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SUPPLY CHAIN RESILIENCE: ANTECEDENTS AND DRIVER IN GLOBAL COMPETITION

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Supply Chain Resilience: Antecedents and Drivers in Global Competition

by

Beatriz Acero López

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Certified by………………………………………………………………………………...……

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Resiliencia en la cadena de suministro: antecedentes y factores en la competencia global

por

Beatriz Acero López

En cumplimiento parcial de los requisitos para obtener el título de
Doctora en Logística y Gestión de la Cadena de Suministro

Resumen

En el actual entorno altamente competitivo, las empresas de todo el mundo buscan formas innovadoras de incrementar la resiliencia de sus cadenas de suministro sin perder eficiencia operacional y ventaja competitiva. En esta tesis doctoral se analiza la creación de resiliencia atendiendo a dos aspectos. En primer lugar, estudiamos el novedoso concepto de sincromodalidad en el mundo del transporte y su efecto sobre la resiliencia y la eficiencia. En segundo lugar, examinamos el efecto que la Gestión de Riesgos en la Cadena de Suministro (SCRM) tiene sobre la resiliencia, cuantificando la reducción de eventos disruptivos.

La sincromodalidad es un concepto de transporte novedoso que integra el uso de diversos modos de transporte en base a información en tiempo real. La sincromodalidad se entiende como un planteamiento operativo para mejorar los objetivos de desempeño en cuanto a eficiencia y resiliencia, con el potencial añadido de generar ventaja competitiva mediante la diferenciación logística. No obstante, el trabajo existente al respecto se encuentra todavía en una etapa incipiente, no existiendo todavía un consenso acerca de los mecanismos que propician el desarrollo de una cadena de suministro sincromodal. Asimismo, sus resultados no se han analizado empíricamente. Para salvar esta brecha, presentamos un análisis pormenorizado de sincromodalidad y de sus dimensiones subyacentes. Mediante la aplicación de una metodología en cuatro etapas, se desarrolla el constructo multidimensional de sincromodalidad, formado por 4 dimensiones (visibilidad, flexibilidad, integración y sistema operativo). Un modelo de ecuaciones estructurales confirma su relación con la diferenciación logística como medida de la ventaja competitiva. Este análisis supone un enfoque del concepto de sincromodalidad respecto a la literatura existente, para comprenderlo mejor desde una perspectiva de gestión de operaciones y sentar las bases de las capacidades de la cadena de suministro que deben desarrollar aquellas empresas que adopten la sincromodalidad.

Utilizando esta investigación como punto de partida, analizamos los efectos que la implantación de la sincromodalidad tiene en la cadena de suministro, medidos en términos de eficiencia y resiliencia. Utilizando información proveniente de 157 empresas logísticas que

trabajan con expedidores de carga que aplican actualmente la sincromodalidad en Europa, presentamos un modelo de ecuaciones estructurales para analizar la relación entre sincromodalidad, eficiencia y resiliencia. Además, adoptamos un enfoque configuracional y realizamos un análisis de clústeres para seguir avanzando en la comprensión del vínculo eficiencia-resiliencia mediante distintos contextos sincromodales medidos por las cuatro dimensiones de sincromodalidad identificadas. Nuestros hallazgos indican que las empresas que fomentan un entorno sincromodal en sus operaciones no sólo son más eficientes desde el punto de vista de la logística y el transporte, sino que además son menos propensas a las disrupciones. Sin embargo, los niveles de eficiencia y resiliencia difieren según el grado de sincromodalidad alcanzado por la cadena de suministro.

En segundo lugar, el estudio de la resiliencia ha suscitado el interés de los investigadores por el análisis de determinadas prácticas de gestión de riesgos en la cadena de suministro, tales como la colaboración y la formalización de procesos. Con todo, son escasas las investigaciones que cuantifican los efectos de estas prácticas, lo que nos animó a examinar en qué medida la Gestión de Riesgos en la Cadena de Suministro (SCRM) colaborativa y formal puede contribuir a reducir la propensión a sufrir un evento disruptivo. Para estimar estos efectos, desarrollamos una metodología de efecto de tratamiento multivariable basada en análisis experimentales y la aplicamos a una base de datos global consistente en 1.461 encuestados procedentes de 69 países. Para terminar, analizamos el efecto moderador que tiene el tamaño de la empresa y el tipo de industria sobre el enfoque de gestión del riesgo adoptado para abordar distintas disrupciones. Nuestra investigación sugiere que los enfoques colaborativos de SCRM son más eficaces en grandes empresas manufactureras que operan en entornos de mercado volátiles, mientras que las estructuras formales de SCRM benefician sobre todo a pequeñas y medianas empresas que afrontan riesgos operativos.

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Discusión y Conclusiones

Discusión e implicaciones industriales

Como consecuencia de la globalización, las empresas han ampliado el número de proveedores y clientes en una búsqueda incesante por reducir los costes y aumentar los ingresos. Sin embargo, las cadenas de suministro globales adolecen de una complejidad creciente y de innumerables fuentes de vulnerabilidad que pueden convertirse en disrupciones. Tales disrupciones pueden deberse a diversos riesgos, tales como errores en el cálculo de la demanda, vulneraciones de derechos de propiedad intelectual, defectos de calidad del producto, quiebra de proveedores, retrasos de transporte, huelgas de empleados o catástrofes naturales. Muchos investigadores han intentado desvelar cuáles son las capacidades y estrategias que las empresas necesitan desarrollar dentro de sus propias organizaciones y con sus proveedores con el objetivo de evitar y mitigar eventos imprevistos, generando así una ventaja competitiva cuando se producen disrupciones. Un ejemplo ilustrativo concierne a la disrupción debida al incendio que destruyó todos los chips de radiofrecuencia del único proveedor de Nokia y Ericsson en 2000 (Norrman & Jansson, 2004). Si bien Ericsson sufrió pérdidas cercanas a los 400 millones de dólares debido a la tardanza en reaccionar a la disrupción, Nokia salió reforzado gracias a la flexibilidad y agilidad de su cadena de suministro, lo cual le permitió conseguir rápidamente suministradores alternativos (Trent, 2015) y obtener una ventaja competitiva frente a sus competidores directos, siendo Ericsson el principal de ellos.

Desde que naciera el ámbito de la gestión de riesgos en la cadena de suministro hacia el año 2000, la mayoría de los esfuerzos se han centrado en la relación entre comprador y proveedor de productos. Gran parte de estos esfuerzos no han tenido en cuenta que los proveedores de servicios de transporte y logística (T&LSPs) pueden aportar una ventaja competitiva a las cadenas de suministro, no solo porque desempeñan una función importante en la optimización de costes sino porque ayudan a crear resiliencia y minimizar las disrupciones. Con todo, esta tendencia se está invirtiendo lentamente con la aparición de nuevos conceptos logísticos, como la sincromodalidad, encaminados a incrementar la resiliencia y la eficiencia en las cadenas de suministro globales.

La finalidad de esta tesis es comprender (1) cuáles son las prácticas de gestión del riesgo en la cadena de suministro que generan resiliencia y cómo impactan en la mejora del rendimiento de la cadena de suministro y la ventaja competitiva, (2) dado que la sincromodalidad ha emergido como concepto novedoso y prometedor en la logística y el transporte pero se encuentra todavía en fase de desarrollo incipiente, nos proponemos ahondar en este concepto y entender cuáles son los factores que contribuyen a su desarrollo e implementación, (3) en base a este trabajo, queremos comprender cómo, siguiendo las hipótesis teóricas de otros autores, la sincromodalidad propicia cadenas de suministro más resilientes y eficientes, y finalmente, (4) en qué medida la implantación de un proceso SCRM activo, reforzado con la formalización de una estructura de gestión de riesgos y un enfoque colaborativo, puede aumentar la resiliencia de una cadena de suministro reduciendo la propensión a sufrir disrupciones. Estos cuatro objetivos se traducen en cuatro preguntas de investigación, cuyos principales hallazgos resumimos a continuación.

Pregunta de investigación 1: ¿Cuáles son las últimas tendencias en procesos de mitigación SCRM que fomentan la resiliencia y creación de una ventaja competitiva?

Basándonos en un análisis detallado de buenas prácticas de SCRM implantadas con éxito por empresas globales en las últimas décadas, presentamos un marco que los gestores de cadenas de suministro podrían aprovechar para desplegar la resiliencia de una manera dinámica. Este trabajo ha sido publicado en nuestro artículo *Aligning supply chain design for boosting resilience* (Saenz, et al., 2018). En él concluimos que no hay una práctica universal de gestión de riesgos y disrupciones en la cadena de suministro y que para diseñar un sistema SCRM, las empresas deben conocer primero la naturaleza de sus cadenas de suministro y comprender las vulnerabilidades y riesgos a los que se enfrentan. Además, la globalización y la diversificación de productos podrían llevar a las empresas a aplicar distintos diseños de cadena de suministro dentro de una misma organización, a su vez con diferentes enfoques de gestión de riesgos.

Pregunta de investigación 2: ¿Qué capacidades deben desarrollar las empresas para aplicar la sincromodalidad en sus cadenas de suministro y cómo afecta esto a la creación de ventaja competitiva?

La sincromodalidad es un concepto novedoso que ha captado la atención de investigadores y profesionales en los últimos años, pues responsables políticos de la UE, profesionales e investigadores en tema de transporte y logística la entienden como un avance en pos de la eficiencia en el transporte, la sostenibilidad, la resiliencia, el cambio modal y, en general, una ventaja competitiva global en la cadena de suministro. No obstante, pese al interés, continúa habiendo escasez de investigaciones teóricas y empíricas. Primero, no se ha llegado a un acuerdo en la definición de sincromodalidad pues ningún estudio ha intentado desarrollar un marco conceptual para ello. Segundo, no tenemos conocimiento de que se hayan desarrollado mediciones válidas de la sincromodalidad. Por último, faltan evidencias empíricas de que se cree una diferenciación logística como resultado de aplicar la sincromodalidad. Teniendo en cuenta todas estas consideraciones, el presente estudio tiene como finalidad profundizar en la teoría y comprender mejor la sincromodalidad mediante el desarrollo conceptual y la validación empírica de un instrumento para medir su constructo.

