PONT D'AQUITAINE IN BORDEAUX : LANE DYNAMIC MANAGEMENT

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ABSTRACT

In 1982, the traffic capacity of the **Pont d'Aquitaine (**2x2 lanes)**,** part of the ring-road of the city of Bordeaux (France) was undersized. The lanes were narrowed to create an additional reversible lane; numerous frontal shocks occurred. Works on the suspension cables offered the opportunity to widen the deck and create 2x3 lanes without hard shoulder and so, to improve traffic flow at rush hours and safety level.

Additional equipments were required to supervise the traffic conditions, neutralise lanes in case of incident… Other measures intervened: reorganisation of the maintenance services, overtaking prohibition for trucks, speed limit; automatic speed control…

The ex-post evaluation highlighted that the dynamic management of three lanes was efficient on traffic flow; the AID system compensates correctly the lack of hard shoulder lane. However, the capacity reserves is now weak and the saturation backwards on the exit lanes of the bridge. The lane allocation information are properly respected, but the access to emergency call posts is now more difficult.
The users and operators are mainly satisfied of the lane operating system. The traffic managers consider this dynamic use of lanes should nevertheless remain limited to short sections.

1. INTRODUCTION

With 80,000 to 140,000 vehicles a day, the Bordeaux Ring Road has a high density of traffic and includes a critical point: the Pont d'Aquitaine.

For many years it was very difficult to cross the Garonne in Bordeaux. Until the 60s, Bordeaux had only one road bridge, the Pont de Pierre. A decision was taken in 1956 to build a new bridge: the Pont d'Aquitaine. When it was inaugurated on 6 May 1967, as "France's second biggest bridge", it appeared to be oversized. Fifteen years later, it was no longer able to cope with the constant increase in traffic along the Ring Road, which by-passes France's sixth biggest urban community in terms of population.

The bridge's managers decide to create extra dynamically managed lanes to meet users' needs.

2. PRESENTATION OF THE STRUCTURE

The main structure of the Pont d'Aquitaine is made up of three spans with a total length of 1,767 m. The central span, 393.75 m long, is 50 metres above the highest level of the Garonne, which has allowed most of the maritime traffic to be maintained. The span is

extended on the left bank by a viaduct 1,014 m long. On the right bank, the suspended lateral span is connected directly to Lormont hill.

Figure 1- Characteristics of the original bridge -Source SETRA

When it came into service in 1967, the bridge had a 14 m wide road surface divided into 4 lanes with two cycle lanes and side pavements separated by low walls.

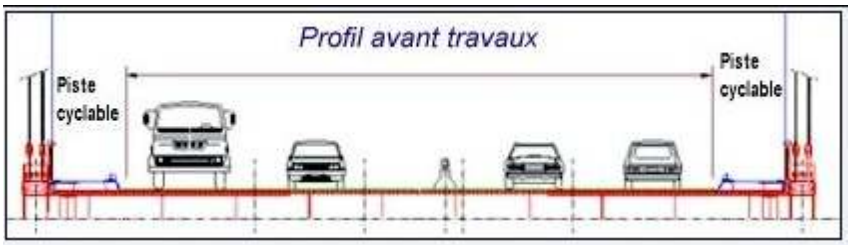

Figure 2- The cross-section before the works – Source SETRA

The North-west section of the Bordeaux Ring Road, of which the Pont d'Aquitaine is a part, was built gradually between 1967 and 1982 with a 2x2 lane cross-section. It carries mainly local commercial and commuters' traffic during working days over the year, with morning and evening rush hours and weekend traffic marked by peaks during the Sunday evening return to the city. Currently known as the A630, it also acts as a through-route for national and international traffic on European north-south journeys.

3. IMPLEMENTATION OF THE DYNAMIC USE OF LANE

3.1. Phase 1 - the reversible lane

In the early 80s, the annual average daily traffic (AADT) was around 90,000 vehicles, of which approximately 15 % were heavy goods vehicles (HGV). Congestion levels were around 20,000 HKM on this part of the ring road, occurring mainly at the Pont d'Aquitaine during morning and evening rush hours and causing 90% saturation on the bridge.

