A New Concept of Central Mobility Management System within Moroccan Cities

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Abstract
In the last decade, the transportation sector has experienced increased demand for transportation for several reasons, including rapid urbanization and the need for transportation. This demand has added another challenge to city challenges. Morocco, as an African country, aims to improve its transport systems. This process has already begun with developing national road safety strategies (SNSR1 and SNSR2) and implementing several projects, such as TGV, electric buses, tramways, Etc. For proposing a new idea of an intelligent transportation system (ITS), a comparison of Morocco's transport systems (conventional and new) was made with those of some African countries (South Africa, Kenya, Senegal, Kenya, Rwanda, and Morocco). The Moroccan Mobility Management Center (3MC) project is a new vision of traffic management, and it acts as a software package that contains intelligent transport systems by default. For 3MC to promote sustainable mobility, it should include some default software like Urban Traffic Management System (UTMS), Intelligent Parking Management System (IPMS), Urban Bus Management System (UBMS), and the Intelligent Taxi Management System (ITMS).

Keywords (12 font)
Moroccan Mobility Management Center, Smart mobility, Comparison, IMMS and Smart city.

1. Introduction
Today, mobility has become a universal necessity due to several factors, such as rapid urbanization, daily needs, etc. This sector contributes to improving the economy of the countries (transport of goods and people). This makes it a

vital sector. Despite the challenges related to this field (environmental, social and economic) that hinder its development, some countries have started this revolution by developing new transport systems. As a result, this field has become a mixture of new and conventional transportation systems. This work proposes a new concept for urban mobility management called the Moroccan Mobility Management Center. It is based on many complementary subsystems to facilitate urban traffic management, especially during peak hours. The idea is developed after an analysis of the various transport systems at the continental level (South Africa, Senegal, Kenya, Rwanda and Morocco). This paper is structured as follows: Sections 2 and 3 present the conventional transport systems implemented in the African countries mentioned above and their challenges. In Section 4, there is a comparison between these transportation systems. Section 5 presents the national strategies for road safety. Regarding the system, it is presented in Section 6.

2. Transport systems in African countries

2.1 Transport systems in South Africa

In 2013, a study was conducted on the most widely used transport systems in South Africa (Statistics South Africa 2014). The results of this study were classified by type of commuters, namely students and workers. Taxis are the most common mode of transport for students with 69.8%, followed by buses with 24.6% and trains with 5.5%. The order is like learners for workers, but in different proportions (68% for taxis, 13% for buses, and 13% for trains). Although minibuses were not included in this study, they captured 67% of the transport market in 2018 (Green Transport Strategy for South Africa: (2018-2050)).
Among the new transport systems adopted in South Africa is the BRT (Bus Rapid Transit), a public road transport system designed to reduce the use of rail systems. Citi BRT and Rea Vaya are two companies that integrated BRT to improve their services) Moreover, High-speed train is known as Gautrain. It was commissioned in 2010 (Nthambeleni 2014, Chris and Graeme 2014.

2.2 Transport system in Senegal

According to a Senegalese study, the number of journeys per day is nearly 1.8 million journeys in public transport (of which only 40% in Dakar, which contains 50% of the country's urban population) (Les déplacements urbains à la loupe 2016). Furthermore, the modes of transport are multiple and diverse and have different rates of use: AFTU buses «35%», ordinary taxis «11%», clandestine taxis «12%», Dakar Dem Dikk (DDD) «6%», because fast «20%» and the train (small train «PTB») «1%» (Les déplacements urbains à la loupe 2016).
To boost Senegal's transport sector, Senegal has invested in two main projects (BRT and TER) to connect the center of Dakar and the north of the city (through the BRT project) and the new Blaise Diagne International Airport "AIBD" (through the TER project "Regional Express Train") (RESUME DE L'ETUDE ENVIRONNEMENTALE ET SOCIALE STRATEGIQUE (EESS) 2016, BRT - Bus Rapid Transit).

