Analysis of High-Speed Rail Implementation Alternatives in the Northeast Corridor: the Role of Institutional and Technological Flexibility

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Abstract

In this paper, an engineering systems framework using the CLIOS Process, scenario analysis, and flexibility analysis is used to study the implementation of a high-speed rail corridor in the Northeast Corridor of the United States. Given the tremendous uncertainty that characterizes high-speed rail projects, the implementation of the alternatives proposed, which are very similar to other commonly accepted ways to implement high-speed rail in the corridor, are analyzed under different scenarios. The results motivate incorporation of flexibility into the alternatives to allow decision makers to adapt as situations evolve. While designing-in this flexibility has a cost, it may facilitate the implementation of the alternatives by enabling adaptation to uncertain outcomes, thereby improving performance.

INTRODUCTION

Although the literature presents an extensive number of studies that analyze different alternatives for the implementation of high-speed rail (HSR) corridors, the substantial uncertainty around these kinds of projects and the possibility of change in the implementation of such long-term investments generate the need for a more comprehensive mechanism for thinking through different alternatives.

In particular, the developing field of engineering systems presents the possibility of looking at the HSR corridors with new methods that could lead to further insights about how to improve mobility. This study applies methods from the engineering systems field to seek those insights:

The *CLIOS Process*: this research builds on a CLIOS representation of a particular application, the Northeast Corridor (NEC) of the United States (*1,2 (chapter 1)*);

Scenario analysis (*3,4*) used in conjunction with *the CLIOS Process* in a unique way to understand the main sources of uncertainty; and

Building "*Flexibility*" (*5,6*) into what are called "bundles of strategic alternatives" to recognize if the uncertain future we face going forward toward implementation.

These concepts have been applied to analyze the NEC – stretching from Boston, MA to Washington, DC – which is the most densely settled region in an economically and politically powerful nation in the world; yet it has been plagued for decades with congestion on its roads, in the air and on its rails. It is arguably the most studied region in the world from a transportation perspective, but is also one of the most challenging to study: for example, the rail system alone has three infrastructure owners and eight passenger rail operators (*7*), operating on infrastructure originally built around the turn of the 20th century.

The overall result has been some useful new ways of thinking about the NEC, such as showing the importance of designing flexibility into the alternatives. Flexibility is useful as even in cases in which there is strong political support for HSR, different factors may prevent HSR for being successfully implemented.

The rest of the paper is structured as follows: the next section presents some background on the methodology proposed. Then, the alternatives analyzed in this paper are presented. Subsequent sections present scenarios used to analyze the alternatives presented, and the evolution of the alternatives under such scenarios. That evolution suggests the benefits of considering flexibility (in technology and institutions structures) in the alternatives proposed. The last section presents the main conclusions of this paper.

BACKGROUND

The CLIOS Process

Transportation systems, and in particular, railway systems, are examples of CLIOS Systems, where CLIOS stands for complex, large, interconnected, open, and sociotechnical. In general, it is very difficult to predict the behavior of and to plan those systems. The CLIOS Process can be used as a methodology for *"understanding a CLIOS system's underlying structure and behavior,*

identifying and deploying strategic alternatives for improving the system's performance, and monitoring the performance of those strategic alternatives", (*1*).

This approach to systems views them as a physical "domain" nested within an institutional "sphere". The strategic alternatives that are chosen to change the performance of the system can involve the physical domain and/or institutional sphere.

The CLIOS Process has three phases encompassing 12 steps. The first stage involves *representing* the physical domain and institutional sphere so that relationships between components and key drivers can be identified. With a system representation developed within the framework of a broad research project about transportation in the NEC (*2*), this research focuses on the next stage where strategic alternatives are *designed* and *evaluated* based on the system representation. Robust bundles of strategic alternatives are then *selected* that should perform reasonably well across a variety of scenarios. The final stage involves *implementing* the strategic alternatives in both the physical domain and on the institutional sphere, monitoring their performance, and preparing to repeat the process based on the results. Background material about the CLIOS representation and the framework to analyze the implementation of HSR projects in the NEC is presented in (*2*).

Scenario planning

According to (*3*), scenarios are "*stories about the way the world might turn out*", but "[not] predictions of the future", nor extrapolations of the past either. They are also "tools for ordering one's perception about alternative future environments in which one's decision might be played out"; "might be rational"; and should "have to do with the driving forces of the system, that is, the key factors that will determine or drive the outcome of the system." In this setting characterized by high stakes and poorly characterized uncertainty, scenarios can help inform decisions, provide inputs to assessments, and provide various forms of indirect decision support, such as clarifying an issue's importance, framing a decision agenda, shaking up habitual thinking, stimulating creativity, etc. (*4*).

The objective of this project is to develop scenarios representative of some plausible future situations. Three different scenarios have been chosen instead to test decisions related to the timing and level of investment in HSR for the NEC vis-à-vis a diverse set of "positive" and "negative" future situations.

Flexibility

Predicting the future is difficult, even for short-term horizons. As Karl Popper said, "*long-term prophecies can be derived from scientific conditional predictions only if they apply to systems which can be described as well-isolated, stationary and recurrent. These systems are rare in nature; and modern society is not one of them.*" Given the significant uncertainties associated with forecasting many driving factors (such as the economy), the performance of a strategic alternative is difficult to predict. The success of HSR is particularly susceptible to these uncertainties due to the high capital costs (on the order of $100 billion for the NEC) and long timelines that will ultimately be required to implement the system. While there may be attempts to reduce these uncertainties, uncertainties will always remain. As a result, this paper explores

how flexibility can be used to achieve better outcomes for HSR, by allowing decision-makers the ability to respond dynamically to different realizations of the future.

In addition to the CLIOS Process and the scenario-planning framework, where appropriate, the real options framework developed by (*6*) has been used to think about flexibility in the system. The definition of a real option provided in (*8*) is "*the right, but not the obligation, [for the option holder] to take some action at a future date at a predetermined price.*" In other words, a potential option holder (decision-maker) can design flexibility now in order to create or maintain the possibility of taking a potential action in the future.