Aplicando una exhaustiva metodología basada en cuatro etapas desarrollamos el constructo de sincromodalidad. Utilizando una revisión sistemática de la literatura y entrevistas a expertos sobre el terreno, diferenciamos las cuatro dimensiones en el constructo de sincromodalidad: visibilidad, flexibilidad, integración y sistema operativo. Seguidamente, se propone una escala de medición de 20 ítems para sincromodalidad que fue depurada y validada con posterioridad en un ensayo piloto dejándola en una escala de 15 ítems. Planteamos cinco modelos para describir el constructo de sincromodalidad: un modelo de primer orden con un factor, un modelo de primer orden con cuatro factores no correlacionados, un modelo de primer orden con cuatro factores correlacionados, un modelo de segundo orden con cuatro factores y un modelo de segundo orden con cuatro factores con errores correlacionados para corregir especificaciones incorrectas. Tras comparar y verificar los diferentes modelos, encontramos evidencias que apuntaban a la sincromodalidad como constructo multidimensional de segundo orden que engloba flexibilidad, visibilidad, integración y sistema operativo.

El presente estudio puede verse como un punto de partida para los gestores de las cadenas de suministro y transporte - empresas expedidoras y T&LSPs - que barajen la implantación de la sincromodalidad en sus operaciones diarias. Esta investigación presenta asimismo una herramienta de diagnóstico para que los profesionales de las cadenas de suministro y transporte evalúen la capacidad sincromodal de su empresa y establezcan un lenguaje común para identificar, implantar y gestionar aspectos relativos a la sincromodalidad. Por lo demás, nuestro marco de cuatro dimensiones empíricamente validado, ayudaría a los gestores a concebir la parte de transporte de su cadena de suministro no como una mera implementación operacional sino de forma holística para operar con la flexibilidad, la visibilidad y la integración como pilares básicos de la cadena de suministro. En consecuencia, el estudio no solo sienta las bases de las capacidades y los recursos que deben generar las empresas que desean establecer la sincromodalidad con los distintos socios y colaboradores de su cadena de suministro, sino que además corrobora la hipótesis teórica de que la sincromodalidad crea ventaja competitiva a través de la diferenciación logística.

Pregunta de investigación 3: ¿En qué medida la sincromodalidad propicia cadenas de suministro más resilientes y eficientes?

Tomando como fundamento las investigaciones disponibles sobre sincromodalidad (Zhang & Pel, 2016; Dong, et al., 2018), nuestro estudio ayuda a comprender los efectos de este concepto novedoso y popular. Hasta ahora, los pocos estudios publicados se han basado en casos únicos (Lucassen & Dogger, 2012; Zhang & Pel, 2016) o simulaciones (Kapetanis, et al., 2016; Lin, et al., 2016; Li, et al., 2017; Van Riessen, et al., 2017). Lin et al. (2016) y Dong et al. (2018) afirmaron que la sincromodalidad estaba relacionada con la eficiencia, mientras Lee and Song (2017) determinaron una relación positiva con la resiliencia. Aunque comenzamos nuestro análisis considerando que las hipótesis teóricas sobre el efecto de los resultados operacionales de la sincromodalidad no se han probado empíricamente, nuestra investigación presenta evidencias sobre estos resultados. Para ello, esta investigación aplica un análisis de ecuaciones estructurales SEM que prueba de forma empírica una marcada relación estadísticamente significativa entre sincromodalidad y eficiencia y resiliencia. Esto implica que las empresas que fomentan un entorno sincromodal en sus operaciones diarias son más eficientes desde la perspectiva de la logística y el transporte, y además son menos proclives a las disrupciones, entre otras cosas porque las dimensiones necesarias para aplicar la sincromodalidad requieren una mayor conciencia situacional.

Complementamos nuestros hallazgos del análisis SEM aplicando un enfoque configuracional. La relación no significativa de los dos efectos de sincromodalidad entre sí, nos llevó a replantear en el equilibrio previamente examinado entre cadenas de suministro resilientes y eficientes. Por consiguiente, abordamos esta dicotomía con un planteamiento configuracional. Nuestra investigación contribuye a la literatura existente sobre desempeño logístico y amplía las investigaciones anteriores sobre la relación entre eficiencia and resiliencia. Hasta donde sabemos, la nuestra es la primeras investigación en adoptar un enfoque configuracional para explorar esta relación, y para ello presentamos un método innovador para analizar distintos patrones en cadenas de suministro sincromodales. Algunos estudios previos relevaron la existencia de una relación inversa entre eficiencia y resiliencia (Ivanov, et al., 2014), mientras otros señalaban una relación directa entre estos dos resultados operativos (Shukla, et al., 2011; Birkie, 2016). Nuestro estudio configuracional basado en un análisis de clústeres indica que sólo se podrá realizar un examen en profundidad de la relación entre eficiencia y resiliencia si se consideran en conjunto todas las dimensiones de la sincromodalidad, como se demuestra en H3 y H4. Definimos tres patrones o perfiles diferenciados en nuestro estudio atendiendo a la dimensiones de eficiencia y resiliencia: desempeño desigual, desempeño moderado y alto desempeño.

Nuestros hallazgos confirman diferencias significativas en los niveles de eficiencia y resiliencia con referencia a los tres patrones de configuración analizados y dependiendo del nivel de sincromodalidad alcanzado por las cadenas de suministro. Los niveles bajos de sincromodalidad se asocian con los grados más bajos de desempeño, lo que refuerza la idea de que las cadenas de suministro sincromodales presentan una ventaja competitiva en cuanto a resiliencia y eficiencia. Las empresas que desarrollan un nivel de sincromodalidad superior a la media consiguen un equilibrio óptimo entre resiliencia y eficiencia e incrementan ambos parámetros simultáneamente. No obstante, también observamos que alcanzar niveles elevados de sincromodalidad no incrementa necesariamente la eficiencia de la cadena de suministro. Estos resultados interesantes concuerdan con la teoría existente a nivel genérico y confirman la hipótesis de que no existe una relación única entre resiliencia y eficiencia en el contexto sincromodal. El nivel más alto de resiliencia caracteriza a los grupos con desempeño desigual y alto, mientras que el grupo de empresas con un desempeño moderado presentan un nivel de resiliencia modesto. Por otra parte, las empresas con desempeño desigual y moderado registran niveles de eficiencia inferiores al promedio, mientras que los niveles máximos de eficiencia corresponden a las empresas del grupo con alto desempeño.

Así pues, cabe deducir que la sincromodalidad y la resiliencia se alían en detrimento de la eficiencia. Tomando como referencia empresas con los niveles más bajos de sincromodalidad (clúster 2, *desempeño moderado*), observamos que las empresas sincromodales que presentan niveles algo más elevados de flexibilidad, visibilidad e integración (clúster 3, *desempeño alto*) no solo aumentan su grado sincromodal sino que además amplían la resiliencia y la eficiencia de la cadena de suministro en la que operan. Sin embargo, en el caso de las empresas sincromodales que hacen un esfuerzo adicional, reforzar su flexibilidad y sistema operativo redunda en un incremento de la resiliencia con una disminución considerable de la eficiencia del sistema (clúster 1, *desempeño desigual*). Una explicación posible a este comportamiento es que las cadenas de suministro sincromodales que aspiran a lograr altos niveles de sincromodalidad y resiliencia deben realizar inversiones adicionales en activos y recursos que, en consecuencia, las hacen menos eficientes. Parece que las empresas que desean aplicar la sincromodalidad necesitan desarrollar un nivel óptimo de flexibilidad, visibilidad, integración y sistemas operativos para poder ganar resiliencia sin comprometer la rentabilidad total de la cadena de suministro. Finalmente, nuestro análisis proporciona evidencias de resultados extremos. Por tanto, aquellas empresas que operan en entornos de alto riesgo cuya meta principal es minimizar las disrupciones pueden beneficiarse de las operaciones sincromodales, puesto que esto incrementa notablemente su resiliencia manteniendo niveles moderados de eficiencia.

Pregunta de investigación 4: ¿Hasta qué punto una SCRM activa, combinada con el despliegue de estructuras colaborativas y formales de gestión de riesgos en la cadena de suministro, reduce la propensión a sufrir determinadas disrupciones?

La complejidad creciente a la que se enfrentan las cadenas de suministro globales, unida a la mayor competencia en la industria, convierte a las estrategias SCRM en herramientas clave para los planes de gestión de la cadena de suministro. Para entender mejor cómo una SCRM activa puede contribuir a aliviar estas disrupciones, investigamos dos aspectos distintos del proceso SCRM que incluyen la formalización de una estructura activa de gestión de riesgos, mediante la puesta en marcha de un plan de continuidad del negocio, y una colaboración dinámica con los distintos proveedores y clientes de la cadena de suministro (Lavastre, et al., 2014). Analizamos los efectos de adoptar de un modo aislado un enfoque de SCRM formalizada y colaborativa.

Nuestros hallazgos sugieren que las empresas han de elegir su enfoque SCRM según el tipo de disrupción que más les preocupe. Aquellas empresas que operen en mercados volátiles, por ejemplo cuando la demanda tiende a sufrir cambios dramáticos e impredecibles, deberían desarrollar estrategias SCRM colaborativas, en especial si se trata de grandes empresas manufactureras. Lo mismo puede decirse de las empresas que necesitan gestionar altos niveles de incertidumbre y vulnerabilidades en sus operaciones de transporte y logística. Por ejemplo, podríamos pensar en empresas que operan en economías emergentes que no logran atraer y retener personal capacitado, con perturbaciones por cierres de fronteras imprevistos u otros riesgos operativos tales como retrasos y cuellos de botella causados por el número creciente de buques más grandes. En este caso, las prácticas colaborativas podrían reducir de forma considerable la propensión a sufrir disrupciones. Para abordar riesgos operativos, la formalización de una infraestructura de gestión de riesgos parece funcionar en el caso de disrupciones internas, aunque nuestros resultados sugieren que es mejor invertir en prácticas colaborativas de gestión para combatir riesgos de proveedores.

Por lo demás, nuestro análisis demuestra el efecto que tienen el tamaño de la empresa y su contexto operativo sobre la propensión a sufrir una disrupción dependiendo del enfoque SCRM adoptado. Si bien las grandes empresas pueden beneficiarse de las prácticas colaborativas, la aplicación de enfoques formales en gestión del riesgo reduciría notablemente los riesgos de las pequeñas empresas asociados con sus propias operaciones internas. Si tenemos en cuenta el efecto que estos dos enfoques tienen sobre las empresas según el tipo de industria a la que pertenecen, observamos que las empresas manufactureras presentan en promedio una mayor propensión a sufrir disrupciones y que una combinación de enfoques colaborativos y formales ayudaría a reducir significativamente los cuatro riesgos analizados en este estudio.

Limitaciones e investigación futura

Esta tesis doctoral, como todo trabajo de investigación, presenta varias limitaciones que a su vez apuntan hacia ampliaciones y propuestas interesantes de investigación futura.