In 1982, the managers looked for ways of coping with the situation and the increase in road traffic, taking its heavily commuter-based characteristics into consideration. They decided to create an extra, reversible lane to raise the number of lanes from two to three in the direction of the heaviest traffic flows at rush hour. As the width of the bridge was limited, the initial profile of 2X2 lanes and 2 cycle lanes was modified and widened to 16 m. This led to a reduction in the width of the hard shoulder and of the lanes. Lane allocation signals were used to manage the alternating use of the extra centre lane.

Although the method met expectations in traffic terms, it was considered to be too much of an accident risk: the accident rate per vehicle and km doubled from 1982 (23 accidents with physical injury reported over the 1.7 km of the bridge and viaduct between 1996 and 1999). The limited width of the bridge did not allow for it to be managed by allocating the centre lane and moving a central barrier.

3.2. Phase 2 – Return to the original situation

In 1999, traffic returned to a 2 x 2 lane system with a central barrier. The period August 1999 to September 2000 saw a significant fall in the number of accidents with physical injury. But the return to the earlier system also led to a mechanical fall in capacity; congestion returned and traffic decreased by around 10% to an annual average daily rate of 85,000 vehicles a day, with more vehicles using the southern bridge over the Garonne.

3.3. Phase 3 - The 2x3-lane dynamic operating implementation

3.3.1. The opportunity for improvement

At the same time, the bridge was beginning to feel its age. The suspension cables were made of non-galvanised steel wires, in line with practices at the time of building. Following the breakage of a cable strand on another French suspended bridge (Pont de Tancarville) in 1995, it was decided to reinforce the monitoring system on the Pont d'Aquitaine by installing acoustic monitoring. Between 1995 and 1998, visual monitoring showed a significant increase in corrosion and the speed at which deterioration was occurring; this was confirmed by the acoustic monitoring. A few clamps were opened for a direct visual examination, which highlighted the need to replace the suspension system very rapidly.

The work to replace the cables was decided in 1999 and offered an opportunity to change the suspension. At the top of the towers, the new cables were moved 2 m outwards from the old ones and directed vertically from these points to the anchoring points.

By moving the suspension cables outwards from the bridge, the width available between the towers after the works was 20 m. This increase from 16 to 20 metres meant that improvements to levels of service on this part of the Bordeaux ring road could be considered, two fundamental aspects of which were expressed by users during interviews: traffic fluidity and user safety. Maintaining an equivalent level of safety turned out to be the most difficult aspect to overcome.

In October 2002, the Gironde Highways Department (DDE) of Transport Ministry drew up a preliminary outline operating project [1]. Two types of operating scenarios were discussed: operating the bridge on the basis of 2 x 3 lanes with no hard shoulder or on an adaptive 5-lane basis with an auxiliary lane used at rush hours only and situated on the left (fast lane) or on the right (slow lane).
The adaptive 5-lane scenario with an adaptive lane was turned down because it was too complex. The operating equipment required to manage an adaptive lane was deemed to be *"by nature and the current state of the art, too "fragile" as it is too exposed to the risk of impacts".*

A comparative risk analysis (from a point of view of road risks) showed that the simplicity of a 2x3 lane scenario offered more future development options and greater safety than the adaptive lane scenario: the reduced width did not allow HGV vehicles to travel on an adaptive auxiliary line on the right of the bridge, and the idea of having cars travelling to the right of HGV vehicles was detrimental to the safety objective; the idea of installing

equipment in a central reservation came up against the same problems, in that it would be detrimental to the safety of an adaptive lane on the left.

3.3.2. The chosen solution

The choice was to adopt a profile of 2x3 lanes without a hard shoulder on the Pont d'Aquitaine with a low central reservation wall; the cycle lanes would be moved to overhanging structures outside the deck.

