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POUR OBTENIR LE GRADE DE

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L'Ecole Doctorale des Sciences Physiques et de l'Ingénieur
Automatique, Productique, Signal et Image, Ingénierie Cognitive

Par Yassine BENRQYA

**Product segmentation and distribution strategy selection:
An application in the Retail Supply Chain**

Soutenue le 15/06/2015

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Titre: Segmentation des produits et choix de stratégies de distribution dans la chaîne logistique de grande distribution

Résumé:

Dans le contexte économique actuel, les entreprises cherchent à développer de nouvelles stratégies de distribution pour leurs performances logistiques. Dans cette quête de performances, les entreprises doivent adapter les stratégies de distribution mises en place avec les typologies de leurs produits. Plusieurs stratégies de distribution existent dans la chaîne logistique de grande distribution. Ces stratégies sont choisies sur la base des caractéristiques des produits, et /ou l'impact sur les performances logistiques. Dans cette thèse, nous étudions l'impact de trois stratégies de distribution, à savoir: stockage traditionnel, cross-docking pick by line et le cross-docking pick by store, sur trois performances de la logistique, à savoir: le niveau de service, les coûts et le bullwhip effect. En outre, nous analysons l'impact des caractéristiques des produits sur les performances des stratégies de distribution et enfin proposer un cadre pour le choix de la stratégie la plus adaptée pour chaque produit. La chaîne logistique étudiée est composée de trois échelons: Centre de distribution du fournisseur, Centre de distribution du distributeur et les magasins. Basé sur un cas réel, nous effectuons une modélisation des processus, qui nous permet de développer un modèle déterministe de coût Macro et un modèle de simulation. Le modèle de coût macro permet d'évaluer l'impact des stratégies de distribution sur des coûts de la chaîne logistique. Après l'analyse macro des coûts, nous développons un modèle de simulation où nous intégrons les données relatives aux produits (la demande, le volume, etc.). Ce modèle permet une simulation dynamique du système la stratégie la plus adaptée pour chaque produit en fonction de ses caractéristiques et de l'impact sur les performances. A la fin de cette recherche, nous présentons une matrice de choix pour la segmentation des produits et choix de la stratégie de distribution.

Mots clés: [Chaîne logistique de grande distribution, cross-docking, Stockage traditionnel, Chaîne logistique multi-échelon, Segmentation des produits, Sélection des stratégies, Performance logistique]

Unité de recherche

[Le laboratoire de l'Intégration du Matériau au Système, UMR 5218 Université Bordeaux, IMS, Talence, France]

Title: Product segmentation and distribution strategy selection: An application in the Retail Supply Chain

Abstract:

Nowadays companies must look to develop new distribution strategies in order to achieve the required performance from their supply chain. In this quest, companies wonder about the consistency of their distribution strategies with the products they are selling. Several types of distribution strategies exist in the retail supply chain. These strategies are chosen based on the products characteristics, and/or the impact on the supply chain performances. In this research, we study the impact of three distribution strategies, namely: traditional warehousing, cross-docking pick by line and cross-docking pick by store, on three supply chain performances, namely: service level, cost and bullwhip effect. In addition, we analyse the impact of the products characteristics on the performances of the distribution strategies and propose a framework for choosing the right strategy for each product. The supply chain studied is composed of three echelons: Supplier Distribution Centre, Retailer Distribution Centre and Stores. Based a real business case, we perform a process modelling, that allows us to develop a deterministic Macro cost model and a simulation model. The macro cost model allows to evaluate the impact of the distribution strategies on the supply chain cost performance. After the macro cost analysis, we develop a simulation model where we integrate the data related to the products (demand, volume, ordering quantities etc.) in the model. This model allows a more dynamic simulation of the system in a large time period and determines the right strategy to select for each product depending on its characteristics and the impact on the performances. At the end of this research, we present a framework for product segmentation and distribution strategy selection.

Keywords: [Retail supply chain, cross-docking, traditional warehousing, multi-echelon supply chain, product segmentation, strategy selection, supply chain performance]

Unité de recherche

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Résumé en Français

1- Contexte de la recherche

Aujourd'hui, les entreprises de grande distribution vivent dans un environnement complexe et changeant, et leur adaptation à cet environnement est un facteur clé de survie et un défi permanent. Les clients sont de plus en plus rigoureux sur le service et la qualité du produit. Pour rester compétitif sur le marché, les produits doivent être livrés à temps, au bon endroit, et en bonne qualité. La concurrence sévère dans la grande distribution oblige les supply chain managers à trouver des solutions innovantes pour satisfaire les demandes des clients et en même temps réduire les coûts et générer des profits.

Industriels et distributeurs sont confrontés à plusieurs défis (Jones, 2012). Le principal défi des distributeurs est la réduction des coûts logistiques afin de leur permettre de maintenir des prix bas, d'investir dans l'expansion de leurs réseaux de magasins, conquérir de nouveaux marchés et fidéliser les clients. Cela signifie que les niveaux de stocks doivent être réduits, ce qui permet de réduire également les coûts d'immobilisation du stock. La nécessité de réduire les coûts d'immobilisations signifie que les distributeurs réduisent les niveaux de stocks dans leurs centres de distribution (CD), qui ont traditionnellement été utilisés pour protéger le niveau de service dans les magasins. La réduction des stocks au niveau du CD et dans les magasins, et le maintien d'un niveau de service optimal est un défi capital pour les distributeurs.

Pour les industriels cela conduit à un défi majeur: s'adapter à ce besoin d'une grande flexibilité en termes de délais de livraison, augmentation des fréquences de livraisons, et d'adaptation aux tendances changeantes de commande. Cette façon de travailler met la pression sur la relation entre distributeurs et industriels, ce qui les pousse à améliorer leur collaboration (Ramanathan & Gunasekaran, 2014).

Dans ce contexte, industriels et distributeurs souhaitent de plus en plus limiter, voire éliminer les stocks sur l'ensemble de la chaîne logistique tout en assurant un service optimal au consommateur final. Le cross-docking est une des approches possibles pour atteindre cet objectif en permettant d'éliminer tout ou partie des stocks au CD.

Dans la littérature différentes définitions ont été données au cross-docking. Dans cette thèse et dans la supply chain de grande distribution, le cross-docking peut être décrit comme une stratégie de distribution qui élimine l'inventaire dans le CD du distributeur, où les produits ne sont plus stockés, mais immédiatement éclatés et consolidés avec d'autres produits provenant de différents fournisseurs et acheminés vers les points de destination finaux (en général les points de vente). Dans cette définition, l'accent est mis à la fois sur l'élimination des stocks, l'éclatement et la consolidation des produits.

Il existe de nombreuses typologies du cross-docking et plusieurs caractéristiques peuvent être considérées pour distinguer ces typologies (Yan et al, 2009;. Vogt, 2010). Dans la supply chain de grande distribution, les principales typologies sont différenciées en fonction de l'endroit où le tri physique (picking) des produits a lieu. Dans cette thèse, nous appelons les deux typologies du cross-docking: le cross-docking pick by line et le cross-docking pick by store. Dans le cross-docking pick by line, le CD du fournisseur (industriel) livre au CD du distributeur la somme des commandes de tous les magasins. Au CD du distributeur, les produits sont triés en fonction de la commande de chaque magasin, combinés avec d'autres produits d'autres fournisseurs et expédiés. En cross-docking pick by store, le CD du fournisseur prépare les commandes pour chaque magasin contrairement au cross-docking pick by line où les commandes sont préparées par produit (somme des commandes de tous les magasins). Dans le cross-docking pick by store le CD du distributeur consolide les livraisons en provenance de différents fournisseurs vers les destinations (magasins).

Le cross-docking est une stratégie de distribution attractive à la fois pour les distributeurs et les fournisseurs. Cette stratégie permet de réduire les temps de réponse, baisser le niveau des stocks, et par conséquent libérer des liquidités. Le plus grand initiateur du cross-docking est le distributeur américain Wal-Mart, qui à son tour est le plus grand distributeur au monde, et aussi la première grande entreprise à appliquer avec succès la stratégie cross-docking (Stalk et al., 1992). Les relations commerciales étroites avec ses partenaires ont permis à Wal-Mart de mettre en œuvre avec succès cette stratégie de distribution (Ste-Marie et Beaulieu, 2002). Wal-Mart a également bénéficié d'un grand réseau de distribution avec des CD et des magasins disposant de grands espaces de stockage, ce qui a aidé les fournisseurs à livrer en quantités plus économiques, sans affecter les coûts de transport (Chandran et Gupta, 2003).

En revanche la stratégie du cross-docking n'est pas sans inconvénients. Le stock dans différents échelons dans la chaîne logistique en raison de l'inadéquation entre l'offre et la demande. Le décalage est souvent intentionnelle car il est plus économique de produire en grandes quantités et de stocker pour une utilisation future, et aussi parce que le stock est construit par anticipation de la demande future. En supprimant l'inventaire chez le CD distributeur, qui est souvent situé géographiquement à proximité des magasins, cela augmente le lead-time vers les magasins et par conséquent augmente le risque de rupture aux linéaires (Van der Vlist, 2007).

Le cross-docking a aussi un grand impact sur les coûts de transport des fournisseurs. Dans la stratégie de stockage traditionnelle, le CD fournisseur livre le CD distributeur en camions complets. Dans la stratégie cross-docking, puisqu'il n'y a pas de stocks au CD distributeur, le CD fournisseur livre les besoins exacts des magasins, ce qui correspond rarement à un camion complet. Cette façon de commander augmente le coût de transport fournisseur, et dans certains cas, cette augmentation des coûts

de transport ne compense pas le bénéfice de la réduction du coût des stocks chez le CD distributeur (Gebennini et al., 2013).

Une solution pour faire face à ce problème est de combiner le cross-docking et le stockage traditionnel dans la même chaîne logistique (Apte et Viswanathan, 2000; Waller et al., 2006). En combinant ces deux stratégies, cela permettrait de réduire les coûts de manutention pour le fournisseur, réduire les coûts de transport et en même temps réduire de façon considérable le niveau de stock chez le CD distributeur. Une préparation de quantités plus économiques, permettrait de réduire le coût de préparation et aussi le coût de transport des fournisseurs. La combinaison se fait au niveau du produit. Certains produits sont en cross-docking et d'autres en stockage traditionnel. La question est de savoir quelle stratégie est adaptée pour chaque produit?

Une façon de choisir la stratégie adaptée pour chaque produit est de développer la segmentation selon les caractéristiques des produits et leur impact sur les performances des stratégies de distribution (Apte Viswanathan, 2000; Waller et al, 2006; Li et al., 2008). La segmentation vise à différencier les produits en fonction de leurs caractéristiques. Pour certains produits dont la demande est élevée, il faut maintenir le stock chez le CD distributeur près des magasins afin d'assurer un niveau de service élevé et minimiser les ruptures aux linéaires (Apte et Viswanathan, 2000). Certains produits ont un volume physique élevée, et sont adaptés au cross-docking, puisque l'espace de stockage est une contrainte chez le CD distributeur, mettre ce type de produits en cross-docking va certainement économiser de l'espace de stockage et donc réduire l'inventaire chez le CD distributeur (Li et al., 2008). D'autres produits ont un cycle de vie court et deviennent obsolètes plus rapidement, par exemple les produits périssables. Il est important de pousser ces produits le plus rapidement possible vers les magasins. La stratégie cross-docking est la plus appropriée pour ce type de produits (Li et al., 2008). Certains produits ont une demande variable. Les produits les plus adaptés pour le cross-docking doivent avoir une demande plus ou moins stable. Les produits avec une demande instable sont plus adaptés pour une stratégie de stockage traditionnel avec un court lead-time vers les magasins, et des centres de distribution géographiquement proches (Apte et Viswanathan, 2000).

Déterminer la stratégie adaptée pour chaque produit n'est pas une tâche facile parce que différents facteurs doivent être pris en compte. Une sélection sur la base de certaines caractéristiques des produits et leur impact sur une seule performance n'est pas toujours suffisante. En effet, un produit peut avoir un impact positif sur la performance d'une stratégie, mais en même temps avoir un impact négatif sur les autres performances. La sélection doit tenir compte de toutes les performances de la chaîne logistique.

2- Positionnement et contributions de la recherche

Dans notre étude, nous considérons une chaîne logistique composée de CD fournisseur, CD distributeur et de plusieurs magasins. Nous comparons le stockage traditionnel et la stratégie du cross-docking (pick by line et pick by store). Cette structure de la chaîne logistique va nous permettre de combiner les objectifs et performances des fournisseurs avec ceux du distributeur, et de proposer une solution qui prend en compte une perspective de la chaîne logistique bout en bout avec un équilibre des objectifs et des performances des différents partenaires.

Les articles traitant la problématique des stratégies de distribution, proposent souvent une analyse des performances des stratégies sans prendre en compte l'aspect de segmentation. De plus dans la plupart de ces études les auteurs prennent en compte souvent une vision partielle de la chaîne logistique avec un nombre réduit d'échelons, souvent CD distributeur et magasins. D'autres articles traitent des études sur le choix des stratégies de distribution pour chaque produit en fonction de leurs caractéristiques et l'impact sur les performances de la chaîne logistique, avec une divergence d'opinion en termes de segmentation des produits. En outre, il existe un manque d'études sur les typologies de cross-docking. En fait, différents auteurs dans la littérature (Yan et Tang, 2009; Vogt, 2010; Pearson Specter 2004) décrivent les typologies de cross-docking sans une étude détaillée de l'impact sur les performances.

Les objectifs de notre recherche visent tout d'abord l'analyse de l'impact des stratégies de distribution (stockage traditionnel, cross-docking pick by line et cross-docking pick by store) sur les performances de la chaîne logistique composée de trois échelons CD fournisseur, CD distributeur et magasins. Les performances de la chaîne logistique analysées sont: les coûts, le niveau de service et de l'effet bullwhip. Aussi, nous analysons l'impact des caractéristiques du produit sur les performances de ces stratégies de distribution et le choix de la bonne stratégie pour chaque produit en fonction de ses caractéristiques et de l'impact sur les performances. Les caractéristiques de produits analysés sont : Le volume physique, l'espace linéaire, la valeur, la variabilité, la demande, le lead-time et les fréquences de livraisons.

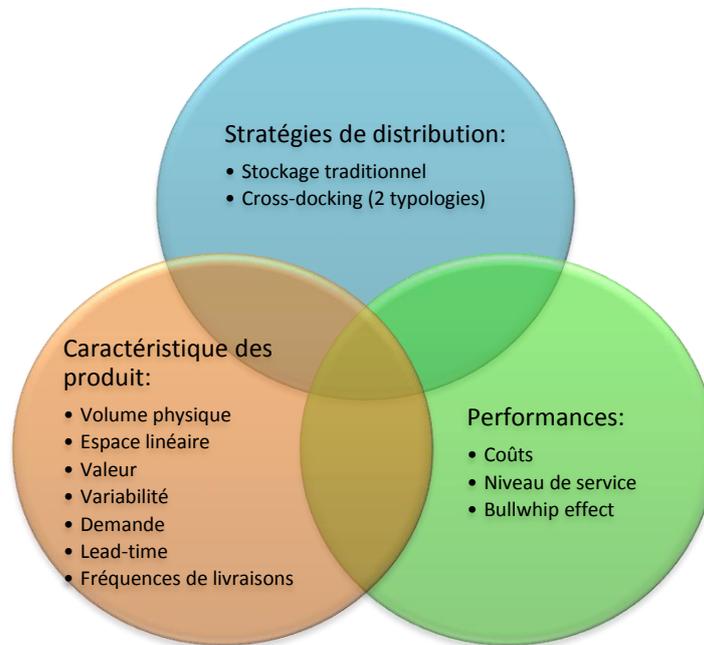


Figure 1: Positionnement scientifique

Les contributions de notre recherche sont: (1) le renforcement des connaissances sur l'impact des stratégies de distribution sur les performances de la chaîne logistique, la sélection de la stratégie de distribution pour chaque produit en fonction de ces caractéristiques et de l'impact sur les performances, (2) le développement d'un modèle et/ou des règles de gestion pour aider les gestionnaires à concevoir et mettre en œuvre une chaîne logistique performante.

Les objectifs de recherche sont les suivants:

- 1- Analyse de l'impact des stratégies de distribution sur les performances de la chaîne logistique.
- 2- Analyse de l'impact des caractéristiques du produit sur les performances des stratégies de distribution.
- 3- Choix de la bonne stratégie pour chaque produit en fonction de ses caractéristiques et de l'impact sur les performances.

3- Méthodologie d'analyse des stratégies de distribution

Dans notre étude nous proposons de définir un modèle de processus des stratégies de distribution, d'évaluer les performances, l'impact des caractéristiques du produit sur les performances et de définir la bonne stratégie pour chaque produit en fonction de ses caractéristiques et performances.

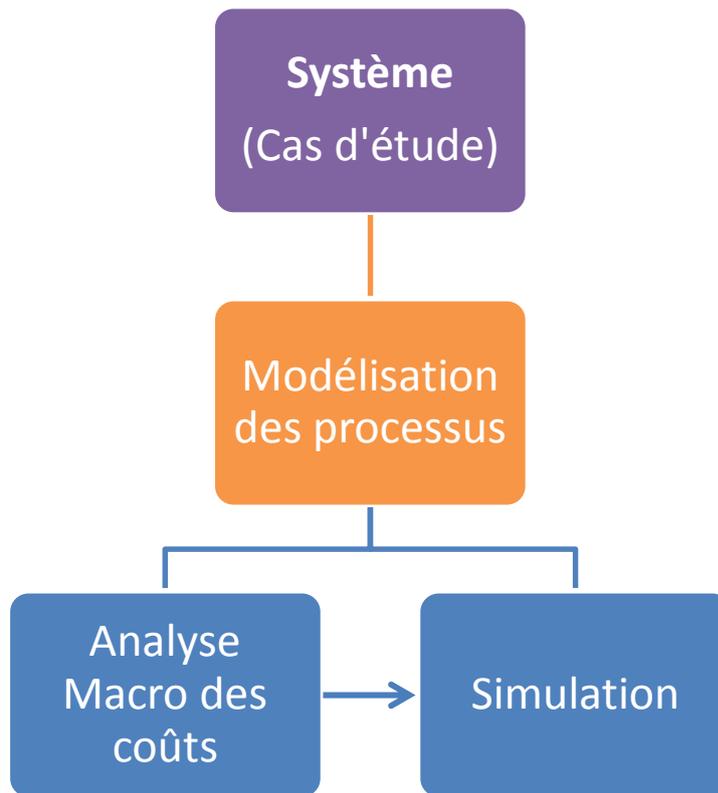


Figure 2: Approche d'analyse des stratégies de distribution

Comme le montre la figure 2, nous allons partir d'un cas d'étude pour réaliser une modélisation des processus. L'étude de cas est une approche de recherche qui met l'accent sur la compréhension de la dynamique dans une chaîne logistique. Dans notre cas, l'étude est basée sur un véritable cas d'un distributeur français et d'une multinationale spécialisée dans les produits de grande consommation. Cela nous permet d'avoir à notre disposition une énorme quantité de données pour effectuer une analyse empirique robuste.

Dans notre recherche, nous nous intéressons à la chaîne logistique de grande distribution afin d'évaluer les performances des stratégies de distribution, l'impact des caractéristiques du produit sur la performance et de définir la bonne stratégie pour chaque produit en fonction de ses caractéristiques. Le cas étudié est composé de trois échelons: CD Fournisseur dans le centre de la France, CD distributeur et 24 magasins dans la région Bretagne.

Toute approche d'analyse doit être précédée d'une étape de modélisation. Cette étape est cruciale car elle permet de décrire les processus au sein de la chaîne logistique, pour comprendre et évaluer la performance. Le modèle proposé doit être une représentation réaliste de la chaîne logistique réelle étudiée. Cela fournira une base pour comparer différents scénarios de simulation, analyser et évaluer le comportement de la performance.

Basés sur l'analyse de l'existant en termes d'outils et d'approches de modélisation, nous optons pour un processus de modélisation basé sur des flowcharts. Ces modèles sont adaptés à notre problème de recherche, car ils peuvent représenter les différents processus.

Basés sur l'étude de cas, nous effectuons une modélisation des processus. Ce modèle permet de décrire les processus au sein de la chaîne logistique, dans un objectif d'analyse et d'évaluation des performances. Après la modélisation des processus, nous pouvons commencer notre phase d'analyse de la performance. Cette phase est divisée en deux grandes parties. Un modèle de coût macro, et une simulation des stratégies de distribution. Le modèle de processus nous permet de réaliser deux études.

Le modèle de coût Macro est un modèle déterministe basé sur des hypothèses et des données issues du cas d'étude. Ce modèle nous permet d'évaluer l'impact des stratégies de distribution sur le coût de la chaîne logistique. Il nous permet de donner une vue d'ensemble sur l'impact sur les différents coûts de la chaîne logistique.

La simulation des stratégies de distribution est basée sur le processus de modélisation, ainsi que le modèle du coût macro. En effet, l'analyse des coûts est une partie intéressante pour donner une image globale de la chaîne logistique et de valider les hypothèses et comparer avec les résultats issue de la littérature sur l'impact des stratégies de distribution sur les coûts. D'autre part, elle seule ne permet pas d'élaborer une étude approfondie sur le choix de la stratégie de distribution pour chaque produit. Par exemple, il est difficile de définir l'impact sur l'inventaire des magasins sans avoir un accès sur des données historiques pour pouvoir comparer les deux stratégies. L'impact sur la disponibilité aux linéaires a été compliquée de définir également, parce que nous ne disposons pas de l'accès aux données et en même temps il n'y a aucune étude sur la littérature concernant l'impact de cross-docking sur cette performance. D'autre part, certaines études dans la littérature (Eftekhar et al, 2008) ont expliqué que cross-docking permet de réduire l'effet bullwhip car il apporte une connexion directe entre le magasin et le CD fournisseur. Cette réduction de l'effet bullwhip permet une réduction sur l'inventaire du fournisseur. Nous avons donc décidé de créer un modèle de simulation qui permet de déterminer l'impact des stratégies de distribution sur la performance de la chaîne logistique, l'impact des caractéristiques du produit sur les performances des stratégies de distribution et de choisir la bonne stratégie pour chaque produit en fonction de ses caractéristiques et de l'impact sur les performances. Nous avons modélisé le processus et utilisé une combinaison d'approche analytique et de simulation. L'approche analytique est très utile pour mieux comprendre la structure des processus de commandes dans la chaîne logistique. Cependant l'approche analytique deviendra ingérable lorsque l'on considère tous les aspects et processus de la chaîne logistique. La simulation permet de tenir compte de la dynamique de la chaîne, et nous permet de relâcher les contraintes pour l'étude du cas. En outre, afin d'inclure tout le processus de la chaîne logistique l'approche de simulation est nécessaire.

4- Analyse des résultats

4.1. Analyse des coûts des stratégies de distribution

Dans le modèle d'analyse des coûts, nous avons étudié quatre stratégies de distribution : Stockage traditionnel, Cross-docking pick by line, Cross-docking pick by store et enfin une combinaison du cross-docking pick by line et le stockage traditionnel dans la même supply chain. Nous avons par la suite comparé les trois dernières stratégies avec le stockage traditionnel que nous avons défini comme stratégie de référence pour la comparaison.

Ce modèle de coût nous a permis de prouver que le cross-docking choix pick by line augmente la totalité des coûts de la chaîne logistique par rapport à la stratégie de stockage traditionnel. En effet, les bénéfices dégagés de la suppression de l'inventaire chez le CD distributeur ne compense pas l'augmentation des coûts de manutention et de transport des fournisseurs. D'autre part, l'augmentation du coût total peut également être expliquée par le processus de picking qui est fait en double (chez le CD distributeur et chez le CD fournisseur).

D'autre part, le cross-docking pick by store est plus économique que le stockage traditionnel. Même avec une augmentation du pourcentage de picking chez le CD fournisseur, la suppression des activités de picking chez le CD distributeur conduit à une réduction du coût total de la chaîne logistique. En effet, dans le cross-docking pick by line, l'activité de picking est effectuée deux fois : - En premier lieu chez le CD fournisseur avec une préparation des commandes cumulées de tous les magasins, - en deuxième lieu chez le CD distributeur avec une préparation des commandes pour chaque magasin. En cross-docking pick by store les commandes des magasins sont préparées chez le CD fournisseur. Le CD distributeur consolide simplement ses produits avec d'autres produits et envoie les commandes aux magasins.

Enfin, la combinaison du cross-docking pick by line avec le stockage traditionnel réduit le coût de la chaîne logistique par 6,4%. En réduisant le pourcentage de picking du CD fournisseur et en augmentant son taux de remplissage des camions à 70% du volume, nous réduisons l'impact sur le coût du fournisseur et en même temps garder le bénéfice de la réduction d'inventaire chez le distributeur.

Comme démontré dans cette étude, certains coûts et paramètres ne sont pas identifiés car il était difficile de recueillir les données (inventaire magasins, inventaire fournisseur, disponibilité aux linéaires..). Pour valider ces hypothèses nous avons besoin d'un modèle plus robuste avec des données réelles et un cas réel. Dans le modèle de simulation, nous analysons l'impact des stratégies de distribution sur les performances de la chaîne d'approvisionnement, et de l'impact des caractéristiques du produit sur les performances des stratégies de distribution fondées sur un cas réel.

4.2. Framework pour la segmentation des produits et choix des stratégies de distribution

a- Impact des stratégies de distribution sur les performances

Dans cette partie de simulation nous avons analysé les performances (coût, niveau de service et effet bullwhip) des trois stratégies de distribution : Stockage traditionnel, Cross-docking pick by line et Cross-docking pick by store.

Tout d'abord, d'un point de vue des coûts, les coûts des magasins augmentent en cross-docking (pick by line et pick by store) comparé au stockage traditionnel. Cette augmentation du coût de magasin est due d'abord à l'augmentation des stocks en raison de l'augmentation de lead-time, et à l'augmentation des coûts de manutention.

Pour le CD distributeur, le cross-docking pick by line est bénéfique. Cette diminution des coûts est due à l'élimination des stocks ainsi que l'élimination du processus de mise en racks. D'autre part, le cross-docking pick by store est plus bénéfique que les autres stratégies. Cela est dû à l'élimination de l'inventaire, à l'élimination du procédé de mise en racks et en même temps à l'élimination des activités de picking qui représentent les opérations les plus coûteuses chez le CD distributeur.

Du côté du CD fournisseur, les coûts augmentent en cross-docking pick by line par rapport au stockage traditionnel. Cette augmentation est due notamment à l'impact sur les coûts du transport et de l'augmentation du coût de picking. Le cross-docking pick by store impact encore plus les coûts du CD fournisseur et cela est due à l'augmentation du picking.

Dans une perspective du coût total, la stratégie de distribution avec le coût le plus bas est le cross-docking pick by store. Le cross-docking pick by line est la stratégie la plus coûteuse. En pick by line par rapport au stockage traditionnel, l'élimination des stocks chez le CD distributeur, ainsi que l'élimination du processus de mise en racks, ne compensent pas l'augmentation en termes de picking et les coûts de transport pour le fournisseur. D'autre part, dans pick by store par rapport au stockage traditionnel, l'élimination des stocks chez le CD distributeur, ainsi que l'élimination du processus de mise en racks, et du processus picking compensent l'augmentation en termes de picking et de coût de transport pour le fournisseur. Et même avec une augmentation du coût dans magasins le pick by store reste la stratégie la plus économique.

Ensuite, du point de vue de disponibilité en linéaire le cross-docking docking (pick by line et pick by store) impact la disponibilité. Cet impact sur la disponibilité est dû à l'augmentation du lead-time vers les magasins. D'autre part, l'espace en linéaire (espace de stockage des produits dans les rayons des magasins) n'a pas augmenté pour compenser la hausse du lead-time vers les magasins. Dans les magasins, la plupart du temps tous les stocks sont dans les rayons. Lors de la conception du plan des rayons (de planogrammes), les gestionnaires assignent à chaque article dans l'assortiment d'un espace

fixe avec un nombre défini de produits. Cette conception est souvent basée sur le chiffre d'affaires généré par chaque mètre du rayon. Dans cette étape de la conception les contraintes logistiques ne sont pas toujours prises en compte, même si le nombre de places affecté à un produit a une grande influence sur les possibilités de réapprovisionnement et de commande des magasins.

Enfin, du point de vue de l'effet bullwhip, le cross-docking (pick by line et pick by store) a toujours un effet positif. Cet impact sur l'effet bullwhip, a deux causes principales : - D'abord, par l'élimination de l'inventaire chez le CD distributeur, qui se traduit par une connexion directe entre les magasins et le CD fournisseur. Avec un inventaire chez le CD distributeur, la variabilité des commandes dans la chaîne logistique est plus élevée en raison de l'amplification des commandes. - Ensuite, dans le cross-docking les commandes proviennent directement au CD fournisseur en petite quantité (caisses) à la place des quantités économiques (palettes ou couches). Cela réduit l'effet de batching et donc réduit considérablement l'effet bullwhip.

b- Segmentation et choix des stratégies pour chaque produit

Dans notre analyse, nous présentons une segmentation pour chaque facteur. Pour cela nous optons pour une segmentation basée sur l'analyse de matrices service/coûts et une analyse basée sur l'effet bullwhip. Nous avons présenté les 200 produits étudiés sur la matrice service/coûts (figure 3). Chaque point de la matrice représente un produit. Sur l'axe des X, nous avons le différentiel de coût total de la chaîne logistique par produit entre le cross-docking et stockage traditionnel (coûts cross-docking - coût stockage traditionnel). Sur l'axe Y, nous avons le différentiel de disponibilité en linéaire entre le cross-docking et stockage traditionnel (niveau de service cross-docking - niveau de service stockage traditionnel).

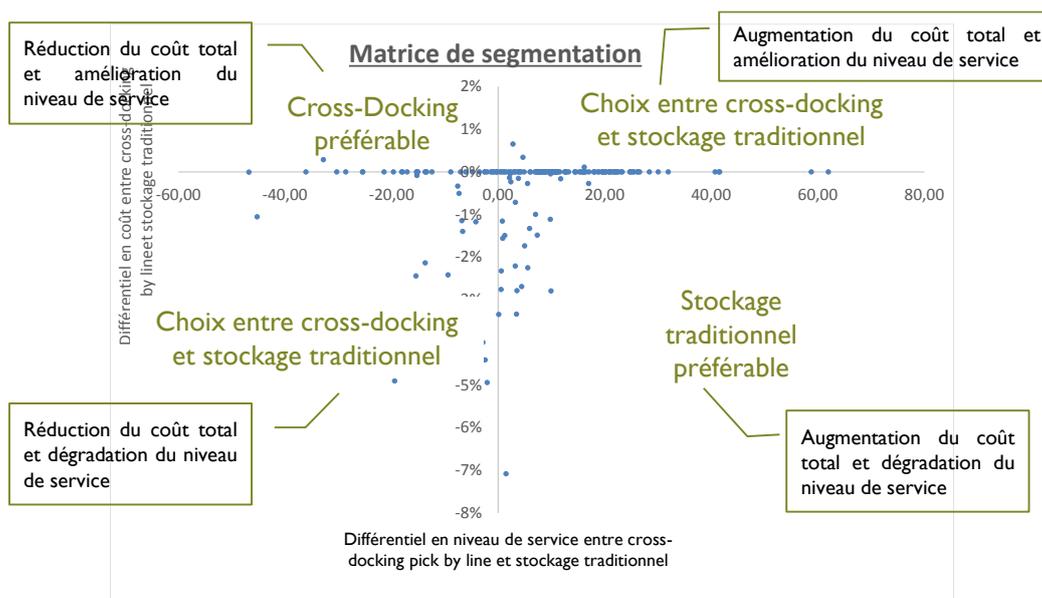


Figure 3: Matrice Service/Coûts

Chaque case de la matrice correspond à une stratégie. Par exemple, les produits dans la case gauche supérieure sont adaptés au cross-docking. Pour ces produits, nous avons une réduction du coût total de la chaîne logistique et une amélioration du niveau de service. Le coût total logistique dans le stockage traditionnel est plus grand que le coût total logistique en cross-docking. Le niveau de service est également plus grand en cross-docking.

Dans cette analyse, et pour chaque facteur de produit nous présentons une segmentation basée sur les attributs « Elevé » et « Faible » de ce facteur. Par exemple, pour l'espace linéaire, nous divisons les 200 produits étudiés en deux catégories en fonction de la médiane (100 produits avec un espace linéaire élevé et 100 produits avec un espace faible). Nous présentons les attributs Elevé et Faible de ces facteurs dans la matrice Service/Coûts, puis nous analysons le positionnement de chaque attribut sur la matrice. Par la suite, nous expliquons les raisons de l'adaptabilité de chaque attribut d'un facteur à une stratégie de distribution. Cette procédure sera effectuée pour tous les facteurs étudiés.

Pour l'effet bullwhip, la segmentation se fait sans matrice. Nous analysons de façon indépendante l'impact de chacun de ces facteurs sur l'effet bullwhip.

La raison pour laquelle nous analysons les coûts et niveau de service conjointement et l'effet bullwhip indépendamment, est que le coût et niveau de service sont des performances indépendantes et qui peuvent être analysées conjointement. D'autre part, l'effet bullwhip est une performance qui est corrélée avec le coût. En fait, les impacts de l'effet bullwhip sur la variabilité des commandes, ont un impact direct sur le coût des stocks.

Les résultats de la segmentation sont les suivants :

Les *produits avec un faible volume*, sont plus adaptés au stockage traditionnel en termes de coûts. Pour ce genre de produits, le nombre de caisses par palette est grand. En cross-docking le CD distributeur commande en petites quantités, souvent des caisses pour tous les produits. Pour ce genre de produits à faible volume le coût de picking augmente car il y'a un grand nombre de produits dans une palette. D'autre part, pour ce genre de produits, le coût des stocks est faible, et par conséquent la réduction des stocks n'est pas assez élevée. D'autre part les commandes en quantité économique (des palettes), créent une plus grande variabilité, avec des pick de volume de commandes suivies de périodes sans commandes. Pour les produits à faible volume, avec un grand nombre de caisses par palette l'effet de batching sur l'effet bullwhip est supérieur.

Pour les *produits à faible espace linéaire*, l'impact sur la disponibilité en cross-docking est important. En effet, en raison de l'augmentation du lead-time vers les magasins, il existe un impact sur le niveau de

service, si l'espace linéaire est faible et s'il ne permet pas de couvrir la demande pendant le lead-time en cross-docking.

Pour les *produits avec une demande faible*, il n'existe pas de risque d'un impact sur la disponibilité aux linéaires. Ceci peut être expliqué par le fait que, pour ces produits, il existe suffisamment d'espace linéaire pour couvrir leur faible demande. D'autre part, pour ces produits les coûts augmentent. En effet, pour ce type le coût des stocks dans les magasins augmente considérablement, car ce sont des produits qui s'écoulent lentement. Pour l'effet bullwhip, le fournisseur commande toujours en palettes complètes à l'usine. Pour les produits avec une faible demande si une palette couvre plus de 20 jours de demande, il n'y a aucun impact sur l'effet bullwhip. La réduction de la variabilité est absorbée par l'effet de batching.

Pour les *produits avec une faible variabilité de demande*, il n'existe aucun impact sur la disponibilité aux linéaires. En fait, un produit avec une faible variabilité de demande variable est adapté pour le cross-docking, même si le lead-time aux magasins augmente avec un espace linéaire adapté il n'y a aucun risque sur la disponibilité.

Les *produits à faible mouvement cubique*, augmentent le coût en cross-docking pick by line par rapport au stockage traditionnel. Le mouvement cubique est la demande du produit multipliée par son volume physique. En effet, pour les produits à faible demande et à faible volume physique, le coût des stocks aux magasins et le coût du picking chez le fournisseur augmentent. Cette augmentation ne compense pas la réduction des stocks chez le CD distributeur.

Les *produits avec un grand lead-time*, augmentent le coût de la chaîne logistique et impactent la disponibilité aux linéaires. En effet, en augmentant le lead-time vers les magasins, le coût de stockage magasins augmente. Les magasins augmentent le stock pour couvrir la demande sur le lead-time. L'augmentation des coûts dans les magasins, ne compense pas la réduction de l'inventaire chez le CD distributeur. D'autre part, en raison de la limitation de l'espace linéaire, si le lead-time est élevé, il y'a un impact sur la disponibilité.

Les *produits avec faible délai de réapprovisionnement*, n'ont aucun impact sur la disponibilité, mais en même temps un impact sur les coûts. Avec un délai de réapprovisionnement bas l'augmentation du lead-time vers les magasins est compensée, ce qui aide à maintenir une disponibilité haute dans les magasins. D'autre part, un faible délai de réapprovisionnement augmente le coût de transport des fournisseurs et peut augmenter considérablement le coût total de la chaîne logistique.

Basés sur cette analyse, nous proposons une matrice qui peut être utilisé par les gestionnaires pour évaluer la stratégie de distribution la plus adaptée pour chacun de leurs produits, et en fonction de leur objectif. Par exemple, si une entreprise veut adopter une stratégie cross-docking et leur accent est mis davantage sur les niveaux de service, les produits adaptés sont les produits avec une faible variabilité,

un espace linéaire élevé, une faible valeur, et un faible lead-time. Si l'accent est mis davantage sur la réduction de l'inventaire du magasin, l'entreprise doit choisir des produits avec un volume élevé de la demande. Si l'accent est mis sur la réduction de l'effet bullwhip, les produits adaptés ici sont des produits avec un volume physique élevé et un volume élevé de la demande. Notez que dans le tableau nous ne spécifions pas la typologie de cross-docking adapté. En effet, nous avons le même impact des caractéristiques du produit sur les performances pour les deux typologies de cross-docking.

La sélection de la stratégie de distribution peut également être basée sur les caractéristiques des produits. Par exemple, si l'entreprise a des produits avec un volume physique élevé, un espace linéaire élevé et un volume élevé de la demande, le cross-docking est certainement la stratégie la plus adaptée.

Caractéristiques des produits			Coût				Niveau de service	Effet Bullwhip
			Stores	Retailer DC	Supplier DC	End-to-End		
Facteurs intrinsèques	Volume physique	Elevé		Cross-docking	Cross-docking	Cross-docking		Cross-docking
		Faible		Stockage traditionnel	Stockage traditionnel	Stockage traditionnel		Stockage traditionnel
	Espace linéaire	Elevé					Cross-docking	
		Faible					Stockage traditionnel	
	Valeur	Elevé				Cross-docking	Stockage traditionnel	
		Faible				Stockage traditionnel	Cross-docking	
Facteurs de demande	Demande	Elevé	Cross-docking			Cross-docking		Cross-docking
		Faible	Stockage traditionnel			Stockage traditionnel		Stockage traditionnel
	Variabilité	Elevé					Stockage traditionnel	
		Faible					Cross-docking	
Facteurs intrinsèques / demande	Mouvement cubique	Elevé	Cross-docking					Cross-docking
		Faible	Stockage traditionnel					Stockage traditionnel
Facteurs de contrôle	Lead-time	Elevé	Stockage traditionnel			Stockage traditionnel	Stockage traditionnel	
		Faible	Cross-docking			Cross-docking	Cross-docking	
	Délai de réapprovisionnement	Elevé	Stockage traditionnel		Cross-docking	Cross-docking	Stockage traditionnel	
		Faible	Cross-docking		Stockage traditionnel	Stockage traditionnel	Cross-docking	

Tableau 1: Framework pour la segmentation des produits et le choix de stratégies de distribution

5- Conclusion

La chaîne logistique de la grande distribution est caractérisée par l'émergence de plusieurs stratégies de distribution. Dans ce contexte, les distributeurs ont mis davantage l'accent sur l'amélioration et l'optimisation de leurs opérations. L'un des défis majeurs est la réduction des coûts logistiques afin de leur permettre de maintenir des prix bas, d'investir dans l'expansion de leur réseau de magasins, conquérir de nouveaux marchés et fidéliser les clients. Une des solutions pour atteindre cet objectif est la réduction des stocks. La réalisation de ces objectifs conduit à l'organisation de nouvelles stratégies de distribution. Dans ce contexte de pression en termes de réduction des stocks et de l'amélioration des niveaux de service, les distributeurs poussent leurs fournisseurs à utiliser la stratégie de distribution cross-docking qui élimine l'inventaire dans leurs centres de distribution (CD).

Comme nous l'avons montré dans cette recherche, le cross-docking peut être bénéfique pour la chaîne logistique en termes de réduction des coûts, ainsi qu'en termes de réduction de l'effet bullwhip. D'autre part, cette stratégie peut impacter le coût et le niveau de service. Une façon de bénéficier du cross-docking, est de combiner cross-docking et stockage traditionnel dans la même chaîne logistique. Afin d'atteindre cet objectif, une segmentation des produits en fonction de leurs caractéristiques et de leurs impacts sur les performances de la chaîne logistique devrait être élaborée.

Dans cette recherche, nous avons proposé un framework pour sélectionner la stratégie de distribution adaptée pour chaque produit en fonction de ses caractéristiques et de son impact sur les performances. Nous avons donné une attention particulière pour une analyse détaillée de l'impact des stratégies de distribution sur les performances de la chaîne logistique, ce qui nous a permis de donner un framework pour la sélection de la stratégie de distribution adaptée pour chaque produit.

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Chapter 1

1. Research context

This chapter presents a general introduction and the scope of the research. We first define the type of considered supply chain, namely the retail supply chain. We then describe the actors of this supply chain, their roles and their challenges. We also define the distribution strategies considered in this work and their impacts on the supply chain performance, and the need of product segmentation. This chapter also describes the research context and positioning of our thesis. Finally, the research questions of this thesis are presented.

1.1 Scope of the research

Nowadays retail companies live in a fast moving and rapidly changing business environment. Customer requirements become rougher on the product's quality and service. To stay competitive in the market, products have to be delivered on time, to the right place, with the correct quantity and damage free. Moreover, severe competition in the market forces supply chain managers to search for innovative solutions to satisfy customer demands and at the same time reduce costs and make profits.

The concept of retail supply chain emerged in the US in the 50s, with the development around cities of retail stores. In France, Edouard Leclerc innovates with the opening of a (small) store, in Bretagne, in which the customers shop directly from the shelves. By the early 60s, Carrefour opened its first big store: the process is initiated and now we count more than 1,500 hypermarkets and 5500 supermarkets.

In the retail supply chain the logistics costs represent about 7% to 20% of the sales price depending on the countries (Arroyo & al., 2006; Sanyal, 2006; Chandra & Jain, 2007). This encourages retailers and suppliers to consider supply chain management as a strategic function. The supply chain includes all the links that allow the distribution of the products from supplier to consumer, including transportation, logistic services (packaging, storage...) and management of the information flows. Lately, the supply chain management, has become a strategic function for companies. Therefore, in order to control or at least manage all the logistics processes efficiently, many different systems and distribution strategies were approached: from simple models of distribution, directly linking the supplier and the point of sale (store), to more complex schemes in which a number of intermediate stages interpose.

Retail supply chains include more than stores in their network. Today's retail supply chain has a multi-echelon structure, with a series of interconnected stock points (Van der Vlist, 2007). Multi-echelon supply chains are difficult to manage, when they are within the same company, and even more complicated when several companies manage them jointly, as is the case in retail distribution. Moreover

there is considerable complexity: assortments of over 30,000 items within a supermarket are not exceptional.

The most common retail supply chain structure is the one that is shown in Figure 1. From right to left in this figure: upstream the plant of the supplier replenishes his regional DC. This operation is based on forecast and driven by the planning and production processes in the supplier plant. The supplier DC subsequently supplies the distribution centres of various retail companies (Retailers DCs), within their service area. This operation is often done with full truckload (FTL) and full pallets (homogenous pallets). It is a demand driven by the retailer's DC replenishment orders. This means that, based on the retailer DC previous orders, the supplier DC organizes his inventory and transportation planning. The retailer DC then takes control over the replenishment of its own stores. This operation is often done with full truckload (FTL) and mixed pallets (heterogeneous pallets). It is always a demand from the stores orders. This means that based on the stores previous orders, the retailer DC organizes his inventory and transportation planning. This structure corresponds to the traditional warehousing strategy.

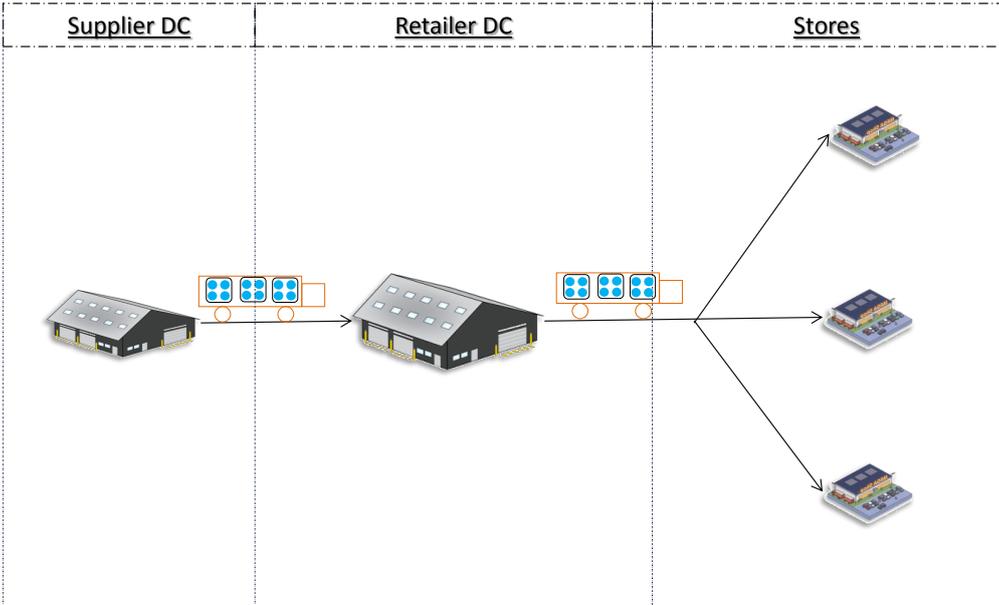


Figure 1: Retail supply chain structure

Suppliers and retailers are faced to several key supply chain challenges (Jones, 2012). Retailers' key challenge is cost reduction in their operations to enable them to maintain low prices, to invest in the expansion of their store network, moving into new channels and retaining shopper loyalty. This means that inventory levels are reduced, decreasing working capital and inventory cost. The need to reduce working capital means that retailers are reducing inventory levels in their DC, which has traditionally been used to protect service level at the stores. Reducing inventory at the retailer DC and at the stores, as well as keeping a good service level is a conflicting challenge.

For suppliers this leads to a major challenge: adapting to this need for greater flexibility in terms of on-time delivery, transportation flexibility reducing lead-time and coping with the changing order patterns.

This new way of working across the chain is putting pressure on the relationship between retailers and suppliers, with both groups looking for more collaborative relationships (Ramanathan & Gunasekaran, 2014).

In this context of stretch target for retailers to reduce inventory, to improve working capital, and to improve service levels altogether, they push their suppliers to use the cross-docking distribution strategy that eliminates the inventory at their distribution centre (DC).

In the literature different definitions were given to the cross-docking. A definition of cross-docking provided by (Kinnear, 1997) is: “receiving a product from a supplier or manufacturer for several end destinations and consolidating this product with other suppliers’ product for common final delivery destinations”. In this definition, the focus is on the consolidation of shipments to achieve economies in transportation costs.

The Material Handling Industry of America (MHIA, 2011) defines cross-docking as “the process of moving merchandise from the receiving dock to shipping dock for shipping without placing it first into storage locations”. The focus is now on transshipping, not holding stock.

Van Belle et al., (2012) defines cross-docking as the process of consolidating freight with the same destination (but coming from several origins), with minimal handling and with little or no storage between the unloading and loading of the goods. Here the focus is on the reduction of handling, the reduction of storage and the consolidation of products.

The Supply-Chain Operations Reference model (SCOR, 2008) defines cross-docking as a “strategy used in many distribution centres (DC) to increase inventory velocity while maintaining shipping efficiency. In a traditional DC, the receiving process is disjointed from the shipping process and storage acts as an intermediary between the two processes. Cross docking actively links the receiving and shipping processes. In a DC, both cross docking (no storage) and traditional (with storage) operations might take place”. Here the focus is on the inventory reduction, and transshipments.

In this thesis and in the retail supply chain, cross-docking can be described as *a distribution strategy that eliminates the inventory at the retailer DC, with a consolidation of products from several suppliers DCs to different destinations (i.e. stores) with no storage between the reception and loading of the products*. In our definition, the focus is on both inventory elimination and consolidation. In our definition we occult the principle of handling because the handling process is different depending on the cross-docking typology.

In fact, there are many typologies of cross-docking distribution strategies and several characteristics can be considered to distinguish the various types (Yan et al., 2009; Vogt, 2010). In the retail supply chain, the major typologies are differentiated related to where the physical sorting (picking of the product)

takes place. We name the two typologies of cross-docking strategy: the cross-docking pick by line and the cross-docking pick by store. In the cross-docking pick by line, the supplier DC delivers the retailer DC the sum per product of all the stores orders. At the retailer DC, the products are sorted based on each store order, combined with other products from other suppliers and shipped. In cross-docking pick by store, the supplier DC prepares the orders for each store unlike the cross-docking pick by store where the orders are prepared per product (sum of all stores orders). In the pick by store the retailer DC takes care of consolidating the deliveries from different suppliers DCs to the destinations (stores).

The cross-docking distribution strategy is attractive to both retailers and suppliers as a way to improve response times, lower inventories, and as a consequence free up cash. The biggest promoter of cross-docking is Wal-Mart Inc, which in turns is the biggest retailer in the world, and also the first big company to successfully apply the cross-docking strategy (Stalk & al., 1992). The reasons of the success of the implementation are due to the close business relationships with its partners (Ste-Marie & Beaulieu, 2002), which helped the company implement the cross-docking easily. The company also benefits from Distribution Centres and stores with big storage spaces, which help the suppliers deliver in more economic quantities and therefore this doesn't impact the transportation costs (Chandran & Gupta, 2003).

Cross-docking strategy is not without drawbacks. Inventory at different echelons in the supply chain serves a reason. Inventory exists in the supply chain because of mismatches between supply and demand. The mismatch is often intentional because it is more economical to manufacture large lots and store them for future use, and also because inventory is held on anticipation of future demand. Also, inventory increases demand as customers can have products ready and available the moment they want them (Chopra & Meindl, 2007). By removing the inventory at the retailer DC, which is often located geographically near the stores, it increases the lead-time to the stores and consequently increases the risk of hurt on the service level (Van der Vlist, 2007).