El Capítulo 4 utiliza exclusivamente datos de empresas globales de transporte y logística con sede en Europa. Aunque la sincromodalidad es un concepto que ha nacido en Europa, resultaría interesante replicarlo en otras áreas geográficas con un mercado de transporte y logística fuerte, por ejemplo, América del Norte o Asia. Asimismo, esta investigación se centra en la red logística de una empresa manufacturera en una industria concreta, pero también convendría ampliar la investigación a otros contextos de red, tales como las industrias electrónicas o de automoción, pues en ellas la intermodalidada es ya una práctica habitual y la sincromodalidad podría reportar beneficios adicionales. Dicha ampliación ayudaría a validar la generalización del marco conceptual propuesto y el correspondiente modelo de medición. Un análisis longitudinal de los efectos de alianzas estratégicas que apliquen la sincromodalidad también arrojaría luz sobre este nuevo concepto. Una reproducción de la investigación a lo largo del tiempo, complementada con datos operacionales, ayudaría a analizar el efecto que tiene la consolidación de la sincromodalidad en el rendimiento logístico y, al mismo tiempo, permitiría un segundo análisis de la endogeneidad del modelo. Finalmente, sería interesante complementar el presente estudio con la utilización de datos secundarios integrando en el modelo datos objetivos de desempeño de las empresas que participaron en la encuesta.

Por último, proponemos que se continúe esta investigación con un análisis de los resultados que cabría esperar de la adopción de este concepto novedoso en las cadenas de suministro, en lo que concierne a sostenibilidad, resiliencia o eficiencia, así como el impacto de posibles variables mediadoras o moderadoras.

Si bien el trabajo presentado en el Capítulo 5 está destinado al público tanto académico como empresarial, se requieren más estudios para comprender a fondo el efecto de la sincromodalidad y sus resultados. A medida que el concepto y la implantación de la sincromodalidad maduren y se expandan a un mayor número de países, los investigadores, en un futuro, podrían recabar información de otras fuentes, tales como datos secundarios, y comparar sus hallazgos con los de este estudio. Por ejemplo, los datos utilizados en este estudio son transversales, pero el uso de datos longitudinales podría aportar información complementaria sobre la evolución de las relaciones entre dimensiones de la sincromodalidad y resultados en capacidad de respuesta y optimización del desempeño. Convendría ahondar también en cómo los niveles de eficiencia y resiliencia de las cadenas de suministro sincromodales evolucionan con el desarrollo de alianzas estratégicas entre expedidores y proveedores logísticos. Finalmente, nuestra investigación se centró en la red de transporte y logística de un expedidor perteneciente a un mercado manufacturero específico. Sería interesante ver si los resultados obtenidos pueden extrapolarse a otras industrias, como los alimentos no perecederos o la tecnología, con diferentes limitaciones temporales y requisitos de envío.

Para concluir, el Capítulo 6 incluye un trabajo explorativo basado en un análisis econométrico acompañado de una encuesta global con resultados agregados. Sería útil complementar esta investigación analizando los efectos de otros mecanismos de moderación, tales como el grado de internacionalización de las empresas o el control central/local de las operaciones gestión de riesgos. Se necesitarían quizá datos adicionales para aumentar el tamaño muestral y trabajar con una metodología econométrica como la AIPW (Augmented Inverse Propensity Weighted estimator). Asimismo, las características del responsable de la toma de decisiones sobre aspectos de riesgo en la cadena de suministro, del tipo nivel educativo, especialización dentro de la cadena de suministro y experiencia laboral previa, pueden influir en la actitud de la empresa hacia el riesgo y su percepción de qué forma debe adoptar la SCRM. Del mismo modo, el género de la persona responsable de los riesgos en la cadena de suministro puede afectar al enfoque de riesgo aplicado por la empresa, ya que algunos estudios señalan que la actitud hacia el riesgo varía con el género. Así pues, merecería la pena explorar en qué medida el perfil de los gestores de riesgos en la cadena de suministro afecta a la percepción de la empresa sobre los riesgos y sus planteamientos de gestión.

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Doctor in Philosophy in Logistics and Supply Chain Management

Abstract

In the current highly competitive environment, companies around the globe are looking for innovative ways to increase their supply chain resilience while maintaining their operational efficiency and competitive advantage. In this dissertation, we analyze the creation of resilience focusing on two aspects. First, we study the novel transportation concept of synchromodality and its effect on resiliency and efficiency. Secondly, we explore the resiliency effect Supply Chain Risk Management (SCRM) quantifying the reduction of disruptive events.

Synchromodality is a novel transportation concept that integrates the use of different transport modes based on real time information. Synchromodality is envisioned as an operational approach to improve performance targets in terms of efficiency and resilience, with the added potential to create a competitive advantage through logistics differentiation. However, the existing research is in an incipient stage, there is no consensus on the mechanisms that create a synchromodal supply chain and its results have not been empirically studied. To fill this gap, we present a thorough analysis of synchromodality and its underlying dimensions. Subsequently, using a four-stages methodology, synchromodality is operationalized as a multidimensional construct formed by 4 dimensions (visibility, flexibility, integration and operating system). A structural equation model confirms its relationship with logistics differentiation as a measure of competitive advantage. This analysis provides a holistic approach of the concept of synchromodality, advancing in its understanding from an operations management perspective and setting the foundations of the supply chain capabilities that companies pursuing synchromodality should develop.

Building on the developed research of synchromodality, we analyze the effect that its implementation has in the supply chain in terms of efficiency and resilience. Based on data from 157 logistics companies involved with a shipper currently implementing synchromodality in Europe, we present a structural equation model that analyzes the relationship between synchromodality, efficiency and resilience. Additionally, we use a configurational approach and a cluster analysis to further advance on the understanding of the efficiency-resilience relationship based on different synchromodal contexts measured by the four identified dimensions of synchromodality. Our findings indicate that that companies that promote a synchromodal environment in their operations are not only more efficient from a logistics and transportation perspective, but they are also less prone to disruptions. However, the levels of efficiency and resilience will differ based on the level of synchromodality achieved by the supply chain.

Secondly, the study of resilience has drove the attention of researchers towards the analysis of certain supply chain risk management practices, such as collaboration and process formalization. However, there is a lack of research presenting a quantification of the effects of these practices, which lead us to explore how collaborative and formal Supply Chain Risk Management (SCRM) can contribute to a reduction of the propensity to suffer a disruptive event. To estimate these effects, we develop a multivalued treatment effect methodology based on experimental analysis and apply it to global dataset of 1,461 respondents from 69 countries. To conclude, we analyze the moderation effect that firm size and industry type has on the type of risk management approach when dealing with different disruptions. Our research suggests that collaborative SCRM approaches are more effective on large manufacturing firms operating in volatile market environments, while formal SCRM structures benefits the most small and medium companies dealing with operational risks.

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Chapter 1

Introduction

1.1. Background

Since globalization interrupted firm's operation in the early 1990's, many firms have focused their resources on supply chain operational initiatives to increase revenues, reduce costs and create a sustained competitive advantage (Hendricks & Singhal, 2003; Sodhi, et al., 2012). However, these initiatives, that in most cases involve offshore outsourcing, make supply chains longer, more fragmented, more complex and, overall, more expose to risks and vulnerable to disruptions (Craighead, et al., 2017).

During the past decade many studies have attempted to list and classify the different type of risks that supply chains face (Harland, et al., 2003; Jüttner, et al., 2003; Chopra & Sodhi, 2004; Christopher & Peck, 2004; Hallikas, et al., 2004; Jüttner, 2005; Trkman & McCormack, 2009). One of the most widely known classifications is the one proposed by Chopra and Sodhi (2004), in which the authors classify risks into nine categories (disruption, delays system, forecast, intellectual property, procurement, receivables and inventory) according to their cause. Others, like Christopher (2005), Kiser and Cantrell (2006) and Trkman and McCormack (2009) classify risks external or internal to the supply chain. As such, external risks will be those that are caused by natural disasters, wars or government-impose restrictions, while internal risks relate to supply chain operational and managerial decisions.

There are many examples in the literature of significant supply chain disruptions starting with the Taiwan earthquake of 1999, a disaster that severely affected major companies around the globe, like Apple and Dell, whose main PC component suppliers' manufacturing capacity and stockage was heavily compromised (Papadakis & Ziemba, 2001). The 9/11 terrorist attach forced the closure of the US air space, which consequently affected manufacturing firms all over the world such as Ford was forced to closed five plants for several days (Sheffi, 2015). In

2000, Ericsson's reported losses of $2.34 billion after its sole semiconductor plant caught on fire (Norrman & Jansson, 2004; Sodhi, et al., 2012). In 2001, Land Rover laid off 1,400 employees after a key supplier became insolvent (Sodhi, et al., 2012). In 2015, Chipotle suffer a significant drop in sales during three consecutive quarters due to a lack of quality control that led to a serious outbreak of E. coli and norovirus (Oyedele, 2016). However, disruptions should not be seen as isolated events affecting just one company, as many disruptions are the consequence of unforeseen events that end up simultaneously affecting a numerous number of global companies, like hurricane Katrina in 2004, the volcanic eruption in Iceland in 2010, the Japanese earthquake in 2011, the Rana Plaza collapse in 2013, Los Angeles port strike in 2014 or the Hanjin financial collapse in 2016 (Chopra & Sodhi, 2004; Sheffi, 2005; Saenz & Revilla, 2014; Sheffi, 2015). Fortunately, previous industry experiences suggest that the negative effects of supply chain disruptions can be effectively mitigated through the right implementation of supply chain risk management strategies. Additionally, supply chain researchers and practitioners have been working for the past decades on the development of risk management and resilience creation strategies to avoid, control and mitigate the negative effects of disruptions (Ho, et al., 2015).

The search of new trends and SCRM strategies has been, with a few exceptions such as Esper et al. (2007), Sanchez et al. (2015) or Wallenburg and Schäffler (2016) concentrated on the buyer-supplier product relationship, leaving aside transportation and logistics companies - although these companies can also play a key role in the optimization and value creation of the supply chain in the time of disruption. For example, during the 2010 volcanic eruption in Iceland, shippers working with FedEx were able to resume normal operation sooner than other affected firms thanks to the company's flexibility in switching transportation modes (Saenz et al., 2018).

Motivated by the search of new trends, companies have started to look at their transportation and logistics partners as strategic supply chain enablers rather than mere commodities that can be easily substituted if the price is not low enough. At the same time, governmental institutions are also looking at ways to encourage freight movers to make more effective and sustainable use of resources (McKinnon, 2015; Dong et al., 2018). With these objectives in mind, researchers have been studying ways in which supply chains can involve their logistics partners to create more resiliency and efficiency (Oonk, 2016). One of these concepts is synchromodality, which was first proposed in 2010 (Reis, 2015).

