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Missouri Freight and Passenger Rail Capacity Analysis

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16. Abstract

The MoDOT Tracker performance measure “Number of Rail Passengers” is directly correlated with the level of passenger train delays. Therefore, the objective of this study was to develop a prioritized list of rail enhancements that addresses current passenger and freight rail performance on the Union Pacific line from St. Louis to Kansas City in order to improve on-time passenger service and reduce freight delays**.**

An integrated systems analysis and modeling approach was used in this study. Based on a Theory of Constraints analysis the core problem was identified as the high level (and increasing) train load, both from a quantity and weight of train perspective. Corresponding to this four issues were identified that impact the overall delay in the system: geographic conditions, maintenance processes, crew scheduling, and Amtrak dispatching priority.

Finally, based on the analysis conducted a set of six primary rail enhancement alternatives (with some having multiple options) were generated, together with potential alternative combinations. The alternatives were generated with respect to minimizing congestion, and therefore delay, within and between freight and passenger trains. The rail alternatives were analyzed by simulating the reduction in overall time for a train to cross the state of Missouri, then a set of recommendations were generated with respect to delay reduction and capital investment.

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FINAL REPORT

R105-053

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Prepared for the
Missouri Department of Transportation
Organizational Results

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July 2007

The opinions, findings, and conclusions expressed in this publication are those of the principal investigators and the Missouri Department of Transportation; Research, Development and Technology. They are not necessarily those of the U.S. Department of Transportation, Federal Highway Administration. This report does not constitute a standard or regulation.

Executive Summary

Missouri Freight and Passenger Rail Capacity Analysis

Study Objective

The primary objective of this study was to develop a prioritized list of rail enhancements that addresses current passenger and freight rail performance on the Union Pacific line between St. Louis and Kansas City in order to improve on-time passenger service and reduce freight delays**.** The MoDOT Tracker performance measure related to this project is the "Number of Rail Passengers" within the performance objective of "Easily Accessible Modal Choices". In this study the key analysis issue is the delay encountered by both Amtrak for passenger and Union Pacific for freight operations. This issue directly impacts the MoDOT Tracker performance measure "Number of Rail Passengers" since it has been found that passenger train delays are directly correlated with the number of passengers utilizing rail service.

Study Approach and Scope

A four step approach was used in this study. First, the St. Louis-Kansas City Union Pacific rail line was assessed using a Theory of Constraints (TOC) approach to determine key capacity restrictions and congestion factors. Second, a simulation model was developed to examine candidate improvement alternatives. Third, a set of rail enhancement alternatives were generated. Fourth, alternatives were analyzed and prioritized with respect to system performance improvement and capital investment requirements.

The Union Pacific rail corridor between Saint Louis and Kansas City is comprised of three Subdivisions. The Jefferson City subdivision between Saint Louis and Jefferson City is mostly two tracks with bi-directional travel (except where the railway has two-way travel on single track bridges over the Osage and Gasconade Rivers). The Sedalia subdivision is single track (with sidings) with bidirectional flow of traffic when there is an eastbound passenger train which currently occurs twice per day. The River Subdivision is a single track (with sidings) with unidirectional flow of several different types of freight traffic.

Study Results and Analysis

The Theory of Constraints analysis identified the core problem as the high level (and increasing) train load, both from a quantity and weight of train perspective. From a train quantity perspective this corridor is handling between 50-60 trains per day which is at the upper limits of capacity for a double track line handling the types of freight that it does. From a train weight perspective this corridor handles a large percentage (roughly 50%) of heavy coal trains. As a result of this core problem there are four issues that ultimately impact the overall level of delay on the corridor.

1. Geographic Conditions – The double track in the Jefferson City Subdivision follows the Missouri River. The sub-grade in this Subdivision requires a substantial amount of maintenance in order to handle the heavy axle loads of a full coal train. Prior to maintenance there are an increased number of slow orders and during major maintenance activities all train traffic is affected due to reduced hours of operation.
2. Maintenance Processes – As a result of the geographic conditions and the high train load level on the corridor, the task of scheduling both routine and major maintenance windows is non-trivial. This is further complicated when combined with the scheduling of signal and track inspections.
3. Crew Scheduling – Increased train load increases the crew scheduling task complexity and has the potential to increase corridor congestion when crews exceed their 12 hours of allowed service and become "dead on hours" before reaching their crew change locations.
4. Amtrak Dispatching Priority – Increased freight load within a high maintenance and partially single track (with limited sidings) rail corridor makes it increasingly difficult to provide passenger train priority.

An analysis of the 2005 Amtrak Delay Reports reveals that the majority of train delay is caused by Freight Train Interference (FTI = 53.38%), Temporary Speed Restrictions (DSR = 15.09%), and Passenger Train Interference (PTI = 9.7%). Figure 1 shows the track segment contribution to overall passenger train delay.

Based on the Theory of Constraint analysis and the delay analysis a set of six primary rail enhancement alternatives (with some having multiple options) were generated, together with potential alternative combinations. The alternatives were generated with respect to minimizing congestion, and therefore delay, within and between freight and passenger trains (i.e. sidings and additional track). This approach is in contrast to improvement alternatives that specifically focus on improving overall train speed (i.e. sealed corridors, track curvature, etc.). However, as congestion and delay is minimized there is a corresponding increase in average train speed. Figure 1 shows the location of these enhancement alternatives.

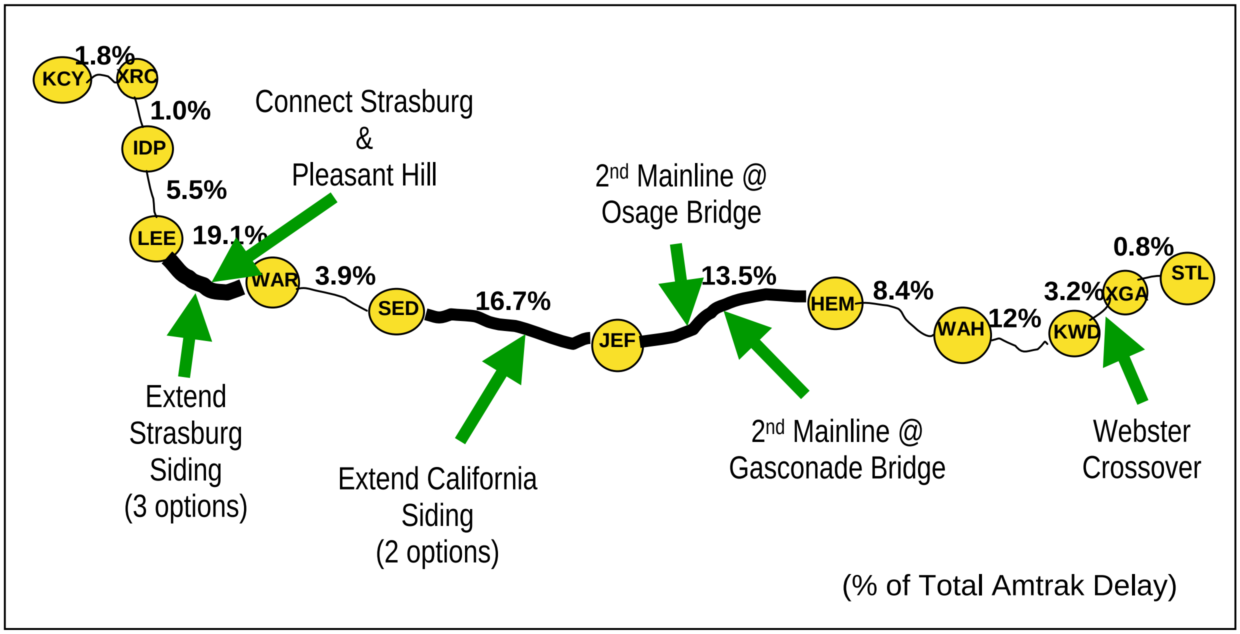


Figure 1: Primary delay locations and associated rail enhancement alternatives

The rail alternatives were analyzed by simulating the reduction in overall time for a train to cross the state of Missouri. The 2005 train volume (approximately 53 freight trains and 4 passenger trains per day) and mix (approximately 7% passenger, 43% commodity, and 50% inter-modal / manifest) was used as the basis of the analysis. The model was developed using Rockwell Automation's Arena simulation modeling software. For this study a performance baseline is assumed based on a scenario where all track from St. Louis to Kansas City is double track (implying that the Sedalia subdivision is double tracked and both the Gasconade and Osage bridges are double track) and then an alternative's overall percentage delay reduction with respect to the baseline scenario for both freight and passenger trains is calculated.

Examining the simulation results revealed two major trends: 1) the Sedalia subdivision alternatives provide more relative benefit with respect to reducing overall delay for Amtrak passenger trains (average benefit of Sedalia subdivision alternatives for Amtrak is 14.4% vs. 6.8% for UP), and 2) the Jefferson City subdivision alternatives provide more relative benefit for UP freight trains (average benefit of Jeff City subdivision alternatives for UP is 20.9% vs. 5.0% for Amtrak). Table 1 presents an analysis of each of the rail enhancement alternatives for both Union Pacific freight and Amtrak passenger rail service with respect to the percentage of delay reduction per million dollars of estimated project cost. Note that the cost used in the analysis is the underlined cost for each alternative (multiple costs for each alternative reflect different implementation options that are detailed in the full project report).

Table 1 - Comparison of Alternatives with respect to % Delay Saved per $M invested

	% UP Delay Savings / $M	**% Amtrak Delay Savings / $M**	**Cost in Millions**
Sedalia Subdivision Alternatives			
S1 - Extend California Siding	1.48	3.97	4 or 2.5
S2 - Extend Strasburg Siding Freight	0.83	0.85	10 or 8 or 2
S3 - Connect Strasburg & Pleasant Hill Sidings	0.01	1.12	10.5
S4 - Both Extend California Siding & Extend Strasburg Siding for Freight	0.90	0.88	14 or 12.5 or 12 or 10.5 or 6.5 or 4.5
S5 - Both Extend California Siding & Connect Strasburg & Pleasant Hill Sidings	0.50	1.62	14.5 or 13
Double Track LEE_JEF (130 miles)	0.08	0.11	260
Jefferson City Subdivision Alternatives			
J1 - Osage Bridge	1.16	0.60	15 or 28
J2 - Gasconade Bridge	0.89	0.26	21
J3 - Gasconade/Osage Bridges	0.76	0.11	36 or 49
J4 - Webster Crossover	8.00	0.56	2.5

The following discussion is based on the objective to maximize the Delay Savings / $M obtained in Table 1. In the Sedalia subdivision alternative S1 (Extend California Siding) clearly dominates all other alternatives as it provides significant benefit with respect to the project cost for both freight and passenger operations. Alternatives S4 and S5 also merit further consideration as they both provide relatively strong benefit; however, S5 tends to provide more benefit to passenger rail service. In the Jefferson City subdivision alternative J4 (Webster Crossover) clearly dominates all other alternatives as it provides a very significant benefit for freight rail operations and a moderate benefit for passenger rail operations Based on the fact that J4 has already been implemented by Union Pacific and J2 is in process of implementation, alternative J1 (Osage Bridge) should also be considered as it provides a significant benefit for both freight and passenger rail operations.

Recommendations

Based on the analysis conducted this study makes the following recommendations to be implemented in the order listed below:

1) Alternative S1 - Extend California Siding - option 2; Estimated cost = $4 million
2) Alternative S3 - Connect Strasburg and Pleasant Hill Sidings; Estimated cost = $10.5 million
3) Alternative J1 - 2nd Mainline on Osage Bridge; Estimated cost = $15-28 million

Additionally, the current Union Pacific Maintenance processes warrant further analysis as they could provide reduction in overall passenger train delay performance without significant investment. Therefore, it is recommended that the scheduling of routine and major maintenance windows, and the scheduling of signal and track inspections, be further analyzed with respect to overall system delay performance.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

A key performance measure for MoDOT is to provide expanded opportunities in Multi-Modal Access and Mobility. A specific performance outcome related to this proposal that is addressed in the MoDOT Tracker system is “Easily Accessible Modal Choices” and the specific performance measure related to this project is the “Number of Rail Passengers”. In general, this measure has increased slightly over the past 4 years, however, due to a major Union Pacific track work program in 2007, that has resulted in increased congestion on the St. Louis to Kansas City rail corridor, passenger ridership is expected to significantly drop. This project seeks to examine the issues that impact both freight and passenger delay on the St. Louis to Kansas City corridor from a systems perspective in order to improve the service of both.

2.0 STUDY OBJECTIVES

To develop a prioritized list of rail enhancements that address current passenger and freight rail performance on the Union Pacific line from St. Louis to Kansas City in order to improve on-time passenger service and reduce freight delays**.**

This objective is pursued with respect to the following research questions:

- What is the passenger / freight capacity of the Kansas City to St. Louis rail corridor?
- What rail system improvements are needed to ensure adequate current and future capacity?
- What relatively low-to-medium-cost solutions can significantly improve existing capacity?
- In the long term, what major improvements will be needed to accommodate growth of both passenger and freight rail?

3.0 STUDY APPROACH AND PROCEDURES

The general approach for this project consisted of the following four steps:

1) Assessment

Assessed Kansas City – St. Louis Union Pacific rail line constraints / variability associated with passenger / freight flow. A Theory of Constraints (TOC) approach was used to determine key capacity restrictions and congestion factors.

2) Model Development

Developed a capacity / variability analysis model to explore constraints. The modeling approach utilized a simulation-based candidate analysis to examine alternatives to improving overall capacity and reducing system congestion.

3) Generation of Alternatives

Generated set of rail enhancements that had potential to reduce overall rail congestion.

4) Alternative Analysis

Conducted capacity enhancement / delay reduction analysis respect to performance and economic criteria and generated a prioritized list with respect to economic objectives.

4.0 PROJECT SCOPE

The focus of this study is the Union Pacific rail corridor between Saint Louis ando Kansas City (figure 1), both eastbound and westbound. The Jefferson City subdivision between Saint Louis and Jefferson City is mostly two-track with bi-directional travel. There are two points along the Jefferson City subdivision (JC sub) where the railway becomes one-track with two-way travel due to single track bridge over the Osage and Gasconade rivers. For the most part main track #1 is for westbound traffic and main track #2 is for eastbound traffic. Situated on the main tracks of the JC sub are three Amtrak depots for passenger trains (Kirkwood, Washington, Herman). The Amtrak depot locations result in short periods of time where passenger trains move against directional flow, which naturally creates train conflicts.

In Jefferson City, there is a yard operation with five tracks, with two being main tracks used for through traffic. The Amtrak depot is located on main track #2. West of Jefferson City is River Junction, the point of intersection between two rail subdivisions, the Sedalia subdivision and River subdivision. The westbound traffic coming from Saint Louis originating on main track #1 switches main track in the Jefferson City area in order to continue westbound on the Sedalia subdivision. Traffic traveling eastbound from Kansas City travels along the River subdivision (which is a single track with single direction traffic flow) and switches onto main track #2 in the Jefferson City area, and continues on to Saint Louis. The meeting and switching operations in the Jefferson City area is a potential point of congestion.

The Sedalia subdivision is single track with bidirectional flow of traffic in the case of eastbound passenger rail traffic, which currently occurs twice per day. The single track is supplemented by sidings that are used for meeting and passing of opposing directional trains. Sidings are also used for overtaking like-directional trains. There are four Amtrak depots along the Sedalia subdivision (Sedalia, Warrensburg, Lee’s Summit, and Independence). The River subdivision is a single track with unidirectional flow of several different types of freight traffic, including coal, grain, automobile, inter-modal, manifest, etc. This railway also includes sidings, which are used primarily for mechanical failures or hold-ups for train sequencing prior to the Jefferson City area.

There are many activities occurring within the terminal operations of both Saint Louis and Kansas City. Based on several factors such as importance of loads, allowed service time of train crews, or destination of train, trains are sequenced before entering the terminal areas or held for long periods of time within terminal yards.

