

**STRATEGIES FOR REDUCED EFFECTS OF
DEMAND VARIABILITY IN RAIL FREIGHT
TRANSPORTATION
A SIMULATION STUDY**

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ABSTRACT

Transport demand uncertainties obstruct rail freight operators from accurately planning and dimensioning their service networks. As a consequence, operators establish service agreements with their customers specifying the commitment from the customer to ship a minimum volume during a pre-specified time period. However, these agreements seldom specify variability restrictions on a daily or weekly basis.

This paper has the purpose of introducing a volume variation allowance policy (VVA-policy) which explicitly specifies how much the demand is allowed to vary to meet the service agreement. In co-operation with the Swedish rail freight operator Green Cargo, we also make an assessment of the impact of this VVA-policy using a simulation based approach with real data. Three main performance measures are adopted; train fill rates, shunting yard work load, and transport lead times.

Achieved results do overall indicate on variability reductions both in terms of train fill rates and shunting yard activities and also reductions in transportation lead times. We argue that the reductions are of such magnitude that increased tactical planning capabilities are reachable.

This paper is limited to a single transportation relation and adopts a full deployment of the suggested VVA-policy. Since customer acceptance is a critical success factor, adjustments of variability allowance levels is a requirement for practical implementations. Future research directions involve investigating e.g. customer acceptance levels, the possibility of resource elimination and externalities following similar policy deployments.

In contrast to previous contributions this paper solely addresses effects of reduced demand variability from the perspective of the rail freight operator.

Keywords: Rail freight transportation, tactical planning, demand uncertainty, simulation.

1. INTRODUCTION

The strong dependency between economic growth and transportation is well-known and the fluctuations in trade can create a sudden increased or decreased demand for transportation. Typical examples are the demand for transportation of raw material such as iron ore, timber, and oil. These uncertainties in transport demand is something all transport operators need to consider to some extent. In addition to trade-dependent, larger fluctuations, transport operators are also subject to daily variations of which some they are bound to accommodate. This is in particular a challenge considering the rail freight carload service segment, where the demand tends to vary on a *day-of-the-week* basis (see e.g. Ireland et al., 2004, Swan and Tyworth, 2001 and Kraft, 1995). Since railway freight systems are based on complex consolidation schemes involving several customers and shunting activities, larger variations make it difficult for the operator to make best use of its resources.

In order to cope with such demand variations, it is common today that rail freight operator's establish service agreements with their customers. These agreements specify the commitment from the customer to ship a minimum volume during a pre-specified time period, while the operator assures it can accommodate also a certain increased transport demand. For the operator, the natural objective is to reduce the overall demand variability while maintaining agreed service levels. However, these agreements seldom specify levels of allowed demand variability on a daily or weekly basis. As pointed out by Swan and Tyworth (2001), finding ways to reduce variability in railway freight transport demand is therefore an important step towards enhanced planning capabilities for the operators.

This paper addresses the issue concerned with railway freight transport demand variability in the railway carload service segment and the consequential challenge to make best use of the transport system resources. In contrast to the majority of previous contributions which focuses on service reliability and service quality of railway freight transportation (e.g. Keaton, 1991; Kraft, 1995; Swan and Tyworth, 2001) and minimum order quantity commitments in supply chain contexts (e.g. Bassok and Anupindi, 1997; Tsay and Lovejoy, 1999; Chen and Krass, 2001; Lim et al., 2006), this paper addresses the issue of demand variability solely from a railway freight planning perspective. We introduce a Volume Variation Allowance policy (VVA-policy), which dictates a minimum expected transport demand. In contrast to similar commitments outlined in previous contributions, the VVA-policy is defined on a daily-basis, and also entails how much the demand imposed by the particular customer is allowed to increase to meet the service agreement (i.e. the policy specifies both a minimum and maximum demand restriction). In co-operation with the Swedish rail freight operator Green Cargo, we also make an assessment of the impact of this VVA-policy using three main performance measures; train fill rates, shunting yard work load, and transport lead times. This is done using a simulation based approach along with historical transport demand data provided by Green Cargo.

In the next chapter we provide a presentation of the context where this problem is occurring, which then is followed by a brief overview of related work. In Chapter 4, the objectives of the policy assessment and the simulation study are outlined, while Chapter 5 presents the results from this study along with discussions. Finally, in Chapter 6 we present concluding remarks and pinpoint interesting directions for future research.

2. RAILWAY FREIGHT TRANSPORTATION

A railway freight transport system can be seen as a *service network* based on an infrastructure of interconnected railway lines and terminals. The terminals represent nodes in the network in terms of major shunting yards and local yards. These terminals provide the critical consolidation and split-up functionality of the service network. Between the terminals, there are scheduled train services with limited capacity in terms of length and weight, and these services operate according to a predefined timetable. A train is composed of a locomotive, serving as the powering unit, to which railway cars (i.e. wagons) and corresponding loading units are attached to carry the freight.