BUNDLES OF STRATEGIC ALTERNATIVES CONSIDERED

Strategic alternatives are essentially the changes considered to improve the performance of the system. Usually, a set of strategic alternatives is selected for simultaneous or phased implementation instead of a single strategic alternative. In CLIOS Process terminology, these sets are called bundles.

Four potential bundles of strategic alternatives have been developed differentiated by four decisions (Figure 1): technology, infrastructure organizational structure, vertical integration/separation, and competitive structure of intercity train operations; these represent the four high-level decisions that decision makers have to make when planning a railway system. The authors recognize that other combinations may be possible but these have been chosen for illustrative purposes. These decisions have been arranged in a hierarchical structure, with technology as the first decision for the analyst to make and competitive structure as the last decision.

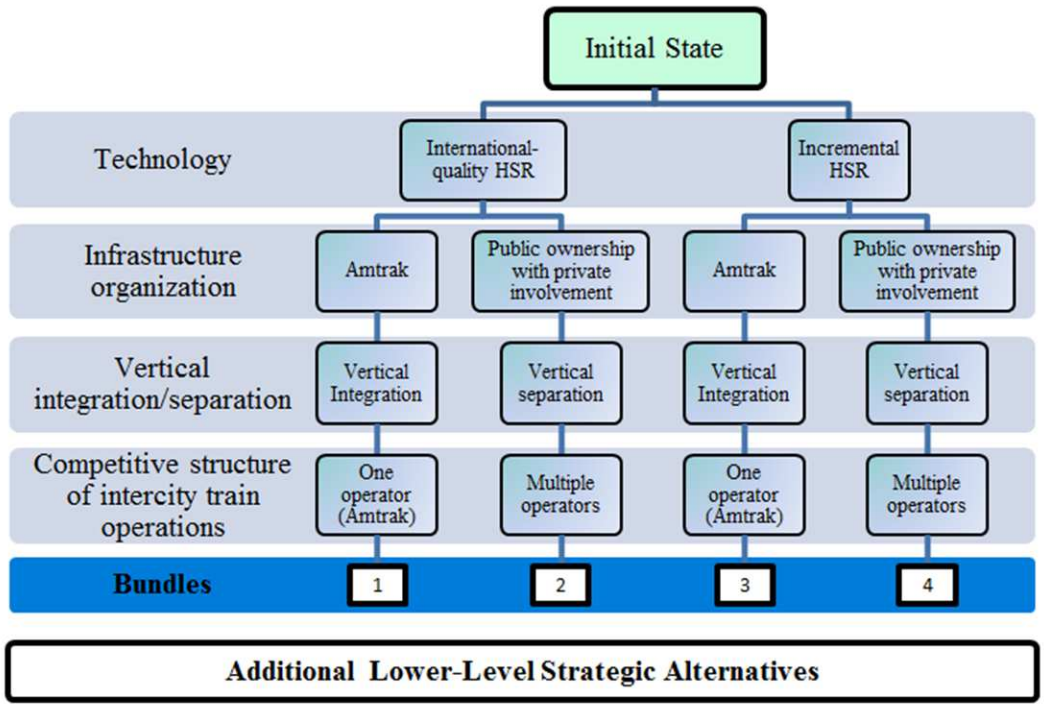

FIGURE 1 Proposed bundles of strategic alternatives for NEC.

The hierarchy chosen is not intended to limit other possible ways to look at the problem but to carry out a first proof-of-concept of the methodology proposed by analyzing the effect of implementing different types of HSR systems with different choices of institutional structures.

In particular, two strategic alternatives in the choice-set for technology have been considered: international-quality HSR and incremental HSR. International-quality refers to developing a HSR system similar in service quality to the Japanese *Shinkansen* or the French *TGV* on a primarily dedicated track alignment. Incremental HSR refers to upgrading the existing NEC alignment gradually to reduce trip times.

There are also two strategic alternatives listed in the infrastructure organizational structure choice-set: Amtrak, and an alternative public ownership structure with private involvement. The third decision has two alternatives within its choice-set: vertical integration vs. vertical separation. Vertical integration refers to having ownership and management of both track infrastructure and train operations handled by one organization; vertical separation refers to having the ownership and maintenance of track infrastructure handled by one organization and train operations handled by one or several other organizations. Finally, the competitive structure of intercity train operations flows out of the decisions made at previous levels. If Amtrak is selected as the organization to own and manage the NEC infrastructure, intercity passenger train operators will likely be limited to Amtrak. However, if public ownership with vertical separation is selected, there could be one or several intercity train operators on the NEC. In addition to these strategic alternatives, it is worth noting that there are a significant number of strategic alternatives that can be considered in the future, focusing on route and service plan decisions for example. However, these issues require detailed engineering analysis, and have thus been excluded from this initial set of higher-level strategic alternatives.

The bundles presented here are similar to existing implementation proposals for HSR in the NEC. Bundle 1 represents the implementation of an international-quality HSR system and organizational structure similar to the plan detailed in (*9*). Bundle 2 is similar to the PennDesign proposal (*10*), which recommends having a regional public benefit corporation take the lead on developing international-quality HSR. Bundle 3, in which Amtrak remains the primary owner of the NEC and develops HSR incrementally, would largely resemble the plan outlined in (*7*). This bundle is the closest to maintaining the “status-quo” on the NEC. Finally, although the physical upgrades to the NEC in bundle 4 would be similar to those of bundle 3, it would consider alternative ownership structure similar to those discussed in the (*10,11,12,13*).

For this study, bundles 2 (*international-quality-HSR*) and 3 (*incremental-Amtrak*) are analyzed. These bundles allow the application of the conceptual framework to evaluate distinctions at both the technology and infrastructure organizational structure decision levels, and overall present the most contrasting bundles (status quo vs. total implementation of an international-quality HSR with a new institutional structure).