Furthermore cross-docking strategy impacts the supplier transportation cost considerably and in some cases increases the supply chain costs. In traditional warehousing the supplier DC often delivers the retailer DC in FTL. In cross-docking strategy since there is no inventory held at the retailer DC, the supplier DC delivers the exact need of the store, which rarely corresponds to a full truck. This way of ordering increases the transportation cost, and in some cases this increase in transportation cost does not offset the benefit from the reduction in inventory cost at the retailer DC (Gebennini et al., 2013). In addition, for suppliers this leads to their main challenges, of adapting to this need for greater flexibility and coping with the changing order patterns. The cross-docking strategy is putting pressure on the relationship between retailers and suppliers, with both groups looking for a more collaborative relationship.

One solution to cope with this issue is to combine cross-docking and traditional warehousing in the same supply chain (Apte and Viswanathan, 2000; Waller et al., 2006). Combining cross-docking and traditional warehousing would reduce the handling cost for the supplier. A preparation of more economic quantities, would reduce the supplier transportation cost with more Full Truck Loads (FTL) and at the same time mean benefits for the retailer with inventory reduction. The combination is done at the product level, some products are in cross-docking and other in traditional warehousing. The question is what is the right product for the right distribution strategy?

One way to choose the right distribution strategy is to develop segmentation according to products characteristics and their impact on the distribution strategies performances (Apte and Viswanathan, 2000; Waller et al., 2006; Li et al., 2008). Product segmentation aims to differentiate products based on their characteristics. This segmentation is an important scheme to help companies determine which distribution strategy is more adapted to their markets and products. Some products have a high demand volume, and need to maintain inventory in the retailer DC near the stores to ensure a high service level and minimize lost sales (Apte and Viswanathan, 2000). Some products have a high physical volume, and cross-docking is very successful for this kind of products, since storage space is a constraint in the retailer DC, assigning this kind of products to cross-docking strategy would definitely save inventory space and therefore inventory cost at the retailer DC (Li et al., 2008). Other products have a short life cycle and become obsolete faster, for example perishable products. It is necessary to push these products to the sales floor as fast as possible. Distribution of these types of products through a cross-docking strategy is appropriate (Li et al., 2008). Some products have a variable demand rate. Products that are more suitable for cross-docking have demand rates that are more or less stable. Products with an unstable demand are more suitable for a traditional warehousing strategy because the downstream customers experience a short lead time for their replenishment, with geographically nearby distribution centres (Apte and Viswanathan, 2000).

Determining the right distribution strategy for a product is not an easy task because different factors have to be taken into account. A selection based on some product characteristics and their impact on one supply chain metric is not always sufficient. Indeed a product can perform well in a distribution strategy based on one metric, but it can affect the other metrics of the supply chain. The selection must take into account all the supply chain performances

1.2 Research context and positioning

In this section, we briefly describe the literature related to our research for positioning our thesis. A detailed literature review is presented in Chapter 3. The literature related to our research consists of papers dealing with distribution strategies performances analysis and the selection of the right distribution strategy for products depending on their characteristics and impact on the supply chain performances.

Kreng & Chen, (2008) compare the traditional warehousing strategy and the cross-docking strategy in terms of transportation, holding and the production costs (more specific the setup costs) of the products at the suppliers. In this study, two models are developed and a case study analysis is used to illustrate the models developed. The results show that the cross-docking distribution strategy results in tremendous savings in the total system cost for the supply chain. Kreng & Chen, (2008) studied a supply chain composed of a manufacturer plant, retailer DC/cross-dock and stores.

Waller et al., (2006) perform the comparison from an inventory reduction perspective. In their work, a two-echelon inventory model including a distribution centre and stores is developed to study the inventory benefits of cross-docking. The results show that cross-docking can reduce inventory in a retail supply chain but in certain situations it can result in more inventory being required in the stores to achieve the same customer service levels. Waller et al. (2006) studied a two-echelon supply chain composed of a retailer DC and stores. Li et al. (2008), the structure studied is composed as well of retailer DC and stores and doesn't include the supplier DC.

Eftekhar et al. (2008) the authors used Lyapunov exponent, a quantity that characterizes the rate of separation of two trajectories, to estimate the difference between the bullwhip effect in traditional warehousing versus cross-docking. The authors of this paper demonstrate the existence of a reduction in bullwhip effect with a supply chain with cross-docking distribution strategy. Here the authors start from the initial assumption that cross-docking distribution strategy suggests that demand information is shared with each stage of the supply chain (supply chain with centralized information), and in the traditional warehousing the information is not shared with all participants in the supply chain (supply chain with decentralized information) and compare the bullwhip effect in the two cases.

Gebennini et al., (2013) present in their work a cost comparison of two different configurations: the "downstream picking configuration" (AS-IS Configuration) which can be assimilated to a traditional warehousing strategy, with picking activities executed at intermediate facilities, and the "upstream picking configuration" (TO-BE Configuration) which can be assimilated to a cross-docking pick by store strategy, where picking activities are performed upstream in the network at a central distribution centre. The study shows that, the transportation costs increase in the TO-BE Configuration by 85% because of the increase of deliveries in Less Than Truck load. On the other hand the operative costs (inventory, commercial, picking and financial) are reduced by 77%. The total costs are reduced by - 22%. The authors mentioned that the cost savings related to the TO-BE Configuration should be compared with the investment and operative costs for centralizing picking activities at the supplier DC, and sharing costs and benefit must be done between the collaborators of the supply chain. Gebennini et al., (2013) studied a three level configuration with a first level composed of a supplier DC, a second level composed of multi retailer DCs and a third level of stores.

In terms of product segmentation and distribution strategy selection for the products, there are many opinions and positions in the literature and also in practice. For instance some consider that the traditional warehousing strategy is more adapted for fast movers' products. Apte and Viswanathan, (2000) consider that for these kind of products we need to maintain inventory in the retailer DC near the stores to ensure a high service level and minimize lost sales. Li et al., (2008) consider another classification by breaking up the fast movers into two categories, the fast movers with low physical volume, and those with high physical volume, and consider that for the latter cross-docking is very successful, since storage space is a constraint in the retailer DC, assigning this kind of products to cross-docking strategy would definitely save inventory cost at the retailer DC.

Apte and Viswanathan, (2000) consider that for products with high value cross-docking is not suitable. In fact, cross-docking inherently leads to eliminate the inventory at the retailer DC, and thereby raises the probability of stock-out situations. However, if the product value is low, cross docking can still be the favourite strategy, but if the product value is high traditional warehousing is the most suitable strategy. On the other hand, the product value is also an important factor in terms of capital cost of inventory. In fact, inventory ties up money that could be used elsewhere, which is the return you could reasonably expect if you invested your money in something other than inventory. The more the product has a big value the more the impact is on capital cost of inventory. So products with high value are more suitable for cross-docking, so we eliminate an inventory point at the supply chain.

Pimor, (2001) considers that products with high physical volume are more adapted for traditional warehousing because this kind of product allows the supplier to optimize the filling of the trucks. Li et al., (2008) consider that these kinds of products are more adapted for cross-docking since it allows reducing inventory at the retailer DC.

In our study, we consider the scope of the retail supply chain from the supplier DC to the retailer stores, comparing traditional warehousing strategy (storage) and cross-docking with its different typologies. This methodology and this structure will allow us to combine the supplier objectives and performances with the retailer objectives and performance, and therefore propose a solution that takes into account an End-to-end perspective with a balance of the objectives and performances of the supply chain partners.

We can notice in these studies that some papers deal with the impact of distribution strategies on the supply chain performances only, often with a partial vision of the structure of the supply chain. Others concern studies on the choice of the distribution strategies for products depending on their characteristics and impacts on the supply chain performances, with divergence of opinion in terms of product segmentation. Furthermore, there is lack of studies on the typologies of cross-docking. In fact, in the literature different authors (Yan & Tang, 2009; Vogt, 2010; Pearson Specter, 2004) describe the typologies of cross-docking without a detailed study on the impact of the traditional warehousing on the supply chain performances.

The objectives of our research are first of all to analyse the impact of the distribution strategies (traditional warehousing, cross-docking pick by store and cross-docking pick by line) on the supply chain performances, of a three echelon retail supply chain; supplier DC, Retailer DC and stores. The supply chain performances analysed are: supply chain cost, service level and bullwhip effect. We also analyse the impact of the products characteristics on the performances of these distribution strategies and the choice of the right strategy for each product depending on its characteristics and the impact on the performances (Figure 2).

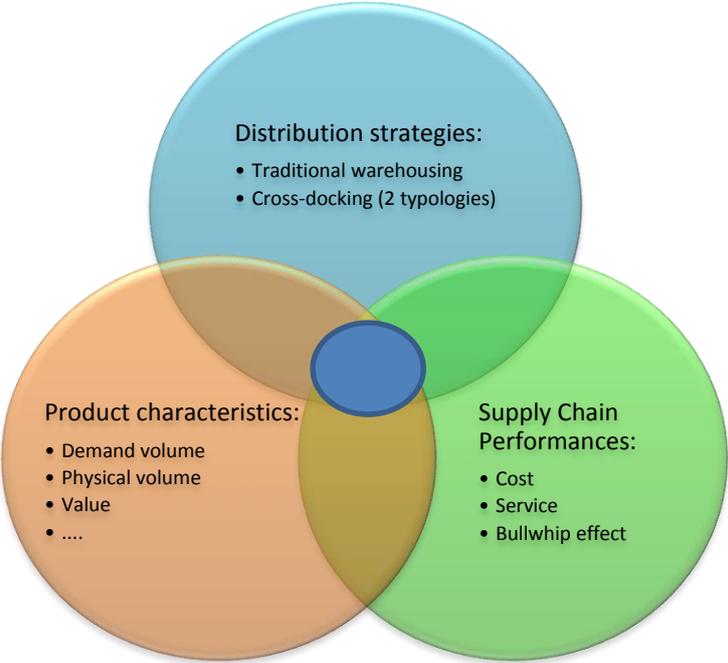


Figure 2: Positioning of the research

1.3 Objectives, contributions and research questions

In our research, we aim to evaluate the impact of the distribution strategies on the supply chain performance, and the choice of the strategy adapted for the products depending on their characteristics. The research is conducted, due to the lack of studies on the product segmentation and distribution strategy selection based on the different impact on the supply chain performances of the different echelons. In addition, the cross-docking distribution strategy is an emergent strategy in the retail supply chain, and more and more retailers adapt this strategy. Due to the novelty of this strategy there is not enough feedback from the different supply chain managers to help choose the right product for each strategy. On the one hand, a deep analysis of the distribution strategies, their characteristics, their impact on the supply chain performances, advantages and disadvantages will help the managers to understand their supply chain. On the other hand, and for the retailers who want to adopt a combination of the cross-

docking and the traditional warehousing strategy, an analysis on the product characteristics and their impact on the performances for each strategies will help managers understand the nature of their products and choose the right distribution strategy for each one.

The contribution of our research lies on: (1) building knowledge on the impact of the distribution strategies on the supply chain performances, and the selection of the right distribution strategy for products depending to their characteristics and impact on the supply chain performances, and (2) developing a model and/or management rules to help managers design and implement an optimal supply chain set-up.

The research objectives are:

1. To analyse the impact of the distribution strategies on the supply chain performances.
2. To analyse the impact of the products characteristics on the performances of the distribution strategies.
3. To choose the right strategy for each product depending on its characteristics and the impact on the performances.

In order to answer these objectives, we highlight the following research questions:

What are the distribution strategies used in the retail supply chain? Why is the cross-docking strategy used in the retail supply chain? What is the advantages of combining different strategies in the same supply chain?

Chapter 2 illustrates the answers from an industrial perspective.

What are the distribution strategies? What are the typologies of these strategies? What are the advantages and drawbacks of each strategy? What is the impact of each strategy on the supply chain performances? What is the impact of the product characteristics on the distribution strategies performances? What is the link between products characteristics and the choice of distribution strategy?

In **Chapter 3** we propose a review of the literature dealing with the performances of distribution strategies and segmentation of products.

What is the process model of each distribution strategy? What is the difference of process between the strategies studied? What are the supply chain performances to be considered?

In **Chapter 4** we develop a process modelling and a framework of performances to analyse.

What is the performance of each distribution strategy in terms of cost? What are the potential gains and hurts in terms of cost for each distribution strategy and for each echelon of the supply chain (supplier, retailer, store)?

In **Chapter 5** we propose a macro cost analysis of the distribution strategies. The cost model relies on a real business case.

What is the impact of the distribution strategies on the supply chain performances? What is the impact of the products characteristics on the performances of the distribution strategies? What is the right distribution strategy for each product depending on its characteristics?

In the **Chapter 6**, we define a process model and we simulate different distribution strategies. We also perform a segmentation based on products characteristics, and finally we propose a framework for product segmentation and distribution strategy selection.

The objectives and two major contributions of the research are presented in Figure 3.

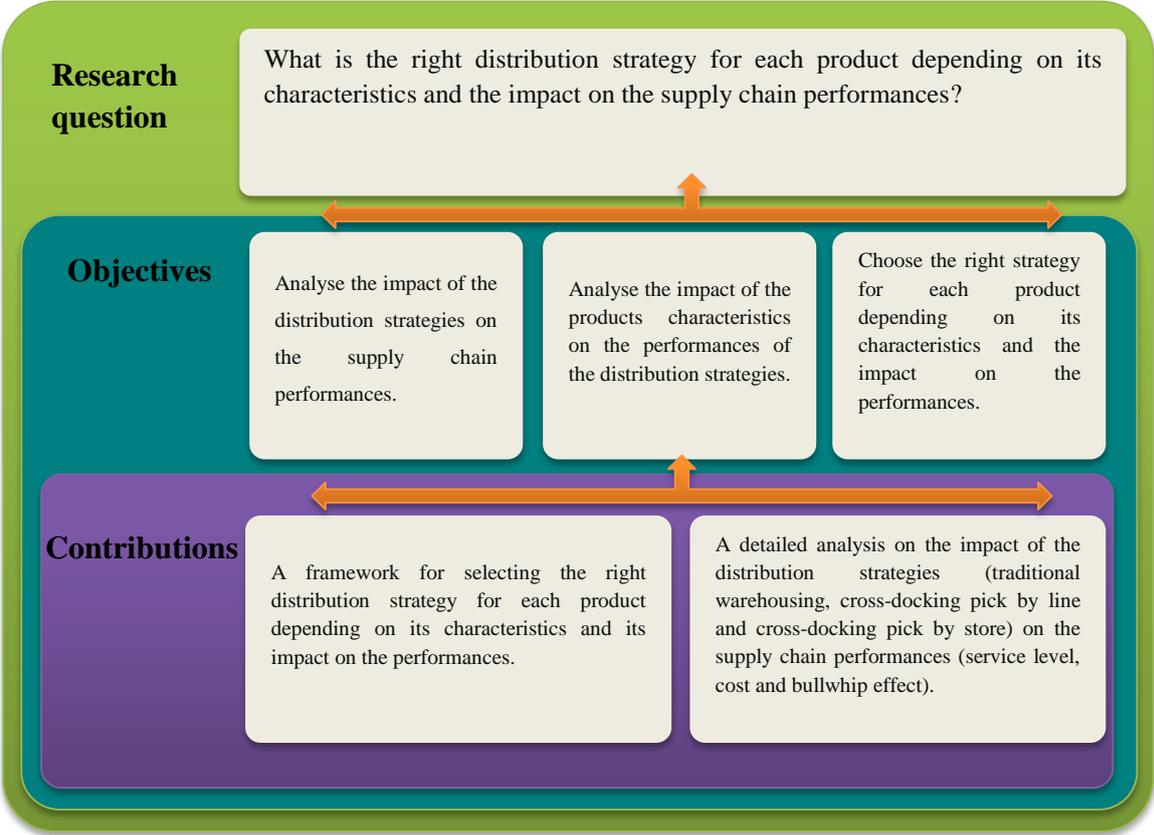


Figure 3: Objectives and contributions of our research

1.4 Structure of the dissertation

This manuscript is divided into six chapters that correspond to the objectives and research questions presented in the previous part.

In the second chapter, we highlighted the industrial context that leads to the cross-docking strategy from a historical perspective.

In the third chapter, we present a detailed overview of the distribution strategies and the product segmentation. We present a state of the art on the distribution strategies to describe their characteristics, typologies, performances, advantages and drawbacks. We also present a literature review on distribution strategy selection based on the product characteristics.

In the fourth chapter, we present a process modelling of the distribution strategies. After a literature review on the supply chain model, we map the physical processes of the distribution strategies. The objective of this chapter is to present and explain the process modelling used in the macro cost model and in the simulation model.

In the fifth chapter, we present a cost analysis to compare the unit costs as well as the total cost of cross-docking strategy and traditional warehousing. A cost model for evaluating the benefits/hurts in costs throughout the supply chain, from the supplier to the stores shelves, was developed and applied on a real business case. This model and results analysis will give us a first understanding of the impact of the distribution strategies on the supply chain cost.

In the sixth chapter, we present and explain the case study. An analysis of the results of the impact of distribution strategies on the supply chain performances is provided. Then, we present an analysis of the characteristics of products and the choice of strategies. We end this chapter with a conclusion and a framework to select the right product for each strategy depending on its characteristics and the impact on the performances.

In the last chapter, we provide a general conclusion and the research perspectives.

Chapter 2

2. Distribution strategies in Retail Supply Chain

Several types of distribution strategies exist in the retail supply chain. These distribution strategies can be differentiated by the number of echelons included in the supply chain, and by their impact on the supply chain performances. The choice of the distribution strategies depend on several elements. The choice can be done based on the products characteristics, on the impact on the supply chain performances, and depends also on external constraints such as the political changes. The thesis is based on a real business case which fits into an overall retail supply chain context with the emergence of new distribution strategies that reconfigured all industrial and commercial channels. The retail supply chain went from simple models of distribution, directly linking the supplier and the stores, to more complex schemes in which a number of intermediate echelons interpose. The cross-docking is an emergent strategy that is more and more used by retailers. However this strategy can have negative impacts on the supplier and/or on the entire supply chain. In the retail supply chain, there exists other hybrid strategies (combining different strategies in the same supply chain). The objective of these hybrid strategies is to achieve a balance between hurts and benefits of the cross-docking strategy. Starting from pooling strategy, to Consolidation and Collaboration Centres (CCC) initiated by Carrefour France, and finally combining traditional warehousing and cross-docking in the same supply chain.

The objective of this chapter is to give an overview of the distribution strategies used in the retail supply chain, based on real cases. This overview gives perspective of the evolution of the retail supply chain from direct to store deliveries to combining cross-docking and traditional warehousing in the same supply chain. This overview provides the context of our research and the motivation of our thesis work.

2.1 Direct to Store Deliveries Strategy

In this strategy, the replenishment of the stores is made by the suppliers who send products directly from their plants and/or warehouses to the stores. In Direct to Store Deliveries (DSD), products are delivered directly by the supplier to the retailer store (Kaipia and Tanskanen, 2003). Each store has a storage area required to meet the safety stock and to satisfy the demand during the large lead-time. The delivery frequency is therefore quite low because the storage space is available in stores. In this distribution strategy, the store is the only "intermediate" between the producer and the consumer (Figure 4).

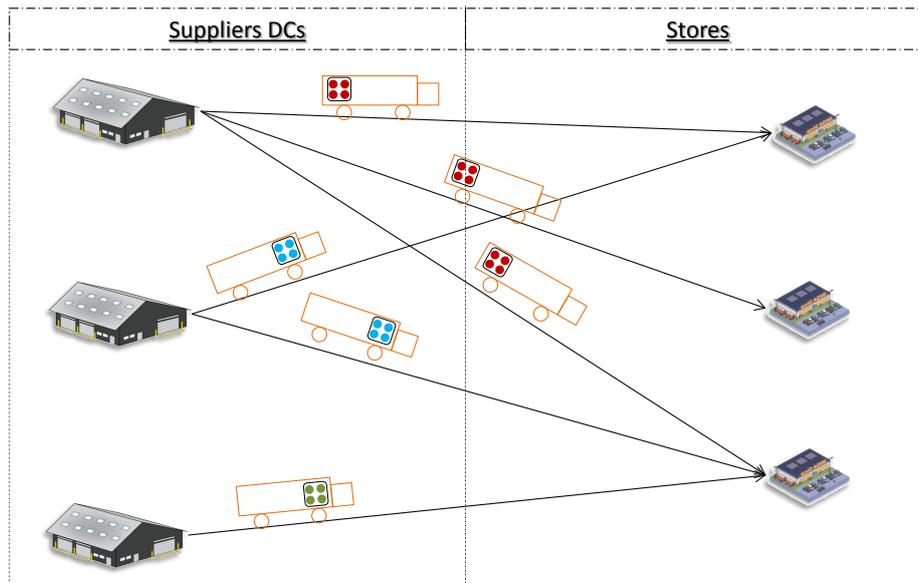


Figure 4: Illustration of Direct to Store Deliveries strategy

Fernie et al., (2000), in their description of the development of the UK retail supply chain over the last 30 years, called this distribution strategy “Supplier Control”. They explain that until the 1980s, deliveries to the stores were made to stores on a weekly (or longer) basis and the stock was held in the backroom and the store managers were buying the stock for their own stores. These managers dealt directly with sales representatives who also could be responsible for merchandizing in the store. Note that Tesco in the mid-1970s to 1980 operated a direct to store delivery (Fernie et al., 2000).

This structure has some clear disadvantages. There is a long lead-time between the stores and the supplier DC and the delivery frequency is low as well. This results on high inventory at the stores, as well as a low service level. The major drawback of this structure however - unless the stores are very large - is that order sizes to the supplier DC are small (less than truckload LTL), resulting in many trucks visiting the store. A typical retailer has virtually hundreds of suppliers (Van der Vlist, 2007).

Whiteoak, (1999) advises that this distribution strategy is adapted for perishable products, typically with large volume and very short life (eg milk, bread). This strategy can be used as well for ‘specials’ products such as display pallets direct from factory to store, or display pallets for promotional products.

Fernie et al., (2000), argue that chilled products, frozen foods and hanging garments are more adapted for this strategy.

Different retailers and suppliers used or still use this strategy. Intermarché, a French retailer, several years after its installation in Portugal, the group operated in direct deliveries. Until June 1994 when, considering it has reached a sufficient number of stores, decided to open a distribution centre to centralize the orders and deliveries (De Carvalho & Paché, 2002).

Auchan, a French retailer and due to its smallest number of stores in Portugal, choses to adopt direct deliveries to the major part of their products deliveries (De Carvalho & Paché, 2002).

Other big suppliers such as Coca-cola or Breweries such as Kronenbourg still use the DSD due to their big volume of sales (Langlois, 2012).

2.2 Traditional warehousing Strategy

Traditionally, the main goals of warehousing have been: (1) to improve the customer service by having available the inventory of products close to the customer; and (2) to obtain economies in the transportation cost by using lower cost FTL shipments. Transportation economies have been obtained by using a warehouse as a consolidation point (Ballou, 1999).

From the 1990s, in the French market the time has come to traditional warehousing (centralization). First with the objective of improving the service to the stores, and at the same time thanks to the “Loi Galland, 1996” the retailers organize their network of platforms between suppliers and stores.

The objectives of the “Loi Galland” No. 96-588 of July 1996 was to improve relations between the suppliers and retailers, by simplifying invoicing, clarifying price negotiations and strengthening the role of the trade terms.

To minimize the acquisition cost and achieve economies of scale as suggested by the “Loi Galland”, the retailers had to increase the volume of orders from the suppliers and to renegotiate new trade terms which contribute to consolidate the flows (Full Truck Load,..), to benefit from reduction and discounts. Stores with insufficient product rotation and a limited space to order Full Truck Load force the retailers to find ways to store these products elsewhere than in the store. This was therefore an argument to create retailers Distribution Centres (Figure 5) instead of direct deliveries to the stores (Morcello, 1998).

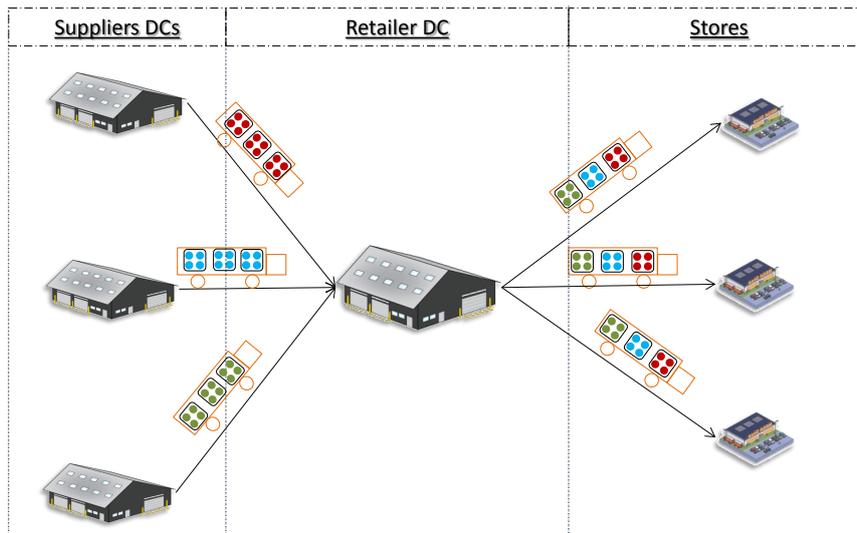


Figure 5: Illustration of the Traditional warehousing strategy

For Carrefour France between 1990 and 2000, the centralization rate of food products has increased from 35% to 90%. Only 10% of the flows are still under direct deliveries between suppliers and stores (De Bourmont, 2012).

The centralization started earlier in the UK market. The pattern of distribution began to change as leading retailers such as Sainsbury and Boots began to build distribution centres in the late 1960s and early 1970s (Fernie et al., 2000). Tesco takes the decision to move away from direct delivery to stores and to implement centralization in 1980s (Smith & Sparks, 2009). Tesco replaced Direct to Stores Deliveries by a centrally controlled and physically centralized distribution network and service delivering the vast majority of stores' needs, utilizing common handling systems, with deliveries within a lead time of a maximum of 48 hours (Sparks, 1986).

There are various benefits from the centralization in the retail supply chain. Retailers and suppliers find their niche in this new strategy:

a. The emergence of retailers DCs favored by a need of sales area

By eliminating, or at least greatly reducing storage space in the store (historically in the backroom), creating distribution centres allowed retailers to convert the backroom onto sales.

b. A reduction in inventory levels resulting in financial gain

Due to the transition from Direct to Store Deliveries to centralization, stores safety stocks were transferred to the retailer distribution centre. Inventories of all stores are then pooled by the retailer DC serving these stores, and the overall level of safety stock is less than the sum of the safety stock of all

the stores, which means a reduction in the total inventory. The retailer reduces the inventory, therefore reduces the inventory holding cost.

c. Improving service levels and the quality of deliveries

The stores replenishment is made easier with a geographic proximity of the Retailer DC. The deliveries to the store are more organized compared to the multiple deliveries and receptions in the DSD strategy. The reception time is fixed in advance. At the same time the pallets are prepared by the retailer DC in order to facilitate the shelf replenishment process. In the DSD strategy the deliveries to stores was carried out in difficult conditions, with trucks waiting, staff mobilized at inopportune moments, delays.

d. Transportation cost reduction

Centralization reduces transportation cost. Whereas before in the DSD strategy suppliers deliver the stores with Less than Full Truckload, thanks to centralization the suppliers are able to fill their trucks and perform deliveries with Full Truck Loads. Downstream, the stores are delivered as well with Full Truck Load and vehicle routing to the stores.

In terms of product segmentation, Li et al. (2008) consider that products with low priority, that is, the ratio of value and life cycle, are more suitable for this strategy. In the same paper the authors, consider that products with a high life cycle, without a risk of obsolescence, are adapted too for this strategy. Apte and Viswanathan, (2000) consider that products with an unstable demand are more suitable for a traditional warehousing strategy because the downstream customers experience a short lead time for their replenishment, with geographically nearby distribution centres. Gue, (2007); Lee et al., (2006); Li et al., (2008) and Yan and Tang, (2009) as well consider that a product with a variable or unstable demand are more suitable for traditional warehousing.

To summarize there are major benefits of traditional warehousing:

On the supplier side this evolution had several consequences:

- Increase in the average orders sizes per product with pallets instead of cases
- Increase in the total orders Full trucks orders instead of Less than truck load
- Reduction of the kilometers traveled by deliveries to retailer distribution centres, whereas before transport to the stores remained problematic.

For the retailer the evolution had several positive consequences as well:

- Retailers exercise greater control over the quality of service provided by the suppliers.
- Minimizes the acquisition cost and achieve economies of scale

In an entire supply chain perspective (from the stores to the supplier DC):

- Cost was reduced
- The service level to the stores was improved

2.3 Cross-docking Strategy

As defined in the previous chapter, Cross-Docking is a distribution strategy in which the products move as directly as possible from the inbound dock to the outbound dock of the retailer DC (Figure 6). Cross docking is simply the direct flow of goods from the receiving area to the shipping area in the warehouse, with a minimum dwell time and as little handling and storage in-between as possible (Apte & Viswanathan, 2000). More largely, in our work we consider the cross-docking distribution strategy where the cross-docking technique is used at the retailer DC. Today the development of such strategy becomes a standard scheme for a number of retailers, especially the larger ones.

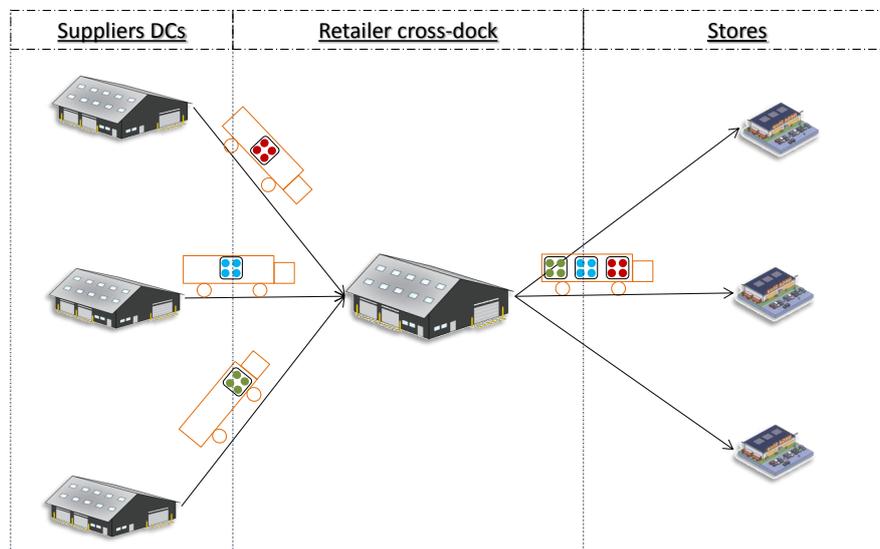


Figure 6: Illustration of the cross-docking strategy

Since 2005, in the French market the time has come to cross-docking. First with the objective of a further inventory reduction, and at the same time cost reduction as the retailers push the suppliers to use the cross-docking strategy.

In 2008 and thanks to the LME (Loi de Modernisation de l'Economie) a French law, the retailers again reorganize their network of platforms between suppliers and stores. The introduction of the LME relies crucially on the issue of inventory reduction. Indeed, the LME impose a shorter payment cycle (45 days against 90 days before the law) (Desfilhes, 2010). In doing so, the new law changes the supply chain objectives and perspectives. Drastically reducing the payment cycle, the LME has indeed crucially rested the issue of inventory reduction, from the point of view of cost reduction as well as financial

immobilization, and at the same time the obsolescence cost for some products. This perspective helps to intensify and generalize the cross-docking strategy.

At the same time and in competitive markets the retailers have to diversify their offer by proposing a large assortment with very regular changes (Rognon, 2009). In a traditional warehousing strategy and with an average 30 days of stock, you have 1 month to replace an old product with a new one. Cross-docking will simplify these changes and gives more flexibility for change in the assortment.

Carrefour France was the first retailer to adopt this distribution strategy in the French market. In 2005, Carrefour France tested cross-docking in one DC and for some specific products. In 2008 it was generalized to all the DCs that deliver hypermarkets (Rognon, 2009). A large number of product categories were concerned (Home care, Fabric care, Beauty, Feminine care, Food.....).

Due to this new strategy Carrefour France observed a reduction in inventory, reduction in handling costs, and benefits in terms of cash immobilization. If the transition to the cross-docking distribution strategy was of benefit for the retailer, the suppliers had a different opinion (Rognon, 2009).

One of the successful stories of implementation of cross-docking was Wal-Mart in the USA (Chandran & Gupta, 2003). The reasons for the success of the implementation were multiple. First, Wal-Mart established a close business relationship with its partners due to the multifunctional approach (Ste-Marie & Beaulieu 2002). This close relationship helped Wal-Mart to implement the cross-docking easily. On the other hand, Wal-Mart benefits from Distribution Centres and stores with big storage spaces, which help the suppliers to deliver in more economic quantities and hence this doesn't impact the transportation costs.

Cross-docking requires a perfect quality of service in delivering the retailer DC, without any delay, since there is a direct impact on service level of the stores. However, the quantities to be delivered are reduced, with Less Than Full truckloads the number of trucks needed increases, and this lead to an increase on the transportation costs as well as increase in CO2 emissions.

Figure 7 summarize the hurts and benefits of the cross-docking strategy on the supply chain performances:

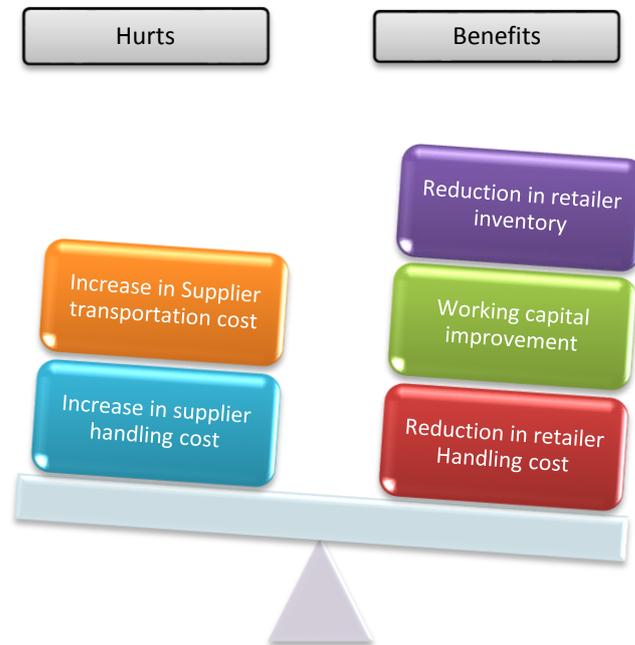


Figure 7: Balance of the cross-docking impacts End-To-End

In the retail supply chain, there exists other hybrid strategies mixing cross-docking and other strategies. The objectives of these hybrid strategies are to achieve a balance between hurts and benefits of the cross-docking strategy. Starting from pooling strategy, to Consolidation and Collaboration Centres (CCC) initiated by Carrefour France, and finally combining traditional warehousing and cross-docking in the same supply chain.

2.3.1 The pooling

Faced to these changes, suppliers and retailers implement collaborative approaches such as the pooling, which consists in grouping in the same truck products coming from several suppliers with a common supply network. More frequent deliveries, made economically possible by pooling and better optimization of vehicle fill rate, reduce the transportation cost while reducing inventory levels.

If the "pooling" is nowadays the subject of interest for suppliers, the firsts implementations date back to more than ten years. For example, for the fresh and frozen products, suppliers of these products were quickly brought to use pooling to best manage the cold chain. This choice of this strategy was primarily dictated by logistical constraints related to the product: frequent small deliveries of short life products, high logistics cost and need of infrastructure to manage the cold chain.

While this strategy raises the question of compatibility between the suppliers as well as products that will be pooled, this strategy has become a success story for a number of suppliers:

The HECORE pooling project:

Henkel, Colgate and Reckitt gather their products in a common pooling distribution centre (Figure 8). The three suppliers combine in the same DC their products and deliver from this DC the retailer cross-docking platform. The project called HECORE was highly encouraged by retailers such as Carrefour, since it was in line with their strategy and obviously favorable to the retailers in terms of inventory reduction and cross-docking implementation (Hiesse, 2009). At the same time, it allows the three suppliers to reduce their transportation costs by combining their deliveries in a Full Truck Load.

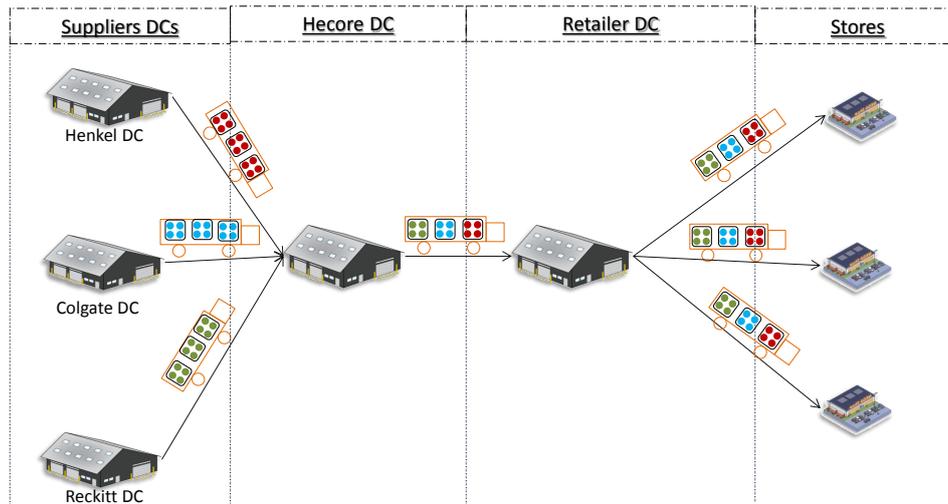


Figure 8: Illustration of the HECORE Pooling strategy

Unilever France has also adapted this approach. They selected products with low sales volume for pooling with two French Cheese makers. The pool is controlled by the company STEF in Plessis-Belleville, France. STEF stores the products in a warehouse shared with a controlled temperature (6 ° C), centralizes the orders sent and supplies several times a week the retailers DCs in large areas of northern France (Monceaux & Polge, 2013). In terms of flows, Unilever France have two types of products, a high-volume category such as food (Knorr soups, Amora mustard ...) or detergents (Skip) representing more 100,000 pallets per year and help fill the trucks. Then they have a product category with lower volumes as margarine, which represents three to five pallets per delivery. The pooling scheme was introduced for the low volume category, since for the first one vehicle fill rate constraint is not existing, and the choice was for the second one to optimize the transportation cost by pooling with products of other suppliers (Monceaux & Polge, 2013).

Another example of pooling was the project between Sara Lee and Cadbury in 2004. Sara Lee and Cadbury were among the first in 2004 to pool their shipments to retailers (Le Moigne & Bouniol 2008).

Benedicta, Nutrimaine and Pastacorp also use the pooling strategy. They decided to deliver certain Carrefour DC from a common platform (Le Moigne & Bouniol, 2008).

2.3.2 Consolidation and Collaboration Centres (CCC) initiated by Carrefour France

For Small and Medium size Business (SMB) and Very Small Business (VSB), which don't have sufficient volumes to perform cross-docking economically (and ecologically), Carrefour France created the Consolidation and Collaboration Centres (CCC), called also 3C (Rognon, 2009). Before this new organization VSB and SMB delivered the Carrefour DC in Less Than Truck Load, with non-optimized transportation cost. The reason behind that, is that there was no inventory hold at the Carrefour DC, since we are in cross-docking strategy and in the same time there was no enough orders from the stores that allow to fill the trucks. This new organization (Figure 9) allow the VSB and SMB suppliers to deliver an intermediate DC (CCC) with full truck loads and to reduce their transportation costs.

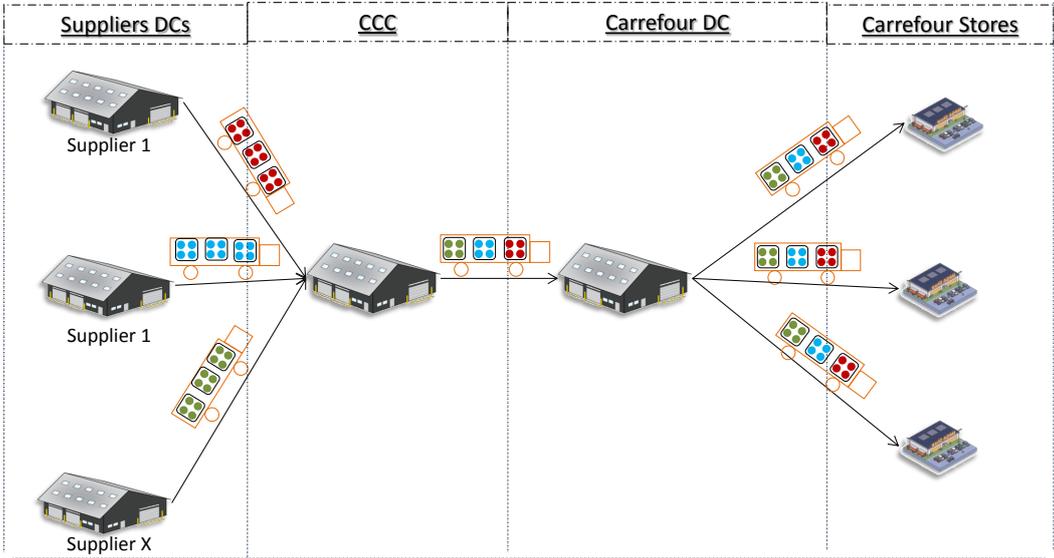


Figure 9: Illustration of the Consolidation and Collaboration Centres (CCC)

The CCC is a multi-supplier operated by a logistics service provider, where the stock belongs to the suppliers. The goal is that each CCC hosts 30 to 60 suppliers stock. This is determined by the overall volume numbers, because the centre will be able to send at least one full truck per day (usually five or six) to regional Carrefour DCs. The goal is to make eligible small and medium suppliers in cross-docking. A CCC contract is signed between the logistics provider and the suppliers, benefiting from a group rate previously negotiated by Carrefour. According to Carrefour, the additional costs to the suppliers should be largely offset by the transport optimization. Another benefit is that the supplier can deliver its products directly from the plant, and will be able to reduce plant inventory.

2.3.3 Combining cross-docking and traditional warehousing strategy

This approach consists of combining the cross-docking strategy and the traditional warehousing strategy in the same supply chain. Some products are in the cross-docking strategy and others in the traditional warehousing one.

Cross-docking with maintaining some products in traditional warehousing as a variable adjustment that optimizes the transportation cost and to fill the trucks. This strategy is already used in different supply chains. Wal-Mart uses this strategy, with a few weeks' worth inventory maintained for fast moving staple goods, since a higher level of stock availability is required for these items to minimize lost sales, and cross-docking for the other products (Apte & Viswanathan, 2000).

The challenge here is to choose the right product for each strategy, depending on the product characteristics and their impact on the supply chain performances.

2.4 Synthesis of Distribution Strategies

In the retail supply chain different distribution strategies can be adapted. Each distribution strategy has its advantages and drawbacks, and in addition each product typology is adapted to a strategy.

In DSD and due to the long lead-time between the stores and the supplier DC and the high delays between deliveries, the inventory at the stores is high, and the service level is low. Moreover, the stores have not enough storage space to order to the supplier in economic quantity that allows to have a FTL which results to a high transportation cost. Despite this impacts of the DSD it still adapted for some products typologies such as products with large sales volume, perishable and frozen products.

Traditional warehousing, allows and increase in the average orders sizes to the supplier DC per product (pallets instead of cases) which allow a reduction in the transportation cost. This strategy allows a high service level at the store due to the geographic proximity of the retailer DC wich lead to a low lead-time for deliveries. On the other hand, this strategy create an additional inventory in the supply chain at the retailer DC. High life cycle, unstable demand, low physical volume products are adapted to this strategy.

Cross-docking distribution strategy complicate and increase picking cost for suppliers, increase the transportation costs, create a risk of impact on the service level with higher lead-time to the stores, and increase CO2 gas emissions with the increase of the number of trucks between the supplier DC and the retailer DC. At the same time cross-docking have positive effect on some performances, for instance the reduction of the retailer inventory. To find a balance between the benefit and the hurts of cross-docking for an optimal supply chain performance, the retailer and supplier organize themselves to find new approaches of collaboration to support this new strategy and reduce its impacts on the cost, service level

and environment impact. Low life cycle, stable demand and high physical volume products are adapted to this strategy.

In the retail supply chain, the solutions to achieve this balance was multiple. Starting from the pooling strategy, to the Consolidation and Collaboration Centres (CCC) initiated by Carrefour France, and finally combing traditional warehousing and cross-docking in the same supply chain. The challenge is to choose the right product for each strategy, depending on the product characteristics and their impact on the supply chain performances. This constitutes the aim of our research.

In the next chapter, we review the academic literature dealing with the distribution strategies and their performances by focusing on the two strategies considered in our thesis, namely: the cross-docking and the traditional warehousing. In the literature review, we also discuss the research that has looked at the issue of product segmentation and distribution strategy selection within supply chains.

Chapter 3

3. Distribution strategies' performances and product segmentation: A literature review

In the current economic environment, retailers put even more focus on the inventory reduction. This to improve their working capital, to free up cash to invest in the expansion of their store network and moving into new channels, and also reduce the inventory cost. One of the solutions to achieve this objective is the setup of the cross-docking distribution strategy. Cross-docking is a strategy that moves products through a consolidation centres or cross-dock without putting them into storage.

The cross-docking distribution strategy has some important advantages over the traditional warehousing because it reduces inventory costs, storage space needs, handling costs, and accelerates cash flow. On the other hand these advantages of the cross-docking can be offset by other impacts on the supplier's transportation costs, supplier's handling costs, increase in inventory at the stores, and the customer service level.

To have a performing supply chain set up the solution in terms of cost and service level the combination of cross-docking distribution strategy and traditional warehousing can help companies to take advantage from the supply chain inventory reduction due to the removal of one inventory location (cross-docking) as well as maintaining a low level in handling operations through the supply chain, and a high vehicle utilization.

In addition, not all products are suitable for cross-docking. For instance, some products have a variable demand and are more critical in terms of delivery times, and others are more functional, with stable and predictable demand (Li et al 2008). These two types of products should be treated differently in order to satisfy the requirements of specific customers or markets. The first category of products need a distribution strategy that reacts quickly and in an efficient way to customers' needs, as it happens for traditional warehousing, the second needs a distribution strategy where the focus is almost exclusively on minimizing physical costs.

In some cases described cross-docking and traditional warehousing are combined in the same supply chain (Waller et al., 2006; Li et al., 2008; Van Belle et al., 2012). Some products are managed with a traditional warehousing distribution strategy and others with a cross-docking distribution strategy (Li et

al., 2008), and in effect not all products are suitable for both, creating a “one size does not fit all” situation (Apte & Viswanathan, 2000; Waller et al., 2006; Li et al., 2008; Yan & Tang, 2009).

In the academic literature, product segmentation is widely used in term of supply chain strategy selection (Fisher, 1997; Payne & Peters, 2004; Lovell et al., 2005). In our literature review, we consider distribution strategy as a part of the supply chain strategy (Vogt, 2010), focusing on both for understanding the relevance of the product segmentation in the supply chain management. Cross-docking or traditional distribution strategies are part of a global supply chain strategy, and some authors have attempted to look specifically at product segmentation in term of distribution strategy selection by specifying other criteria.

The objective of this chapter is to give a literature review and a research background on (1) the performance of the two distribution strategies within supply chains, and (2) the factors influencing the distribution strategy selection. These factors are classified in four categories: product factors, markets factors, product/market factors, and source/supply factors.

3.1 Cross-docking and traditional warehousing: Characteristics and Performances

3.1.1 Impact of traditional warehousing on supply chain performances

Traditional warehousing is a widely used distribution strategy, especially in the retail supply chain (Li et al., 2008). Suppliers and retailers keep stock at their DCs (Yan & Tang, 2009). Products are first received and stored at the DC, and when a customer requests an item, workers pick it from storage and ship it to the destination.

In the retail supply chain, the sourcing and planning process are divided into two major parts: (1) the store orders and replenishes and (2) the retailer DC orders and replenishes (Li et al., 2008) (Figure 10). When the inventory at the store achieves the reorder level, the purchaser orders replenishment of products needed from the retailer DC and the retailer DC prepares and delivers orders to the store. The retailer DC ships according to an inventory control policy and if the stock runs low, the retailer orders replenishment from the supplier, who prepares and delivers orders. Here the major functions of the DC are receiving, storage, order picking, and shipping (Van Belle et al., 2012).

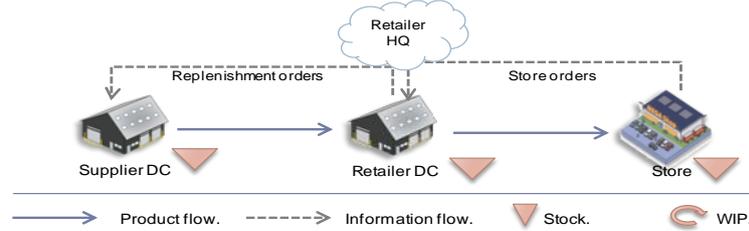


Figure 10: Illustration of traditional Warehousing

3.1.1.1 Impact of traditional warehousing on costs

In this strategy, the stores generally have a short lead time for their replenishment, being geographically nearby the retailer DCs (Van der Vlist, 2007). With a short lead-time the inventory costs is low at the stores. However, the inventory costs of this strategy are high because the retailer, the supplier, and the stores are keeping stock (Van der Vlist, 2007; Yan & Tang, 2009).

On the other hand, this strategy suggests that suppliers deliver products using a full truckload, and in Economic Order Quantities per SKU (Pallets or layer) which reduces supplier transportation costs, and handling cost.

3.1.1.2 Impact of traditional warehousing on the bullwhip effect

The bullwhip effect is known as the tendency of orders to increase in variability as one move upstream the supply chain (Dejonckheere et al., 2003). This occurs when the variance of orders placed is distorted along the supply chain. The bullwhip effect is a topic widely studied in the last years. (Forrester, 1961) was the first who demonstrate the existence of the bullwhip effect, and discussed its causes and the possible solutions to avoid or soften this phenomenon.