2.1. The Rail Freight Planning and Distribution Process

The complexity of planning and scheduling railway freight operations has led to the development of a sequential and iterative planning process (Ireland, 2004). In literature the process has been well described, see e.g. Ahuja et al. (2005) for a comprehensive introduction.

The planning process is based on forecasts of future demand and is divided in four planning stages in which the following are defined; (A) *blocking plan*, (B) *timetable*, (C) *train schedule* and (D) *crew schedule*. The *blocking plan* specifies how the different shipments (based on a forecasted demand) should be grouped into *blocks* depending on their origin and destination. The *timetable* is then constructed to specify train departures for these blocks and the *train schedule* to assign operational resources to each of the departures. In the final stage, the crew that is required to operate the trains is assigned resulting in a *crew schedule*. Together, these four elements constitute the operating plan (a.k.a. production- alt. master plan).

An alternative approach to scheduled rail freight services where the trains only are allowed to depart according to their predefined slot (independent of if they are fully loaded or not), is the North-American tonnage-based approach. In the tonnage-based approach, the trains depart only when they have been sufficiently loaded (Cordeau et al. 1998). If the trains are not loaded with enough freight when they are supposed to depart, their departure will be postponed or even cancelled. The tonnage-based approach is obviously more flexible by operations and can handle temporary demand fluctuations, though, the approach may on the other hand also result in a relatively low service reliability towards customers (Ireland, 2004).

In Sweden, the railway traffic administration and dispatching is handled by the rail authority and since the market is deregulated, a timetable for all operators (freight and passenger traffic) is defined approximately one year in advance. The slots provided dictates when the freight train can depart, though in reality trains may depart ahead of schedule if they are already fully loaded and if the responsible dispatcher permits. In such situations, the train is only given way during its trip if surrounding traffic is unaffected.

After the operating plan has been defined, it needs to be adapted to the actual demand, with corresponding daily variations. On this operational level in the planning process, the question of how to prioritize between incoming bookings is of great importance. In Sweden, the most common approach is to use a First-Booked-First-Served (FBFS) principle. That is, to let the time of booking decide how shipments are prioritized and assigned to the existing services and remaining capacities. A transport booking inquiry consists of a release date describing when the freight (loaded rail cars) is ready to be picked-up, a transport volume specification, and other important information about e.g. actual transport relation, the sender and the receiver. Depending on the contract and the service agreement between the customer and the

rail freight operator, the inquiry might be managed differently. Especially in terms of the capacity control procedure, as certain service agreements might enable capacity reservations on trains.

Another booking principle is the First-In-First-Out (FIFO) principle, also known as the conveyor belt principle. The FIFO-principle prioritizes shipments according to the order of arrival of rail cars at each intermediate yard in the service network. This booking policy is frequently adopted by the North-American operators.

To gain insight on how well rail freight transport operations are planned and executed, rail freight operators compute and analyze a number of key performance measures. Martland (1992) addresses some of the most common ones. In this paper we focus on train fill rates, shunting yard work load, and transport lead times.

2.2. Handling demand uncertainty in the planning process

For the rail freight operator, key objectives of the planning process are to ensure that the service network is dimensioned to be able to satisfy the upcoming actual transport demand while simultaneously maximizing profit. Even though the planning process relies on good demand forecasts and predefined customer agreements specifying commitments of service levels and accumulated minimum transport volumes, the influence of demand fluctuations is still significant and a critical challenge to handle.

Depending on the nature of the uncertainty alternative strategies are adopted. If customers have a clear insight on future demand, it would be beneficial for the operator to get an indication of this as soon as possible, instead of getting information about the transport demand along with the actual booking. It is possible, that customers retain shipments that are ready to be transported well in advance of the actual distribution date. Alternatively, customers might be open for postponement of shipments for one or several days. If this level of urgency is communicated to the operator, it has more alternatives throughout the operational planning process. The customer, however, needs some kind of incentive to provide the operator with information that would increase the operator's planning flexibility.

In this paper, the use of a volume variation allowance policy (VVA-policy) is proposed and assessed. The purpose of the VVA-policy is to limit the unexpected variations in transport demand and thereby enable increased resource utilization. The design and effect of the policy is dependent on the customer, its needs and demand patterns as well as its service contract established in agreement with the rail freight operator.

Given a specific customer that imposes a transport demand including larger daily variations, the VVA-policy could state that the customer must pay for a minimum transport volume per weekday. Meanwhile, the operator assures it can accommodate an increase in demand up to a certain level with certain time restrictions. In other cases, the policy could be more detailed and tailored, all depending on the customer needs and how those comply with respect to other customers that the operator may schedule on the same services.

3. RELATED WORK

Within the area of industrial production and material distribution, demand uncertainty has received significant attention. In particular, the issue of how to accurately forecast demand and adjust production levels accordingly has been well explored. The Bull-whip effect (see

Forrester, 1961) is one suitable example of concepts identified through research within the area of forecast-driven distribution.