DEVELOPMENT OF SCENARIOS

As noted above, the scenarios should address the evolution of the *driving forces* of the system. The most critical components of the NEC and their relation to the major driving forces in the system can be identified examining the CLIOS representation (background material on the process followed to identify the driving forces from the CLIOS representation is available in

(*2*)):

- *economic growth*,
- *political support*,
- *congestion*,
- *technological change*,
- *public perception*,
- *environmental changes*,
- *energy*,
- *funding sources*,
- *multimodal cooperation*,
- *changes in land use*,
- and *social attitudes toward the environment*.

In the classic scenario-planning manner, the scenarios will be stories about plausible evolutions of these driving forces into the future. In particular, three scenarios have been considered:

- **Scenario *no-growth-support*:** This scenario will assume that the US experiences very slow economic growth, but at the same time there is strong political support for HSR in the NEC.
- **Scenario *growth-no-support*:** This scenario will assume that the US experiences rapid economic growth. However, there is little political support for HSR projects.
- **Scenario *modest-growth*:** This scenario will assume some years of medium economic growth, as well as political support for development of HSR in the NEC.

In the definition of the scenarios, the research team incorporated the interaction of different driving forces. Extremely optimistic or pessimistic scenarios that might lead to obvious conclusions have not been considered. At the same time, sufficiently diverse stories are told to avoid the mistake of only considering the "most likely" scenario. Hence different levels of political support have been combined with different levels of economic growth, and with other realizations of driving forces such as energy (e.g. availability of a new oil extraction technology), severe weather and environmental changes, new technologies, etc.

These kinds of scenarios might point out different strategies (like the possibility of private investment in HSR, or postponing investment decisions, or any other alterations in the bundles). In order to identify these strategies, the specific characteristics of these scenarios must be specified, along with the point in time at which every event occurs. It might happen that the political support is weak now, but might be stronger in two years. Consequently, each scenario has been developed considering different decision stages: decisions about the system might be implemented at time 0 (now, before US presidential elections), time 1 (in two years, before the next US congressional elections), time 2 (in four years, just before the next presidential election), time 3 (in eight years, just before the following presidential election), and in time 4 (in sixteen

years). The evolution of the scenarios in the periods between those decision stages is provided, so in this scenario world, decision makers make decisions without using information that they would not have available at that time. A timeline of these three scenarios can be found in Figure 2.

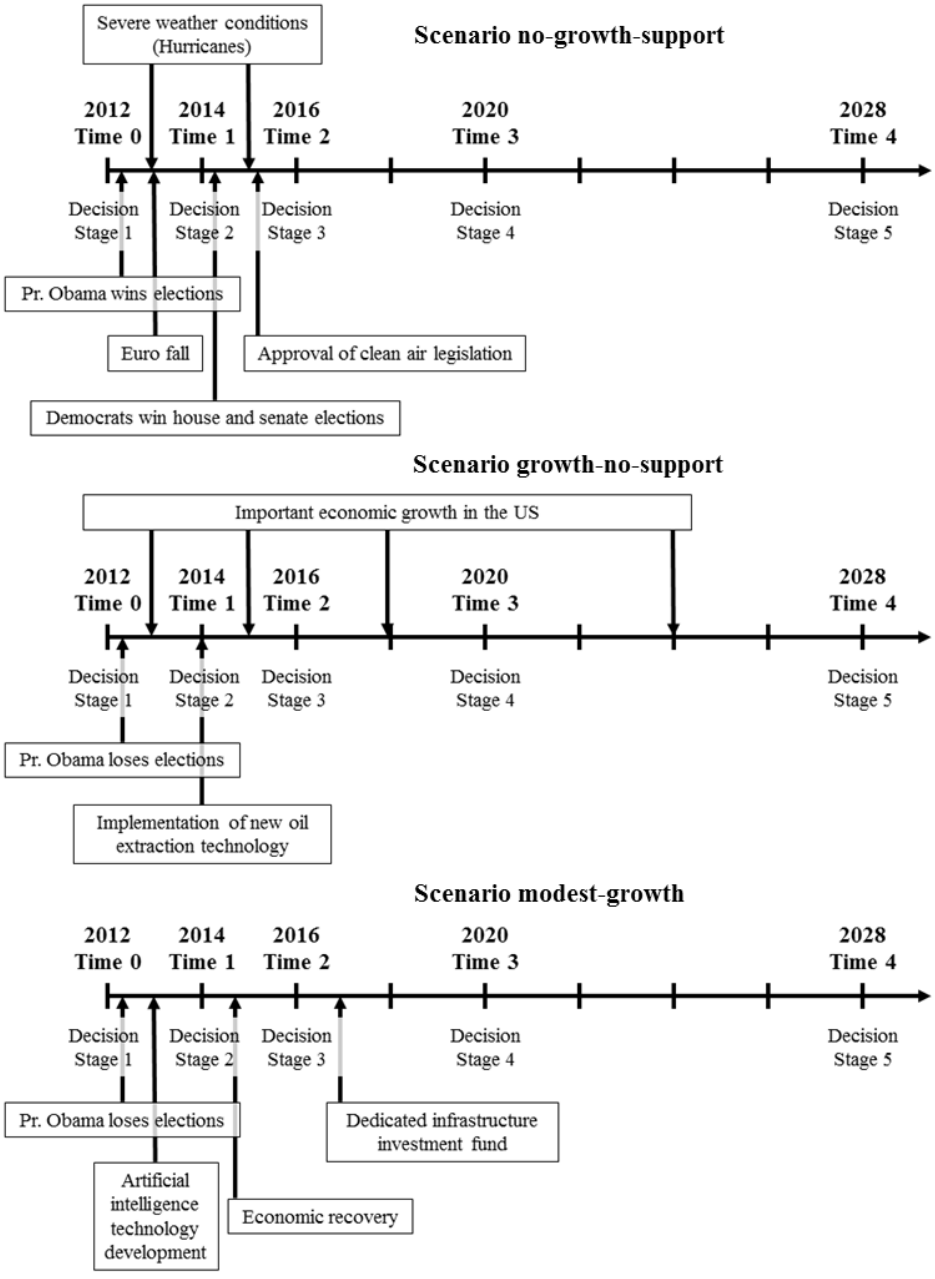

FIGURE 2 Scenarios *no-growth-support, growth-no-support,* and *modest-growth* timelines.