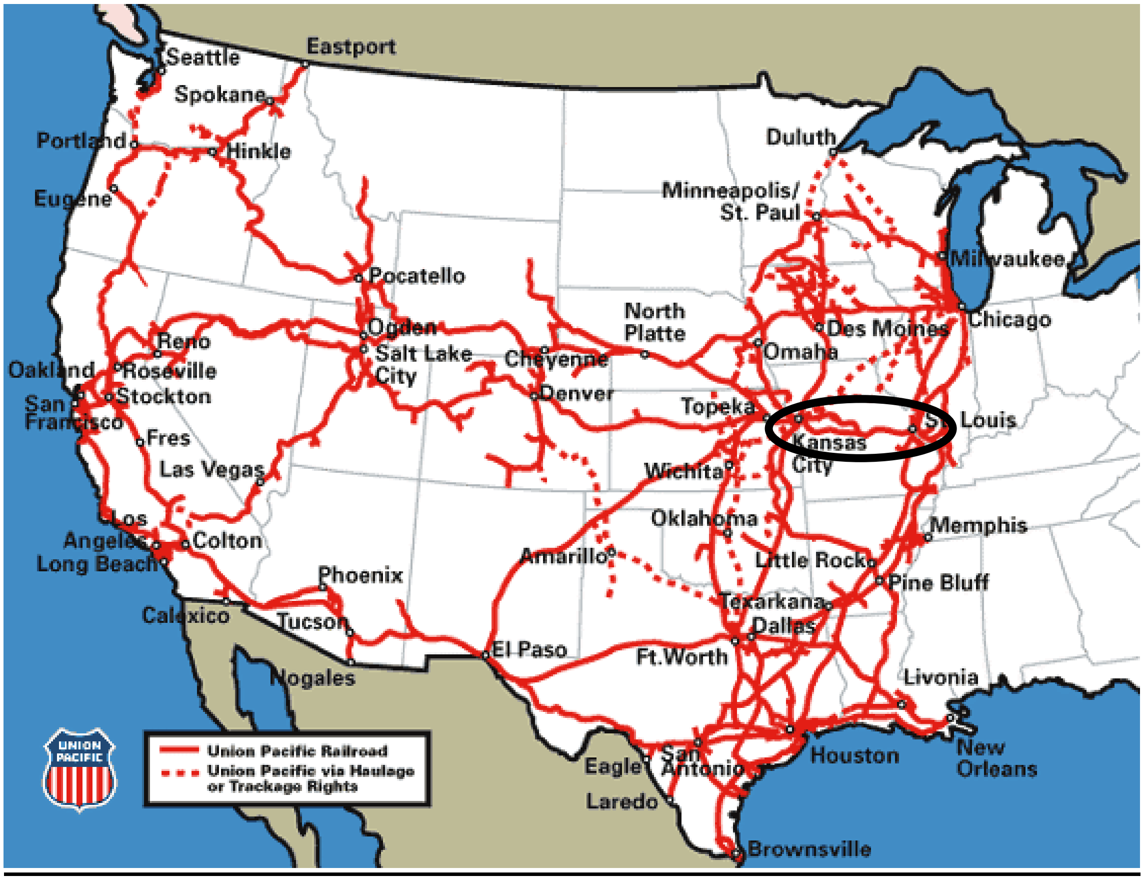


Figure 1 – Union Pacific System Map

5.0 RESULTS AND DISCUSSION

5.1 Amtrak On-time Performance and Delay Analysis

Table 1 presents the 2005 Amtrak on-time performance for all westbound trains (301/311/303/313). As can be seen from this data the majority of the westbound train lateness occurs between STL and JEF (31.3 – 5.6 = 25.7 minutes). The distribution of on-time performance shows that for 90% of the trains, the STL departure is within 30 minutes, JEF departure is within approximately 90 minutes and KCY arrival is within 120 minutes.

Table 1 - Westbound 2005 Amtrak On-time Performance

301/311/303/313 (Westbound)	STL Departure	JEF Departure	KCY Arrival
On-time 0 min	79%	10%	27%
On-time 15 min	86%	44%	50%
On-time 30 min	90%	70%	65%
On-time 60 min	95%	86%	76%
On-time 120 min	99%	96%	89%
Later 120 min	1%	4%	11%
Average Lateness	5.6	31.3	33.1
Min Lateness	0	0	-20
Max Lateness	317	312	405

Table 2 presents the 2005 Amtrak on-time performance for all eastbound trains (304/314/306/316). As can be seen from this data the majority of the eastbound train lateness occurs between KCY and JEF (42.7 – 4.5 = 38.2 minutes). The distribution of on-time performance shows that for 90% of the trains, the KCY departure is within 15 minutes, JEF departure is within approximately 120 minutes and STL arrival is within 120 minutes.

Table 2 - Eastbound 2005 Amtrak On-time Performance

304/314/306/316 (Eastbound)	KCY Departure	JEF Departure	STL Arrival
On-time 0 min	86%	8%	15%
On-time 15 min	94%	29%	30%
On-time 30 min	96%	50%	43%
On-time 60 min	97%	78%	68%
On-time 120 min	99%	94%	90%
Later 120 min	1%	6%	10%
Average Lateness	4.5	42.7	53.1
Min Lateness	0	0	-23
Max Lateness	185	358	570

Table 3 provides a summary of the assigned cause of Amtrak delays for 2005 and the total minutes attributed to this delay cause. This data is based on train engineer delay reports that are filed for each train. As can been seen the majority of the delay is caused by Freight Train Interference (FTI = 53.38%), Temporary Speed Restrictions (DSR = 15.09%), and Passenger Train Interference (PTI = 9.7%). Figure 2 illustrates the relative percentage of each delay type. A complete listing and description of the different delay codes can be found in Appendix B.

Table 3 – 2005 Amtrak Delay Sources

Delay Code	Total Delay Minutes	% of Total Delay	# of Delay Occurrences	Average Delay	Std Dev Delay
FTI	57272	53.38%	4022	14.2	18.2
DSR	16190	15.09%	4196	3.9	3.6
PTI	10411	9.70%	816	12.8	11.3
DCS	5206	4.85%	611	8.5	9.2
HLD	3840	3.58%	1400	2.7	2.5
DMW	3477	3.24%	189	18.4	30.8
ITI	3077	2.87%	90	34.2	38.3
RTE	1594	1.49%	324	4.9	6.7
ENG	1526	1.42%	53	28.8	57.4
NOD	867	0.81%	193	4.5	10.8
SYS	867	0.81%	95	9.1	17.9
OTH	539	0.50%	52	10.4	13.7
TRS	488	0.45%	27	18.1	35.4
SVS	434	0.40%	25	17.4	28.3
ITT	345	0.32%	22	15.7	24.0
CAR	223	0.21%	24	9.3	8.0
POL	218	0.20%	7	31.1	59.9
CON	201	0.19%	11	18.3	37.6
ITM	161	0.15%	6	26.8	29.6
INJ	133	0.12%	5	26.6	20.4
DTR	108	0.10%	6	18.0	40.7
DBS	34	0.03%	4	8.5	9.3
WTR	29	0.03%	5	5.8	5.3

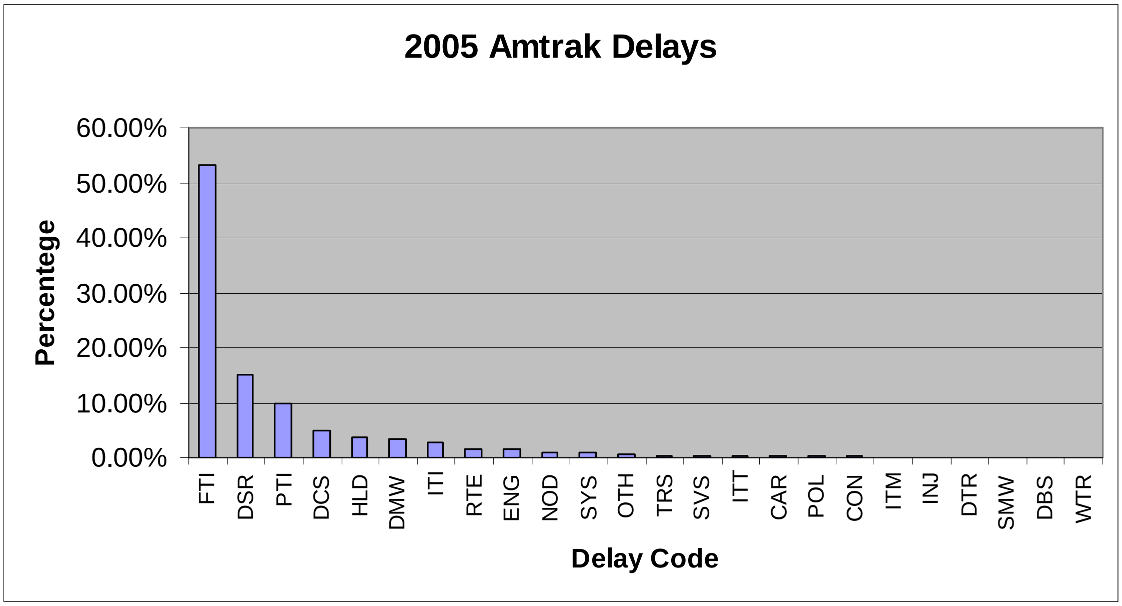


Figure 2 – Pareto Diagram of 2005 Amtrak Delay Sources

Figure 3 illustrates the aggregate delay on each segment of the line between stations (in green) and at stations (in red). Appendix C presents a summary of all delays both between stations (From-To based upon direction) and at stations, as well as the portion of delay that is caused by train congestion (FTI and PTI) for each From-To link in the route (with overall 69% of all From-To delay caused by FTI and PTI). From this delay data it is possible to highlight where the majority of Amtrak delay occurs. The track segment that contributes the most to the overall delay is between Lee's Summit (LEE) and Warrensburg (WAR) (19.1% of which 73% is FTI/PTI delay), followed by the track segment between Sedalia (SED) and Jefferson City (JEF) (16.7% of which 92% is FTI/PTI delay), followed by the segment between Jefferson City (JEF) and Herman (HEM) (13.5% of which 63% is FTI/PTI delay), followed by the segment between Washington (WAH) and Kirkwood (KWD) (12.0% of which 43% is FTI/PTI delay).

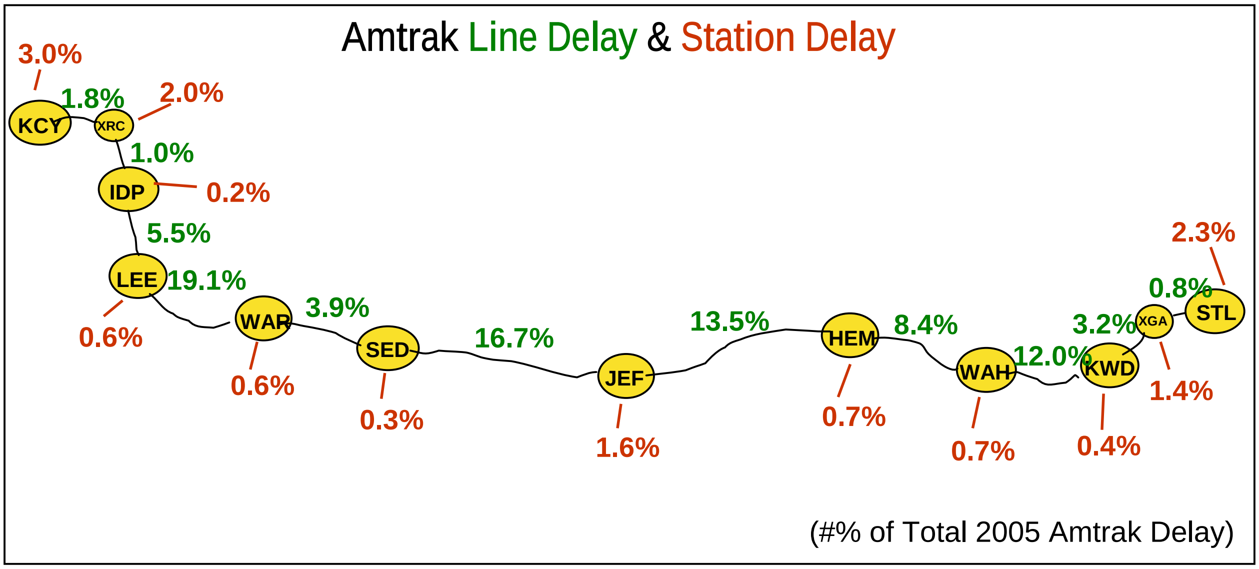


Figure 3 – 2005 Amtrak Line and Station Delay

5.2 Current Reality Tree – Root Causes

Figure 4 illustrates the general form of a current reality tree (CRT) which is a representation of an underlying core problem (CP) and the symptoms or undesirable effects (UDE) that arise from it. A CRP maps out a sequence of cause and effects from the core problem to the symptoms or undesirable effects (Youngman, 2006).

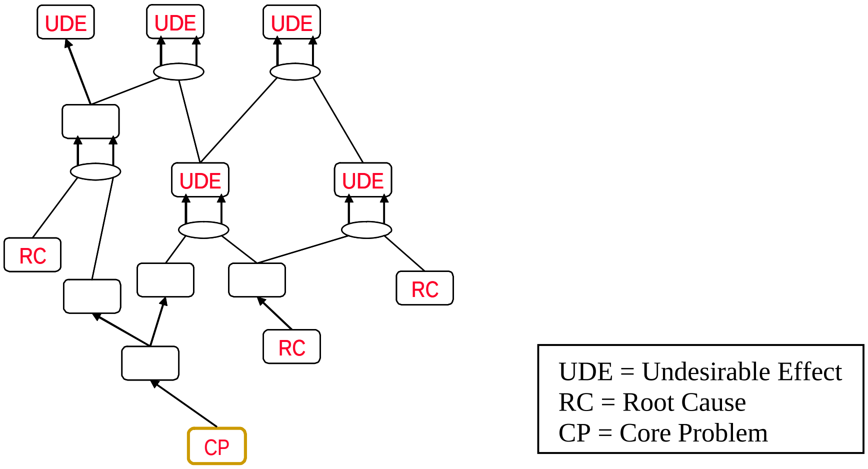


Figure 4 - CRT: Identify the Core Problem Source

In this project a current reality tree was constructed after extensive interviews with key rail personnel from Amtrak, Union Pacific, and Kansas City Terminal, together with supporting data they supplied. The resulting current reality tree is given in figure 5.

In this analysis the primary undesirable effects are the delays encountered by both Amtrak for passenger operations and Union Pacific for freight operations. This undesirable effect directly impacts the MoDOT Tracker performance for “Number of Rail Passengers” since as delays increase the advantages of train travel decrease and as a result the number of passengers decreases as well.

The core problem (CP) was identified as the high level (and increasing) of train load, both from a quantity of trains and weight of trains perspective. From a train quantity perspective this corridor is handling between 50-60 trains per day which is at the upper limits of capacity for a double track line handling the types of freight that it does. From a train weight perspective this corridor handling a large percentage (roughly 50% of total trains) of heavy coal trains. As a result this core problem either directly or indirectly impacts four root causes (RC) that impact the overall undesirable effects associated with this system.

The following will discuss how each of the four root causes identified (Geographic Conditions, Maintenance Processes, Crew Scheduling and Dispatching Priority) are a result of the core problem (Train Load) and ultimately impact the overall level of delay in the system.

1. Geographic Conditions – The double track in the Jefferson City subdivision follows along the side of the Missouri River. The sub-grade in this area is particularly unsuited to handle the heavy axle loads of a full coal train. The degradation of the sub-grade is further compounded by the number of heavy coal trains that traverse the track. In order to maintain the track in useable condition a substantial amount of maintenance is required. As a result of the sub-grade deterioration, prior to maintenance there can be a increased number of slow orders and during major maintenance activities all train traffic is affected due to reduce hours of operation.
2. Maintenance Processes – As a result of the geographic conditions and the high train load level on the corridor, the task of scheduling both routine and major maintenance windows is non-trivial. This is further complicated when combined with the scheduling of both signal and track inspections. Therefore, both the planning and scheduling associated with maintenance significantly affects the congestion and overall level of train delays.
3. Crew Scheduling – Due to the increased train load the crew scheduling task becomes more complicated and has the potential to add to the overall corridor congestion when crews exceed their allowed 12 hours of service and become “dead on hours” before reaching their crew change locations.
4. Amtrak Dispatching Priority – Increased freight load within both a high maintenance and partially single track (with limited sidings) rail corridor makes it increasingly difficult to provide passenger train priority and requires increased scheduling/control efforts to reduce overall system delays.