Figure 3 - The future profile -Source SETRA

This solution tied in with the initial aims: 3-lane capacity would be re-established in both directions at rush hour, significantly improving traffic flows in the area and its access routes; the physical separation of traffic flows, which significantly improved safety levels since it was introduced in June 1999, would be installed once and for all[2].

The final aims of the chosen project were to:

- increase the bridge's capacity and improve traffic fluidity on the Bordeaux Ring Road;
- prevent the occurrence of incidents by adopting regulatory measures to control the speed and driving conditions of HGV vehicles;
- detect incidents as quickly as possible so that the required means could be implemented;
- manage incidents effectively with regard to the intervention of the emergency services, the protection of involved users and the protection of other vehicles.

The three lanes are 2.8m, 2.9m and 3.2m wide respectively, from left to right. In view of the extremely restrictive geometrical layout of the bridge, the new project required an exemption from the "Instruction concerning the technical conditions for the construction of urban expressways" (ICTAVRU) and extra technical, organisational and regulatory arrangements to maintain the required level of safety, and particularly to provide for the rapid intervention of the emergency services in the event of an incident and for the safety of users if a lane had to be closed.

The extra static and dynamic operating means included, in addition to remote surveillance equipment and emergency telephones (ET), an automatic incident detection system (AID) using cameras and image processing, a lane allocation display system (LAS), variable message panels (VMP) on certain slip roads and on the ring road section, a closure system for the ring road section, certain slip roads and cycle lanes and an automatic system for controlling and issuing fines to drivers travelling over the speed limit.

To operate the three traffic lanes, employee numbers had to be raised at the Interdepartmental Atlantic Roads Authority (DIR ATLANTIQUE) Traffic Information and Management Centre (CIGT), the bridge's managing authority, to ensure that an operator was on hand 24 hours a day.

The speed limit would be 70km/h between the North and South interchanges and HGV vehicles would be required to travel on the slow lane; obligation combined with a "no overtaking" rule covering an area that included the Pont d'Aquitaine and some of its access routes.

The 2x3-lane operating method also required works to widen the access viaduct on the left bank of the Garonne and the road section built on land. A Special Danger Study was carried out in October 2002 as part of the move to a 2x3-lane format on the section surrounding the Pont d'Aquitaine.

The final project also included setting up a monitoring committee representing all the groups involved (administration and central technical services, operators, emergency services, maintenance, etc.). It would be responsible for annually checking the correlation between the goal to be achieved and the resources placed at the operators' disposal. The evaluation should cover traffic conditions and also the organisational and technical aspects. An analysis of any variances from the operating objectives should enable the monitoring committee to offer the contracting authority solutions for improving the system.

The works to renew the suspension systems took place under normal traffic conditions between 2000 and 2005. The cycle lanes were closed and replaced – under pressure from cycling associations – by a coach shuttle service between the two banks morning and evening. Work to widen the road section between the interchanges, to the north of the bridge, started at the same time.

At the end of December 2005, the new operating system went through a transitional period in which the 3 traffic lanes were used only during the rush hours, for in-bound traffic in the morning and outbound traffic in the evening. Full 3-lane operation was officially introduced on 20 March 20 mars 2006.

4. EX-POST EVAUATION

In 2003, the DIR Atlantique asked a technical service of Transport Ministry: CETE du Sud-Ouest (CETE SO), to carry out a global evaluation, the aims of which were to analyse changes in traffic conditions, quantify the impact of operating measures on congestion, alert times and the time taken to bring the police and emergency services into action, medium-term accident statistics, measure the level of user compliance with regulations, analyse – from a qualitative standpoint – the conditions under which the police and emergency services are brought into action and the consequences for users and, finally, assess acceptability and the satisfaction of users and the various groups involved (operators, police, emergency services, etc.).