EVOLUTION OF THE BUNDLES UNDER EACH SCENARIO

In this section, the evolution of the bundles of strategic alternatives previously described is analyzed under each of the three scenarios.

Scenario no-growth-support

This scenario is characterized by strong political support for HSR from both the president of the U.S. and the Congress, and by an economic recession in the US caused by a recession in Europe. Under this scenario, low levels of economic activity might be expected, which will cause a decrease in transportation demand and hence in the congestion level of the NEC. At the same time, the adoption of a strict environmental regulation (e.g. a cap and trade policy on emissions or a carbon tax) might on the one hand increase the budget available to invest in transportation, but on the other hand discourage even further transportation demand, which would likely decrease air emissions, congestion and transport revenues (*2*).

Imagine that under these circumstances, the president commits to the incremental-Amtrak bundle. If a clear strategy is adopted, modest but tangible improvements along NEC services would likely be seen. Even though the economic situation is not promising during the early time periods, the political support for HSR projects would help ensure that adequate funds are committed to the incremental-Amtrak bundle. After the first time periods, support for HSR in the NEC could increase for two reasons. Firstly, there will have been tangible improvements on the corridor, which will have a direct impact on the trip attributes and hence in the modal split and the railway transportation demand. Secondly, the adoption of strict environmental legislation through the adoption of cap and trade policies on emissions will also favor social support for a more efficient transport system. Therefore, although the results coming from the incremental-Amtrak bundle will be modest, political support for the bundle will ensure that tangible improvements to intercity passenger rail on the NEC (possibly designed to accommodate an eventual international-quality HSR alternative) will result, which would ultimately encourage more funding for an international-quality NEC HSR system.

If the president and Congress commit to proceeding with the international-quality-HSR bundle instead, the difficulty of raising funds for the project given the economic recession, together with the fact that the investment of these funds might be spread out over the U.S. (since the political agenda will not have NEC as a target) will generate a situation in which it would be very difficult to make tangible movements towards an international-quality HSR corridor. Furthermore, because there will be little federal funding available for HSR, there may be limited cooperation amongst the Northeast states to develop an appropriate alternative ownership structure. Ultimately, lack of progress might mean that in five years' time there is increasing opposition to construct HSR in the NEC.

Scenario growth-no-support

The main characteristics of this scenario are the political party's decision to postpone HSR investment in the US, as well as important economic growth during the time period, enhanced by trade with China and South America and by the discovery of a new oil extraction technology that reduces oil extraction cost and increases lower-cost fuel availability. The first implication of economic optimism in the US will be an increase in economic activity, and hence, increased transportation demand starting in the initial time period. An increase in transportation demand in the NEC will imply a higher level of congestion in an already congested corridor. In this environment, different national and foreign companies would be willing to invest in railway

technology, although the political situation has to be favorable in order to allow the creation of public-private partnerships. In addition, the adoption of the new oil extraction technology that lowers fuel prices in 2014 will support a highway-based transport system (*2*).

Under these assumptions, the adoption of the incremental-Amtrak bundle without adequate funding will likely lead to a degradation of intercity passenger rail. The lack of adequate and consistent funding would also hamper Amtrak's ability to properly manage upgrades to NEC as it will have to: (a) constantly lobby for funds and (b) constantly be changing the sequencing of projects to match available funds. As a result, Amtrak's weakened state could then potentially be used as an argument to create a new institutional structure on the NEC. The poor performance of rail may also provide an argument to pursue a strategy of highway expansion. Furthermore, the adoption of the oil extraction technology in the US might challenge railway investment for some years, further supporting the construction of more highways and the support of car-based transportation.

Under this scenario, the adoption of the international-quality-HSR bundle as currently defined will not be feasible. It is not possible to postpone railway investment and, at the same time, promote an international-quality HSR project.

Scenario modest-growth

Scenario *modest-growth* is characterized by political support for HSR in the NEC, and by a modest economic recovery. The development of an artificial intelligence technology that allows lowering the cost of constructing HSR will make infrastructure investment more appealing, though the project will not create as many jobs as predicted. However, the construction companies might benefit from that situation, enhancing economic activity and creating jobs in other industries. The economic growth starting in 2014 will also promote economic activity and higher levels of transportation demand. In this case, transportation benefits will increase, due to lower construction cost, and high ridership levels. These revenues, together with the growth of a dedicated infrastructure bank and other innovative financing mechanisms such as the Railroad Rehabilitation and Improvement Financing program (RRIF), may have a positive impact on transportation infrastructures (*2*).

The adoption of the incremental-Amtrak bundle in this situation will lead to modest, tangible improvements in the NEC. However, the recovery of the economy will cause an increase in transportation demand, making NEC even more congested. Under this situation, the corridor will continue to be constrained.

The adoption of the international-quality-HSR bundle in this case will likely be successful. During the first period of limited (or negative) economic growth, the NEC will benefit from government support over other possible railway corridors; support from the institutional sphere, for a new public ownership of the NEC; and the advantages of the new technologies, that will lower the cost of constructing the international standard HSR lines. One might expect to observe big increases in transportation demand, due to the economic activity and the improvements in transportation infrastructure. This situation will provide a unique opportunity to develop intermodal passenger transportation policies that will provide a high-quality mobility service for all users and potentially result in positive economic gains.