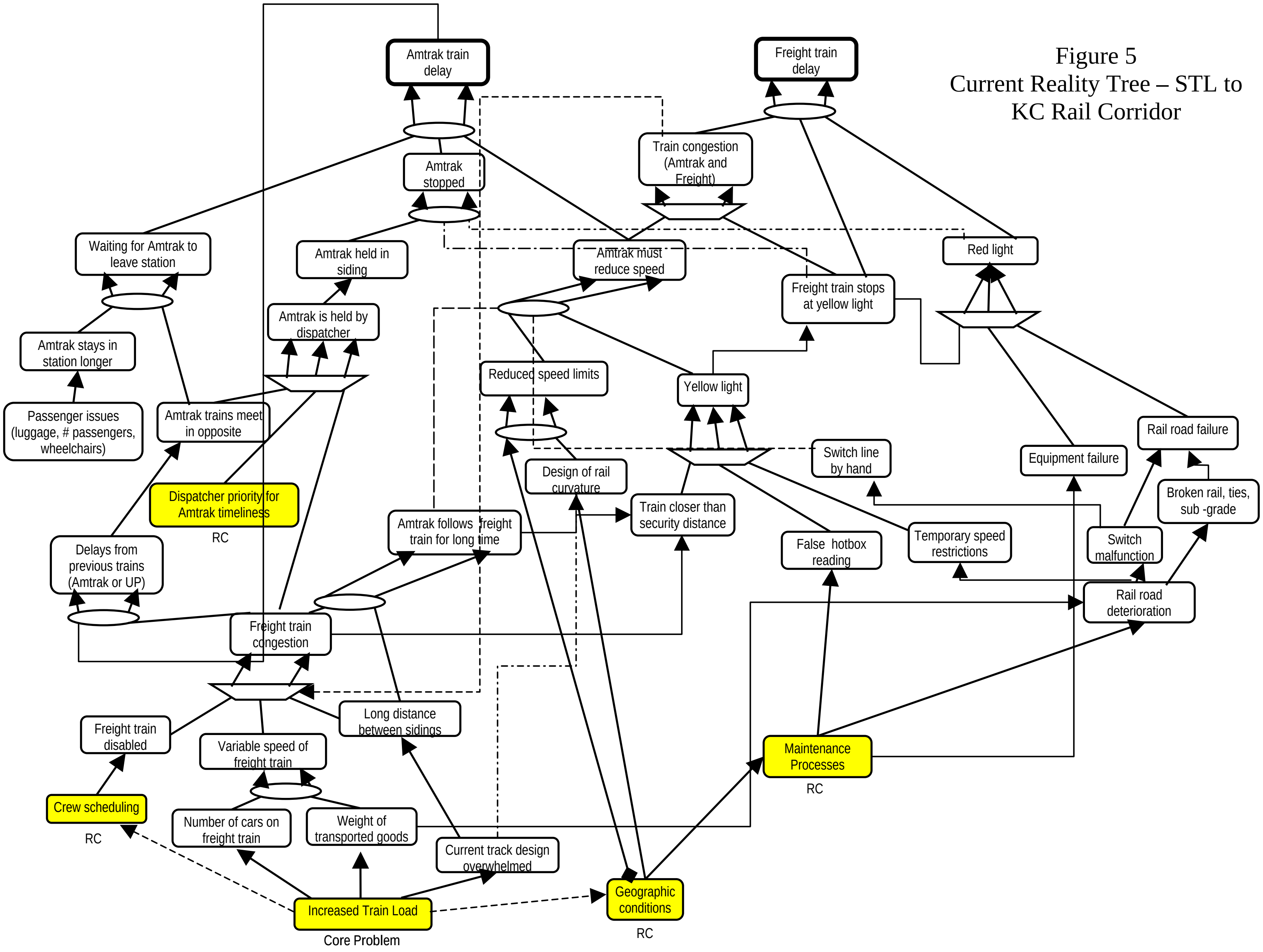


Figure 5
Current Reality Tree – STL to KC Rail Corridor

5.3 Rail Enhancement Alternative Specifications and Estimated Cost

Based on the delay analysis and current reality tree a set of six primary rail enhancement alternatives (with some having multiple options) have been generated, together with potential alternative combinations. The alternatives were generated with respect to minimizing congestion, and therefore delay, within and between freight and passenger trains (i.e. the addition of sidings and double track). This approach is in contrast to improvement alternatives that specifically focus on improving overall train speed (i.e. sealed corridors, track curvature, etc.). However, as congestion and delay is minimized there is a corresponding increase in average train speed. Figure 6 shows the location of these alternatives.

The following section provides the specifications for each enhancement alternative and the estimated cost. (Note all cost estimates were developed by Hanson-Wilson unless noted otherwise). The performance characteristics will be given separately in the results section of the report.

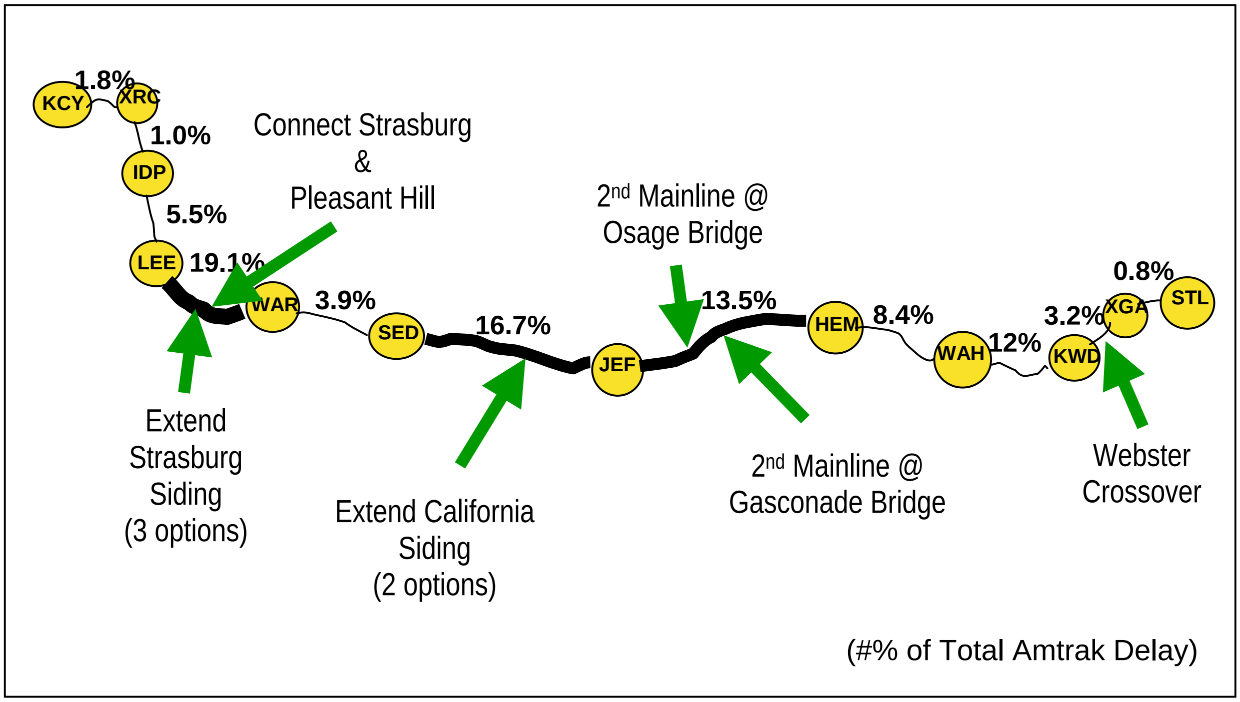
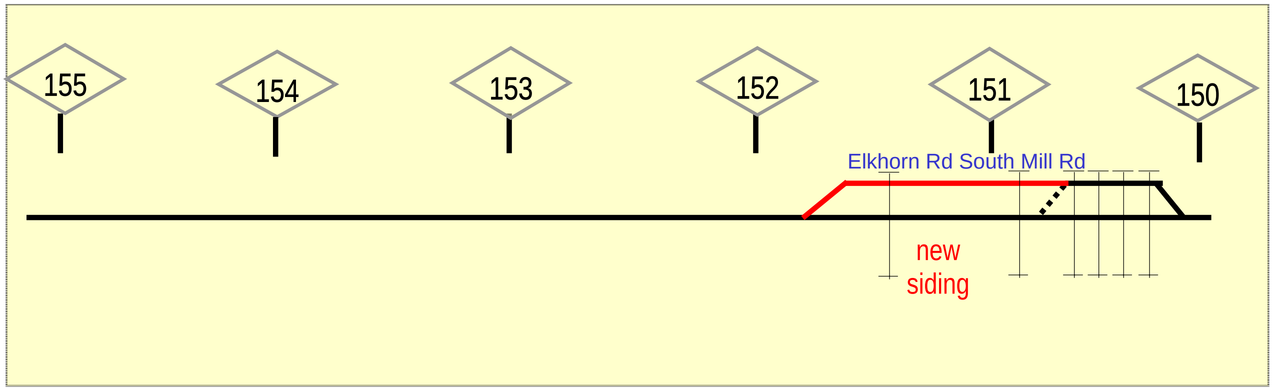


Figure 6: Rail Enhancement Alternatives

S1.1 Extension of Existing California, MO Siding – Alternate #1 (Extension of Siding to West)



Description of Site: The existing siding located at California, MO is located mostly within the city limits. The existing turnouts at each end of the siding are hand thrown #10 turnouts. The existing siding currently crosses three of the five north-south roads located within the main part of the City. These three roads are Williams Street, Oak Street/Missouri Route 87, and East Street. Based on available information, it appears the siding is only about 3,500 foot long total. Other major north-south roads in the vicinity of Oak Street/Missouri Route 87 are South Industrial Drive, located about 0.5 miles to the east, and South Mill Street, located about 0.25 miles to the west. Any extension of the siding in either direction would cross one of these roads.

Scope of Work: Extend existing siding to the west to provide an 8,500 foot long siding.

Assumptions:

1. The existing hand thrown #10 turnouts are in inadequate and require replacement.
2. The existing signals are either inadequate or in the wrong location and require replacement.
3. Assume 25 foot spacing between the siding and the mainline (for the purpose of computing preliminary quantities of work).
4. Since no information is available regarding the limits of existing right-of-way, assume that new right-of-way will be required for the limits of work.

Advantages:

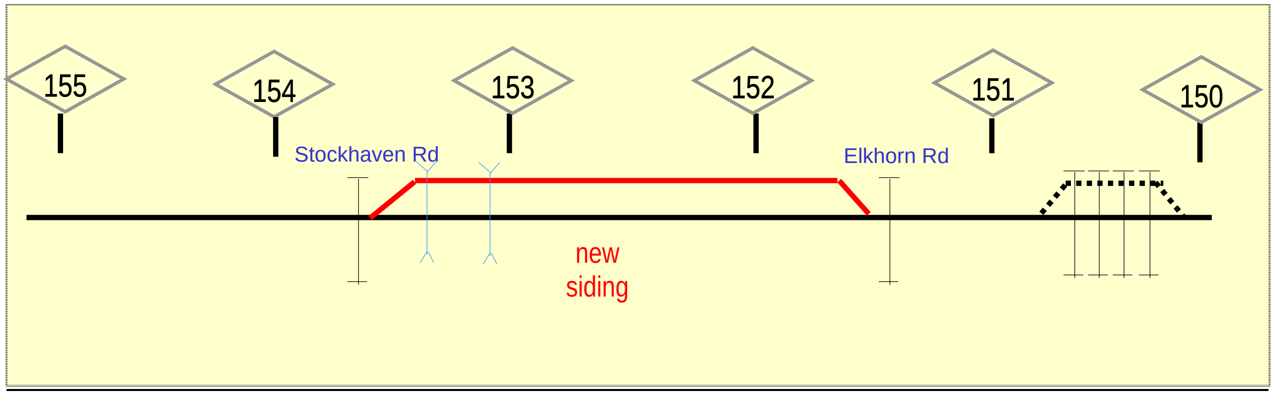
1. Potentially cheaper construction cost.

Disadvantages:

1. Additional grade crossings at South Mill Street and Elkhorn Road could adversely impact traffic flows and emergency response.
2. More potential for land acquisition problems due to the urban nature of the proposed site.

Estimated Project Cost: $2,500,000

S1.2 California, MO Siding – Alternate #2 (New Siding Location)



Description of Site: The existing siding located at California, MO is located mostly within the city limits. The existing turnouts at each end of the siding are hand thrown #10 turnouts. The existing siding currently crosses three of the five north-south roads located within the main part of the City. These three roads are Williams Street, Oak Street/Missouri Route 87, and East Street. Based on available information, it appears the siding is only about 3,500 foot long total. Other major north-south roads in the vicinity of Oak Street/Missouri Route 87 are South Industrial Drive, located about 0.5 miles to the east, and South Mill Street, located about 0.25 miles to the west. Any extension of the siding in either direction would cross one of these roads.

Scope of Work: Because any extension of the existing siding will result in an additional road crossing which would be blocked by a parked train, we recommend a new siding located west of town between Elkhorn Road and Stockhaven Road.

Assumptions:

1. New signals will be required.
2. Assume 25 foot spacing between the siding and the mainline (for the purpose of computing preliminary quantities of work).
3. Since no information is available regarding the limits of existing right-of-way, assume that new right-of-way will be required for the limits of work.

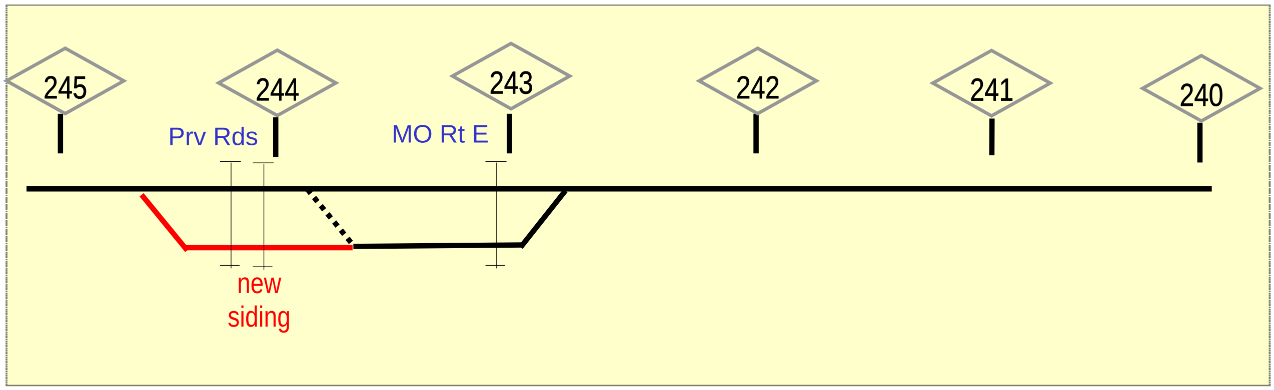
Advantages:

1. The proposed siding will be located between two existing roadways and will not block any roadways.
2. Proposed siding will not adversely impact traffic flow or emergency response. It may actually result in improvements in the City due to the fact that the shorter existing siding likely won’t be used that often.

Disadvantages: 1. Since this siding will be an entirely new siding, construction costs will likely be higher than extending the existing siding.

Estimated Project Cost: $4,000,000

S2.1 Extension of Existing Strasburg, MO Siding – Alternate #1 (Extension of Siding to West)



Description of Site: The existing siding located at Strasburg, MO begins within the city limits and extends approximately 5,000 feet to the west. The existing turnouts at each end of the siding are powered #16 turnouts. The existing siding crosses Missouri Route E near the east end of the existing siding. Based on available information, it appears the siding can only hold about a 4,000 foot long train clear of Missouri Route E. Since this is the only north-south road crossing the tracks in Strasburg, it would be desirable to avoid blocking this crossing with a train parked in the siding.

Scope of Work: Based on the stated desire to have a siding that can hold an 8,500 foot long train, one alternative would be to extend the existing siding to the west to provide an 8,500 foot clear storage length between the proposed west end of the siding and the crossing at Missouri Route E.

Assumptions:

1. Both existing power-operated #16 turnouts are in good condition and are suitable for re-use.
2. The existing signals are in good condition and can be relocated.
3. Assume a 25 foot spacing between the siding and the mainline (for the purpose of computing preliminary quantities of work).
4. Since no information is available regarding the limits of existing right-of-way, assume that new right-of-way will be required for the limits of work.

Advantages:

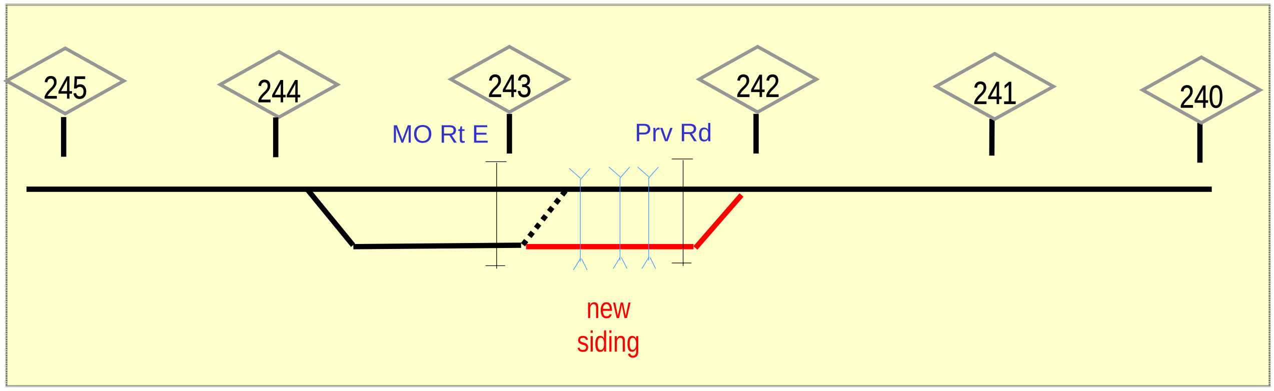
1. Extension of the siding to the west should minimize the cost of the siding extension by utilizing a majority of the existing siding length.
2. If the siding were extended as described above, it would allow an 8,500 foot long train to be parked in the siding without blocking traffic on Missouri Route E, the only north-south road through Strasburg. This would provide significant advantages in terms of traffic flow and emergency response.