Research on how to handle and incorporate transport demand uncertainty in the planning process (rather than to predict it) tend to mostly address the correlation between demand variation and service quality and service reliability. Kraft (1995) conducted Monte-Carlo based simulations to establish the link between demand variability and transit time reliability. Several different production strategies, such as scheduled and tonnage-based strategies, were included in the study along with varying levels of demand variability. In contrast to the study outlined in this paper, Kraft (1995) applied non-commercial simulation software and assumed daily traffic to be normal distributed. In line with the previous author, Swan and Tyworth (2001) aimed at determining the influence of transit time reliability on logistic costs in the car load service segment by using the Logistic Cost Model (LCM). In their paper, they argued that the car load service segment suffers from unreliable services and low profitability, much due to high variability in demand. They also emphasized the importance of future efforts aimed at reducing demand variability.

A similar perspective was before taken by Keaton (1991), whom addressed service-cost tradeoffs for the car load service segment. The focal point was on how the degree of service levels in terms of train service frequencies affected costs for the rail freight operator. One of the conclusions was that the cost and effort required for improved customer service in the car load segment significantly exceeds the value of the service improvement itself.

Related to this is also the concept of yield management which aims to maximize profit given certain demand pattern and hints of possible variations. The concept is mostly used in other domains (foremost air and rail passenger transportation) and only a handful of railway freight operators have today realized these concepts in practice (Swan and Tyworth, 2001).

Other approaches, of more preventive character, towards reduced demand uncertainty have considered buyer-supplier contractual agreements. To state examples of such contributions, Bassok and Anupindi (1997) derive optimal purchasing policies given certain minimum total order quantity (TOQC) commitments. Chen and Krass (2001) extend the model developed by Bassok and Anupindi (1997) to include non-stationary demand and differentiated price settings. Lim et al. (2006) consider a transportation problem involving minimum quantity (MQC) commitments and Tsay and Lovejoy (1999) investigate performance impacts of quantity flexibility (QF) contracts in supply chain contexts. The use of QF-contracts includes a somewhat different approach and aims to prevent major forecast revisions near the time of order execution. All four contributions assume the contractual commitment to be beneficial for both parties of the relationship (see e.g. Tsay and Lovejoy, 1999). Service differentiation is one common approach to incorporate price reduction strategies for the buyer (Chen and Krass, 2001). However, in contrast to the VVA-policy, these commitments are not intended to reduce daily variability, as accumulated quantity commitments solely are defined over extended time periods.

Further on, this study assumes the existence of a pre-established operating plan and only transport demand is manipulated in order to fit the given service network. In a related problem area, the focus is instead on how to design a service network to best suit a given demand. Service network design (SND) models are well-known and the related work has been surveyed by Crainic (2000). Railway freight SND-applications have been presented by e.g. Andersen and Christiansen (2009) and Andersen et al. (2009a and 2009b).

4. OUTLINE OF THE SIMULATION STUDY

This chapter presents the outline of the simulation study. The primary objective is to assess effects of the previously introduced VVA-policy with respect to the three performance measures 1) train fill rates, 2) shunting yard work load, and 3) transport lead times. Actual names of companies and cities are replaced to ensure anonymity.

4.1. Potential effects of the VVA-policy

Dependent on how a potential VVA-policy is configured, how it is applied and in which context, it may give rise to a number of effects. In the reality based case we focus on here, the transport demand is varying on a day-to-day basis while the available train and terminal services remain the same. This mismatch between available resources and varying transport demand results in an imbalanced work load on shunting yards, high fill rates on certain trains and low on others, as well as difficulties predicting the transport lead time for shipments during peak times.

If the VVA-policy cuts off the demand peaks, as illustrated in Figure 4.1 below, and the remaining freight is scheduled earlier or later, it may give rise to a more even distribution of freight on the trains, and a more balanced work load at the shunting yards. Another possible effect of decreased uncertainty is that the transport lead time, and consequently also the delivery time, might be easier to predict.

