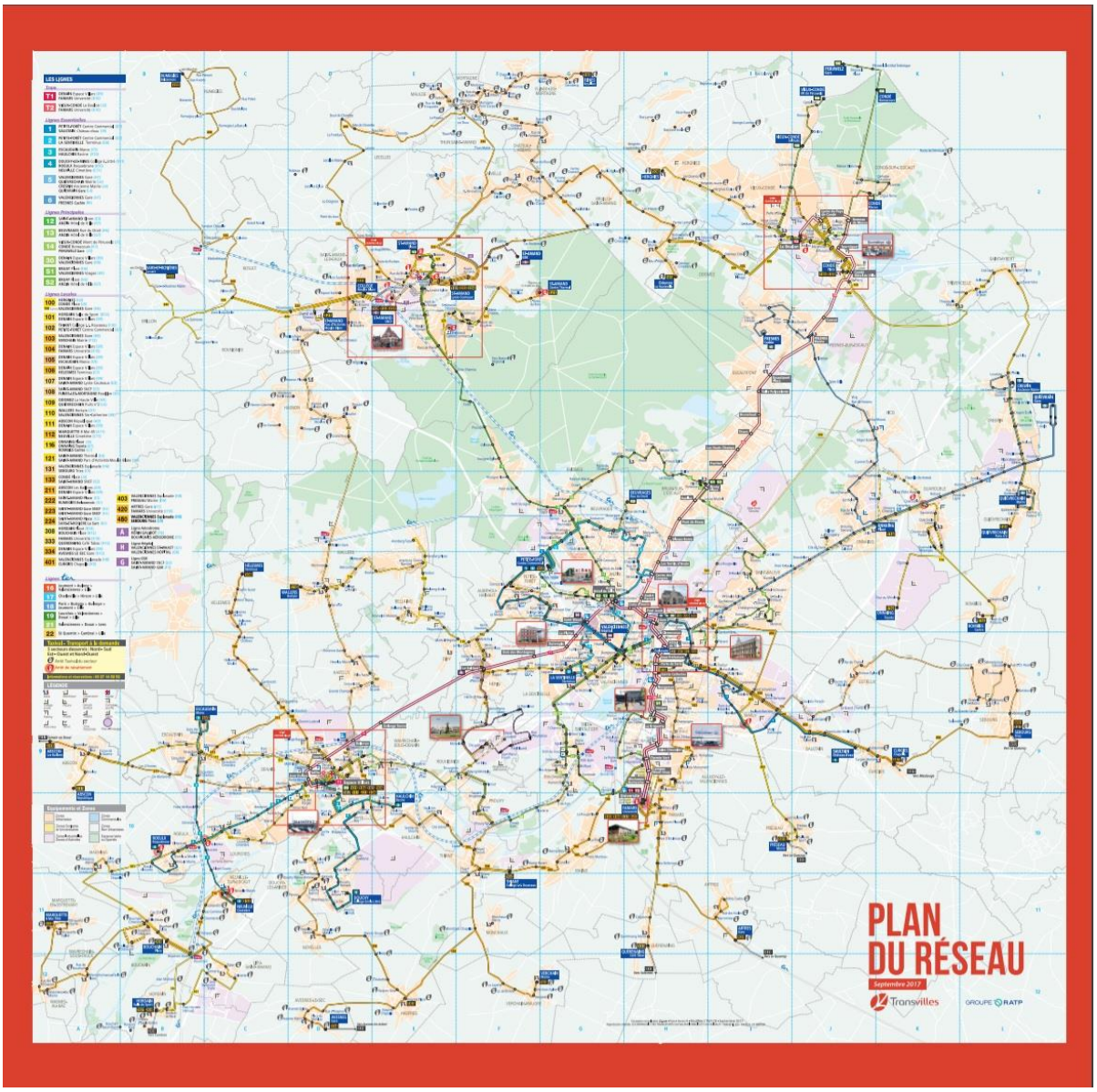

Figure 3. Public transport network, Valenciennes, France
(Source: https://www.transvilles.com/plan-reseau)

Conclusion

Valenciennes is pervasive, rather dense, but combines very various densities. It has the distinction of being a multipolar agglomeration. It has also undergone strong peri-urbanization in recent years and its population, after a period of decline, is tending to stabilize.