Disadvantages:

1. If the siding were extended as described above, it would extend across two private residential access roads. This would likely inhibit the on demand use of their driveway by these residents and could have an impact on emergency response to these residences. (Note that other north-south roads exist and are located 1.3 miles east and 2.1 miles to the west of the crossing at Missouri Route E).

Estimated Project Cost: $2,000,000

S2.2 Extension of Existing Strasburg, MO Siding – Alternate #2A – 8500' Total Length Siding



Description of Site: The existing siding located at Strasburg, MO begins within the city limits and extends approximately 5,000 feet to the west. The existing turnouts at each end of the siding are powered #16 turnouts. The existing siding crosses Missouri Route E near the east end of the existing siding. Based on available information, it appears the siding can only hold about a 4,000 foot long train clear of Missouri Route E. Since this is the only north-south road crossing the tracks in Strasburg, it would be desirable to avoid blocking this crossing with a train parked in the siding.

Scope of Work: Based on the stated desire to have a siding that can hold an 8,500 foot long train, one alternative would be to extend the existing siding to the east to provide an 8,500 foot clear storage length.

Assumptions:

1. Both existing power-operated #16 turnouts are in good condition and are suitable for re-use.
2. The existing signals are in good condition and can be relocated.
3. Assume 25 foot spacing between the siding and the mainline (for the purpose of computing preliminary quantities of work).
4. Since no information is available regarding the limits of existing right-of-way, assume that new right-of-way will be required for the limits of work.

Advantages:

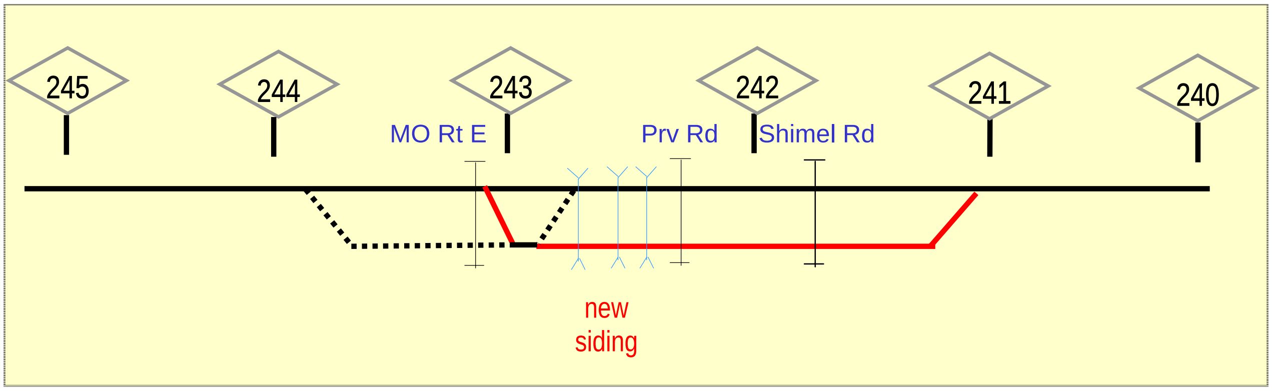
1. If the siding were extended as described above, only one residence (farm) would be affected versus two residences affected by Alternate #1.

Disadvantages:

1. If the siding were extended as described above, it would extend across one private residential access road. This would likely inhibit the on demand use of their driveway by this resident and could have an impact on emergency response to this residence.
2. This alternative would likely result in the crossing at Missouri Route E being blocked more frequently and for longer durations than it is now. This could have a significant impact on emergency response within the Strasburg. (Note that other north-south roads are located about 1.3 miles east and 2.1 miles west of the crossing at Missouri Route E).
3. This alternative would require the construction of three new bridges across Crawford Creek, the West Branch of Crawford Creek, and another unnamed waterway.
4. This alternative will cost more to construct than Alternative #1, primarily due to the three bridges required for this alternative.

Estimated Project Cost: $8,000,000

S2.3 Extension of Existing Strasburg, MO Siding – Alternate #2B – 8500' Total Length Siding (Clear of Missouri Route E)



Description of Site: The existing siding located at Strasburg, MO begins within the city limits and extends approximately 5,000 feet to the west. The existing turnouts at each end of the siding are powered #16 turnouts. The existing siding crosses Missouri Route E near the east end of the existing siding. Based on available information, it appears the siding can only hold about a 4,000 foot long train clear of Missouri Route E. Since this is the only north-south road crossing the tracks in Strasburg, it would be desirable to avoid blocking this crossing with a train parked in the siding.

Scope of Work: Based on the stated desire to have a siding that can hold an 8,500 foot long train, one alternative would be to extend the existing siding to the east to provide an 8,500 foot storage length clear of Missouri Route E

Assumptions:

1. Both existing power-operated #16 turnouts are in good condition and are suitable for re-use.
2. The existing signals are in good condition and can be relocated.
3. Assume 25 foot spacing between the siding and the mainline (for the purpose of computing preliminary quantities of work).
4. Since no information is available regarding the limits of existing right-of-way, assume that new right-of-way will be required for the limits of work.

Advantages:

1. If the siding were extended as described above, only one residence (farm) would be affected versus two residences affected by Alternate #1.
2. This alternative would not block Missouri Route E like Alternate 2A would.

Disadvantages:

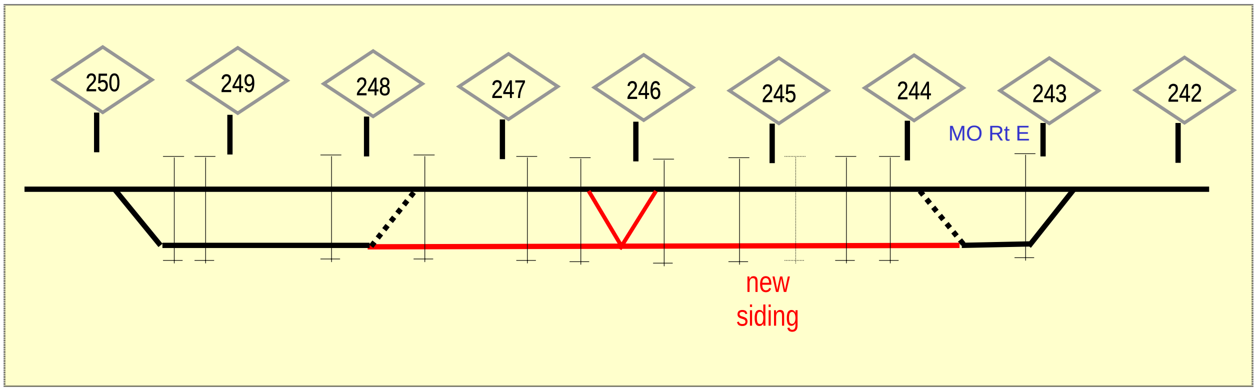
1. If the siding were extended as described above, it would extend across one private residential access road. This would likely

inhibit the on demand use of their driveway by this resident and could have an impact on emergency response to this residence.

2. While this alternative would allow for Missouri Route E to remain unblocked, Shimel Road (another north-south road east of town) would likely be blocked more frequently and for longer durations than it is now.
3. This alternative would require the construction of three new bridges across Crawford Creek, the West Branch of Crawford Creek, and another unnamed waterway.
4. This alternative will cost more to construct than either Alternative #1 or Alternative #2A, primarily due to the three bridges required for this alternative versus Alternative #1 and the additional track construction required for this alternative versus Alternative #2A.

Estimated Project Cost: $10,000,000

S3.1 Connection of Existing Sidings at Pleasant Hill, MO and Strasburg, MO



Description of Sites: The existing siding located at Strasburg, MO begins within the city limits and extends approximately 5,000 feet to the west. The existing turnouts at each end of the siding are powered #16 turnouts. The existing siding crosses Missouri Route E near the east end of the existing siding. Based on available information, it appears the siding can only hold about a 4,000 foot long train clear of Missouri Route E.

The existing siding located at Pleasant Hill, MO is located within the city limits and is about 10,000 feet long. The existing mainline turnouts are #20 power operated turnouts. The siding crosses Walker Street/Missouri Route 7, Commercial Street, and Wyoming Street. Additionally, within its length, there are two short spur tracks and a wye connection to the MNA Railroad.

Scope of Work: Due to the fairly close proximity of these two sidings (about 4 miles apart), extend a siding between them to connect the two sidings together creating a 7 mile double track with a universal cross over in the middle.

Assumptions:

1. The existing power operated turnouts at the near ends of the sidings are suitable for removal and re-use elsewhere.
2. The existing power operated turnouts at the far ends of the sidings are in good condition and suitable for re-use.
3. The existing signals are at the far ends of the sidings and within the length of the proposed siding extension are in good condition and are suitable for re-use.
4. Assume 25 foot spacing between the siding and the mainline (for the purpose of computing preliminary quantities of work).
5. Since no information is available regarding the limits of existing right-of-way, assume that new right-of-way will be required for the limits of work.

Advantages:

1. Extremely long siding that has the capability to either operate as a 7 mile section of double track or to store numerous 8,500 foot long trains.

Disadvantages:

1. Potentially high construction cost.
2. Additional grade crossings will be required at 4 private residential access roads and at 4 public roadways (Karg Road, Francy Road, Rodgers Road, and Beattie Road). This could affect traffic flows and emergency response if numerous long trains are parked in the siding blocking numerous grade crossings at any one time.

Estimated Project Cost: $10,500,000

S4.0 California Siding-Alternate #2 (New Siding Location) and Extension of Existing Strasburg, MO Siding – Alternate #2B

Scope of Work: A combination of alternatives S1.2 and S2.3.

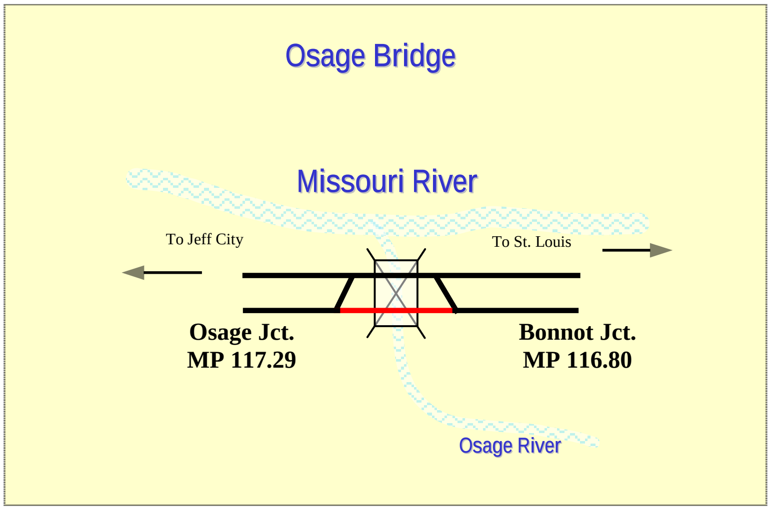
Estimated Project Cost: $14,000,000

S5.0 California Siding-Alternate #2 (New Siding Location) and Connection of Existing Sidings at Pleasant Hill, MO and Strasburg, MO

Scope of Work: A combination of alternatives S1.2 and S3.1.

Estimated Project Cost: $14,500,000

J1.1 Proposed 2nd Mainline at Osage City, MO, including Bridge over Osage River – Alternate #1 (New Bridge) (Union Pacific 2007 Capacity Plan)



Description of Site: The Union Pacific Railroad has a single mainline bridge across the Osage River near Osage City, MO. The existing bridge is 1,166 feet long and consists of the following span arrangement (west to east): an 80 foot deck plate girder span, 5 spans of through plate girders totaling 769 feet, a 100 foot through truss span, a 158 foot through girder span, and a 59 foot deck plate girder span. The Osage River at this location is considered to be a navigable waterway. Additionally, based on the current (2005) FEMA Flood Insurance Study compared to information contained on the UPRR track charts and a USGS benchmark located on the bridge, it appears the bridge may be drawn incorrectly on the flood profile drawing (bridge likely should be drawn at a higher vertical elevation than currently shown).

Scope of Work: Construct a new bridge utilizing the same span types and arrangements as the existing bridge.

Assumptions:

1. Due to the fact that the Osage River at this location is navigable, we assume that the United States Army Corps of Engineers and the Missouri Department of Natural Resources will require the proposed bridge utilize a similar span arrangement as the existing bridge.
2. We assume the existing bridge is hydraulically adequate and is constructed at a suitable elevation. We also assume the proposed bridge would be constructed at a similar elevation as the existing bridge. We also assume the United States Army Corps of Engineers and the Missouri Department of Natural Resources would permit such a bridge to be constructed.

Advantages: 1. A new superstructure would be designed in accordance with current loading and fatigue requirements. Thus, it should have a more certain service life.

Disadvantages: 1. This alternative would likely cost more to construct that the cost of Alternate #2.

Estimated Project Cost: $28,000,000

J1.2 Proposed 2nd Mainline at Osage, MO, including Bridge over Osage River – Alternate #2 (New Foundations with Use of Existing Truss Superstructure from Bridge over Missouri River at Boonville, MO) (Union Pacific 2006 Capacity Plan)

Description of Site: The Union Pacific Railroad has a single mainline bridge across the Osage River near Osage City, MO. The existing bridge is 1,166 feet long and consists of the following span arrangement (west to east): an 80 foot deck plate girder span, 5 spans of through plate girders totaling 769 feet, a 100 foot through truss span, a 158 foot through girder span, and a 59 foot deck plate girder span. The Osage River at this location is considered to be a navigable waterway. Additionally, based on the current (2005) FEMA Flood Insurance Study compared to information contained on the UPRR track charts and a USGS benchmark located on the bridge, it appears the bridge may be drawn incorrectly on the flood profile drawing (bridge likely should be drawn at a higher vertical elevation than currently shown).

Scope of Work: Based on stated desire of Union Pacific Railroad per their 2006 Capacity Plan for the Central Region, construct new foundations to support the existing truss spans to be removed from the former MKT Railroad Bridge over the Missouri River at Boonville, MO. This bridge has four through truss spans that could be utilized. Based on available information, their spans lengths are three spans of 300 feet and one span of 247 feet.

Assumptions:

1. Assume the existing truss spans are in good condition and are suitable for re-use at the new location with minor rehabilitation and painting.
2. Assume this plan would be approved by applicable permitting agencies.

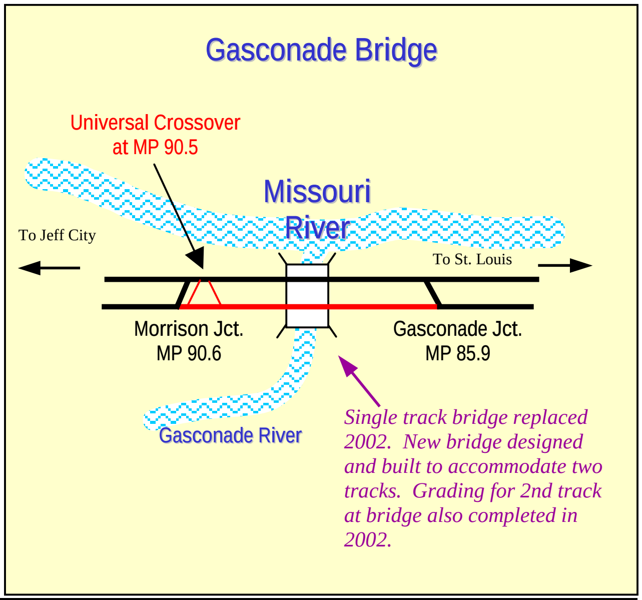
Advantages: 1. Suspect this plan would be less expensive than the cost of building a new bridge at this location.

Disadvantages: 1. Re-use of an existing superstructure that was originally built in 1932 and was last used in 1986 reduces remaining service life.