Table 1 presents a summary of the evolution of the bundles of strategic alternatives under each scenario.

The imaginative nature of the scenario planning process helps us to think more deeply about the NEC, and can lead to unexpected results. Without this analysis, one might expect the incremental-Amtrak bundle to perform well under scenarios that presents low levels of economic growth (or economic recession); whereas the international-quality-HSR bundle should perform best under scenarios in which economic growth dominates. However, these results suggest that other factors, particularly political support, strongly influence the performance of the bundles.

		Scenarios		
		Scenario no-growth-support (economic recession, political support for HSR in the NEC)	**Scenario growth-no-support** (economic growth, weak political support for HSR)	**Scenario modest-growth** (new technology, moderate economic growth)
Bundles of Strategic Alternatives	**International-quality-HSR bundle** (bundle 2)	• Difficult to achieve international-quality HSR • Increasing opposition to HSR due to lack of results	• Not feasible • Commitment to car-based transport system (highways)	• Success of international-quality HSR • Transportation demand and benefits increase
	Incremental-Amtrak bundle (bundle 3)	• Modest but tangible improvements along NEC • Stronger support to HSR	• Degradation of intercity passenger rail • Commitment to car-based transport system (highways)	• Modest but tangible improvements along NEC • Constrained NEC (in terms of capacity)

TABLE 1 Performance of the bundles under each scenario without flexibility

BENEFITS OF DESIGNING FLEXIBILITY INTO THE BUNDLES

The above process largely assumed that once a bundle was in the process of being implemented, deviations would not occur. That assumption leads to implementing the bundle that performs acceptably across the broadest range of scenarios, even if there are other bundles that perform better under a subset of the scenarios. Recognizing, however, that the process of implementing HSR in the NEC would take place over many years, it seems worthwhile to consider flexibilities in the bundles of strategic alternatives that would allow the bundles to be altered under changing circumstances. These flexibilities will allow adapting to the situation and taking advantage of the evolution of the system.

The scenario framework shows that the strict adherence to a bundle (e.g. international-quality-HSR bundle) does not lend itself to a scenario with postponed investment, whereas bundles with greater flexibility might allow a gradual transition between incremental and international quality HSR. However, using flexibility presents challenges as the real options that could be applied in the NEC are "complex" (*8*): different actors will be involved in purchasing, designing-in and exercising the options (Amtrak, federal and state governments, etc.); multiple

actions may need to exercise an option; and the option may change over time (e.g. if a technology like maglev becomes the appropriate technology to pursue). In addition, the cost to exercise the flexibility may change dramatically due to inflation or deflation, and there might be significant political "costs" associated with actually exercising a real option. As a result both quantitative and qualitative analysis techniques (such as cost-benefit analysis, sensitivity analysis, etc.) are required to evaluate the benefits and drawbacks associated with designing-in and exercising flexibility in the bundles of strategic alternatives for the NEC.

With these challenges in mind, potential opportunities to design-in flexibility in the bundles of strategic alternatives have been identified. The flexibilities identified relate to the decision levels presented when the bundles of strategic alternatives were created, including: institutional structure, technology, and competitive structure.

The following subsections identify flexibilities that could be designed-into the bundles. A brief description of how the flexibilities discussed below would play out in the different scenarios is then presented.

Table 2 show the institutional and technological flexibility options discussed below. The first column describes what is meant by "designing-in" the flexibility into each of the bundles of strategic alternatives, and the second column describes the result from exercising the flexibility.

Technological flexibility

The first type of flexibility that could be designed-into the bundles is the option to change from implementing international-quality HSR to incremental HSR and vice-versa as future economic or political conditions demand.

If the incremental-Amtrak bundle were implemented, a flexible approach would focus on upgrades that would benefit both international-quality and incremental HSR systems. Some examples of these projects include expanding the capacity of New York Penn Station and its access tunnels and increasing the capacity of Boston South Station. In addition to upgrading the NEC infrastructure incrementally, the planning, permitting and design processes associated with international-quality HSR could be pursued. If this process were to start soon even if future funding is uncertain, implementing international-quality HSR would not be delayed (as much) by regulatory and design issues.

If the international-quality-HSR bundle were chosen initially, flexibility could be designed-in by allowing the construction of the new alignment in phases. For example, a section from New York to Philadelphia could be constructed first, and HSR could run between the two cities. If demand were lower than expected, the infrastructure owner would not incur such big losses (as trying to build out the system all at once), as the infrastructure owner could stop construction of the new international-quality alignment on other links, North of New York or South of Philadelphia. There would still be inherent value to this construction, however, as trains would be able to run on the new alignment for part of the route (from Philadelphia to New York, for example), and thus trip time would be reduced (provided that the new train sets could operate on the new and existing system). If demand were higher than expected, then the new riders of the HSR system would represent a new stakeholder group who could push for the further expansion of the system. (*9*) presents a potential phasing scheme in their report.

In summary, under circumstances of low transportation demand or low economic growth, this research suggests a transition (and hence to design-in flexibility that allow that transition) from the international-quality-HSR to the incremental-Amtrak bundle. Conversely, under circumstances of significant economic growth and well received upgrades of the railway system, a change from the incremental-Amtrak to the international-quality-HSR one is suggested. Again, there are risks and costs with implementing flexibility into the system that should be explicitly considered.

An international example of this type of flexibility occurs in the French TGV system. Travelers taking a TGV trip between Paris and Nice will travel on an international- quality HSR alignment between Paris and Marseille, but, while staying on the same train, will travel on a conventional rail network between Marseille and Nice. Even though the international-quality link does not go all the way to Nice (and may not be built for several years), the upgraded link still provides value to those travelers continuing to Nice.