4.1. Dynamic lane management description

The technical systems used include automatic speed control systems combined with speed limitation, a lane allocation system (LAS), a network of twenty-two automatic incident detection cameras (AID) with centralised management by POS software and an

emergency call network (ECN) linking 10 emergency telephones in each traffic direction, only one of which has protected access.
Although these systems are individually automatic, they are independent and the decision and means or arrangements for using them are the outcome of a decision by the operators of the traffic control centre (TCC). For example, if a vehicle breaks down in the right-hand lane, the AID system detects the stoppage on the camera covering the 200 m of the section concerned and records a 3-minute sequence before and after detection. The TCC control monitors receive an alarm: the screen for this camera is automatically displayed and framed in red. Having been alerted by the detection of the incident, the operators can also look at the standard surveillance cameras which have a much wider field than the AID cameras. The system does not automatically offer assistance in making the decision to use the LAS. If they think fit, the operators decide to use the LAS manually and set the location and geographical range. The decision to use the LAS following an incident may also occur after operators have observed images on the standard surveillance cameras, if the AID system malfunctions, breaks down or is simply delayed. As far as the ECN is concerned, the CRS receiving the call automatically knows its origin; the trace is recorded on a list but there is no automatic assistance in searching for a link with the images or in taking the decision to use the LAS.

Figure 4 - LAS and VMP- source DDT 33

Two operators are allocated to activating the information panels (panels with shutters and illuminated variable message panels). Each physical lane closure requires a team of 5 or 6 operators to implement safety procedures: coning and closing the different ring road access points at the access interchanges. This type of intervention on the lanes is very tricky as it must ensure the safety of both users and employees, and is often carried out at night.

4.2. Evaluation method

The evaluation method proposed was based on the classical principle of a “before / after” comparison with the establishment of a benchmark situation before any new operating systems are introduced. In addition, as the operating system was an evolving one that

would be introduced in several phases, it was decided, for the quantitative aspects, to define the most relevant quantitative indicators to measure and analyse periodically, after the achievement of each phase. For the qualitative aspects, the evaluation was based on exploiting the results of a survey of the people concerned.

4.3. The benchmark situation

It was established in December 2003 [3] and had four key aspects: the identification of congestion, and in particular the location and volume of traffic jams, an analysis of incidents and their effects on congestion, the results of an observation of HGV behaviour using video recordings from 3 surveillance cameras covering the Pont d'Aquitaine and the access viaduct on the Bordeaux side, and a statistical analysis of accidents involving physical injury over the period 1996-2002.

Despite the fact that many parts were prefabricated, the reduced number of lanes made traffic conditions worse throughout the time taken to complete the works. Traffic on the Pont d'Aquitaine fell by around 10% compared to 1996; from 2001, le AADT stabilised at around 85,000 vehicles per day. Some traffic migrated to the southern section of the ring road, where congestion increased significantly. Despite this change in user behaviour, the fall in the number of accidents observed in 1999 since the installation of the central divider was clearly halted when the works began; the accident rate returned to the levels reached in the 1996-1999 period. The volume of congestion on the 7 km section covering all the road sections and interchanges on either side of the bridge was extremely high. The viaduct giving access to the bridge was particularly saturated, concentrating nearly 90% of the total volume of the traffic jam during the evening rush hour in the direction leading out of Bordeaux and in the other direction during the morning rush hour.

In 2004, as the bridge renovation works were coming to an end, Bordeaux' drivers perceived the Pont d'Aquitaine area as being the traffic black spot on the ring road.

4.4. Ex-post evaluation results

The ex-post evaluation was carried out over the period 2006 to 2008. The analysis of the measurements that were taken took account of the disruption that was occurring when the benchmark situation was being drawn up. In October 2006, an initial document entitled "Intermediate evaluation report on traffic flows" analysed the traffic characteristics measurements taken over the short term after the 3-lane operation had been introduced in April and May 2006. A second document entitled "Intermediate evaluation report on the exploitation of user surveys", produced in January 2007, recorded the results of user surveys carried out in late 2006. The final report [4], delivered in May 2008 contained all the evaluation results relating to traffic conditions, the functioning of the AID, LAS and ET systems, incidents and how associated interventions were dealt with, and acceptability to users and operators. An evaluation of the impact of the new bridge operating method on energy consumption and environmental pollution was not carried out.

