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Adopting a systems approach to the analysis of a contemporary civil engineering project: Thameslink Programme, London

For 19th Century engineers, the Earth was a source of resources and a receptor for waste. In the 21st Century, the negative impacts of the work of civil engineers are, however, coming to the fore. The increasing consideration of impacts and their causes, as opposed to simply meeting demand, has forced civil engineers in to taking a systems approach; one where technological systems are considered alongside human systems to create considered, sustainable civil engineering solutions (Hall & O'Connell, 2007).

Defined as interconnected sets of elements organized in a way that achieve something (Meadows 2008) , systems can be used in civil engineering to consider the conceptual building blocks of a project and their effect not just on one another but beyond the project's physical and technical boundaries too. Whether it is simple (few elements, considering a single purpose) or complex (many elements, considering multiple demands and aims), systems analysis can provide clarity to the purpose and impacts of engineering projects.

This document charters the significance of a systems led approach to civil engineering, by considering and analyzing one of Network Rail's current projects, the Thameslink Programme.

The Thameslink Programme is a scheme to improve and expand the existing Thameslink rail network running through London, linking Bedford and Brighton. Still underway and worth £6 billion (First Capital Connect Ltd. 2010), the project plans to extend the service from 50 to 150 stations. Its capacity throughout the central London section will be increased, thereby easing overcrowding. The complex scheme includes increasing rolling stock, lengthening platforms and station refurbishments.

The main aim of the project is to address overcrowding on the Thameslink and other London commuter services (DfT 2005a), for example the London Underground. It also aims to accommodate for the introduction of new cross-London services to improve public transport accessibility in areas of expected demand growth, such as the London Bridge area, Docklands, King's Cross/St Pancras and London's airports (DfT 2005a). Wider aims, as seen by the end user, are to expand the network and increase its passenger capacity (Whitelaw 2010) therefore improving the quality and efficiency of passenger journeys across areas of South-East England.

From the viewpoint of an engineer, the targets would be to design and construct the individual components of the scheme to successfully achieve the client's aims with consideration of any possible wider impacts. A crucial engineering aim is to lengthen platforms at all stations on the Thameslink service (Whitelaw 2010) to accommodate longer trains to increase passenger capacity. Secondly, engineers need to upgrade existing rail routes to extend the service to more stations (Alexander 2002). In addition, Blackfriars station will be reconstructed while Farringdon and London Bridge stations need to be redesigned and remodeled (Alexander 2002) with new ticket halls and entrances to improve their access.

This is a particularly intricate project given its technological complexity, economic and social importance, interaction with other public transport schemes, and the size and diversity of the demands on the project (Harms *et al.* 2004). By analyzing this project as a system of combined individual elements, however, one can observe how these influence each other, affect the common goal they strive to deliver, and, crucially, afford clarity and perspective to the civil engineer.

History and Legislation

After the initial, 50-station Thameslink rail network was launched in 1988 it quickly became congested resulting in severe peak time overcrowding by 2001. Proposals to upgrade the service were originally submitted in November 1997 under sections 1 and 3 of the Transport and Works Act 1992 (Butcher 2010). Following extensive public consultation, with local authorities, residential and commercial property owners and statutory undertakers, a revised order was submitted in September 1999. This included amendments such as a better mainline/underground interchange at Blackfriars, improved station facilities at Farringdon and increased capacity at London Bridge (Croydon Council 2009).

These applications were reviewed at the first of two public enquiries in June 2000 (Croydon Council 2009). In 2002 an independent inspector, Mr. David Ward reported Thameslink would provide 'substantial public travel and economic benefits to London' (Butcher 2010). Three deficiencies were also highlighted (DfT 2005b): poor quality proposals for the redevelopment of London Bridge station, lack of proposals for a resulting redundant space near Blackfriars and lack of proposals for the replacement of listed buildings at Borough Market. Subsequently, improved proposals were resubmitted along with an environmental impact assessment that also had to be conducted. These were discussed at a second public enquiry in September 2005 (Croydon Council 2009). The inspector published a second report in which he was satisfied with the changes and recommended approval for the project, which was granted in October 2006.