Institutional flexibility

Other significant debate regarding HSR in the NEC is whether Amtrak or another alternative entity should be responsible for the implementation of infrastructure upgrades. Amtrak currently owns most of the NEC infrastructure and already operates higher-speed *Acela* service, and therefore could begin the process of upgrading NEC infrastructure and service immediately (*14*), although other stakeholders, like commuter rail operators, may prefer the implementation of an alternative public ownership structure (*12*). Implementing a structure like the "regional public benefit corporation" proposed in (*10*) could take months if not years of negotiations to set up, however, which would hold up improving HSR service in the NEC.

There appears to be value in ensuring that an institutional structure is in place that can appropriately manage the significant capital investment projects that will be required in the NEC and balance the needs of all NEC users. Arguably, Amtrak, in its current state (as represented in the incremental-Amtrak bundle), may not be best suited to handle these tasks, but has the advantage of being already in place and able to begin implementing any upgrades. It may be possible to design-in flexibility within Amtrak that allows for (but does not require) a transition into a new organizational structure (*15*). Some of this flexibility could be designed-in immediately, while some of it could be included at a later date (see Table 2). Additionally, some of the flexibility presented could also have inherent value, even if the flexibility is never exercised.

There would be advantages and disadvantages to such a flexible approach. The first advantage is that Amtrak could begin upgrading infrastructure almost immediately (subject to availability of funding). At the same time, the flexibility in the approach would provide Amtrak and other decision-makers some ability to redefine their operation if they later choose to exercise that option. If an alternative public-ownership structure were pursued immediately, years might go by before any actual upgrades (incremental or otherwise) take place on the NEC. The second advantage is that the flexibility provides stakeholders the ability to compromise. Splitting Amtrak into separate entities acknowledges the views of both Amtrak supporters (as Amtrak will still exist) and detractors (as the flexibility provides some potential to reopen the debate about future institutional structure). Finally, the flexibility allows decision-makers gradually change the ownership structure of the NEC and test additional reforms without having to jump completely to a radically different ownership structure.

There are some disadvantages to this approach, however. For example, although many of the proposals above have inherent value, designing-in flexibility adds cost. For instance, there is the added cost of separating the accounting of Amtrak into profit centers based on NEC operations that may not be needed if Amtrak is otherwise operating well (but it will substantially reduce the cost of implementing a new institution from scratch, in terms of time, political willingness, money, etc.). Note also that this research does not study whether Amtrak (or a private firm) has the expertise to construct and manage international-quality HSR in the NEC but simply recognizes the possibility of having different ownership formulas.

One example of the use of institutional flexibility internationally occurred in Germany; where the government split up their rail operator into "entrepreneurial areas" and "public sector areas" in the early 1990s with the idea of potentially privatizing the entrepreneurial services at a later date (*16*).

	Design-in flexibility at various times	**Exercise flexibility in the future**
Institutional Flexibility		
Incremental-Amtrak bundle (bundle 3)	Institute accounting separation within Amtrak and separate NEC operations into separate business units (i.e. NEC business division[s])	Separate NEC operations into separate subsidiaries of a larger Amtrak holding company
	Separate NEC operations into separate subsidiaries of a larger Amtrak holding company	Take NEC subsidiaries and place them under a new public ownership structure
International-quality-HSR bundle (bundle 2)	Negotiate contracts with train operators that allows public owner to buy back access rights or cancel access rights if train operators are not providing an adequate level-of-service	Buy-back/cancel access rights from train operators, and sign a contract with only one operator to offer service on the NEC
	Design the organizational structure such that there is a well-defined separation between oversight functions and day-to-day operating functions Include in any contracts with private-partners the ability to sell operating rights to the private sector	Sell operating functions to private sector
Technological Flexibility		
Incremental-Amtrak bundle (bundle 3)	Upgrade portions of the existing corridor that would also benefit an international-quality HSR alignment Undertake planning activities for an international-quality HSR alignment	Begin implementing an international-quality HSR alignment
International-quality-HSR bundle (bundle 2)	Construct the international-quality HSR alignment in geographic phases (e.g. starting between New York and Philadelphia) and connect the new alignment with the existing system	Under an “optimistic” situation in which demand is high, garner support from the current users of the system to further expand international-quality HSR Under a “pessimistic” situation in which demand is lower than expected or the economy is poor, discontinue implementing international-quality HSR and focus on incremental upgrades to the existing corridor

TABLE 2 Summary of institutional and technological flexibilities considered

Using flexibility in the bundles based on different scenarios of the future

An analysis of the NEC that allows designing-in flexibility and exercising it in when the circumstances are suitable reveals that it is possible to mitigate some of the weaknesses of the bundles of strategic alternatives presented. For instance, the economic recession situation presented in scenario *no-growth-support* can be handled by delaying many of the investment decisions under the incremental-Amtrak bundle. In addition, since these investments are planned to obtain tangible results with the available resources, social and political support for HSR throughout the period can be ensured. Under scenario *growth-no-support*, despite political support during the first two years not being as positive as needed, the increase in demand caused by both economic growth and by improvement of trip attributes obtained with carefully planned initial investments in HSR will ensure higher levels of political support in the next time periods. Finally, under scenario *modest-growth*, the projected decrease of HSR construction cost, together with the economic recovery might generate interest and investment in international-quality HSR.

Table 3 shows a plausible set of flexibility options to design-in and exercise for each of the two bundles proposed, and under each scenario developed. The main advantage provided by the inclusion of flexibility in the bundles is that the decision maker may be able to alter the bundles to better adapt to the circumstances as they play out. Note again that this research does not say that any of these are going to happen; it just represents a way of training the decision maker's thinking to deal with future uncertainties.

