Right timing: unseen delays and stocks in implementation of transport systems

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Abstract

Increasing travel demand and motorization rates pose challenges to city planners to design successful transport systems that offer enough coverage and service quality for citizens. These challenges are even more dramatic in developing countries due to poor conditions of their transport systems in terms of transport supply, service and infrastructure quality and accessibility. To respond to this challenge city planners design new transport systems that can improve urban mobility conditions. Nevertheless, implementing new transport systems requires design, infrastructure modifications and teaching the population how to use the new system. In this paper we use small system dynamics models to show that these elements involve delays that produce accumulations that can generate negative consequences on the success of the transport system that is implemented. One of these consequences may affect user satisfaction which can be understood as an accumulation of users' experiences on the transport system. Interaction among these delays and stocks, and the absence of planning and coordination that takes into account these elements may produce congestion and low transport system users' satisfaction. Combating inertia produced by a low level of satisfaction may turn into a difficult and long run task compromising the success of a new transport system. We use the cases of Bogota, Colombia and Santiago, Chile to illustrate the consequences of ignoring these elements in the process of implementing a new transport system.

Key words: System dynamics, delays, accumulations, inertia, urban mobility, transport systems

I. Introduction

With a rapidly increasing population, cities around the world face challenges to secure an acceptable, if not higher, quality of life for its citizens. Among the different aspects that determine quality of life is urban mobility (Alcaldía Mayor de Bogotá y Secretaría de Tránsito y Transporte, 2006). As populations increase, economies and the demand for travelling abroad or within a city grow. Furthermore, motorization rates grow as well in response to growing economies (Corporación Andina de Fomento, 2010). Particularly in developing countries, decision makers face an even greater challenge given that transport systems in their cities, if there are any, have not been planned or designed to accomplish a particular goal but, in turn, have evolved randomly according to the need of the population (Alcaldía Mayor de Bogotá y Secretaría de Tránsito y Transporte, 2006). Putchera (2005) identifies the following factors as part of the immobility problem particularly in large cities of developing countries: limited and poor quality of the road network; rapidly increasing ownership and use of private cars and motorcycles; inadequate roadway accommodations for buses and non-motorized transport; extremely high and rapidly rising traffic fatalities, inefficient, unreliable and poor quality public transport; extremely high levels of transport-related pollution, noise and other environmental impacts. This situation poses a challenge to decision makers to design and implement successfully transport systems that can respond to a growing travelling demand and that can alleviate the traffic congestion generated by constantly increasing populations and motorization rates in addition to taking care of other problematic factors such as those identified by Putchera (2005). Moreover, this challenge is complex because it involves different types of stakeholders that may have different interests and perspectives about the system (Corporación Andina de Fomento, 2010).

Implementing a new transport system requires adequate planning and design especially in developing countries given the poor quality of infrastructure used for transportation, infrastructure construction can greatly improve urban mobility conditions within a city; however, they also take time to be accomplished and while they are under construction they can affect negatively urban congestion levels. In addition, implementation of a new transport system requires planning, design and execution, all of which take time. Furthermore, the population requires time to learn how to use the new transport system in order to be able to access it and use it appropriately. These delays, if ignored, can bring negative consequences in terms of efficiency costs and user satisfaction. The latter can largely determine the success of a transport system (Hidalgo & Graftieaux, 2007). User satisfaction is a product of the accumulation of users' experiences with the transport system and hence, can generate an inertia that, when negative, can be very difficult to overcome. In this paper we explain each of the four concepts previously mentioned: delays in infrastructure construction, delays in population learning, delays in implementation of transport systems, and user satisfaction as an accumulation of user experiences. We use stock and flow diagrams and the cases of Bogota, Colombia and Santiago, Chile to illustrate these concepts. Finally we underline several elements that we identified with the use of system dynamics models that could and should be taken into account when implementing a new transport system.

II. Context: the cases of Bogota, Colombia and Santiago, Chile

Bogotá: Transmilenio and SITP

Bogota is a city with 7 million habitants that has grown significantly in the past years due to its economic growth. Considering the economic growth, transport demand has also increased without a public supply that can support those needs of transportation. The use of private vehicles in Bogota is one of the main concerns for the city: by 2011, 92% of the vehicles in the city were private vehicles (cars and motorcycles) and 7% were public transport vehicles (Alcaldía Mayor de Bogotá, 2011). This dramatic disproportion of public versus private vehicles generates an urban congestion problem that aggravates each year with new private vehicles entering the system; for example, in 2011 the average speed within the city was 23,27 km/hr. High use of private vehicles can be explained, in part, with the general discontent among citizens with the service that the public transport system offers in terms of quality, coverage and security. The city has approximately 14.000 km of road network but according to Bogota's Mayor's Office (Alcaldía Mayor de Bogotá, 2011) 51% of these were in poor condition, 20% were in moderate condition and only 29% were in good conditions. The conditions of the road network in Bogota has had a negative impact in urban mobility and hence pose a need for the construction of infrastructure that supports the public transport systems that should be implemented to alleviate the mobility problems.