Nevertheless, public transport is not efficient. The network is enduring an increasingly marked division: good frequentation of the tramway but disaffection with the rest of the network. Few complementarities have been put in place to support the development of public transport. In the Valenciennes, there is a diversity of offers (TER, Tram, Bus, TAD), which must be able to serve the development of public transport in the area. The entire travel

chain has to be improved (buildings, roads, public spaces, transport, and housing). It is essential to find a specific solution for rural areas and walk side accessibility. This paper has collected almost all elements based on real database in order to analyse the possible applicable location models to the network of Valenciennes. For this reason, we will consider the location-routing model addressed in this paper more deeply and propose adequate solutions that will further improve the overall service quality and user satisfaction.

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References

Alumur, S., & Kara, B. Y. (2008). Network hub location problems: The state of the art. *European Journal of Operational Research, 190*(1), 1-21. doi:https://doi.org/10.1016/j.ejor.2007.06.008

Archetti, C., Speranza, M. G., & Weyland, D. (2018). On-demand public transportation. *Int. Trans. Oper. Res*.

Bast, H., Delling, D., Goldberg, A., Müller-Hannemann, M., Pajor, T., Sanders, P., . . . Werneck, R. F. (2016). Route Planning in Transportation Networks. In L. Kliemann & P. Sanders (Eds.), *Algorithm Engineering: Selected Results and Surveys* (pp. 19-80). Cham: Springer International Publishing.

Cordeau, J.-F., & Laporte, G. (2007). The dial-a-ride problem: models and algorithms. *Annals of Operations Research, 153*(1), 29-46.

Darbéra, R., Westerlund, Y., & Cazemier, O. (2012). *Introducing Taxis in the Provision of Subsidized Transport in Rural Areas (How to Minimize Social Exclusion in Times of Economic Hardship).* Paper presented at the European Transport Conference 2012Association for European Transport (AET) Transportation Research Board.

EgisFrance Villes & Transport. (2013). *Plan de Déplacements Urbains du Valenciennois 2013-2023*. Retrieved from https://www.simouv.fr/la-mobilite/le-pdu-les-pde/le-pdu-du-valenciennois/

Gelareh, S., & Nickel, S. (2011). Hub location problems in transportation networks. *Transportation Research Part E: Logistics and Transportation Review, 47*(6), 1092-1111. doi:https://doi.org/10.1016/j.tre.2011.04.009

L'Institut national de la statistique et des études économiques France. (2016). *Populations légales 2016 Commune de Valenciennes (59606)*. Retrieved from https://www.insee.fr/fr/statistiques/3681328?geo=COM-59606

Labbé, M. (1998). Facility location: models, methods and applications. In *Operations Research and Decision Aid Methodologies in Traffic and Transportation Management* (pp. 264-285): Springer.

Meyer, M. D., & Miller, E. J. (2001). *Urban transportation planning : a decision-oriented approach* (2nd ed ed.). Boston: McGraw-Hill.

Molenbruch, Y., Braekers, K., & Caris, A. (2017). Typology and literature review for dial-a-ride problems. *Annals of Operations Research, 259*(1-2), 295-325.

Pallottino, S., & Scutella, M. G. (1998). Shortest path algorithms in transportation models: classical and innovative aspects. In *Equilibrium and advanced transportation modelling* (pp. 245-281): Springer.

SIMOUV. (2018). *Rapport d'activité 2018*. Retrieved from https://www.simouv.fr/fileadmin/Public/Espace_documentaire/Rapport_activite/RA_2018_32p_PAP_HD.pdf

Turner, L. (2011). Variants of shortest path problems. *Algorithmic Operations Research, 6*(2), 91-104.