2. It is possible that the trusses could be damaged during removal, transport, or re-installation.

Estimated Project Cost: $15,000,000

J2.1 Add Second Main Track to Gasconade Bridge (Union Pacific 2006 Capacity Plan)



Single track bridge replaced 2002. New bridge designed and built to accommodate two tracks. Grading for 2nd track at bridge also completed in 2002.

Scope of Work: Based on the Union Pacific Railroad's 2006 Capacity Plan for the Central Region, the proposed scope of work includes:

- Construct a second main line across Gasconade River
- Construct 4.5 miles second main track along existing right of way
- Add universal crossover at MP 90.5; distance between crossovers 18.2 miles - future project to add crossover near MP 82.0
- Added superstructure for double-track bridge completed in 2002

Assumptions: 1. Since this project is already identified in the Union Pacific Railroad's 2006 Capacity Plan, assume that the needed right-of-way for this project already exists.

Advantages:

1. Eliminate train delay caused by single track bottlenecks over bridges
2. Reduce need to fleet trains in order to accommodate Amtrak
3. Increase maintenance of way flexibility by adding crossovers

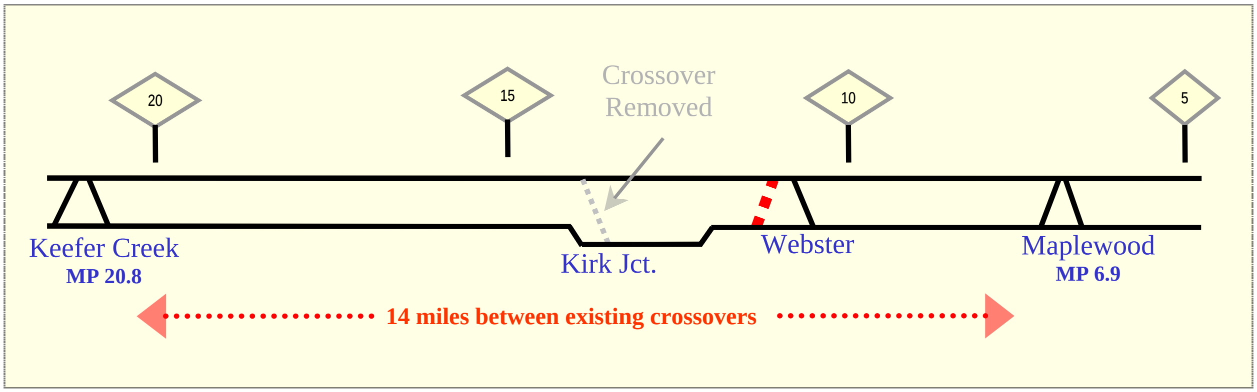
Estimated Project Cost: $21,000,000 (UP 2006 Estimate)

J3.0 Proposed 2nd Mainline at Osage City, MO, including Bridge over Osage River and Add Second Main Track to Gasconade Bridge (Union Pacific 2006 Capacity Plan)

Scope of Work: A combination of alternatives J1.1 and J2.1.

Estimated Project Cost: $36,000,000 (Combined Hanson-Wilson and UP 2006 Estimate)

J4.0 Complete Webster Crossover (Union Pacific 2006 Capacity Plan)



Scope of Work: Based on the Union Pacific Railroad’s 2006 Capacity Plan for the Central Region, the proposed scope of work includes constructing a LH crossover completing the universal crossover at Webster – MP 10.75 and removing the crossover at Kirkwood Junction.

Assumptions:

1. Since this project is already identified in the Union Pacific Railroad’s 2006 Capacity Plan, we assume that the needed right-of-way for this project already exists.

Advantages:

1. Increase ability to sort trains into and out of St. Louis Terminal.
2. Facilitate maintenance access to either main line between Keefer Creek and Maplewood.

Estimated Project Cost: $2,500,000 (UP 2006 Estimate)

5.4 Rail Enhancement Alternative Analysis

The rail alternatives were analyzed by simulating the reduction in overall time for a train to traverse between St. Louis and Kansas City, accounting for both eastbound and westbound trains and coal trains that traverse a portion of the distance between the two cities. The 2005 train volume (approximately 53 freight trains and 4 passenger trains per day) and mix (approximately 7% passenger, 43% commodity, and 50% inter-modal / manifest) was used as the basis of the analysis (note: increased train volume scenarios were analyzed but the results proved to reinforce the recommendations that are made). The model was developed using Rockwell Automation's Arena simulation modeling software (Kelton et al. 2007). Figure 7 shows the animation developed for the simulation model. The following will provide a brief description of the model assumptions, followed by the results obtained (further detail on the model can be found in Appendix E).

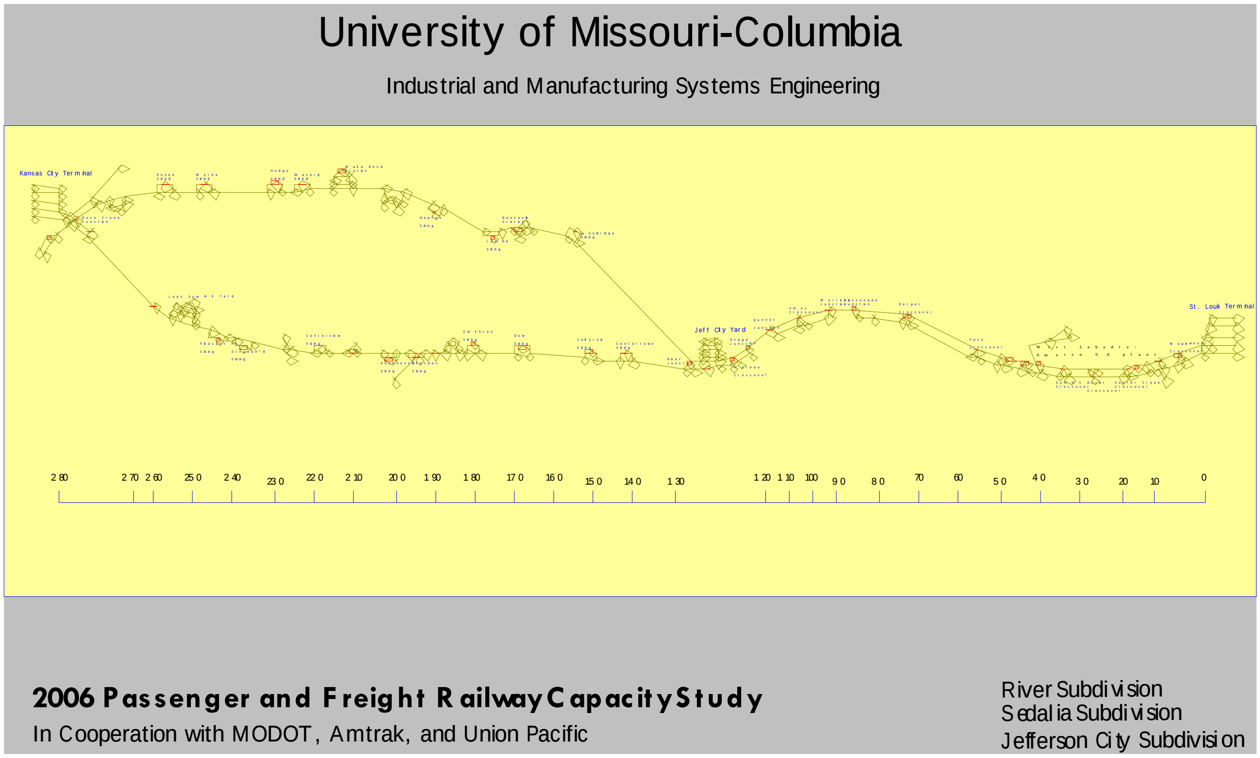


Figure 7 – Arena Animation for Rail Simulation Model

5.4.1 Base Case Simulation Model Description

Traffic originating in St. Louis

Westbound freight and coal trains enter the system directly on main line #1 at milepost 0. Westbound Amtrak trains enter the Jefferson City subdivision from a link off the main line #1 at milepost 2.3 from the North, which represents the track that Amtrak currently uses to arrive and depart its depot. Once westbound traffic has started traveling on main track #1, it continues along main track #1 until westbound Amtrak reaches the Kirkwood depot, which lies on main track #1. When Amtrak trains are stopped at the depot for a passenger load/unload delay, freight trains will back up behind the Amtrak train. Following the Kirkwood station, westbound traffic travels along main track #1 until it reaches the crossover directly east of the West Labadie Power Plant.

Eastbound coal trains that need to enter the West Labadie coal-fired power plant take the nearest crossover to the West Labadie exit and enter via an opposing directional track. To avoid head-on collisions, westbound trains are held at the intersection preceding the exit along main line #1, Summit Crossover, and wait for the track to be clear of opposing directional traffic. Once track is clear of east-bound traffic along main track #1, west-bound traffic continues along track #1 towards Washington, MO. At Washington, west-bound Amtrak must stop to load/unload passengers at an Amtrak depot. During this event, other westbound traffic is stopped behind the Amtrak train until it continues its westward travel. From Washington, westbound traffic continues towards the Gasconade Bridge.

The one-track Gasconade River bridge segment is approximately 4.5 miles long. East of the Gasconade Bridge, westbound Amtrak trains need to use main track #2 to access the Hermann Amtrak station for load/unload. Therefore, Amtrak trains wait for track #2 to clear of eastbound traffic. Once clear, Amtrak switches to track #2 and proceeds to the Hermann Amtrak depot. Here Amtrak loads/unloads passengers and attempts to use the one-track Gasconade Bridge. To keep eastbound trains from colliding with the westbound Amtrak, there is a holding point at the control point preceding the bridge to the west that require the eastbound trains to wait for all links on main track #2 to show no westbound traffic. Westbound freight and coal trains proceed directly along main track #1 until they reach a control point prior to the one-track bridge segment. At this point, the simulation model treats the bridge as a single resource that must be obtained by a train before traversing the segment. This process requires all trains needing to traverse the bridge to request the resource in the order of arrival to the intersection immediately preceding the bridge. The bridge queue is processed on a first-in, first-out basis, except for Amtrak which are given priority over freight trains and immediately jump to the front of the queue and are granted access to the single-track segment.

After westbound traffic has traversed the one-track gasconade bridge segment, trains proceed along main track #1 until they approach the Osage bridge. The segment of single track with bi-directional traffic at the Osage Bridge is only 0.5 miles in length. Due to the short length of this segment slightly different logic is used. Trains are held at the intersections preceding the bridge in both directions. If a segment shows a certain direction of flow, opposing traffic is required to hold until the traffic from the other direction is finished. Once westbound traffic travels across the Osage Bridge, trains proceed towards Jefferson City along main track #1.

From the Osage River Bridge, westbound traffic proceeds along main track #1 through the Jefferson City yard area until it reaches the River Junction. However, west-bound traffic must hold near the Jefferson City yard in case when approaching eastbound traffic along the River Subdivision or eastbound Amtrak traffic along the Sedalia subdivision is close. When track is clear until the Centertown Siding along the Sedalia subdivision, west-bound freight and coal traffic proceeds to River Junction and uses a crossover at that junction to switch to main track #2, which immediately splits and becomes the Sedalia subdivision.

Following the Osage Bridge, Westbound Amtrak trains travel along main track #1 until they reach the Moreau crossover. At this point they check for eastbound Amtrak, freight, and coal trains along main track #2. Once clear, westbound Amtrak switch to the lower main track #2 and proceed to the Amtrak depot for passenger load/unload at the Jefferson City depot. After the stop, Amtrak proceeds west onto the Sedalia subdivision and arrives at the Centertown siding, where it checks for approaching eastbound Amtrak trains. If clear, it proceeds to the next siding west of Centertown.

The control of opposing traffic along a single track requires a fairly complex process using sidings. When an eastbound Amtrak train is initiated, a variable is set to 1 that indicates to all trains along the Sedalia subdivision that an opposing Amtrak train is approaching in due time. At this point, all westbound freight trains are required to space themselves out by at least the distance between sidings. This is done by stopping a freight train at the eastern intersection of a siding location. The freight train is held until the following two or more segments are clear of traffic. After waiting for clear segments of like-directional traffic, the freight train then checks for upcoming Amtrak traffic that has already passed the next available siding. If the Amtrak train is in close proximity, the freight train proceeds into the siding to let the Amtrak train pass. The majority of sidings are large enough to accommodate freight trains. However, in the case where the siding is not big enough to accommodate freight train lengths, the freight train will wait for the Amtrak train to use the siding, after which the freight train will continue. Once the Amtrak train has gone onto a siding and the freight train has passed, the Amtrak train proceeds back on the main line. Any subsequent freight trains will be held at the next siding to allow the Amtrak to continue to pass. This is done to ensure that eastbound Amtrak has absolute priority.

The logic given above addresses both the congestion that tends to occur in the areas with long distances between sidings (caused by eastbound Amtrak trains meeting westbound freight trains) and the congestion in the area immediately west of Jefferson City (caused by eastbound and westbound Amtrak trains crossing paths). Once the eastbound Amtrak train has completed its travel across the Sedalia subdivision, it resets the value of the eastbound control variable to 0. After the eastbound control variable has been reset, all westbound traffic travels uninterrupted in the Sedalia subdivision. However, delays for westbound freight are still caused by westbound Amtrak trains at Amtrak depots along the main line.

At milepost 271.3, westbound Amtrak trains use main track #1 to proceed to the Independence, MO Amtrak depot for passenger load/unload. After leaving the Independence Amtrak depot, westbound trains proceed to the Rock Creek Junction. At this point they switch to a track that travels south to the Kansas City Union Station. After reaching the Kansas City Union Station and incurring a delay for passenger load/unload, westbound Amtrak trains leave the model, recording the entire trip time from St. Louis to Kansas City. Westbound freight and coal trains split onto main track #2 before Independence and travel uninterrupted until they leave the model in the Kansas City terminal area, recording their trip time.

Trains originating in Kansas City

In the Kansas City area, there are three main lines that converge at Rock Creek Junction and then diverge eastbound on two lines. Eastbound Amtrak starts on the southernmost track in Kansas City, which represents the current location of Kansas City Union Station Amtrak depot. From there, eastbound Amtrak travels to Rock Creek Junction and proceeds onto the Sedalia subdivision on the top track, because Independence Amtrak depot is located on main track #1. Eastbound freight and coal traffic begins from the upper main track in Kansas City.

From Kansas City, eastbound freight trains switch onto BNSF/UP track and travel north to the River subdivision. Once arriving to the River subdivision at milepost 436.5, trains switch onto the River subdivision and proceed towards Jefferson City. In our model, these trains travel uninterrupted for the entire duration and follow the speed restrictions set by Union Pacific and/or Federal regulations.

Eastbound freight and coal traffic arrive at the River Junction in Jefferson City, Missouri from the River subdivision. Before reaching River Junction, traffic holds for any westbound traffic along main track #1 switching to the Sedalia subdivision at River Junction and westbound Amtrak along main track #2 at or near the Amtrak depot. Once clear, eastbound freight and coal traffic switches track at River Junction and proceeds east along main track #2 until reaching the Osage Bridge.

From Kansas City, eastbound Amtrak trains travel along the single-track Sedalia subdivision and are given priority. The model logic is explained in the previous description for westbound traffic. Eastbound Amtrak arrive to main track #2 from the Sedalia subdivision after holding at Centertown siding for west-bound traffic. Once in Jefferson City, eastbound Amtrak proceed to the Amtrak depot situated on main track #2. After load/unload at the depot, eastbound Amtrak stay on main track #2 and proceed to the Osage Junction and wait for the bridge to become available.

Eastbound freight and coal traffic arrive at the River Junction in Jefferson City, Missouri from the River Subdivision. Before reaching River Junction, traffic holds for any westbound traffic along main track #1 switching to the Sedalia subdivision at River Junction and westbound Amtrak along main track #2 at or near the Amtrak depot. Once clear, eastbound freight and coal traffic switches track at River Junction and proceeds east along main track #2 until reaching the Osage Bridge.

At a control point west of the Osage bridge, eastbound traffic waits for the opportunity to pass along the one-track segment. Once the track is clear ahead, eastbound trains cross the bridge, switch back to main track #2, and proceed to the Gasconade Bridge segment. Preceding the Gasconade Bridge, eastbound trains enter the “queue” and await access to the bridge. To safeguard from eastbound trains colliding with the westbound Amtrak along the single-track segment, there are hold modules at the intersection preceding the bridge that require the eastbound trains to wait for all links on main track #2 to have a status showing no westbound traffic. Once eastbound traffic has crossed the Gasconade bridge, they switch onto main track #2 and proceed east.