2.3 Transport system in Kenya

The transport systems in use in Kenya (Nairobi) are classified as follows: train "0.20%", bus (KBS) "12.2%" and minibus (matatus) "28.40%". All these statistics were made in 2013 (Tembe et al. 2018). While KBS strives to meet customers' needs, it does not cover the entire city of Nairobi.
Kenya has commissioned the digital matatus project to alleviate the various public transport problems, offering information on matatus. This information is presented on a map to locate and track this means of transport (Williams et al. 2015). The BRT project has entered the focus of Kenya but is currently in the construction phase (BUS RAPID TRANSIT). It is possible to exploit IT solutions to request a means of transport, such as Uber, Bolt, Little Cabs, Etc. (Daisy 2021).

2.4 Transport system in Rwanda

In the capital of Rwanda (Kigali), more than 80% of the population lives in remote areas (Niyonsenga D 2012). The modes of transport used in Kigali are similar to those in African countries of the same socio-economic level. Transport usage in the Rwandan capital equals 18% for buses, 21% for motorcycle cabs, 25% for minibuses, and 23% for commuters using private cars (NJW VAN et al. 2014). Regarding the train, it is in the implementation phase, and the

project aims to connect Rwanda "Kigali" and Tanzania "Ithaca" to improve the economy between the two countries (COLLINS 2019).

Aiming to evolve the transport sector, Rwanda has put some projects into operation and others under construction. These include: the Tap & Go system is a solution that facilitates the purchase of tickets using smart cards, integration of public Wifi in buses to ensure transport connectivity, and the BRT project, which is in the discussion and planning phase (Rodier 2021, "Tap & Go" révolutionne le transport urbain à Kigali 2017, Ben Said 2016, Nkurunziza 2021). In addition, IT solutions are used in the transport sector, allowing commuters to request reliable and safe transport (motorcycle cab or private cab). Among the applications used, there are Safe motos and Yego Moto for motorcycle cabs and Taxis Fores and Uber, Yego Cab for private cabs (How to Navigate Transport in Rwanda 2018).

2.5 Transport system in Morocco

In general, Morocco has a wide variety of transport modes in use, and their use varies depending on the availability of transport modes and the socio-economic level of the region in which they are located. According to Morocco's 2014 national statistics (Indicateurs sur la mobilité et transport de la population hors nomade par commune selon le RGPH 2014 2020), mobility use is divided into two categories: workers over the age of 15 and learners. For workers, the use of the transport system is as follows: "10.65%" for taxis, "8.23%" for buses and "0.42%" for trains. For learners, the use rate of the previous means of transport is different, namely: taxis have "3.38%", bus have "6.32%" and "0.33%" for train. There are other modes of transport such as: minibuses (MOUZDAWIJ transport) and informal transport.
The development wheel of transport systems in Morocco has already started. There are as many projects that are being implemented, such as: Tramway, TGV, BRT, Bike Taxi, etc. In 2030, all stations in Morocco will be connected by LGV, It can be explained that TGV reaches all stations connected by LGV (Le Maroc inaugure le premier TGV d'Afrique, made in SNCF 2018). Regarding the BRT project, it is implemented the first time in 2017 at COP 22, this project will be implemented the second time in Agadir (BUS ÉLECTRIQUES 2022, Project for the creation of a Bus Rapid Transit system in Greater Agadir 2022). IT solutions are essential for the management of the mobility sector. Some several mobile applications and websites are used, such as Careem, solutions for purchasing train and bus tickets (by booking online tickets for the train), automatic tolling on highways (via ADM's Jawaz solution) and the proposal of the traffic state of highways (Qu'est-ce que la réservation de voyage ?, Le Pass Jawaz, ADM Trafic: Information trafic en temps réel des Autoroutes du Maroc).

3. Challenges of conventional transport systems

Although the efforts of governments and all actors in the transport sector to improve it, there are still points to discuss. These points shed light on the difficulties and challenges of this field, which will help solve the problems that hinder the achievement of the programmed objectives. Therefore, the evolution domain depends on identifying these challenges, which vary from one country (or region) to another.