The bullwhip effect is influenced by four major parameters (shopper demand variability, shopper demand variability distortion, reliance between the supply chain operators, and price fluctuation (Potter et al., 2006). The shopper demand variability is the natural variability that occurs. It includes the daily variations, promotions. The shopper demand variability distortion is the increase of the variability noticed when passing upstream. The lack of reliance between the supply chain operators on their capabilities may increase the bullwhip effect (Potter et al., 2006).

Several researchers present the drivers and the causes of the bullwhip effect, and numerate more or less the same main causes, that can be summarized in four major causes: Separate demand forecasting, Lead Time, Batch ordering and Price fluctuation (Forrester, 1961; Houlihan, 1987; Machuca et al., 2004).

For the separate demand forecasting, let suppose that a store got a surge of demand in a short period. This surge will be considered as a signal of high future demand and the store will order a more important quantity. This quantity includes both of the forecasted demand and the additional safety stock (the safety

stock increases with the increases of the demand). The same reasoning is considered for the upstream facility but with the shop demand and not with the shopper demand. Thus, the safety stock increases in the whole supply chain for just a peak of demand. The variability of demand is also amplified as the difference between the facilities' orders and the shopper demand increases more and more when passing upstream (the symmetric reasoning is considered for a decrease of demand) (Lee et al., 1997a; Graves, 1999; Dejonkheere et al., 2003).

Lee et al., (1997) demonstrated in their paper that an important lead time (including the information processing time) tends to distort the variability and increases the safety stock. This is mainly due to the fact that the downstream facilities order for next periods assuming that the demand will continue to increase (or decrease) and will order an important additional quantity that includes the supposed demand increases during the lead time. And the supplier would see only an instant huge increase of demand that will lead to an important distortion of the variability.

The batch ordering is also a main cause of the bullwhip effect. When a retailer orders in batches, it creates a large order followed by several periods of no orders. This way of ordering, don't reflect the real shopper demand and increases the variability of the demand seen by the supplier and magnifies the bullwhip effect (Lee et al., 1997a; Moinzadeh & Nahmias, 2000; Riddalls & Bennett, 2001).

Finally, when prices become low the retailers often build up stocks. And this creates a fictive demand trend variation since the orders will be stored and sold after. Once the stock is built up and the prices rose, the retailer will lower the orders and creates a pit. These practices create a false and high demand variation. The same impact is caused by the promotions.

The bullwhip effect has a number of negative consequences on the supply chain. The main consequences are:

1. Loss of track of real demand patterns: this is mainly due to the amplification of the demand variation (unreal variation), (Mc Cullen & desnis, 2002).
2. Increased safety stock: as each node of the supply chain bases its forecast on the demand of the other actor and not on the shopper demand, each one need to build up its own safety stock to prevent itself from OOS (Lee et al., 1997a).
3. Reduced service level: this is due to the high variation distortion caused by the Bullwhip Effect, and also the inefficient methods used to try to cope with the increase of the safety stocks (Lee et al., 1997a).
4. Inefficient allocation of resources: as the demand is amplified, the plant and the DCs may product or store products, which they don't need in reality, instead of needed products (Lee et al., 1997a).

5. Increased transportation costs: to cope with extra unreal demand, facilities may produce sub-optimal transportation costs in emergency (Chan et al., 2002).
6. Missed productions schedules: when reacting to some peak of demand, the plant may change their schedules to have enough capacities. However, a part of the need can be postponed (Chan et al., 2002).

3.1.2 Impact of cross-docking on supply chain performances

Cross-docking is a distribution strategy in which DCs operate as transfer points to harmonize the continuous physical flow through a supply chain with the least storage (Shakeri et al., 2012; Waller et al., 2006). In comparison with traditional warehousing, in a cross-docking strategy the DC functions as an inventory coordination point rather than an inventory storage point (Waller et al., 2006). In cross-docking systems, there is one end-to-end process to replenish the stores. The unconstrained demand of all stores is aggregated at the retailer headquarters and sent to the supplier (Figure 11). The supplier DC sends the exact quantities to the retailer DC, which acts as a cross-docking platform. In the cross-docking platform the information and physical flows are synchronized across the supply chain. As such there is no stock kept at the retailer DC, only work in progress (WIP). Stock is kept at the supplier DC and the stores. The order picking at the DC can be eliminated depending on the cross-docking typology (Yan & Tang, 2009).

There is some impact on the supply chain performance for cross-docking compared to traditional warehousing. In the retailer side, first there is a cost benefit from the inventory reduction in the retailer's warehouse. However, this benefit might be balanced by an increase of the inventory in stores. Second, there is no inventory to be handled and managed, but the product flow within the cross-docking platform is not a pure no-touch operation; some handling operations need to be done. The cost impact depends on the organization and the specific cross-docking application. In the supplier side, there is often a cost through the increase of handling (picking) because products are handled at a case level and not in full pallets. Second, the transportation costs of the supplier increase because the products are not sent in full truckloads any more.

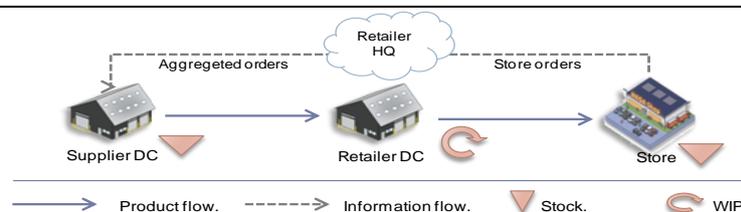


Figure 11: Illustration of cross-docking strategy

This strategy minimizes unnecessary inventory in the supply chain (Musa et al., 2010), reduces inventory costs (Shakeri et al., 2012; Waller et al., 2006), and improves and accelerates cash flows

(Dondo et al., 2011; Shakeri et al., 2012). This strategy also minimizes cycle times (Dondo et al., 2010; Musa et al., 2010) and increases inventory customer responsiveness (Soltani & Sadjadi, 2010). The total order cycle time is reduced because of the elimination of a storage point in the supply chain (Dondo et al., 2010); at the same time and in some cases the total order lead time seen by the store increases (Van der Vlist, 2007). The lead time seen by the store is greater than in traditional warehousing strategies (Van der Vlist, 2007; Waller et al., 2006).

There are numerous modes or typologies of cross-docking distribution strategies and several characteristics can be considered to distinguish between the various types (Yan & Tang, 2009; Vogt, 2010).

A first classification can be done according to the number of touches (Pearson Specter, 2004) (i.e., the number of times the product will be touched in the cross-docking platform). In one-touch cross-docking, products are touched only once, as they are received from the supplier DC they are loaded directly in an outbound truck to be delivered to the store. This is also called pure cross-docking. In the case of a multiple-touch cross-dock, products are received from the supplier DC and staged on the dock, then they are reconfigured for shipment to the stores and are loaded in outbound trucks.

Other classifications are done based on where and when the products are allocated to the stores (Yang & Tang, 2009) (called pre-allocation when the allocation is done by the supplier and post-allocation when it's done by the retailer). In Pre-allocation, stores review their inventory levels and send the needed orders to the retailer DC. The retailer DC places an order, which is the sum of all store orders to the supplier. It is the same as saying that stores receive the same quantity ordered directly from the supplier after a lead time of $l_1 + l_2$ periods, with l_1 the lead-time from the stores to the retailer DC, and l_2 the lead-time from the supplier DC to the retailer DC.

In Post-allocation orders have a degree of freedom to be reallocated at the retailer cross-dock if there was a variation of demand during the supplier-to-retailer lead time. Retailer DC order depending on a centralized system and then when the order arrives, the quantity sent to the stores is reallocated according to the store inventory and demand variation during the ordering delays to the supplier.

Vogt, (2010) summarizes the different classification for cross-docking distribution strategy in three major axes. The first is where in the supply chain the identification of specific items for a specific customer is done (barcode attachment, RFID, etc.). The second is where the products are sorted and prepared for final destination. The last is whether the supplier is providing only one or multiple products.

In our research, we focus on the classification related to the sorting and the allocation of the products:

- ✓ Allocation of the Destination: where in the supply chain the identification of products for a given destination is done (e.g. the store)? The allocation can be done via labelling or grouping in a dedicated box (then it covers also the sorting).
- ✓ Physical sort of the product: where the sorting (physical allocation) of the products per destination is done? This requires the consolidation of products per destination (e.g. stores), on a pallet, in a box...

From this classification we identify two types of cross-docking strategy. The pick by line cross-docking and the pick by store cross-docking.

3.1.2.1 Pick by store cross-docking strategy

In this strategy the orders are prepared (picking) at destination (e.g. store) level by the supplier DC with identification of the final destination (e.g. store), and shipped together to the cross-docking platform, where the product are combined with other products coming from different suppliers and shipped to the stores (figure12).

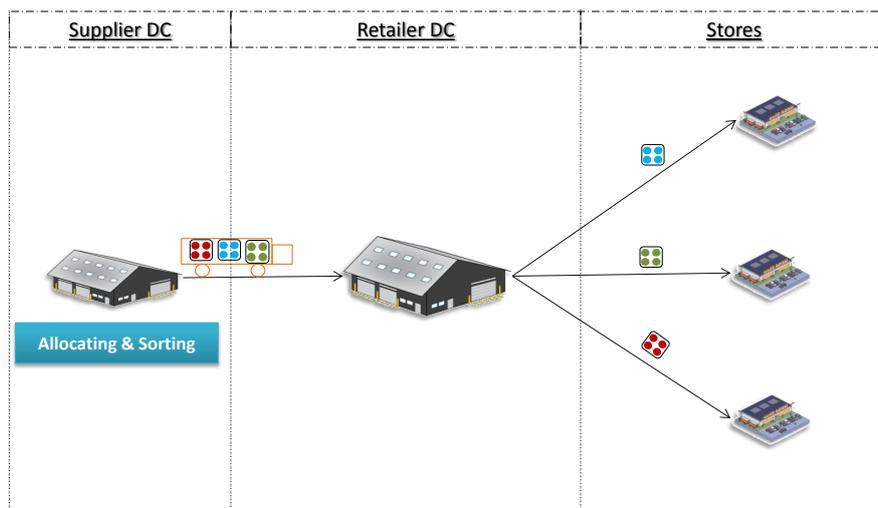


Figure 12: Illustration of the cross-docking pick by store strategy

The advantages of this typology is that the products are touched only once at the supplier DC and then flow through the retailer DC for consolidation and then delivered to these store. The handling cost is deducted only once at the supplier DC. On the other hand, this typology presents different disadvantages. First since the flow to the stores are multi-suppliers, the combination of pieces at the retailer DC results in pallet design not optimal which impact the shelf replenishment process at the stores. On the other hand, preparing orders at a stores level increase the number of wooden pallets at the supplier level and then impact the vehicle utilization (Pearson Specter, 2004).

3.1.2.2 Pick by line cross-docking strategy

The orders are prepared at product level by the supplier DC, which mean that the orders are prepared in bulk (the sum of stores' orders), and no more at store level. The products are shipped then to the retailer cross-docking platform, product is sorted based on order per destination, combined with other products and shipped.

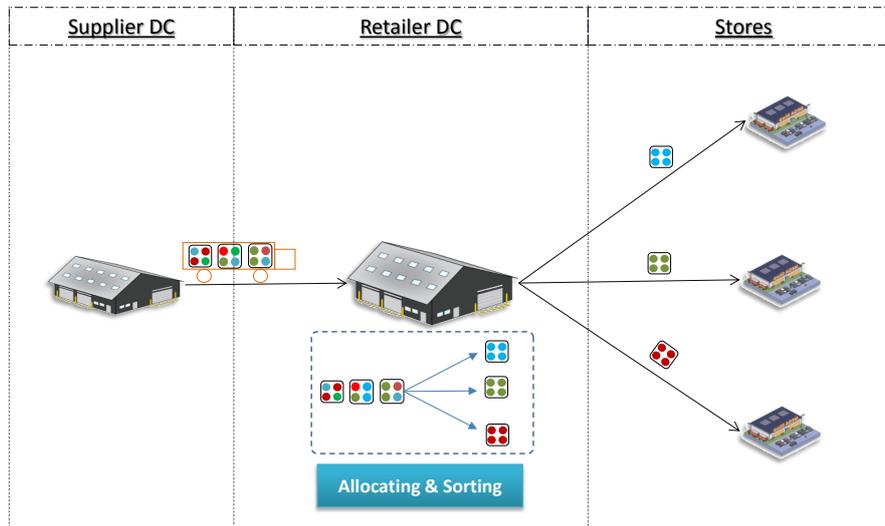


Figure 13: Illustration of the cross-docking pick by line strategy

The advantages of this typology is that the complexity of picking is kept low at the beginning of the supply chain (supplier DC to Retailer DC) and there is flexibility to adapt the orders to the store. The combination of products from several suppliers is possible to ship an optimal pallet to the store. The drawback is that the product is touched several times, which increase the handling costs (Pearson Specter, 2004).

3.1.2.1 Impact of cross-docking on the costs

ECR France (2000) was the first who develop a model and a study to highlight the potential gains/hurts from the implementation of cross-docking. Supervised by ECR France, a working group was established for evaluating the benefits/hurts on the entire supply chain from the supplier to the shelves, was developed. The working group was composed on different logistic managers coming from different companies. For the supplier such Ballantine's, Bestfoods France, LU, Nestlé France, Panzani, Procter & Gamble and others were present. On the retailer side, Auchan, Carrefour, Casino, Comptoirs Modernes and Promodès were present.

A cost model was developed in advance and used during this working group. Different pairs composed each one from a supplier and a retailer used the model to evaluate the economic challenges of cross-

docking for their particular situation based on the volume and the nature of their flows and their logistics constraints.

In the model, each pairs must inform their specific parameters and assumptions about the impact that cross-docking could bring. From this information and standard parameters, the model calculates the total cost of the chain. The results show that the potential savings on the supply chain varies significantly depending on the product, the type of flow and the personal situation of the partners.

Gebennini et al., (2013) present in their work a cost comparison of two different configurations: the “downstream picking configuration” (AS-IS Configuration) which can be assimilate to a traditional warehousing strategy, with picking activities executed at intermediate facilities, and the “upstream picking configuration” (TO-BE Configuration) which can be assimilate to a cross-docking pick by store strategy, where picking activities are performed upstream in the network at a central distribution centre. The study shows that, the transportation costs increase in the TO-BE Configuration by 85% because of the increase of deliveries in Less Than Truck load. On the other hand the operative costs (inventory, commercial, picking and financial) are reduced by 77%. The total costs are reduced by -22%. The authors mentioned that the cost savings related to the TO-BE Configuration should be compared with the investment and operative costs for centralizing picking activities at the supplier DC, and sharing costs and benefit must be done between the collaborators of the supply chain.

3.1.2.2 Impact of cross-docking on the Bullwhip Effect

The benefit of cross-docking which is the reduction of the bullwhip effect was not often considered in the literature. Cross-docking is reducing the bullwhip effect as it brings a direct connection between the store and the supplier DC, as the orders came directly from the stores (Eftekhar et al., 2008).

Towill, (1991) is one of the first researchers who described that the removal of intermediates echelon in the supply chain can have a positive impact on the variability reduction. This impact is explained by the improvement of forecasting accuracy upstream in the supply chain and the reduction of the total cycle time.

A detailed study about the impact of cross-docking on the bullwhip effect was presented by (Eftekhar et al., 2008). The authors used lyaponov exponent which is a quantity that characterizes the rate of separation of two trajectories, to estimate the difference between the bullwhip effect in traditional warehousing versus cross-docking. The study is done in a multistage supply chain where the store demand is autoregressive and the actors of the supply chain use a moving average forecasting techniques. The authors in this paper demonstrate the existence of a reduction in bullwhip effect with a supply chain with cross-docking distribution strategy. Here the authors start from the initial assumption that cross-docking distribution strategy suggests that demand information is shared with each stage of the supply chain (supply chain with centralized information), and in the traditional warehousing the

information is not shared with all participants in the supply chain (supply chain with decentralized information) and compare the bullwhip effect in the two cases. This assumption not always reflects the reality. In fact, moving to cross-docking strategy not necessarily imply the sharing of information in all stages. If the supply chain with traditional warehousing is decentralized, it will remain the same when moving to cross-docking. The information sharing is not dependent to the distribution strategy used.

3.2 Product segmentation and distribution strategy selection

As we can notice, a considerable number of articles dealing with product segmentation and the adapted supply chain strategy have been published. Several articles discuss the supply chain strategy in a more general way (e.g., efficient, responsive, lean, agile, ...), and other articles refer to a specific type of problem (cross-docking, traditional warehousing, postponement, decentralized, ...). The first category is considered to be the orientation of the supply chain and the second one is more specific and concerns the distribution and inventory location strategy. In this literature review we will focus on product segmentation and distribution strategy selection (cross-docking and traditional warehousing). We presented in a previous work a detailed literature review on the product segmentation and distribution strategy selection (Benrqya et al., 2014).

Furthermore, most of the classification criteria for supply chain strategy selection are based on product characteristics, especially in relation to market and demand improvements (Aitken et al., 2003; Fisher, 1997; Pagh & Cooper, 1998; Payne & Peters, 2004), whereas some articles studied other criteria (Hoekstra & Romme, 1992; Mason-Jones et al., 2000; Naylor et al., 1999). Hoekstra & Romme, (1992) studied the position of a decoupling point, process constraints, and inventory consideration. Naylor et al., (1999) classify the supply chain strategies (lean, agile, leagile) based on cost, quality, lead time, and service level. Mason-Jones et al., (2000) present in their work different criteria for selecting the right supply chain (lean, agile, leagile). The attributes are divided into three major categories: product attributes, cost-related attributes, and operational attributes.

The other research in this area, highlights the importance of segmentation based on the product attributes. In fact, companies often sell many different products with different characteristics in different markets, and use a single supply chain strategy that is rarely questioned. No matter how good the supply chain characteristics are, if the product fundamentally does not fit with the dominant supply chain design, optimum service and cost cannot be achieved (Payne & Peters, 2004). By segmenting the product range of a company and matching the specific needs of the product segment to a particular supply chain design, supply chain performance can be improved (Aitken et al., 2003; Fisher, 1997; Pagh & Cooper, 1998; Payne & Peters, 2004). In addition, in some cases cross-docking and traditional warehousing are combined in the same supply chain (Apte & Viswanathan, 2000; Lee, 2002; Van Belle et al., 2012).

Some products are managed with a traditional warehousing distribution strategy and others with a cross-docking distribution strategy (Lee, 2002), and in effect not all products are suitable for both, creating a “one size does not fit all” situation (Apte & Viswanathan, 2000; Lee, 2002; Waller et al., 2006; Yan & Tang, 2009).

In the literature, many factors have been described as influencing distribution strategy selection and product segmentation. In our research we group these factors into four categories, intrinsic product factors, demand factors, intrinsic-demand factors, and supply control factors. Intrinsic factors are closely related to the product and define the nature of the product. For example, a product can be described by its weight, size, value, and complexity, number of its variants, and its life cycle. Demand factors are related to the nature of the demand and its influence on the supply chain strategy. They include demand level (throughput) and demand variability. Intrinsic-demand factors are those combining the intrinsic factors and demand factors, for example, the cubic movement (Li et al., 2008) that represents the demand level and the physical volume of the product. And finally the supply control factors of a product are those that are dependent on lead time, the availability of components and/or raw materials, and that have production flexibility.

3.2.1 Intrinsic factors

Li et al., (2008) consider that products with high priority, that is, the ratio of value and life cycle, are more suitable for a cross-docking distribution strategy. Since products with short life become obsolete faster, it is necessary to push these products to the sales floor as fast as possible. Distribution of these types of products through a cross-docking strategy is appropriate.

Another factor described in the literature is the *shelf life*, which is the length of time perishable items are given before they are considered unsuitable for sale, use, or consumption. Li et al., (2008) consider that products with a short life become obsolete faster, and cross-docking distribution strategy is most appropriate for this type of product.

Another factor in product segmentation is the *value* and the product's weight. Apte and Viswanathan, (2000) consider that for products with high value cross-docking is not suitable. In fact, cross-docking inherently leads to eliminate the inventory at the retailer DC, and thereby raises the probability of stock-out situations. However, if the product value is low, cross docking can still be the preferred strategy, but if the product value is high traditional warehousing is the most suitable strategy.

Another factor in product segmentation is the *shelf space* of the product. Benrqya et al., (2014) presents the shelf space as the inventory space of a product at the store. In this paper the authors consider that for

products with low shelf space the traditional warehousing is the strategy the most adapted. In fact, since the cross-docking strategy increases the lead-time to the store, and in case of the shelf space is not big enough to cover the demand during this lead-time, there will be an impact on the service level.

Table 1 summarizes the literature on intrinsic factors and supply chain strategy selection.

Factors		Distribution	Key performance for selection	Authors
Life cycle length	Short	Cross-docking	<i>Inventory excess (obsolescence)</i>	Li et al., (2008)
	Long	Traditional warehousing		
Shelf life	Short	Cross-docking	<i>Product expiring</i>	Li et al., (2008)
	Long	Traditional warehousing		
Value	High	Cross-docking / Traditional warehousing	<i>Inventory cost (capital cost)</i> <i>Stock-out cost</i>	Li et al., (2008) Apte and Viswanathan, (2000), Benrqya et al., (2014)
	Low	Traditional warehousing / Cross-docking		
Shelf space	High	Cross-docking	<i>Service level</i>	Benrqya et al., (2014)
	Low	Traditional warehousing		

Table 2: Products Intrinsic and distribution Strategy Selection

In Table 1, we present the intrinsic factors, their attribute. For each attribute, we present the distribution strategy adapted, the key performance metric used for the selection and finally the authors that present this study. We can notice that there is a divergence in opinion for choosing the right strategy for products with high value. This divergence is due to the perspective taken in the analysis. Li et al., (2008) consider the selection based on the inventory cost, and Apte and Viswanathan, (2000) from a stock-out cost perspective. This two metrics are sometimes contradictory. Reducing the inventory lead to a reduction in the cost and in terms of capital cost for high value product, but at the same time a risk in terms of service level, and the stock-out cost is more impacted with products with high value.

3.2.2 Demand factors

Apte and Viswanathan, (2000) consider that the *demand rate* is a major factor that influences the suitability of cross-docking compared with traditional distribution. Hence, goods that are more suitable for cross-docking have demand rates that are more or less stable. Products with an unstable demand are more suitable for a traditional warehousing strategy because the downstream customers experience a short lead time for their replenishment, with geographically nearby distribution centres. This selection also is based on the unit stock-out cost because the probability of a stock-out situation is greater in cross-docking strategies than in traditional ones.

Gue (2007), Lee et al., (2006), Li et al., (2008), Benrqya et al., (2014) and Yan and Tang, (2009) as well consider that a product with a constant demand is more suitable for a cross-docking strategy and traditional warehousing should be chosen for products with erratic demand to cope with variability.

Therefore, apart from demand rate, the *demand volume* of the product, Apte and Viswanathan, (2000) consider that product with high demand volume result in scale economies in terms of transportation. Wagar, (1995) considers that the products with high demand volume are adapted for cross-docking. In fact, the high demand volume allows suppliers to deliver a significant amount of products that maximizes the cubic space of trucks. Pimor, (2001) also considered also that this kind of products are more adapted for cross-docking, because they allow a high optimization of the truck fill and reduce the transportation costs.

Table 2 summarizes the literature on demand factors and the supply chain strategy selection.

Factors		Distribution strategy	Key performance for selection	Authors
Demand uncertainty	High	Traditional warehousing	Reliability / Store inventory	Apte and Viswanathan, (2000); Lee et al., (2006); Li et al., (2008); Yan and Tang, (2009); Benrqya et al. (2014)
	Low	Cross-docking	Reliability	Apte and Viswanathan, (2000); Lee et al., (2006) ; Li et al. (2008); Yan and Tang, (2009)
Demand volume	High	Cross-docking	Transportation cost	Apte and Viswanathan, (2000); Pimor, (2001); Wagar, (1995)
	Low	Traditional warehousing		

Table 3: Tableau 1: Products Intrinsic and distribution Strategy Selection

3.2.3 Intrinsic-demand factors

Li et al., (2008) present a factor called *cubic movement* that refers to the product’s physical size or volume multiplied by demand rate. They consider that a product with high cubic movement is suitable for a cross-docking strategy because space is a constraint in a facility and assigning a product with a high cubic movement through this distribution strategy would save inventory costs. Table 3 summarizes the literature on products/market factors and supply chain strategy selection.

Factors		Distribution strategy	Key performance for selection	Authors
Cubic movement	High	Cross-docking	Inventory cost	Li et al., (2008)
	Low	Traditional warehousing		

Table 4: Intrinsic-demand Factors and distribution Strategy Selection

3.2.4 Supply control factors

Another important factor for product segmentation is the delivery lead time. Yan and Tang, (2009) studied the suitability of a cross-docking distribution strategy based on outside supply lead time including production and transport of products from supplier to retailer DC. Their conclusions are that pre-C is preferred with short outside supply lead times and post-C with big lead times. Benrqya et al., (2014) consider that the lead-time has an impact on the service level and on the store inventory. Products with high lead-time are more adapted for traditional warehousing.

Table 4 summarizes the literature on Supply control factors and supply chain strategy selection.

Factors		Distribution strategy	Key performance for selection	Authors
Outside lead time	High	Post-C cross-docking / Traditional warehousing	<i>Cost / Service level</i>	<i>Yan and Tang, (2009); Benrqya et al., (2014)</i>
	Low	Pre-C cross-docking/ cross-docking	<i>Cost</i>	

Table 5: Supply control factors and distribution Strategy Selection

3.3 Synthesis of the literature review

As described in this section, some papers deal with the impact of distribution strategies on the supply chain performances only, with often a partial vision of the structure of the supply chain. In fact, the problems that cross-docking practitioners are facing are not all widely discussed. There are several kinds of applications of cross-docking that correspond to different industries, business cases, and circumstances. From one case to another, the segmentation factors can be different and have different impacts. For instance, product lead time is critical in some industries, such as the retail supply chain, because storage capacities are limited at the downstream point (stores), and there should be a short lead time with frequent deliveries. In other cases, lead time is less critical and a segmentation based on this factor is also less important.

Second, supply chain performances are not all studied in terms of product segmentation. In the articles reviewed, the performance attributes can be classified in three categories: customer satisfaction, inventory cost, and transportation cost. The bullwhip effect is not studied in the literature in terms of product segmentation. This performance is important to set the right supply chain or distribution strategy of a product.

Third, some papers deal with impact of distribution strategies on the supply chain performances only, with often a partial vision of the structure of the supply chain. Others concerns studies on the choice of

the distribution strategies for products depending to their characteristics and impacts on the supply chain performances, with divergence in opinion in terms of product segmentation.

The objectives of our research are to first analyse the impact of the distribution strategies (traditional warehousing, cross-docking pick by store and cross-docking pick by line) on the supply chain performances, for a three echelon supply chain supplier DC, one Retailer DC and the stores delivered by this DC. The performances studied are the supply chain cost, the service level and the bullwhip effect (integration). Second to analyse the impact of the products characteristics on the performances of these distribution strategies and the choice of the right strategy for each product depending to its characteristics and the impact on the performances.

3.3.1 Distribution strategies performances

The main objective of supply chain management is to achieve local performance of each partner and on the other hand, the performance of the entire supply chain (Mentzer et al., 2001). The concept of supply chain performance evaluation is widely studied in the literature.

Companies rely on metrics to assess their performance. A performance metric is a measurement tool to evaluate a situation, a process, a strategy, etc. This is a quantified data that measures the effectiveness and/or efficiency of a process or a system compared to a standard or a specific objective of a business strategy (Fortuin, 1998). Indicators can have a dual function as they are used either to evaluate the targets already achieved or to set goals to achieve in the future (Bhagwat & Sharma, 2007).

Several researchers have studied the issue of performance metrics and agree to say that the use of a single performance measure to evaluate a system, a process or a strategy is inadequate (Bititci et al., 1997; Beamon, 1999; Trienekens et al., 2008). Supply chain performance is captured under different axes, it is appropriate to use multiple performance measures.

The performance metrics used to analyse the impact of the distribution strategy on the supply chain performances and to select the right strategy for each product are based on Cost, Service Level and Bullwhip effect (Table 5).

Inventory cost as described in (Li et al., 2008; Yan and Tang, 2009; Kreng & Chen, 2008; Waller et al., 2006), refers to the cost of holding products in stock over a period of time. As explained in this chapter each distribution strategy has its characteristics in terms of inventory. In traditional warehousing, the inventory is hold in the store, in the retailer DC and in the supplier DC. In cross-docking the inventory at the retailer DC is eliminated, and at the same time the stores' inventory may increase due to the increase of the lead-time to the store. Comparing the strategies in terms of inventory cost is very useful due to the major difference in inventory between the strategies.

Performance		Authors
Cost	Inventory cost	Li et al., (2008); Yan and Tang, (2009); Kreng & Chen, (2008); Waller et al., (2006)
	Ordering cost	Waller et al., (2006)
	Transportation cost	Apte and Viswanathan, (2000); Pimor (2001); Wagar (1995); Kreng & Chen, (2008); Gebennini et al., (2013)
	Handling cost	Gebennini et al., (2013)
Service level		Apte and Viswanathan, (2000) ; Lee et al., (2006) ; Li et al., (2008); Yan and Tang, (2009)
Bullwhip effect		Eftekhar et al., 2008

Table 6: Performances of the distribution strategies

Inventory cost as described in (Li et al., 2008; Yan and Tang, 2009; Kreng & Chen, 2008; Waller et al., 2006), refers to the cost of holding products in stock over a period of time. As explained in this chapter each distribution strategy has its characteristics in terms of inventory. In traditional warehousing, the inventory is hold in the store, in the retailer DC and in the supplier DC. In cross-docking the inventory at the retailer DC is eliminated, and at the same time the stores' inventory may increase due to the increase of the lead-tie to the store. Comparing the strategies in terms of inventory cost is very useful due to the major difference in inventory between the strategies.

Ordering cost represents the cost of managing the orders. The ordering cost is incurred in preparing and processing purchase orders. In cross-docking strategy compared to the traditional warehousing, the orders come directly from the stores. And since there is no intermediate inventory, and due to the limit of shelf space at the stores, the number of orders will tend to increase. Analysing the inventory cost is useful as well.

The transportation consist of the cost per km of a truck independently of the fill of this truck (Gebennini et al., 2013). As explained before, the supplier transportation cost increases in traditional warehousing and this cost may have a big influence on the choice of the distribution strategy.

Handling cost represents the costs of movement of products over short distance, usually inside a distribution centre or a store. The handling cost includes, the cost of receiving and docking a truck, unloading cost of the pallet from the receiving truck, cost of controlling pallet received, cost of moving pallets from inbound doors to the racks, or to the shelves in the stores, cost of picking, and finally cost of loading a pallets to the trucks. All the handling cost are interesting to analyses, since in each strategy

the quantities handled are different. In fact, in traditional warehousing, the supplier DC deliver the retailer in economic quantities, often in pallets. In cross-docking and since there is no inventory at the retailer DC, the supplier DC delivers the exact need of the stores.

The service level have several definitions in the literature as well as in practice. In our study the service level is a quantity-oriented performance measure describing the proportion of total demand within a period which is satisfied without delay from stock on hand (Bowersox et al., 2012). The stock on hand here corresponds to the stock in the shelves. In retail supply chain this measure is called On Shelf Availability (OSA). We will use this term in our study.

The bullwhip effect is known as the tendency of orders to increase in variability as one move up a supply chain (Dejonckheere et al., 2003). This occurs when the variance of orders placed is distorted along the supply chain. The bullwhip effect is calculated as ratio of the variability of customers demand and the variability of orders. As described in this chapter, the bullwhip effect decreases in cross-docking strategy. A selection of the strategy based on this performance can be very useful and important. In fact, for some companies where the production is the most costly in the supply chain, decreasing the variability can improve the production by getting more stable demand which allows the plant to level production schedules throughout the week.

In our research, we decide to go deeper in the analysis and study all these performances in a three echelon retail supply chain including stores, retailer DC and supplier DC. All these performances will be analysed for selecting the right distribution strategy for each product.

3.3.2 Product segmentation and distribution strategy selection

In this research, we first analyse the impact of the distribution strategies (traditional warehousing, cross-docking pick by line and cross-docking pick by store) on the performances. In a second step, we analyse the impact of products' characteristics on the performances of the distribution strategies. The products' factors will defined based on four major categories (Table 6):

- 1- Intrinsic factors including the physical volume, shelf space and value.
- 2- Demand factors including the variability and the demand volume.
- 3- Intrinsic/Demand factors including the cubic movement.
- 4- And Supply control factors including the lead-time and review period.

	Intrinsic factors			Demand factors		Intrinsic/ Demand factors	Supply control factors	
	Physical volume	Shelf Space	Value	Demand Volume	Variability	Cubic Movement	Lead- time	Review period
Service level								
Cost								
Bullwhip Effect								

Table 7: Framework for product segmentation and distribution strategy selection

In this chapter we presented a literature review on the distribution strategies, their performances, advantages and drawbacks. We presented a literature review on product segmentation and distribution strategy selection. Based on this literature review we developed a framework of product segmentation and distribution strategy selection.

In the next chapter we will develop a process modelling of the distribution strategies based on a real business case.

Chapter 4

4. Modelling of the distribution strategies processes

4.1 Modelling approaches

4.1.1 Introduction

In any analytical approach, the modelling phase is an important step. Modelling allows to describe the processes and flows, structure the organization to understand the operation in order to improve performance. Therefore, it is essential to choose the model that will be used for our study.

The aim of this chapter is to present and analyse the existing models to propose the model that is adapted to our study. This is to choose the model that map the distribution strategies process, include the dynamics of ordering and inventory management, and to help the deployment of the performance evaluation of the distribution strategies.

Supply chain modelling is a critical step because it is the first step in improving and optimizing the performance of organizations.

In our research, we wish to highlight the impacts of the distribution strategies on the performance of the Supply Chain, and to find the right strategy for each product depending to its characteristics.

We need to specify our needs in supply chain modelling languages to choose the most appropriate models to our context of study. We seek to identify tools that describe the processes as well as taking into account the dynamics of the demand, ordering and inventory management. The business case studied operate in a dynamic environment. The designs should consider modelling the behaviour of the supply chain and management of events. They should also identify needs in terms of performance evaluation and propose a system of performance indicators adapted to the specificities of the distribution strategies studied.

In this chapter, we present an overview on the analysis system method existing. Then we describe the supply chain modelling in the literature. Next, we describe the enterprise modelling tools existing. Finally, and according to our research needs, we propose a set of criteria on which we rely to present the characteristics of the tools and compare them. To conclude these comparisons, we determine the most appropriate models to our research context.

4.1.2 System modelling approaches

There exist various methods to study systems. We present an overview of the main tools by focusing on their principles and specific aspects.

- **SADT**: Structured Analysis and Design Technique (Lissandre, 1990; Santarek & Buseif, 1998; Valla, 2008). Developed in the USA by Doug Ross in 1977 and was introduced in Europe in 1982 by Michel Galiner. SADT is a method of modelling activities and processes. This is a top-down, modular, hierarchical and structured a system. This is a standardized graphical language for the description of a complex system by a functional analysis which travels down the general ("the level A-0") to the individual.

In the SADT modelling, functions are represented by boxes (Actigramme) that represent the actions of the system being modelled. They are linked by data inputs (data, materials or resources), data outputs (data, materials, resources), means used (resources human, material) and control elements (guidelines, procedures, rules, constraints, etc.). Modelling can be done also by the datagrams which it is the data that are linked together by activity flow.

- **IDEF 0 / IDEF 3**: Mayer et al., (1995), Lutherer, (1996), Vernadat, (1999), and Zakarian & Kusiak, (2001) models have been proposed by a unit of the US Air Force, ICAM (Integrated Computer Aided Manufacturing) to analyse the systems functionality. IDEF0 follows from the SADT method and is adapted to the needs of ICAM. It represents the functional aspects using a hierarchical decomposition of actigrammes.

The IDEF model presented was established in 1992 to address the deficiencies of IDEF 0 in terms of modelling the company's behaviour. IDEF 3 models the process by describing a sequence of steps called behavioural units connected by junction boxes and links. IDEF 3 can show the relationship between the activities to be modelled (precedence, timing, etc.).

- **Petri Nets** (Dicesar et al, 1993) Petri networks emerged in 1962 in the doctoral thesis of Carl Adam Petri. This is mathematical modelling and analysis tools discrete dynamic systems. They are ideal for process analysis because they take into account the concepts of parallelism, synchronization and resource sharing. The Petri graph presented by an example in Figure 10 comprises a plurality of square (or condition status) and transition (events). It represents the state of a network by chips placed inside the seats. The transition of the latter to another place indicates the change of state.

- **CIMOSA**: Computer Integrated Manufacturing Open System Architecture (Vernadat, 1999). It is an architecture developed by the SPIRIT Consortium AMICE project to analyse and design manufacturing systems. This is a conceptual model that allows a complete modelling of physical and information flows. The model takes into account the static and dynamic aspects of the business as well as the temporal

dimension through the events occurrence dates and times of implementation. CIMOSA provides no graphic representation associated with the methodology.

- **GRAI**: Model Research Group Automatic Integrated (Doumeingts and Vallespir, 1995) Established in 1993 by the Research Group on Integrated Automatic from the University of Bordeaux

The GRAI model is distinguished by its ability to model the decision-making system of the company (decision-making and information flows). It highlights the decision-making structure of the company's business and is based on the notion of temporality decisions.

One of the tools of the GRAI method is the GRAI grid which breaks down the decision-making system in two axes. The vertical axis that describes the temporal levels corresponding to levels of decision making and the horizontal axis specifying the nature of the decision. The method aims to describe the activities of a decision centre by modelling the flow of information and the flow of decision.

- **SCOR**: Supply Chain Operation Reference Model was established in 1996 by the Supply Chain Council (SCC). This is a standard model that revolves around five management process: PLAN, SOURCE, MAKE, DELIVER and RETURN. The performance evaluation focuses on five levers: reliability, responsiveness, flexibility, costs and assets. SCOR is used for all companies and allows a common language and standardized between different actors. The model defines a number of indicators associated with each process and offers the best practices from the experience of the most successful companies.

- **UML Diagrams**: Unified Modelling Language (Booch et al., 2000). This is the result of the merger of three languages that influenced object modelling in the mid 90: OMT, Booch and OOSE. This is a standard language by the OMG (Object Management Group) in 1997. In December 2006, the OMG has continued its work on the UML 2.0 to complete certain aspects suitable for architectural modelling. UML is a standardized graphical notation language used to describe the management process. This essential standard features seven diagrams interested in different views of modelling:

1. Diagram of use cases (use case) is interested in the functions of the system from the user's point of view. It represents actors symbolized by small characters and use cases symbolized by ellipses
2. Diagram of classes is a diagram used to present static elements (classes), their content and the various relationships between them. A class is designated by a name with associated attributes and methods.
3. Diagram of objects: it is a representation of objects and their relationships,
4. Diagram sequences: it is a chart has specifying behavioural interactions between objects. The temporal aspect is favored,

5. Diagram of collaboration: it is an interaction diagram that represents the states of objects that interact. The temporal aspect is taken into consideration but the spatial aspect (objects and link them) is favored,
6. Transition Diagram of states: it is a representation of the behaviour of a class in terms of state,
7. Activity diagram: describes the flows between activities within and between the processes of a system.

4.1.3 Supply chain models

Modelling is an essential step in the process analysis. It is the first step towards optimization and improvement of the system. We have identified in the previous section the component of a system: the task, the event, resource, information and other objects. Their representation allows to provide a formal and quantitative modelling, a representation of the dynamic aspects of the model (Giaglis, 1997).

There exist different ways of representing the processes. Aguilar (2004) identifies these models:

- **Flowchart:** This is a simple graphic representation or symbols represent the activities, resources, and data. The Flowchart is a very easy tool to use. It can be oriented data on the activities or interactions
- **Gantt chart:** modelling a process is performed via the a table; on the vertical axis are represented the activities of the process and on the horizontal axis the length;
- **IDEF:** modelling tool presented in the previous paragraph;
- **Colored Petri Network:** This is a graphical language for modelling. Like Petri networks, the model consists of a network of places, transitions and arcs. In addition , different types of entities are differentiated by color. This is a simple and interesting way in the case of systems composed of many processes that communicate and synchronize;
- **Object-oriented methods:** the process is described by objects, which are transformed by the activities throughout the process. These include both structural elements (attributes) and behaviour (operations). Similar objects are grouped into classes (eg UML considered the reference object oriented language).

In the literature there exist various classification schemes to categorize supply chain models. Min & Zhou, (2002) propose a taxonomy to classify and categorize the different supply chain models:

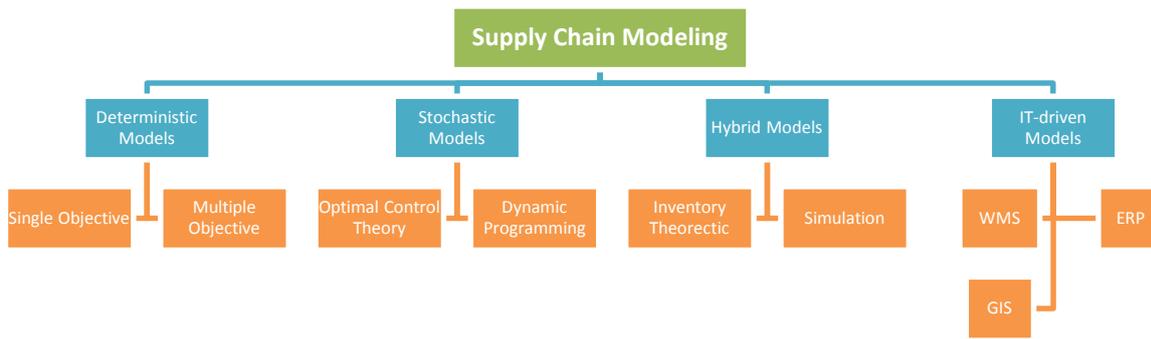


Figure 14: Taxonomy of supply chain models (Min & Zhou, 2002)

In this taxonomy, they divide the supply chain models in four categories: (1) Deterministic Models, (2) Stochastic Models, (3) Hybrid Models, (4) IT-driven Models. Deterministic models assume that all the model parameters are known and fixed with certainty, whereas stochastic models take into account the uncertain and random parameters. Deterministic models are divided into single and multi-objective models. Stochastic models are sub-classified into optimal control theoretic and dynamic programming models. Hybrid models have elements of both deterministic and stochastic models, and include inventory theoretic and simulation model. IT models aim to integrate and coordinate various phases of supply chain planning on a real-time basis using application software to enhance visibility throughout the supply chain. These models include, WMS, GIS and ERP.

4.1.4 Discussion and choice of model

The approach chosen in our study is the process modelling based on flowcharts. First, it is clear that the process modelling provides a comprehensive approach to the supply chain. It considers an activity sequence (flowchart) starting from the supplier to the end customers. This is an integrated vision in which all the resources and information that contribute to their achievement is considered at the same time. This proves the value of an integrated and comprehensive approach taking into account the interactions within the supply chain.

In addition, the implementation of a methodology for assessing the performance of a supply chain requires a structured approach to guarantee the completeness of the analysed elements. Process modelling enables such a description in the extent that the process will be a sequence of tasks. This can thus be considered as an element facilitating the modelling.

In summary, we can conclude that the relevance of the process modelling approach corresponds to our objectives: the need for a comprehensive modelling of the system studied (a real business case of a retail

supply chain) and the need for a structured approach easily transmissible and potentially reusable approach.

4.1.5 Distribution strategies analysis approach

As explained in the previous part, we propose to define a process model of the distribution strategies, to evaluate the performances, the impact of the products characteristics on performances and define the right strategy for each product depending on its characteristics and performances.

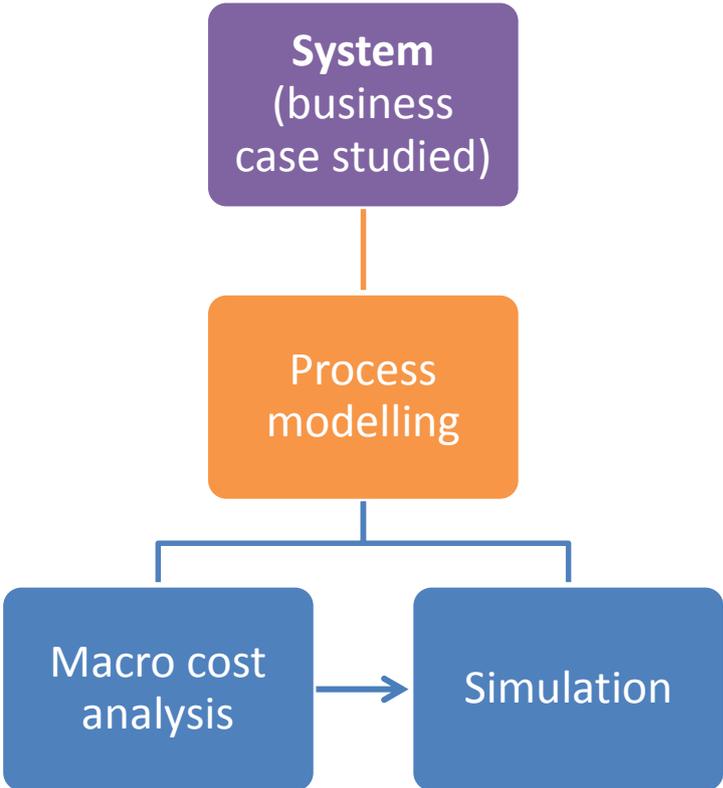


Figure 15: Distribution strategies analysis approach

As shown in figure 15, the approach used for the process modelling and the distribution strategy analysis is a case study

Case study method is more applicable to the type of question like "How" or "Why" (Yin,1994). The case study is a research strategy which focuses on understanding the dynamics present within a supply chain. In our case, the study is based on a real case of a major French retailer and a multinational Fast Moving consumer Good company. Working in this context allows us to have at our disposal a huge quantity of data and a test framework available to perform a robust empirical analysis.

In our research, we are interested in the retail supply chain in order to evaluate the performances of the distribution strategies, the impact of the products characteristics on performances and to define the right

strategy for each product depending on its characteristics and performances. This is a Supply Chain with three echelons: Supplier DC, retailer DC and 24 stores in France.

Any system analysis approach must be preceded by a modelling stage. This step is crucial because it helps to describe the processes within the supply chain, to understand and evaluate the performance. The proposed model has to be a realistic representation of the actual supply chain studied. This will provide a basis to compare various simulation scenarios, analyse behaviour and evaluate performance.

Based on the review of the modelling tools and approach conducted in the previous part, we opted for a process modelling based on flowchart. These models are suitable for our research problem because they can clearly represent different processes.

Based on the case study we perform a process modelling. This model helps to describe the processes within the supply chain, in an objective to analyse it and evaluate the performance. After the process modelling we can start our performance analysis phase. This phase is divided into two major analysis. A macro cost model, and a simulation of the distribution strategies. The process model allows us to perform both studies.

The Macro cost model is a deterministic model based on hypothesis and data from the business case studied. This model allows us to evaluate the impact of the distribution strategies on the supply chain cost. It allows us to give an overall picture on the different impact on the supply chain costs with hypothesis and values based on field experience.

The simulation of the distribution strategies is based on the process modelling, as well as the macro cost model. In fact, the cost analysis is interesting to give an overall picture of the supply chain and validate the hypothesis and the literature of the impact of the distribution strategies on the supply chain cost. But at the same time, working and researching alone doesn't allow oneself to elaborate a deep study on the choice of the distribution strategy for each product. For instance, it was difficult to define the impact on the store's inventory, not having access to the data. The impact on the service level was also complicated to define, because we don't have access to the data and at the same time there is no study on the literature concerning the impact of cross-docking on this performance. On the other hand, in the literature some studies such as (Eftekhari et al., 2008) explain that the cross-docking is reducing the bullwhip effect as it brings a direct connection between the store and the supplier DC, as the orders came directly from the stores. This reduction on the bullwhip effect allows a reduction on the supplier inventory. From this we decide to create a model including the distribution strategies processes model and the macro cost model, to analyse the performance related to these processes. This model will determine the impact of the distribution strategies on the supply chain performances, the impact of the products characteristics on the performances of the distribution strategies and choose the right strategy for each product depending on its characteristics and the impact on the performances. We have modelled the process and use a

combination of analytical approaches, and simulation. The analytical approach is very useful to gain insight into the structure of the ordering process as it moves up the supply chain. However the analytical approach will become rather unmanageable when we consider all the aspects and processes of the supply chain, to take into account the dynamic of the supply chain, and will allow us to relax the constraints required for the real case studied. In addition, to include all the process of the supply chain a simulation methodology is needed.

4.2 The business case

4.2.1 Supply chain configuration

The study will be based on a real case of a major French retailer (We will use from now on the term **Retailer X** to refer to this French retailer) and a multinational Fast Moving consumer Good Company (We will use from now on the term **Supplier Y** to refer to the multinational Fast Moving consumer Good Company).

The business case studied, were a supply chain of the retailer X and the supplier Y. The supply chain studied is situated in France.

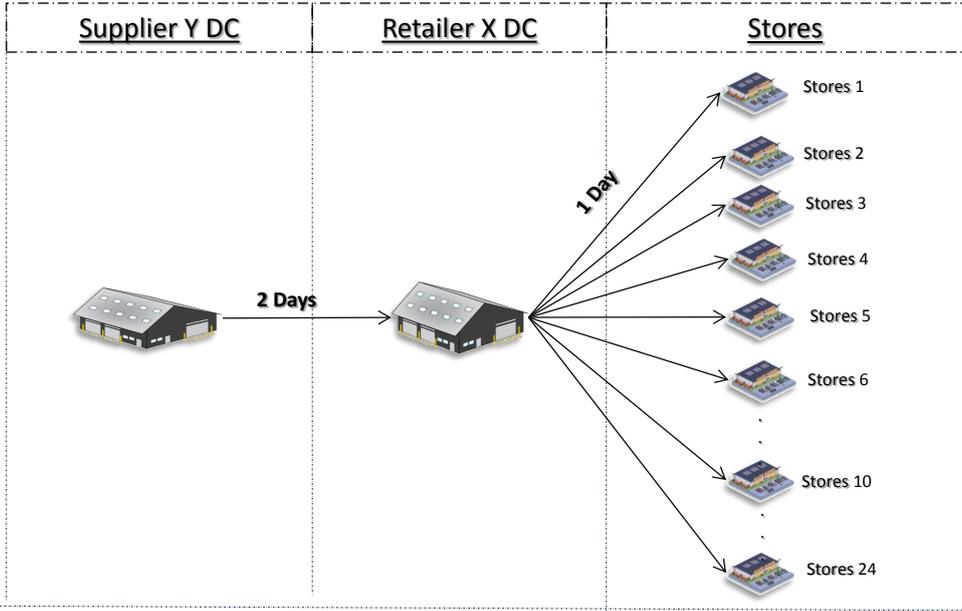


Figure 16: Retail Supply chain business case

The supply chain is composed of one supplier DC, on retailer DC and 24 stores.