Public transport in Bogota has evolved in a disorganized manner with very little planning and design. However, in 2000 a new and innovative Bus Rapid Transit (BRT) system *Transmilenio* was implemented and functioned parallel to the traditional public transport system (buses). In order to implement this system, several infrastructure construction, including modifications to the existing road network, were necessary. Even today, more and more constructions have been carried out to allow the expansion of this system. According to CAF-Development Bank of Latin America (2010) this system has proven to be effective because by 2008 *Transmilenio* transported 1.5 million passengers per day with an average speed of 28 km/hr, which can be compared to the productivity of the majority of metro lines in the world. However, the capacity of the system has become limited and is not enough for the increasing public transport demand, which is why the city is now implementing a new transport system that integrates Transmilenio with other transport modes, called *SITP*. The *Integrated Public Transport System* (SITP) is a new transport system that aims to integrate the different modes of public transportation that exist in Bogota, designed mainly to increase transport system coverage and integrate transport fares. SITP faces two mayor challenges: discouraging use of private vehicles and achieving a greater coverage of public transport. The implementation of this system has been gradual; and as new SITP buses have been introduced in the city some users have started to use it. Nevertheless, many of the buses are underutilized because the majority of the citizens still do not know how to use the system and has not been integrated with Transmilenio yet. Furthermore, the city's road network is in poor quality conditions and hence, implementing the SITP system requires infrastructure construction such as the building of stations, road signs, new and improved road networks and bus stops. Infrastructure construction however, both for the implementation of SITP and

Transmilenio, have generated serious congestion problems for the city while they are being carried out as several of the main streets have been closed or blocked by construction sites.

Santiago: Transantiago

The situation in Santiago was not different from the situation in Bogota as it also presented a significant economic growth in the last decade. "As in many other cities such economic growth has resulted not only in more trips, but also in an increment in the share of these trips taken by car. Indeed, the car modal split rose from 18.5% to 38.1%, meaning that the number of car trips grew 250% in 10 years. Bus and Metro trips, on the other hand rose only slightly, their combined modal split shrinking from 68.1% to 49.5%." (Muñoz & Gschwender, 2008). Muñoz and Gschwender mention that the decrease in the public transport share of the market was not only associated with economic growth but also with a deficient level of service of the traditional bus system. Some of the problems that could be observed in the transport system in Santiago were related to agency problems because different stakeholders were interacting and making decisions that could bring the greatest profits for them.

Because of the problems that the transport system had, the government was interested in implementing a new system that could increase the transport modal split in the city, taking into account that it should be modern and provide a high quality of service (Muñoz & Gschwender, 2008). *Transantiago* was designed as a network in which the metro would function as the backbone and the other services would be articulated to it, offering a unified tariff in order to allow users to have access to the all the transport modes available. The implementation process was initially planned to be gradual, however this did not happen and instead the system started working from one day to another. The only achievement was that new operators began offering the old routes and by the day in which the system began functioning (called Big Bang) several problems were encountered: the payment system was not operating or integrated throughout the whole system, some periphery areas were left unattended, there was a significant decrease in the number of buses and their frequency, and finally there was an increase in the number of metro passengers (Gómez-Lobo, 2007). These problems generated low user satisfaction with the system and eventually caused people to be reluctant to use it. Many of these problems were solved since the day of the implementation (2007) and the quality of the service has increased after a significant effort from the government, however, the initial low user satisfaction has been difficult to overcome.

III. Unseen delays

In the cases presented in the preceding section decision makers failed to consider at least one of the delays (infrastructure construction, learning and implementation) in the implementation process. In the following sections we will explain the delays, explore their possible consequences on behavior and illustrate these using the cases of Bogota and Santiago.

i. Consequences of the unseen

As Sterman (1992) underlines, “there are multiple delays in carrying out programs (…) and such dynamic elements mean that the short run response of a system to a perturbation may differ from the long run response”. Implementing a program, or in this case a transportation system, is not immediate and therefore decision makers should not expect immediate results. Part of recognizing the impossibility of obtaining immediate results is recognizing the delays that are involved in the process as well as identifying their possible consequences on behavior. Along the process, delays produce stocks that can generate behaviors that are different from the effect that the new transportation system is expected to produce. These behaviors should be taken into account in decision makers’ implementation plans, given that they alter the system and in the end may alter the final result. For example, if during the implementation of a transport system users suffer negative consequences they may later respond negatively to the system even once it is completely implemented; first impressions count.

Including delays in implementation plans is usually done by decision makers. However, we state that including them successfully requires understanding their possible consequences in behavior and hence coordinating their occurrence in time so that their effects are not as negative as they can be. This is not an easy task, in part because many of the delays that occur in the implementation process are not planned and usually correspond to decisions that are not in the decision makers’ domain of control. This situation adds difficulty to the planning process as decision makers do not have complete control over the implementation process and will not be able to avoid some of the effects produced by delay stocks. This is why we consider important to call for decision makers’ attention towards the importance of considering delays in implementation plans and understanding their possible consequences for a more successful implementation.

ii. Infrastructure construction delays

Implementing a new transport system generally requires infrastructure constructions, including modifications to the existing infrastructure. Once these constructions are finished, the system can function adequately and traffic conditions can become better, at least in the short term (Rhoads & Shorgen, 2006). However, infrastructure construction takes time to be fully executed; that is, there is a delay that generates the accumulation of infrastructure that is under construction. This accumulation can bring about traffic complications such as bottlenecks that could act as barriers for the adequate functioning of the new transport system (Vickrey, 1969).

The model in Figure 1 illustrates this concept. There are two stocks: *infrastructure* contains infrastructure that has been already built and is ready to be used; *infrastructure under construction* contains infrastructure that is being developed. There is a delay on the *finished construction* flow that incorporates the time taken to build infrastructure. The *infrastructure under construction* stock grows with the new infrastructure projects that arise with the implementation of the transport system and empties gradually as construction is finished. While the stock of *infrastructure* alleviates congestion, the stock that is generated by the construction delay aggravates this problem. One thing to note is that when the *start of infrastructure construction* inflow is larger than or increases at a higher pace than the *finished construction* outflow, the *infrastructure under construction* stock grows generating more congestion. Deterioration of the already built infrastructure is not taken into account in this model given that it is not part of an implementation process however this deterioration can also lead to congestion problems if it is no attended promptly.