The way to interpret Table 3 is the following: the first row of the table represents which flexibilities are designed-in the international-quality-HSR bundle first and the incremental-Amtrak bundle next under scenario *no-growth-support* at different time periods. In particular, no flexibility can be exercised at time 0 (now) because the bundles have not been implemented yet. At time 0 (now) the decision-makers will not have any information about the scenario, so the flexibilities designed-into the bundles will be identical for each scenario. In the first time period, after having some information about how the situation has evolved, and after two years of economic recession, the decision-makers might decide to exercise the technological flexibility (TF) designed-in, and focus exclusively in constructing HSR from New York to Philadelphia. The situation will still be similar to the initial situation, so they may not identify new flexibilities to design-in the bundles. In time period 2 (four years later), since the economic recession continues, the decision-makers may want to design new flexibilities in the bundle to be able to stop the construction of international-quality HSR and to continue with the incremental-Amtrak bundle (upgrade the system) instead. This flexibility will be exercised in time period 3, when decision makers will also design-in new technological flexibilities allowing a focus on those upgrades that might be especially helpful in case that they are able to continue constructing international-quality HSR in the future. The future evolution column of Table 3 presents the evolution of the system that one might expect to observe after the last decision stage. This evolution highlights the positive effects of flexibility, since the performance of each bundle under each scenario considered is better than the one without flexibility (higher levels of political support, public perception, possibility of obtaining tangible results, etc.). Of course, the sunk costs of designing-in flexibility will never be recovered if the real option is never exercised.

CONCLUSION

In this research, two bundles of strategic alternatives developed within the framework of the CLIOS Process have been analyzed under three scenarios developed by the research team. There were instances in which the scenarios provided insights that were congruent with those derived *a priori*. For example, if the economy is growing and there is a significant demand for travel, the incremental-Amtrak bundle will be unable to accommodate the generated transportation demand.

In other cases, as the scenarios allowed consideration of contrasting futures in which some driving forces are strong but others are weak, new insights were obtained that challenged prior assumptions. For example, if the economy is weak, even if political support is fairly strong, the incremental-Amtrak bundle may perform best, as there would be modest but tangible improvements to HSR that could demonstrate Amtrak's competence at managing the NEC, whereas the international-quality-HSR bundle might stall because of insufficient funding.

The evolution of the bundles under each scenario suggested the potential of adding flexibility to the bundles of strategic alternatives, as a way to be able to easily adapt the bundle to different future scenarios and improve its performance. For example, under scenario *no-growth-support*, after several years of successfully improving HSR incrementally, there might be the opportunity for greater investment in an international-quality system, allowing the transition between two bundles.

In order to think about how the bundles of strategic alternatives might change over time, different types of flexibilities that could be designed-into the bundles of strategic alternatives were identified, using a "real options" framework. With real options a potential option holder (decision-maker) may pay extra now in order to create or maintain the possibility of taking a potential action in the future. The cost of designing-in and exercising the flexibility must be lower than the cost of taking the potential action when the flexibility is not designed-in the system, in terms of money, time, or political feasibility of taking the action, etc.

First examined was how the system could benefit from designing flexibility into the strategic alternatives related to the *institutional structure*, recognizing that there might be different options for the ownership of the NEC. Then *technological* flexibility was considered, with options to phase the construction of both an incremental or international-quality HSR system. The possibility of adapting the bundles to new situations by designing-in these different types of flexibility and exercising them when the circumstances are appropriate leads to improved results. This flexibility will allow the decision maker to get tangible results under each possible future realization of the different uncertainties. Note however that while many of the flexibilities identified might sound good in theory, there are certainly hurdles associated with applying them in practice when the price of designing-in or exercising the flexibility is unknown, or when the entities that design-in and ultimately exercise the option are not the same.

Finally, the research successfully demonstrates the theoretical usefulness of combining the CLIOS Process, scenario planning, and the real option flexibility approach to allow decision makers to think more deeply about the future of HSR. Even though many of the ideas were not novel, this framework highlights key issues that should be considered for the NEC planning. Future research may use this framework to analyze the impacts of different driving forces in the systems (fuel prices, connections with public transit, etc.), and the performance of other bundles of strategic alternatives.

International-quality-HSR bundle						
Flexibility	**Time 0 (2012)**		**Time 1 (2014)**		**Time 2 (2016)**	
	Exercise	**Design-in**	**Exercise**	**Design-in**	**Exercise**	**Design-in**
Scenario no-growth-support		• **Institutional flexibility – IF** (negotiate contracts to allow public owners to buy back access rights) • **Technological flexibility – TF** (construction of new alignment in phases, in particular, focus on the construction of the international-quality HSR from New York to Philadelphia).	• **TF** (focus exclusively on the construction of the first phase of HSR).	N/A	N/A	• **TF** (sign contracts that allow decision maker to stop constructing new HSR, but to upgrade current corridor instead – go back to the incremental-Amtrak bundle)
Scenario growth-no-support			• **TF** (continue only with the construction of HSR from New York to Philadelphia).	N/A	N/A	• **TF** (construction of second phase of the HSR corridor from Philadelphia to Washington D.C.).
Scenario modest-growth			N/A	N/A	N/A	N/A

TABLE 3 Possible time periods to design-in and exercise flexibility options under the different scenarios

International-quality-HSR bundle					
Flexibility	**Time 3 (2020)**		**Time 4 (2028)**		**Future Evolution**
	Exercise	**Design-in**	**Exercise**	**Design-in**	
Scenario no-growth-support	• **TF** (go back to the incremental-Amtrak bundle, commitment with successive upgrades of the NEC).	• **TF** (start upgrading the system on those points in which the upgrades might be helpful for future construction of HSR).	N/A	N/A	• Although the economic situation is not favorable to proceed with HSR, there will be social and political support to railway transportation, allowing HSR in the future.
Scenario growth-no-support	• **TF** (focus on the construction of the second phase of the HSR corridor from Philadelphia to Washington D.C.).	• **TF** (continue with the construction of the HSR corridor from Boston to New York).	• **TF** (continue with the construction of the HSR corridor).	N/A	• After the success of different HSR phases, the transportation service in NEC will improve, and so the transportation demand.
Scenario modest-growth	N/A	• **TF** (continue with the construction of the second phase of the HSR corridor from Philadelphia to Washington D.C.).	• **TF** (focus on the construction of the second phase of the HSR corridor).	• **TF** (continue with the construction of the HSR corridor from Boston to New York).	• Success of HSR implementation. The construction of this corridor will inspire the construction of other HSR corridors in the US.