The 24 stores are divided in three categories: the big stores (A), the medium stores (B) and the small stores (C). The stores are differentiated in terms of annual sales as shown in the table 7. In Table 7, the annual sales data are indexed with a scale of 100.

Stores	Annual sales	Category
Store 1	100	A
Store 2	94	A
Store 3	93	A
Store 4	82	A
Store 5	78	A
Store 6	75	A
Store 7	72	A
Store 8	72	A
Store 9	69	B
Store 10	64	B
Store 11	63	B
Store 12	60	B
Store 13	60	B
Store 14	57	B
Store 15	56	B
Store 16	56	B
Store 17	50	C
Store 18	47	C
Store 19	47	C
Store 20	43	C
Store 21	38	C
Store 22	37	C
Store 23	34	C
Store 24	24	C

Table 8: Stores' categories

The lead-time (lead time between the placement of an order and the delivery) between the supplier DC and the retailer DC is 2 days. The lead-time between the retailer DC and the stores is 1 day. In this supply chain the supplier DC delivers the retailer DC 2 or 3 times per week depending on the product category and demand typology of a product. Three times per week for fast movers products, and twice a week for slow movers products.

The rationale behind the choice of this supply chain, is that we have data available, already collected for previous studies, which allows us to have a complete business case.

4.2.2 Product characteristics and market demand

We choose to analyse the 200 products of the assortment of the supply chain. The 200 products studied belong to different categories, and this will allow us to have an efficient analysis. The category studied were baby care products, feminine care, home care and fabric care. The products have different characteristics in terms of volume, weight, price, pallets, design and demand. The Minimum Order Quantity is also different for each product. Figure 17 describes the products studied in detail:

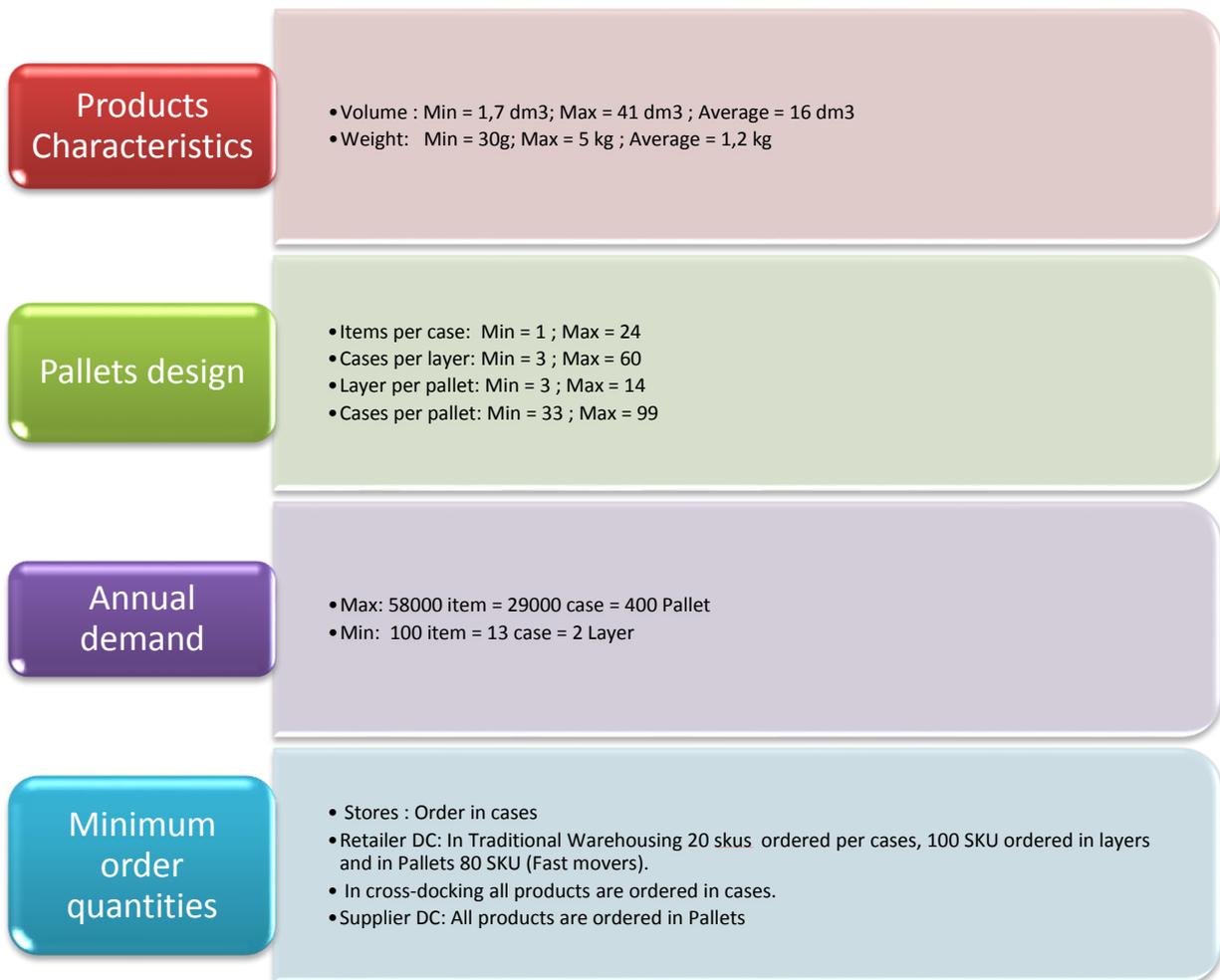


Figure 17: Products studied

4.3 The distribution strategies modelling

In this section, we describe the processes of the distribution strategies model based on the business case. For each distribution strategy (traditional warehousing, cross-docking pick by line, and cross-docking pick by store) we present the stores' processes, the retailer DC processes and the supplier DC processes. We describe each process and the metrics associated to these processes. We also explain the hypothesis

and assumptions taking to develop the model. The process modelling of the distribution strategies is based on literature review as well as visits to the supply chain studied (stores, retailer X DC, and supplier Y DC).

4.3.1 Traditional warehousing

4.3.1.1 The stores processes

Each store carries about tens of thousands SKU's, this number can vary depending on the size of the store. These SKUs are composed of three main categories, Dry Grocery, Frozen, and Perishable. Each category of products have different transportation requirements and delivered separately. In our project we focus on Dry Grocery. For the other categories there are slight differences in terms of storage and deliveries due to the perishable and frozen nature of the products.

The processes of the physical flow are as follow:

When the truck arrives at the store, it is docked and the products are unloaded, and moved to a staging. The products are then staged for inspection, such as damage, incorrect counts, wrong descriptions, and so on. The products are then staged for shelf replenishment. After, the stockers fill the shelves with the products received. In our research we assume that there is no intermediate storage (backroom storage).

Figure 18 illustrates the processes in the store in traditional warehousing:

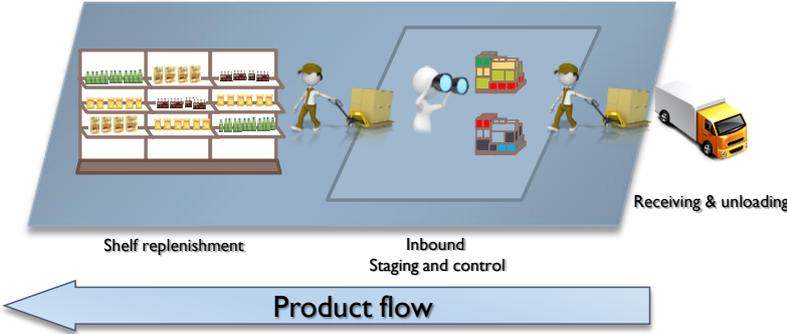


Figure 18: Store processes in traditional warehousing

4.3.1.2 The Retailer DC processes

A retail distribution centre typically supplies product to retail stores. The immediate customer of the distribution centre is a retail store. A typical order might comprise hundreds or thousands of items; and because the distribution centre might serve hundreds of stores, the flow of product is huge (Bartholdi & Hackman 2008).

In other words, an important function of this warehouse is to break down large volume of products and redistribute it in smaller quantities. For example, some products may arrive from the supplier manufacturer in pallet but be shipped out to the stores in case. In such an environment the downstream warehouse operations are generally more labor-intensive.

The physical processes in a typical retailer DC in traditional warehousing include two major phases: Inbound processes (Receiving and storing), and outbound processes (Order-picking, checking, packing and loading).

The reorganization of product in the retailer DC takes place through the following physical processes (Figure 19):

Inbound processes:

- Receiving
- Put-away

Outbound processes

- Order-picking
- Checking, packing, shipping



Figure 19: Retailer DC processes in traditional warehousing strategy

Figure 20 illustrates the processes at the retailer DC in traditional warehousing:

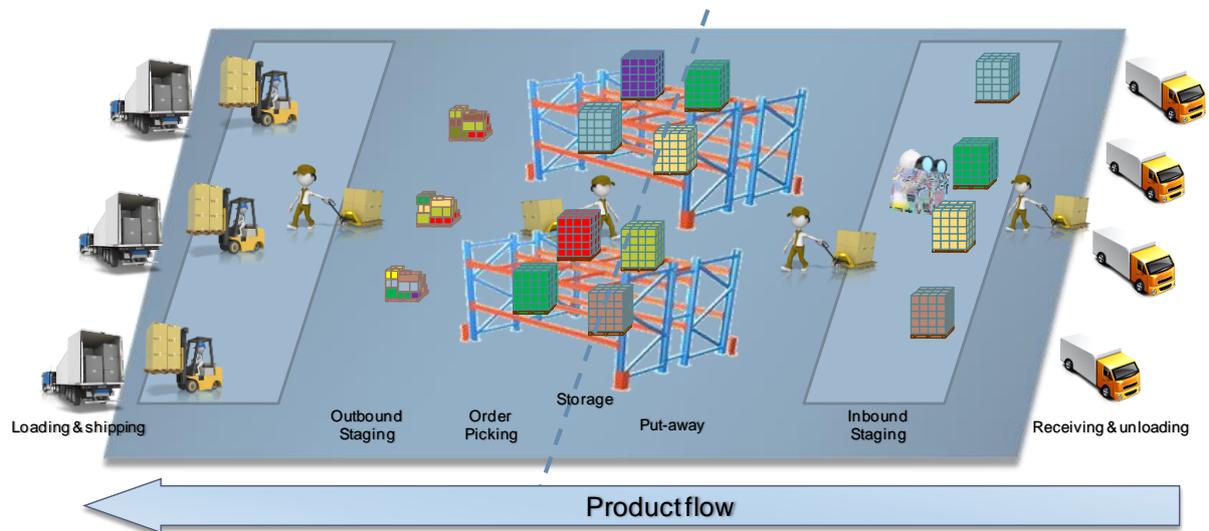


Figure 20: Illustration of the Retailer DC processes in traditional warehousing

Receiving:

Receiving begins with advance notification from the supplier of the arrival of products. This allows the warehouse to schedule receipt and coordinate efficiently with other activities and anticipate the workforce needed.

Once the product has arrived, it is unloaded, scanned to register its arrival and staged for controlling and putting away after.

In traditional warehousing products usually arrive in larger units, such as pallets, from suppliers in this case the receiving cost including unloading and controlling is less expensive. When the pallets received are heterogeneous this process is more expensive since pallets need to be broken out into separate cases or layers for putting away storage.

Put-away:

After controlling the product, a storage location must be determined. When product is put away, the storage location should also be scanned to record where the product has been placed. This information will subsequently be used to construct efficient pick-lists to guide the order-pickers in retrieving the product for customers (Bartholdi & Hackman, 2008).

Order-picking:

When the retailer DC receives an order from the store, a check is done to verify if the inventory is available to satisfy this order. After checking the availability a pick list is produced to guide the order-picking. These activities are typically accomplished by a warehouse management system, a large

software system that coordinates the activities of the warehouse (Bartholdi & Hackman 2008). Once the picking list is produced the workers can start preparing the store order.

Figure 21 illustrates the order-picking process in the retailer DC under traditional warehousing strategy:

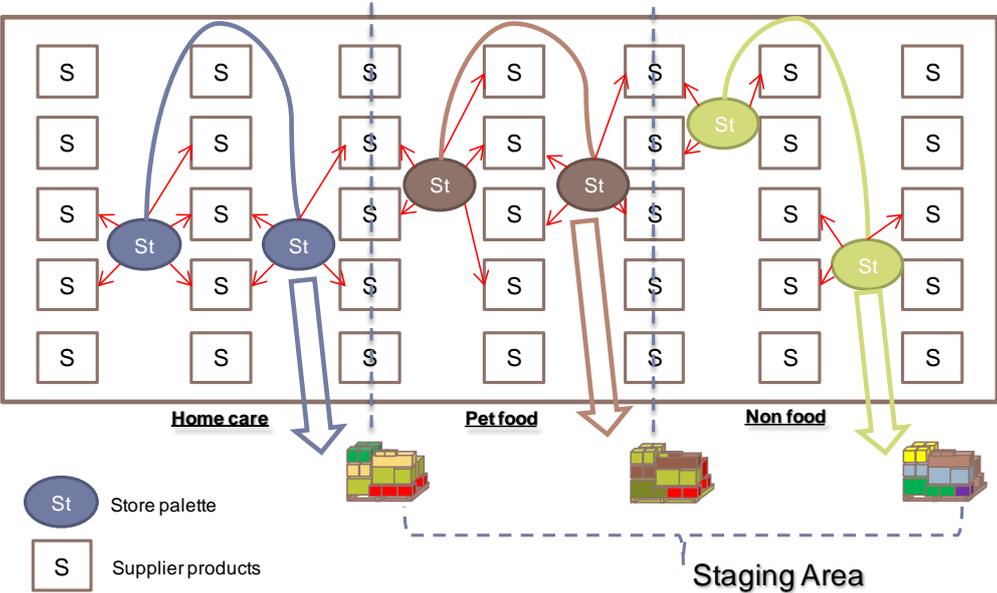


Figure 21: Order picking process in the retailer DC in traditional warehousing

Every aisle contains a product family. The warehouse operator takes an empty pallet and follows his order picking path through the aisle. Once the order picking is complete the operator put the picked pallet in the staging area waiting for loading and shipment to the stores.

This picking process takes into account the shelf replenishment process, since the products are picked by family.

Packing and shipping:

The order picking consist of regrouping cases of each products in one store order. Since the granularity of picking is low, the workers need check that the customer order is complete and accurate. Order accuracy is a key measure of service to the customer, which is, in turn, that on which most businesses compete. After checking the accuracy of orders the pallets are loaded in trucks and ready for shipping to the stores.

In this part we present the ordering model of the retailer DC. On the retailer DC side, at the beginning of time period t, the retailer receives orders from the stores and perform a verification of the availability of the inventory. After the DC produce pick lists to guide the order-picking. Each entry on the picking list is referred to as an order-line and consists of the item and quantity requested. This process consists

of picking this order-lines and regrouping products in pallets for shipping to the stores. The granularity of picking for retailer DC is cases. When the stores orders are prepared, the operators check the products, scan to register their departure to the stores, and load in the trucks. We assume that the retailer trucks are always full; the rationale behind this is that the retailer has the capacity to full their trucks and perform a routing of the trucks.

The retailer DC will then review its inventory depending to its own review period (daily review, every two days, three days or weekly review) and place an order to the supplier DC. The order sent to the supplier is a multiple of the Minimum Order Quantity (Pallets, Layers or cases). After a lead-time L_2 the retailer DC receives the quantity ordered, and docks the truck in the DC docks. After docking the truck, the operators unload the pallets. The products are then staged for inspection, such as damage, incorrect counts, wrong descriptions, and so on. The operators determine the storage location, store the product and scan the storage location where product has been placed.

4.3.1.3 The Supplier DC processes

A supplier distribution centre supply the retailer DC. The immediate customer of the supplier DC is a retail DC. A typical order might comprise hundreds of items; and because the distribution centre might serve hundreds of stores, the flow of product is huge (Bartholdi & Hackman 2008).

The physical processes in the supplier DC is identical to those of the retailer DC and include two major phases:

Inbound processes (Receiving and storing), and outbound processes (Order-picking, checking, packing and loading).

The reorganization of product in the supplier DC takes place through the following physical processes (figure 22):

Inbound processes:

- Receiving
- Put-away

Outbound processes

- Order-picking
- Checking, packing, shipping

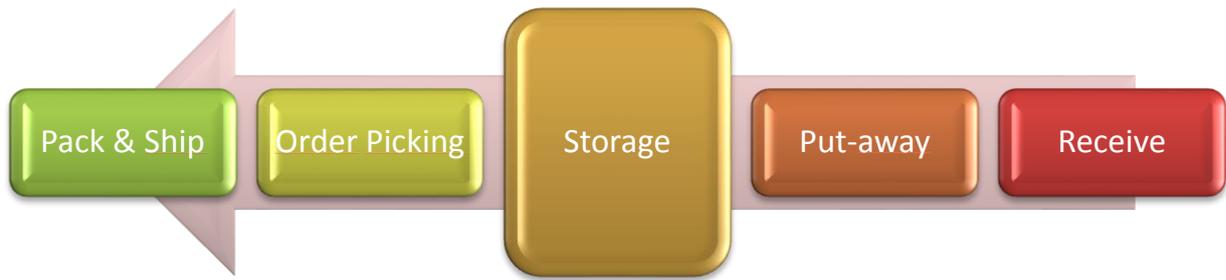


Figure 22: Supplier DC processes under traditional warehousing strategy

Figure 23 illustrates the processes at the supplier DC in traditional warehousing:

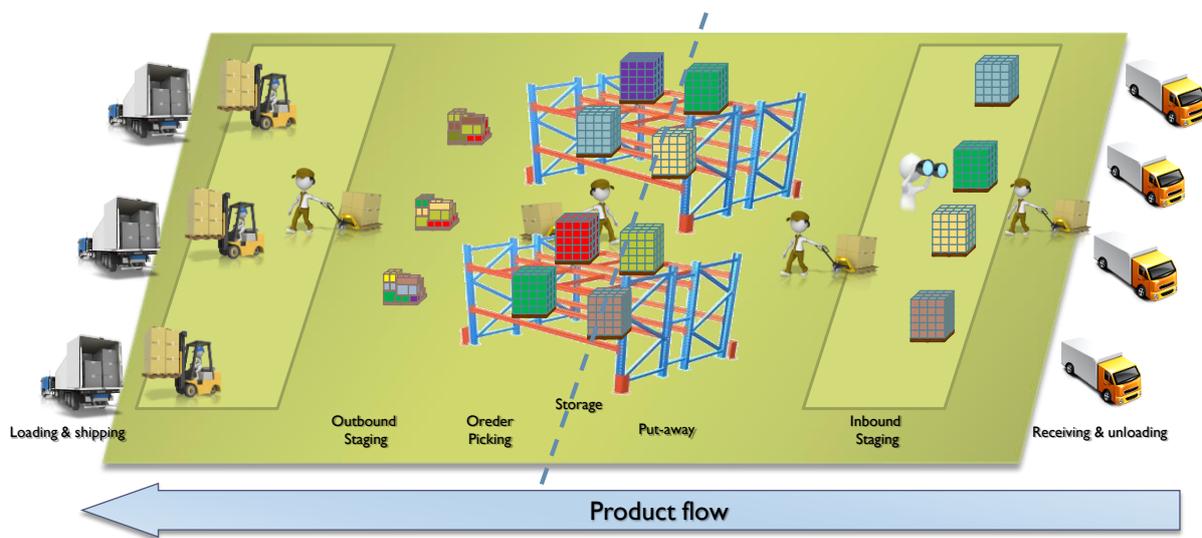


Figure 23: Illustration of the Supplier DC processes under traditional warehousing strategy

Ordering model of the supplier DC:

On the supplier DC side, after the reception of the retailer orders the DC perform a verification of the availability of the inventory. The order is then prepared. When the retailer orders are prepared, the operators check the products, scan to register their departure to the retailer DC, and load in the trucks. We assume that the trucks are filled with heterogeneous pallets and the filling depend on the dynamic of orders (no full truck constraint). The supplier DC update the stock level by taking into account, orders in transit, on hand and products delivered.

After that the supplier decides the ordering quantity according to the demand forecasting, lead-time demand and safety stock needed. The order is then sent to the source DC. After a lead-time the supplier DC receives the quantity ordered, and docks the truck in the DC docks. After docking the truck, the operators unload the pallets. The operators determine the storage location, store the product and scan the storage location where product has been placed.

4.3.2 Cross-docking pick by line

4.3.2.1 The stores processes

Moving to cross-docking pick by line, the only change in terms of physical flow concern the shelf replenishment process. In fact, as we will see in the next part the picking and preparation operations at the retailer DC are different in cross-docking. In fact the pallet received by the store is not built in the same efficient way as in traditional warehousing. As a consequence the replenishment of the shelf might be delayed.

In Figure 24, the green pallet is organized in such a way that it can be moved step by step in the aisle while replenishing the shelves. The cases of product are organized on the pallet to roughly follow the shelves plan.

On the contrary, the products on the orange pallet are not organized. The pallet has been built in the warehouse without taking into account the shelves plan. It is less efficient in terms of shelf replenishment process. This is the case for cross-docking pallets preparation. In fact in cross-docking mode the store order preparation/ pallet preparation is done according to the product family (beverage, home care, snacks...), and without respect to the planogram design. The preparation is carried according to the products received.

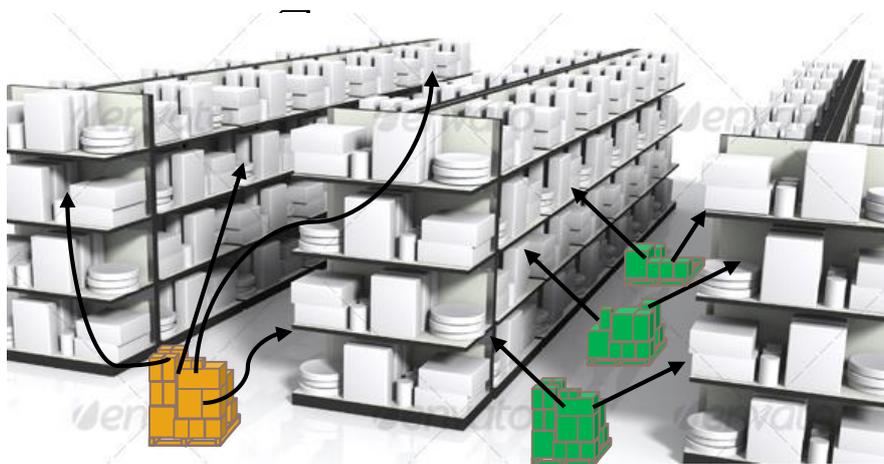


Figure 24: Shelf replenishment “Pallet traditional warehousing vs Pallet Cross-docking”

In terms of ordering, in the traditional warehousing strategy the inventory kept at the retailer DC is decoupling the store replenishment and retailer DC replenishment process. When moving to cross-docking, this decoupling point disappears. From a store point of view the delivery lead-time increases, since the products arrive from the supplier and no more from the retailer DC. With cross-docking, the stores face a much longer lead time, namely (Lead-time between the stores and the retailer DC + Lead-time between the retailer DC and the supplier DC) (Waller et al. 2006). In addition, on other change between cross-docking and traditional warehousing and which is not directly linked to moving to cross-

docking but can happen in parallel is the change in the review period. For instance, in most cases the store review period does not need to be changed when using cross-docking. However it can be reduced (if possible) to balance the increase in the lead-time.

For the stores, the lead-time increases since the products are coming from the supplier DC, instead of the retailer DC in traditional warehousing. Consequently, the re-order level will increase since we will need more safety stock to cover demand during the lead-time, and the stores will orders more frequently in smaller quantity.

4.3.2.2 The retailer DC processes

On the retailer side, the storing process is eliminated since there is no more inventory at the DC. The retailer DC will receives the stores orders per product, aggregate these orders and send them to the supplier DC. The supplier DC will receives the total need of the stores by products without details on the need by store. Once the retailer DC receives the products, they are unloaded, controlled and pre-prepared for picking. After picking the products per store order, the products are loaded and delivered to the stores.

Compared to the traditional warehousing processes in the retailer DC, in cross-docking pick by line the put-away process is removed. The reorganization of product in this strategy are (figure 25):

Inbound processes:

- Receiving

Outbound processes

- Order-picking
- Checking, packing, shipping

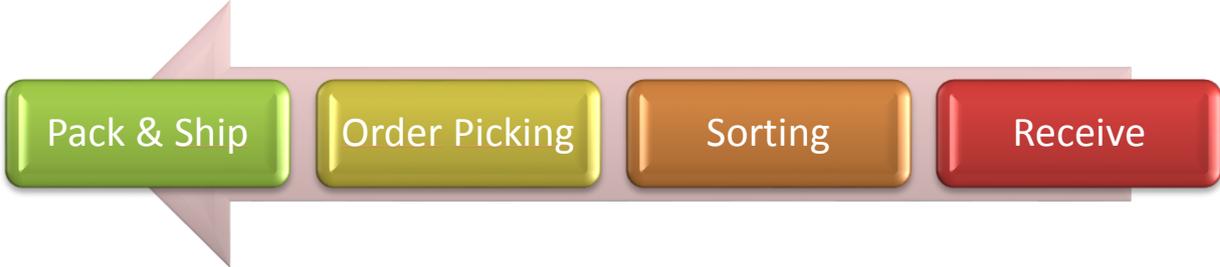


Figure 25: Retailer DC processes under cross-docking pick by line

Figure 26 illustrates the processes at the retailer DC in cross-docking pick by line:

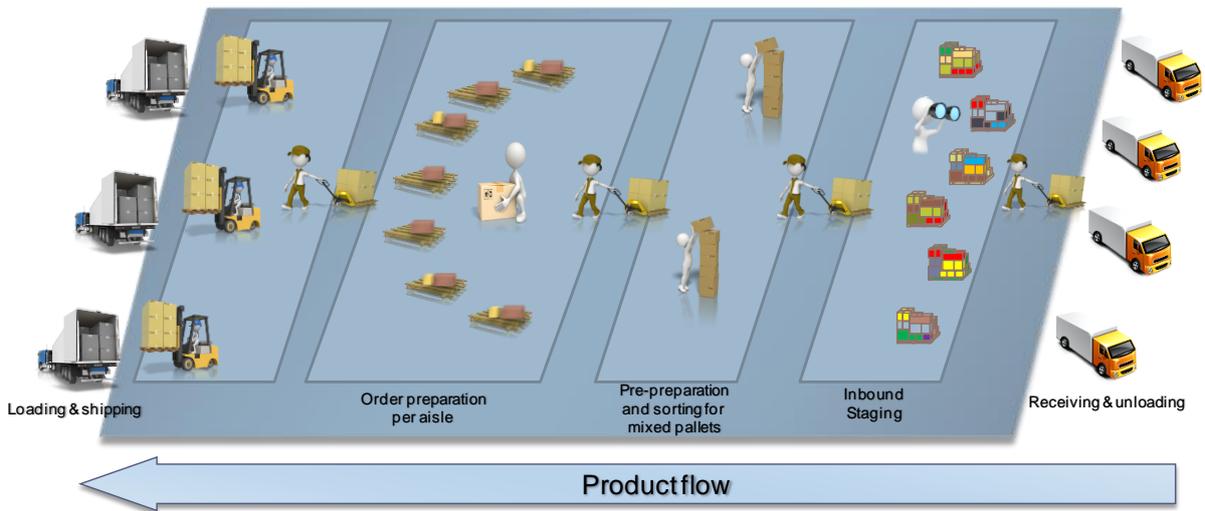


Figure 26: Illustration of the Retailer DC processes in the retailer DC in cross-docking pick by line

The processes that change in cross-docking pick by line are the order-picking which require a pre-preparation and sorting.

Figure 27 illustrates the order-picking process in the retailer DC under cross-docking pick by line strategy:

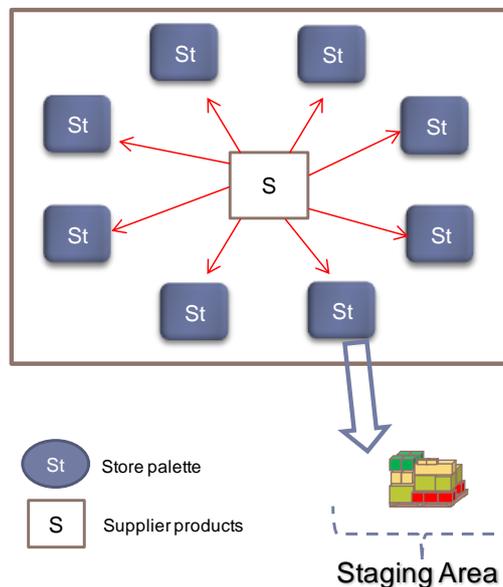


Figure 27: Order picking process in the retailer DC cross-docking pick by line

The picking operations in the retailer DC in cross-docking pick by line are as follow: In the picking area, empty pallets of different stores (St) are arranged in a circle in this picking zone.

A supplier delivers their products on heterogonous pallets. These pallets are sorted according to the product family. After sorting, the products (S) positioned in the picking area in the middle of the circle.

The warehouse operator takes case by case the products from the supplier pallet (S) and puts these cases on the stores pallets (St) according to their orders.

This procedure is repeated until the stores orders and pallets are completed.

This picking process has a major disadvantage: the order pick pallets to the stores are prepared according to the products arrivals from different suppliers, resulting in a great mix in product families. The stores receive a puzzled pallets and the shelf replenishment is more complicated.

In terms of ordering processes, the retailer function as a transfer point and no inventory control model, or forecasting is needed at this echelon of the supply chain.

4.3.2.3 The supplier DC processes

In terms of processes there is no major changes when moving to cross-docking. The only change that rise is, the granularity of picking. In fact, instead of preparing the products for the retailer DC in economic order quantity (usually pallets or layers), the granularity of picking will decrease. The picking is done by cases. On the other hand, the truck filling will change. With smaller quantities and more heterogonous pallets the truck fill rate is lower.

4.3.3 Cross-docking pick by store

4.3.3.1 The stores processes

As in cross-docking the lead-time to the stores will increase. On the other hand, the shelf replenishment process will be more complicated and will takes more time. This is due to the preparation process of pallets heterogeneous more puzzled at the supplier DC.

4.3.3.1 The Retailer DC processes

For the retailer DC, the storing process and the picking process are eliminated. The supplier DC will receives the exact need by store. Once the retailer DC receives the products, they are unloaded, controlled and consolidated by other products from other supplier. The picking process is replaced by a consolidation of orders from the suppliers.

Compared to the cross-docking pick by line processes in the retailer DC, in pick by store the picking process is removed and replaced by a simple consolidation of products received. The reorganization of products in this strategy is (Figure 28):

Inbound processes:

- Receiving

Outbound processes

- Order consolidation
- Checking, packing, shipping

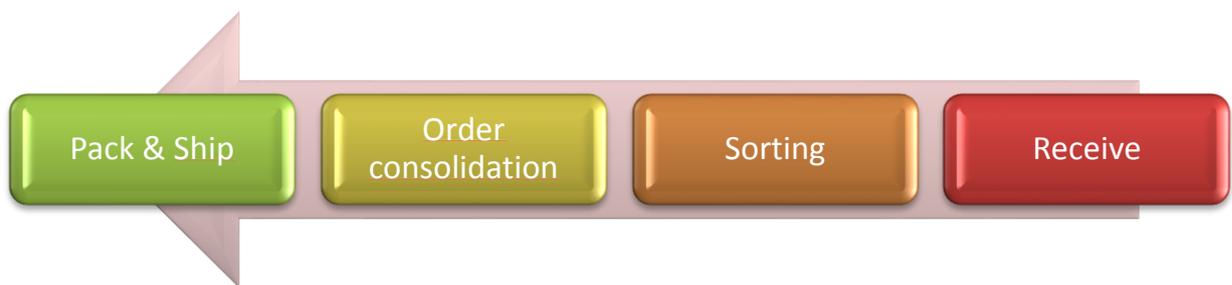


Figure 28: Retailer DC processes under cross-docking pick by store

Figure 29 illustrates the processes at the retailer DC in cross-docking pick by store:

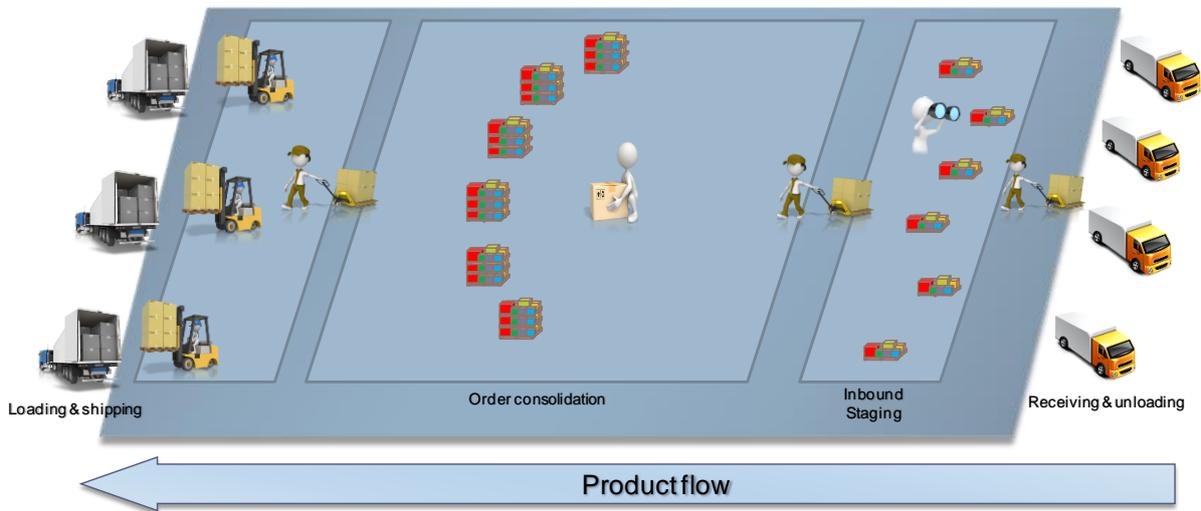


Figure 29: Illustration of the Retailer DC processes in the retailer DC in cross-docking pick by store

In this strategy the orders are prepared (picking) at destination (e.g. store) level by the supplier DC with identification of the final destination (e.g. store). This means that every supplier prepares the exact need of the store, instead of bulk preparation in cross-docking pick by line. Afterwards the products are shipped together to the cross-docking platform, where the products are combined with other products coming from different suppliers and shipped to the stores.

This picking process has a major disadvantage: the order pick pallets to the stores are prepared at the supplier with no respect to the planogram at the store, resulting in a great mix in product families.

4.3.3.2 The supplier DC processes

On the supplier DC side, the picking process changes. In fact, instead of preparing the sum of stores orders, in cross-docking pick by store, the preparation is done by store. A pallet for each store is prepared, composed of the order of the store. On the other hand, the truck filling will change. With smaller quantities and more heterogenous pallets the truck fill rate is lower.

Chapter 5

5. Supply Chain Macro Model Cost

5.1 Introduction

We propose a cost model to evaluate and compare the cost of the three distribution strategies studied. This cost model captures the relevant cost components affected by changing the distribution strategies.

The dimension for comparing different distribution strategies focuses on **the total cost of delivering a product from the supplier DC up to the store**, according to the three strategies (Traditional warehousing, Cross-docking pick by line, cross-docking pick by store). In addition, a combination of the traditional warehousing and cross-docking compared to pure cross-docking is also studied.

The objective of this cost analysis is to highlight the potential gains and hurts from the implementation of cross-docking. A cost model for evaluating the benefits/hurts in costs throughout the supply chain, from the supplier to the stores' shelves, was developed. This model allows to evaluate the economic issues of cross-docking for each particular situation based on the demand volume and the nature of the flow and their logistics constraints. In general, cross-docking has positive and negative effects on several costs in the supply chain. The profits come primarily from the elimination of the inventory at the retailer DC, in whole or in a large part. The extra costs also come from the increase of inventory at the stores, often necessary to compensate the elimination of inventory at the retailer DC. They can also come from the increase of picking at the supplier DC, and in the increase of the supplier transportation cost.

The retail supply chain model used for this Model Cost is:

- The admin, handling and inventory cost of the supplier DC
- The transport from the supplier warehouse to the retailer warehouse
- The admin, handling and inventory cost of the retailer warehouse
- The transport from the retailer DC to the retail store
- The admin, handling and inventory cost at the retail store

5.2 Cost Model

The cost model is a deterministic model based on hypothesis and data from the business case studied.

Moving to cross-docking has three types of impacts on the total supply chain cost. It changes the way certain handling operations are carried out, it has network impacts due to changes in inventories and

consolidation opportunities, and it increases the admin cost. These network impacts are also converted into cost, so the comparison can be done solely on a financial level.

For the handling operations, moving to cross-docking affects different costs at different stages of the supply chain:

- Shelf replenishment at the store
- Receiving cost at the retailer DC. Moving to cross-docking implies an increase of the supplier DC deliveries, with vehicles less filled, since the deliveries are composed of the exact need of the store.
- Storing cost at the retailer DC, since we don't have inventory.
- The transportation cost from the supplier to the retailer DC. The cross-docking impact the vehicle fill rate of the supplier which implies an increase in the transportation cost.
- The supplier DC picking cost, with more heterogonous pallets.

For the admin cost, moving to cross-docking affects different processes at different echelons of the supply chain:

- The retailer DC admin cost increases due to an increase of the orders to the supplier DC (more invoices to the supplier and order management of the store orders)
- The supplier DC admin cost increases as well due to the increase of the retailer DC orders.

For the inventory cost, moving to cross-docking will affect the retailer DC cost, since there is no inventory at the retailer DC.

Table 8 presents the list of variables used for the model:

Variable	Description
i	Subscript, 4 refers to the <i>supplier plant</i> , 3 refers to the <i>supplier DC</i> , 2 refers to the <i>retailer DC</i> , 1 refers to <i>the store</i> .
VC	Total year volume per cases
VP_i	Total year volume per pallets
C/p	Average number of cases per pallet
P/t	Average number of pallets per truck
Val	Total value of the products
$WACC$	Weighted Average Cost of Capital
VT_i	Total volume of trucks
S	Total store cost

Ret	Total Retailer DC cost
Sup	Total Supplier DC cost
Adm_i	Administrative cost
Hnd_i	Handling cost
Inv_i	Inventory cost
$Sales$	Lost sales cost
SR_i	Shelf replenishment cost
OSA_i	On Shelf Availability
RC_i	Reception cost
UN_i	Unloading cost
PC_i	Picking cost
e	Explosion factor
ST_i	Storing cost
LO_i	Loading cost
CAP_i	Capital cost of inventory
SC_i	Inventory cost
DOH_i	Days on hand
Ad_1	Unitary administrative cost per case
$Oret$	Ordering cost for the retailer DC
$Osup$	Ordering cost for the supplier DC
Usr_i	Unitary shelf replenishment cost per case
Uun_i	Unitary unloading cost per pallet
$Uctr_i$	Unitary control cost per pallet
Urc_i	Unitary reception cost per truck
Utr_i	Unitary transportation cost per km
DT_i	Distance between the echelon
Ust_i	Unitary storing cost per pallet
Upc_i	Unitary picking cost per case
Cpc_i	Percentages of picking per case
Udk_i	Unitary docking cost per truck

Ulo_i	Unitary loading cost per pallet
Usc_2	Unitary storage cost per pallet (case for the store)

Table 9: List of variables and parameters

5.2.1 Store

The **store's cost (S)** is composed of **administrative cost (Adm₁)**, handling cost, inventory and lost sales cost:

$$S = Adm_1 + Hnd_1 + Inv_1 + Sales$$

The **administrative cost** of the store is the **unitary admin cost** per cases times the total number of cases.

$$Adm_1 = Ad_1 \times VC$$

The **handling cost** is composed of the cost of replenishing the shelves, the cost of reception of trucks and the cost of unloading pallets from the trucks received:

$$Hnd_1 = SR_1 + RC_1 + UN_1$$

The shelf replenishment cost of the store is the unitary replenishment cost per cases times the total number of cases.

$$SR_1 = Ustr_1 \times VC$$

The unloading cost includes the cost of unloading plus the cost of controlling the pallets received:

$$UN_1 = (Uun_1 + Uctr_1) \times VP_2$$

Note that the total volume of pallets VP_2 received by the store, is the total volume of cases VC divided by the average number of cases per pallets and multiplied by the explosion factor e :

$$VP_2 = \frac{VC}{C/p} \times e$$

The explosion factor correspond to the ratio of physical volume of a pallets composed of picked cases (heterogeneous pallet) and a homogenous pallet. In fact, there is a picking explosion factor when pallets move from being a full pallet of only one SKU to a picked pallet that holds several SKUs. In our study we consider an explosion factor of 1,1. The explosion factor represent the ratio between the volume of products in a homogenous pallets and the volume of products in a heterogeneous pallet. In fact, when pallets is heterogeneous, it tends to be more puzzled that a homogenous pallet. In our study we consider an explosion factor of 1.1 based on the business case data.

In fact, the pallets received by the store are prepared in the retailer DC and they are all heterogeneous.

The total volume of trucks sent to the stores VT_2 is the total volume of cases VP_2 divided by the average pallets per truck times the Vehicle Fill Rate of the retailer trucks:

$$VT_2 = \frac{VP_2}{\left(\frac{P}{T}\right) \times VFR_2}$$

For the retailer DC we assume that the vehicle is always full, and that the stores are delivered by Full Trucks Load, since they have the flexibility to perform vehicle routing between the stores.

$$RC_1 = Urc_1 \times VT_2$$

The inventory cost is the sum of the capital cost of inventory and the cost of space:

$$Inv_1 = CAP_1 + SC_1$$

$$CAP_1 = \frac{Val \times WACC \times DOH_1}{365}$$

$$SC_1 = \frac{Usc_1 \times DOH_1 \times VC}{365}$$

For the store 33% of out of stock results in lost sales. In fact, (Gruen et al. 2007, Gruen et al., 2002) based on a study shows that in 33% of cases when customers are confronted to an empty shelf they buy the product in another store:

$$Sales = \frac{Val \times (1 - OSA_1)}{3}$$

5.2.2 Transport to the store

The transportation cost to the stores depends on the unit transportation cost per km traveled, the distance and the number of trucks sent:

$$TR_2 = Utr_2 \times VT_2 \times DT_2$$

5.2.3 Retailer DC

The Retailer DC's cost is composed of administrative cost, handling cost, and inventory:

$$Ret = Adm_2 + Hnd_2 + Inv_2$$

The administrative cost of retailer DC is composed of store management cost related to the management of orders from the stores, and the cost of managing the order to the supplier:

$$Adm_2 = Oret \times VT_3$$

VT_3 is the number of trucks sent to the retailer DC. Here each truck is an order.

The number of supplier trucks depend on its Vehicle Fill Rate:

$$VT_3 = \frac{VP_3}{\left(\frac{P}{t}\right) \times VFR_3}$$

The handling cost is composed of the cost of storing products on the racks, the cost of reception of trucks, the cost of unloading pallets from the trucks received, picking cost, and cost loading trucks:

$$Hnd_2 = RC_2 + UN_2 + PC_2 + ST_2 + LO_2$$

$$RC_2 = Urc_2 \times VT_3$$

The unloading cost includes the cost of unloading plus the cost of controlling the pallets received:

$$UN_2 = (Uun_2 + Uctr_2) \times VP_3$$

$$\text{With } VP_3 = \frac{vc}{c/p} \times e$$

VP_3 is the number of pallets received by the retailer DC from the supplier DC. The pallets sent are heterogeneous and then are calculated with an explosion factor.

$$ST_2 = Ust_2 \times VP_3$$

Note that the unit storing cost includes the cost of handling in, and cost of handling out a pallet.

The picking cost depends on the percentage of volume picked by cases. In the retailer DC, for preparing the stores' orders all the products are picked in cases:

$$PC_2 = Upc_2 \times VC \times Cpc_2$$

The loading cost includes the cost of docking a truck for loading products, and the cost of loading the pallets on the trucks:

$$LO_2 = (Udk_2 \times VT_3) + (Ulo_2 \times VP_2)$$

The inventory cost is the sum of the capital cost of inventory and the cost of space:

$$Inv_2 = CAP_2 + SC_2$$

$$CAP_2 = \frac{Val \times WACC \times DOH_2}{365}$$

$$SC_2 = \frac{Usc_2 \times DOH_2 \times VP_3}{365}$$

5.2.4 Transport to the Retailer DC

The transportation cost to the retailer DC depends on the unit transportation cost per km traveled, the distance and the number of trucks sent:

$$TR_3 = Utr_3 \times VT_3 \times DT_3$$

5.2.5 Supplier DC

The supplier DC's cost is composed of administrative cost, handling cost, and inventory:

$$Sup = Adm_3 + Hnd_3 + Inv_3$$

The administrative cost of retailer DC is composed of cost of managing the retailer DC order, and the cost of accounting and invoicing:

$$Adm_3 = Osup \times VT_3$$

The handling cost is composed of the cost of storing products on the racks, the cost of reception of trucks, the cost of unloading pallets from the trucks received, picking cost, and cost loading trucks:

$$Hnd_3 = RC_3 + UN_3 + PC_3 + ST_3 + LO_3$$

$$RC_3 = Urc_3 \times VT_4$$

VT_4 is the number of trucks sent from the supplier plant to the supplier DC. Here each truck is an order. The total volume of trucks sent to the supplier DC VT_4 is the total volume of cases VP divided by the average pallets per truck times the Vehicle Fill Rate of the retailer trucks:

$$VT_2 = \frac{VP_2}{\left(\frac{P}{t}\right) \times VFR_2}$$

From the supplier plant to the DC we assume that the vehicles are always full, and that the supplier DC is always delivered by Full Trucks Load.

The unloading cost includes the cost of unloading plus the cost of controlling the pallets received:

$$UN_3 = (Uun_3 + Uctr_3) \times VP_4$$

$$\text{With } VP_4 = \frac{VC}{c/p}$$

We consider here that the pallets received from the plant are homogenous.

$$ST_3 = Ust_3 \times VP_4$$

Note that the unit storing cost includes the cost of handling in, and cost of handling out a pallet.

The picking cost depends on the percentage of volume picked by cases:

$$PC_3 = Upc_3 \times VC \times Cpc_3$$

The loading cost includes the cost of docking a truck for loading products, and the cost of loading the pallets on the trucks:

$$LO_3 = (Udk_3 \times VT_4) + (Ulo_3 \times VP_3)$$

The inventory cost is the sum of the capital cost of inventory and the cost of space:

$$Inv_3 = CAP_3 + SC_3$$

$$CAP_3 = \frac{Val \times WACC \times DOH_3}{365}$$

$$SC_3 = \frac{Usc_2 \times DOH_3 \times VP_4}{365}$$

5.3 Retail supply chain configurations analysis

5.3.1 Retail Supply chain configurations

We to compare the cost performance between four retail supply chain configuration.

5.3.1.1 Retail supply chain configuration 1 (RSCC1): Traditional warehousing

The Retail supply chain configuration 1 corresponds to a traditional warehousing strategy with all products on this strategy. In our study we consider the traditional warehousing as a reference strategy, and we compare it with the other strategies.

We present in this table the variables that will change from one strategy to the other:

- 1- The days on hand at the stores DOH_1 , which can increase due to the increase in the safety stock at the stores.
- 2- The days on hand at the retailer DC DOH_2 , which are equal to 0 in cross-docking since there is no inventory at the retailer DC.
- 3- The On Shelf Availability at the stores OSA . We assume that the increase of lead-time to the store can lead to an impact in service level.
- 4- The supplier vehicle fill rate VFR_3 , which decrease in cross-docking.

- 5- The percentage of volume picked by cases at the supplier DC Cpc_3 , which increases in cross-docking strategy.

Variable	Unit	Description
DOH_1	Days	The average days on hand at the stores (for all the products).
DOH_2	Days	The average days on hand at the Retailer DC (for all the products).
OSA	% OSA	The average On Shelf Availability at the stores (for all the products).
VFR_3	% VFR	This percentage correspond to the cube fill which is Net volume of load / Volume per vehicle.
Cpc_3	% picking	The percentage of picking per case at the supplier DC.

Table 10: Retail Supply Chain configuration 1 “Traditional Warehousing distribution strategy”

5.3.1.2 Retail Supply Chain configuration 2 (RSCC2): Cross-docking Pick by line

In Table 10, we present the variation of the variable related to their value in the reference strategy namely the traditional warehousing strategy:

Variable	Variation compared to RSCC1	Description
DOH_1	0%	There is no change in this value.
DOH_2	-100%	In cross-docking we have zero inventory.
OSA	-0,5%	We estimate that there is a hurt on the average On Shelf Availability at the stores (for all the products) of when moving to cross-docking pick by line.
VFR_3	-52%	The average vehicle fill rate for Supplier Y is reduced by almost half of its capacity 52%.
Cpc_3	70%	The percentage of picking per case at the supplier DC in cross-docking strategy pick by line increases by 70%. In fact, since in this strategy the orders received by the supplier DC are done in cases, and represents the sum of all the stores need. So the picking per case is not 100% (for example, it can be a rounding number of pallets and the remaining quantity in cases).

Table 11: Retail Supply Chain configuration 2 : Cross-docking Pick by line

5.3.1.3 Retail Supply Chain configuration 3 (RSCC3): Pick by store

The data of this configuration are as follow:

Variable	Variation compared to RSCC1	Description
DOH_1	0%	There is no change in this value.
DOH_2	-100%	In cross-docking we have zero inventory.
OSA	-0,5%	We estimate that there is a hurt on the average On Shelf Availability at the stores (for all the products) of when moving to cross-docking pick by store.
VFR_3	-80%	The average vehicle fill rate for Supplier Y is reduced by almost half of its capacity 80%.
Cpc_3	76%	The percentage of picking per case at the supplier DC in cross-docking strategy pick by line increases by 76%.