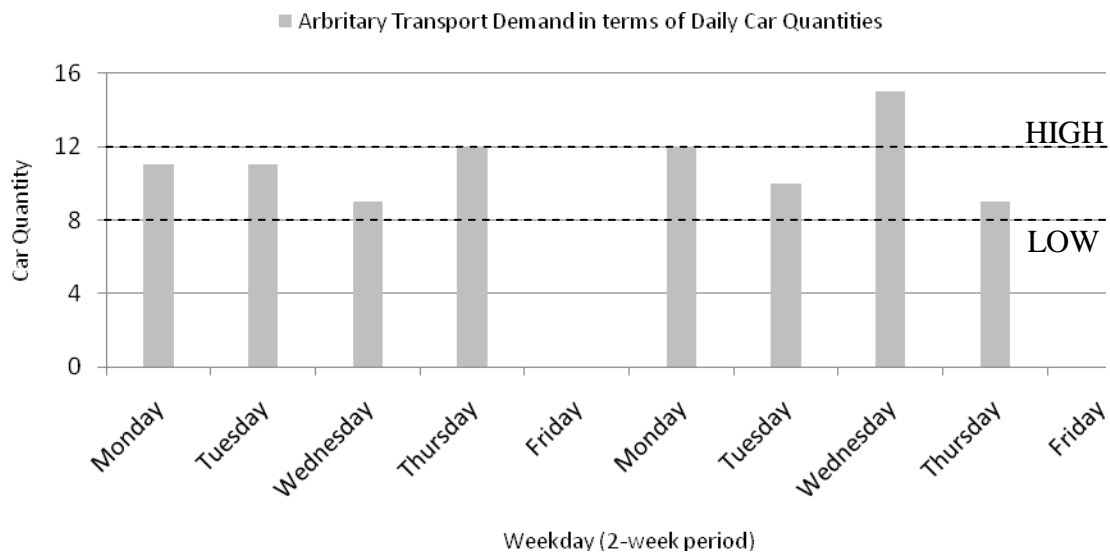


Figure 4.1. Illustrative example of a certain customer demand with corresponding limits Monday-Thursday imposed by the potential VVA-policy. 'HIGH' refers to the maximum transport demand the operator has promised to accommodate and 'LOW' the minimum volume the customer must pay for.

4.2. Case description

In this study, we have selected a transport corridor and rail freight service network consisting of a partial railway line with four shunting yards. See Figure 4.2 for an overview of the service network. On this stretch a customer (denoted Customer A) has shipments on weekdays from

yard (A) to be transported via yard (B) and yard (C) to yard (D) using train services A-G. There are two trains operating on the first fare-stage (denoted train A and B), three trains on the second fare-stage (denoted train C, D and E) and again two trains on the final fare-stage (denoted train F and G). The capacities of the seven trains are utilized by in particular customer (A), but also by around 60 other customers.

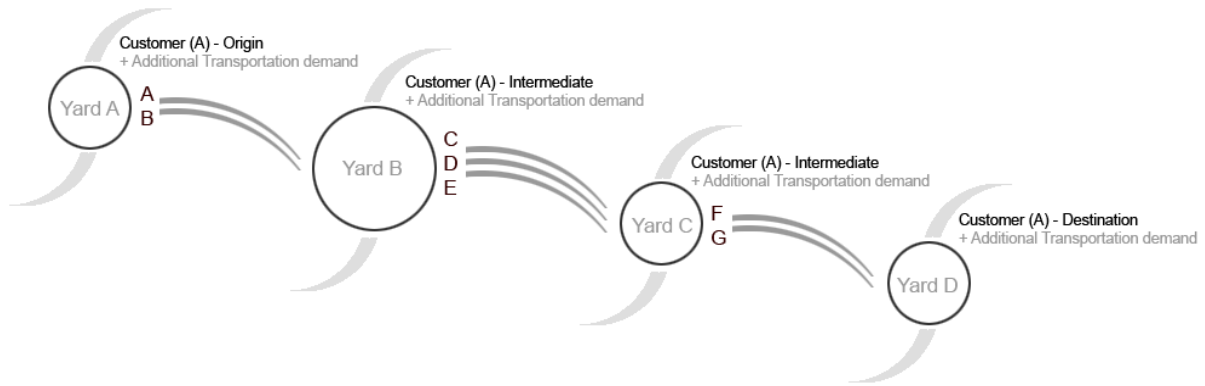


Figure 4.2. Overview of the service network.

Important to point out is that there are additional trains operating on the three fare stages, but these are not utilized by customer (A). We only consider the transport flows in the direction from yard (A) towards (B), (C) and (D). An overview of the seven train services and their capacity restrictions are presented in Table 1.

Table 4.1. Details on the trains services A-G.

Train-ID	Fare-stage	Departure frequency	Departure time	Capacity dimensions	
				Tons	Meters
A	1	Once every weekday	1:50 PM	1200	630
B	1	Once every weekday	2:47 PM	1200	630
C	2	Once every weekday	7:35 PM	1400	700
D	2	Once every weekday	8:40 PM	1400	700
E	2	Once every weekday	11:35 PM	1400	700
F	3	Once every weekday	4:13 AM	1600	630
G	3	Once every weekday	5:44 AM	1400	630

Overall, capacity dimensions span from 1200 - 1600 tons and 630 – 700 meters on the trains services. With an average length of 20 meters and an average weight of 43 tons for a loaded rail car within the considered service segment, the train service capacity limits are approximately 28–38 cars if restricted by the weight and 32–35 if restricted by length.

We have chosen to assess the impact of using a VVA-policy on customer (A), based on the historical demand data in Figure 4.3 (left graph). In order to simulate the application of the VVA policy, we leveled the historic demand to an even distribution over the weekdays, as depicted in Figure 4.3 (right graph). The commercial software MultiRail is used to simulate two main scenarios. The first scenario was based on the historic transport demand for all customers using train service A-G (S1). In the second scenario the demand of customer (A) was out-leveled to represent a full deployment of the VVA-policy (S2). All additional transport demand, apart from customer (A), remained the same in the two scenarios.