Table 1. The different challenges in each country

	Congestion	Infrastructure	Security	Old mode of transport	Pollution
South Africa	X	X	X	X	-
Senegal	X	X	X	-	X
Kenya	X	-	X	X	X
Rwanda	X	X	-	-	X
Morocco	-	X	-	X	X

There are several problems with the African transport system. Table 1 lists some of them. The absence of some challenges in Table 1 does not mean that the above countries do not have such problems, as it represents the results of our internet research. South Africa is a country that suffers from problems of congestion, infrastructure, insecurity, and the state of transport modes (Ngubane). Senegal also faces many challenges, including lack of infrastructure (in 2012, 16.13% of roads were in good condition, 23.32% in average condition and 15.03% in poor condition), road insecurity, pollution (in 2014, the transport sector contributed to 38.85% of Co2 production (Perspective Monde Outil pédagogique des grandes tendances mondiales depuis 1945)) and old mode of transport. Kenya suffers from six

problems: congestion, infrastructure, insecurity, old modes of transport, pollution, and rapid urbanization (ACHWOKA 2016). According to Rwanda Transport Sector Review and Action Plan (2013), Rwanda includes many problems such as rapid urbanization, lack of infrastructure, pollution, and congestion. Regarding Morocco, rapid urbanization (equal to 62.9% in 2019), pollution (the transport sector consumes 41% of Morocco's national energy), lack of infrastructure, road insecurity (in 2018, 949944 accidents including 69830 in agglomeration).

4. Comparison of Existing Conventional Transportation Systems

The conventional transport systems implemented in the aforementioned countries are almost similar, but there are some exceptions due to the limitations and peculiarities of each country and region.

Table 2. Table of utilization rates of the transport systems of Morocco, South Africa, Senegal, Rwanda and Kenya (bus, taxi, train, motorcycle taxi and minibus).

	Bus	**Taxi**	**Train**	**Motocycle Taxis**	**Minibus**
	In the city				
Morocco	7.28% (2014) (Indicateurs sur la mobilité et transport de la population hors nomade par commune selon le RGPH 2014 2020)	7.02% (2014) (Indicateurs sur la mobilité et transport de la population hors nomade par commune selon le RGPH 2014 2020)	0.4% (2014) (Indicateurs sur la mobilité et transport de la population hors nomade par commune selon le RGPH 2014 2020) 8% of Morocco's transport sector (ONCF RAPPORT ANNUEL 2016 2016)	-	-
South Africa	22.3% (2013) (Statistics South Africa, 2014)	68.9% (2013) (Statistics South Africa, 2014)	09.25 % (2013) (Statistics South Africa, 2014)	-	67% (2018) (Green Transport Strategy for South Africa: (2018-2050))
Senegal	6% DDD bus (in Dakar in 2015) (Les déplacements urbains à la loupe 2016)	10.5% (in Dakar in 2015) (Les déplacements urbains à la loupe 2016)	1% de PTB (in Dakar in 2015) (Les déplacements urbains à la loupe 2016)	-	35% (in Dakar in 2015) (Les déplacements urbains à la loupe 2016)
Rwanda	18% (in Kigali in 2012) (NJW VAN et al. 2014)	23% private (private cars offering taxi service) (NJW VAN et al. 2014)	Not yet commissioned	21% (in Kigali in 2012) (NJW VAN et al. 2014)	25% (in Kigali in 2012) (NJW VAN et al. 2014)
Kenya	12,2% (Nairobi 2013) (Tembe et al. 2018)	Using apps to book a car (like Uber)	0.2% (in Nairobi 2013) (Tembe et al. 2018)	-	Matatus (28.4%) Nairobi in 2013 (Tembe et al. 2018)

The use of transport varies from country to country. Table 2 shows the rates of use of transport modes. These values were collected on different dates but may reflect traffic patterns. The maximum use of buses, taxis, and minibuses is in South Africa, under the following ratios: 23% for buses, 68.9% for taxis, and 9.25% for trains (in 2013), for

minibusses, the utilization rate equals 67% (in 2018). Concerning motorcycle taxis, the Rwandan capital (Kigali) had a ratio of 21% (2012). In Morocco, the transport use also varies. The values below represent the ratio of workers and students using some traditional means of transportation (buses, taxis, and trains). According to the RGPH 2014 (Recent General Population and Housing 2014), the most common modes of transport used by workers and students are 7.28% for buses, followed by 7.02% for taxis and trains with 0.4%. The percentage of train use increased from 0.4% (in 2014) to 8% (in 2016) (ONCF RAPPORT ANNUEL 2016 2016).