In order to make improvements, Thameslink required consent for the closure of some services. This had to be applied for in conjunction with the Railways Act 1993 (DfT 2005c). Planning permission also had to be applied for, for structures such as the Farringdon station roof extension and the reconstruction of Blackfriars station entrance, under the Town and Country Planning Act 1990 (DfT 2005c). Applications also had to be made corresponding the Planning (Listed Building and Conservation Areas) Act 1990 (DfT 2005c) to be able to remodel Farringdon Station and to demolish listed buildings at Borough Market.

Feasibility studies for conceptual designs of structures were conducted in the early planning stages. Three particularly congested sections, South Bermondsey, New Cross Gate and Borough Market were analyzed by consultant engineers Trevor Crocker & Partners. Complications of the project were acknowledged, including severe space constraints (Kumar 2002). This contributed to delays of the project that was originally going to be introduced by 2000. However construction finally commenced after overcoming these problems and when governmental funding was finally granted in 2007 (First Capital Connect Ltd. 2010).

Parties Involved

The client for Thameslink is Network Rail (Network Rail 2010). Due to the magnitude of the project, different components have been contracted out separately and have independent consultants.

Network Rail appointed Balfour Beatty as the contactor to redevelop Blackfriars station (Network Rail 2008). They are undertaking the task of building two new entrance halls and resorting Blackfriars Bridge; along which newly lengthened platforms will sit. Jacobs Engineering consultancy firm, supported by Tony Gee & Partners (Lynch 2010), are providing valuable advice throughout these works. A subcontractor, Keltbray, is signed-up to deal with the management of construction and demolition waste (Keltbray 2010).

The remodeling of Farringdon station is being carried out as a joint venture between contractors Costain and Laing O'Rourke (Network Rail 2008). Aukett Fitzroy Robinson architects firm will design the main ticket hall (Transport Xtra 2010). Consultants at Atkins (Transport Xtra 2010) were commissioned to provide concept and detailed designs for the station entrances, concourses and platform layout.

To the west of London Bridge Station, the railway at Borough Market will have a new rail viaduct built to relieve the current bottleneck. The Skanska Construction Group is contracted to do this (Network Rail 2008), while Haley’s Ltd. will consult the project.

Various fields of engineering are needed to complete Thameslink. Initially geotechnical engineers need to review and design foundations upon which structures will sit to ensure they will stand. Particularly during the redevelopment at Blackfriars, the ground movement has to be continually monitored by geotechnical engineers, to protect an Underground line running directly beneath. Primarily, transport engineering is required to review the old Thameslink network using urban transport models. This identifies problem areas and indicates how to increase its efficiency. Structural engineering is involved when lengthening the platforms at stations, the reconstruction of Blackfriars station and its bridge restoration, and building the new viaduct at Borough Market. These structures need to be designed and analyzed according to what loads they have to resist. The management of construction and demolition waste is where environmental engineers play a part in the project, ensuring its environmentally sensitive disposal.

Demands and Impacts – The Detail Behind The Theory

The details of a civil engineering project’s demands and impacts, be they from public inquiry, engineering studies, or even informal information sources, can all be “plugged in” to diagrams of system structure and system behavior. This can support the development of the project at both conceptual and detailed design stages.

The instigation behind the Thameslink project came when it was found passenger overcrowding of the service at peak times reached 3.6% in 2001 (BBC News 2001). As 3% overcrowding during peak times was deemed to exceed acceptable overcrowding thresholds, improvements to the service were needed. Coupled with a 2.6% rise in people traveling into London between 1999 and 2001 (BBC News 2001), and this forecasted to increase, there was demand to enhance London's transport links.

Following the project, there will be new 12-car trains to replace old 8 car ones, which will provide an additional 33,000 seats (Whitelaw 2010). Trains will also run more frequently at up to 24 trains per hour passing through central London during peak times. The impact of this will be less overcrowding and fewer delays. Passengers will benefit from less stressful journeys resulting in a better quality of life. A growth in passenger numbers due to induced demand is also set to occur, where passengers will use Thameslink as an alternative to the overcrowded London Underground. The Thameslink programme is an example of self-organization within a system; where the structure of the previous service evolves and diversifies to meet changing human demands.