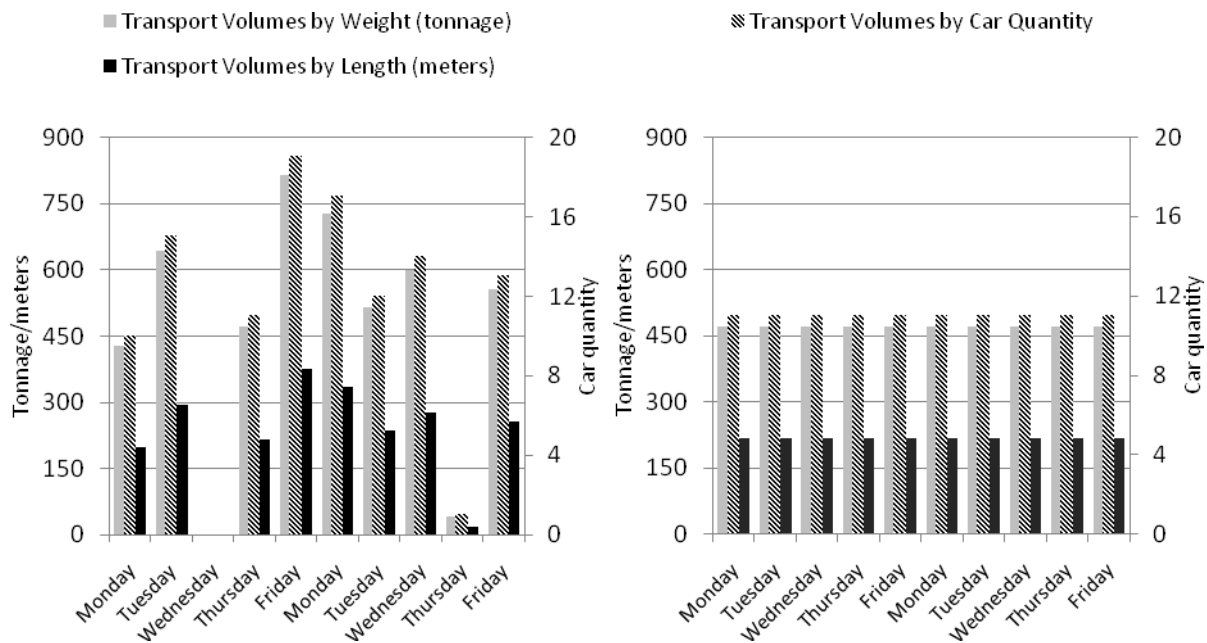


Figure 4.3. Overview of historical demand imposed by customer (A) for a two week period (left-hand-side) and the leveled demand as enforced by the VVA-policy (right-hand-side).

4.3. Simulation software

The simulation software MultiRail offers several functionalities to support the different steps in the planning process. Briefly described, it uses an algorithm to assign transport demand to blocks according to the predefined blocking plan. The result is a *block plan* which assures that transport demands are handled according to established service contract characteristics by the use of differentiated service classes, i.e. different traffic blocks depending on the class served. The block plan specifies traffic routings throughout the service network and provides crucial support for consolidation concepts. Further on, MultiRail adopts the information given by the timetable and establishes a *train plan*, specifying the block movement on specific trains in the network for a given *standard week*. Information on train departures, pre-defined in the timetable, is collected from external databases. Finally, MultiRail performs a discrete event simulation using the built in simulation software SuperSim to establish a detailed *trip plan*. The trip plan explicitly outlines the movement of transport demand on blocks and blocks on trains throughout the service network.

Through simulation, MultiRail can provide several key performance measures on a day-of-the-week basis for a given *standard week*. For a comprehensive guideline to the functionality of MultiRail we refer to Ireland et al. (2004). Simulations in MultiRail were performed using the configurations carried out by Green Cargo to imitate their production system, including the adoption of the FBFS-principle.

4.4. Performance measures

The customer selection procedure involved discussion with Green Cargo, whom also provided all necessary data and the access to MultiRail. We focused on three key performance measures; *train fill rates*, *transport lead times* and *shunting yard work load*. The selection was

a compromise between the simulation software capability and recommendations by Green Cargo.

Train fill rates are calculated as the percentage of the load capacity that is used w.r.t. both its capacity dimensions: weight and length. Consider e.g. the weight dimension and a train with the capacity of 630 tons loaded with rail cars of an accumulated weight of 500 tons. The resulting train fill rate is approximately 80%. Transport lead times are defined as the time required for a shipment to be transported from its origin to its destination yard, local distribution towards customer facilities excluded. In the service network, transport lead times constitute transit times on railway lines and dwell times at origin-, intermediate- and destination yards. Rail freight operators normally apply standard conditions to define acceptable transport lead times within certain service segments. For example, for the carload services Green Cargo adopts a standard condition of a maximum transport lead time of 60 hours.

Finally, the shunting process is known to consume a considerable amount of resources, see e.g. Zhu et al. (2009), which motivates the inclusion of the corresponding performance measure. The shunting yard activity is calculated based on the number of pick-up and set-out activities required at each yard. Note that, by leveling the demand in scenario (S2) the accumulated number of shunting activities will not change but the activities may become more evenly distributed over the weekdays.