Synchromodality is defined as multimodal and mode-free transportation planning in which shippers and logistic companies work in an integrated and flexible way, making operational decisions based on real-time information from stakeholders, customers, and other involved agents (Pfoser, et al., 2016; Dong, et al., 2018). It has emerged as an innovative concept towards a more sustainable, efficient, mode balance and optimized freight service network (ALICE, 2015; Dong, et al., 2018). However, synchromodality is still at an incipient stage (Kurapati, et al., 2017; Dong, et al., 2018) and yet, to our knowledge, no study has presented it from a unified and holistic perspective. As a result, current theory and understanding of the practices leading to synchromodality is uncomplete, and additional research is needed to comprehend the theoretical and applied aspects of synchromodality in both managerial and practical ways.

Even though synchromodality benefits have been largely theoretically hypothesized (ALICE, 2015; Zhang & Pel, 2016) and several pilot projects are being implemented in Europe, only a limited number of studies have analyzed its benefits (Kurapati, et al., 2017). The study carried out by Dong et al. (2018) concluded that the application of synchromodality could lead to an increase in efficiency, while research presented by Zhang and Pel (2016) or Lee and Song (2017) suggests that the adoption of synchromodality can create a competitive advantage in the event of a disruption, leading to more resilient supply chains, which contributes to position this novel concept as a promising operational management research topic as disruptions in the supply chain can represent up to a 40% reduction in stock returns (Hendricks & Singhal, 2005). Consequently, one of the main goals of this dissertation is to delve in the understanding of the concept of synchromodality, its antecedents and outcomes in terms of efficiency and resilience.

A common practice among successful global firms operating in disruptive contexts is the implementation of a Supply Chain Risk Management plan. Supply Chain Risk Management (SCRM) becomes decisive in successfully managing business processes in a proactively manner (Lavastre, et al., 2012). It is based in the understanding of the vulnerabilities of the supply chain, the risks it faces and the planning of the adequate responses (Lavastre, et al., 2012). However, there is no single supply chain risk management approach that could be generalized. Consequently, SCRM plans should not be seen as static or simple one-size-fits-all formulae that would, with minor adjustments, serve all firms. Companies need to understand the environment in which they operate, the vulnerabilities they face and how an active work with other members of the supply chain can help them to better face disruptions. The first thing that companies do to face vulnerabilities and mitigate potential disruptions is to develop an active risk management strategy within their operations. However, not all firms materialize their work on SCRM through a formal structure in the form of dedicated personnel and departments that follow what is widely known as a Business Continuity Plan (BCP). Additionally, it should be noted that many of the vulnerabilities that firms face are externally caused by other supply chain partners (key suppliers, transportation and logistics partners…) and by the environment where the firm is operating. Consequently, it makes sense to deploy collaborative risk management practices to deal with disruptions.

The remainder of this chapter is structured as follows. In section 1.2, we highlight the scope and structure of the thesis, presenting the research questions further developed during the dissertation. In section 1.3, we present the methodology used in each of the chapters to address our research questions. Finally, in section 1.4, we discuss the main contribution of this thesis.

1.2. Scope and outline of the thesis

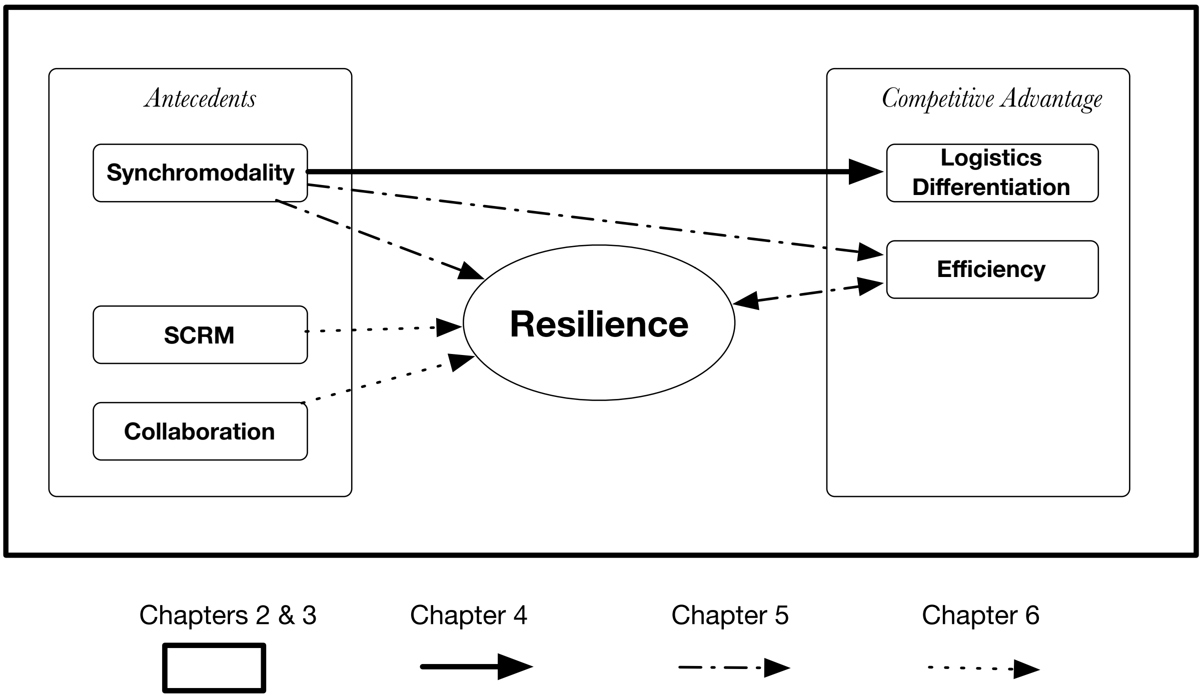
The structure and content of this dissertation is motivated by the search and understanding of new trends that can contribute to the development of supply chain resilience and generate, as a consequence, competitive advantage. In particular, we are going to focus on the concept of synchromodality, analyzing this novel transportation concept from a holistic perspective and studying its effects on supply chain efficiency and resilience. Additionally, we will analyze how the implementation of formal and collaborative SCRM structure can reduce the propensity of suffering a disruption. Table 1.1 outlines the structure of the dissertation and summarizes the research questions that the thesis aims to answer. The relationships analyzed in the different chapters of the thesis are presented in Figure 1.1: Dissertation relationships.

Table 1.1: Structure of the dissertation

Research Questions and Business Concerns		Thesis Contents		Publications
What are the latest trends on SCRM mitigation processes that lead resilience and competitive advantage?	→	Chapter 2: Managerial Motivation Chapter 3: Academic Literature Review and Gaps Identification	→	Paper #1 (Annex 2.1.) and Book Chapter
Which are the supply chain capabilities that companies pursuing synchromodality should develop and how it affects the creation of competitive advantage?	→	Chapter 4: Synchromodal and the effect on logistics differentiation: construct development and empirical examination	→	Paper #2
To what extent does synchromodality lead to more resilient and efficient supply chains?	→	Chapter 5: The trade-offs of Resilience and Efficiency in Synchromodal Supply Chains: An Empirical Analysis	→	Paper #3
How does and active SCRM, along with the deployment of collaborative and formal supply chain risk management structure can reduce the propensity to suffer certain disruptions	→	Chapter 6: Implementation of a collaborative and formal supply chain risk management structure on disruption minimization	→	Paper #4

Chapters 2 and 3 focus of the antecedents and practices that lead to supply chain resilience. In particular, Chapter 2 presents a summary of the most successful SCRM practices that have been analyzed up to this day from a managerial perspective. It throws some light on how by the deployment of a right SCRM plan, companies can face their risks, reduce the impact of disruptions and gain competitive advantage. Some of the findings from this chapter were used in the first peer-review publication of this dissertation (refer to Annex 2.1). Chapter 3 presents the resilience concept, its antecedent and consequences from an academic point of view. It presents a literature review of resilience that is used to identify both the gaps on the literature and potential avenues for future research. The work done in this chapter is used as the foundation to design and develop the survey questionnaire that will be used to test the models of chapters 4 and 5. Chapter 4 analyzes the concept of synchromodality from an empirical perspective and studies the effect of its implementation on logistics differentiation. This chapter is written in a paper format and represents the second paper of this dissertation. Chapter 5 goes in depth in the synchromodality approach by analyzing two of its most mentioned outcomes: resilience and efficiency. Additionally, it analyses the relationship between efficiency and resilience in synchromodal context. This chapter, also presented in a paper format, represents the third paper of the dissertation. Chapter 6 uses an explorative approach to analyze how SCRM processes can benefit from the formalization of a risk management structure and also from collaborative strategies by reducing the propensity of disruption occurrences. This chapters uses a second survey that was developed by the MIT Global SCALE Risk Initiative and launched in collaboration with several supply chain and logistics professional associations. As the two previous sections, this chapter will be translated as the fourth paper of the thesis. Finally, chapter 7 summarizes the main conclusions and managerial implications of the dissertation and establishes avenues for future research.

Figure 1.1: Dissertation relationships



1.3. Methodology

The present dissertation uses a combination of empirical methodologies, including qualitative and quantitative research techniques, such as expert interviews, exploratory factor analysis, confirmatory factor analysis, structural equation modelling, cluster analysis and econometric analysis. The different methodologies are explained below.

Chapter 4 explores the novel transportation approach of synchromodality and its potential to create competitive advantage measured by logistics differentiation. With a multi-research methodology based on a four-stages approach, this paper conceptualizes, develops, and validates a new measurement model that reflects the multidimensional nature of synchromodality. In the first two stages, grounded in a systematic literature review and expert interviews, a conceptual framework is defined based on four dimensions: flexibility, visibility, integration, and operational system. Synchromodality is consequently operationalized as a multidimensional construct, and the measures are refined using a pilot test. The third research stage uses confirmatory factor analysis (CFA) to analyze the data collected in a survey, whose results confirm that synchromodality can be operationalized as a second-order factor consisting of 4 dimensions. Finally, a SEM path analysis helps to confirm the effect of synchromodality on logistics differentiation as a measure of competitive advantage.

The paper developed in chapter 5 extends the developing body of literature on synchromodality, studying its impact on supply chain efficiency and resilience. In our survey research, we collected data from 157 European logistics companies with global coverage. Structural equation modeling was used to assess the relationship of synchromodality with efficiency and resilience. The results from the path model provide evidence of a significant relationship between synchromodality, efficiency, and resilience. Furthermore, this study aimed to shed light on the relationship between efficiency and resilience, as existing research presents conflicting theories. Based on a configurational approach, a cluster analysis was used to develop a taxonomy of the efficiency-resilience relationship based on different synchromodal contexts measured by the four underlying dimensions of synchromodality (visibility, flexibility, integration, and operating systems).