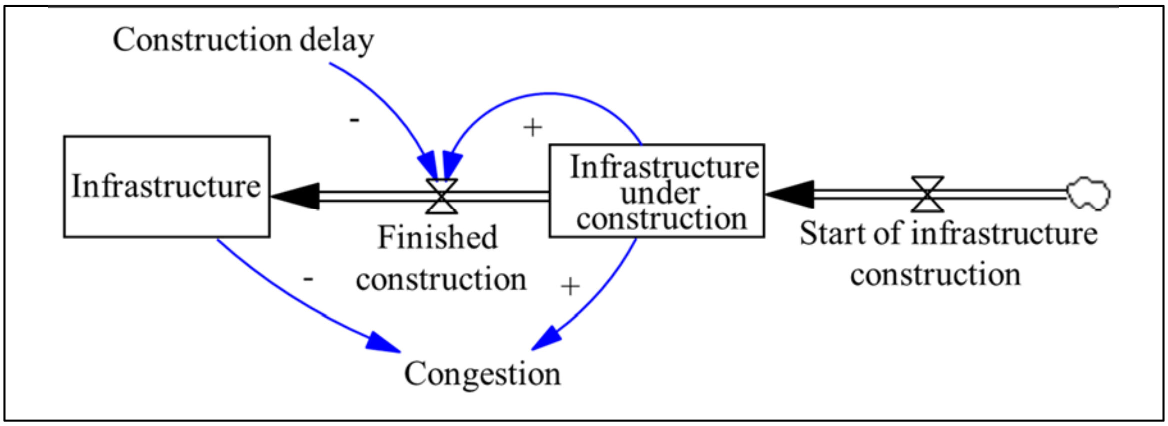

Figure 1 Stock and flow diagram for infrastructure construction

Figure 2 illustrates a possible behavior[1] of this system in terms of the consequences of the construction delay. As shown, infrastructure under construction increases gradually as more infrastructure construction is initiated. We assume that initially there are more infrastructure constructions and in time they are less until all required constructions are completed. As the stock of infrastructure under construction grows, congestion increases rapidly. The stock of infrastructure grows slowly as construction is finished; this illustrates the fact that infrastructure construction is not immediate and that the stock generated by this delay produces the opposite (congestion) of what is expected: congestion improvement. Congestion rises initially and then slowly diminishes; the positive effect of the finished infrastructure is noticed only after a long period of time.

[1] The behavior shown in this figure as well as those shown for the other graphs (figures 4, 6 and 8) are not based on real data, instead we use hypothetical examples to illustrate what the structure of each subsystem could produce.

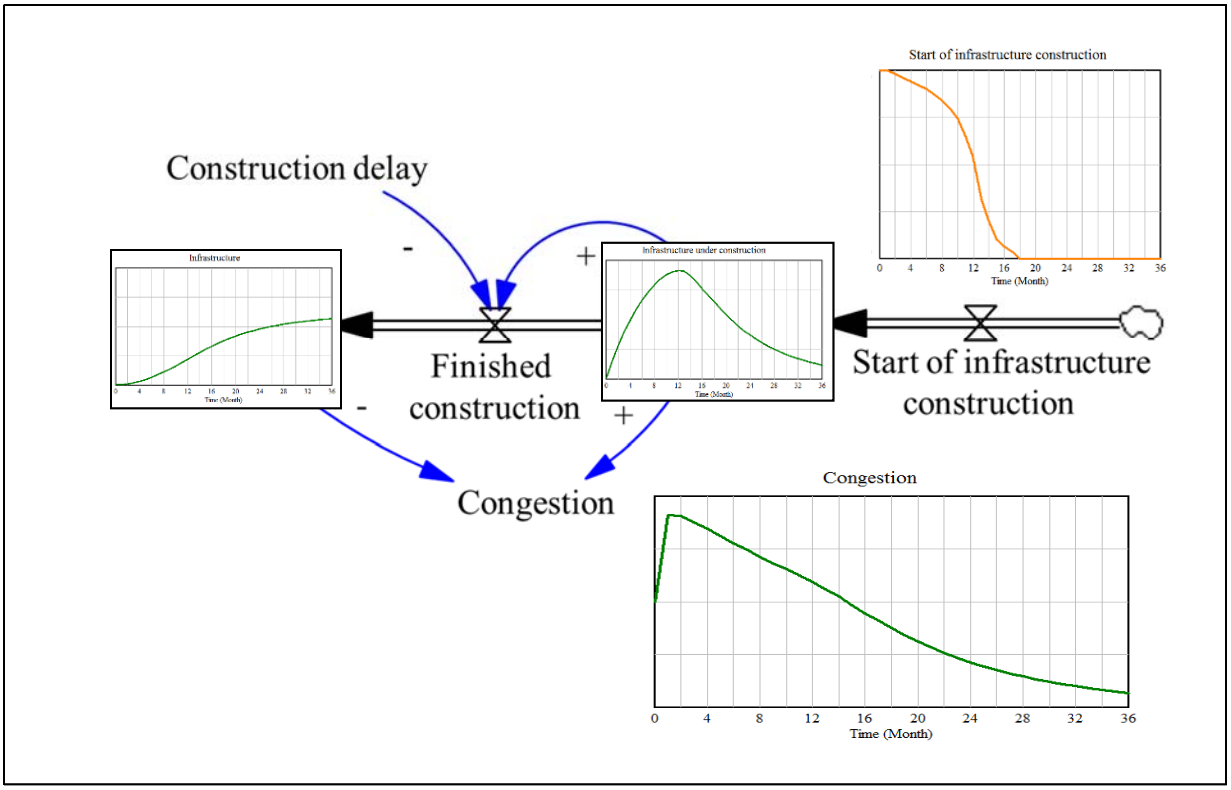

Figure 2 Behavior of stock and flow model for infrastructure construction

Decision makers usually take into account the benefits of the new built infrastructure but forget the delays in process of building it. As illustrated in figures 1 and 2, ignoring these delays can generate congestion on a short term. Moreover, infrastructure transformations take place in several locations around the city and do not take the same time to be fully executed. Hence, a detailed planning of how to coordinate the infrastructure transformations is a necessary element to avoid collapse of urban mobility within a city.