At Hermann Amtrak depot, eastbound Amtrak trains are delayed for load/unload and any other eastbound traffic behind must hold as well. After eastbound Amtrak is finished at Hermann, all traffic continues east until Washington, Missouri. At this point, eastbound Amtrak must switch to main track #1 to reach the Amtrak depot on opposite track. Because Amtrak trains have priority over freight, freight trains are held at an intersection preceding the crossover that the Amtrak needs to use to switch back to the proper directional track. In this case, the control point east of Washington is 34.8, West Labadie. No trains use crossovers to pass Amtrak trains on opposing directional links, because there are high amounts of freight travel along each main track. Any switching of tracks will cause congestion and complicate the task of dispatching and controlling the logic for train travel along this subdivision. Once finished at Washington, eastbound Amtrak uses the Southpoint crossover to switch onto main track #2 where it meets other eastbound traffic traveling towards West Labadie.

Often eastbound trains carry coal to the West Labadie Coal Plant. These eastbound coal trains enter track #1 from Southpoint crossover and enter the spur that stems off the main tracks. As soon as the transporter enters the West Labadie loop off the main network it records trip length. Freight or coal trains that do not need to enter the West Labadie coal plant continue traveling along main track #2 towards St. Louis. However, eastbound Amtrak trains must switch track once more at Kiefer Creek crossover to access the Kirkwood Amtrak depot for passenger load/unload. Once again, westbound traffic must be held at a control point east of Kirkwood, particularly Webster station. When finished in Kirkwood, eastbound Amtrak trains switch back to main track #2 at Kirkwood crossover and continue towards the St. Louis terminal.

In St. Louis, eastbound freight and coal traffic continue along main track #2 until they reach the end of the model. At Milepost 0, they record trip length and leave the model. Eastbound trains switch onto Main track #1 briefly until they arrive at an outlet track at milepost 2.2 that leads to St. Louis Union Station. At St. Louis Union Station, Amtrak incurs a load/unload delay, records trip length and leaves the model.

Base Case Model Validation

The simulation model was designed to capture the steady state passenger train operation on the STL-KC rail corridor; therefore, after a warm-up period of 24 hours, five independent replications of 31 days were run in order to obtain statistically valid results. These results were then compared to the 2005 actual average time for all passenger trains (scheduled time + average delay). It was found that the simulated time for a passenger train to traverse the state was within 1.2% of the 2005 actual time, therefore, it was concluded that the simulation model was sufficiently capturing the congestion related delays in the system.

5.4.2 Alternative Descriptions

1 - Second Osage Bridge Track

In the case of the two tracks across the Osage River, westbound freight, coal, and Amtrak traffic remains on main track #1 from the Gasconade Bridge to the Jefferson City area. Eastbound trains along the Jefferson City subdivision travel on the lower main track #2 and travel westbound until they reach the Gasconade Bridge.

2 - Second Gasconade Bridge Track

In the case of the two tracks across the Gasconade River, westbound trains remain on main track #1 arriving from the east. However, westbound Amtrak continues to use the Berger crossover to travel along main track #2 towards the Hermann Amtrak station. The Amtrak trains hold at Berger until the track is clear to travel west. Eastbound trains along the Jefferson City subdivision travel on the lower main track #2 until they reach the bridge, where they may wait for a westbound Amtrak train at the Hermann depot to switch back to main track #1. Once clear, the eastbound traffic will continue east over the Gasconade Bridge. Eastbound Amtrak also uses the Hermann Amtrak depot for load/unload.

3 - Webster Crossover

Currently, there are parallel crossovers on the Jefferson City subdivision near Kirkwood Junction and Webster. Union Pacific has proposed that the Kirkwood crossover be removed and the Webster crossover be made a universal crossover. This is proposed to help sequence trains arriving and departing the St. Louis terminal. In the event that the crossover near to Kirkwood Amtrak station is removed and placed at MP 10.8, this requires eastbound Amtrak to travel longer on main track #1, with opposing traffic approaching. Therefore, westbound traffic must hold at Maplewood crossover for eastbound Amtrak to use the new universal crossover to return to main track #2.

4 - Restore/Extend California Siding to Accommodate Freight

The California Siding is not used in the base model. In this alternative, it is restored and extends between Dow and Centertown to accommodate westbound freight when the eastbound Amtrak train is on the Sedalia line. The logic of using this siding is the same as most of the sidings along the Sedalia subdivision.

5 - Extend Strasburg Siding to Accommodate Freight

Currently the Strasburg Siding is too short to accommodate freight trains, so it is used for the eastbound Amtrak when meeting westbound trains. The Strasburg siding is extended and allows westbound freight to enter and wait until eastbound Amtrak trains pass the Strasburg station.

6 - Connect Strasburg and Pleasant Hill Sidings

Due to the fact that the Strasburg siding is currently too short to accommodate freight or coal traffic and Pleasant Hill Siding is within 5 miles west, the possibility of connecting the two to make approximately a 7 mile long stretch of dual track is examined. Amtrak uses the original line in both directions, while westbound freight uses the second track. From the delay data it was found that the track segment from Lee’s Summit to Warrensburg includes the most delay time. Allowing freight and coal to use a considerably long siding (i.e. double track) to meet and pass on-coming eastbound Amtrak should decrease delay. The stretch of double track can fit up to 4 long trains, which allows more freight to continue west instead of spacing them out to all sidings when on-coming Amtrak trains approach.

7 - Restore/Extend California Siding and Extend Strasburg Siding to Accommodate Freight

Changes are made in both California Siding and Strasburg Siding as described above. This alternative combines the logic in both sidings.

8 - Restore/Extend California Siding and Connect Strasburg and Pleasant Hill Sidings

Changes are made in both California Siding and Connecting Strasburg/Pleasant Hill Siding as described above. This alternative combines the logic in both sidings.

9 - Dual Track from Lee’s Summit Siding to Jefferson City

All existing sidings within the Sedalia subdivision from Lee’s Summit Siding to Jefferson City are connected, thus building a second track for freight trains. The westbound freight trains use this second line and both the eastbound and westbound Amtrak trains keep using the original main track since they must stop at the Amtrak depots.

10 - Baseline Scenario: Dual Track from Lee's Summit to Jefferson City and both Bridges

This alternative includes the logic changes for both dual track on the Sedalia subdivision and creating dual track over both Gasconade and Osage Bridge.

5.5. Rail Enhancement Simulation Results

The following presents and discusses the simulation results for each rail enhancement alternative. For this study a performance baseline is assumed based on the scenario where all track from STL to KC is double track (implying that the Sedalia subdivision is improved by double tracking it and both the Gasconade and Osage bridges are double track). The results are given with respect to two criteria: 1) the alternatives overall percentage delay reduction with respect to the baseline scenario for both freight and passenger trains, and 2) the alternatives number of Amtrak FTI/PTI (Freight Train Interference and Passenger Train Interference) delay minutes that are recovered for a specific track segment. Table 4 summarizes all of the results.

Table 4 – Simulation Results

	Overall % Reduction in Delay		Amtrak Line Segment Results	
	Union Pacific	Amtrak	Minutes currently lost due to FTI/PTI delay	Minutes recovered by Alternative
Sedalia Subdivision Alternatives				
S1 - Extend California Siding	5.9%	15.9%	11.3	8.5
S2 - Extend Strasburg Siding Freight	8.3%	8.5%	10.2	4.5
S3 - Connect Strasburg & Pleasant Hill Sidings	0.1%	11.7%	10.2	6.3
S4 - Both Extend California Siding & Extend Strasburg Siding for Freight	12.6%	12.3%	21.7	6.6
S5 - Both Extend California Siding & Connect Strasburg & Pleasant Hill Sidings	7.3%	23.5%	21.7	12.7
Double Track LEE_JEF	20.6%	28.2%	24.0	15.1
Jefferson City Subdivision Alternatives				
J1 - Osage Bridge 2nd Mainline	17.5%	9.0%	6.2	4.8
J2 - Gasconade Bridge 2nd Mainline	18.7%	5.5%	6.2	2.9
J3 - Gasconade/Osage Bridges 2nd Mainlines	27.4%	4.0%	6.2	2.2
J4 - Webster Crossover	20.0%	1.4%	1.7	0.7

Examining the results in Table 4 reveals two major trends: 1) Sedalia subdivision alternatives provide more relative benefit with respect to reducing overall delay for Amtrak passenger trains (average benefit of Sedalia sub alternatives for Amtrak is 14.4% vs. 6.8% for UP), and 2) Jefferson City subdivision alternatives provide more relative benefit for UP freight trains (average benefit of Jeff City sub alternatives for UP is 20.9% vs. 5.0% for Amtrak). The alternatives for each subdivision that provide the most benefit is S5 (extending California siding and connecting Strasburg-Pleasant Hill sidings) for the Sedalia subdivision with 23.5% and J3 (adding second track to both Gasconade and Osage bridges) for the Jefferson City subdivision with 27.4%.

A further observation can be made concerning the number of Amtrak delay minutes that are recovered for a given track segment. In each subdivision there is an alternative that recovers a significant percentage of the overall FTI/PTI delay. For the Sedalia subdivision it is alternative S1 (Extend California Siding) which provides a 75% recovery of the 11.3 minutes that are lost in the Sedalia-Jefferson City track segment. For the Jefferson City subdivision it is alternative J1 which provides a 77% recovery of the 6.2 minutes that are lost on the Jefferson City-Herman track segment.

5.6 Rail Enhancement Alternative Economic Analysis

Based on the results of the simulation analysis and the cost estimates for each rail enhancement alternative a dominance curve can be constructed that illustrates the economic/performance dominance for given alternatives for both Union Pacific freight and Amtrak passenger train service. Figures 8 and 9 provide the dominance curves for Union Pacific and Amtrak, respectively.

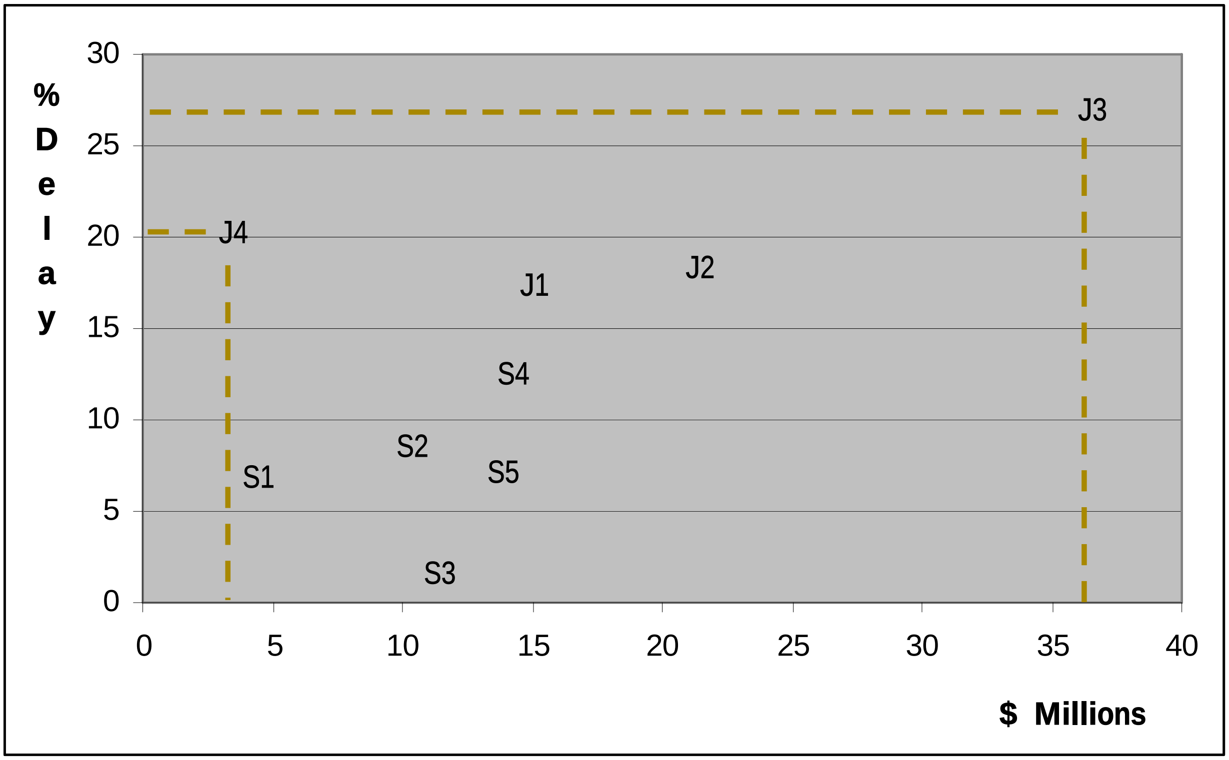


Figure 8 - Union Pacific Percentage Delay Reduction vs. Cost ($M)

In figure 8 alternatives J4 and J3 define the economic/performance dominance curve. This implies that both J4 and J3 provide the greatest reduction in overall Union Pacific delay with the least total cost. This does not mean that other alternatives might not be desirable. For instance, in the case of figure 8 alternatives J1 and J2 both provide a significant reduction in delay at a far less cost than alterative J3. In fact, from a marginal cost to benefit perspective they would be preferred (as will be discussed in the following section with respect to Table 5). A further observation regarding figure 8 is that all Sedalia subdivision alternatives (S1-S5) are dominated by Jefferson City subdivision alternatives from Union Pacific's economic/performance perspective.

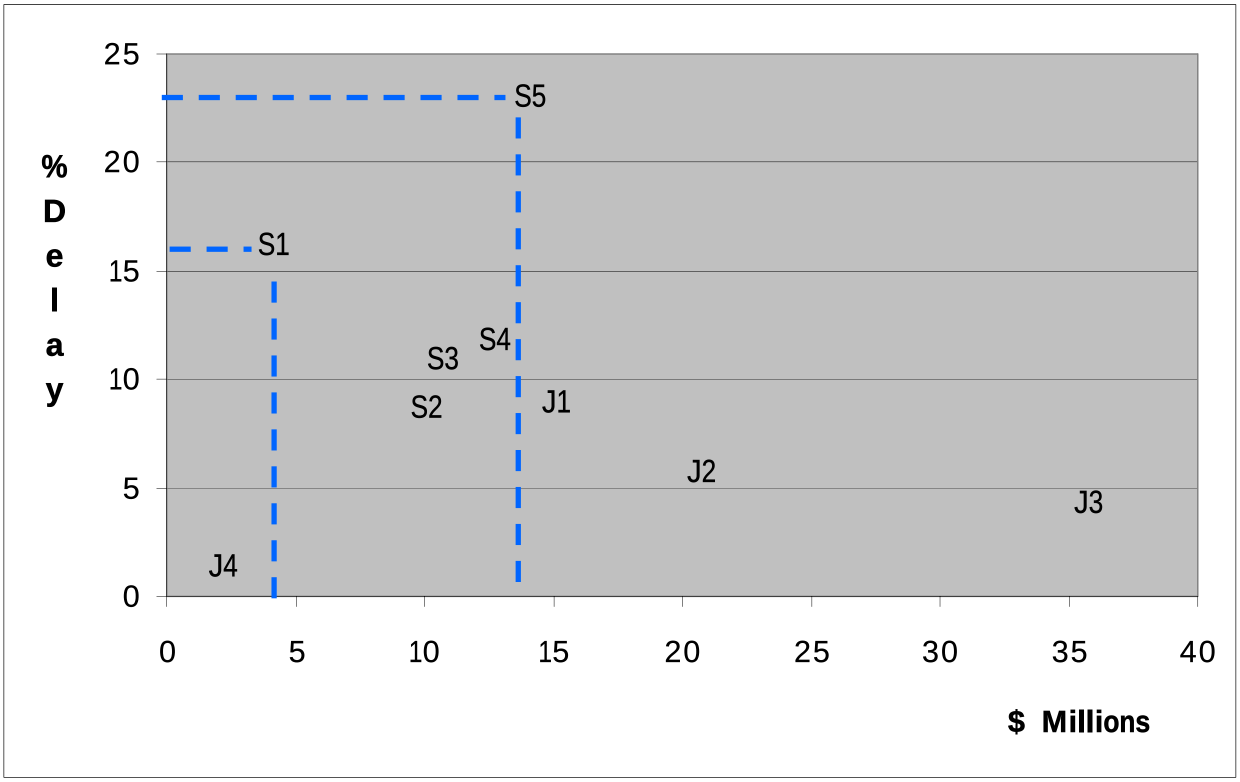


Figure 9 - Amtrak Percentage Delay Reduction vs. Cost ($M)

In figure 9 alternatives S1 and S5 define the economic/performance dominance curve and provide the greatest reduction in overall Amtrak delay with the least total cost. In this case these two alternatives also provide the greatest marginal cost to benefit. It again can be observed in figure 9 is that all Jefferson City subdivision alternatives (J1-J4) are dominated by Sedalia subdivision alternatives from Amtrak's economic/performance perspective.