Table 11: Retail Supply Chain configuration 3 : Pick by store

5.3.1.4 Retail Supply Chain configuration 4 (RSCC4): Combining pick by line and traditional warehousing

The configuration corresponds to a combination pick by line and traditional warehousing, with a part of products in cross-docking and the remaining parts of products in traditional warehousing. The products in traditional warehousing allow a better Supplier Y vehicle utilization. This split is based on a real business case of the supply chain of the retailer X and supplier Y.

The data of this configuration are as follow:

Variable	Variation compared to RSCC1	Description
DOH_1	+20%	The average days on hand at the stores (for all the products) increases by 20%.
DOH_2	-76%	The average days on hand at the Retailer DC (for all the products) is reduced by 76%. This is due to the % of volume that is managed in traditional warehousing.
OSA	0%	The average On Shelf Availability at the stores is the same as in traditional warehousing. In this configuration we estimate that there is no hurt on OSA when moving to cross-docking due to the rounding of orders and the effect

		of increase of inventory at the stores which might offset the increase of the stores lead-time.
VFR_3	-9%	The average vehicle fill rate for Supplier Y is reduced by only 9% compared to traditional warehousing.
Cpc_3	20%	The percentage of picking per case at the supplier DC increases by only 20%. This reduction in the amount of picking is due to the % of products in traditional warehousing.

Table 12: Retail Supply Chain configuration 4: Combining pick by line and traditional warehousing

5.3.2 Scenarios analysis

Based on the retail supply chain explained, we define three scenarios to analyse:

- SC1: Comparing cross-docking strategy pick by line with a traditional warehousing strategy
- SC2: Comparing cross-docking strategy pick by store with a traditional warehousing strategy
- SC3: Comparing a combination of cross-docking pick by line and traditional warehousing with a traditional warehousing strategy

5.3.2.1 Comparing cross-docking strategy pick by line with a traditional warehousing strategy

Supplier Y DC

Figure 30 shows the supplier Y DC cost variation between the RSCC1 and RSCC2.

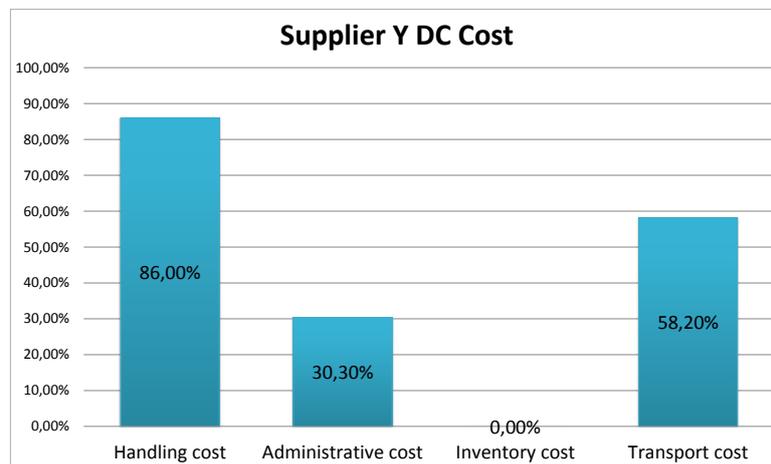


Figure 30: Supplier Y Logistics cost variation in RSCC1 vs RSCC2 configuration

The handling cost at the Supplier Y DC increases by 86%. The increase in handling cost is due first to the increase in the amount of picking. In traditional warehousing strategy the amount of picking was 24%. When moving to cross-docking this amount is 80%. The second reason for the increase of

handling, is the increase in the loading activities. The VFR increase implies an increase of the number of trucks sent to the retailer DC and then an increase in loading cost (Figure 31).

The administrative cost increases by 30%, due to the increase in the retailer DC orders and invoices.

Here we notice that the inventory cost don't increase in the TO-BE 1 compared to the AS-IS configuration. In reality the inventory decreases thanks to the reduction on the bullwhip effect due to the cross-docking. We will demonstrate this in the next chapter. At this time we didn't have data demonstrating this decrease.

The transportation cost increases by 58%. This increase due to the impact of cross-docking on the Supplier Y vehicle fill rate, and then by the number of trucks used over the year.

Retailer X DC

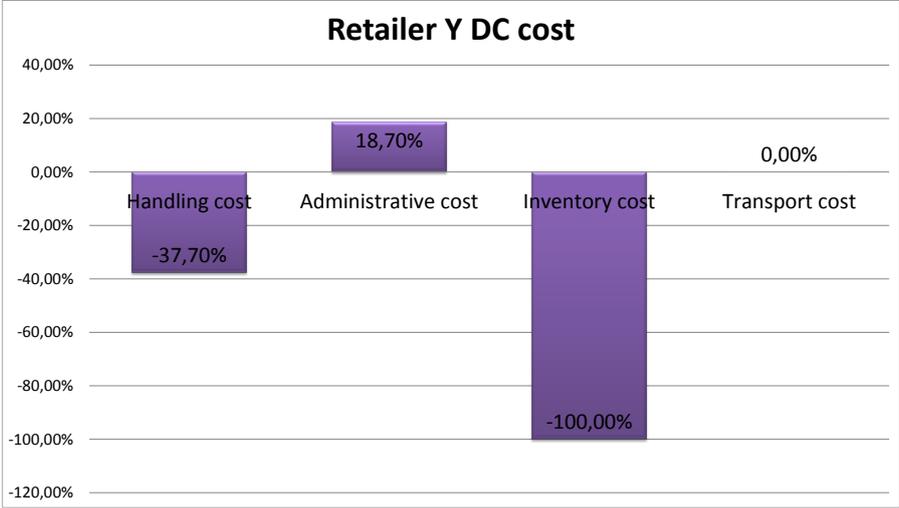


Figure 31: Retailer X DC Logistics cost variation in RSCC1 vs RSCC2 configuration

The handling cost at the Retailer X DC decreases by 38%. The decrease in handling cost is due to the elimination of the storing operations (figure 34)

The administrative cost increases by 18%, due to the increase in the orders and invoices.

The inventory at the retailer DC in TO-BE 1 configuration is eliminated, and then the inventory reduced by 100%.

The transportation cost increases don't change. We assume that in both strategies the retailer Dc has the flexibility to always full the trucks and perform vehicle routing between the stores.

Retailer X stores

In our analysis, there is no impact on the stores cost except for the lost sales. In fact we estimate that there is a hurt of 0,5% on OSA when moving to cross-docking. Depending on the products value, this hurt in OSA expressed in cost (figure 32).



Figure 32: Retailer X stores Logistics cost variation in RSCC1 vs RSCC2 configuration

End-to-end costs

In an End-to-end perspective we can note an increase of 5% in the total supply chain cost. This increase is due to the increase in the supplier transportation and handling cost, increase in the retailer administrative cost, and increase in lost sales cost. With an increase in the deliveries involved by the cross-docking strategy, the transportation cost of the supplier increase as well as the administrative costs. On the other hand the increase of the End-to-end cost can be explained as well by the double picking activities in the supply chain. In fact picking activities in cross-docking are done twice, at the Supplier Y DC and after at the retailer DC (figure 33)

In a pure cross-docking and the supply chain studied, the decrease and benefit of the retailer DC cannot offset the increase for Supplier Y. In this case the traditional warehousing strategy is more economic.

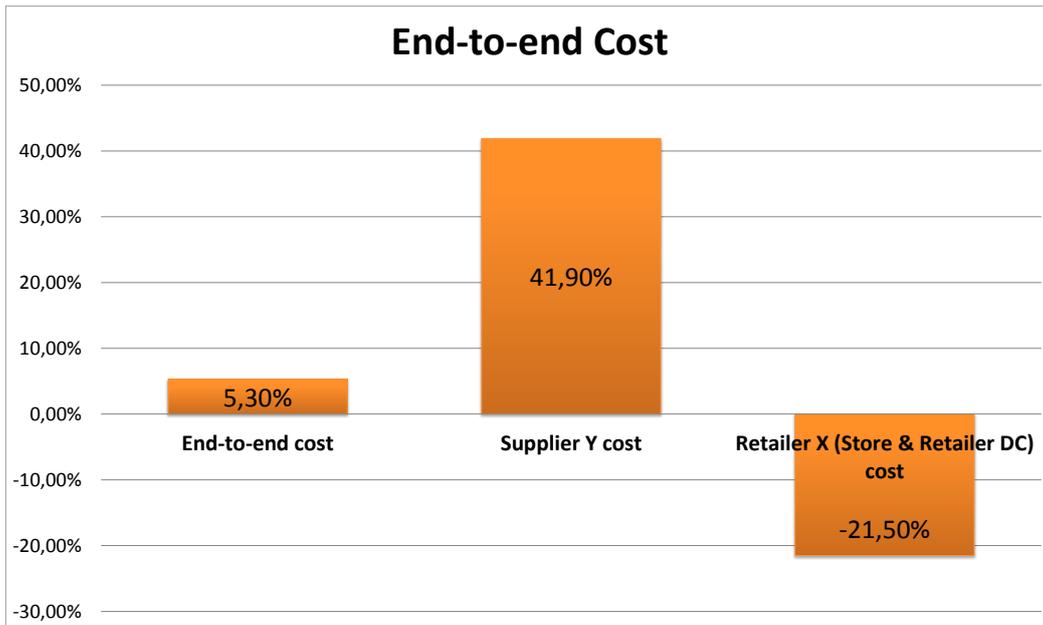


Figure 33: End-to-end logistics cost variation in RSCC1 vs RSCC2 configuration

5.3.2.2 Comparing cross-docking strategy pick by store with a traditional warehousing strategy

Supplier Y DC

The percentage of picking per case at the supplier Y DC increases from 80% to 100%. As explained in the chapter 3, in cross-docking pick by line, the orders are prepared at product level, which means that the orders are prepared in bulk (the sum of stores' orders). In cross-docking pick by store the orders are prepared at store level, which means that the supplier Y DC prepare the exact needs of each store, and since the stores order by cases the percentage of picking is 100%.

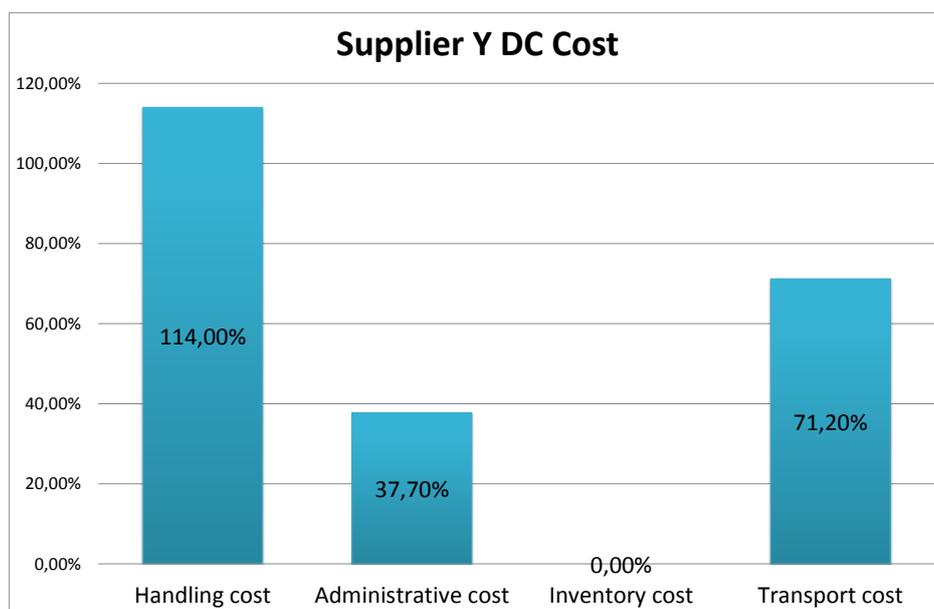


Figure 34: Supplier Y Logistics cost variation in RSCC1 vs RSCC3 configuration

Compared to the evolution of cost in the scenario, the increase of the handling cost at the Supplier Y DC reach 114%. This increase is due to the increase of the percentage of picking by cases.

On the other hand, the administrative costs increase. In fact, with the increase of the percentages of picking per cases, and due to the explosion factors, the number of trucks increases. Since the invoicing and accounting cost is done per number of trucks sent to the retailer DC, the administrative costs for the supplier increases.

The transportation cost increases also due to the increase of the number of trucks as explained before.

Retailer X DC

For Retailer X DC the costs we can note a more significant reduction compared to the comparison of traditional warehousing and pick by line. In fact, in pick by store the picking activities at the retailer DC is removed. The product are unloaded from the inbound trucks consolidated with other products from other supplier and loaded to the outbound trucks.

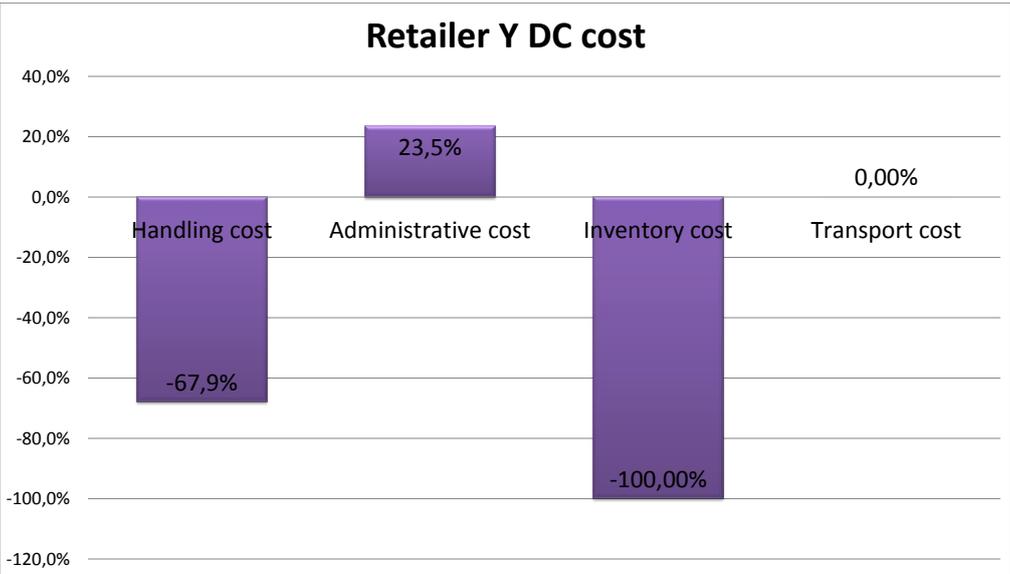


Figure 35: Retailer X DC Logistics cost variation in RSCC1 vs RSCC3 configuration

The administrative cost increases also due to the increase of the number of trucks. For the other cost, namely the transport and inventory costs there is no change compared to the pick by line.

Retailer X stores

For the stores we have the same impacts as on the traditional warehousing scenario:

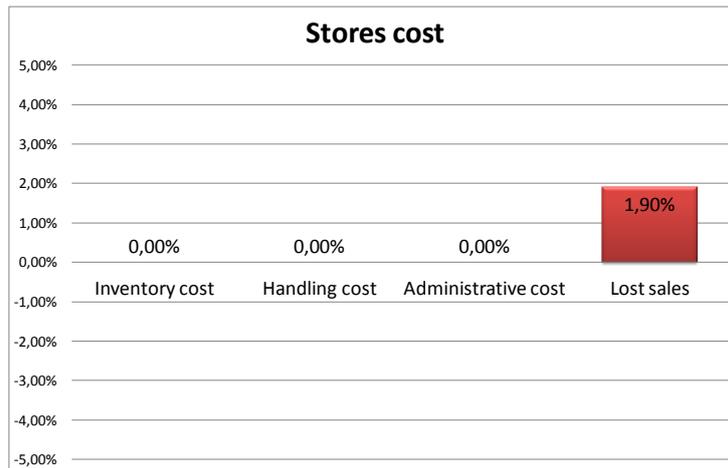


Figure 36: Retailer X stores Logistics cost variation in RSCC1 vs RSCC3 configuration

End-to-end costs

In an End-to-end perspective in this scenario the End-to-end cost decreases of 0,6 %. We note here that the cross-docking pick by store is more economic than the cross-docking pick by line compared to traditional warehousing. Even with an increase in the percentage of picking per case at the supplier DC, removing the picking activities in the retailer DC led to a reduction in the E2E. In fact, in cross-docking pick by line the picking activity is done twice. At the retailer DC with a preparation of the aggregated need of the stores, and at the retailer DC with a preparation of the pallets per store orders. In cross-docking pick by store the orders for the store are prepared once at the supplier DC and the retailer DC just consolidated with other products and send the orders to the stores.

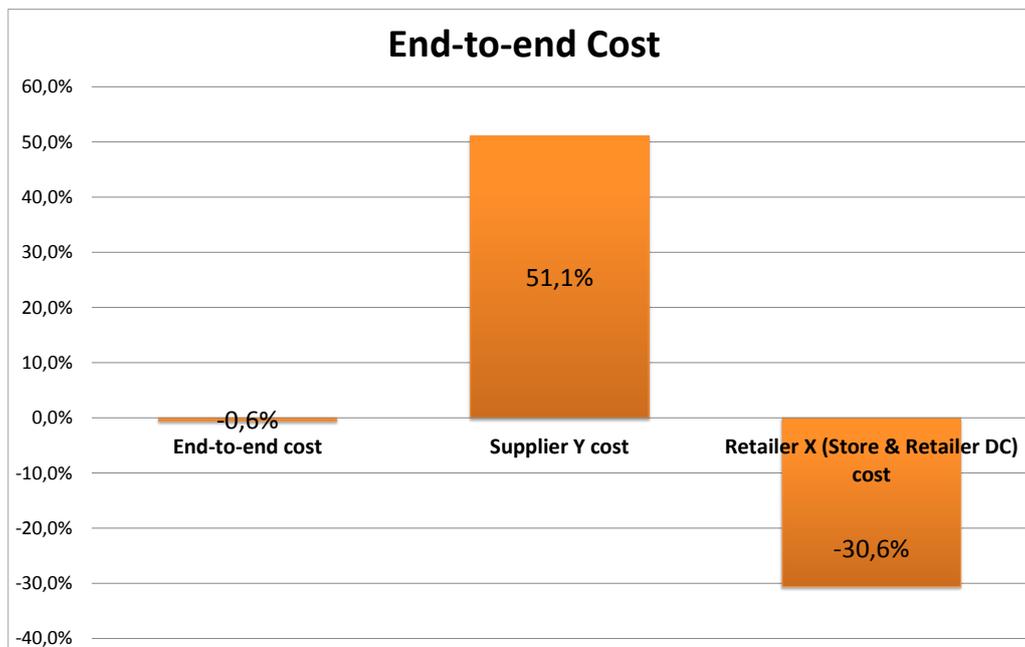


Figure 37: End-to-end logistics cost variation in RSCC1 vs RSCC3 configuration

5.3.2.3 Comparing a combination of cross-docking pick by line and traditional warehousing with a traditional warehousing strategy

Supplier Y DC

Due to this combination of two strategies and rounding, the vehicle fill rate is improved and the picking amount is reduced.

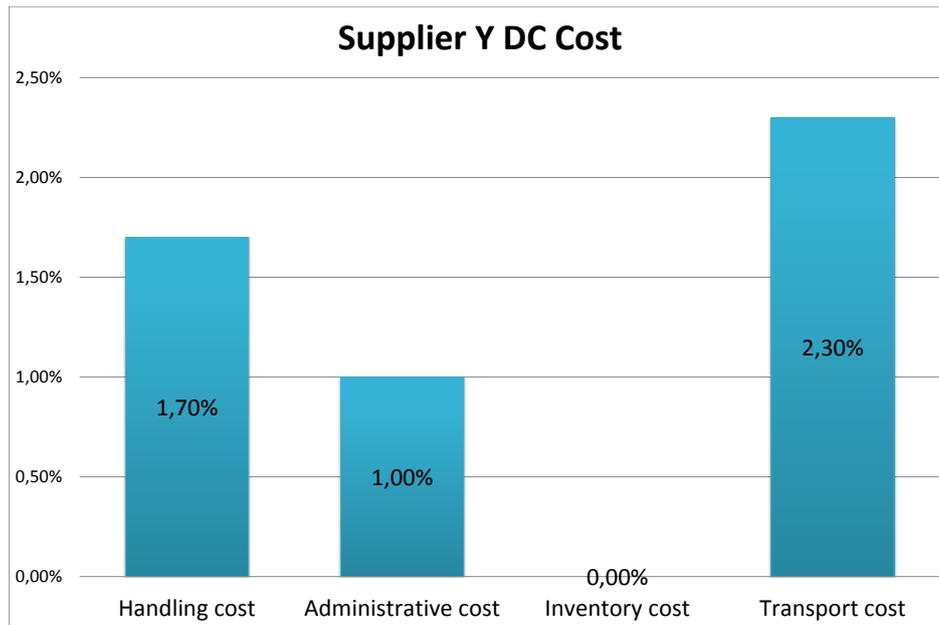


Figure 38: Supplier Y Logistics cost variation in RSCC1 vs RSCC4 configuration

In this scenario we can note a slight increase in the handling cost. This increase is due to the loading process since we still have an increase in the total number of trucks (the optimal VFR of 76% is not achieved in this configuration). On the other hand the administrative cost are increased by 1% and the transport cost by 2,3%.

Retailer X DC

For Retailer X DC and compared to the other scenarios, the inventory cost is not eliminated but reduced by 64%. This is due to the 30% of volume managed in traditional warehousing. For the administrative cost, the increase is very low compared to the other scenario, and this is due to the reduction of the number of trucks:

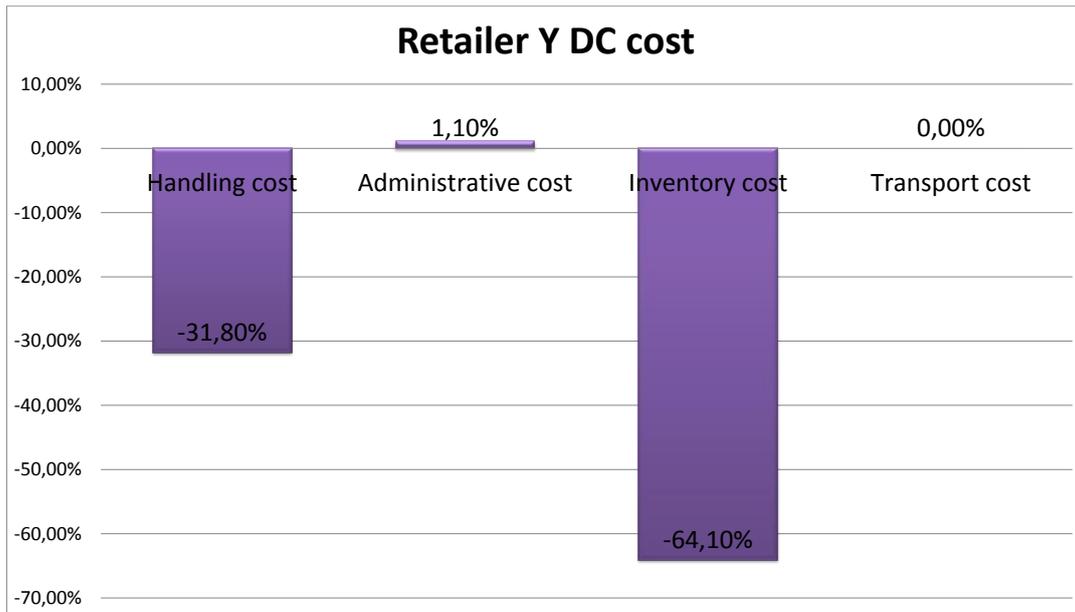


Figure 39: Retailer X DC Logistics cost variation in RSCC1 vs RSCC4 configuration

Retailer X stores

For Retailer X stores the costs are the same as in the Pick by line scenarios:

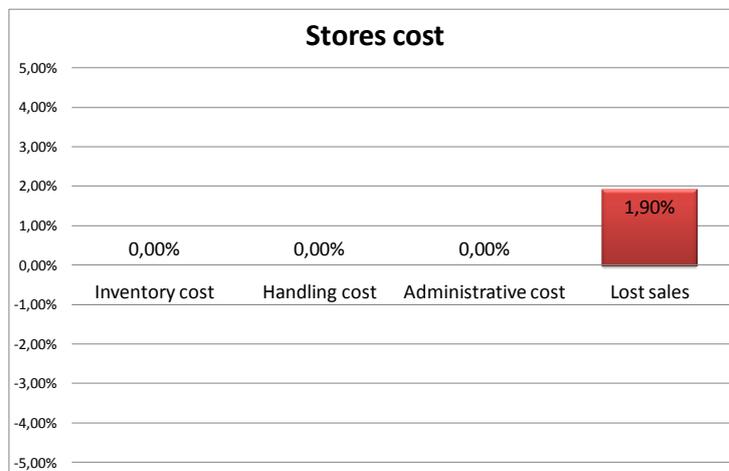


Figure 40: Retailer X stores Logistics cost variation in RSCC1 vs RSCC4 configuration

End-to-end costs

In an End-to-end perspective in this scenario the End-to-end cost decrease by 6,4%. With reducing the picking percentage of the supplier DC, and managing 70% in the volume in traditional warehousing this reduce the impact on Supplier Y cost and at the same time keep the benefit for the retailer which is in this case -16%:

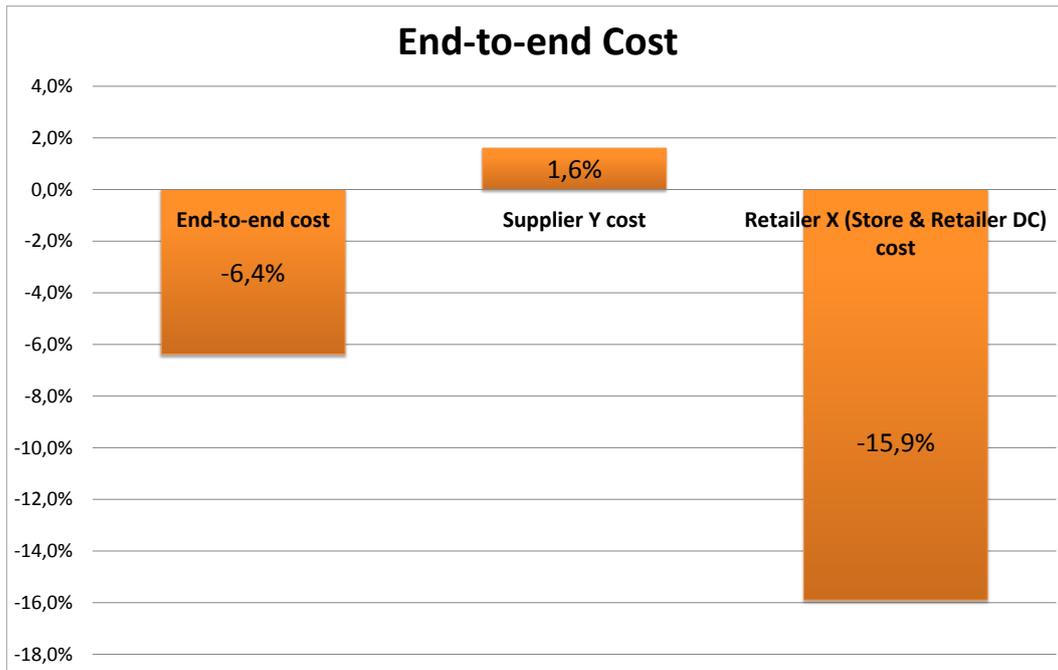


Figure 41: End-to-end logistics cost variation in RSCC1 vs RSCC4 configuration

5.4 Synthesis of different scenarios

In this chapter we have proven that cross-docking pick by line strategy increases the entire supply chain cost. The benefits of removing the inventory at the retailer DC doesn't counterbalance the increase in the supplier handling cost and transportation cost. On the other hand the increase of the End-to-end cost can also be explained by the double picking activities in the supply chain. In fact picking activities in cross-docking are done twice, at the Supplier Y DC and after at the retailer DC.

Cross-docking pick by store is more economical than traditional warehousing. Even with an increase of the percentage of picking per case at the supplier DC, removing the picking activities from the retailer DC leads to a reduction in the E2E. In fact, in cross-docking pick by line the picking activity is done twice. At the supplier DC with a preparation of the aggregated need of the stores, and at the retailer DC with a preparation of the pallets per store orders. In cross-docking pick by store the orders for the store are prepared once at the supplier DC and the retailer DC just consolidates with other products and sends the orders to the stores.

Finally, combining cross-docking pick by line and traditional warehousing reduces the supply chain cost by 6,4%. By reducing the picking percentage of the supplier and increasing its vehicle fill rate by managing 70% of the volume we reduce the impact on the Supplier Y cost and at the same time keep the benefit for the retailer.

As demonstrated in this study, some costs and parameters have not been identified as it was difficult to collect the data. Indeed, the variation of the inventory at store from a strategy to another was not identified. Store service level was also not identified. The inventory at the supplier DC was not identified either. To validate these hypotheses we need a more robust model with real data and a real business case. In the following chapter, we analyse the impact of the distribution strategies on the supply chain performances, and the impact of the products characteristics on the performances of the distribution strategies based on a real case.

5.5 Conclusion and limitations of the macro cost analysis

5.5.1 Conclusion

ECR France (2000) was the first to develop a model and a study to highlight the potential gains/hurts from the implementation of cross-docking. Supervised by ECR France, a working group was established to evaluate the benefits/hurts on the entire supply chain from the supplier to the shelves. The working group was composed of different logistic managers coming from different companies. Suppliers such as Ballantine's, Bestfoods France, LU, Nestlé France, Panzani, Procter & Gamble and others were present. On the retailer side, Auchan, Carrefour, Casino, Comptoirs Modernes and Promodès were present.

A cost model was developed in advance and used during this working group. Different pairs, each one composed of a supplier and a retailer, used the model to evaluate the economic challenges of cross-docking for their particular situation, based on the volume and the nature of their flows and their logistics constraints.

ECR France model shows that the cross-docking pick by store decreases the entire supply chain cost by an average of 1,2% for all the working groups. This conclusion confirms our results. In our simulation we find that cross-docking pick by store reduces the entire supply chain cost by 0,6%. On the other hand, this study does not take into account a scenario of a combination of cross-docking and traditional warehousing. On the contrary, (Gebennini et al. 2013) present in their work a cost comparison of two different configurations: the “downstream picking configuration” (AS-IS Configuration) which can be assimilated to a traditional warehousing strategy, with picking activities executed at intermediate facilities, and the “upstream picking configuration” (TO-BE Configuration) which can be assimilated to a cross-docking pick by store strategy, where picking activities are performed upstream in the network at a central distribution centre. The study shows that, the transportation costs increase in the TO-BE Configuration by 85% because of the increase of deliveries in Less Than Truck load. On the other hand the operative costs (inventory, commercial, picking and financial) are reduced by 77%. The total costs are reduced by -22%. In our study we found that cross-docking pick by line increased the entire supply chain cost by 6% and cross-docking pick by store decreased the entire supply chain cost by 0,6%. The rationale behind this difference is the scope taking into account by (Gebennini et al. 2013). In fact, the

authors Gebennini et al. (2013) studied a three level configuration with a first level composed of a supplier DC, a second level composed of multi retailers DCs and a third level of stores.

Moreover, we demonstrate that combining traditional warehousing and cross-docking strategy in the same supply chain is beneficial for all the actors. This demonstrates the importance of analyzing the impact of the products characteristics and their impact on the performances and choose the right strategy for each product. This is the aim of the next chapter.

5.5.2 Limitations

The Macro cost analysis doesn't allow us to achieve a deep study on the choice of the distribution strategy for each product, it just allows us to give an overall picture of the different impacts on the supply chain costs with hypothesis and values based on field experience. The parameter values for Supplier Y supply chain have been defined and based on a data extract from internal documents and tools. We have conducted several interviews with regional experts and operational managers in DCs. On the retailer side it was more difficult to define the values for each parameter. We used some public data available as well as studies done with some customers. We have averaged the values.

For instance the impact on the store's inventory was difficult to define, because we didn't have access to this data. The impact on the on shelf availability was also complicated to define, because we didn't have access to this data either, and at the same time there is no study in the literature about the impact of cross-docking on this performance. On the other hand, in the literature some studies such as (Eftekhar et al 2008) explain that cross-docking is reducing the bullwhip effect as it brings a direct connection between the store and the supplier DC, because the orders come directly from the stores. This reduction on the bullwhip effect allows a reduction on the supplier inventory.

Chapter 6

6. A Framework of product segmentation and distribution strategy selection.

The objective of this chapter is to analyse the impact of the distribution strategies on the supply chain performances, analyse the impact of the products characteristics on the performances of the distribution strategies and finally propose a framework to choose the right strategy for each product depending on its characteristics and the impact on the performances.

As described in the previous chapters, the cost analysis is interesting to give an overall picture of the supply chain and validate the hypothesis and the literature of the impact of the distribution strategies on the supply chain cost. But working on a research alone doesn't help achieving a deep study on the choice of the distribution strategy for each product. In this chapter we present the simulation of the distribution strategies based on the process modelling, as well as on the macro cost model and inventory management rules. In addition to the cost model and process modelling, the simulation includes data about the products. This data is related to the demand, volume of products, pallets design and Minimum order quantities:

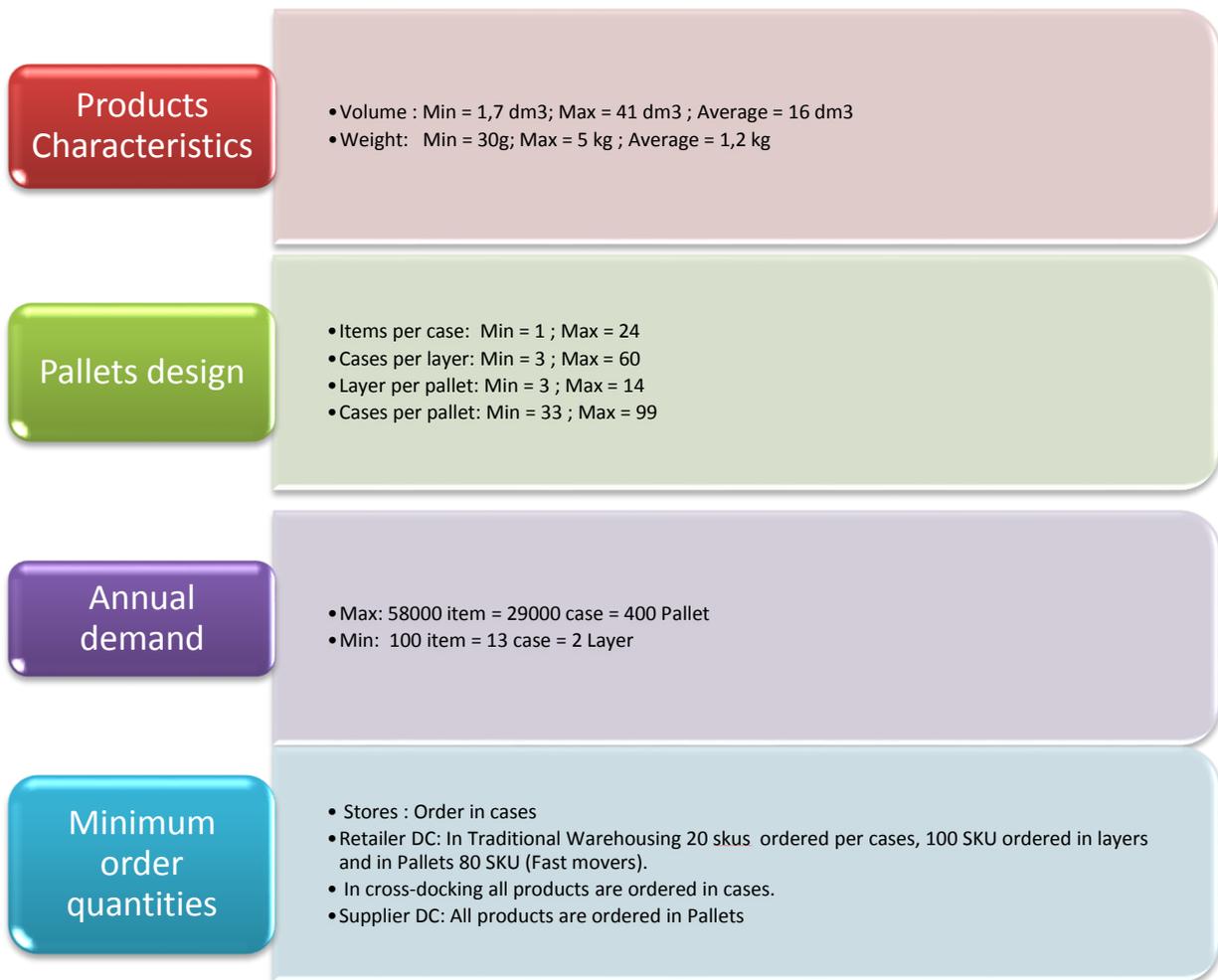


Figure 42: Products studied

Including data related to the demand requires an analytical approach of inventory management. We opt for a combination of analytical approaches and simulation. We studied the supply chain of a retailer X and a supplier Y. We gathered data from a retailer X and a supplier Y. The data collected was related to the supply chain network, with the location of the supplier DC, the location of the retailer DCs, the number of stores and their location. We also collected data related to the product (demand, lead-time, review period, etc.). We also collected data related to cost. This data is in the form of unitary data cost for each process and for each echelon in the supply chain.

We will use Microsoft Excel and VBA (Visual Basic for Applications) to conduct the numerical experiments and simulation. The simulation will be run on the basis of one year. We have a one-year data basis. We simulate the ordering and inventory management day per day. Every day we simulate the stores sales based on the demand data for each product. Each store based on its inventory rules sends orders to the retailer DC, which in turns sends orders to the supplier DC.

First in this chapter, we describe the supply chain configurations studied, the inventory management rules for each configuration and an illustration of the configuration. Then we present results analysis.

These results are divided in two parts. The first one concerns the impact of the distribution strategies on the supply chain performances (Cost, service level and bullwhip effect). The second one concerns product segmentation and distribution strategy selection based on the intrinsic factors, demand factors, intrinsic-demand factors and supply control factors. Finally we present a framework for the product segmentation and distribution strategy selection.

6.1 The simulation model of the distribution strategies

6.1.1 Traditional warehousing

6.1.1.1 The stores

Inventory and ordering rules at the store for each product:

The logic is as follows: Each store is replenished on a regular weekly schedule. Stores are replenished two to five times a week, also on fixed days. Every 'review period' days (daily review, every two days, three days or weekly review), the store checks the inventory availability for all the products. If the inventory position of some products is low, the store will order the enough to bring the inventory position above to fill the shelf.

To represent this inventory control policy different model was described in the literature. The inventory control models are either periodic or continuous (Scarf 1959, Karlin 1960, Iglehart 1963, Hadley and Whitin 1963). In continuous review models, when the inventory position is below a certain point called the re-order level, the store order to the retailer DC. The order quantity is either fixed (r,Q) or variable (s,S).

In the periodic review models, unlike the continuous models, the inventory check is done every review period days. In the literature different periodic review models, we can cite the (T,S) model, (T,r,S) model and (T,r,Q) model (Babai 2005).

In the (T,S) model, in the beginning of every review period T , if inventory position is below a given value, called Order Up To Level S , the store orders to bring the position of the inventory to S .

In the (T,r,S) model, at the end of each review period T , if inventory position is below a given value r (re-order level), the store orders to bring the position of the inventory to S . The quantity orders is different in every period (When et al. 2012). The (T,r,Q) is similar to the (T,r,S) model, with one difference is that in the (T,r,Q) model the quantity orderd is fixe.

In our study, and inspired from the business case studied. The ordering policy adapted by the stores is the (T,r,S) policy. With T the review period, r the re-order point (in our example I), and S the shelf space.

Inventory model:

The re-order point $I_{t,s,i}$ is set such as to provide a specified service level (to the consumer) for a given demand variability, reaction time (sum of the Lead time and the review period) and order quantity:

$$I_{t,s,i} = \widehat{D}_{t,s,i} (L_1 + T_1) + K\sigma_{s,i} \sqrt{L_1 + T_1}$$

with $\widehat{D}_{t,s,i}$ the forecast daily demand for the store s , product i , in period t , and $\sigma_{s,i}$ the standard deviation of the one day forecast error for product i in store s , K a service factor and L_1 the replenishment lead-time in days and the review period in days T_1 .

To estimate the demand at time t we use exponential smoothing scheme:

$$\widehat{D}_{t,s,i} = \alpha D_{t-1,s,i} + (1 - \alpha)\widehat{D}_{t-1,s,i}$$

With α the smoothing parameter.

We assume that each echelon in the supply chain (Stores, Retailer DCs, and Supplier DC) uses an exponential smoothing forecasting scheme. It's a weighting method, In other words, recent observations are given relatively more weight in forecasting than the older observations. We choose this method for its simplicity and robustness. In fact for the type of products we choose (normal distribution without trend or seasonality) this type of forecasting method is the more adapted. The review of sales data shows that there is no seasonality or trends.

$NS_{t,1,i}$, the inventory level of the product i at the beginning of the period t , is given by:

$$NS_{t,s} = NS_{t-1,s} + O_{t-1,s} - D_{t,s}$$

The order quantity $O_{t,s,i}$ of the product i at the period t , is as follow:

$$O_{t,s,i} = S_i - NS_{t,s,i}$$

With S_i the shelf space, $NS_{t,1}$ is the store inventory position at the end of period t . The order $O_{t,s,i}$ is rounded to the higher multiple of case size, which represent the Minimum Order Quantity of the store.

After a lead-time the store receives the quantity ordered $O_{t,s,i}$.

6.1.1.2 The Retailer DC

The retailer DC handles his ordering process as follows.

In terms of inventory policy, we assume that the Retailer DC follows an order-up-to policy with a review interval of T and lead-time of L (Dejonckheere et al 2003, Zhang 2004, Kim et al. 2006, Kelepouris et al. 2008, Hosoda et al 2008). In this policy, the inventory position is reviewed periodically, and if it is below a certain level, an "order" is placed to bring the inventory position "up-to" a defined level. This

model represents a standard inventory control model that captures the elements of the inventory management. This method is based on a periodic inventory replenishment, it allows to consolidate orders and it is close to what is used in reality. This inventory control model is used in the business case studied.

At the beginning of time period t , the retailer receives and ships the required order quantity for the product i to the store s $O_{t,s,i}$. The retailer DC will review its inventory and place an order $O_{t,2,i}$ to the supplier DC.

The order placed by the retailer DC at the end of beginning of t can be expressed as:

$$O_{t,2,i} = O_{t-1,1,i} + (OUT_{t,2,i} - OUT_{t-1,2,i})$$

$$OUT_{t,2,i} = \hat{O}_{t,1,i} (L_2 + T_2) + K \sqrt{\sum_{s=1}^n \sigma_{s,i}^2} \sqrt{(L_2 + T_2)}$$

with $\sigma_{s,i}^2$ the variance of demand of product i in store s , and n the total number of stores.

The retailer inventory level at the beginning of the period t , is given by:

$$NS_{t,2,i} = NS_{t-1,2,i} + O_{t-1,2,i} - O_{t,s,i}$$

To estimate the store's demand at time t we use exponential smoothing scheme:

$$O_{t,2,i} = O_{t-1,s,i} + \hat{O}_{t,s,i} (L_2 + T_2) - \hat{O}_{t-1,s,i} (L_2 + T_2)$$

6.1.1.3 The Supplier DC

The supplier DC uses an Order up to level policy. The supplier DC handles his ordering process as follows. At the beginning of time period t , the supplier receives and ships the required order quantity for each product i to the retailer $O_{t,2,i}$ to the stores. The supplier DC will review its inventory and place an order $O_{t,3,i}$ to the plant.

The order placed by the supplier at the beginning of period t can be expressed as:

$$O_{t,3,i} = O_{t-1,2,i} + (OUT_{t,3,i} - OUT_{t-1,3,i})$$

$$OUT_{t,3,i} = \hat{O}_{t,2,i} (L_3 + T_3) + K \sigma_{2,i} \sqrt{(L_3 + T_3)}$$

with σ_2 the variance of orders of the retailer DC for product i .

The supplier inventory level at the beginning of the period t , is given by:

$$NS_{t,3,i} = NS_{t-1,3,i} + O_{t-1,3,i} - O_{t,2,i}$$

To estimate the retailer's mean demand we use exponential smoothing scheme:

$$\hat{O}_{t,2,i} = \alpha O_{t-1,2,i} + (1 - \alpha)\hat{O}_{t-1,2,i}$$

To summarize, Figure 43 below shows the simulation model of the traditional warehousing model. (Appendix A) shows the description of each process of the model:

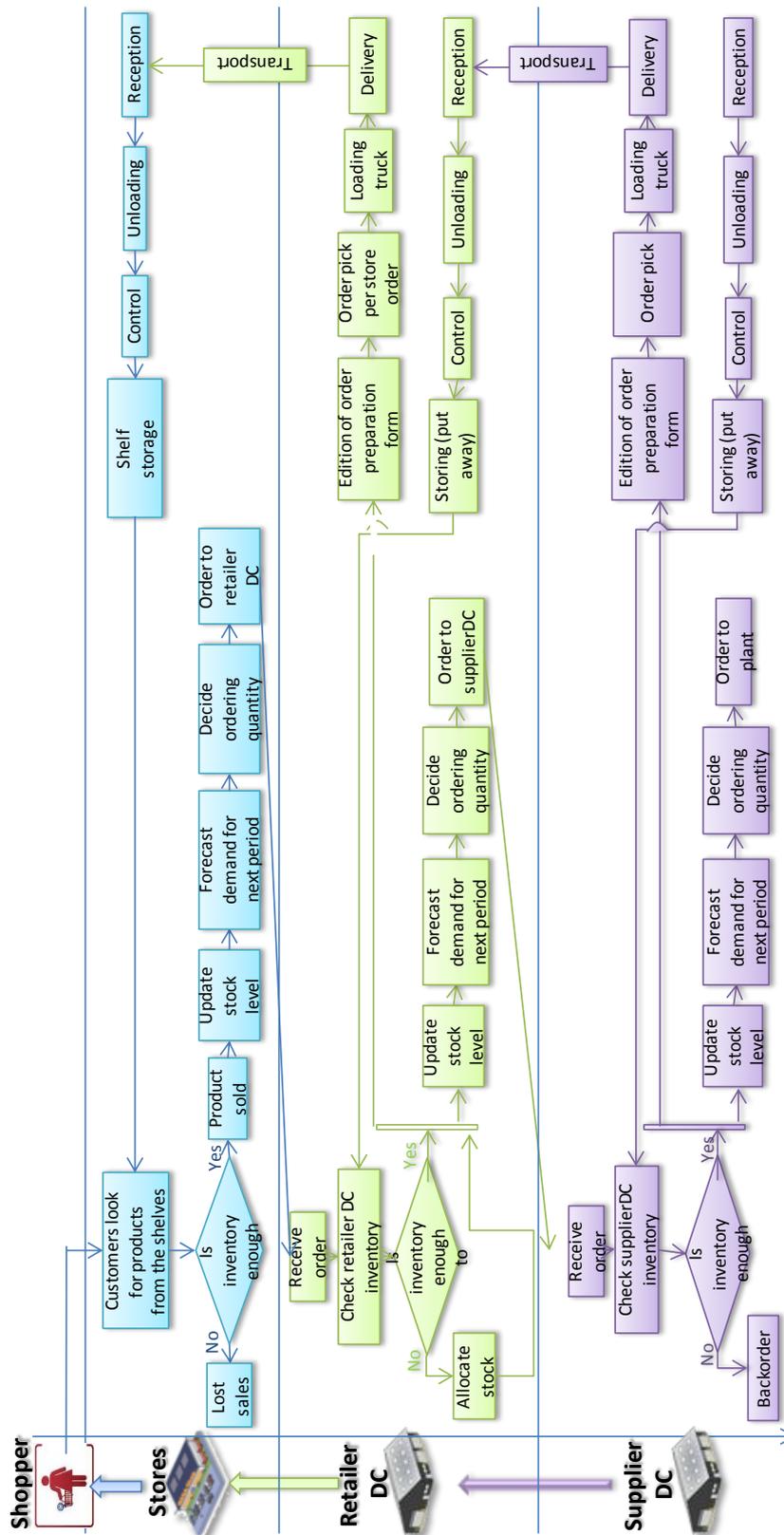


Figure 43: Traditional warehousing model

6.1.2 Cross-docking pick by line

6.1.2.1 The stores

The re-order point $I_{t,1,i}$ is set such as to provide a specified service level (to the consumer) for given demand variability, reaction time (sum of the Lead time and the review period) and order quantity. In cross-docking and due to the increase of the lead-time and the potential change in the review period, the re-order point is:

$$I_{t,s,i} = \widehat{D}_{t,s,i} (L_1 + L_2 + T'_1) + K\sigma_{s,i} \sqrt{L_1 + L_2 + T'_1}$$

with $\widehat{D}_{t,1,i}$ the forecast daily demand for the store 1, product I, in period t, and $\sigma_{1,i}$ the standard deviation of the one day forecast error for product i, k a service factor and L_1 the replenishment lead-time in days and the review period in days T_1 .

To estimate the demand at time t we use exponential smoothing scheme:

$$\widehat{D}_{t,s,i} = \alpha D_{t-1,s,i} + (1 - \alpha)\widehat{D}_{t-1,s,i}$$

With α the smoothing parameter.

$NS_{t,1,i}$, the inventory level of the product i at the beginning of the period t, is given by:

$$NS_{t,s} = NS_{t-1,s} + O_{t-L1} - D_{t,s}$$

The order quantity $O_{t,1,i}$ of the product i at the period t, is as follow:

$$O_{t,s,i} = S_i - NS_{t,s,i}$$

With S_i the shelf space, $NS_{t,1}$ is the store inventory position at the end of period t. The order $O_{t,s,i}$ is rounded to the higher multiple of case size, which represent the Minimum Order Quantity of the store. We notice that the shelf space don't change when moving to cross-docking.

After a lead-time the store receives the quantity ordered $O_{t,s,i}$.

6.1.2.2 The retailer DC

No ordering processes in cross-docking.