One example that illustrates the possible consequences of the construction delay is the transformation of the transportation system in Bogotá. Bogotá has undergone a process of transformation of its transportation system. Among other problems such as the quality of the public transport system service, the city has an insufficient road network. This network has grown at a very slow pace and is in very poor conditions. As a result, local authorities have invested in infrastructure construction to improve urban mobility conditions. In addition, the implementation of a new transportation system, the integrated transport system (SITP) requires several transformations of the existing road network. Such transformations have generated accumulations of roads under construction and reconstruction that, in turn, have aggravated the problem of traffic congestion in the city.

iii. Learning delays

New transport systems require people to learn how to use them in order to access the system and use it appropriately. As Hidalgo and Graftieaux (2007) mention, this learning process may take some time in order for a citizen to fully learn how the system works and interact with it in the way that is expected. In spite of information given to citizens about the operation of a new transport system, at the time of implementation few people know how to use it and it takes some time for all the population to get to learn how the system works. These dynamics are shown in figures 3 and 4.

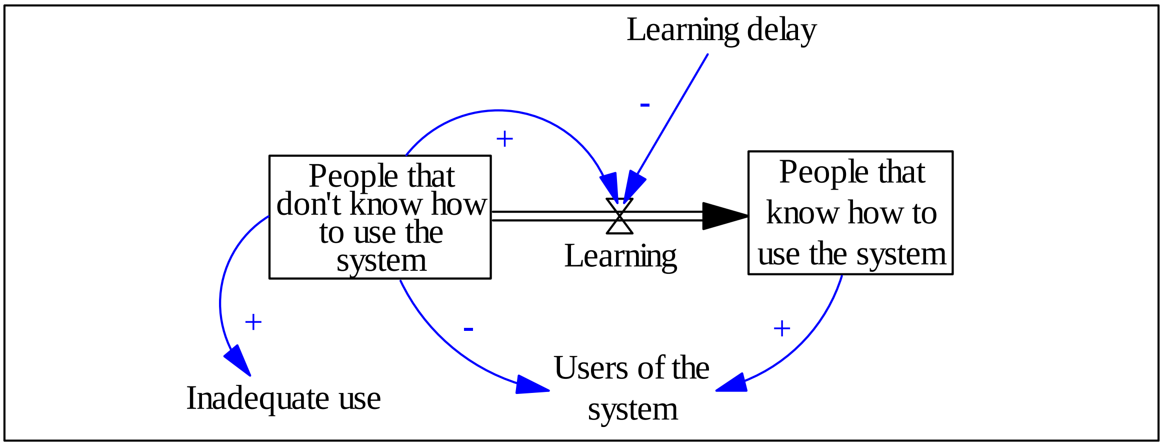

Figure 3 Learning how the transport system works, generic stock and flow structure

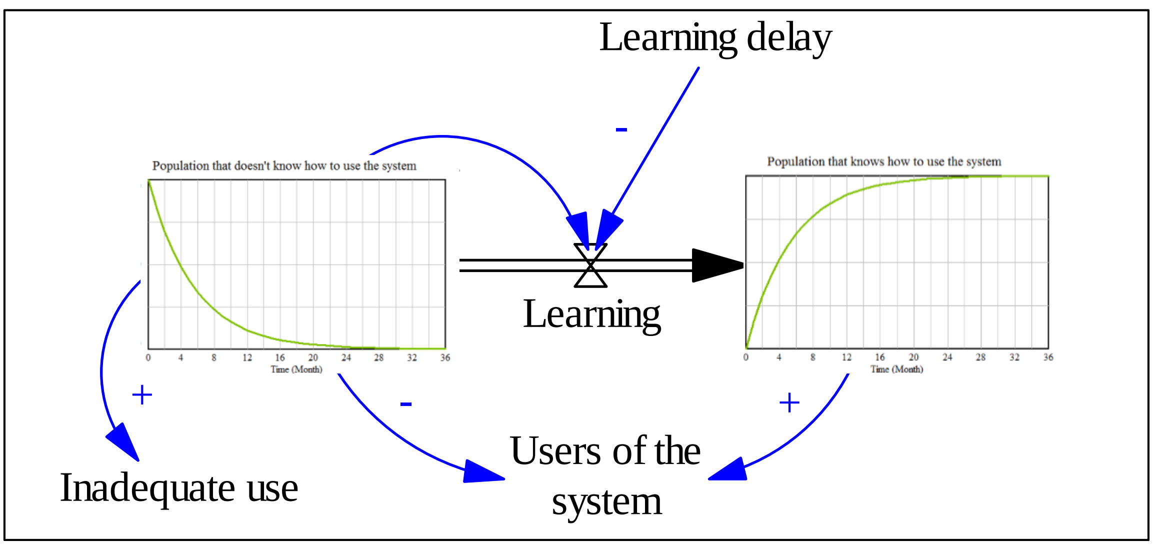

Figure 4 Learning how the transport system works - Behavior

Figure 4 illustrates how the population learns gradually how to use the system. As more people learn how to use it, more people can use the system; however, this is a gradual process given the existence of the learning delay. This delay is due to the government's capacity to diffuse information about how the system works and the time it takes for the population to learn and interact with the system. Similar to the infrastructure transformation delay, a population that knows how to use a new transportation system is not immediately produced and hence will not generate immediate results; instead, during the learning process people who do not know how to use the new transportation system are possibly going to use it inadequately if they use the system at all. While part of this delay can be controlled by decision makers, given that they can coordinate when and for how long should they diffuse information, the learning delay should be taken into account in their implementation plans allowing for some extra time to allow the learning process of the population.