The last chapter, chapter 6, presents an initial attempt to understand how different approaches of Supply Chain Risk Management plans, based on structure formalization and collaboration, can contribute to a reduction of the propensity of suffering disruptive events. Drawing on a global data set collected through the MIT Global SCALE Risk Initiative and several supply chain professional institutions, we gathered data from 1,461 supply chain managers at risk management decision-making level. Using a multivalued treatment effect econometric methodology, we estimate the causal effects (measured as expected potential means and average treatment effects) that the implementation of formalization and collaborative mechanisms on the firm's SCRM process has on disruptions caused by internal, supplier, market and transportation related risks. Additionally, we analyze the moderate effect that firm size and industry type has on the type of SCRM approach when dealing with different risks.

1.4. Contribution

With the increasing concern of supply chain companies to increase their competitive advantage, the search for new trends to increase resilience and efficiency has positioned itself in the center of the research agenda of academics, practitioners and policy makers, and as such the European Union or the Organization for Economic Cooperation and Development. This thesis begins in Chapter 2 with a thorough analysis of the supply chain risk management best practices that global companies have successfully implemented in their daily operations and that have help them to obtain a competitive advantage during disruptive times. This analysis was used in the already published paper "*Aligning supply chain design for boosting resilience*" by Sáenz, M.J., Revilla, E. and Acero, B. (2018) which analyzes how the application of the previously mentioned successful SCRM practices can help in the design of the supply chain that balances both proactive and reactive capabilities to mitigate and disruptive incidents.

The analysis presented in Chapter 2 is complemented in Chapter 3 with an academic analysis of the supply chain capabilities and new trends that leads to resilience, identifying the existing research gaps and potential research avenues not only for the present dissertation but for future research. Consequently, this thesis investigates two of these trends: synchromodality and active SCRM and finds that (1) the implementation of synchromodality increases both the resilience and efficiency of the supply chains; and (2) the active SCRM along with formalization of the risk management processes and collaboration strategies can reduce the propensity to suffer certain type of disruptions.

In Chapter 4, we analyze the novel transportation and logistics concept of synchromodality and found out that despite the increasing expectation received from the past years from researchers, practitioners and even policy makers in the EU, there was a lack of theoretical and empirical studies, and the few studies that exist are based on two case studies. Additionally, there is still no consensus on the definition of synchromodality, mainly due to a lack of agreed conceptual framework. Consequently, we developed a comprehensive four-stage methodology (figure 4.3) to develop and validate a new construct in operations management, based on the work done by Menor and Roth (2007) and Chan et al. (2016). This methodology identifies the underlying dimensions of the construct based on a systematic literature review and interviews with field experts. Then, the measurement item scales are developed and subsequently purify and validate using a pilot test composed of supply chain and logistics experts and faculties. Finally, to determine the type of model that best defined the relationship between synchromodality and its defining dimensions, several measurement models are hypothesized and tested. To our knowledge, this is the first study that not only provides a holistic approach to synchromodality but operationalize it as a construct, providing valid and reliable measures. Furthermore, no other previous study has been published providing empirical evidence of the role that synchromodality has on logistics differentiation creation.

Chapter 5 builds upon the work developed in Chapter 4 by analyzing and providing empirical evidence of the implications that the application of synchromodality has on the overall supply chain. The systematic literature review performed in Chapter 4 showed that even though theoretical research agrees upon the benefits of synchromodality, there is limited evidence on how synchromodal supply chains possess a competitive advantage when compared to traditional ones. As such, most researchers point out towards more resilient and efficient supply chains, but studies are limited to several case studies and some simulation analysis (Zhang & Pel, 2016; Dong, et al., 2018). Consequently, to the best of our knowledge, this is the first study that empirically analyzed the implications of applying synchromodality to the overall supply chain. However, we do not stop here, and we develop a taxonomy of efficiency and resilience based on the level of both synchromodality and its underlying dimensions. Finally, although most studies have focused on supply chain efficiency or resilience either separately (Ambulkar, et al., 2015; Liu, et al., 2018) or in terms of trade-offs (Birkie, 2016; Saenz, et al., 2018), this study goes further by empirically proving the dual impact that synchromodality and its four underlying dimensions have on resilience and efficiency at the same time.

Finally, Chapter 6 explores how an active SCRM along with formalization of the risk management processes and collaboration strategies affect the propensity to have certain type of disruptions. To the best of our knowledge, no research study has analyzed how the implementation of these practices can help in the development of active SCRM process to reduce disruption occurrences. Additionally, this paper presents an innovative methodology that has rarely been applied in the supply chain management field but that has been largely used in econometric studies to analyze treatment effects. With it, we will assess the causal relationships between supply chain risk management practices and disruption minimization.

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Chapter 2

Managerial Motivation

2.1. Introduction

This chapter presents a literature review on the latest supply chain risk management trends that global companies all over the world are developing. We hereby introduce the concept of supply chain risk and supply chain risk management, reviewing the best practices that companies have been successfully implementing in their operations. This work was used in the paper *Aligning supply chain design for boosting resilience* published by *Business Horizons* and included in Annex A (Saenz, et al., 2018).

2.2. Supply Chain Risks

In the past decades, we have witnessed how globalization helped companies not only to position themselves in international markets and increase sales, but also to minimize operating costs through the outsource of commodities and workforce. With this objective, companies relied on global value networks. However, as supply chains span around the globe, the number of sourced commodities and products are larger and so are the number of suppliers, warehouses and distribution center locations, all of these increasing operational complexities. These so-called efficiency practices are deployed to gain economic and operational competitiveness; however, they have also made supply chains more vulnerable (Tang, 2006) which translates into a loss of efficiency if risks are not controlled (Chopra & Sodhi, 2004). In fact, Hendricks and Singhal (2005) reported that disruptions in the supply chain translated into 33-40% reduction in stock returns relative to similar industries that did not suffer said disruption.

Supply chain risk studies started to develop in the aftermath of the Taiwan earthquake of 1999. This disaster severely affected Apple and Dell, among other major global companies, that relied on local PC component suppliers whose manufacturing capacity and stockage was compromised (Papadakis & Ziemba, 2001). Since then, other major natural disruptions like hurricane Katrina in 2004, the volcanic eruption in Iceland in 2010, the Thailand floods or the Japanese earthquake in 2011 have attracted academics and practitioners from the supply chain field (Chopra & Sodhi, 2004; Sheffi, 2005a; Saenz & Revilla, 2014). However, major disruptions are not necessarily the result of natural hazards as they can be direct or indirect consequences of terrorist attacks (Sheffi, 2001), suppliers' insolvency, economic crisis, fuel price and exchange rates fluctuation, or even cyber-attacks (Chopra & Sodhi, 2004; Geriant, 2014).

Even though several multiple definitions for risk have been developed either by researchers or practitioners (Rao & Goldsby, 2009; Ho, et al., 2015), we will adopt the definition of risk presented by Rowe (1980, p.23) as the potential for unwanted or negative consequences of an event or activity. When talking about supply chain risks, a distinction between operational risks and disruptions is needed. The first ones refer to inherent uncertainties that relates to supply and demand, while the latter refers to major breaches due to man-made or natural disasters such as terrorist attacks, economic crisis, hurricanes or earthquakes (Tang, 2006). Probably major natural disasters such as hurricanes or earthquakes and terrorist acts are among the disruptions with more severe consequences. Sheffi (2001) was one of the first authors to analyze terrorist disruptions in the aftermath of 9/11, studying the strategies that companies should follow to mitigate the effects of acts of terrorism.

Many authors have attempted to classify risks and, as a result there is not a universal classification. Chopra and Sodhi (2004) classify risks into nine categories based on the cause of those risks (disruption, delays system, forecast, intellectual property, procurement, receivables and inventory), identifying the drivers of each of them. Christopher (2005) classifies risks as external to the supply chain (natural disasters, wars, terrorism and epidemics or government-imposed legal restrictions), or internal risks (resulting from managerial decisions and supply chain structure).

Other authors, however, classify risks according to their nature. Kleindorfer and Germaine (2005) classify supply chain risks in three major groups: 1) Operational contingencies, 2) Natural hazards earthquakes, hurricanes and storms, and 3) terrorism and political instability. Rao and Goldsby (2009) classify risks in three large categories: 1) by the source of risk, 2) by the nature of its impact and 3) by the extent of its influence. While others like Tang and Tomlin (2008) expand that classification into six major groups: supply risks, process risks, demand risks, intellectual property risks, behavioral risks and political social risks. Trkman and McCormack (2009) suggest that supply chain risks are not only environmental disruptions or other discrete events, but the result of the continuous changes in the company's surrounding, classifying risks according to the sources of uncertainty:

1. Endogenous: the source of the risk exists within the supply chain and can lead to changes in the relationships between the company and its supplier. An example of endogenous based risks would be market and technology turbulence.
2. Exogenous: the source of the risk is external to the supply chain. These risks could be divided into discrete (terrorist attacks, contagious diseases, strikes) and continuous (inflation rate, changes in the consumer price index).

In the same way as researchers have attempted to classify risks, disruptions have also received an increased attention. (Kleindorfer & Germaine, 2005) divide disruptions in three categories according to the source they arose from:

1. Operational contingencies, such as equipment malfunction, systemic failures, bankruptcy on a main supplier or strikes, among others.
2. Natural hazards earthquakes, hurricanes and storms
3. Terrorism and political instability

Probably major natural disasters such as hurricanes or earthquakes and terrorist acts are among the disruptions with more severe consequences. Sheffi (2001) was one of the first authors to analyze terrorist disruptions in the aftermath of 9/11, studying the strategies that companies should follow to mitigate the effects of acts of terrorism. Some of the major disruptions that have occurred in the past years and that we can recurrently find in the academic and consulting literature are:

Table 2.1: Major supply chain disruptions

Disruption	Year	Main Companies affected	Reference
Hurricane Mitch	1998	Dole	(Sodhi, et al., 2012)
Taiwan Earthquake	1999	Dell, Inc Gateway, Inc Compaq Apple	(Papadakis & Ziembra, 2001; H. L. Lee, 2004; Tang, 2006)

Fire in a Phillips Fabricator, Albuquerque, NM	2000	Nokia Ericsson	(Sheffi, 2005b)
World Trade Center terrorist attack, US	2001	Ford Toyota	(Sheffi, 2001; Sodhi, et al., 2012)
Eruption of the Eyjafjallajokull Volcano in Iceland	2010	Time sensitive air shipment, such as flowers, fruits and other perishable goods.	(Lee & Preston, 2012; Allianz, 2013)
Japan's Earthquake and Tsunami	2011	Cisco Telecom	(Saenz & Revilla, 2013)
Thailand Flooding	2011	Siemens Dell	(Allianz, 2013)
Rana Plaza collapse	2013	Benetton JC Penney Primark Walmart	(Sheffi, 2015; Comyns & Franklin-Johnson, 2018)
Tianjin explosions	2015	Toyota Deer & Co.	(The Wall Street Journal, 2015)
Hanjin financial collapse	2016	Walmart Target JC Penny	(Saenz et al., 2018)

One of the most recent classifications of risks are the ones done by Tang and Musa (2011) and Ho et al. (2015), both of them done based on an extensive literature review of existing work. Tang and Musa (2011) group all risks in four major categories: (1) Material flow risk (source, make, deliver and supply chain scope), (2) Financial flow risk (exchange rate, price and cost, financial strength of supply chain partners and financial handling and practice), (3) Information flow risk (information accuracy and information system security and disruption) and (4) Intellectual property (information outsourcing); while Ho et al. (2015) develop a classification based on seven categories: (1) macro risks, (2) demand risks, (3) manufacturing risks, (4) supply risks, (5) financial risks, (7) information risks and (7) general risks.