5. RESULTS AND DISCUSSION

In the simulation study we have assessed the impact of the VVA policy w.r.t. the three performance measures train fill rates, transport lead times and shunting yard work load. Achieved results are from here on outlined and discussed for each performance measures in the order of appearance above.

5.1. Train fill rates

Train fill rates are presented in terms of the capacity dimensions weight (tons) and length (meters), assuming that trains are full when either capacity limit is reached. Table 2 outlines train fill rate statistics and highlight situations where the limiting capacity dimensions for filled trains differ between the scenarios. As we can see, the differences in train fill rates are frequently small, probably because the manipulated demand of customer (A) put in relation to train capacities and additional transport demand is also considerable small. Though, there are occasionally situations where we can observe remarkable differences comparing the two scenarios, consider e.g. train (A) and (B) on Wednesday, train (D) on Monday and Train (G) during all weekdays.

The results indicate that independent of the reduced demand variability, certain train departures tends to be preferred. Consider train service (B-D) and (F), which are almost full during all weekdays. Additional resources e.g. train (A), however, are only partly filled. Possible explanations relate to an over-dimensioned capacity in the system along with the influence of the FBFS-policy, train departure times and demand release time aspects.

Along with the variability reductions observed on e.g. train (A) and train (D), it can be argued that in situations where trains experience very low fill rates, minor capacity increases on trains that today operate at full capacity could be sufficient for train cancellations. These capacity

increases could on a short-term basis be achieved through power unit interchanges. From a planning perspective, the information required in terms of demand patterns and the potential monetary savings that are realized due to train cancellations have to be further investigated. One major drawback of periodical cancellation of train departures is e.g. that it in itself will contribute towards increased demand variability weekdays in between. Though, variability now managed and controlled by the rail freight operator.

In the other way around, it can also be argued that with reduced variability in train fill rates, additional demand imposed by potentially new customers, might be introduced on already existing resources in the service network without the risk of e.g. increased transportation lead times during peak demand periods. Consider e.g. train (E), where the train fill rate variability in terms of standard deviation over the *standard week* reduces with approximately 14% by dimension weight and 24% by dimension length in scenario (S2).

How to configure the VVA-policy to achieve low fill rate variability and at the same time reach the capability of resources elimination requires further investigation. It is reasonable that the policy should be applied to several customers at once to reach the most out of benefits, instead of as in this study only to one customer. We also want to point out that applying the VVA-policy at the same extent during all weekdays will occasionally introduce demand on days where previously no demand existed; refer back to the demand imposed by customer (A) in Figure 4.3 and e.g. Wednesday of week one. This further underlines the importance of investigating possibilities for resource elimination as a consequence to the VVA-policy.

In order to affect the train fill rates, and e.g. cancel train (A) on certain Mondays to increase the fill rate of train (A) on the following days, the booking principle would need to be re-configured to enable postponement of certain demand towards later train departures. Furthermore, since the train services (C-E) have a high fill rate already, an increased fill rate on train (A) would possibly not increase throughput anyway, but rather the time spent in yard (B) and consequently also transportation lead times.

Table 5.1. Train fill rate statistics per weekday of standard week for scenario (S1) and (S2)

ID	Scenario (S1)					Scenario (S2)				
	Mon	Tues	Wed	Thurs	Fri	Mon	Tues	Wed	Thurs	Fri
A	23;16	69;64	55;60	14;23	51;43	23;16	65;60	44;53	14;23	71;63
B	F.W.	94;71	76;65	97;84	F.W.	F.W.	95;71	91;75	F.W.	92;80
C	99;96	F.W.	F.W.	F.W.	F.W.	93;98	F.W.	F.W.	F.W.	F.W.
D	63;68	F.W.	F.W.	F.W.	F.W.	70;67	F.W.	F.W.	F.W.	F.W.
E	20;21	43;54	90;97	60;64	66;56	20;21	51;62	89;97	59;65	64;54
F	78;97	89;97	F.W.	95;97	78;97	72;97	99;97	92;97	F.W.	83;97
G	F.W.	68;48	46;33	95;66	31;22	99;65	72;51	51;37	94;61	40;29

* F.W. = Filled by weight, N;N indicate on percentile train fill rates (weight and length respectively) and boldfaced notations highlights changes in terms of overload status scenarios between.

5.2. Transport lead times

The effects of the VVA-policy deployment in terms of transport lead times for the transport demand relative to customer (A) can be observed in Figure 5.1. An aggregation has been made based on the level of change in transport lead times scenarios in between. The base time unit (T) represents 1 day, 1 hour and 15 minutes and Figure 5.1 outlines the number of cars experiencing lead times within each of the four observed time intervals.