6.1.2.3 The supplier DC

For the ordering process, the major change noticed concern the variability of orders. In fact, in traditional warehousing the orders comes from the retailer DC with a variability of σ_2 . In cross-docking the orders are received directly from the stores, and their variability are equivalent to the sum of the variability of

all the stores. In this case there is an echelon of inventory which add the variability that is removed. The variability of orders is then $\sqrt{\sum_{s=1}^n \sigma_{s,i}^2}$.

The order placed by the supplier at the beginning of period t can be expressed as:

$$O'_{t,3} = O_{t-1,1} + (\text{OUT}'_{t,3} - \text{OUT}'_{t-1,3})$$

$$\text{OUT}'_{t,3} = \hat{O}_{t,1} (L_3 + T_3) + K \times \sqrt{\sum_{s=1}^n \sigma_{s,i}^2} \times \sqrt{(L_3 + T_3)}$$

Compared to the traditional warehousing strategy, here the supplier set his safety stock based to the variability of stores' orders. This will change the expected inventory at the supplier DC.

The retailer inventory level of the store at the beginning of the period t, is given by:

$$\text{NS}'_{t,3} = \text{NS}'_{t-1,3} + O_{t-L_3,3} - O_{t,1}$$

To estimate the retailer's mean demand we use exponential smoothing scheme:

$$\hat{O}'_{t,1} = \alpha \times O'_{t-1,1} + (1 - \alpha) \times \hat{O}'_{t-1,1}$$

To summarize, Figure 44 shows the simulation model of the cross-docking pick by line model. (Appendix A) shows the description of each process of the model:

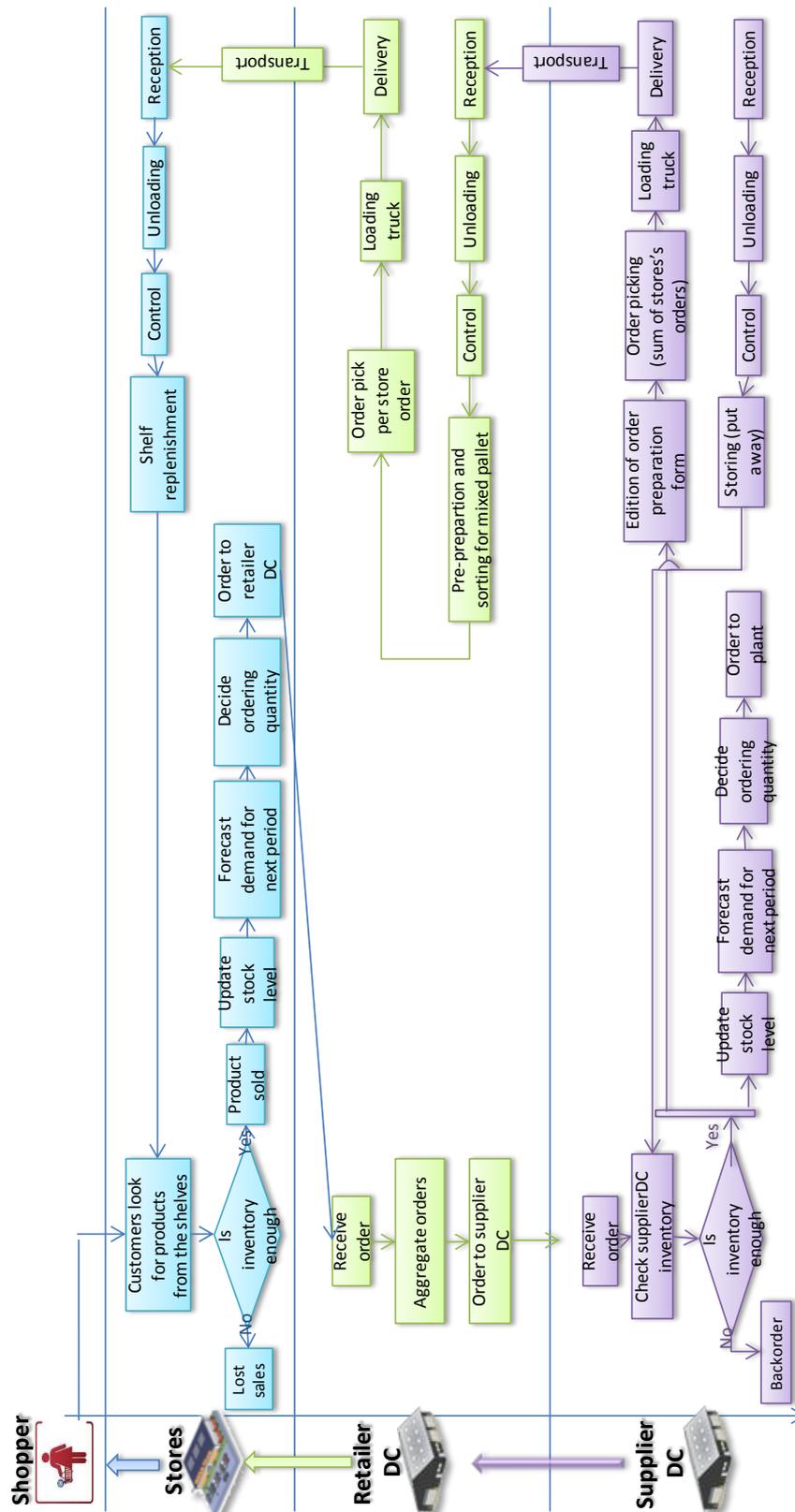


Figure 44: Cross-docking pick by line model

6.1.3 Cross-docking pick by store

For cross-docking pick by store we have the same ordering processes for all the echelons as for the pick by line. The difference relays in the handling process. To summarize, Figure 45 shows the process modelling of the cross-docking pick by line model. (**Appendix A**) shows the description of each process of the model:

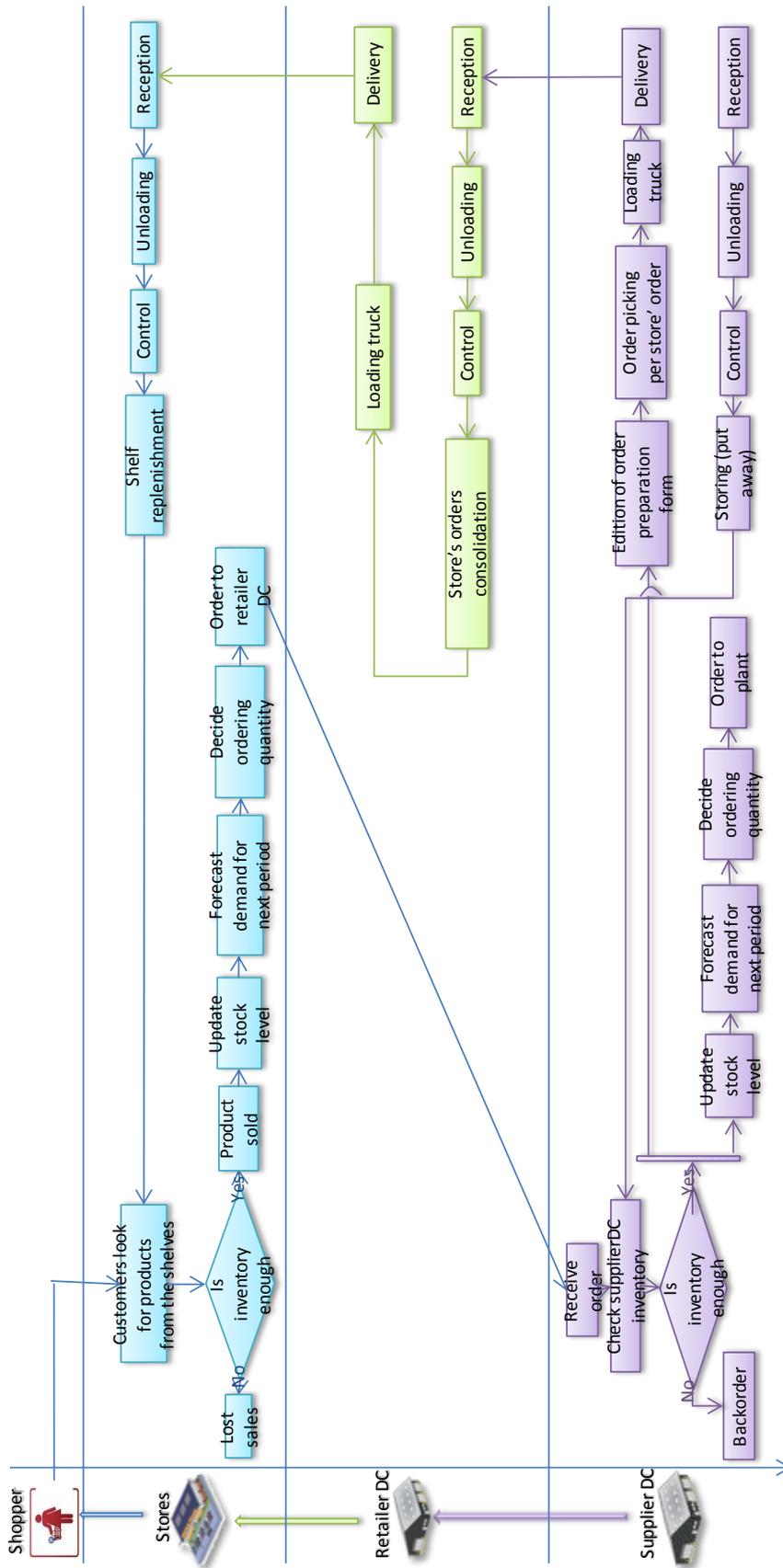


Figure 45: Cross-docking pick by store model

6.2 Retail Supply Chain performance analysis

6.2.1 Scenarios description

In this analysis we will compare the three configurations for each performance studied and for each echelon.

6.2.2 Cost analysis of the retail supply chain configurations

6.2.2.1 Cost Analysis at Store level

Impact on the inventory cost at the stores:

Figure 46 shows the variation of inventory cost in cross-docking pick by store and pick by line compared to traditional warehousing, for all the 200 products and the 24 stores. In this figure we have the variation of inventory cost for the 24 stores. On the horizontal axis we have the store index. On the vertical axis we have the variation of inventory cost for the 200 products. The red color the cross-docking pick by line and the green color the cross-docking pick by line.

In this figure 46 we can see that the variation of the inventory cost for all the strategies increase by the decrease of the sales volume at the store. Which mean that the inventory cost increases as well by the decrease of the sales volume at the store. As explained in the last part, the stores are sorted from the largest store in terms of sales to the smallest. In fact, based on the data collected, all the stores have the same storage space per product, which is the shelf space. Due to this observation, stores with a small volume of sales the days on hand of inventory are greater than the stores with large volume of sales. In stores with large volume of sales the shelf empties more quickly.

On the other hand, we can see that the inventory cost increases in cross-docking pick by line and pick by store compared to traditional warehousing strategy for all the stores expect for store 1 and store 2. For the stores where the inventory cost increases, this increase is due to the increase of the lead-time to the stores. In fact, with a higher lead-time, the store needs to increase its inventory to cover the demand during the lead-time. If the delivery frequency doesn't change, the inventory at the store must be increased.

For store 1 and store 2, the inventory decreases in cross-docking pick by line and pick by store compared to traditional warehousing.

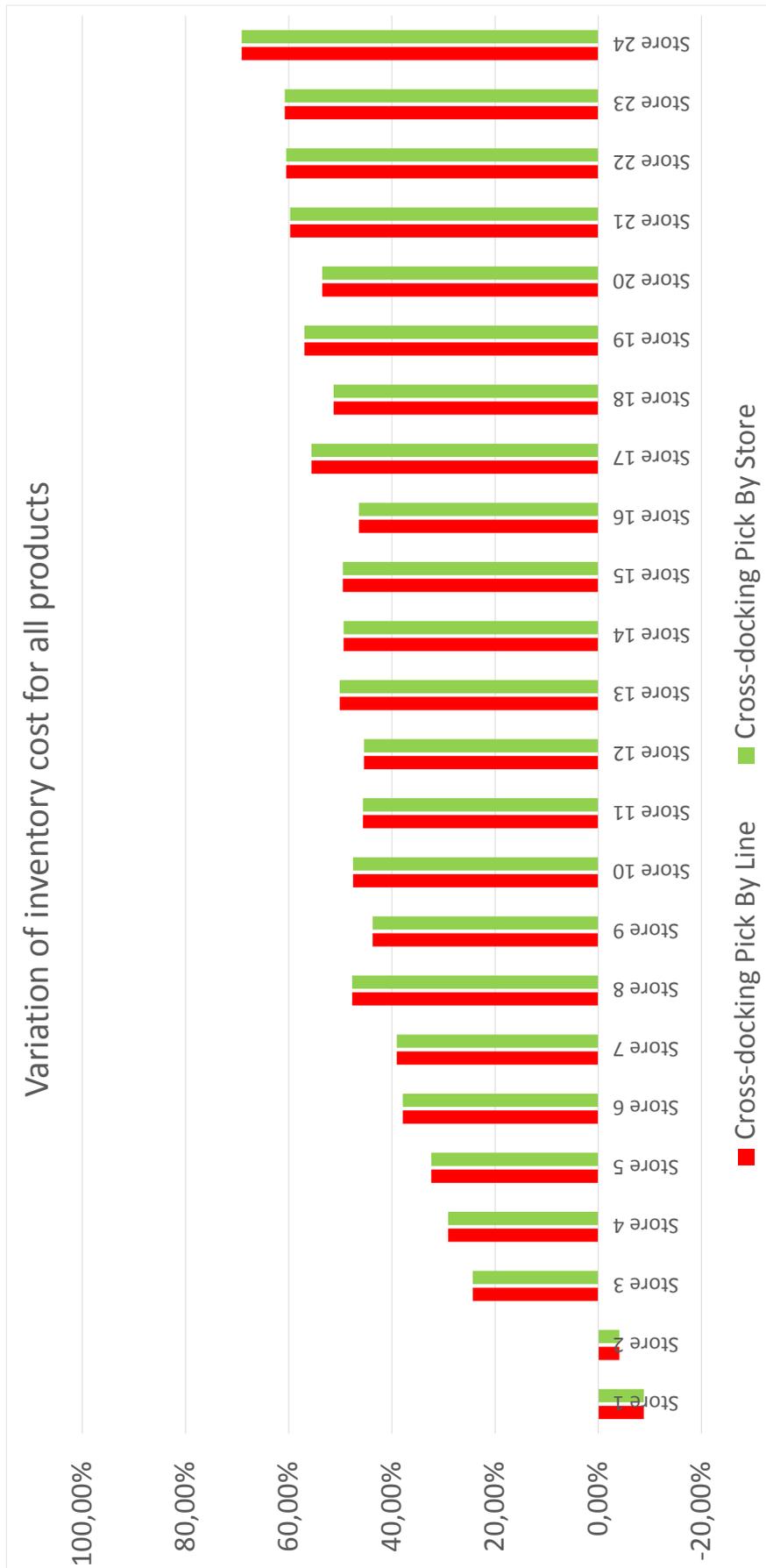


Figure 46: Variation of Inventory Cost for all products all stores

Impact on the handling cost at the stores:

The figure 47 shows the the variation of ordering cost in cross-docking pick by store and pick by line compared to traditional warehousing, for all the products in all the stores. We can see that in cross-docking compared to traditional warehousing, for most of cases the ordering cost increase, except for the last five store where the ordering cost decreases. In fact, due to the increase of the lead-time, the re-order level increase as well, and in case of non-increase of the shelf or inventory space at the stores, the later will order more often with smaller quantities to satisfy the demand. This will increase the number of orders and then increase the ordering cost.

For the last five stores and due the fact that they belong to the small sales volume category of store. For most of products the re-order level don't increase significantly and then the number of orders remains more or less the same, which explain the reduction or stagnation of the ordering cost.

On the other hand, the figure 48 shows the variation of handling cost in cross-docking pick by store and pick by line compared to traditional warehousing, for all the products in all the stores. We can see that the handling cost increase in all the situations. The increase of handling cost is due to the increase of the time spent in shelf storage process. The increase is more significant in cross-docking pick by store.

In fact, as explained earlier, moving to cross-docking pick by line, the only change in terms of physical flow concern the shelf storage process (the process of filling the store shelves by the pallets received from the retailer DC). In fact, the picking and preparation operations at the retailer DC are different in cross-docking. In fact the pallet received by the store is not built in the same efficient way as in traditional warehousing. As a consequence the replenishment of the shelf might be delayed.

In the traditional warehousing the pallet is organized in such a way that it can be moved step by step in the aisle while replenishing the shelves. The cases of product are organized on the pallet to roughly follow the shelves plan.

On the contrary, the products of cross-docking are not organized. The pallet has been built in the warehouse without taking into account the shelves plan. It is less efficient in terms of shelf replenishment process. This is the case for cross-docking pallets preparation. In fact in cross-docking mode the store order preparation/ pallet preparation is done according to the product family (beverage, home care, snacks...), and without respect to the planogram design. The preparation is carried according to the products received from the suppliers DCs. In case of non-coordination if the reception (for example each category must be delivered in a specific day) the pallet will be not organized.



Figure 47: Variation of ordering cost at the stores

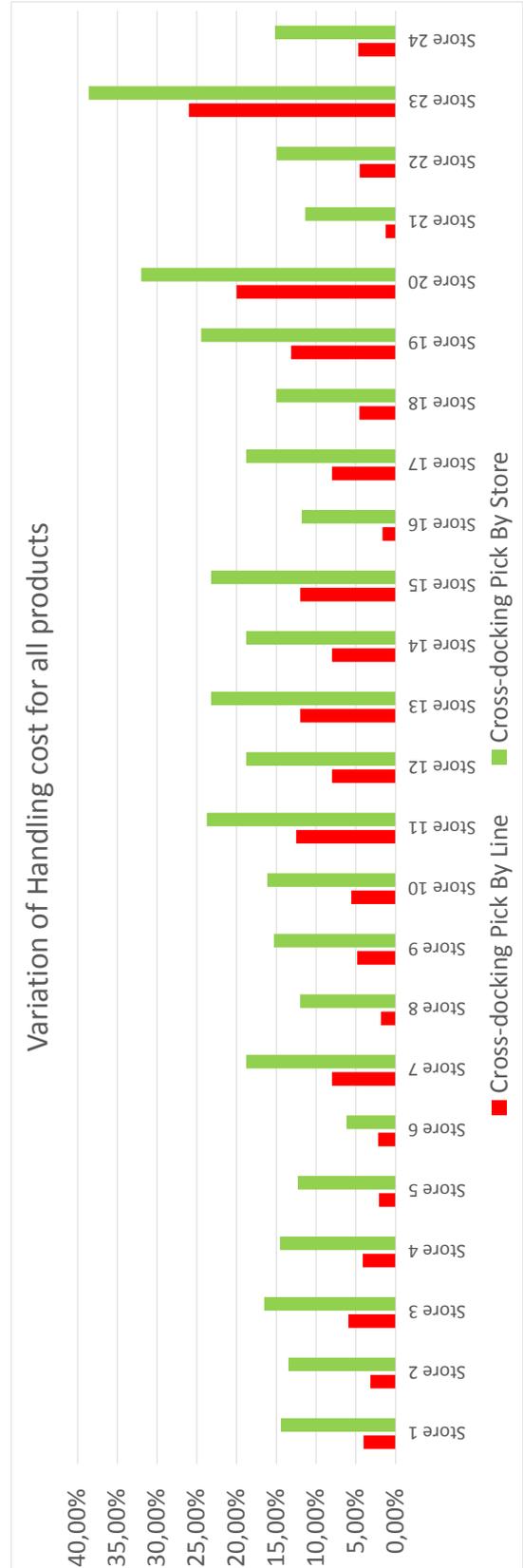


Figure 48: Variation of handling cost at the stores

6.2.2.2 Cost Analysis at Retailer level

Figure 49 shows the cost variation in the DC of the retailer in cross-docking pick by store and pick by line compared to traditional warehousing:

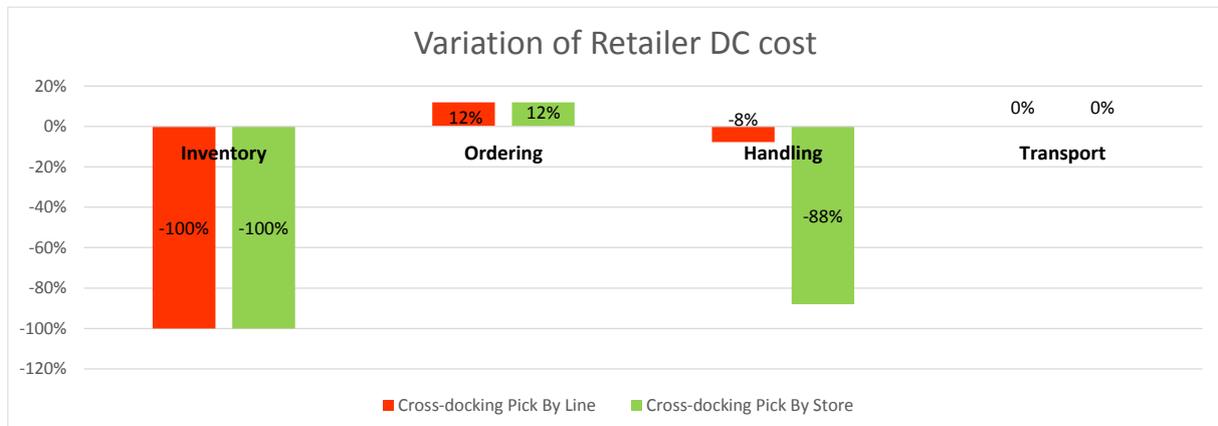


Figure 49: Retailer DC cost variation

In cross-docking, the inventory cost at the retailer DC is eliminated with a reduction of 100%. In cross-docking there is no storage at the retailer DC.

On the other hand, the ordering cost increases. This increase is due to the increase of the number of orders. In fact, in traditional warehousing the retailer DC orders in pallets or layers in economic quantity which allows reducing the number of orders. In cross-docking, the orders from the retailer are the exact needs of the stores, so the orders increase.

The handling cost in cross-docking pick by line decreases. This decrease is due to the elimination of the storing process. In fact, since in cross-docking there is no inventory and no rack for storage the storing process is eliminated and products go directly from the inbound doors to the picking zone.

In cross-docking pick by store, this decrease is more important, since in this the storing and the picking process are eliminated. The products move directly from the inbound doors, are consolidated with other products from other suppliers and sent directly to the stores.

For the transport cost there is no change. In fact in our model, we assume that the retailer trucks are always full; the rationale behind this is that the retailer has the capacity to full their trucks and perform a routing of the trucks.

6.2.2.3 Cost Analysis at Supplier level

Figure 50 below shows the variation of cost at the supplier DC in cross-docking pick by store and cross-docking pick by line compared to traditional warehousing:

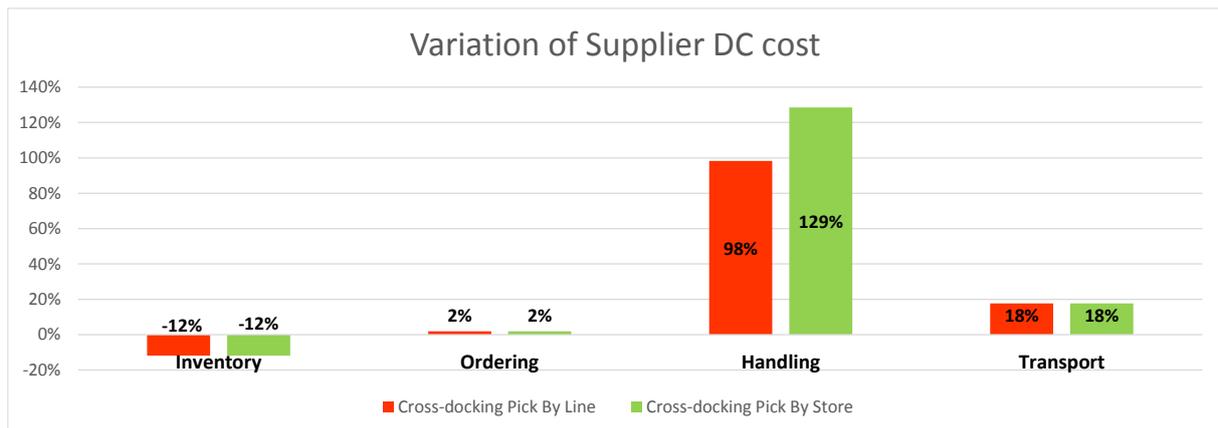


Figure 50: Supplier DC cost variation

The inventory cost at the supplier DC decreases in cross-docking (pick by line and pick by store). This decrease is due to the reduction of safety stock level due to the reduction of variability of orders (Bullwhip effect). More details on the impact of cross-docking on the bullwhip effect are described in section 5.6.3.

On the other hand, the handling cost in traditional warehousing is low due to full pallet preparation (economic orders). In cross-docking pick by line the handling cost increases due to the increase in picking (aggregated stores orders, no full pallet). In cross-docking pick by store the increase is more important due to the increase in picking (stores orders).

The transportation cost in cross-docking increases due to the impact on the Vehicle Fill Rate. In cross-docking we have more regular orders with a low volume.

In fact, cross-Docking tends to decrease the performance in terms of the Vehicle Fill Rate Cube Fill (supplier to retailer).

Cross-docking impacts the trucks cube fill in two ways:

- The total quantity ordered by the stores is not constrained to fulfill a truck,
 - The granularity of picking at case level is generally less effective in terms of pallet utilization.
- This inefficiency is known as the explosion factor.

The inefficiency of a picking pallet is around 1,1 and 1,3. In our simulations we used an average explosion factor of 1,2. Automated picked is considered to provide the capability to build picking pallet with an explosion factor close to 1. 10 to 15% loss of truck cube fill has been experienced due to the picking pallet inefficiency.

The figure below shows the impact of cross-docking on the Vehicle Fill Rate. Here we present the number of trucks per delivery to Retailer DC for a period of 100 days. The blue line corresponds to the

number of trucks in traditional warehousing per delivery, the red line to cross-docking pick by line, and the green to cross-docking pick by store:

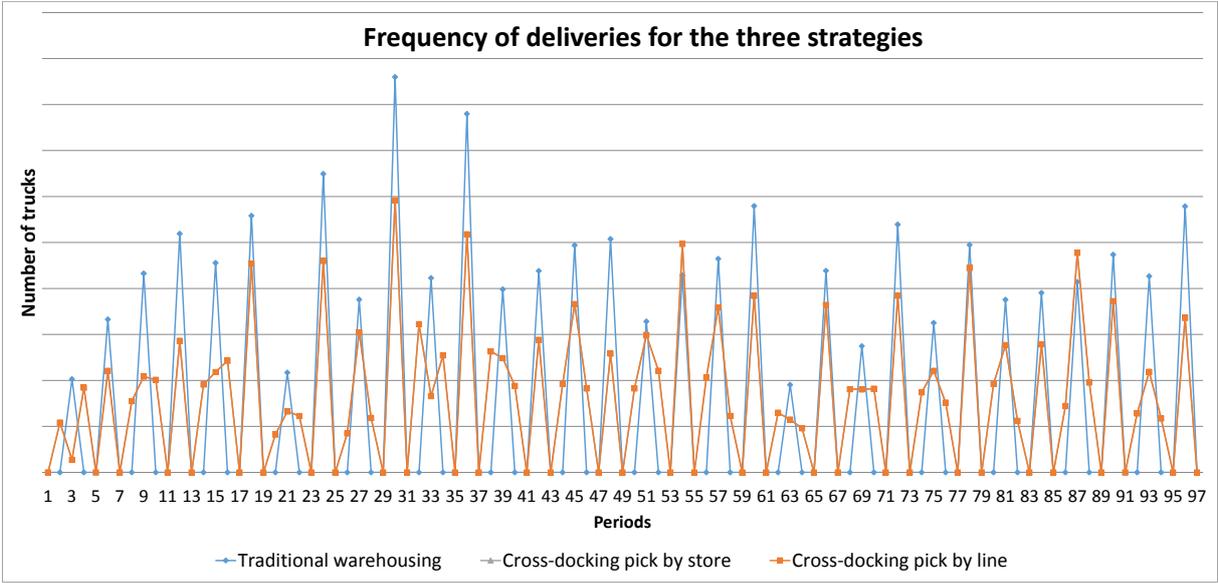


Figure 51: Frequency of deliveries for the three strategies

We can see in the figure 51, that in cross-docking compared to traditional warehousing we have a more regular orders with a low volume. In cross-docking we use 25% more trucks than in traditional warehousing.

On the other hand, in terms of Vehicle Fill Rate we have a VFR of 81% in traditional warehousing and 73% in cross-docking. So we have a loss of 7 % in cross-docking.

This impact on the vehicle fill rate is the cause of the increase in transportation cost.

6.2.2.4 Cost Analysis on the End to End supply chain

The figure 52 shows the variation of the total cost of the three echelons in cross-docking pick by store and cross-docking pick by line compared to traditional warehousing:

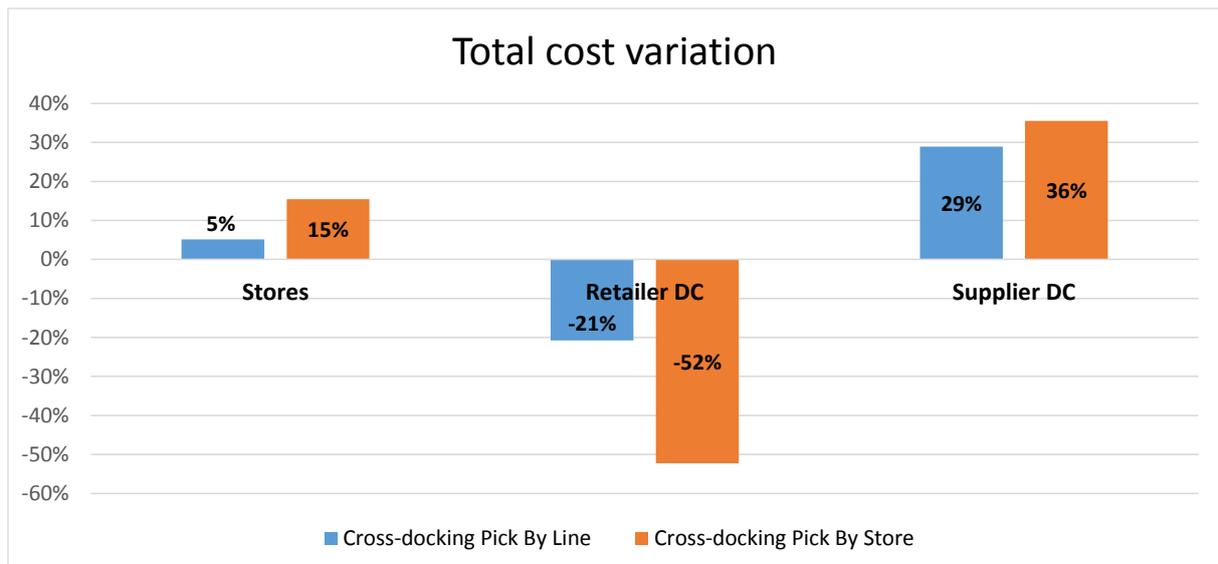


Figure 52: End-to-end cost variation

In this figure we can see that the stores cost increase in cross-docking pick by line and pick by store. This increase in the store cost is due to first the increase of inventory due to the lead-time increase, and second the increase in the handling cost.

On the retailer DC side, we can see that in cross-docking pick by line we have a decrease in cost of 21%. This decrease, is due to the elimination of inventory of this product as well as the elimination if the storing process. On the other hand, in cross-docking pick by store the retailer DC cost is reduced by almost a half. This is due to the elimination of inventory, the elimination of the storing process and in the same time the elimination of the picking activities which represent the most costly operations at the retailer DC.

On the supplier DC side, we can see that the cost increase of 29% in cross-docking pick by line compared to the traditional warehousing. This increase is due particularly to the impact on the transportation cost and on the increase in the picking cost.

In an End-to-end perspective, the distribution strategy with the lowest cost is the cross-docking pick by store. The cross-docking pick by line is the strategy the most expensive.

In pick by line compared to traditional warehousing, the elimination in inventory at the retailer DC and the reduction in cost due to that, as well as the elimination of the storing process at the retailer DC, does not offset the increase in terms of picking and transportation cost for the supplier DC. On the other hand, in pick by store compared to traditional warehousing, the elimination in inventory at the retailer DC, as well as the elimination of the storing and picking process at the retailer DC, offset the increase in terms

of picking and transportation cost for the supplier DC. And even with an increase in the handling cost at the stores the cross-docking pick by store strategy remains the most economic.

6.2.3 Service level (On Shelf Availability) analysis of the retail supply chain configurations

The figure 53 shows the average On Shelf Availability for all the 200 products in the 24 stores. The first observation learned from this figure is that the cross-docking pick by line and cross-docking pick by store have an impact for almost all the stores. Second, the impact on the On Shelf Availability is more important for the stores with large volume of sales, and for all the strategies, and this impact increases in cross-docking.

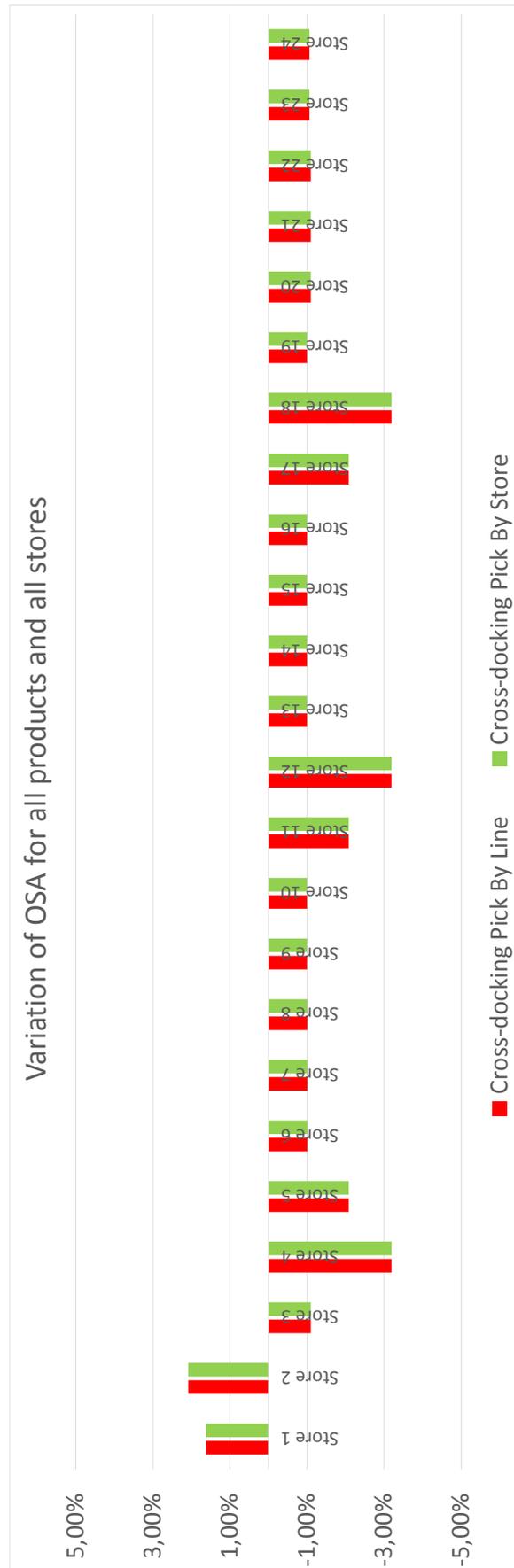


Figure 53: Variation of the On Shelf Availability for all products for all stores

To illustrate and describe the impact of the cross-docking pick by line and pick by store on the On Shelf Availability we take a sample of one product from the assortment and we see the impact on the OSA for one store. Let's first present the SKU studied. The figure 54 shows the characteristics of the product studied.

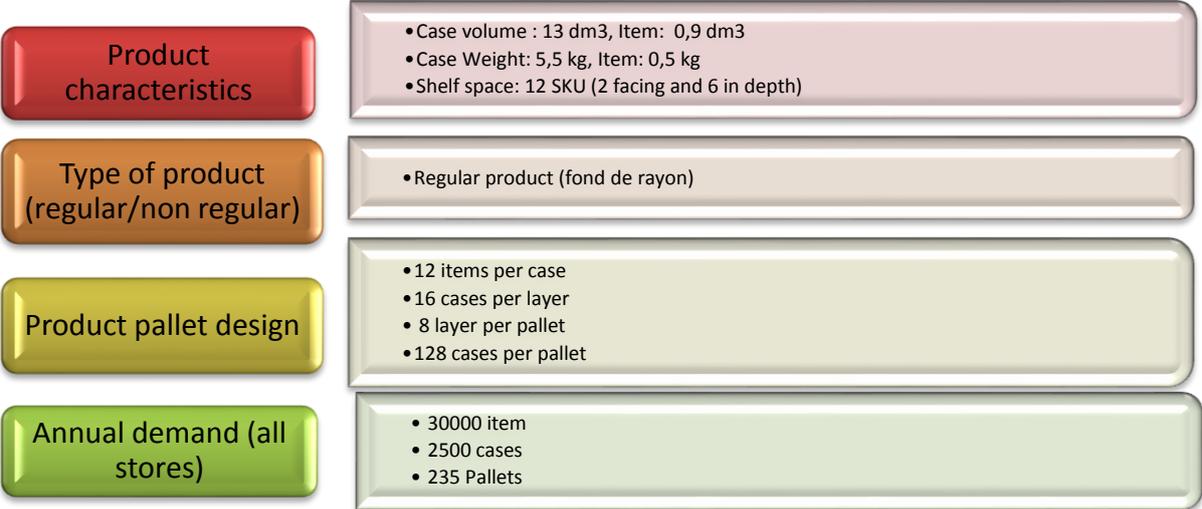


Figure 54: Description of the SKU analysed

This product is a regular product (fond de rayon), its sale price at the stores is about 2 Euros. In terms of demand, this product is a fast movers compared to the other products in the assortment (figure R), with an annual sales of 235 pallets.

The shelf space allocated to this product is 24, with 6 in facing and 4 in depth.

The store analysed is the store 12, which belong to the category B of stores, the medium stores.

As shown in the figure 55, for this product when moving to cross-docking compared to traditional warehousing we have an impact on the OSA of 3%.

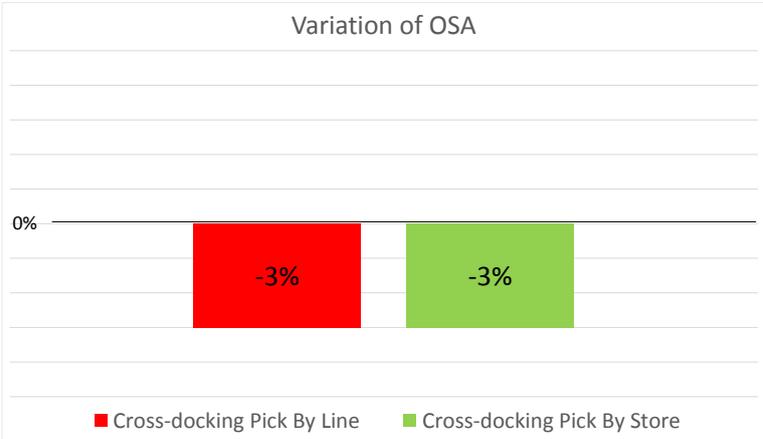


Figure 55: Store OSA

The impact on service level is a function of the increase of lead-time, shelf space and variability.

For this product, the shelf space is not adapted. In fact, due to the increase of the lead-time the re-order level increases (Figure 56) and the stores has to order more earlier than in traditional warehousing and need more space to cover demand during the lead-time.

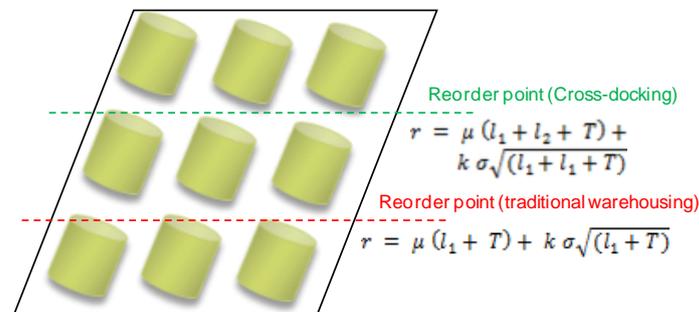


Figure 56: Re-order level and shelf space

To balance the effect of cross-docking on the OSA, different solutions are possible:

- Increase delivery frequency. If the stores order more frequently this can reduce the impact on the OSA.
- Increase storage space at the store. Increasing the shelf space allow to balance the increase in lead-time and cover the demand.
- Reduce lead-time
-

6.2.4 Bullwhip analysis of the retail supply chain configurations

A benefit of cross-docking distribution strategy, compared to traditional warehousing which is not often considered in the literature, is the reduction of the bullwhip effect. Cross-docking is reducing the bullwhip effect as it brings a direct connection between the store and the supplier DC. The inventory normally hold at the Retailer DC creates a decoupling point which adds variability in the supply chain due to forecasting, ordering and safety stock. As a matter of fact, cross-docking is removing several elements which normally drive the bullwhip effect:

The two major benefits of cross-docking which can reduce the bullwhip effect are: First, the removal of intermediates echelons in the supply chain which has a positive impact on the bullwhip reduction. In fact, removing an echelon in the supply chain will reduce the variability of orders in the echelons upstream this removed echelon. And second, the cross-docking will force both of the retailer and the supplier to order and deliver only the needed quantities, which reduce the effect of batches and then reduce the bullwhip effect.

The bullwhip effect in the Supplier Y and Retailer X supply chain is propagated in all the supplier chain starting by the customers' orders and the due to the bullwhip effect phenomenon the amplification of orders have an effect on the supplier Y DC orders to the plant.

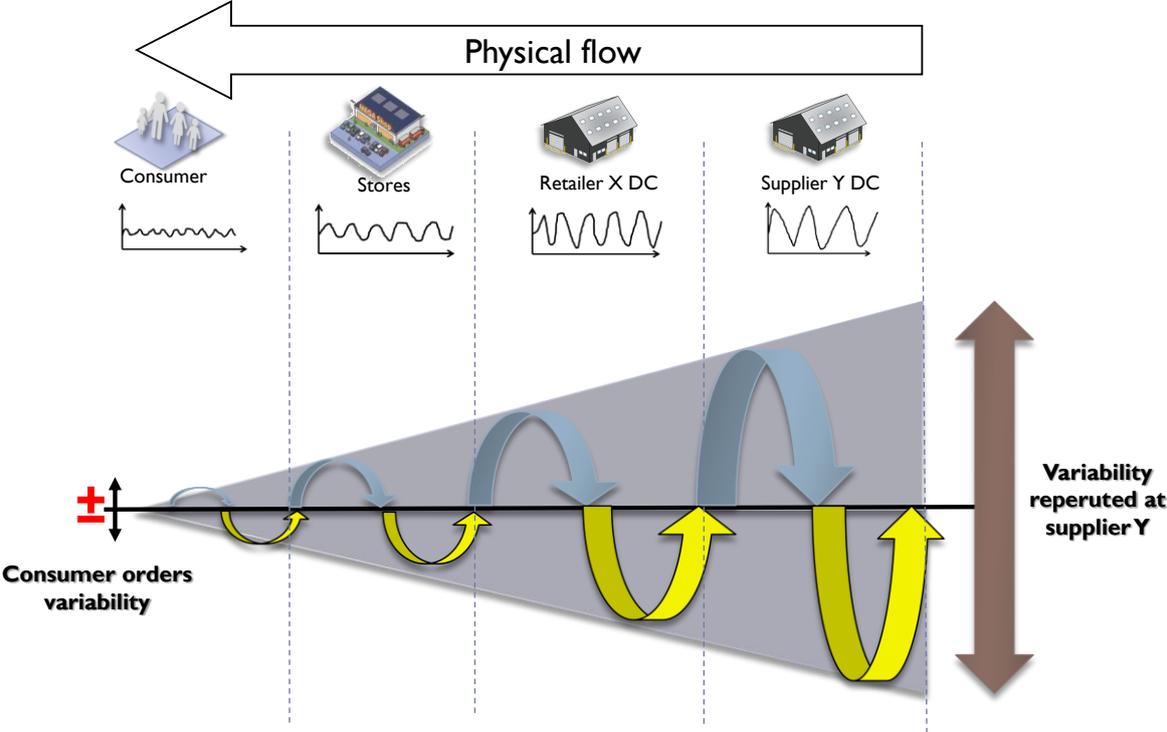


Figure 57: Bullwhip effect in traditional warehousing

+

In cross-docking strategy, the bullwhip effect is reduced and the reduction is propagated until the Supplier Y plant (Figure 58):

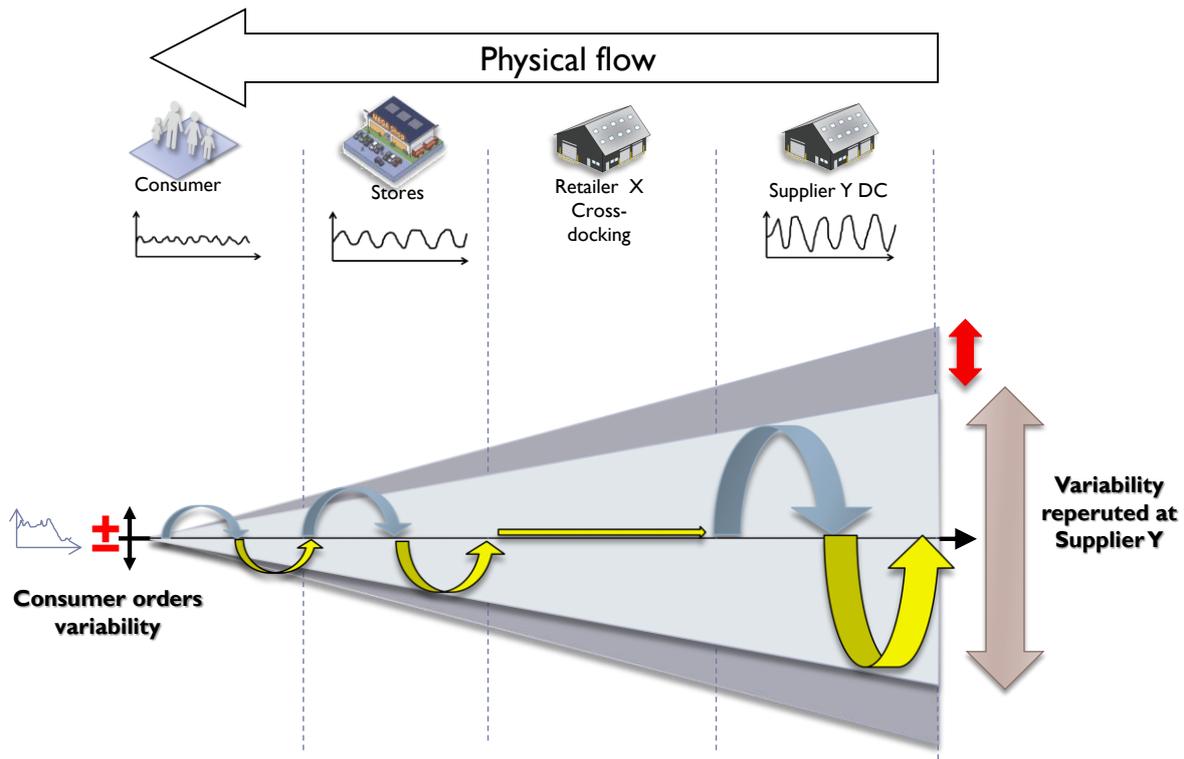


Figure 58: Bullwhip effect in cross-docking

As shown Figure 58, in cross-docking strategy the amplification of orders is reduced by the removal of inventory at the retailer X DC. This reduction is propagated until the supplier Y DC. The effect of this reduction in the bullwhip effect is translated first in a reduction in the inventory at the supplier DC, and second in a reduction of the supplier Y DC orders upstream the chain (supplier Y plant).

The reduction in inventory at the supplier Y DC, is due to the reduction in orders variability from the retailer X DC. In fact, in cross-docking the orders comes directly from the stores, which mean that the bullwhip effect created by the retailer X DC inventory management and orders is removed.

Taking the example of the product studied and presented in the section 6.2.3. The figure 59 shows the variability of the retailer DC orders to the supplier Y DC for this product in the three strategies. For cross-docking pick by line and cross-docking pick by store we have the same impact on the bullwhip effect:

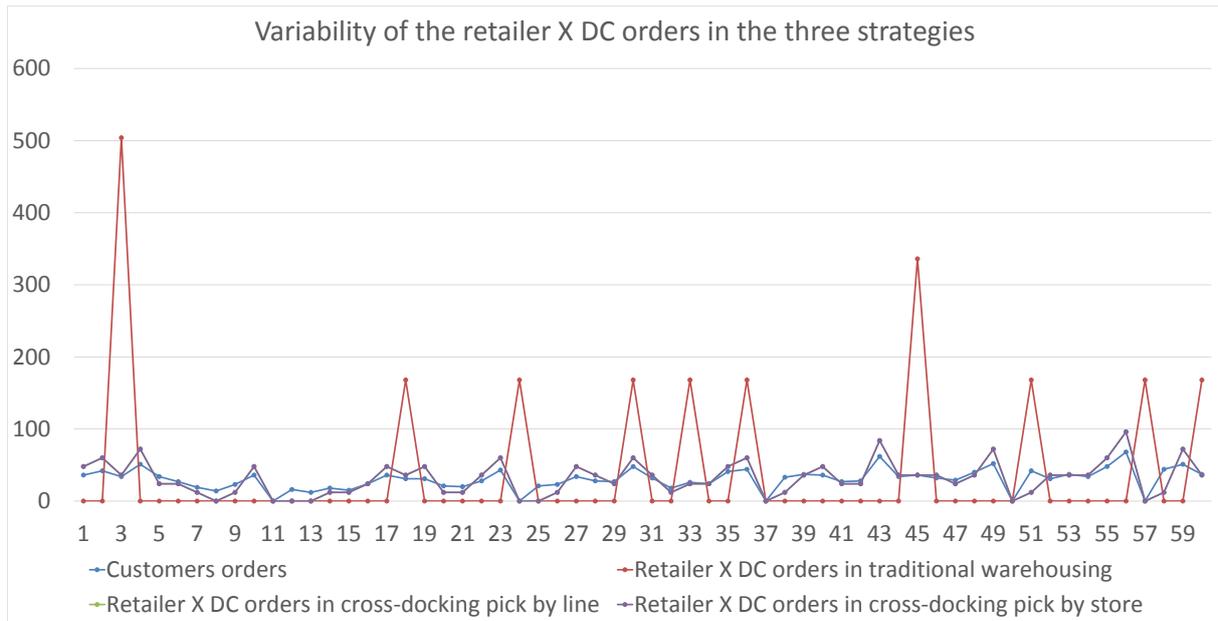


Figure 59: Variability of the retailer X DC orders in the three strategies

Let's express for this SKU, the variability of orders received by supplier Y DC in traditional warehousing as σ_{TW}^2 , and express the variability of this SKU in cross-docking pick line and pick by store by σ_{XD}^2 . The safety stock depend on the variability of orders received. In traditional warehousing the safety stock is calculated based on the variability of the retailer DC, the safety factor k and the lead-time and review period (period between two orders) from the supplier to the plant:

$$SS = k \times \sqrt{\sigma_{TW}^2} \times \sqrt{L + T}$$

In cross-docking strategy the safety stock becomes:

$$SS = k \times \sqrt{\sigma_{XD}^2} \times \sqrt{L + T}$$

With a reduction in the variability of orders received by the supplier Y DC as shown in the figure, the safety stock is reduced as well.