5. National Strategies for Road Safety and Intelligent Transport Systems

Morocco has developed two strategies to reduce this problem: national road safety strategies 1 (SNSR1) from 2004 to 2013 and national road safety strategies 2 (SNSR2) from 2017 to 2026.
In general, most of the causes of accidents are human errors (speeding or excessive speed "50.19%", traffic without precaution "24.86%" and failure to respect priority "5.47%") (Stratégie Nationale de la sécurité routière 2017-2026). Therefore, all these causes require the integration of ICT in the transport field to reduce human errors.

5.1 National Road Safety Strategy 2017-2021 and ITS

Developing efficient, safe, and multi-modal transport systems is an international trend. Morocco has adopted this policy by integrating it into the national transport strategies of the country. Among the orientations of the national transportation strategy, orientations 3 and 4 (PLAN STRATEGIQUE 2017 – 2021 2018):

- Orientation 3: Move towards an efficient, safe, clean, multimodal transport system and integrated and competitive logistics services.
- Orientation 4: Successfully modernize the METLE through performance and optional excellence.

The above guidelines encourage the Moroccan authorities to promote transport systems by integrating ITS. There are several implementations, including:

- Improvement of road geographical information systems
- The generalization use of electronic toll (JAWAZ) on the entire motorway network
- The generalization of the system (PORTNET) to the kingdom's ports.
- Booking tickets for trains online.
- Etc.

6. Mobility management central system

Mobility has become a significant problem for the planning and management of cities, and it requires a new vision to improve the urban area (conventional or smart cities). This vision is reflected in the production of eco-mobility and autonomous and intelligent vehicles. Eco-mobility (or sustainable mobility) is based on many dimensions, including economic, environmental, and social dimensions.
The integration of ICT and the internet of things has contributed to innovation and the emergence of a new paradigm called the VIP environment "vehicle-infrastructure-personal". In a VIP environment, the exchange of information can be in different forms: vehicle-to-vehicle "V2V", vehicle-to-infrastructure "V2I", pedestrian-to-infrastructure "P2I", and vehicle-to-pedestrian "V2P". This environment and the different forms of information exchange are part of ITS and aim to reduce energy consumption, the production of Co2, and the greenhouse effect.
For proposing a new system, it haves offer certain features, like:

- Control
- Treatment
- Answer
- Planning

Moroccan Mobility Management Center (3MC) is a new vision of traffic management. It aims to promote Moroccan transport systems, including several systems such as traffic management, parking management, management of buses and cabs, Etc.

6.1. Urban Traffic Management System (UTMS)

UTMS aims to facilitate urban traffic management and minimize fuel consumption and the production of CO2. This solution is based on integrating several systems, including The Intelligent Road and Variable Message Signs that will relate to the Mobility Management Center and UTMS. The system is based on P2I and V2I information exchange modes. Integrating IoT in road infrastructures offers them specific characteristics such as autonomy and communication. That allows them to collect and transmit the data necessary for traffic light management. At the traffic

light level, the system detects the critical points (with the most significant number of vehicles) by exploiting the data sent by the intelligent roads (the same information will be transferred to the mobility management center) to take the appropriate decision to solve the congestion problem. The process of operation of the system is as follows:

- Identify the critical points (the busiest traffic lights).
- Send the information to the management center.
- The traffic light that has more vehicles will be the first to turn on the green light.

6.2. The Intelligent Parking Management System (SGPI)

The Intelligent Parking Management System (SGPI) manages the parking lots. It contributes to reducing traffic problems, such as drivers who circulate in the city looking for a place to park and mismanagement of parking lots (the manual management). These problems can disrupt traffic in the city.
The operation of the SGPI is divided into four parts: before the entrance, at the entrance to the parking lot, after entering (including parking and leaving the space), and after exiting the parking lot.