Figure 5 - View of the new bridge -source: Le Routard website

The ex-post evaluation highlighted the following points:

4.4.1. Impact on traffic conditions

The conversion of the Pont d'Aquitaine to 3 lanes increased the bridge's capacity by approximately 40 % and improved traffic conditions.
Observation of the data showed an increase in working day flows of around 7 % between October 2003 and March/April/May 2006, bringing average daily traffic (both directions) to approximately 100,000 vehicles per day. Despite a reduction in the width of the middle and left-hand lanes, the addition of a third traffic lane reduced the average capacity per lane by under 5%.
The overall increase in capacity allowed new users or users who previously used alternative routes to use the Pont d'Aquitaine. However, from 2006, the third lane was almost fully used, leaving little hope of finding any extra capacity. Between 2006 and 2008, annual average daily traffic remained stable.

Changes to the regulations brought changes to vehicle speeds and to the division of traffic. Nearly 80% of drivers stayed within the 70 km/h speed limit in the presence of the automatic control system, which was significantly higher than the figure obtained in the other direction, which was approximately 60%. HGV traffic stabilised obediently in the right-hand lane in the Bordeaux direction, whereas in the other direction at the start of the bridge, it remained dependent – particularly for semi-trailers – on how traffic flowed in from the interchange and on the change in width profile (change from 2 free-flowing lanes to 3 lanes on the bridge).

With flows virtually doubling on the bridge at rush hour, the sections that were previously saturated immediately prior to the bridge saw a significant reduction in average saturation and traffic jam times. In relative terms, saturation times fell by -70 % to -85 % and traffic jam times by–82 % à –96 %, depending on the stations. As in 2003 and in previous periods, traffic jams were concentrated in the out-bound direction outside Bordeaux during the evening rush hour and in the opposite direction during the morning rush hour, but the conversion to 3 lanes on the Pont d'Aquitaine changed the position and shape of the jams, particularly in the morning rush hour, due to saturation at the Bordeaux interchange exit.
Despite the appearance of traffic jams or an increase in their duration on the roads accessing the bridge, in 2006, excluding incidents and taking the number of lanes into consideration, the relative reduction in the volume of traffic jams in a 7 km area around the Pont d'Aquitaine was approximately 50 %.

A comparative measurement of incidents with the benchmark period and previous years has been difficult due to the fact that there have been changes to the methods and means used to detect incidents. However, the number of breakdowns involving the intervention of the breakdown services has appeared to be relatively stable. There is a high concentration of incidents (80%) on the upward section of the viaduct and bridge on the way out of Bordeaux.

4.4.2. Benefits due to the associated technical systems

During the first year of operation, there was a high rate of false detections on the automatic incident detection system (around 60 %), with rain and night-time creating very critical conditions from the point of view of reliability. It took almost a full year of operation to obtain acceptable results. In normal operation, the AID system proved effective in detecting incidents rapidly and automatically. In 2006, the average duration of these was 7 % lower (15 % for cars and vans) than in 2003.

The frequency of calls to the emergency call network is an average of one call every 2 days. The lack of a hard shoulder makes it difficult to access the ETs, as to use them means stopping the vehicle in the lane; over half of all calls are made from just 2 telephones (out of 22) which have a small refuge.

The lane allocation system (LAS), which consists of closing two lanes in the event of incidents (accidents or breakdowns) works well. During the first few months of operation, lane restrictions for incidents were almost always applied to the entire length of the bridge. Experience and increased traffic have led the operators to reduce the LAS activation areas and rapidly return traffic to 3 lanes downstream from the incident. Overall, 600 LAS activations occurred during the first year of operation, i.e. an average of 1.6 activations per day, with an average length of 42 minutes. Thereafter, the system was activated once a day on average for an average length of 27 minutes and 40 % of activations have not exceeded 10 minutes. Observations carried out in 2006 and 2007 showed reasonable compliance with the instructions issued by the LAS system. Whatever LAS arrangements are introduced, users move back into position quite routinely once they have got past the incident location. The lane allocation system makes up for the lack of a hard shoulder in dealing with incidents.