On the other hand, for the supplier Y DC, the cross-docking strategy has also a positive effect on the reduction of the supplier Y DC orders upstream the chain (supplier Y plant). In this part we will be interested in the reduction of the bullwhip effect upstream the chain at the supplier Y DC, in other words the variability orders from the supplier Y DC to the supplier Y plant. The figure below shows the bullwhip effect upstream the chain for the supplier Y DC in the three strategies:

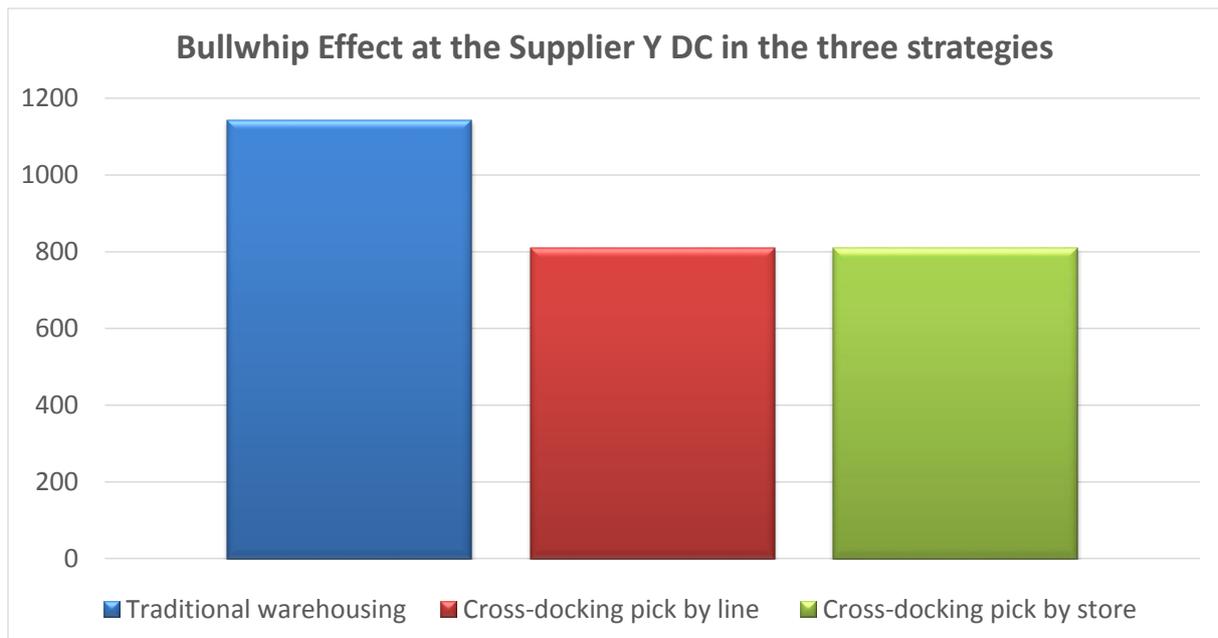


Figure 60: Bullwhip effect at the supplier Y DC in the three strategies

As shown in the figure 60, the bullwhip effect is reduced in cross-docking pick by line and pick by store compared to the traditional warehousing. The reduction is equal to 30%.

Figure x shows that the demand bullwhip effect in cross-docking strategy is reduced. When moving to cross-docking strategy, this has the following impacts:

A stable and leveled production schedule.

The demand gets more stable which allows the plant to level production schedules throughout the week. There are also less needs to schedule urgent production runs to avoid out-of-stocks as the Demand Variability decreases.

A stable and leveled distribution plan.

As the Demand Variability is reduced through cross-docking strategy, distribution Centres can benefit from this reduction in terms of transport and warehousing costs as there is less need for peak capacity requiring extra manpower and express shipments.

A productivity improvement in forecasting:

The reduction of Demand Variability allows the Demand Planers to rely more on statistical forecasting, hence reducing the manual touches needed on the forecast to cope with Bullwhip Effect caused Demand Variability.

An improvement of service to the customers:.

Indeed, all of the above effects increasing forecast accuracy and Supply Chain stability increase the service to the customers.

6.2.5 Synthesis of the retail supply chain performances analysis

First, on a cost perspective the stores cost increase in cross-docking pick by line and pick by store. This increase in the store cost is due to first the increase of inventory due the lead-time increase, and second the increase in the handling cost.

On the retailer DC side, the cross-docking pick by line is beneficial. This decrease, is due to the elimination of inventory of this product as well as the elimination if the storing process. On the other hand, the cross-docking pick by store is more beneficial. This is due to the elimination of inventory, the elimination of the storing process and in the same time the elimination of the picking activities which represent the most costly operations at the retailer DC.

On the supplier DC side, the cost increase in cross-docking pick by line compared to the traditional warehousing. This increase is due particularly to the impact on the transportation cost and on the increase in the picking cost. The cross-docking pick by store impacts more the supplier DC costs.

In an End-to-end perspective, the distribution strategy with the lowest cost is the cross-docking pick by store. The pick by line is the strategy the most expensive. In pick by line compared to traditional warehousing, the elimination in inventory at the retailer DC and the reduction in cost due to that, as well as the elimination of the storing process at the retailer DC, does not offset the increase in terms of picking and transportation cost for the supplier DC. On the other hand, in pick by store compared to traditional warehousing, the elimination in inventory at the retailer DC, as well as the elimination of the storing and picking process at the retailer DC, offset the increase in terms of picking and transportation cost for the supplier DC. And even with an increase in the handling cost at the stores the cross-docking pick by store strategy remains the most economic.

Second, from an OSA perspective the cross-docking pick by line and pick by store impact the OSA. This impact on the OSA is due to the increase in the lead-time to the stores. On the other hand the shelf space (inventory space at the stores) doesn't increases to offset the increase on the lead-time. In retailer's stores, most of the time all inventory is on the shelves. Only for very fast-moving and voluminous articles (drinks, toilet paper, diapers, and promotional products) there might be limited backroom space available to keep extra inventory.

When designing the shelf layout plan (planogram), category managers assign to every article in the assortment a fixed location with a defined number of product 'facings' on a certain shelf. The number of facing and shelf design are often based on Gross profit per shelf meter. In this step of designing the shelves the logistical arguments are not always taken into consideration, even though the number of

facings assigned to a product has great influence on the replenishment possibilities and thus on the replenishment costs. Also when changing distribution strategies, this parameter which is very important is not taking into account. And if the shelf space is not adapted, there will be an impact on the OSA.

Third, from a bullwhip effect perspective the cross-docking pick by line and pick by store have always a positive effect on this metric. This impact on the bullwhip effect, has two major causes. First, by the elimination of the inventory at the retailer DC, results in a direct connection between the stores and the supplier DC, which smoothens the product flow. When holding inventory at the Retailer DC, the variability in the supply chain is higher due to amplification of the orders when moving upstream the chain. Second, in cross-docking pick by line or pick by store the stores orders directly to the supplier DC in smaller quantity (cases) instead of economic quantities (pallets or layers) ordered in traditional warehousing from the retailer DC. This reduces the batching effect and therefore reduce considerably the bullwhip effect.

On the other hand not all products are adapted to cross-docking strategy. When dealing with product segmentation and distribution strategy selection, different product characteristics for different performance metrics are involved.

6.3 Product segmentation and distribution strategy selection.

6.3.1 Introduction

The realization of a typology classifies groups of subjects based on their characteristics. It can be used to simplify the reading of data by combining observations with common characteristics, or to bring out homogeneous groups of individuals collected data.

The 200 products studied have different characteristics in terms of demand volume, physical volume, shelf space, variability, etc. This sample of products will give us a robust understanding of the impact of products characteristics on the distribution strategies performances.

We analyse the impact of products' characteristics on the performances of the distribution strategies. The products' factors are defined based on four major categories (Table 12):

- 1- Intrinsic factors including the physical volume, shelf space and value.
- 2- Demand factors including the variability and the demand volume.
- 3- Intrinsic/Demand factors including the cubic movement.
- 4- And Supply control factors including the lead-time and review period.

	Intrinsic factors			Demand factors		Intrinsic/ Demand factors	Supply control factors	
	Physical volume	Shelf Space	Value	Demand Volume	Variability	Cubic Movement	Lead- time	Review period
Service level								
Cost								
Bullwhip Effect								

Table 13: Outline of product segmentation and distribution strategy selection

We present an analysis of the impact of product characteristics on the distribution strategies performances. The performances studied are the service level (On Shelf Availability), the cost, and the bullwhip effect. As we can see in this table different characteristics and different performances have to be studied.

Shelf space is an important factor to analyse. In fact, since the cross-docking strategy increases the lead-time to the store, and in case the shelf space is not big enough to cover the demand during this lead-time, there will be an impact on the *service level* (Benrqya et al. 2014). With a high enough shelf space, the service level will not be impacted.

The *physical volume* is an important factor as well. The physical volume has an impact on the *transportation cost* as well as on the inventory cost. Pimor (2001) considers that products with high physical volume are more adapted for traditional warehousing because this kind of product allows the supplier to optimize the filling of the trucks. On the other, hand Li et al (2008) consider that these kinds of products are more adapted for cross-docking since it allows to reduce *inventory* at the retailer DC.

The product *value* has an impact on the *lost sales*. Apte and Viswanathan (2000) consider that for products with a high value cross-docking is not suitable. In fact, cross-docking inherently leads to eliminate the inventory at the retailer DC, and thereby raises the probability of stock-out situations. However, if the product value is low, cross docking can still be the preferred strategy, but if the product value is high traditional warehousing is the most suitable strategy.

As shown the intrinsic factors have an impact on the supply chain performance and on the selection of the distribution strategy. An analysis of these factors on the retail supply chain configurations studied is very important.

Furthermore, the demand *volume* of the product is an important factor. The demand volume has an impact on the *transportation costs* (Apte and Viswanathan, 2000; Wagar, 1995; Pimor, 2001). The demand volume also has an impact on the *inventory cost* (Li et al. 2008).

The *demand variability* is a major factor that impacts the *service level*. Apte and Viswanathan (2000) consider that demand rate products with an unstable demand are more suitable for a traditional warehousing strategy because the downstream customers experience a short lead-time for their replenishment, with geographically nearby distribution centres. (Gue, 2007 ; Lee et al. 2006 ;, Li et al. 2008; Benrqya et al. 2014; Yan and Tang, 2009).

As shown the demand volume and physical volume of the products have major impacts on the supply chain performances. A combination of these two factors is interesting to analyse. Li et al. (2008) present a factor called *cubic movement* that refers to the product's physical size or volume multiplied by the demand rate. They consider that a product with high cubic movement is suitable for a cross-docking strategy because space is a constraint in a facility and assigning a product with a high cubic movement through this distribution strategy would save *inventory costs*.

Another important factor for product segmentation is the delivery *lead-time*. Benrqya et al. (2014) consider that the lead-time has an impact on the *service level* and on the store *inventory*. Products with a high lead-time are more adapted for traditional warehousing.

In addition these factors were not analysed in the literature in terms of impact on the bullwhip effect. In our study we include the impact of intrinsic, demand and supply control factors on the bullwhip effect.

In our analysis, we present a segmentation for each factor, based on OSA and Cost matrix. In Figure 61 we have a mapping of the 200 SKUs studied. Each point represents an SKU. On the X axis we have the differential in total supply chain cost between cross-docking pick by line and traditional warehousing $(\text{cross-docking pick by line cost} - \text{traditional warehousing cost}) / \text{cross-docking pick by line cost}$.

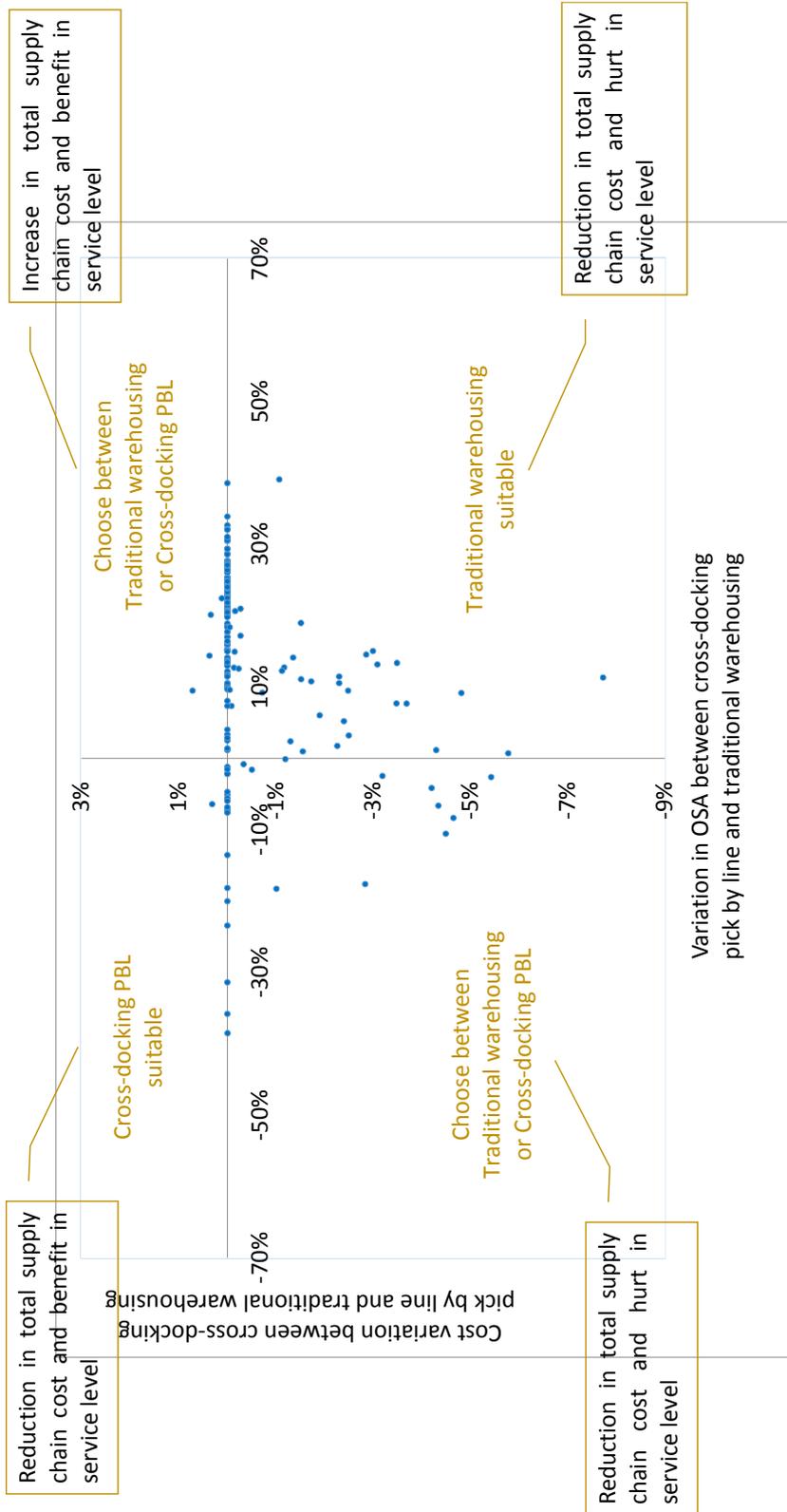


Figure 61: OSA and cost matrix for traditional warehousing vs cross-docking pick by line strategy

On the Y axis we have the differential in On Shelf Availability between cross-docking pick by line and traditional warehousing (cross-docking pick by line OSA – traditional warehousing OSA) / cross-docking pick by line OSA.

Each case of the matrix corresponds to a strategy. The products at the left hand top corner are suitable for cross-docking pick by line. For these products we have a reduction in the total supply chain cost and a benefit in service level. The cost of these products the total supply chain cost in traditional warehousing is greater than the total cost in cross-docking pick by line. The OSA is also greater in cross-docking. Products at the right hand bottom corner are adapted to cross-docking. For these products we have a decrease of the supply chain cost and a hurt at the service level (OSA). For the other corners a choice is to be made depending on the priority, for instance cost reduction or service level improvement.

For products positioned on the X axis, the decision to make depends on the cost. On the right hand of the axis we have an increase in the total supply chain and the service level remains unchanged. For these products the strategy adapted is traditional warehousing. It is the same for the Y axis.

In the next section, for each product factor we present a segmentation based on the high and low attributes of this factor. For example, for the shelf space we divide the 200 products studied into two categories based on a median. We present the high and low attributes of these factors in the OSA/Cost matrix, and then we analyze the positioning of each part on the matrix. After which we explain the reasons of the adaptability of each attribute of a factor to a distribution strategy. This procedure will be done for all the product factors.

For the bullwhip effect, the segmentation is done without a matrix. We analyze independently the impact of each one of these factors on the bullwhip effect.

The rationale for analyzing the Cost and OSA jointly and after the bullwhip effect, is that the cost and OSA are an independent performances and can be analyzed jointly. On the other hand, the bullwhip effect is a performance that is correlated with the cost. In fact, the bullwhip effect impacts the variability of orders, which have a direct impact on the inventory cost.

Figure 62 below shows the matrix for the 200 SKUs in cross-docking pick by store compared to traditional warehousing:

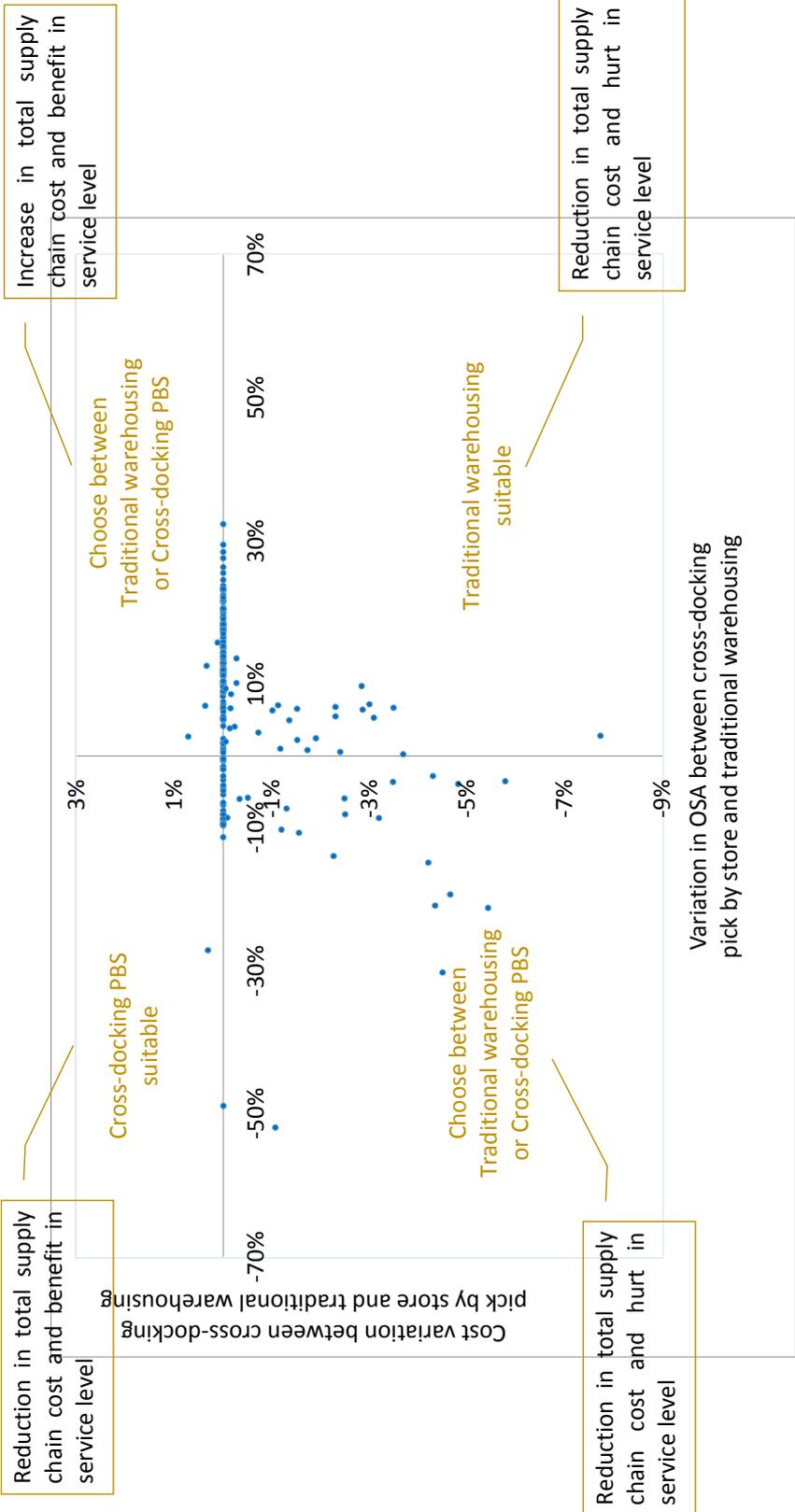


Figure 62: OSA and cost matrix for traditional warehousing vs cross-docking pick by store strategy

6.3.2 Segmentation with Intrinsic factors

6.3.2.1 Matrix OSA/Cost/Physical volume

Based on the matrix and the 200 SKU, we carried out a segmentation based on the physical volume: products with the highest physical volume, and products with the lowest physical volume. For this we use a median value to separate the SKU studied into two categories based on their physical volume:

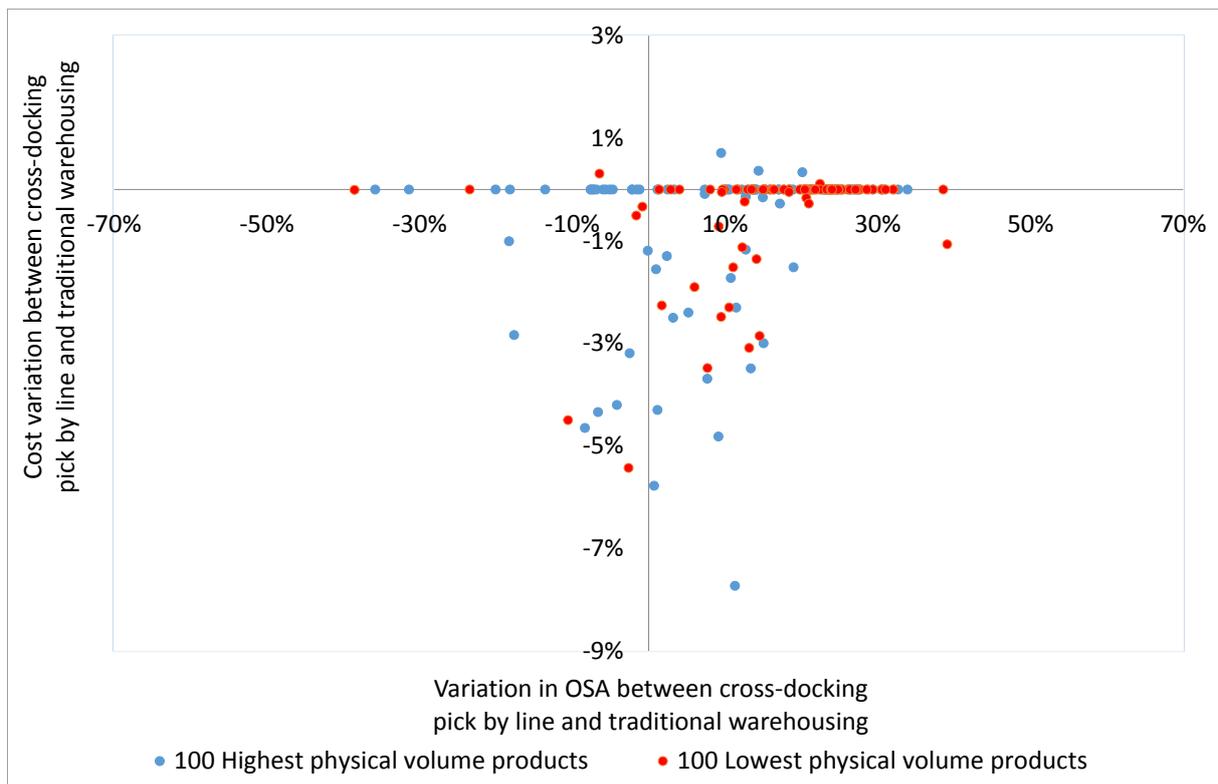


Figure 63: Impact of physical volume on the OSA and cost

Figure 63 shows that for most products with lowest volume, the cost increases when moving to cross-docking pick by line.

This can be explained by the increase in the picking cost at the supplier DC due to the low granularity picking for these category of products. In fact for products with low volume, the number of cases per pallet is big. In traditional warehousing strategy the retailer X DC orders in more economic quantities, often pallets or layers. In cross-docking the retailer X DC orders in small quantities, cases for all the products. For this kind of products with low volume the picking cost increases since there is a big number of products in a pallets.

On the other hand, for this kind of products the inventory cost is low, and consequently the reduction in inventory is not high enough. As space is a constraint in a facility, and for products with high volume the number of cases per pallet is high, they therefore take up more space than products with low volume.

So assigning a product with a high volume to cross-docking strategy would definitely save inventory cost.

Figure 64 shows the differential in cost between the cross-docking pick by line and traditional warehousing:

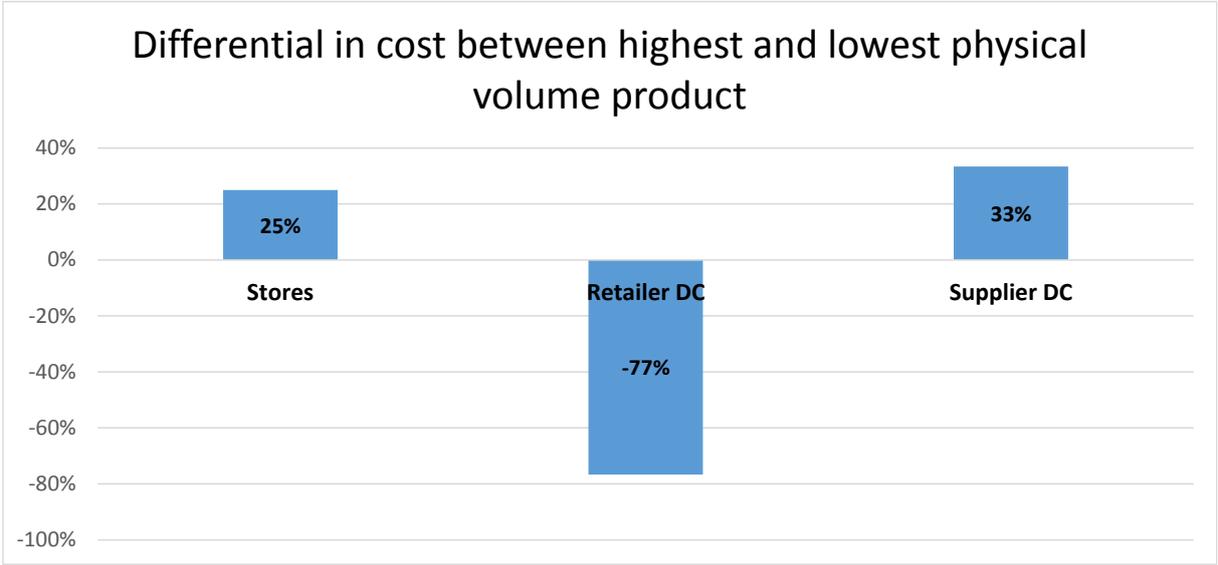


Figure 64: Differential in cost (traditional warehousing vs cross-docking pick by line) for high and low physical volume products

We can see in this figure that for products with low volume compared to products with high volume, the supplier cost increases due to the increase in the handling cost as explained earlier. We also see that the reduction in the retailer DC cost is not enough to make cross-docking pick by line economic and this is due to the low reduction in inventory cost for this kind of products. For products with low volume the reduction in cost at the retailer DC is 77% lower than for products with high volume.

In the figure 65 we do the same segmentation for the traditional warehousing versus the cross-docking pick by store:

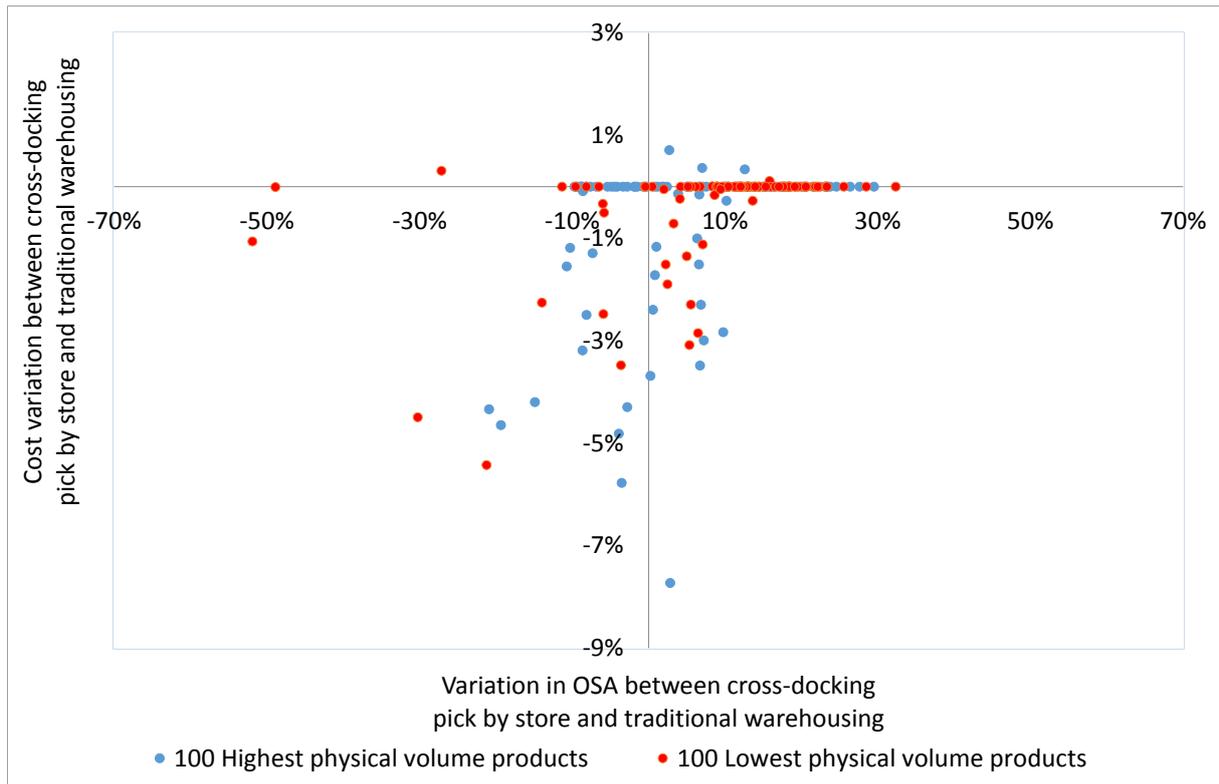


Figure 65: Impact of physical volume on the OSA and cost for cross-docking pick by store

We can see the same impact of the physical volume on the supply chain cost.

6.3.2.2 Physical volume / Bullwhip effect

On the other hand, the products volume also has an impact on the bullwhip effect. As shown in the previous part, we are interested in the reduction of the bullwhip effect upstream the chain at the supplier Y DC, in other words the variability of the orders from the supplier Y DC to the supplier Y plant. To do so we calculate a ratio of the reduction of bullwhip effect at the supplier DC, called BWEgain:

$$BWE_{gain} = 1 - \frac{BWE_{CD}}{BWE_{TW}}$$

BWE_{CD} represents the bullwhip effect at the supplier Y DC in the traditional warehousing strategy, and BWE_{CD} the bullwhip effect at the supplier Y DC in the cross-docking pick by line and pick by store strategy.

This ratio represents the gain in bullwhip effect in percentage. The figure 66 shows the evolution of the bullwhip gain versus the products physical volume:

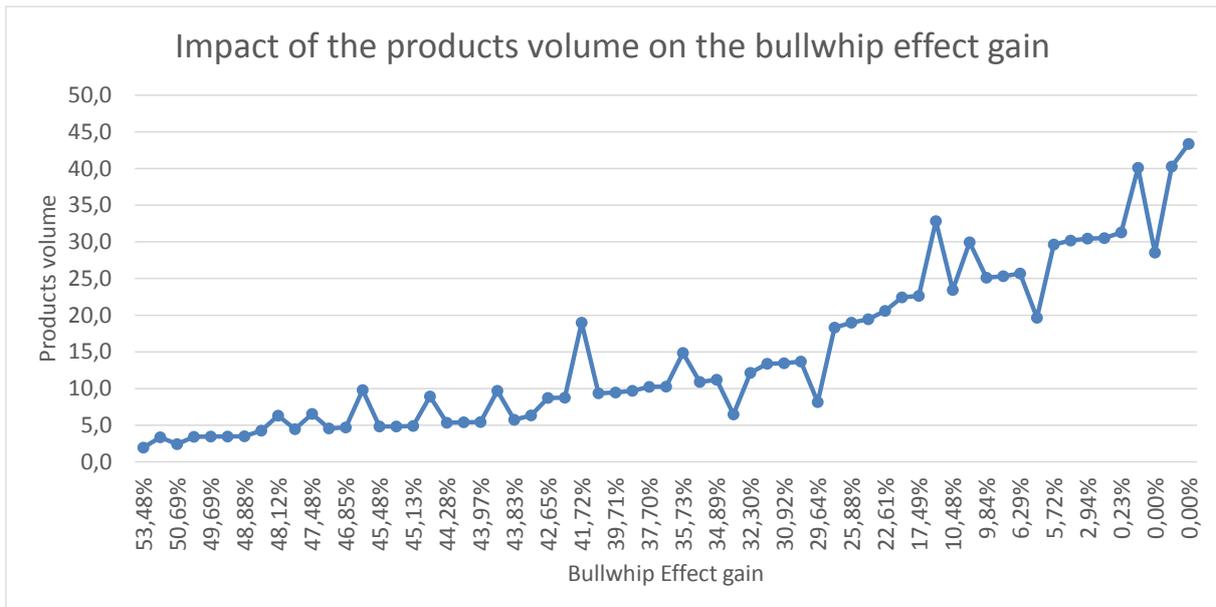


Figure 66: Impact of physical volume on the bullwhip effect

We can clearly see in this figure that the bullwhip effect gain is reduced when the products physical volume is high. In fact, as explained earlier, the products with low volume have a big number of cases. Here the impact is related to the batching, unlike the picking cost. In traditional warehousing the retailer orders in pallets or layers, and in cross-docking the orders are in cases. Ordering in pallets, creates more variability in orders, with a big volume orders followed by periods without orders. For products with low volume, and a big number of cases per pallet the batching effect on the bullwhip is greater.

6.3.2.3 Matrix/OSA/Cost/Shelf space

In retailer's stores, most of the time all inventory is on the shelves. Only for very fast-moving and voluminous articles (drinks, toilet paper, diapers, and promotional products) there might be limited backroom space available to keep extra inventory.

When designing the shelf layout plan (planogram), category managers assign to every article in the assortment a fixed location with a defined number of product 'facings' on a certain shelf. The number of facing and shelf design are often based on Gross profit per shelf meter.

In this step of designing the shelves the logistical arguments are not always taken into consideration, even though the number of facings assigned to a product has great influence on the replenishment possibilities and thus on the replenishment costs. If these costs were taken into consideration, the optimal shelf layout plan would be different. The first question to ask when moving to cross-docking strategy is "Does the shelf have enough space to cover demand during the lead time or not?".

Figure 67 shows the segmentation of the products studied based on their shelf space: Products with the highest shelf space, and products with the lowest shelf space. For this we use a median value to separate the SKU studied into two categories based on their shelf space:

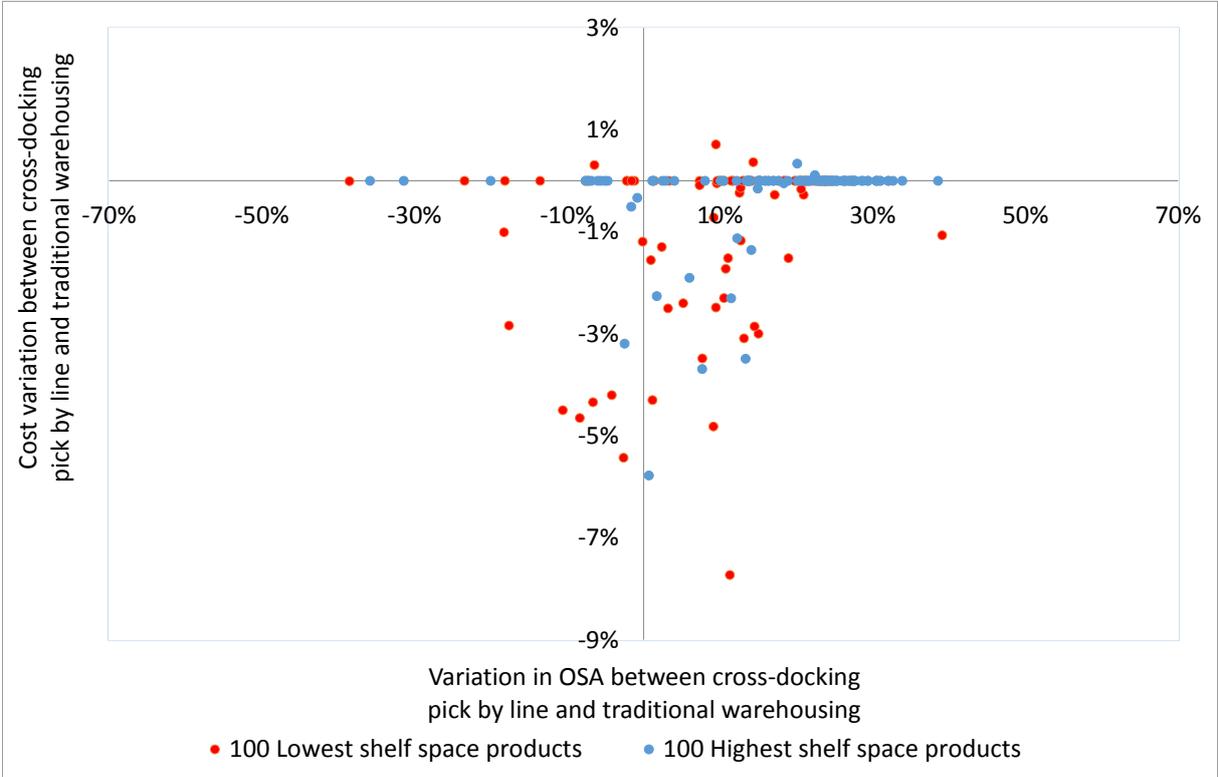
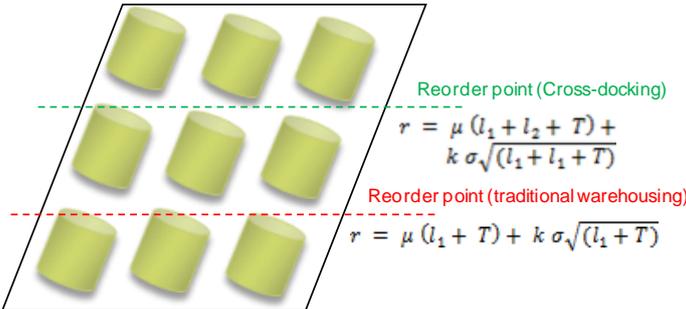


Figure 67: Impact of shelf space on the OSA and cost for cross-docking pick by line

We can see in this figure that for almost all the products with the highest shelf space the impact on the OSA when moving to cross-docking pick by line is not significant. For the other products in blue, and with an impact on the service level, even if the shelf is high the demand is high as well. For these products, the shelf space is not adapted. In fact, due to the increase of the lead-time and for high demand there is an impact on the service level.



For cross-docking pick by store, we have the same effect on the service level. With a small shelf space there is a risk of an impact on the OSA.

6.3.2.4 Value

The metrics impacted by the value of the products are the stock-out-cost and the capital cost of inventory. In our study these metrics are not studied.

6.3.3 Segmentation with Demand factors

6.3.3.1 Matrix OSA/Cost/Demand volume

Based on the matrix and the 200 SKU we did a segmentation of the products into two categories: products with the highest demand, and products with the lowest demand. For this we use a median value to separate the SKU studied into two categories based on their demand:

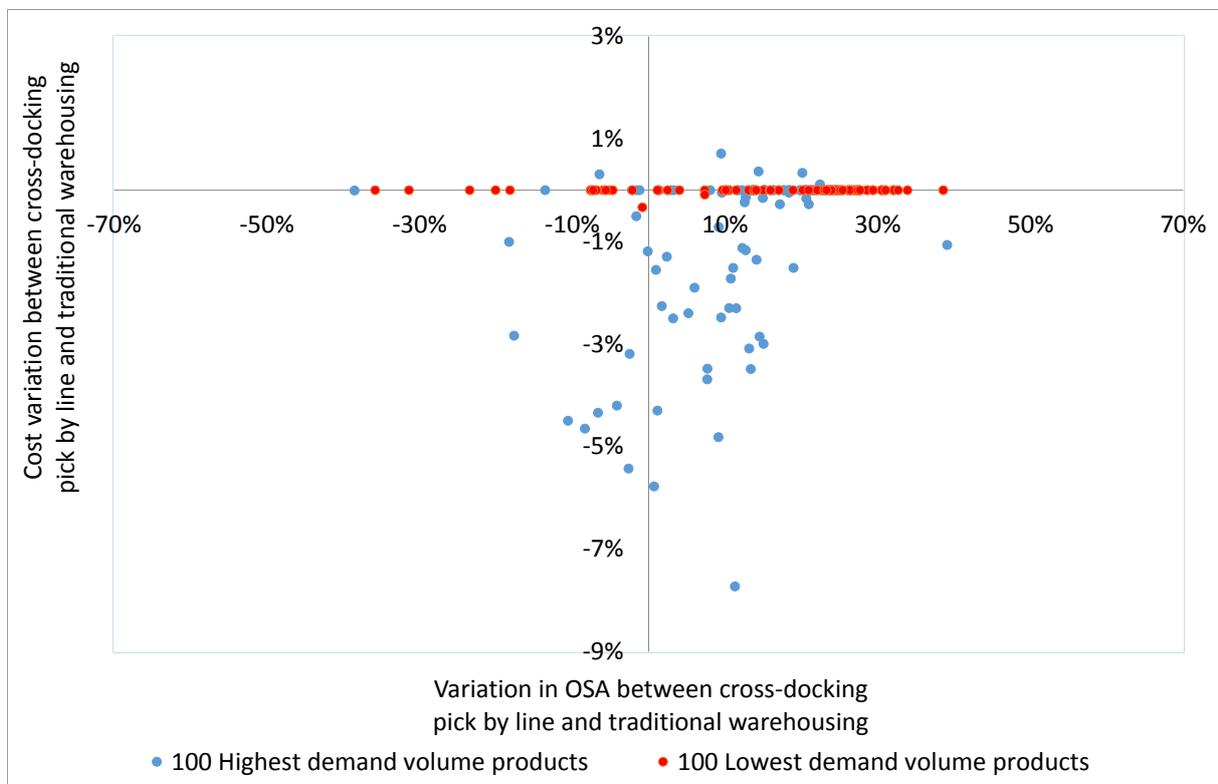


Figure 68: Impact of demand volume on the OSA and cost for cross-docking pick by line

All the 100 products with the lowest demand are positioned on the X axis, which means that for these products there is no impact on the OSA. This can be explained by the fact that for these products there is enough shelf space to cover their low demand.

For most of the products with the lowest demand the cost is increased when moving to cross-docking. This conclusion may be seen as counterintuitive. In fact, one can imagine that with products with the lowest demand the reduction in inventory in the retailer DC can be very beneficial. In fact, on the other hand the inventory cost in the stores for this category increases considerably, since there are slow movers

and the inventory holding cost at the stores is greater than in the retailer DC. On the supplier side, there is no change in handling cost for this category of product.

The figure 69 shows the differential in cost between traditional warehousing and cross-docking pick by line:

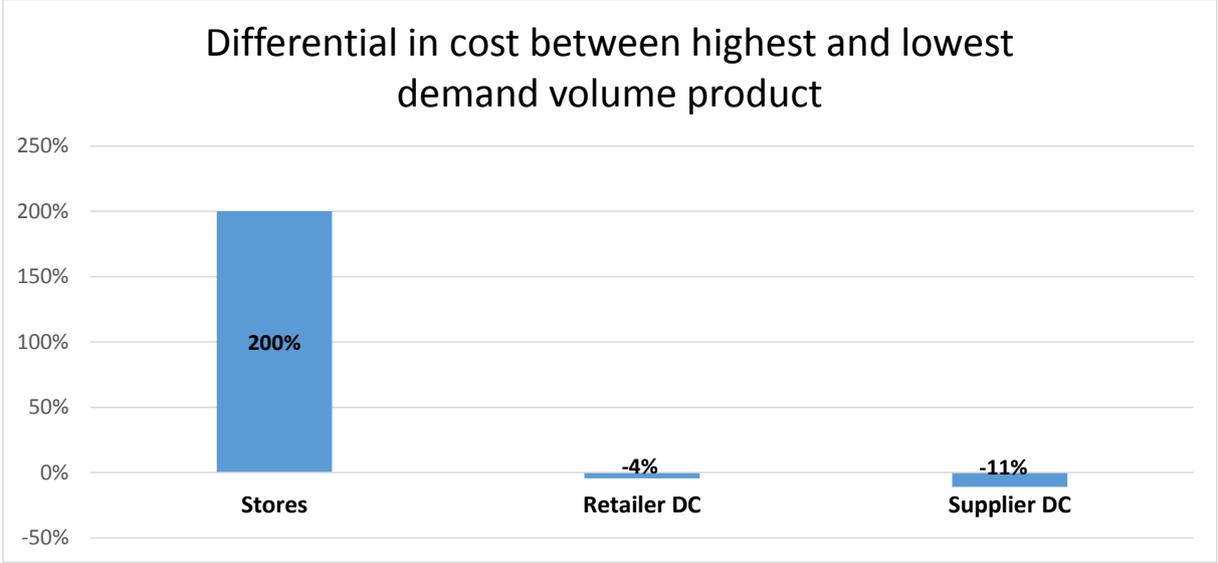


Figure 69: Differential in cost (traditional warehousing vs cross-docking pick by line) for high and low demand volume products

We can see in this figure that for the stores, the cost for products with the lowest demand volume is 200% greater than for products with highest demand volume. As explained earlier, this is due to the increase in inventory cost at the store. For the retailer DC and the supplier DC we can see that the cost doesn't change.

For the pick by store the same conclusion can be drawn.

6.3.3.2 Demand volume / Bullwhip effect

The bullwhip effect gain, the demand has a positive effect:

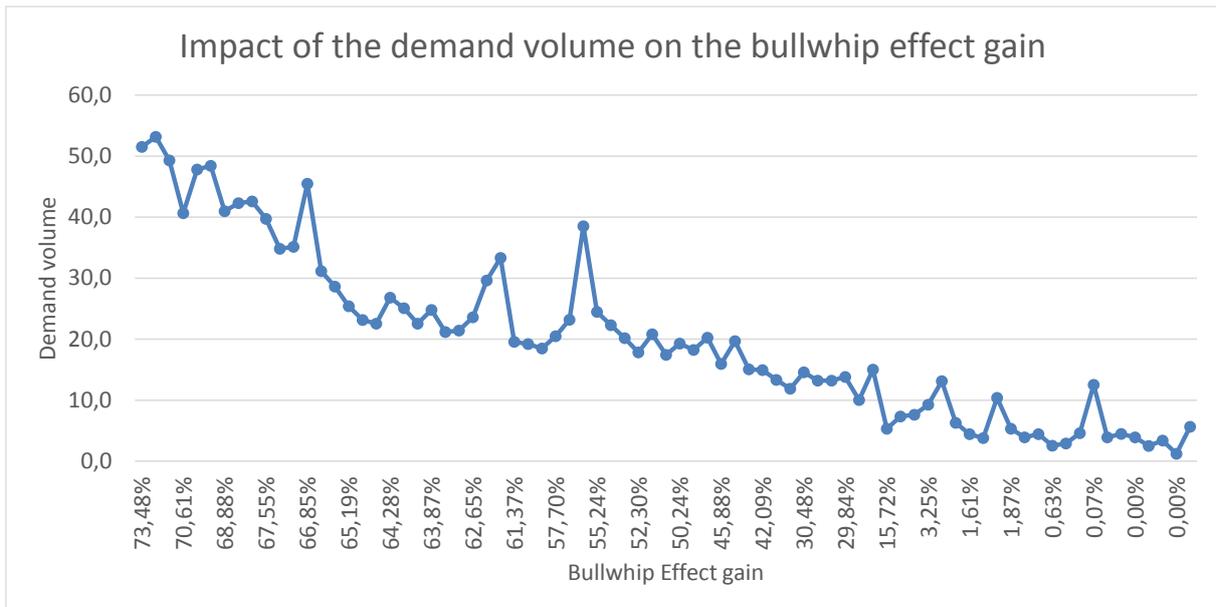


Figure 70: Impact of the demand volume on the bullwhip effect

For products with small demand volume there is no benefit in Bullwhip Effect reduction when moving to cross-docking pick by line and pick by store. This is due to the effect of the demand and also to the effect of batching. In fact, the supplier DC orders always in pallets to the plant. For products with low demand if a pallet covers more than 20 days of demand there is no impact on the bullwhip effect. The variability reduction is absorbed by the batching effect.