Once extended to more stations, the Thameslink network will become more resilient. Essentially, including more stations within the system increases the amount of sub-systems and feedback loops. This gives the Thameslink service to survive in variable environments. For example, trains during peak travel times trains could be diverted to different stations to cope with congested routes.

Economic impacts will be both positive and negative. Costing £6 billion of governmental money this could potentially divert money from other services such as healthcare and education. However economic benefits include the creation of permanent station staff and maintenance jobs, including the 1000 created at Farringdon Station (Transport Xtra 2010). Temporary jobs due to construction works are also created. The jobs then generate tax that can then be offset against the initial investment outlay. The Eddington Review (DfT 2006), however, articulates what will be the greatest economic benefit of the project. The tackling of congestion and capacity restraints in and around London will surely support economic prosperity for years to come. More efficient travel can boost economic growth in London as it encourages more work and leisure travel into and around the area, meaning local businesses can benefit.

Having longer and more frequent trains means an increase in energy demand, thus resulting in higher greenhouse gas emissions. This negatively impacts the environment on a global scale. However, the new, electrified trains replacing the old diesel ones are more energy efficient. They can cut energy use by up to 20%, resulting in lower energy costs and reduced carbon emissions of 14 tonnes per train per year (Booth 2009). Also, once renewable energy generation technology advances, they have the ability to use energy from renewable sources, therefore potentially having a decreased impact on the environment.

The environment is also affected by noise and air pollution a local scale. Temporary noise and vibrations from machinery, also dust in the air during demolition and construction works will be created. This may affect the health of local communities and commercial owners. There will also be additional noise pollution of levels between 0.2dB and 3.5dB (Giesler 2005), heard inside surrounding commercial buildings (from the new, more frequent trains running). Nevertheless noise and air pollution levels will be kept within allowable standards to minimize their impact.

In the short-term, the project may decrease accessibility to some parts areas of London. Some roads and Blackfriars Underground station will have to be closed to allow for the construction of stations. Also some rail services may get delayed owing to unforeseen problems during the construction works.

At Farringdon station and Borough Market some listed buildings need to be demolished to accommodate for the developments. This results in a negative social impact in surrounding areas as the cultural heritage of the area is affected. A localized economic impact could follow, due to a decrease in tourism of the area.

<u>The Thameslink Programme as a System</u>

Once completed, the Thameslink programme can be considered a system as it consists of elements, interconnections and a function. The main elements of Thameslink are newly constructed and refurbished stations, extended platforms and the Borough Market viaduct. These are identified as elements, because separately they are ineffective, but together they reach a common goal of fulfilling the main aims for the project. Railway lines and new longer trains will tie these elements together. The interconnected elements perform the function of more efficient travel, increased passenger capacity and reduced overcrowding. This system of inputs and outputs can be summarized in the following diagram (figure 1):

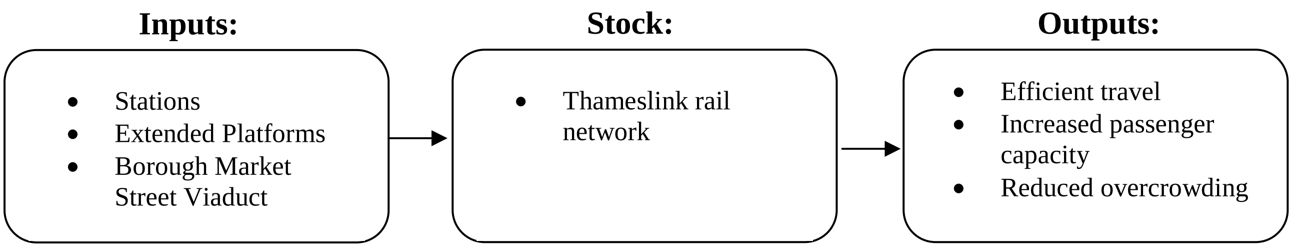

Figure 1: A technical stock-and-flow system diagram for the Thameslink Programme.

However, a systems approach allows the project to be analyzed in both a technical and societal manner. For example, the outputs from the technical system flow (figure 1) can be considered as inputs to a societal flow diagram (figure 2).