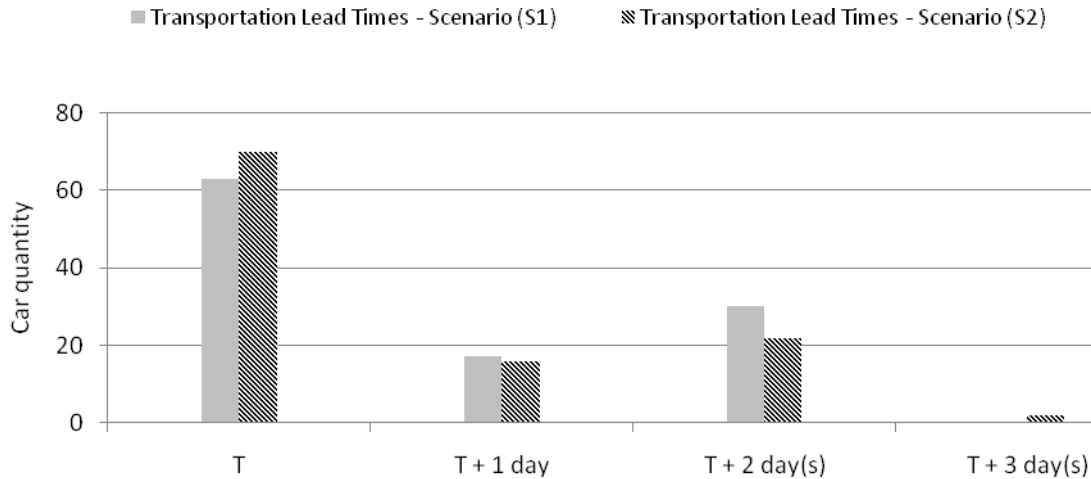


Figure 5.1. Number of cars with transport lead time according to the four resulting time intervals ($T = 1$ day, 1 hour and 15 minutes).

As seen in Figure 5.1, the simulation resulted in four time intervals regards the transport lead time of individual shipments of customer (A) in the transportation relation. The results show that the number of cars experiencing a transport lead times of (T + 2) days are significantly reduced along with an increase of the number of shipments in time interval (T) for the leveled scenario (S2). One exception where the transport lead time increases in scenario (S2) can, however, be observed for the fourth interval (T+3) days. This small increase might be due to that the total demand by customer (A) on Thursdays and Fridays in scenario (S2) is larger than in scenario (S1) and since there are no train services operating during the weekend, some shipments may be held at one of the intermediary yards until Monday. This would result in a transport lead time of three or four days.

5.3. Shunting yard work load

In the service network, there are four shunting yards denoted yard (A), (B), (C) and (D). Based on their size and position in the network, 1-3 working shifts apply. Shunting activities are distinguished by yards and working shifts. Put in relation, yard (B) is by far the largest in terms of transport volume throughput and yard (A) and yard (D) are to be considered the smallest. Yard (C) is in size and throughput, somewhere in between. Figure 5.2 and Figure 5.3 present the standard deviation in between scenario (S1) and (S2) in terms of the number of set-outs and pick-ups respectively. Set-out activities indicate on both slight variability increases as well as reductions. Though, at the destination yard (D), percentile variability reductions of up to 15% are observed, see Figure 5.2.

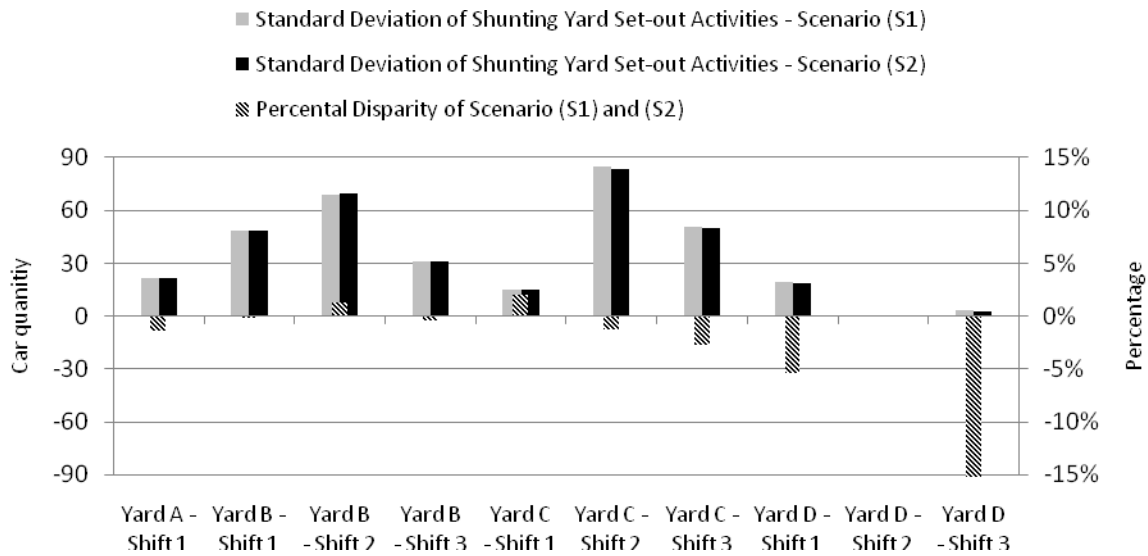


Figure 5.2. Standard deviation in terms of set-outs for each yard and working shift and percentile disparity scenarios in between (dashed)

Considering pick-up activities, yard (A) and yard (D) experience remarkably decreased variations going from scenario (S1) to scenario (S2). The first working shift at yard (D) indicates on variability reductions of 28%, see Figure 5.3. Also yard (B) and yard (C) indicate on slight improvements for certain working shifts. The relative magnitude of the transport demand of customer (A) is to be considered minor at the intermediate yards, which could explain the result where neither variability reductions nor increases are to be observed.