United Nations. (2006). *Convention on the Rights of Persons with Disabilities*. Retrieved from https://www.ohchr.org/EN/HRBodies/CRPD/Pages/ConventionRightsPersonsWithDisabilities.aspx?fbclid=IwAR37eOFZ0Jc1cJlEwAbTeuRxcz3Hynyr169hP0Xinm5e09KdVI-uV4w_MPY

World Health Organization, World Bank. (2011). *World report on disability*. Retrieved from https://www.who.int/disabilities/world_report/2011/report.pdf

Alumur, S., & Kara, B. Y. (2008). Network hub location problems: The state of the art. *European Journal of Operational Research, 190*(1), 1-21. doi:https://doi.org/10.1016/j.ejor.2007.06.008

Archetti, C., Speranza, M. G., & Weyland, D. (2018). On-demand public transportation. *Int. Trans. Oper. Res*.

Bast, H., Delling, D., Goldberg, A., Müller-Hannemann, M., Pajor, T., Sanders, P., . . . Werneck, R. F. (2016). Route Planning in Transportation Networks. In L. Kliemann & P. Sanders (Eds.), *Algorithm Engineering: Selected Results and Surveys* (pp. 19-80). Cham: Springer International Publishing.

Cordeau, J.-F., & Laporte, G. (2007). The dial-a-ride problem: models and algorithms. *Annals of Operations Research, 153*(1), 29-46.

Darbéra, R., Westerlund, Y., & Cazemier, O. (2012). *Introducing Taxis in the Provision of Subsidized Transport in Rural Areas (How to Minimize Social Exclusion in Times of Economic Hardship).* Paper presented at the European Transport Conference 2012Association for European Transport (AET) Transportation Research Board.

EgisFrance Villes & Transport. (2013). *Plan de Déplacements Urbains du Valenciennois 2013-2023*. Retrieved from https://www.simouv.fr/la-mobilite/le-pdu-les-pde/le-pdu-du-valenciennois/

Gelareh, S., & Nickel, S. (2011). Hub location problems in transportation networks. *Transportation Research Part E: Logistics and Transportation Review, 47*(6), 1092-1111. doi:https://doi.org/10.1016/j.tre.2011.04.009

L'Institut national de la statistique et des études économiques France. (2016). *Populations légales 2016 Commune de Valenciennes (59606)*. Retrieved from https://www.insee.fr/fr/statistiques/3681328?geo=COM-59606

Labbé, M. (1998). Facility location: models, methods and applications. In *Operations Research and Decision Aid Methodologies in Traffic and Transportation Management* (pp. 264-285): Springer.

Molenbruch, Y., Braekers, K., & Caris, A. (2017). Typology and literature review for dial-a-ride problems. *Annals of Operations Research, 259*(1-2), 295-325.

Pallottino, S., & Scutella, M. G. (1998). Shortest path algorithms in transportation models: classical and innovative aspects. In *Equilibrium and advanced transportation modelling* (pp. 245-281): Springer.

SIMOUV. (2018). *Rapport d'activité 2018*. Retrieved from https://www.simouv.fr/fileadmin/Public/Espace_documentaire/Rapport_activite/RA_2018_32p_PAP_HD.pdf

Turner, L. (2011). Variants of shortest path problems. *Algorithmic Operations Research, 6*(2), 91-104.

United Nations. (2006). *Convention on the Rights of Persons with Disabilities*. Retrieved from https://www.ohchr.org/EN/HRBodies/CRPD/Pages/ConventionRightsPersonsWithDisabilities.aspx?fbclid=IwAR37eOFZ0Jc1cJIEwAbTeuRxcz3Hynyr169hP0Xinm5e09KdVI-uV4w_MPY

World Health Organization, World Bank. (2011). *World report on disability*. Retrieved from https://www.who.int/disabilities/world_report/2011/report.pdf