- SGPI is a solution that proposes the location of the parking lots (on a Map) in which the SGPI is implemented, it also allows to know in real time the number of available spaces.
- At the entrance to the parking lot, a fixed camera reads the vehicle registration number to reserve a place and remove it from the system on the exit. This information allows us to know the number of available spaces in each parking. At the parking, a sensor helps the driver park his vehicle by turning on a light when the vehicle is correctly placed. In addition, another sensor is supposed to detect the vehicle's presence.
- The driver must pay the parking fee to get out of the parking lot. Payment mode can do that in two ways: either in cash or by a smart card (monthly subscription or reload the card). After payment, the barrier is automatically removed so that the vehicle can exit. The system increases the number of places available when the camera outside validates the vehicle exit.

6.3. Urban Bus Management System (UBMS)

UBMS is a system that aims to improve the management of urban buses and offer certain quality services (in particular: easy access to information for all those who have a direct relationship with buses, for example, commuters, controllers, and the management center). This solution allows:
MUBMS seeks to ensure the safety and comfort of bus users. Among its services:

- Schedule consultation: For better planning, UBMS offers the option of consulting the arrival time of each bus at all stations. This information will be necessary for late commuters.
- Location of stations: Getting around and taking the bus in big cities is quite complicated. With the help of UBMS, commuters will be able to quickly find the stations (on the city map), despite being foreigners from this city.
- The number of seats: the number of seats available on a bus directly impacts the decision to board a bus or wait for another. For example, once a passenger has this information, he can decide to board or wait for the next bus.
- Priority of public transport systems: In Morocco, bus delays were included in the daily routine of commuters, and the problem was mainly due to traffic congestion and failure to observe traffic lights or give priority. The urban mobility management center will be able to resolve this dilemma. UBMS aims to speed up traffic by detecting buses near traffic lights (via GPS) to give them priority by UBMS on the green light quickly. This action decreases the usual time to travel the route.
- Ticket management: Usually, the purchase of bus tickets is a non-computerized operation that requires cash to complete. This part hinders the transformation of the nozzles (to intelligent buses). UBMS solves this dilemma, and it will facilitate the work of drivers and controllers, thus helping commuters pay their transport bills in a fast and straightforward way.

6.4. Intelligent Taxi Management System

The fourth integrated system in the Moroccan mobility management center is for taxi management. This public transport mode covers an integral part of the transport market. The utilization rate of this mean is 7.02% (according to RGPU 2014) (HCP). Although the importance of this mode of transport has been recognized, it has not benefited from an initiative to integrate ICT into standard cabs. The intelligent system for taxi management (ITMS) offers features to help customers, drivers, and the mobility management center. The services offered by the system are classified according to system users (customer, driver, and the management center).

7. Conclusion

The transport field is an indispensable element in the economic activity in different countries. However, the increased travel in the urban environment has led to several problems that hamper traffic (congestion, state of transport modes, pollution, rapid urbanization, Etc.). The idea of the 3MC system is to relieve urban traffic by exploiting the intelligent transportation systems integrated into or imported. The solutions in 3MC are UTMS, SGPI, UBMS, and ITMS. All these systems will promote sustainable mobility.

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Nomenclature

Symbol	Description
IMMS	Intelligent Mobility Management System
ITS	Intelligent Transportation System
IoT	Internet Of Things
ICT	Information and Communication Technologies
GPS	Global Positioning System
V2I	Vehicle-To-Infrastructure
P2I	Person-To-Infrastructure
SNSR1 or SNSR2	Stratégie Nationale de la Sécurité Routière (National road safety strategy)
3MC	Moroccan Mobility Management center
UTMS	Urban Trafic Management System
IPMS	Intelligent Parking Management System
UBMS	Urban Bus Management System
ITMS	Intelligent Taxi Management System
BRT	Bus Rapid Transit
TGV	Train à Grande Vitesse (High-speed train)
ADM	Autoroutes Du Maroc
HCP	Haut-Commissariat au Plan
CO2	Carbon dioxide