From the different classifications, it can be observed that risks categorization has evolved towards a dynamic concept. As supply chains gets more global and new technology emerges, different disruptions take place, and as a consequence risks categorization evolves. Following this line of thought, risk analysis has progressively changed from a purely risk identification to a development of interconnected risks (World Economic Forum, 2015), evolving from a more conceptual approach based on the researchers' knowledge and experience with specific firms, to classifications based on large surveys made to companies operating in a global environment. In this regard, there are two publications worth mentioning: Geriant (2014) and Simchi-Levi et al. (2015). The first one categorized risk based on 962 surveys done between 2014 and 2015, while the latter bases its conclusion on surveys done to 209 global companies. Based on all these works, in Table .2, we present a new risk classification that could be used as a guideline to categorize the potential risk that different global supply chain organizations could face.

Table 2.2: Proposed Risk Categorization based on the literature reviewed

Category	Risk	Drivers
Disruption	Natural disaster	▪ Hurricanes ▪ Earthquakes ▪ Flooding
	Geopolitical instability	▪ War ▪ Terrorism ▪ Riots / civil conflict
	Operational	▪ Labor disputes ▪ Supplier bankruptcy ▪ Technology failure
Recurrent Risks	Supply	▪ Supplier solvency ▪ Supply quality ▪ Supply reliability ▪ Dependence on a single supplier ▪ Shortages of material
	Process	▪ Capacity ▪ Quality
	Demand	▪ Inaccurate forecast ▪ Inventory related risks (such as holding cost, obsolescence, overstocking, understocking) ▪ Bankruptcy of a critical customer
	Information / Behavioral	▪ Lack of upstream and downstream communication
	Financial	▪ Financial strength of partners ▪ Currency fluctuations ▪ Lack of credit ▪ Insolvency
	Legal / Political	▪ Regulatory policies (such as taxes, border, import/export restrictions) ▪ Lack of protection in intellectual property rights ▪ Counterfeit products
	Market	▪ Commodity price volatility ▪ Restricted number of suppliers ▪ Energy and fuel prices volatility

2.3. Supply Chain Risk Management

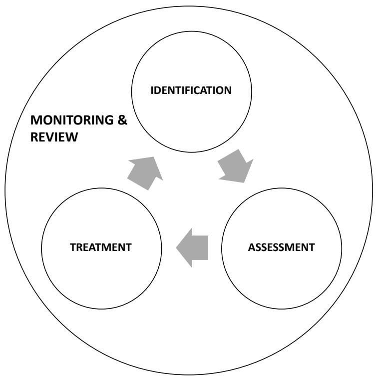
Supply Chain Risk Management was conceived as the group strategies and practices aimed to mitigate supply chain disruptions associated to different types of risks and is defined as "the management of supply chain risk through coordination or collaboration among the supply chain partners so as to ensure profitability and continuity" (Tang, 2006, p. 453). From a managerial perspective, Supply Chain Risk Management is defined by the Supply Chain Risk

Leadership Council (SCRLC) as the coordination of activities to direct and control an enterprise's end-to-end supply chain with regard to supply chain risks.

Supply Chain Risk Management practices are deployed in organizations with two main objectives: mitigation of risk and disruption effects and development of resilient supply chains to create competitive advantage. Jüttner et al. (2003, p. 9) define SCRM as the identification and management of risks for the supply chain, through a coordinated approach amongst supply chai members, to reduce supply chain vulnerability as a whole, where vulnerability is understood as the propensity of risk sources and risk drivers to outweigh risk mitigating strategies, thus causing adverse supply chain consequences.

Many companies, researchers, consulting firms and supply chain related institutions like SCRLC agree on the process to successfully control and mitigate risks and disruptions: Identification, Assessment, Treatment and Control and Monitoring.

Figure 2.1: Supply Chain Risk Management recommended approach (adapted from Dittman (2014))



Each of these steps will give answer to the questions presented in Figure 2.2

Figure 2.2: Supply Chain Risk Management stages (adapted from Dittman (2014))

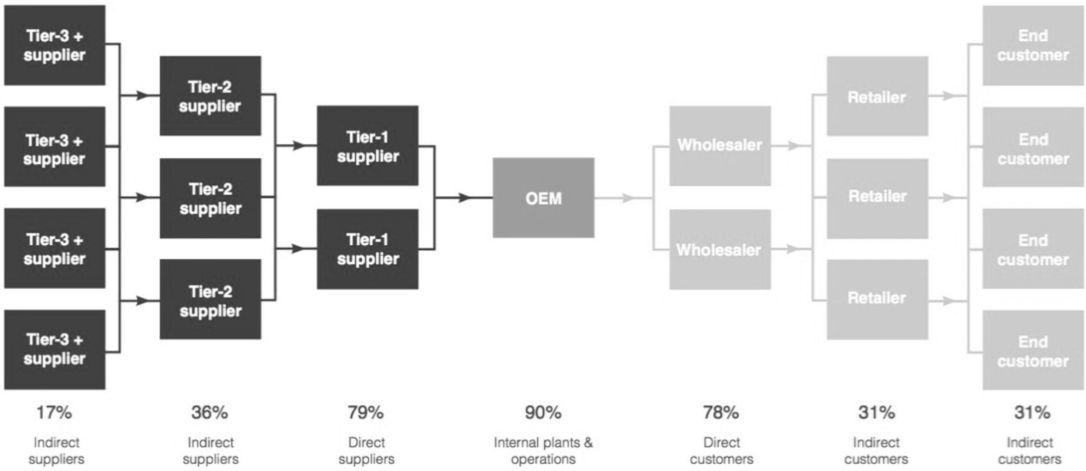
Identification	**Assessment**	**Treatment**	**Monitoring and Review**
• What can go wrong?	• What is the likelihood it will go wrong? What is the magnitude of the consequences and overall impact of the firm? • How quickly will the problem be discovered?	• What options are available to mitigate the risks? • What are the costs and benefits of each options?	• Is the treatment being properly implemented? • Has any situation occurred which implies a review of the identification assessment or treatment phase?

Identification

This first step in the process consists in the identification of all possible risks. Mapping the supply chain is a powerful tool as it helps not only to identify the risks but also to prioritize them. One of the advantages of mapping is that the whole supply chain can be analyzed at different levels of detail like geography, supplier or product line, which allows managers to identify dependencies (Simchi-Levi, et al., 2014) or discover previously hidden risks. For example, it was only when Ford Motors mapped its supply chain that it discovered that just 2% of their suppliers' sites would have a significant impact on the company's performance under a two-month shutdown scenario (Simchi-Levi, et al., 2014). If mapping is accompanying by KPIs, it can be a powerful tool to identify nodes or links representing a threat, so mitigation measures or contingency actions can be developed and implemented (Simchi-Levi, et al., 2014). Another relevant example would be CISCO, a company whose SCRM strategies have been widely studied and referenced as best practices, maps the location of their tier 1 suppliers to assess suppliers' risks. The location is also used to feed the company's incident-monitoring system (Saenz & Revilla, 2014; Sheffi, 2015).

Mapping the supply chain should not be limited to first or even second tier suppliers as it may not provide complete visibility of the supply chain, potentially hiding some undesirable and dangerous situation. In fact, over 40% of the disruptions are generated by second or lower tier suppliers (Business Continuity Institute, 2013). We could think about the case of all of a company's providers for a given component sharing the same sub-suppliers; or one of the suppliers engaging in a contractual relationship with a sub-supplier that does not comply with ethical or sustainable practices. For example, electronic manufacturer companies relying on mineral suppliers' face conflict mineral, traceability and human rights related scandals which could be translated into loss of sales. In these cases, companies such as Flextronics International Ltd map beyond 1st-tier suppliers using a platform developed by the Electronic Industry Citizenship Coalition and the Global e-Sustainability Initiative for tracking and reporting the use of conflict mineral (Sheffi, 2015).

Figure 2.3: Risk visibility across the supply chain (source Geriant (2014))



Ignoring or lacking control on sub-tier suppliers can generate serious ethical or brand image damage to the firm. For example, when in April 2013, the Rana Plaza factory complex collapsed, killing more than 1,100 workers in Bangladesh, many companies believed they were not affected. Walmart believe it was not affected as over a year before the collapse, the company had banned its only supplier working in the Rana Plaza complex. However, that same supplier was later subcontracted by an authorized Walmart's supplier, leaving Walmart exposed and affected by the disruption. Having had Walmart controlled of its sub-tier suppliers, Walmart's brand image would have not been affected in this terrible accident (Sheffi, 2015). The results of lack of control on sub-tier suppliers can have drastic consequences. In 1996, Nike lost more than half its market capitalization as a result of an image on the *Life* magazine showing a twelve-year-old boy sewing a Nike soccer ball for just six cents an hour (Sheffi, 2015).

Unfortunately, it is not always possible nor easy to map the supply chain beyond first tier, with many direct suppliers using competitive advantage as an excuse for not disclosing this information. For example, during the aftermath of the 2011 tsunami in Japan, half of Toyota's suppliers refused to provide information about their own suppliers. During a pilot program in 2012, Boeing discovered that among the suppliers who were willing to provide information about their suppliers, they actually refused to disclose sensitive information regarding dollar value of their business with them or Boeing's competitors (Geriant, 2014).