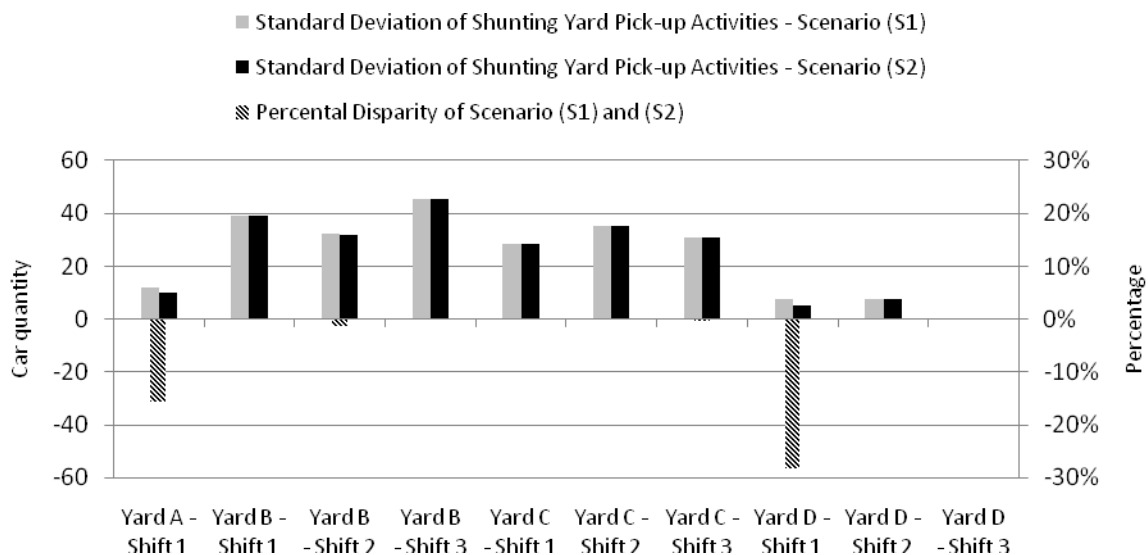


Figure 5.3. Standard deviation in terms of pick-outs for each yard and working shift and percentile disparity scenarios in between (dashed)

6. CONCLUDING REMARKS AND FUTURE RESEARCH

The results obtained for train fill rates and shunting yards activities indicates on reduced variability, though, are not fully unequivocal and occasionally the effects are considerable small. There are e.g. single situations where trains in the transportation relation experiences variability increases. These observations might be due to the limited capacity on trains in combinations with the priority policy adopted in the service network. Shunting yard activities for each of the yards are presented by means of all transport demand traversing the nodes. Effects of the policy deployment might consequently be hidden, since the adjusted transport demand is relatively small compared to total yard throughput in the service network.

Given the observed variability reduction of train fill rates, we find two main perspectives that are of interest for rail freight operators. Considering an already fixed operating plan, it can be argued that due to the low capacity utilization on fare-stage one, this fare-stage allows for higher levels of variability. Comparing to fare-stage two and three, where the capacity utilization on all of the active trains is considerable high, VVA-policy deployments might bring larger benefits. On the other hand, we find it reasonable that the possibility for introducing additional transport demand on resources in the service network increases along with reduced train fill rate variability. Consequently, making fare-stage one more suitable for VVA-policy deployments where the excess capacity is already relatively high.

The approach to adopt a full deployment of the VVA-policy is well motivated considering the objectives of the study. However, for practical implementations, policy adjustments are required. Questions of how to configure variability restriction levels, towards which customer groups the policy preferably is aimed and to what extent the policy should be applied, have to be addressed. It is plausible, that the policy should be applied in such extent that several customers within the same transportation relation are affected to provide the most of benefits.

Customer acceptance is another crucial aspect for successful policy implementations. In particular, customers prepared to accept these types of agreements have to be rewarded with benefits seen elsewhere. Benefits can be e.g. reduced transportation costs or by other means differentiated services.

We identify several plausible future research directions. Some to be considered as continued research on the variability issue; investigate minimum requirements on the level of variation allowed without loss of perceived benefits within transportation relations, prolong this study to involve effects on other customers in the service network, further explore on acceptability levels of the VVA-policy and similar agreements within the rail freight industry. In addition, future research activities could be aimed at exploring how the advancement of booking related information can enhance planning capabilities and to further analyze the possibility of resource elimination due to reduced transport volume variability.

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