The learning process influences the quantity of users that the new implemented system will have because if people do not understand how the system works, they probably will not use the transportation system. If this process takes too long and there are not enough users of the system, efficiency costs will be significantly high thanks to an under-utilization of the system´s infrastructure (Hidalgo & Graftieaux, 2007). On the other hand if by any chance people that do not know how to use the system begin to use it, they will most likely use it inadequately, which will bring negative side effects such as a careless use of infrastructure and decrease users' satisfaction consequently producing less users.

Transantiago is an example of an implementation process that ignored this delay. When the system was implemented, Santiago's citizens did not understand how the system worked as well as the bus routes and hence people overflowed the already known metro system. In fact, the day of the inauguration of the system, the metro system reached occupancy factors of about 6 passengers/m2 (Muñoz & Gschwender, 2008). Furthermore, Muñoz and Gschwender (2008) write that to date, "… the government, city residents and especially the users of the system are far from convinced of its benefits. Indeed, many "Santiaguinos" consider it to be a complete failure". Experts that participated in the planning process remark some of the mistakes in the project's implementation were the almost inexistent public participation and the sudden implementation of the system from one day to another (Muñoz & Gschwender, 2008). Transantiago´s case leaves many lessons among which is the need to consider that the population getting acquainted with the system takes some time (Hidalgo & Graftieaux, 2007).

iv. Implementation delays

We refer to implementation of a new transport system as the installation and start-up of the system. This installation and start-up take time. The implementation must meet some efficiency and effectiveness criteria especially because it involves the use of public resources. This situation can be illustrated through a stock and flow diagram (Figure 5). For illustrating purposes, implementation can be measured in a numeric scale where 0 means the system has not been implemented and 100 means the system has been fully implemented. Implementation can then be a stock that gradually grows as the transport system is implemented. Given that the system needs to be designed and planned and hence requires a time to be implemented, a *system to be implemented* stock is generated. The transportation system will not be entirely effective until it is fully implemented (Figure 6).