There are some tools that can help in this complicated and tedious work of mapping like the software ACHILES, Resilinc Corp, Razient, Metric-Stream or SOURCEMAP, developed by

MIT. There are also companies providing supply chain service companies mapping such as TradeMerit, CDC Software or Manhattan Associate. Other companies such as CISCO or IBM have developed their own in-house applications to map their own supply chain (Sheffi, 2015). The amount of risks identified through supply chain mapping can be overwhelming, depending on the complexity of the supply chain, hence a priorization of risks should also be implemented based, for example, on level of impact.

Apart from disruption risks, supply chains face recurrent risk, which are defined as those derived from daily operations such as inventory practices, demand fluctuations or supply demands (Chopra & Sodhi, 2014). For this reason, risk identification is an imperative step to focus resources on the threats that really matter, and it should be supported with the supply chain mapping. This identification might begin with brainstorming sessions of risks that will include purchases, supply chain, finance and quality managers and supplement the results of these meetings with information from previous risk assessments, surveys (Supply Chain Risk Leadership Council, 2011) and information from specialized publications. Risk identification can be done using analytical methods like the fuzzy set theory, Bayesian methods or Probability theory-based methods.

The Council of Supply Chain Management Professionals (CSCMP) and competitive Insights LLC developed *The Supply Chain Risk Identification Structure (SCRIS)*, a tool that provides a reference model for identifying, mitigating, and measuring supply chain risk. SCRIS takes overall business continuity risk and breaks it down into multiple categories and multiple tiers. Thus, it provides an excellent framework and checklist to manage overall supply chain risk. SCRIS can be used to develop supply chain risk management strategies. It also facilitates communications across the organization and the appropriate level of focus on supply chain risk management (Dittman, 2014).

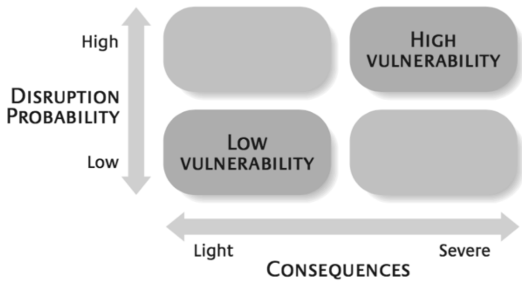
According to the Supply Chain Risk Leadership Council (Supply Chain Risk Leadership Council, 2011), during the identification process, firms should also take into account:

1. Number and location of suppliers
2. Number and origin of shipments
3. Contractual terms defining responsibility for shipping
4. Modes of transport and routes for shipments
5. Other logistics providers or partners involved in the supply chain

Assessment and Evaluation

Once risks are identified, the company should assess them and evaluate the potential consequences on the company's performance. Chopra and Sodhi (2004) and Sheffi and Rice Jr. (2005) established that risk assessment should be done based on two variables: disruption probability or likelihood of occurrence and magnitude of the impact. These two dimensions are widely agreed to be the basic dimensions of risks in the SCRM academic and managerial literature.

Figure 2.4: Preliminary risk assessment (source Sheffi and Rice Jr. (2005))



While the disruption probability can be measure using historical data, consequences should be measured in terms of financial, operational or strategic impact. However, this approach will only be useful when analyzing disruptions such as natural disasters but will not work for predicting a supplier bankruptcy or a fire in a warehouse. For that reason, trying to put numbers to predict risks can be a dangerous strategy and instead, companies should rethink their supply chain designs in order to achieve resiliency (Fisher, 2013; Saenz, et al., 2018).

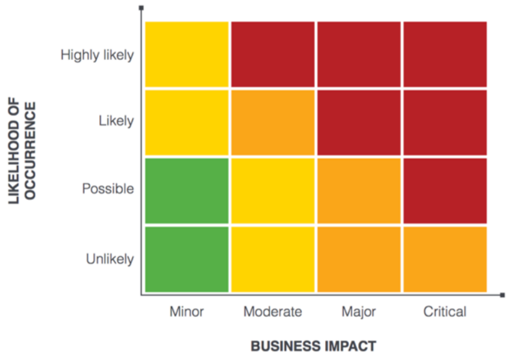
According to Dittman (2014) some companies use Failure Mode and Effect Analysis (FMEA) to prioritize risks, which is then summarized in Table 2..

Table 2.3: Example of risk prioritization technique (source Dittman (2014))

	Risk: Safety on product	**Risk: Freshness of Product**
Severity (1-10)	9	6
Probability of Occurrence (1-10) **High Probability =1** **Low Probability = 10**	2	4
Probability of Early Detection (1-10) **High Probability =1** **Low Probability = 10**	6	2
Probability Index **(Multiply three items above)**	108	48
Recommended Action	Purchase Insurance	Audit inventory and ensure stock rotation
Responsibility	Safety engineering	Third party with company oversight

Once risks are identified and prioritized, the next step should be determining what has caused the risk, which will help the organization to focus on the exact cause of the risk and optimize the allocation of resources. This step will help the enterprise to realize that risks cannot be avoided 100%, and some sort of risk-tolerance level should be developed (Supply Chain Risk Leadership Council, 2011). A useful tool to determine the tolerance frontier is the heat-map as shown in Figure 2..

Figure 2.5: Heat Map (source (Geriant, 2014))



The following step involves the quantification of the risks. Table 2. is an example of how a company tests different risk scenarios and evaluates the potential loss and the probability of occurrence.

Table 2.4: Example of risk quantification (source Dittman 2014)

Risk	Estimated Potential Loss ($/unit)	Subjective Probability of Occurrence	Net Loss Per Unit
Quality Failure	25.00	0.10	$2.50
Safety Failure	100.00	0.01	$1.00
Unexpected Demand Spike	30.00	0.25	$7.50
Currency Change	20.00	0.25	$5.00
Intellectual Property Problem	10.00	0.25	$2.50
Source Disruption, Force Majeure	30.00	0.10	$3.00
Port Problem	25.00	0.025	$0.62
		TOTAL	$22.12

However, we should note here, that the probability of occurrence is simply estimated by consensus and the results could largely vary if the external situations change or if the committee evaluating those figures do not have complete information. In the recent years, however, a new methodology has been developed to numerically evaluate risks . This methodology is based on two not so innovative concepts: Time to recovery (TTR) and Risk Exposure Index. The model helps managers to prioritize risks and distribute resources by mapping the supply chain and evaluating the impact of having a disruption on a given node (Simchi-Levi, et al., 2014).

Mitigation

Risk identification, evaluation and assessment enables the enterprise to understand its supply chain and its threats. Because these threats can be realized and generate real catastrophes, companies must take preventive measures. Successful supply chain risk management strategies are based on a deep knowledge of early detection strategies like disruption lead time (DLT) (Sheffi, 2015).

Depending on the nature of the disruption, detection lead time (DTL) can range from minutes to years and even take negative values. For example, preschedule events such as new regulations or contractual deadlines have detection lead times of months or even years, meteorological events may have detection lead times of no more than a couple of days, disruptions due to sudden events such as fire or terrorist attacks have DLT of zero, while disruptions due to cyber-attacks or quality issues, which are mostly discovered once they have occurred, have negative DLT (Sheffi, 2015). Others, like quality disruptions can take several weeks to be detected, for example: a manufacturing consumer product firm discovered a quality problem when it had two months' worth of defective supply in transit on the Pacific Ocean (Dittman, 2014). These types of situation could be reduced with the deployment of good practices. To that extent, Sheffi (2015) suggest developing a preventive strategy based on:

- ✓ Compliance with regulations and responsiveness to social concerns
- ✓ Good labor relationships
- ✓ Avoid situations prone to disruptions (geographical concentration of suppliers, political unstable countries….)

Other mitigating risk practices are summarized by Liberatore and J Miller (1998) and Jüttner et al. (2003), encompassing all mitigating actions in five big strategies or categories: Avoidance, Control, Co-operation and Flexibility.

Table 2.5: Risk Mitigation Strategies in Supply Chains (source: Jüttner et al. (2003))

Avoidance	• Dropping specific products/geographical markets/supplier and/or customer organizations
Control	• Vertical integration • Increased stockpiling and the use of buffer inventory • Maintaining excess capacity in productions, storage, handling and/or transport • Imposing contractual obligations on suppliers
Co-operation	• Joint efforts to improve supply chain visibility and understanding • Joint efforts to share risk-related information • Joint efforts to prepare supply chain continuity plans
Flexibility	• Postponement • Multiple sourcing • Localized sourcing

Sheffi (2015a, 2015b) proposes 9 strategies or best practices that leading companies follow to avoid disruptions: Monitor the weather, track the news, use sensor data, monitor the suppliers' database, visit suppliers, be alert for deception, develop traceability, monitor social media and track regulatory developments. We summarized these 9 strategies along with the best practices described by Sheffi (2015):

1. **Monitor the weather**
   Monitoring is especially useful and complementary of Business Continuity Plans. For example, UPS has a team of meteorologist working for its global operations center, so the company can anticipate to disruptions due to meteorological events. P&G developed in 2014 a new Winter BCP. The team monitor the weather via *accuweather* and based on this information, risks are identified and assessed. In the case of a severe weather threat, a bulletin is released to all operations facilities in the affected area. The bulletin is released 4-day prior the expected weather event and includes meteorological information of the event, and a 96-hour, 48-hour, 24-hour, 0-hour and recovery checklist that all affected facilities should rigorously follow. The checklist includes actions such as pulling forward orders, ensure emergency rations for workers, volunteer identification for overtime, ensuring all tractors have full tank of gas or stay in touch with authorities to assess roads conditions.
2. **Track the news** to quickly identify facilities or suppliers that could be affected by blocked roads, lockdowns or any other undesired situation caused by violent demonstrations, strikes or even shutdowns. Some companies such as NC4, Anvil, iJet or Cargonet offer event-monitoring services by collecting and selecting relevant news that could give hints of potential threats.
3. **Use sensor data** to gather real-time information such as shipment, inventory, cargo vehicles… Best practices include Walgreen Co., which uses in-store sensors to monitor

each of its 8,200 locations in the U.S. which allows the company to centralized information regarding safety, security and information response (for example, they monitor blackouts through electrical power sensors which let the company quickly respond with the right mitigation measures such as contacting the power company, dispatching generator or installing refrigerated trucks to recover perishable inventory like food or temperature-sensitive pharmaceuticals).

Scheneider National Inc, a provider of truckload, intermodal and logistics services, uses GPS sensors to improve freight security by tracking to containers and trailers. Dow Chemical Co. uses a similar procedure to track the location of trucks carrying hazardous materials. In this sense, if a given truck deviates from its schedule route, the system automatically alerts the company which can then take the necessary contingency measures. FedEx Corp's uses sensors to detect problems regarding location and status (pressure, temperature, light) while the packages are in transit.