Intervention times “in situ” are down to approximately 10 minutes on average (36 %). In terms of incident duration or intervention times, the potential gain seems to be limited to a reduction in the time taken to become aware of the occurrence of an accident, which, thanks to AID, may be virtually immediate.

4.4.3. Acceptability

The survey, which took the form of a questionnaire with a pre-stamped envelope sent to 4,000 users of the Pont d’Aquitaine after approximately 6 months of operation in a 2x3-lane configuration, received over 1000 responses, which is a very high overall response rate for a questionnaire of this type.
86 % of users of the Pont d’Aquitaine felt that the new operating system was satisfactory or very satisfactory, although 40 % thought that it could be improved in terms of operation; only 10 % mentioned disadvantages relating to safety. Drivers of light vehicles appreciated the reduction in traffic jams and the fact that HGV vehicles were restricted to the right-hand lane. Grievances concerned the 70 km/h speed limit (34 %), the deterioration in traffic conditions at the bridge approach sections, difficulties in pulling over into the right-hand lane (17 %) and the consequences of dealing with incidents (13 %). HGV drivers saw the

“no overtaking” restriction more as an aid to driving comfort (32 %) than as a loss of time (12 %). The level of appreciation of the LAS was quite low: half of users thought it was comprehensible and clear and a third thought it was effective in terms of the safety of the people involved in the incident, but only a quarter thought that users followed the instructions.

When questioned face to face, the operators and other intervening groups felt overall that there had been an improvement in their working conditions compared to the previous situation. Lane closures using LAS are deemed to be an acceptable compensation in terms of safety for the absence of a hard shoulder. However, they feel that this type of organisation should be restricted to short sections and should not be transferred to more geographically extended sections.

In 2009 and 2010, managers undertook further works to maximise safety for users and intervening groups during bridge maintenance and servicing operations.

5. INVESTMENT COSTS

The work to replace the Pont d'Aquitaine suspension system cost 55 million euros. It was totally financed by the State – Ministry of Transport. The work to convert the ring road to 2x3 lanes cost 29 million euros, including 20 million for widening the access viaduct. It was financed under the State-Region planning contract with contributions divided as follows: 27.5 % Government, 27.5 % Aquitaine Regional Council, 22.5 % Gironde Departmental Council and 22.5% Bordeaux Urban Community Council.

The maintenance costs are not known.

CONCLUSION

Dynamic road management is one of the responses to managers’ aims of running existing infrastructures more efficiently [5].

The example of the various methods used to operate the Pont d'Aquitaine that have been tested since the 80s to meet increasing traffic demands while maintaining an acceptable level of safety shows, to an extent, the limitations of this strategy. It demonstrates that certain solutions cannot be considered for technical or geometric reasons, such as a structure of insufficient width. However, by incorporating the concept of dynamic lane management into the design or restructuring phase, its future introduction can be optimised or, at least, can help to minimise operating constraints.

In 2010, the Pont d’Aquitaine is still being run according to the 2x3- lane system with no hard shoulder. Considering its popularity with drivers and professional users, the clearly positive impact on traffic conditions remains the predominant advantage of the solution chosen by managers in 2003. The systems (lane allocation system, automatic incident detection system) associated with this operating method and the organisation that has been introduced appear to be an appropriate compensation for the lack of a hard shoulder in terms of safety and traffic management. In 2010, the “DIR Atlantique” decided to replace the system analysers and man-machine interface (MMI).

However, the operating method currently in use on the Pont d'Aquitaine concerns a very local geographical area and provides a response to a very local issue. The possibility of transferring it to other sites would seem to be limited to short sections of road.

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