Table 5 provides a marginal analysis of each of the rail enhancement alternatives for both Union Pacific freight and Amtrak passenger rail service with respect to the percentage of delay reduction per million dollars of estimated project cost. Note that the cost used in the analysis is the underlined cost for each alternative (multiple cost for each alternative reflect the different options given in the previous section of the report).

Table 5 – Marginal Analysis Comparison of Alternatives

	% UP Delay Savings / $M	**% Amtrak Delay Savings / $M**	**Cost in Millions**
Sedalia Subdivision Alternatives			
S1 - Extend California Siding	1.48	3.97	4 or 2.5
S2 - Extend Strasburg Siding Freight	0.83	0.85	10 or 8 or 2
S3 - Connect Strasburg & Pleasant Hill Sidings	0.01	1.12	10.5
S4 - Both Extend California Siding & Extend Strasburg Siding for Freight	0.90	0.88	14 or 12.5 or 12 or 10.5 or 6.5 or 4.5
S5 - Both Extend California Siding & Connect Strasburg & Pleasant Hill Sidings	0.50	1.62	14.5 or 13
Double Track LEE_JEF (130 miles)	0.08	0.11	260
Jefferson City Subdivision Alternatives			
J1 - Osage Bridge	1.16	0.60	15 or 28
J2 - Gasconade Bridge	0.89	0.26	21
J3 - Gasconade/Osage Bridges	0.76	0.11	36 or 49
J4 - Webster Crossover	8.00	0.56	2.5

Given that the objective is to maximize the Delay Savings / $M, several values in table 5 are highlighted and warrant further discussion.

In the Sedalia subdivision alternative S1 (Extend California Siding) clearly dominates all other alternatives as it provides significant benefit with respect to the project cost for both freight and passenger operations. Alternatives S4 and S5 also merit further consideration as they both provide relatively strong benefit; however, S5 tends to provide more benefit to passenger rail service. Alternative S2 is not recommended for further consideration as it is slightly dominated by alternative S4.

In the Jefferson City subdivision alternative J4 clearly dominates all other alternatives as it provides a very significant benefit for freight rail operations and a sufficient relative benefit for passenger rail operations. Alternative J1 should also be considered as it provides a significant benefit for both freight and passenger rail operations.

6.0 RECOMMENDATIONS

Based on the analysis conducted this study makes the following recommendations to be implemented in the order listed below:

1. (S1) Extend California Siding- Alternative 2
   Project cost estimate = $4 million
2. (S3/S5) Connect Strasburg and Pleasant Hill Sidings
   Project cost estimate = $10.5 million
3. (J1) 2nd Mainline on Osage Bridge
   Project cost estimate = $15-28 million
   (UP already completing Gasconade Bridge)

Recommendation 1 is based on the fact that extending the California siding is the lowest cost alternative considered, yet provides a significant reduction in overall delay for both passenger and freight rail operations.

Recommendation 2 would be the next phase in improving the Sedalia subdivision as it provides a significant amount of additional double track that could be operated as either a extended siding for multiple freight trains or just a segment of double track where trains from different directions could pass.

Recommendation 3 provides a significant delay reduction impact for the Jefferson City subdivision and is the only recommendation for the Jefferson City subdivision due to the fact that based on information obtain during this project it was found that alternative J4 has already been implemented and alternative J2 is currently being implement, therefore they do not require any investment to complete.

Finally, apart from the simulation and data analysis that formed the basis of this project, the Theory of Constraints – Current Reality Tree highlighted the fact that the current Union Pacific Maintenance processes warrant further analysis as they could provide reduction in overall passenger train delay performance without significant investment (especially given the small percentage of scheduled passenger rail trains on the STL-KC corridor). Therefore, it is recommended that the,

   a) scheduling of routine and major maintenance windows, and
   b) scheduling of signal and track inspections,

be further analyzed with respect to overall system delay performance.

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APPENDIX A – Work Plan

Missouri Freight and Passenger Rail Capacity Analysis

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Statement of Work and Approach

1) Project Objective

To develop a prioritized list of rail enhancements that addresses current passenger and freight rail capacity on the Union Pacific line from St. Louis to Kansas City in order to improve on-time passenger service and lesson freight delays.

2) Project Rationale

A key performance measure for MoDOT is to provide expanded opportunities in Multi-Modal access and Mobility. Specific performance measurement areas related to this proposal that have been addressed in the MoDOT Tracker system include: 1) partnering with others to deliver transportation services, 2) efficient movement of goods and 3) easily accessible modal choices. One specific performance measure related to this project is the "Number of Rail Passengers". In general, this measure has been relatively constant over the past 4 years, with a potential increase noted recently. However, Missouri operates at only 40-45% the level for state sponsored trains when compared with Washington State's data which is the benchmark state system identified in Tracker. The MoDOT objectives must also be considered with respect to the Midwest Regional Rail Initiative's (MWRRI) (together with the Midwest Interstate Passenger Rail Commission) economic objectives. The MWRRI goal is for the St. Louis to Kansas City portion of the Midwest Regional Railroad System (MWRRS) to increase from 2 to 6 daily Round Trips and for One Way trip times to decrease from 5.66 to 4.25 hours.

Though there is a significant amount of knowledge and expertise available for the design and analysis of specific rail capacity projects, it is crucial prior to embarking on a specific capacity improvement project to ensure that an integrated systems view of the passenger and freight rail system is obtained. Therefore, this project proposes to consider the MoDOT Tracker criteria and MWRRI objectives/economic criteria as input to a system engineering analysis aimed at improving overall rail system capacity and performance.

3) Research Questions:

- What is the passenger / freight capacity of the Kansas City to St. Louis rail corridor?
- What rail system improvements are needed to ensure adequate current and future capacity?
- What relatively low-to-medium-cost solutions can significantly improve existing capacity?
- In the long term, what major improvements will be needed to accommodate growth of both passenger and freight rail?

4) Project Approach / Methodology

4.1 A Theory of Constraints based approach to Capacity Analysis

The Theory of Constraints (TOC) is a systems analysis approach developed by E. M. Goldratt (1992). It is based on the fact that in a complex system at any point in time, there is most often only one component of that system that is limiting its ability to achieve more of its goal. For the system to attain any significant improvement that constraint must be identified and the whole system must be managed with respect to it. The TOC approach provides the ability to support the development of breakthrough solutions based on the premise that all systemic conflicts that inhibit action are the result of unexamined assumptions that can be identified and corrected in order to deliver real benefits in terms of increased capacity or cost savings.

TOC, taken as a whole, provides an integrated problem-solving methodology that addresses not only the construction of solutions, but also the communication and collaboration required for a successful implementation. The TOC approach to system performance improvement includes:

1. Identification and prioritization of system constraints.
2. Analysis on how to exploit the system's constraints.
3. Subordination of everything else to the results in Step 2.
4. Elevation of the system's constraints.
5. Return to Step 1 to find next constraint that is limiting system performance.

A railway can be viewed as a system with a number of bottlenecks, capacity restrictions or constraints. However, in railway operations planning it is not always clear which is the constraint, as there are often a number of bottlenecks that appear to be constraints. Therefore, we need to model each of the possible constraints to establish which is the most severely constrained and thus the constraint that determines the capacity of the whole system. Since TOC identifies the most constrained part of the network one of the strengths of it is that it facilitates the rapid elimination of large numbers of options. Then more time can be spent on developing options that have a chance of succeeding. Therefore, TOC is a pragmatic approach to analyzing the capacity constraints on the rail infrastructure.

4.2 Capacity Modeling Approach

When modeling capacity it is important to consider the key factor that impacts overall system performance: variability. Too often capacity analysis occurs from a deterministic perspective and the curse of variability is not addressed (Parkinson and Fisher, 1996; Krueger, 1999). In a railroad scenario this would include variability due to passenger and freight loading time, train length, train speed, track congestion, etc. (Chen and Shi, 2003). The modeling approach proposed would utilize TOC to identify the constraints limiting performance and a simulation-based candidate analysis to examine alternatives to improving overall capacity (Weigel, 1994; Dalal and Jensen, 2001). What is not being proposed is to use a detailed, deterministic, control-oriented simulation model such as the Rail Traffic Controller (Berkeley Simulation) due to the fact that it is quite expensive and its ability to consider system variability is questionable.

4.3 Economic Analysis of Capacity Improvement Alternatives

All viable capacity enhancements will be evaluated to ensure that the economic/financial aspects of the enhancements are consistent with the MWRRI objectives.

5) Workplan and Schedule (with project team responsibilities)

Task 1 (Months 1-2) – Assessment (MU / Hanson-Wilson)
Assess Kansas City – St. Louis Union Pacific rail line constraints / variability associated with passenger / freight flow.

Task 2 (Months 2-3) – Model Development (MU)
Develop capacity / variability analysis model required to explore constraints.

Task 3 (Months 3 - 4) – (Hanson-Wilson / MU)
Generate set of rail enhancements that would increase overall rail capacity.

Task 4 (Months 4 -5) – Alternative Analysis (MU / Hanson-Wilson)
Conduct capacity enhancement analysis with respect to performance and economic criteria and generate prioritized list with respect to MoDOT and MWRRI objectives.

Task 5 (Months 5 - 6) – Final Report (MU)
Write final project report and present results to MoDOT.

6) Project Deliverables

1. Analysis of current capacity.
2. Integrated set of results with respect to MoDOT's Tracker objectives and MWRRI's objectives / economics analysis.
3. Prioritized list of rail enhancements to improve on-time passenger service and reduce freight delays.
4. Final report and presentation.

Key Project Personnel

Phillip E. Borrowman, PE, SE
Hanson-Wilson Inc
Kansas City, MO

References

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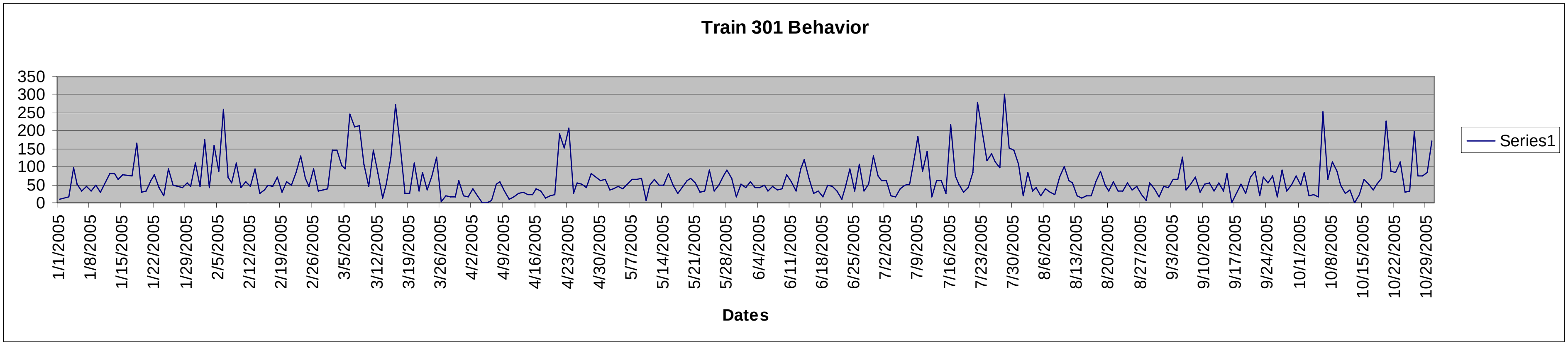
Appendix B - AMTRAK DELAY REPORT CODES

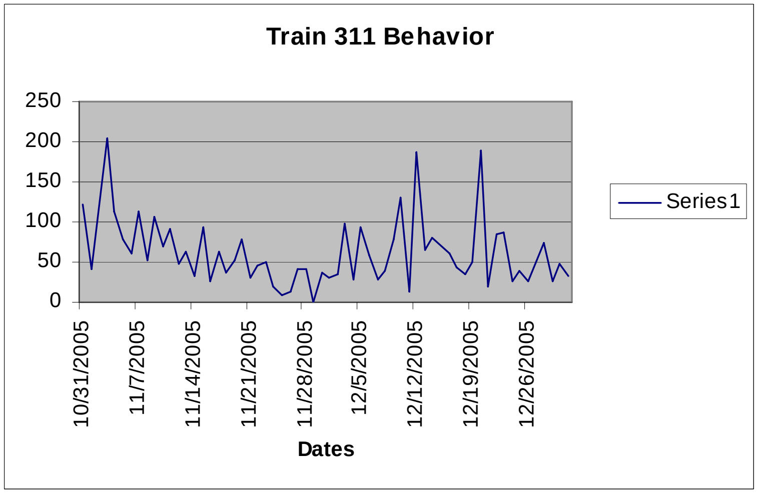
CODE:	EXPLANATION OR EXAMPLES:
ADA	Passenger-Related delays specifically related to disabled passengers (wheelchair lifts, exercising guide dogs, etc.)
CAR	Car Failure (includes HEP failure, legitimate HBD or DED actuations, set out / pick up defective / repaired cars)
CON	Hold for Connection (holds for train or bus connections, including en-route holds; includes connection delay at Initial Terminal)
CTI	Commuter Train Interference (meets, overtakes)
CUI	Customs and Immigration
DBS	Debris Strike (emergency braking, damage, set-outs from same; also debris blocking track ahead)
DCS	Signal Delays (false wayside detector actuations, defective road crossing protection, bad wayside or cab signals from unknown cause or from signal, power-switch or CTC system failure, efficiency tests of the crew; drawbridge stuck open)
DMW	M/W Work (holding for defect repair or M/W forces to clear; inability to contact M/W Foreman on radio; routed around the M/W work.)
DSR	Temporary Speed Restrictions (slow orders, slows through M of W site)
DTR	Detour Delays (**all** delay or time lost while operating on a detour, regardless of cause)
ENG	Engine Failure (HEP failure, HBD or DED actuations, cab signal failure on engine, set out / pick up defective / repaired engines, operating with freight engine, undesired emergency applications, air problems)
FTI	Freight Train Interference (meets / overtakes, bad signals known to be caused by freight trains, holds due to freight derailments, non-scheduled stop to pick-up/drop-off freight train crew)
HLD	Passenger-Related (multiple spots, checked bags, smoke breaks, disorderly, any other passenger-related delay; except for disabled passengers, see delay code "ADA".)
INJ	Injury Delays (injured or sick passenger or employee)
ITE	Initial Terminal Delay -- Engineering Causes (track, signals, M of W work, etc.)
I T I	Initial Terminal Delay -- Late-Arriving Inbound Train (causing late release of equipment or late crew rest -- if mechan.-failure delay is **not** involved)
ITM	Initial Terminal Delay -- Mechanical Failure (car or locomotive)
ITT	Initial Terminal Delay -- Transportation (eg., freight / passenger / commuter-train interfer., dispatching-related, late bulletins, etc.)
MBO	Drawbridge openings for marine traffic. (Note: replaces code "DBB" which is no longer used.)
NOD	Wait for time at station, kill time to prevent early arrival at station.
OTH	Miscellaneous (unable to make normal speed, heavy train, engine(s) isolated for fuel conservation, person pulling emergency cord)
POL	Police Related (DEA; police / fire department holds on right-of-way, bomb threat delays)
PTI	Passenger Train Interference (meets, etc. - does *not* include commuter trains)
RTE	Routing (crossover moves, lining manual or spring switch, run via siding, late track bulletins, inability to contact DS, dispatcher holds)
SVS	Servicing (fuel, water, toilet / trash dumping, inspection; switching private/ office, express cars, or section of train, **normal** engine change)
SYS	System (late crew, unscheduled re-crew, lone engineer copying authorities or restroom break, hold due to passenger train derailment; alleged crew rules violation; delayed-in-block after station stop)
TRS	Trespasser Incidents (includes crossing accidents, trespasser or animal strikes, vehicle on track ahead; "near-miss" delays; bridge strikes by vehicles or boats)
WTR	Weather (includes heat / cold orders, floods, washouts and detours around same; earthquake related delays; also, autumn-leaf-caused delays such as slippery rail due to wet leaves or burning leaves caught in truck of car)