TABLE 3 Possible time periods to design-in and exercise flexibility options under the different scenarios

Incremental-Amtrak bundle						
Flexibility	**Time 0 (2012)**		**Time 1 (2014)**		**Time 2 (2016)**	
	Exercise	**Design-in**	**Exercise**	**Design-in**	**Exercise**	**Design-in**
Scenario no-growth-support		• **Institutional flexibility – IF** (creation of a division within Amtrak dedicated to NEC). • **Technological flexibility -- TF** (start upgrading the system on those points in which the upgrades might be helpful for future construction of HSR as Penn Station in NY, tunnels to access NY, increase capacity in South Station in Boston).	• **TF** (focus on the upgrades proposed).	N/A	N/A	• **TF** (continue with upgrades in other bottle-necks of the corridor).
Scenario growth-no-support			• **TF** (focus on the upgrades proposed).	• **TF** (continue with upgrades in other bottle-necks of the corridor).	• **TF** (continue with the upgrades proposed). • **IF** (creation of a regional public benefit NEC corporation).	N/A
Scenario modest-growth			• **TF** (focus on the upgrades proposed).	• **TF** (continue with upgrades in other bottle-necks of the corridor).	• **TF** (continue with the upgrades proposed).	• **TF** (prepare a transition to the international-quality-HSR bundle, studying the construction of international-quality HSR from New York to Philadelphia).

TABLE 3 Possible time periods to design-in and exercise flexibility options under the different scenarios

1

Incremental-Amtrak bundle					
Flexibility	**Time 3 (2020)**		**Time 4 (2028)**		**Future Evolution**
	Exercise	**Design-in**	**Exercise**	**Design-in**	
Scenario no-growth-support	• **TF** (continue with the upgrades proposed).	N/A	N/A	• **TF** (prepare a transition to the international-quality-HSR bundle, studying the construction of international-quality HSR from New York to Philadelphia).	• After several years of tangible improvements of the NEC, social and political support to HSR will allow the construction of international-quality HSR.
Scenario growth-no-support	N/A	N/A	N/A	• **TF** (prepare a transition to the international-quality-HSR bundle, studying the construction of international-quality HSR from New York to Philadelphia).	• After several years of tangible improvements of the NEC, social and political support to HSR will allow the construction of international-quality HSR.
Scenario modest-growth	• **TF** (start the construction of international-quality HSR from NY to Philadelphia). • **IF** (creation of a regional public benefit NEC corporation).	N/A	N/A	• **TF** (construction of second phase of the HSR corridor from Philadelphia to Washington D.C.).	• After different success constructing international-quality HSR, the situation will be favorable to end with the construction of a NEC HSR system.

2 **TABLE 3 Possible time periods to design-in and exercise flexibility options under the different scenarios**

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REFERENCES

(1) J. Sussman, et al. *The CLIOS Process: A User's Guide*. 2009. http://esd.mit.edu/Faculty_Pages/sussman/CLIOS-PROCESS.pdf. Accessed Jul. 23, 2012.

(2) J. Sussman, et al. *Transportation in the Northeast Corridor of the U.S.: A Multimodal and Intermodal Conceptual Framework*. 2012. http://esd.mit.edu/Faculty_Pages/sussman/Trans-Northeast-Corridor.pdf. Accessed Jul. 23, 2012.

(3) E.A. Parson, et al. *Global-Change Scenarios: Their Development and Use.* 2007.

(4) P. Schwartz. *The Art of the Long View: Planning for the Future in an Uncertain World.* Doubleday: New York, NY, 1996.

(5) R. de Neufville. Uncertainty Management for Engineering Systems Planning and Design. Monograph, *1st Engineering Systems Symposium.* MIT, Cambridge, MA, 2004.

(6) R. de Neufville, Scholtes, S. *Flexibility in Engineering Design*. Cambridge, MA: MIT Press, 2011.

(7) NEC Master Plan Working Group, *The Northeast Corridor Infrastructure Master Plan.* Washington, DC.: Amtrak, 2010.

(8) J.B. McConnell. *A Life-Cycle Flexibility Framework for Designing, Evaluating and Managing "Complex" Real Options: Case Studies in Urban Transportation and Aircraft Systems.* MIT PhD dissertation, 2007.

(9) Amtrak, *Vision for High-Speed Rail in the Northeast Corridor.* Washington, DC., 2010.

(10) PennDesign, *High-Speed Rail in the Northeast Megaregion: From Vision to Reality.* Philadelphia, PA: University of Pennsylvania School of Design, 2011.

(11) M.E. Robins. *Northeast Corridor Action Plan: A Call for a New Federal-State Partnership.* Alan M. Voorhees Transportation Center: New Brunswick, NJ, 2006.

(12) L.S. Thompson. *Options for the Federal Ownership of Northeast Corridor (NEC) Infrastructure.* 2005.

(13) Amtrak, *Intercity Rail Passenger Service in America: Status, Problems and Options for Reform.* Washington, DC: Amtrak Reform Council, 2011.

(14) D.L. Roth, Aggarwala R.T. Whose railroad is this, anyway? Opportuinities and challenges in regionalizing the Northeast Corridor, in *Transportation Research Records*: *Journal of the Transportation Research Board*, No. 1785, Transportation Research Board of the National Academies, Washington, D.C., 2002.

(15) Business Alliance for Northeast Mobility. *Back on track: Northeast Corridor, the path forward to high-speed rail*. April, 2012. http://www.rpa.org/northeastbizalliance/library/pdf/BackOnTrack-NEC.pdf. Accessed Jul. 24, 2012.

(16) OECD Policy Roundtables. *Railways: Structure, Regulation and Competition Policy*, 1997.