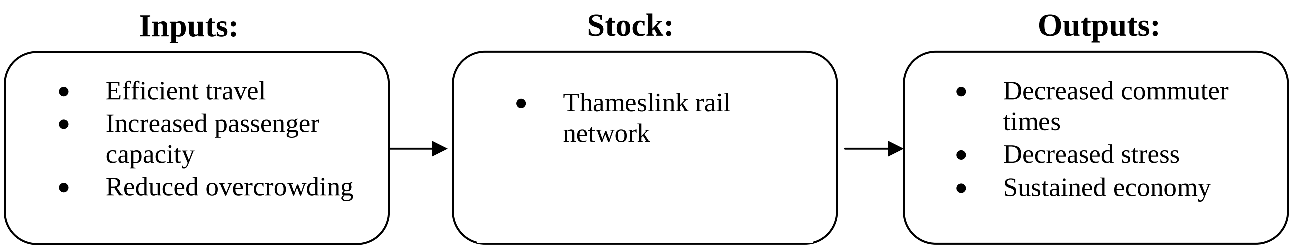

Figure 2: A societal stock-and-flow system diagram for the Thameslink Programme.

The elements of this system can also be divided into sub-elements. For example, the redevelopment of Blackfriars station can be split into north and south side entrance halls, the restored bridge, ticket halls and interchange facilities to the Underground. The resulting function is a more efficient interchange between Thameslink and Underground services and increased passenger capacity and accessibility within the station. The elements of Blackfriars station are represented in a stock-and-flow diagram (figure 3). Combined these meet the localized aims of Blackfriars station, a sub-system within the larger Thameslink system. This arrangement of sub-systems and systems, working from the bottom up, forms the hierarchy of the Thameslink Programme.

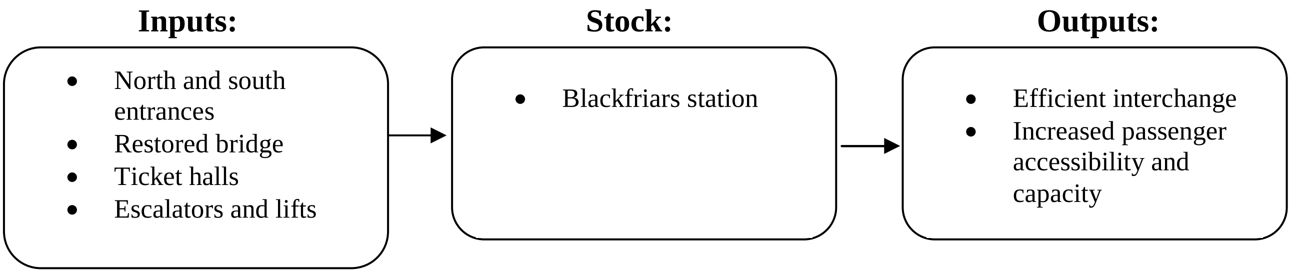

Figure 3: A stock-and-flow system diagram for Blackfriars Station

In addition to using a systems approach to break a civil engineering project in to different elements (system structure), one can also look at the project's behavior. Where changes in the stock of a project affect the inputs and/or outputs of the system, a feedback loop is formed.

There are various feedback loops present in the Thameslink system. The major runaway feedback loop is likely to occur at a system scale owing to "induced demand". Induced demand can be thought of as a "build it and they will come" principle. The redevelopment of the Thameslink system may result in a system that is not only better for the current users but one that attracts more users to it. An increase in use will result in an increase in revenue and, potentially, an increase in future investment in the system (figure 4).