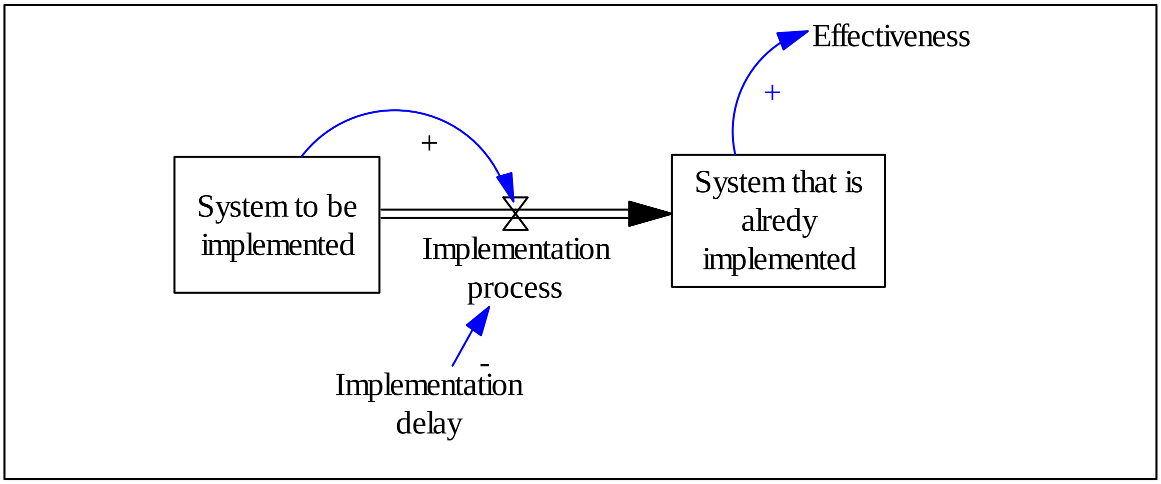

Figure 5 Generic stock and flow structure for transport system implementation

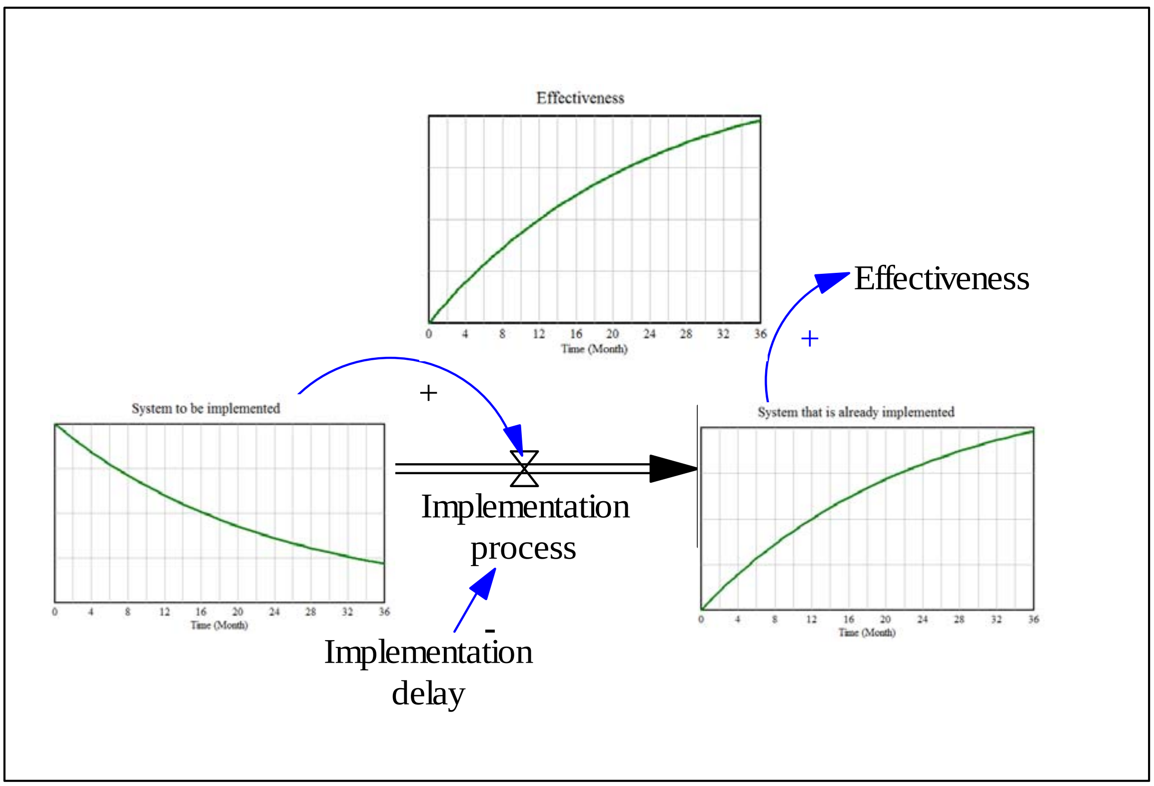

Figure 6 Transport system implementation behavior

While the stock generated by the implementation delay does not bring about negative effects, it does delay achieving effectiveness. Hence implementation delays should be considered in the planning process and time should be allowed before decision makers expect full system effectiveness.

The case of Bogota serves as an example of gradual implementation and gradual achievement of effectiveness. As part of the implementation of a new integrated transit system in Bogota, buses have been gradually introduced in the system; that is, only some of the buses that will be part of the system have started to circulate in the city and periodically more and more buses are being introduced in the system. According to data collected by transport authorities, in its first 80 days of functioning there were 19 passengers on average per day for each bus. According to Bogota´s finance manager Ricardo Bonilla, this underutilization of the system has led to a loss of 1.000 million pesos (600.000 USD) per week since the collection is not enough to cover the operating costs (Caracol Radio, 2012). In this case the problem might not be the implementation delay itself but the need to coordinate it with the learning delay; parallel to the buses being introduced in the system, people should be taught how to use it so that the system is not underutilized.

IV. Satisfaction inertia : the unseen stock

Satisfaction (or dissatisfaction) of users of a transport system can be understood as a product of users' experience with the system. Hence, satisfaction is built over time and can be considered as a stock that changes over time according to new users' experiences. Even though this satisfaction level depends on specific events in a person´s daily life, it also takes into account past experience whence it should not be considered as something that changes instantaneously (see Figure 7).

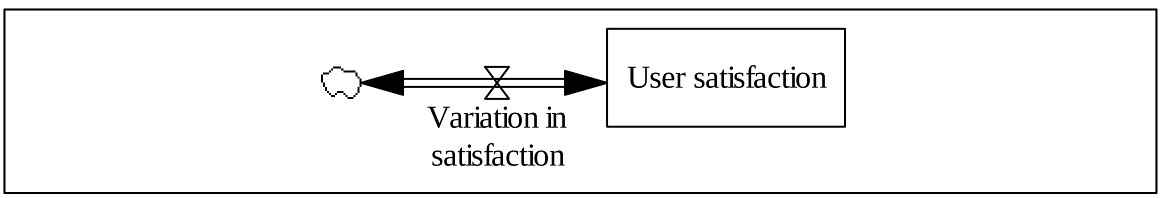

Figure 7 Stock and flow structure for user satisfaction

Considering user satisfaction with the system as a stock implies that there is an inertia that cannot be changed instantaneously. If people are unsatisfied with the transport system it is most likely that they do not use the system or do not use it correctly which will bring more dissatisfaction, implying that government's effort to revert these effects should be significant (Hidalgo & Graftieaux, 2007). The level of satisfaction, then, not only gives information about the past (memory) but it also determines the future dynamics in the system (Sterman J. , 2000). The accumulation of user satisfaction highlights the importance of the quality of users' first experiences with the system. Negative experiences, such as the one in Transantiago's case, generate a negative inertia difficulty and timely to revert; likewise, positive experiences will produce a positive inertia that can eventually tolerate some negative experiences without lessening user satisfaction in great amounts. (Hidalgo & Graftieaux, 2007)

Figure 8 illustrates two hypothetical examples of how user satisfaction inertia could behave. In example A, quality of users' experiences is negative and hence produces negative user satisfaction. In month 20 user satisfaction reaches its lowest level even though the quality of users' experiences has been improving over the last ten months. Moreover, the quality becomes positive on month 20, however the user satisfaction level becomes positive only until the inertia of the initial negative experiences is overcome, 30 months after quality of users' experience has been positive. Similarly in example B, the initial experiences with the system are of positive quality and hence the level of user satisfaction increases during the first 20 months; nevertheless, the quality has been dropping since month 10. The positive inertia of user satisfaction impedes this stock from decreasing instantaneously; even though the quality of users' experiences becomes negative from month 20, user satisfaction only becomes negative almost 30 months afterwards.