6.3.3.3 Matrix OSA/Cost/Demand variability

Based on the matrix and the 200 SKUs we carried out a segmentation based on the demand variability: products with the highest demand variability, and products with the lowest demand variability. For this we use a median value to separate the SKU studied into two categories based on their physical volume. The variability is calculated based on the coefficient of variation for each product, which is the ratio of the standard deviation and the means of the demand. This measure shows the dispersion of the demand compared to the mean demand.

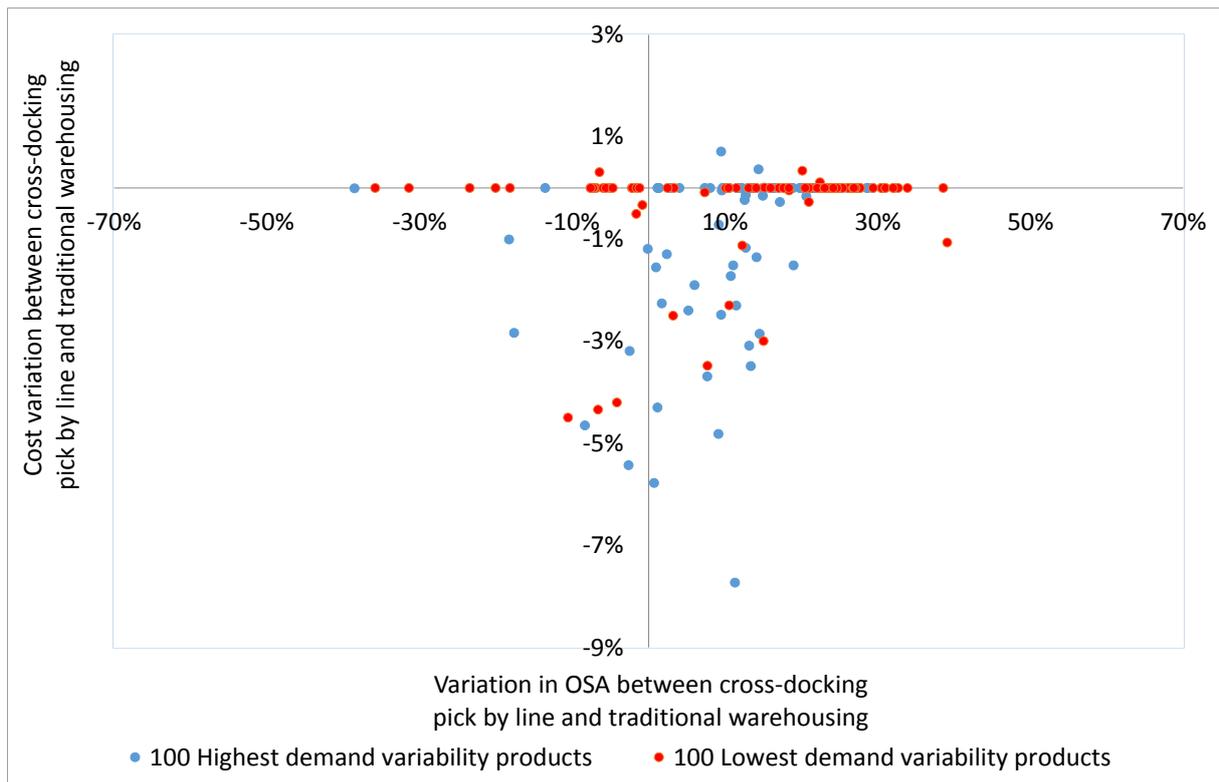


Figure 71: Impact of demand variability on the OSA and cost for cross-docking pick by line

We can see in figure 71 that we have an impact on the On Shelf Availability for most products with the highest demand variability (blue dot). On the other hand, most of the products with a stable demand are positioned on the X axis. For these kind of products there is no impact on the OSA.

The demand variability mainly impacts the On Shelf Availability. In fact, a product with a variable demand is not suitable for cross-docking pick by line since the lead-time to the store increases and with a limit of inventory space at the store (shelf space) there is a risk on the OSA. For this kind of products it is more suitable to keep an inventory at the retailer DC near the store.

The figure 72 shows a segmentation for traditional warehousing versus cross-docking pick by store. The segmentation is based on the demand variability: products with the highest demand variability, and products with the lowest demand variability:

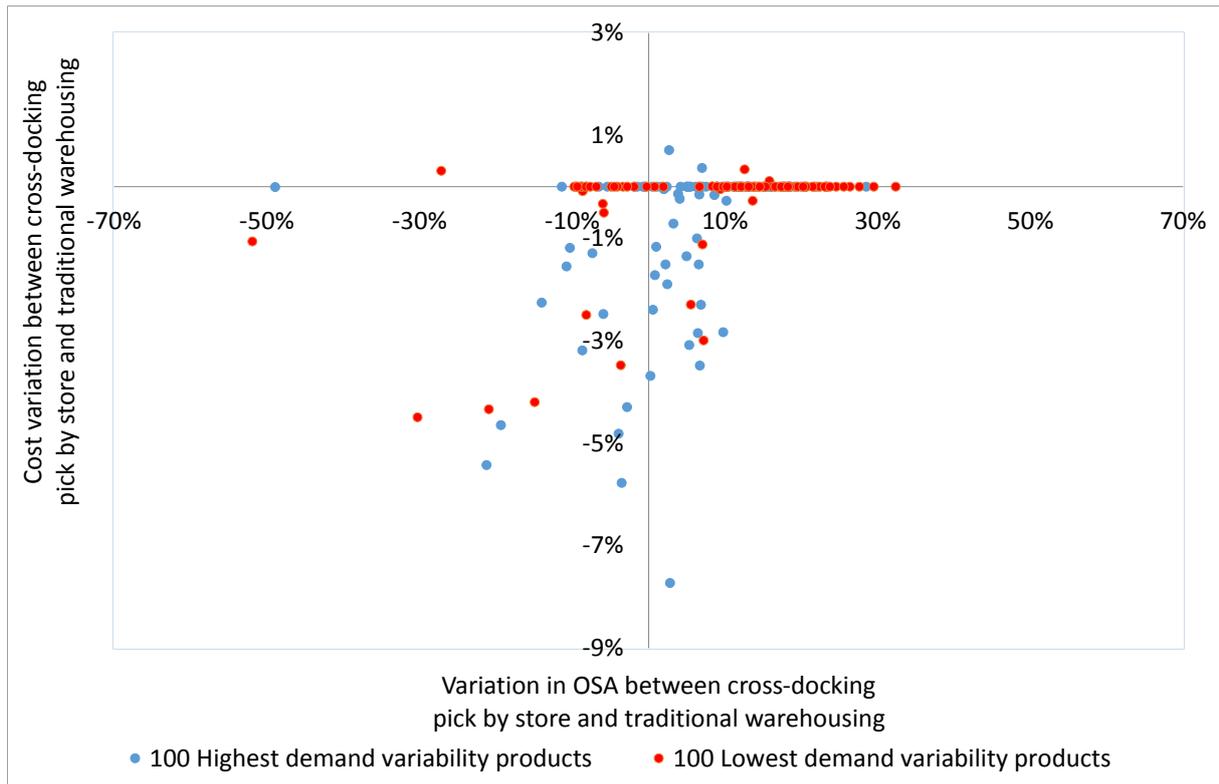


Figure 72: Impact of demand variability on the OSA and cost for cross-docking pick by line

As in cross-docking pick by line, in cross-docking pick by store the impact on OSA is more important for products with a high variability.

6.3.3.4 Demand variability / Bullwhip effect

The demand variability has no effect on the reduction of the variability. In fact, the bullwhip gain is calculated based on the following formula:

$$BWE_{gain} = 1 - \frac{BWE_{CD}}{BWE_{TW}}$$

BWE_{CD} represents the bullwhip effect at the supplier Y DC in the traditional warehousing strategy:

$$BWE_{CD} = \frac{\sigma_{CD}^2}{\sigma_d^2}$$

σ_{CD}^2 represents the variability of the supplier orders in cross-docking pick by line and pick by store strategies, and σ_d^2 the variability of the customers demand.

BWE_{CD} the bullwhip effect at the supplier Y DC in the cross-docking pick by line and pick by store strategy:

$$BWE_{TW} = \frac{\sigma_{TW}^2}{\sigma_d^2}$$

σ_{TW}^2 represents the variability of the supplier orders in traditional warehousing strategy, and σ_d^2 the variability of customers demand.

This shows that the customers demand variability has no effect on the bullwhip effect gain.

6.3.4 Segmentation with Intrinsic/Demand factors

6.3.4.1 Matrix OSA/COST/Cubic Movement

Below a figure representing a segmentation based the cubic movement: products with the highest cubic movement, and products with the lowest cubic movement. For this we use a median value to separate the SKU studied into two categories based on their cubic movement:

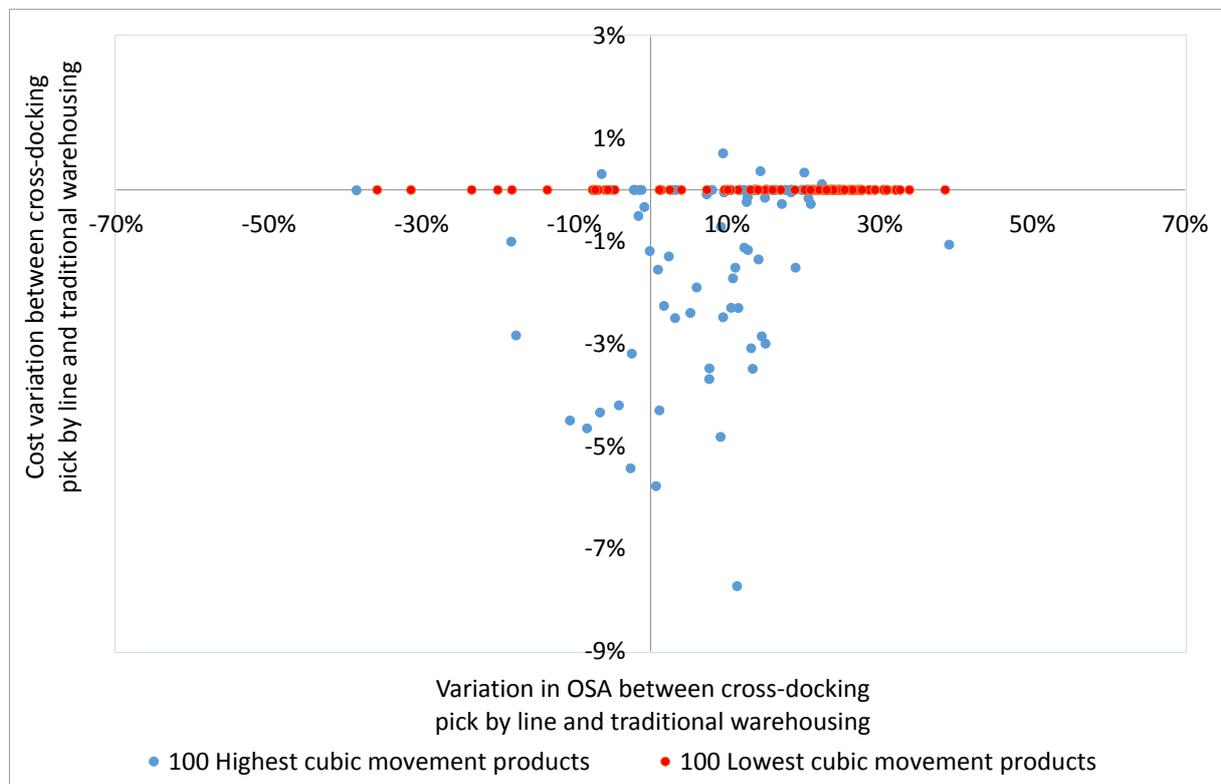


Figure 73: Impact of cubic movement on the OSA and cost for cross-docking pick by line

The cubic movement refers to the physical volume of a product multiplied by its demand volume.

We can see that for most of the products with the lowest cubic movement the cost increases in cross-docking pick by line compared to traditional warehousing. In fact, as explained in the previous parts for products with low demand and low physical volume, the inventory cost at the store and the picking cost for the supplier DC increase, and this increase doesn't offset the reduction in inventory at the retailer DC.

As shown in the figure 74 the same effects can be seen for cross-docking pick by store:

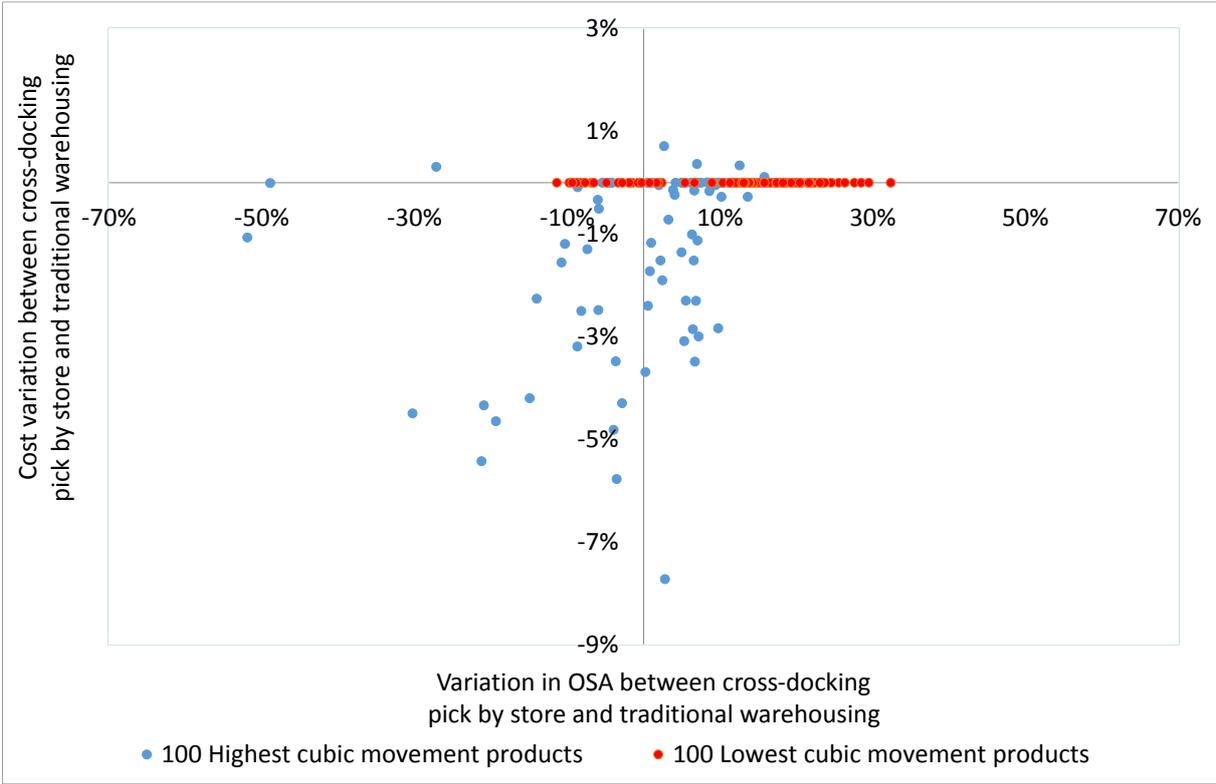


Figure 74: Impact of cubic movement on the OSA and cost for cross-docking pick by store

On the other hand and for the bullwhip effect, the cubic movement has no effect. In fact, as shown in the previous parts, for both products with low physical volume, and high demand there is a positive effect and gain on the bullwhip effect for cross-docking pick by store or pick by line compared to the traditional warehousing strategy. Therefore the cubic movement (demand volume multiplied by physical volume) is not a representative product factor in this case.

6.3.5 Segmentation with Supply control factors

In the supply chain studied all the products have the same lead-time and review period. To highlight the impact of the lead-time on the distribution strategies performances we take as a sample the SKU studied in 6.3.1.2 section.

6.3.5.1 Impact of Lead-time on the supply chain cost and OSA

As explained earlier moving to cross-docking increases the lead time to the store. To highlight the effect of the lead-time on the distribution strategies performances we vary the lead-time to the store. Figure 75 shows the impact of the lead-time on the cost:

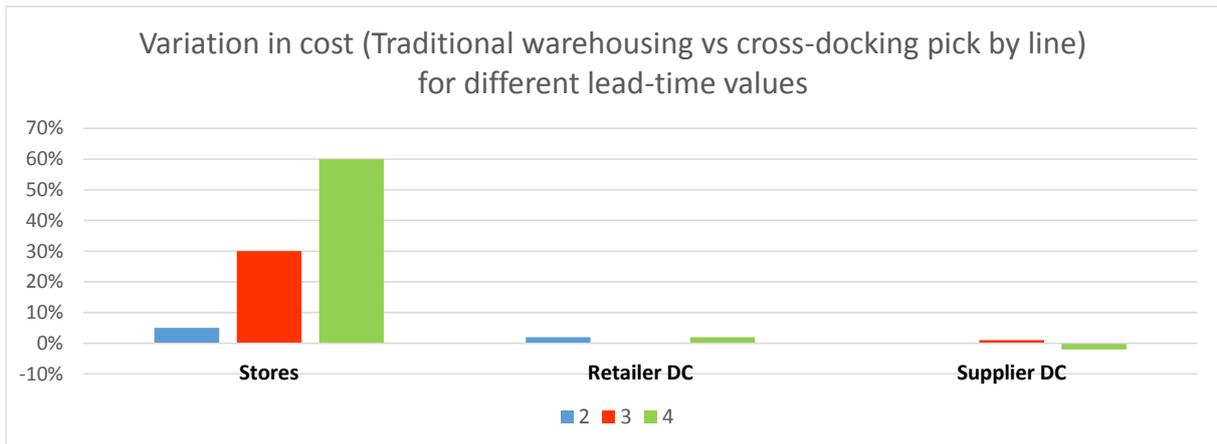


Figure 75: Differential in cost (traditional warehousing vs cross-docking pick by line) for different lead-time values

In figure 75 we present the evolution of the cost of each echelon with the evolution of the stores lead-time. We take a lead-time to the stores of 1 day as reference and we compare it with different values. We can see in this figure that the cost increases for the stores and have no effect on the retailer DC and supplier DC. In fact, by increasing the lead-time to the store the inventory cost increases. The stores need more inventory to cover the demand over the lead-time. The increase of the store cost, doesn't offset the reduction in the retailer DC inventory and handling cost and the cross-docking will be more costly if the lead-time increases.

On the other hand, the lead-time increase has a negative impact on the OSA:

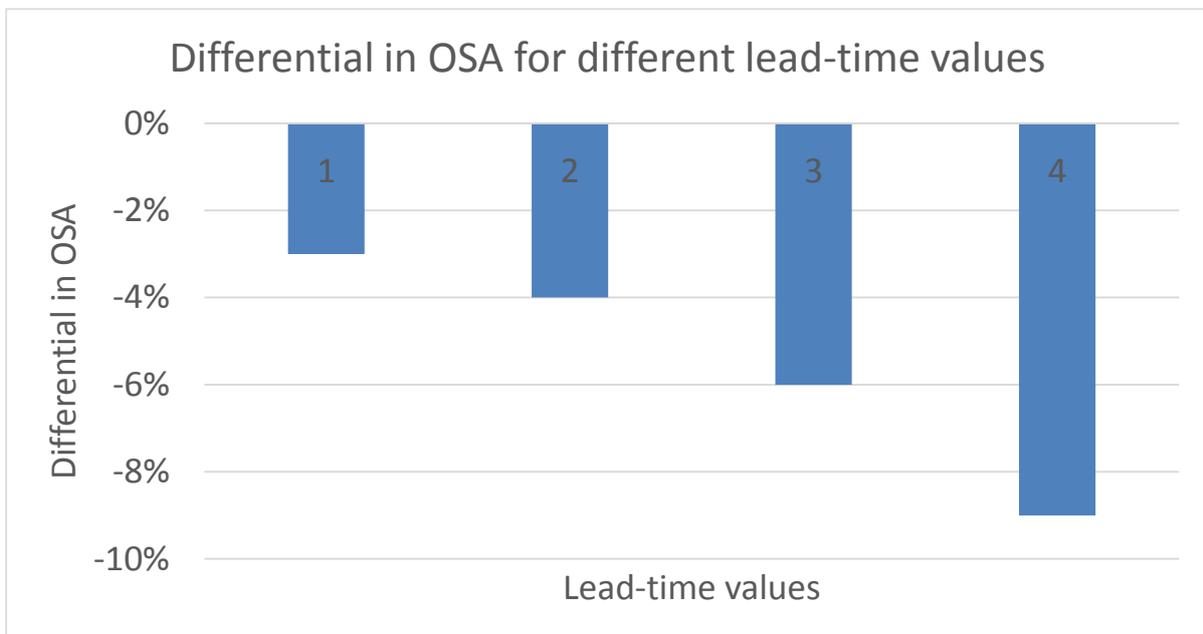


Figure 76: Differential in OSA for different lead-time values

6.3.5.2 Impact of Review period on supply chain cost and OSA

In this part and for the same product studied, we analyze a scenario in which we increase the delivery frequency for this product from (2 deliveries per week) to (3 deliveries per week). The other parameters of the supply chain are fixed. In this case we take an average of the OSA for all the stores to analyze the impact on the E2E cost for this product.

As shown in the figure 77, by increasing the delivery frequency the OSA in cross-docking is 100%.



Figure 77: Store OSA in case of decreasing review period

This increase in the OSA goes against an increase in the supplier transportation cost. The figure below shows the effect of the increase in the delivery frequency on the total supply chain cost:

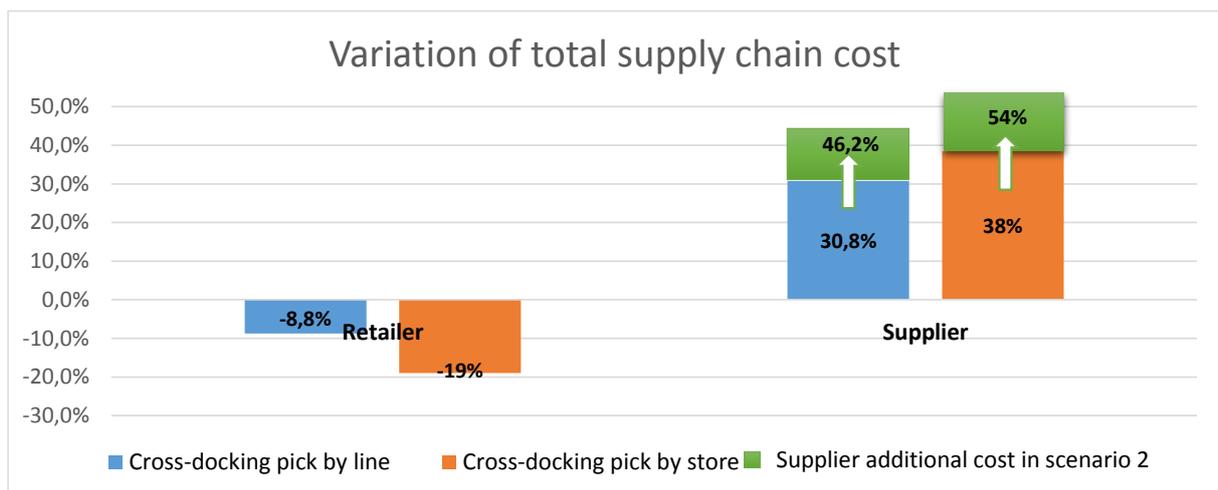


Figure 78: Variation of total supply chain cost in case of decreasing review period

In blue we have the variation of the retailer and supplier cost in cross-docking pick by line compared to traditional warehousing. In orange, we have the variation of the retailer and supplier cost in cross-

docking pick by line compared to traditional warehousing. In green we have the supplier additional cost in case of an increase of the delivery frequency

In green we have the additional transportation cost for the supplier in scenario 2 (increase in delivery frequency). We can see in this figure that by increasing the delivery frequency we keep the same service level, but at the same time more deliveries increase the supplier transportation cost.

In scenario 1 (without increase in deliveries), the retailer cost decreases in cross-docking pick by line and pick by store. For the supplier DC the cost increases in both cross-docking strategies. In this scenario the most economic strategy is the cross-docking pick by store. In scenario 2 (increasing of the delivery frequency), the situation changes, we can see that the benefit of OSA goes against an increase in the supplier transportation cost and at the same time in the total supply chain cost. In this case the traditional warehousing becomes the economic strategy.

6.3.6 Synthesis of product segmentation and distribution strategy selection

Different parameters and metrics have to be taken into account to have the right decision for choosing the right distribution strategy.

Products with low volume, are more adapted to traditional warehousing in terms of costs. For this kind of products the number of cases per pallet is big. In cross-docking the retailer X DC orders in small quantities, cases for all the products. For this kind of products with low volume the *picking cost increases* since there is a big number of products in a pallet. On the other hand, for this kind of products the inventory cost is low, and consequently the reduction in *inventory* is not high enough. On the other hand ordering in pallets, creates more variability in orders, with a big volume of orders followed by periods without orders. For products with low volume, and a big number of cases per pallet the batching effect on the *bullwhip* is greater.

For products with low shelf space, the impact on the *OSA* when moving to cross-docking is important. In fact, due to the increase of the lead-time and of the high demand there is an impact on the service level, if the shelf space is low and doesn't allow to cover the demand during the cross-docking lead-time there is definitely an impact on the *OSA*.

Products with low demand volume, have no is no impact on the *OSA*. This can be explained by the fact that for these products there is enough shelf space to cover their low demand. On the other hand, for these products the cost increases. In fact, the *inventory* cost in the stores for this category increases considerably, since they are slow movers and the inventory holding cost at the stores is greater than in the retailer DC. For the *bullwhip effect*, the supplier DC always orders in pallets to the plant. For products with low demand if a pallet covers more than 20 days of demand there is no impact on the bullwhip effect. The variability reduction is absorbed by the batching effect.

Products with low demand variability, have no impact the On Shelf Availability. In fact, a product with a low variable demand is suitable for cross-docking even if the lead-time to the store increases with an adapted shelf space there is no risk on the OSA.

Products with low cubic movement, increases the *cost* in cross-docking pick by line compared to traditional warehousing. In fact, as explained in the previous parts, for products with low demand and low physical volume, the inventory cost at the store and the picking cost for the supplier DC increase, and this increase doesn't offset the reduction in inventory at the retailer DC.

Products with high lead time, increases the supply chain *cost* and impacts the OSA. In fact, by increasing the lead-time to the store the inventory cost increases. The stores need more inventory to cover the demand over the lead-time. The increase of the store cost, doesn't offset the reduction in the retailer DC inventory and handling cost and the cross-docking is more costly if the lead-time increases. On the other hand, due to the limitation of shelf space, if the lead-time is high there is an impact on OSA.

Products with low review period, have no impact on OSA but at the same time impact the costs. With a low review period the increase of lead-time to the store is offset, which help to maintain a high OSA. On the other hand, a low review period increases the supplier *transportation cost* considerably and can increase the total supply chain cost for cross-docking strategy.

Based on this analysis, we propose a matrix that may be used by managers to assess the right distribution strategy for their products, and depending on their objective. For example, if a company wants to adopt a cross-docking strategy and their focus is more on service levels, the products adapted here are the products with low variability, high shelf space, low value, and short lead-time. If the focus is more on the store inventory reduction, they must choose products with a high demand volume. If the focus is on the bullwhip effect reduction, the products adapted here are products with a high physical volume and a high demand volume (high cubic movement). Note that in the table we do not specify the typology of cross-docking adapted. In fact, as shown in the previous section we have the same impact of products characteristics on the performances for the two typologies of cross-docking.

The selection of the distribution strategy can also be based on the products' characteristics. For example, if the company has products with a high physical volume, high shelf space and high demand volume, the cross-docking is definitely the strategy most adapted.

Products factors			Cost				Service level	Bullwhip Effect
			Stores	Retailer DC	Supplier DC	End-to-End		
Intrinsic factor	Physical volume	High		Cross-docking	Cross-docking	Cross-docking		Cross-docking
		Low		Traditional warehousing	Traditional warehousing	Traditional warehousing		Traditional warehousing
	Shelf Space	High					Cross-docking	
		Low					Traditional warehousing	
	Value	High				Cross-docking	Traditional warehousing	
		Low				Traditional warehousing	Cross-docking	
Demand factor	Demand Volume	High	Cross-docking			Cross-docking		Cross-docking
		Low	Traditional warehousing			Traditional warehousing		Traditional warehousing
	Variability	High					Traditional warehousing	
		Low					Cross-docking	
Intrinsic/Demand factor	Cubic Movement	High	Cross-docking					Cross-docking
		Low	Traditional warehousing					Traditional warehousing
Supply Control factor	Lead-time	High	Traditional warehousing			Traditional warehousing	Traditional warehousing	
		Low	Cross-docking			Cross-docking	Cross-docking	
	Review period	High	Traditional warehousing		Cross-docking	Cross-docking	Traditional warehousing	
		Low	Cross-docking		Traditional warehousing	Traditional warehousing	Cross-docking	

Table 14: Framework for product segmentation and distribution strategy selection

Chapter 7

7. Conclusions and perspectives

7.1 Conclusion

The current business environment is characterized by the emergence of several distribution strategies and collaboration approaches. These new strategies rise with the objectives of continuous improvement and optimization of the supply chain. In this context, retailers put even more focus on improving their working capital. This is to free up cash to invest in the expansion of their store network, moving into new channels and continuing to keep prices low and satisfy customers. One of the solutions to achieve this objective is the reduction of inventories. The achievement of these objectives leads to the organization of new distribution strategies and collaboration approaches. In this context of stretch targets and pressure in terms of both inventory reduction and service levels, retailers push their suppliers to use the cross-docking distribution strategy that eliminates the inventory at their distribution centres (DC).

As we have shown in this research, cross-docking can be beneficial for the supply chain in terms of cost reduction, as well as in terms of bullwhip effect reduction. On the other hand, this strategy can impact the supply chain cost and the service level. A way to benefit from cross-docking, is to combine cross-docking and traditional warehousing in the same supply chain. In order to achieve this objective, a segmentation of the products based on their characteristics and their impact on the supply chain performances should be developed.

In this research we have proposed a framework to select the right distribution strategy for each product depending on its characteristics and its impact on the supply chain performances. We have payed a particular attention on giving a detailed analysis of the impact of the distribution strategies on the supply chain performances, which allows us to give a comprehensive framework for selecting the right distribution strategy for each product.

We have started our dissertation by positioning our research in the literature. In this chapter and after a general introduction and scope of the research, we give the major related works to our research. After, we have given the objectives and contribution of our research.

Chapter 2 provides an industrial context for our research. We present the different distribution strategies existing in the retail supply chain. We describe their performances, advantages, drawbacks and the products adapted to each strategy. We also showed how cross-docking strategy impacts the supply chain costs and other performances, and how the retail supply chain gets organized and proposes new a collaboration approach to support cross-docking, such as pooling, consolidations and collaboration centres (CCC), and finally combining cross-docking and traditional warehousing.

Chapter 3 provides a literature review on the distribution strategies and their impacts on the supply chain performances. In this chapter we also provide a detailed literature review on the issue of product segmentation and distribution strategy selection. Based on this literature review, we carry out a framework for selecting the right distribution strategy for each product, including different product factors and performances.

In chapter 4, we present a review on modelling approaches of the supply chain. After which we present the process modelling adopted for our study. Based on this process modelling we explain how we carry out the analysis based on a macro cost model and a simulation. This modelling allows a better understanding of the different processes of each echelon and for each distribution strategy (traditional warehousing, cross-docking pick by line and cross-docking pick by store).

Chapter 5 provides a cost comparison between the distribution strategies. It presents a macro cost model to compare the distribution strategies, as well as a cost analysis of the potential gains and hurts of each distribution strategy.

Finally chapter 6, gives a detailed study and analysis of the impact of the distribution strategies on the supply chain performances (service level, cost and bullwhip effect),it analyses the impact of the products characteristics (intrinsic factors, demand factors, intrinsic/ demand factors and supply control factors) on the performances of the distribution strategies and finally proposes a methodology to choose the right strategy for each product depending on its characteristics and the impact on the performances. This chapter shows that selecting the right distribution strategy is not an easy task. Different parameters and metrics have to be taken into account to have a right selection.

When dealing with the product segmentation and distribution strategy selection, as shown in the Table 13, different product characteristics for different performance metrics are involved:

Products factors			Cost				Service level	Bullwhip Effect
			Stores	Retailer DC	Supplier DC	End-to-End		
Intrinsic factor	Physical volume	High		Cross-docking	Cross-docking	Cross-docking		Cross-docking
		Low		Traditional warehousing	Traditional warehousing	Traditional warehousing		Traditional warehousing
	Shelf Space	High					Cross-docking	
		Low					Traditional warehousing	

	Value	High				Cross-docking	Traditional warehousing	
		Low				Traditional warehousing	Cross-docking	
Demand factor	Demand Volume	High	Cross-docking			Cross-docking		Cross-docking
		Low	Traditional warehousing			Traditional warehousing		Traditional warehousing
	Variability	High					Traditional warehousing	
		Low					Cross-docking	
Intrinsic/ Demand factor	Cubic Movement	High	Cross-docking					Cross-docking
		Low	Traditional warehousing					Traditional warehousing
Supply Control factor	Lead-time	High	Traditional warehousing			Traditional warehousing	Traditional warehousing	
		Low	Cross-docking			Cross-docking	Cross-docking	
	Review period	High	Traditional warehousing		Cross-docking	Cross-docking	Traditional warehousing	
		Low	Cross-docking		Traditional warehousing	Traditional warehousing	Cross-docking	

This table can be used as a framework or a tool to help managers to assess the right distribution strategy for their products, depending on their objective. For example, if a company wants to adopt a cross-docking strategy and want to focus more on service levels, the products adapted here are products with low variability, high shelf space, low value, and a short lead-time. If they focus more on store inventory reduction, they must choose products with a high demand volume. If the focus is on the bullwhip effect reduction, the products adapted here are products with high physical volume and high demand volume (high cubic movement).

The selection of the distribution strategy can also be based on the products characteristics. For example, if the company has products with high physical volume, high shelf space and high demand volume, the cross-docking is definitely the strategy most adapted.

7.2 Research perspectives

Several perspectives could be opened to research. We offer several complementary research perspectives for several levels:

First, in terms of performances' perspectives, as we have shown in this research the most important supply chain performances were studied. At the same time other supply chain metrics can be taken into account to conduct a complete analysis about which products to choose for which distribution strategy. For example the supply chain's sustainability can be studied in terms of product segmentation. This performance is important to set the right distribution strategy of a product. For instance, in a supply chain where we can combine the cross-docking with traditional warehousing, determining the right products for each category can enable a high vehicle use and then reduce CO2 emissions. We can imagine, a product segmentation combined with an optimisation to choose the optimal ranking of the products which allows a reduction in cost, a good service level, a reduction in bullwhip effect, and in the same time an optimal filling of the truck. Optimal filling of the truck would allow a reduction in the number of trucks between the supplier DC and the retailer DC and will definitely reduce the CO2 emissions.

Second in terms of structure of the supply chain, in our research we study a supply chain composed of a supplier DC, a retailer DC and stores. Other structures can be studied. For example a supply chain including a supplier DC, different retailer DC (belonging to the same retailer), and stores. In fact, the retailer DCs can be different in terms of assortment, number of stores delivered, and of sales volume. A product segmentation based on a more complex supply chain structure would be an interesting avenue for future research.

Finally, in terms of product segmentation, in our research we have done a segmentation for products on a one year basis. In fact, for some products the demand volume, variability or lead-time can change over its life cycle, or over one year. One can imagine a more dynamic product segmentation over the product life cycle. For example, a product in the first half of the year, can have a low sales volume and in the second half its demand volume can increase considerably. In this case, the product will be adapted for cross-docking strategy in the second half of the year, and for traditional warehousing in the first half. A study of the variation of the product characteristics over its life cycle would be interesting. On the other hand, this kind of study needs a detailed investigation of the capabilities of the supply chain to change the distribution strategy of a product over its life cycle. For example, to move from cross-docking to traditional warehousing a stock needs to be constructed at the retailer DC for this product, and this phase can impact the performances of the supply chain. At the same time to move from traditional warehousing to cross-docking, the retailer DC needs to sell off the inventory already held for this product before starting cross-docking and this can disrupt the supply chain.

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Appendices

Appendix A: Detailed description of the distribution strategies processes

Traditional warehousing processes

Below a table describing each process in the model, the metric associated and the hypothesis taking into account:

Process		Description and hypothesis	Metric associated
Store	S.1	Reception After a lead-time the store receives the quantity ordered, and docks the truck in the store dock.	Reception cost
	S.2	Unloading After docking the truck, the operators unload the pallets.	Unloading cost
	S.3	Control The products are then staged for inspection, such as damage, incorrect counts, wrong descriptions, and so on. The products are then staged for shelf replenishment. We assume that there is no intermediate storage (no backroom storage).	Controlling cost
	S.4	Shelf storage The shelves are replenished with products received.	Shelf replenishment cost
	S.5	Sales The customers look for products from the shelves We assume that when there is no inventory and a demand occurs it's lost.	On Shelf Availability
	S.6	Update stock level At the end of the period the store updates the stock level by taking into account, orders in transit and on hand inventory.	
	S.7	Forecast for next period The demand forecasting is done according to historical demand of previous periods. We assume an exponential smoothing forecast.	
	S.8	Decide ordering After that the store decides the ordering quantity according to the demand forecasting, lead-time demand and safety stock needed, and shelf space available. We assume that we order when the stock level achieve the reorder point. Which represent the demand during the lead-time plus a safety stock. The orders are in cases.	Ordering cost
	S.9	Order to retailer DC The order is then sent to the retailer DC.	
Retailer DC	R.1	Receive orders from stores Reception of orders from the stores delivered by the DC.	Order management cost
	R.2	Inventory check After the reception of the stores orders the DC perform a verification of the availability of the inventory. We assume that the retailer DC adopt a Order Up To Level policy.	
	R.3	Edition of order preparation form After the DC produce pick lists to guide the order-picking.	
	R.4	Order pick (per store order) Each entry on the picking list is referred to as an order-line and consists of the item and quantity requested. This process consists of picking this order-lines and regrouping products in pallets for shipping to the stores. The granularity of picking for retailer DC is cases.	Picking cost

R.5	Loading the truck	When the stores orders are prepared, the operators check the products, scan to register their departure to the stores, and load in the trucks.	Loading cost	
R.6	Delivery	When the truck is filled the delivering to the stores can start. We assume that the retailer trucks are always full; the rationale behind this is that the retailer has the capacity to full their trucks and perform a routing of the trucks.	Transportation cost	
R.7	Update stock level	The retailer update the stock level by taking into account, orders in transit, on hand and products delivered.		
R.8	Forecast for next period	The demand forecasting is done according to historical demand of previous periods. We adopt an exponential smoothing forecasting scheme.		
R.9	Decide ordering	After that the retailer decides the ordering quantity according to the demand forecasting, lead-time demand and safety stock needed. The orders are in cases, layers or pallets depending to the MOQ agreed between P&G and the retailer.		
R.10	Order to supplier DC	The order is then sent to the supplier DC.	Ordering cost	
R.11	Reception	After a lead-time the retailer DC receives the quantity ordered, and docks the truck in the DC docks.	Reception cost	
R.12	Unloading	After docking the truck, the operators unload the pallets.	Unloading cost	
R.13	Control	The products are then staged for inspection, such as damage, incorrect counts, wrong descriptions, and so on.	Controlling cost	
R.14	Storing (put away)	The operators determine the storage location, store the product and scan the storage location where product has been placed.	Storing cost	
Supplier DC	Su.1	Receive orders from stores	Reception of orders from the retailer DC.	Order management cost
	Su.2	Inventory check	After the reception of the retailer orders the DC perform a verification of the availability of the inventory.	
	Su.3	Edition of order preparation form	After the DC produce pick lists to guide the order-picking.	
	Su.4	Order pick (per store order)	Each entry on the picking list is referred to as an order-line and consists of the item and quantity requested. This process consists of picking this order-lines and regrouping products in pallets for shipping to the stores. The granularity of picking for supplier DC depends on the MOQ agreed between the supplier and the retailer.	Picking cost
	Su.5	Loading the truck	When the retailer orders are prepared, the operators check the products, scan to register their departure to the retailer DC, and load in the trucks.	Loading cost
	Su.6	Delivery	When the truck is filled the delivering to the stores can start. We assume that the trucks are filled with heterogeneous pallets and the filling depend on the dynamic of orders (no full truck constraint).	Transportation cost
	Su.7	Update stock level	The supplier DC update the stock level by taking into account, orders in transit, on hand and products delivered.	
	Su.8	Forecast for next period	The demand forecasting is done according to historical demand of previous periods.	
	Su.9	Decide ordering	After that the supplier decides the ordering quantity according to the demand forecasting, lead-time demand and safety stock needed. The orders are in pallets.	
	Su.10	Order to supplier DC	The order is then sent to the source DC.	Ordering cost / Bullwhip Effect

	Su.11	Reception	After a lead-time the supplier DC receives the quantity ordered, and docks the truck in the DC docks.	Reception cost
	Su.12	Unloading	After docking the truck, the operators unload the pallets.	Unloading cost
	Su.13	Control	The products are then staged for inspection, such as damage, incorrect counts, wrong descriptions, and so on.	Controlling cost
	Su.14	Storing (put away)	The operators determine the storage location, store the product and scan the storage location where product has been placed.	Storing cost

Cross-docking pick by line processes description

Below a table describing each process in the model, the metric associated and the hypothesis taking into account:

Process		Description and hypothesis	Metric associated
Store	S.1	Reception After a lead-time the store receives the quantity ordered, and docks the truck in the store dock. The lead-time to the store increases in cross-docking.	Reception cost
	S.2	Unloading After docking the truck, the operators unload the pallets.	Unloading cost
	S.3	Control The products are then staged for inspection, such as damage, incorrect counts, wrong descriptions, and so on. The products are then staged for shelf replenishment. We assume that there is no intermediate storage (no backroom storage).	Controlling cost
	S.4	Shelf storage The shelves are replenished with products received. The time spent to replenish the shelves by 10%. This is due to the fact that the picking and preparation operations at the retailer DC are different. This might not allow to build the pallet/cage in the same efficient way. As a consequence the replenishment of the shelf might be delayed.	Shelf replenishment cost
	S.5	Sales The customers look for products from the shelves	On Shelf Availability
	S.6	Update stock level At the end of the period the store updates the stock level by taking into account, orders in transit and on hand inventory.	
	S.7	Forecast for next period The demand forecasting is done according to historical demand of previous periods.	
	S.8	Decide ordering After that the store decides the ordering quantity according to the demand forecasting, lead-time demand and safety stock needed, and shelf space available. The orders are in cases.	Ordering cost
	S.9	Order to retailer DC The order is then sent to the retailer DC.	
Retailer DC	R.1	Receive orders from stores Reception of orders from the stores.	Order management cost
	R.2	Aggregate orders Aggregate the stores orders and send one order to the supplier DC	
	R.3	Order to supplier DC The order is then sent to the supplier DC.	Ordering cost
	R.4	Reception After a lead-time the retailer DC receives the quantity ordered, and docks the truck in the DC docks.	Reception cost
	R.5	Unloading After docking the truck, the operators unload the pallets.	Unloading cost
	R.6	Control The products are then staged for inspection, such as damage, incorrect counts, wrong descriptions, and so on.	Controlling cost
	R.7	Pre-preparation The operators sort the products received by family for picking.	Picking cost
	R.8	Order pick (per store order) This process consists of picking and regrouping products in pallets for shipping to the stores. The granularity of picking for retailer DC is cases.	Picking cost
	R.9	Loading the truck When the stores orders are prepared, the operators check the products, scan to register their departure to the stores, and load in the trucks.	Loading cost
	R.10	Delivery When the truck is filled the delivering to the stores can start.	Transportation cost

Supplier DC			We assume that the retailer trucks are always full; the rationale behind this is that the retailer has the capacity to full their trucks and perform a routing of the trucks.	
	Su.1	Receive orders from stores	Reception of order from the retailer DC.	Order management cost
	Su.2	Inventory check	After the reception of the retailer orders the DC perform a verification of the availability of the inventory.	
	Su.3	Edition of order preparation form	After the DC produce pick lists to guide the order-picking.	
	Su.4	Order pick (per store order)	Each entry on the picking list is referred to as an order-line and consists of the item and quantity requested. This process consists of picking this order-lines and regrouping products in pallets for shipping to the stores. The orders are prepared in bulk (some of stores orders). The granularity of picking for supplier DC in cross-docking is cases.	Picking cost
	Su.5	Loading the truck	When the retailer orders are prepared, the operators check the products, scan to register their departure to the retailer DC, and load in the trucks.	Loading cost
	Su.6	Delivery	When the truck is filled the delivering to the stores can start. We assume that the trucks are filled with heterogeneous pallets and the filling depends on the dynamic of orders (no full truck constraint).	Transportation cost
	Su.7	Update stock level	The supplier DC update the stock level by taking into account, orders in transit, on hand and products delivered.	
	Su.8	Forecast for next period	The demand forecasting is done according to historical demand of previous periods.	
	Su.9	Decide ordering	After that the supplier decides the ordering quantity according to the demand forecasting, lead-time demand and safety stock needed. The orders are in pallets.	
	Su.10	Order to supplier DC	The order is then sent to the source DC.	Ordering cost / Bullwhip Effect
	Su.11	Reception	After a lead-time the supplier DC receives the quantity ordered, and docks the truck in the DC docks.	Reception cost
	Su.12	Unloading	After docking the truck, the operators unload the pallets.	Unloading cost
	Su.13	Control	The products are then staged for inspection, such as damage, incorrect counts, wrong descriptions, and so on.	Controlling cost
Su.14	Storing (put away)	The operators determine the storage location, store the product and scan the storage location where product has been placed.	Storing cost	

Cross-docking pick by store processes description

Below a table describing each process in the model, the metric associated and the hypothesis taking into account:

Process		Description and hypothesis	Metric associated
Store	S.1	Reception After a lead-time the store receives the quantity ordered, and docks the truck in the store dock. The lead-time to the store increases in cross-docking.	Reception cost
	S.2	Unloading After docking the truck, the operators unload the pallets.	Unloading cost
	S.3	Control The products are then staged for inspection, such as damage, incorrect counts, wrong descriptions, and so on. The products are then staged for shelf replenishment. We assume that there is no intermediate storage (no backroom storage).	Controlling cost
	S.4	Shelf storage The shelves are replenished with products received. The time spent to replenish the shelves by 20%. This is due to the fact that the picking and preparation operations at the retailer DC are different. This might not allow to build the pallet/cage in the same efficient way. As a consequence the replenishment of the shelf might be delayed.	Shelf replenishment cost
	S.5	Sales The customers look for products from the shelves	On Shelf Availability
	S.6	Update stock level At the end of the period the store updates the stock level by taking into account, orders in transit and on hand inventory.	
	S.7	Forecast for next period The demand forecasting is done according to historical demand of previous periods.	
	S.8	Decide ordering After that the store decides the ordering quantity according to the demand forecasting, lead-time demand and safety stock needed, and shelf space available. The orders are in cases.	Ordering cost
	S.9	Order to retailer DC The order is then sent to the retailer DC.	
Retailer DC	R.1	Receive orders from stores Reception of orders from the stores.	Order management cost
	R.2	Aggregate orders Aggregate the stores orders and send one order with the details of the need of each store to the supplier DC	
	R.3	Order to supplier DC The order is then sent to the supplier DC.	Ordering cost
	R.4	Reception After a lead-time the retailer DC receives the quantity ordered, and docks the truck in the DC docks.	Reception cost
	R.5	Unloading After docking the truck, the operators unload the pallets.	Unloading cost
	R.6	Control The products are then staged for inspection, such as damage, incorrect counts, wrong descriptions, and so on.	Controlling cost
	R.7	Order consolidation Consolidate the stores orders by the products coming from different suppliers.	Picking cost
	R.8	Loading the truck When the stores orders are prepared, the operators check the products, scan to register their departure to the stores, and load in the trucks.	Loading cost
	R.9	Delivery When the truck is filled the delivering to the stores can start. We assume that the retailer trucks are always full; the rationale behind this is that the retailer has the capacity to full their trucks and perform a routing of the trucks.	Transportation cost

supplier DC	Su.1	Receive orders from stores	Reception of order from the retailer DC.	Order management cost
	Su.2	Inventory check	After the reception of the retailer orders the DC perform a verification of the availability of the inventory.	
	Su.3	Edition of order preparation form	After the DC produce pick lists to guide the order-picking.	
	Su.4	Order pick (per store order)	Each entry on the picking list is referred to as an order-line and consists of the item and quantity requested from each store. This process consists of picking this order-lines and regrouping products in pallets for shipping to the stores. The orders are prepared and picked by store order. The granularity of picking for supplier DC in cross-docking is cases.	Picking cost
	Su.5	Loading the truck	When the retailer orders are prepared, the operators check the products, scan to register their departure to the retailer DC, and load in the trucks.	Loading cost
	Su.6	Delivery	When the truck is filled the delivering to the stores can start. We assume that the trucks are filled with heterogeneous pallets and the filling depends on the dynamic of orders (no full truck constraint).	Transportation cost
	Su.7	Update stock level	The supplier DC update the stock level by taking into account, orders in transit, on hand and products delivered.	
	Su.8	Forecast for next period	The demand forecasting is done according to historical demand of previous periods.	
	Su.9	Decide ordering	After that the supplier decides the ordering quantity according to the demand forecasting, lead-time demand and safety stock needed. The orders are in pallets.	
	Su.10	Order to supplier DC	The order is then sent to the source DC.	Ordering cost / Bullwhip Effect
	Su.11	Reception	After a lead-time the supplier DC receives the quantity ordered, and docks the truck in the DC docks.	Reception cost
	Su.12	Unloading	After docking the truck, the operators unload the pallets.	Unloading cost
	Su.13	Control	The products are then staged for inspection, such as damage, incorrect counts, wrong descriptions, and so on.	Controlling cost
	Su.14	Storing (put away)	The operators determine the storage location, store the product and scan the storage location where product has been placed.	Storing cost