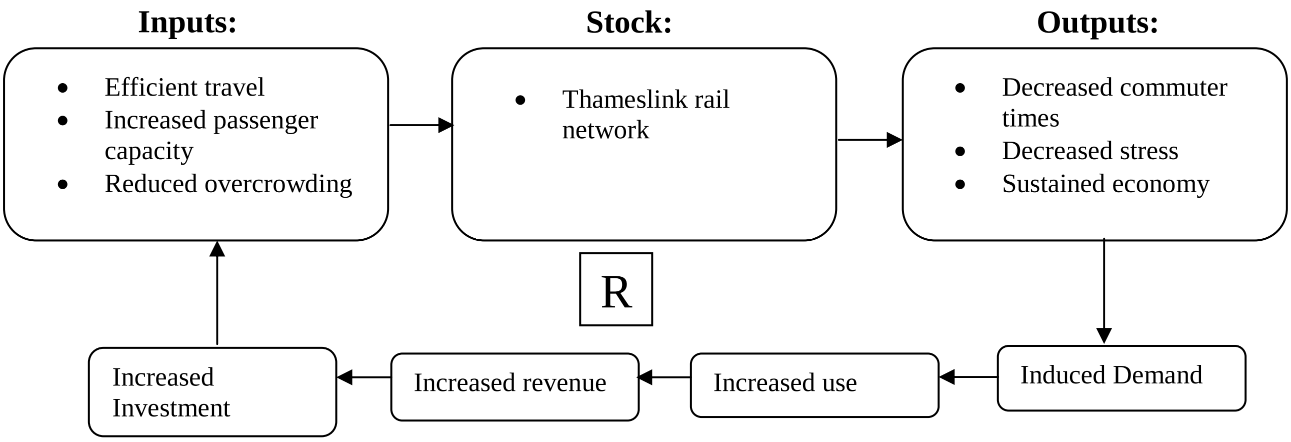

Figure 4 – A runaway feedback loop for Thameslink system

A stabilizing feedback loop occurs when the stations begin to reach full capacity (figure 5). Overcrowding and congestion may persuade some users to seek alternative methods of travel or change their own travel needs (e.g. find new work where

Thameslink is not the natural commuting method). Similarly, price increases, driven by inflation or other factors, without in-tandem improvements to the system may also reduce use. This reduction in passenger numbers following any induced demand can be thought of as a stabilizing loop.

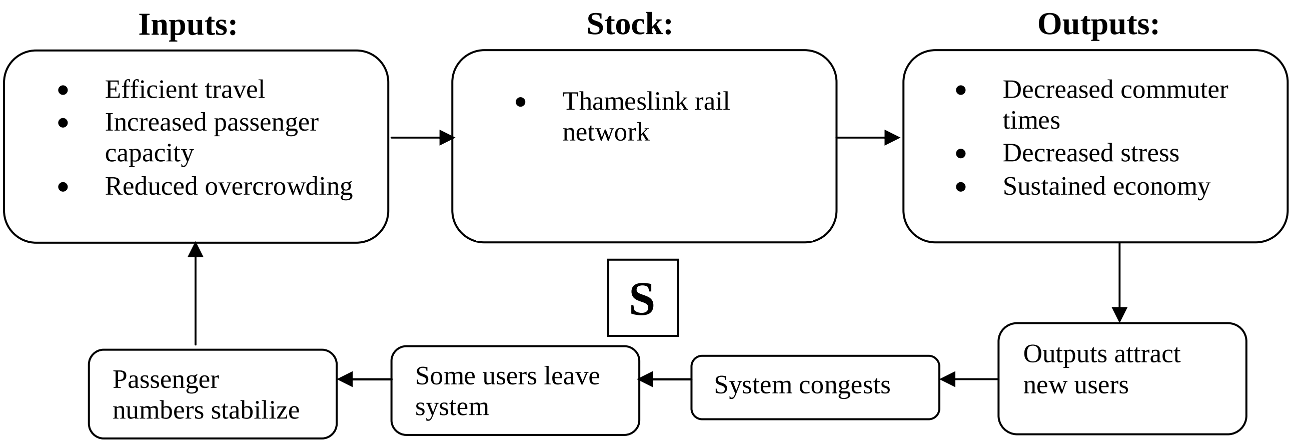

Figure 5: A stabilizing loop for the Thameslink system

The potential to break complex projects in to their constituent parts, show how they affect one another, and show how the project may behave over time is what makes systems theory an attractive tool to the civil engineer. The adoption of system thinking and analysis can support the civil engineer in their understanding, decision making, management and analysis of their project.

<u>About the Authors and Paper Background</u>

Charlotte Owen is a Stage 1 student on the MEng Civil and Structural Engineering course at Newcastle University.

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