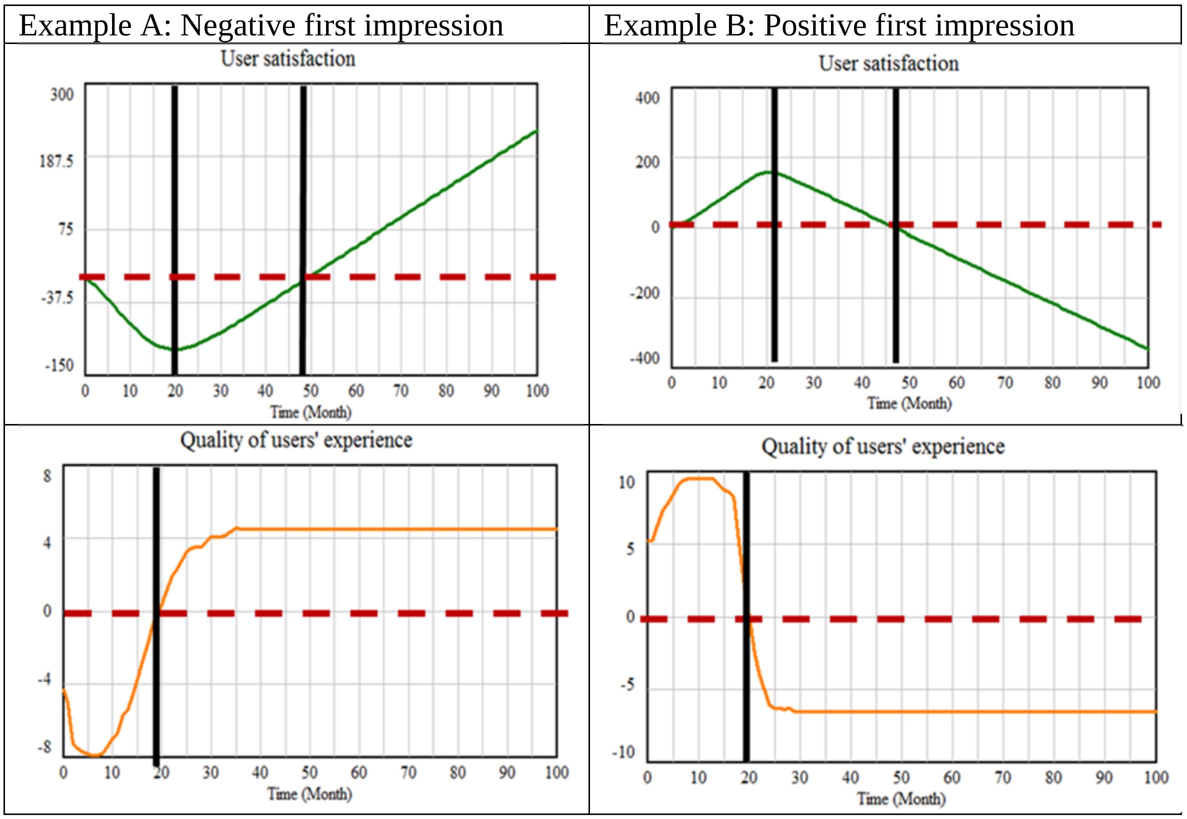

Figure 8 Examples of behavior of user satisfaction

Interaction between delays and satisfaction inertia

In the case of Transantiago, ignoring of the learning delay provoked a general dissatisfaction that led to a complete rejection of the transport system and an eminent failure of its implementation. This inertia caused by low satisfaction levels, turned out to be a burden for the local government as it had to invest a significant amount of money in information campaigns in order to let the population learn how the system works and to change users' satisfaction. It is evident that the unseen interaction of the learning delay with the inertia generated by user satisfaction represented great costs for Santiago´s government.

V. Transport system implementation as a system

Implementing a transport system is a complex process whose complexity arises not only from the magnitude of the project but as well of the different elements that have to be considered in the process and that interact with each other. We have identified some of these elements and have discussed their possible consequences. In this section we suggest that the implementation process should be considered as a system (Figure 9). Each of the delays we have identified are interrelated and interact with the stock of user satisfaction. Considered separately, each of these has its own complexity as has been discussed in the previous sections; however, complexity is greatly increased when all of these elements are combined. Learning delays, implementation delays, infrastructure delays and satisfaction inertia interact and produce a dynamic behavior. As shown in the conceptual model in Figure 9, we believe effectiveness of the system will be a product of the system's structure and hence it becomes necessary to consider these elements in a systemic manner in order to achieve better results.

In section III we discussed the consequences of each delay considered separately. However, the interaction among these delays may eventually produce counterintuitive behaviors in addition to their individual consequences. As a result, we underline that coordination of such delays is also necessary to avoid or at least minimize negative effects on behavior. To aid this coordination, planners could use systemic dynamics models in order to explore possible behaviors under different delay times and eventually consider distinct possibilities of delay coordination.