Appendix C - 2005 Amtrak Delay Summary

			Westbound		Eastbound		Overall						
From	**To**	Miles	# Delays	Total Minutes	# Delays	Total Minutes	# Delays	Total Minutes	Percent	Average Delay per Train (min)	% Delay per mile	FTI&PTI Delay minutes	FTI&PTI %
STL	XGA	1.8	45	684	45	224	90	908	0.85%	0.62	0.55%	0.29	0.67%
XGA	KWD	11.1	107	1026	311	2380	418	3406	3.19%	2.33	0.33%	1.66	3.79%
KWD	WAH	46.7	744	5793	890	7075	1634	12868	12.05%	8.81	0.30%	3.79	8.67%
WAH	HEM	29.3	591	4485	629	4516	1220	9001	8.43%	6.17	0.33%	2.71	6.21%
HEM	JEF	44.5	909	7666	804	6732	1713	14398	13.48%	9.86	0.35%	6.21	14.22%
JEF	SED	61.8	685	8251	844	9753	1529	18004	16.86%	12.33	0.32%	11.34	25.97%
SED	WAR	29.5	121	1005	368	3203	489	4208	3.94%	2.88	0.15%	2.48	5.67%
WAR	LEE	40.6	711	5337	1426	15107	2137	20444	19.14%	14.00	0.55%	10.22	23.40%
LEE	IDP	15.2	221	3889	135	1981	356	5870	5.50%	4.02	0.42%	3.62	8.28%
IDP	XRC	3.7	101	1055	16	58	117	1113	1.04%	0.76	0.33%	0.70	1.61%
XRC	KCY	6.1	83	541	158	1357	241	1898	1.78%	1.30	0.34%	0.66	1.52%
	From-To Totals	290.3	4318	39732	5626	52386	9944	92118	86.25%	63.09		43.69	
At Station													
STL							93	2490	2.33%	1.71			
XGA							164	1456	1.36%	1.00			
KWD							140	431	0.40%	0.30			
WAH							253	803	0.75%	0.55			
HEM							209	783	0.73%	0.54			
JEF							286	1664	1.56%	1.14			
SED							177	336	0.31%	0.23			
WAR							199	660	0.62%	0.45			
LEE							287	628	0.59%	0.43			
IDP							70	172	0.16%	0.12			
XRC							154	2093	1.96%	1.43			
KCY							143	3175	2.97%	2.17			
						Station Totals	2082	12201	11.42%	8.36			
					OVERALL TOTAL			106809	100.00%	73.16			

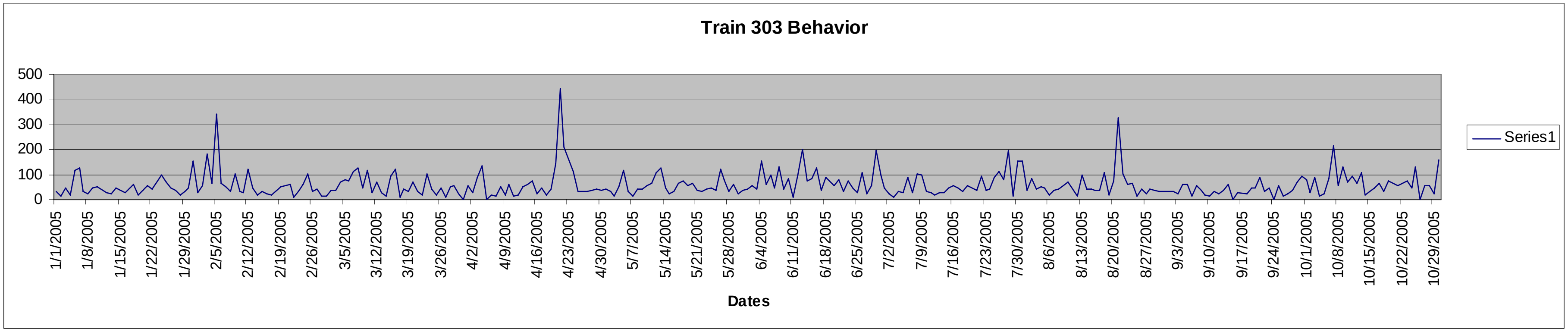
Appendix D - Analysis of Delay by Train

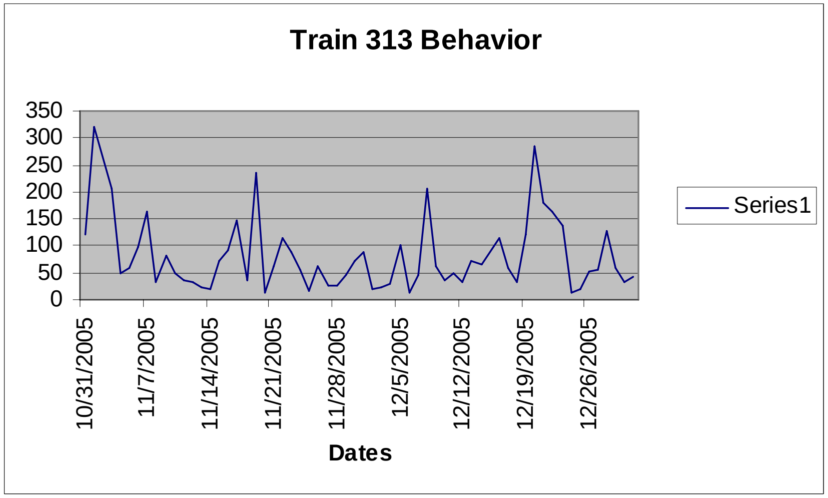




Train 301 became train 311.

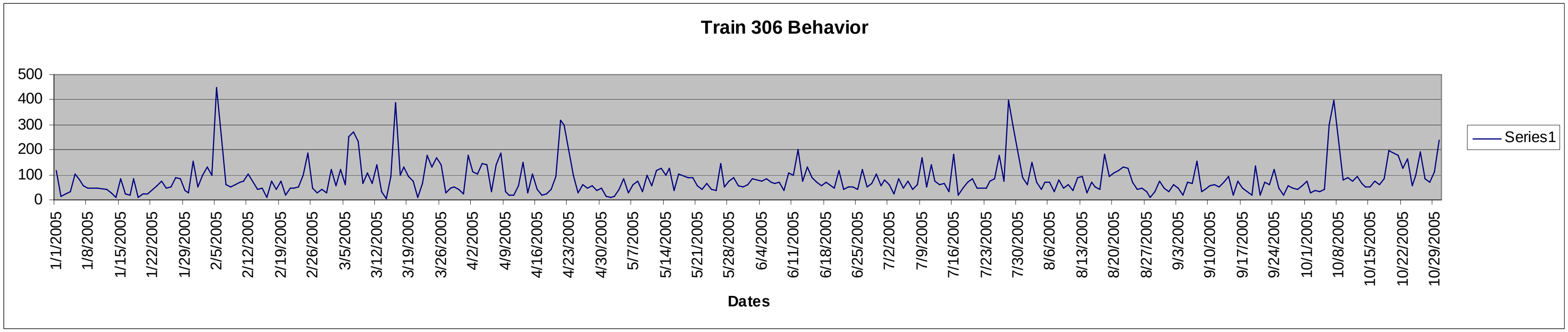
Periods with high delays (minutes lost for each train at the same line): End of January to Beginning of February; March; April 20$^{\text{th's}}$; July; October; and December.

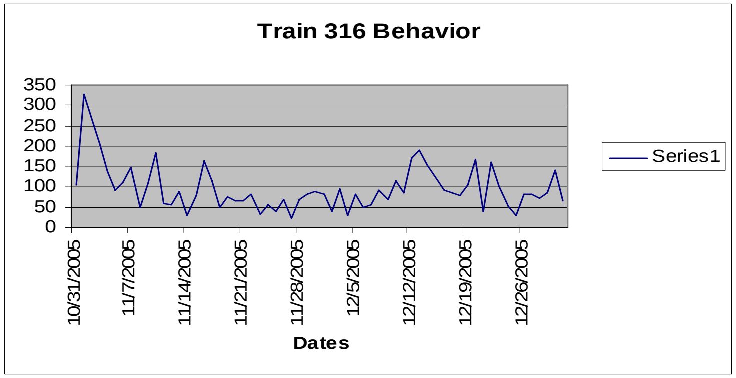




Train 313 replaced train 303.

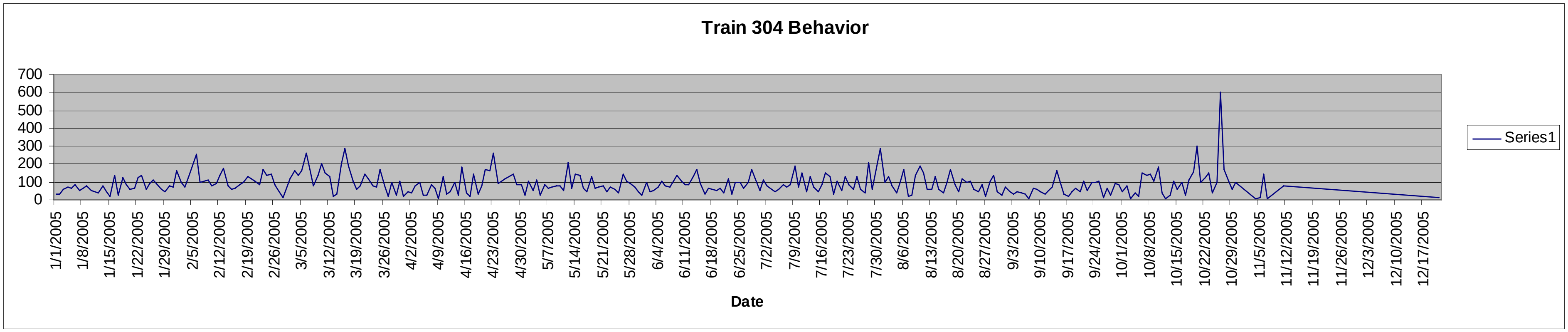
Periods with high delays (minutes lost for each train at the same line): End of January to Beginning of February; April 20$^{\text{th's}}$; August 20$^{\text{th's}}$; and from October to December.





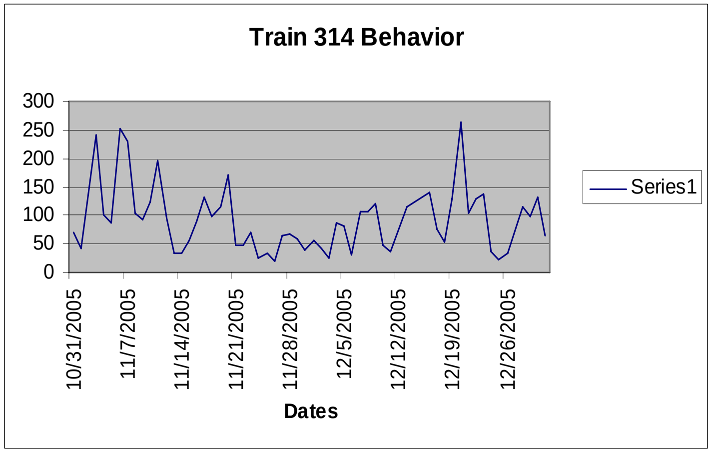
Train 316 replaced train 306.

Periods with high delays (minutes lost for each train at the same line): Beginning of February; Between March and April; at the end of July; beginning of October and end of October.



Periods with high delays (minutes lost for the train): Middle of January to middle of February; end of February to middle of March; middle of April to end of April; middle of May to end of May; beginning of July to end of August; beginning of October to beginning of November.

Train 314 replaced train 304. (there is something that does not match since Train 304 keeps data for those days)



Periods with high delays (minutes lost for the train): Beginning of November to middle of November; and middle of December.

APPENDIX E – General Description of the Rail Simulation Model

Guided Transporters

The basis of the simulation model of this rail corridor is the guided transporter. At each terminal operation, an entity (or train type) is created following a probabilistic inter-arrival rate and requests a guided transporter, which has associated with it a length (in generic units), default velocity, and acceleration/deceleration rate. The transporters then follow a path defined by nodes and arcs connected between two nodes. When an entity is created, it requests the transporter that resides at the closest proximity in the model to the terminal.

Network Links and Networks

Guided transporters travel along pre-set networks of arcs connected by nodes. The arcs are defined as Network Links and have a length and associated direction that describes the angle between two links. In the model, the first step is to choose and define the important control points or nodes and the links connecting nodes. Network links can be defined as bidirectional or one-way, but are always only one transporter unit wide. This implies transporters cannot pass at any point in the middle of a link. To avoid deadlock, node specific logic is developed based on each unique combination of siding, track, and depot configurations.

Transport Modules

As entities travel through and finish model logic they come to transport modules which tell the transporter the direction to travel next. Within this module it is necessary to specify what transporter is controlled, the destination intersection or station of the transporter, and the velocity at which the transporter travels. This velocity take precedence over the default velocity specified when defining the transporter.

Model Assumptions and Logic:

Terminal Operations

There are many activities occurring within the Saint Louis and Kansas City terminal operations. Based on factors such as load importance, train crew age, or train destination, trains can be sequenced before entering the terminal areas or held for long periods of time within terminal yards. All terminal operations are capture in this model by the arrival parameters used. That is, inter-arrival times of trains follow a probability distribution and account implicitly for the sequencing, congestion, and dispatching behavior of the terminals.

Priority

As provided by Union Pacific, there are approximately six levels of priority for trains on the Saint Louis-Kansas City corridor. Priority is based on a function of crew age, type of train, destination location, and other factors. However, in this modeling effort it was decided to generalize priority to be solely determined by train type. Currently there are more than fifteen different types of trains that travel the route, but priority was generalized by the most prominent train types. Furthermore, priority did not affect the simulation for like-directional trains because overtaking like-directional trains was not allowed. Therefore, priority is only taken as a significant issue for Passenger trains, as they are given the highest priority by Union Pacific and are the only type of train that travels against opposing traffic. The following train types are shown with their respective priority. In the model, we created these different trains to represent the priority levels.

Priority / Transporter	Train types
1 / Amtrak Train	Passenger Train
2 / Train 2	Z-Inter-modal
3 / Train 3	K-Inter-modal, Q-Priority Manifest, N-Double Stack, I-Inter-modal , A-Automobile
4 / Train 4	M-Manifest
5 / Train 5	Commodity: O-Ore, G-Grain, R-Rock
5 / Coal Train	C-Coal

Parameters:

Input/Arrivals

Train inter-arrival rates were approximated from historical data in order to most accurately reflect the behavior of the real system. Therefore, all Union Pacific train data between STL and KC for 2005 was analyzed. The time interval between arrivals for all train priority types were analyzed using Arena's Input Analyzer to fit a probability distribution to the inter-arrival times. The following chart shows the input distributions and parameters for each train type used in the model.

Train Type	Input Distribution (min)
Westbound Amtrak	24 hours at 7:30 AM , 2:30 PM
WB Train 2	Gamma (115, 1.45) + 1
WB Train 3	Gamma (605, .895) + 12
WB Train 5	Exponential (146) + 1
WB Coal Train	Described under next heading
Eastbound Amtrak	24 hours at 7:30 AM , 4:30 PM
EB Train 2	Normal (1050, 731)
EB Train 3	Exponential (132)
EB Train 4	Weibull (801,1.44)
EB Train 5	Exponential (99.2)
EB Coal Train	Described under next heading

West Labadie Coal Plant

Based upon data supplied by Union Pacific, the percentage of coal traffic was approximated for that which originates from the Kansas City terminal and exits the Jefferson City subdivision at MP 43.3, the location of an Ameren UE Corporation coal plant in West Labadie, Missouri. Conversely, the rate at which trains exit this plant and travel back to the Kansas City terminal were approximated. The data shows that, on average, 15 percent of all commodity trains enter the West Labadie plant. The exit rate of trains leaving this plant was approximated based on the historical data and Arena's Input Analyzer was used to determine that the departure rate can be approximated as a Weibull distribution with a mean value of inter-departure time of 939 minutes and an offset value of 16 minutes.

Amtrak stations stop times

Delay times at the various Amtrak depots along both the Sedalia subdivision and Jefferson City subdivision were approximated using 2005 delay data supplied by Amtrak. The following chart shows the various stops traveling from Saint Louis to Kansas City and the associated delay times.

STATION	Delay Distribution (min)
Saint Louis Station	Uniform (5,8)
Kirkwood Station	Uniform (3,6)
Washington Station	Uniform (0,3)
Hermann Station	Uniform (0,3)
Jefferson City Station	Uniform (3,6)
Sedalia Station	Uniform (0,3)
Warrensburg Station	Uniform (0,3)
Lee's Summit Station	Uniform (0,3)
Independence Station	Uniform (0,3)
Kansas City Station	Uniform (5,8)

Transporter Sizes

Most sidings on the Sedalia subdivision are large enough to accommodate freight trains up to approximately 8000 feet in length (except for the California siding). Therefore, size was not found to affect the model and therefore was abstracted to a common value for all trains, except for passenger trains.

Replication Parameters

The model does not take long to reach steady state operation, therefore, the base model and all alternatives were run with 5 replications of 31 days to create a large sample size of possible events. Each replication includes an initial 24 hours of warm-up to load the system and reach steady state.

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