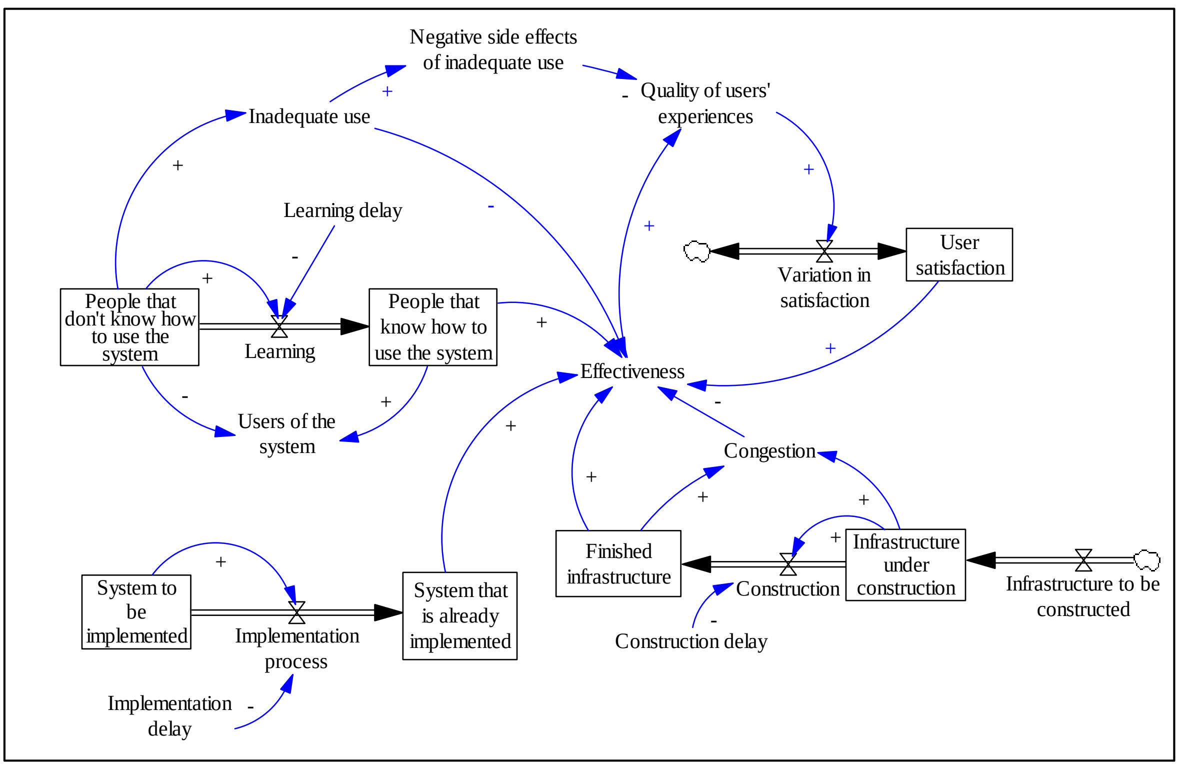

Figure 9 Transport system implementation as a system

VI. Outlook

In this paper we have identified three delays that are typically involved in the process of implementing a transport system. These delays generate stocks that affect urban mobility and the effectiveness of the transportation system that is being implemented (see Figure 10). To avoid or at least minimize unwanted behaviors, planners should recognize the existence of these delays and also identify their possible consequences.

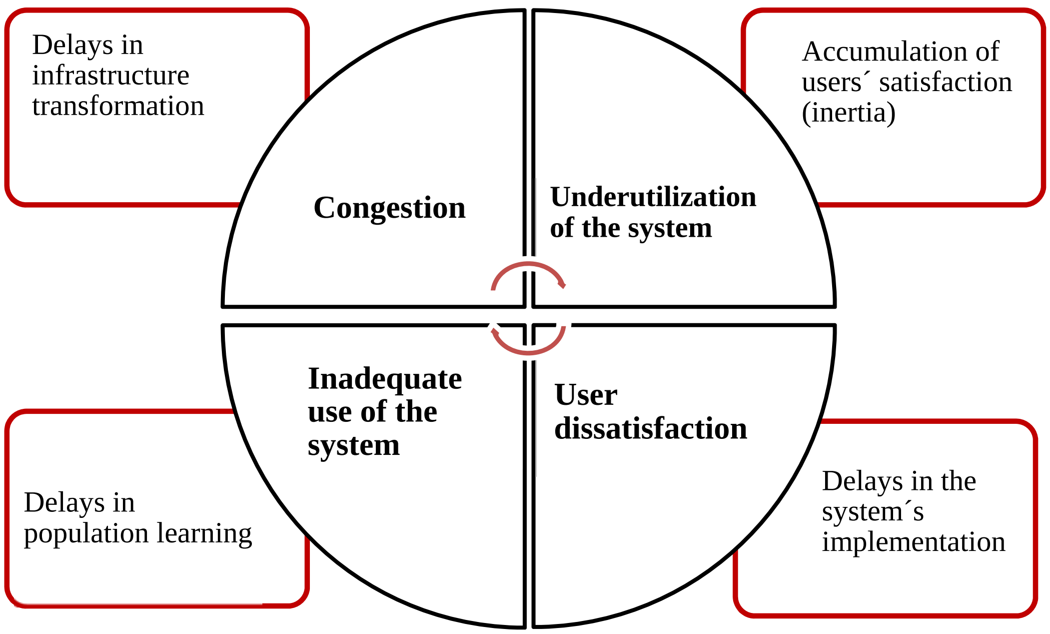

Figure 10 Consequences of unseen delays and stocks

The implementation of a transport system should be considered as a system, and delays and the stocks generated should be considered as part of this system. These should be tackled in a coordinated and systemic manner. Unsuccessful coordination can generate costs in terms of sub-utilization (lack of coordination between learning and implementation delays) and congestion while infrastructure is built. The overall performance of the new transport system, including the congestion that can arise from the delays mentioned above can negatively affect user satisfaction. User satisfaction as an accumulation of user experience has a historical behavior, which means that if negative, has an inertia that can dramatically affect the success of the transport system.

Finally, understanding these concepts and the transport system implementation process from a system dynamics perspective evidences the importance of considering delays and stocks in implementation planning. This perspective also allows decision makers to understand the need and the challenge that is coordinating delays and stocks in a transport system implementation process in a timely manner. Moreover, the use of simulation models is a tool that can aid coordination and implementation planning.

VII. Future developments

The discussion presented in this paper is part of a work in progress. Future developments include characterizing the implementation of transport systems in the cases of Bogotá and Santiago and building a simulation model for each of these cases. Eventually we would like to compare systems' effectiveness and user satisfaction in each of the systems.

VIII. Acknowledgments

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