4. **Monitor the supply base.** Mapping the suppliers might not be sufficient by itself. Some leading companies are also monitoring their key supplier's performances, strategy, quality failures, financial indexes or corporate social responsibility. An example of monitored indicators could include high employee turnover, operating losses, lack of capital investment missed deliveries, incomplete shipments or quality issues.

   Boston Scientific Corp., a worldwide developer, manufacturer and marketer of medical devices, created through brainstorming a list of 20 warning signs which were later used to monitored suppliers.

   Professor Christopher Craighead, from University of Tennessee, also believes that one of the most cost-effective mitigation strategies is monitoring the supplier's performance as it helps to unveil hidden risks or warm the organization that something at the supplier's side is not working properly (SupplyChainOpz, 2016).

   SAPinfonet has developed a system that crowd-sources supplier information from over 13,000 sources. It helps the company to anticipate the future behavior of suppliers by predicting future performance, proactively managing alternative supply continuity, understanding the impact of negative events affecting n-tier suppliers and triggering alerts based on user-defined risk thresholds (World Economic Forum, 2013).

5. **Visit suppliers.** When remote monitoring of the suppliers is not enough, companies visit suppliers and try to identify incipient signs of warning. Companies that are successfully doing this include EMC Corp, who visits suppliers looking for quality

problems, capacity reduction, stopped lines or excessive inventory; Shaw's Supermarkets Inc, who have personnel visiting farms to check product quality and food handling procedures; The Limited, a fashion retailer that also visit its suppliers looking for potential threats in working conditions or workplace safety with the objective to avoid sweatshops or child labor; and finally Ikea performs unannounced visits to suppliers mainly looking for flaws on environmental sustainability and working conditions.

6. Be on alert for **deception**, which implies doing recurrent quality test and be attentive to any signal that could imply that the company is being fouls played such as adulterer lab test results, record falsification or sugarcoating data. Companies like IKEA or Timberland rely on experienced auditors who can spot telltale signs during their unannounced visits.
7. Develop **traceability** capabilities which can enable the company to track product design defects, manufacturing errors or contaminations. For example, EU traceability rules was key to detect the contamination origin of milk showing high levels of dioxin. In 2013, Toyota, Honda, Nissan and Mazda had to recall over three million vehicles worldwide because of a quality issue in the airbags manufactured by Takata (Sheffi, 2015).
8. **Monitor social media** as it can alert of natural disasters even before than official channels. According to Paul Earle, a US Geological Survey seismologist, in some cases, it gives us a heads-up that it happened before it can be detected by a seismic wave. Social media such as Twitcident has been proven to provide real-time damage assessment. Following this strategy, Dell Inc., created a Social Media Listening Command Center to monitor via Twitter, Facebook and Dell.com product defect, negative product reviews or adverse consumer attitudes towards Dell products. This monitoring helps the company address overlooked problems and follow trends. BMW monitors suppliers and potential risks using social media. The company developed together with the Manchester Business School a system called Enterprise 2.0 which uses data from social media, blogs, chatrooms and other to gather information that can be used in real-time risk assessment (Geriant, 2014). Coca-Cola, on the other hand, uses its Customer Response Centers network to detect any risk such as water usage, waste treatment, fleet safety or product quality. This system is called The Hub (Geriant, 2014).
9. **Track regulatory developments** as changes in government policies and regulations can heavily affect the company regular operations. These changes can be expected with

months, so companies have time to prepare to those changes, others, unfortunately are announced with little time to react. On top of that, the continuous changes in country's laws and regulations, motivates the continuous monitoring of the supply chain risk management process.

However, best practices are not limited to this nine listed above. Other practices are:

10. **Supplier segmentation** can determine the most suitable mitigation strategy to be applied in each of the supply chain stages. Some examples of the strategies include Ford and BorgWarner. Ford tracks daily inventory levels for components supplied by critical suppliers, although with lower spend levels. BorgWarner uses the information from monitoring the supplier performance to allow its supply chain manager to reduce inventory safety stock (Geriant, 2014).
11. **Qualified alternative suppliers** to increase redundancies. Some companies like Toyota or Ericsson faced serious complications because they were not able to get alternative suppliers when one of their key and sole suppliers suffered a disruption. In this sense, some companies have invested in having alternative qualified suppliers, either waiting or in production. For example, Apple gradually shifted production from its primary contract manufacturer to other Taiwanese firms to diversify risks. Cisco identifies, through visibility tools, which suppliers are critical and also sole suppliers, to qualified alternative ones if needed (Geriant, 2014).

    Not all experts agree with the strategy of qualifying more suppliers. For Professor Christopher Tang states that this strategy is costly and instead, companies should look for more robust strategies such as using several suppliers in different locations (using this strategy Western Digital Corporation was minimally affected during the Thailand flooding disruptions) or through the use of dynamic pricing (after the Taiwan earthquake, Dell managed to meet the demand of its products by dynamic pricing and limiting the supply of the different products) (SupplyChainOpz, 2016).
12. **Segmentation**. Production segmentation is another mitigation strategy used by many companies that realized that globalization is can hardly hit their supply chains. For example, Diageo, a British multinational alcoholic drinking company, has divided its Asian supply chain into three categories according to the product complexity and demand predictability. It also uses 13 local manufacturing plants to timely serve customers and minimize the impact of their global supply chain (Geriant, 2014).

    Supply chain segmentation can also help to reduce transportation costs. For example, P&G's supply chains were designed in the 80s and 90s, when oil barrel price was about $10. At the time, P&G designed a more centralized production network with the primary objective of keeping capital spending and inventories to a minimum. With oil prices much higher today, the most cost-effective network is more distributed, with multiple plants even within a single country like China (Birchall & Rigby, 2008; Chopra & Sodhi, 2014).

13. Another best risk management practice worth mentioning is **flexibility**, which is the ability of a system, such as a manufacturing process, to cost effectively vary its output within a certain range a given time frame (Trent, 2015, p. p. 20).

Important SCRM researches such as Chopra, Sodhi, Sheffi and Lee have exposed in their studies that efficient companies such as Dell, Amazon or Wal-Mart have invested in the design of a flexible supply chain and have also excel at identifying risks within their supply chains in order to create powerful mitigating strategies (Chopra & Sodhi, 2004; Lee, 2004; Sheffi, 2005).

On March 2000, lighting hit an electric line in New Mexico causing power fluctuation throughout the state, causing a ten-minute fire in a small production cell plant at a sub-supplier of both Nokia and Ericsson. The fire dust destroyed all radio-frequency chips from both Nokia and Ericsson's sole supplier (Norrman & Jansson, 2004). However, Nokia's flexible supply chain design allowed them to quickly secure other sources while Ericsson struggled to respond (Trent, 2015), which resulted in losses of about $400 million. Other examples of disastrous consequences because of lack of flexibility and reliance in just one supplier includes the manufacturer Evonik or Toyota (Nishiguchi & Beaudet, 1998).

In March 2012, the resin manufacturer Evonik suffered an explosion in its plant in Marl, Germany. Evonik was one of the few world specialized manufactures in a resin called nylon 12, which is used in the manufacture of fuel tanks, brake components and seat fabrics. This major disruption, which took Evonik six months to restart production severely disrupted the production lines of major automaker firms like Ford. Surprisingly, all of them relied on the same supplier and had no previously identified or qualified any alternative resin supplier (Simchi-Levi, et al., 2014).

On February 1997, a fire destroyed one of the main Aisin's Kariya plants. Aisin Kariya was at the time of the incident, Toyota's sole supplier of p-valves, a simple, inexpensive but yet critical component in the brakes of all Toyota's car models. Because of Toyota's and Aisin's dedication to the principles of Just in Time, there was only up to three days' worth of stock on hand (Nishiguchi & Beaudet, 1998). Toyota faced one of the worst crises in its history which caused loses of 70,000 vehicles (~$325million) and $195 million in costs (Norrman & Jansson, 2004).

However, Toyota didn't seem to learn its lesson. On July 16, 2007, a magnitude 6.8 earthquake in Japan severely damaged the facilities of Riken Corp., which supplies piston ring to all major Japanese carmakers as Toyota. It is worth noting that piston rings had a cost of $1.5. Toyota was forced to cease production at all of its 12 domestic plants, causing a production delay of 55,000 vehicles. Other companies such Honda, Nissan, Mitsubishi or Mazda were also affected although at a lower scale. Two main causes were behind of the severe consequences that Toyota faced because of Riken disruption (Chozick, 2007; Pettit, et al., 2013):

- Rinken had located all of its plants in a single area of Japan in aim of efficiency. This concentration made them more vulnerable to a natural catastrophe.
- Toyota and Riken worked following the just-in-time philosophy, keeping inventory as low as possible.

On December 2001, UPF-Thomson unexpectedly claimed for bankruptcy. UPF-Thomson was Land Rover sole supplier of chassis frames for the Discovery four wheels' models. In order to avoid a halt in its production, Land Rover had no choice but finance UPF and even pay off some of its debt in order to continue production of the chassis while finding an alternative supplier. Having Land Rover had not concentrated all the chassis components on one supplier or at least had identified alternatives suppliers, they would have not incurred in financial losses, as they could have rapidly switched their chassis frame purchases to a different company (Christopher, 2005; Sheffi, 2005). On the contrary, Samsung Electronics always try to have at least two suppliers for each component (Sodhi & Lee, 2007). The challenge here resides in finding the right balance between cost increment due to the reduction of concentration and resources and the desirable reduction of supply chain fragility.

Dell Computer has redesigned its supply chain to support its expansion from make-to-order online sales into retail sales. It has now developed four different supply chains, each one dedicated to a different customer segment, which provides much more flexibility to respond to a wider array of market opportunities (Trent, 2015).

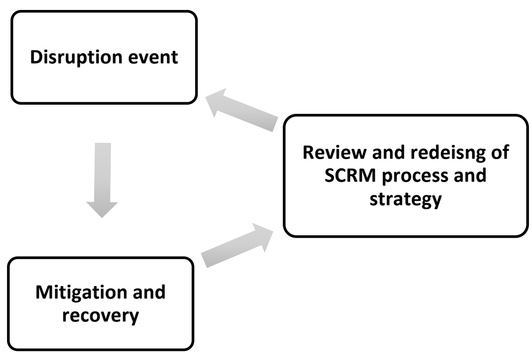
14. **Cooperation** and partnership should not be overlooked as a best practice strategy. We could illustrate it with two examples (World Economic Forum, 2013):
    - TradeXchange® is a multi-agency initiative led by Singapore Customs, Economic Development Board and Infocom Development Authority of Singapore (IDA), which works as a platform in which shippers and freight forwarders can exchange information and launch collaboration efforts, enabling flexibility and rapid collective response to supply chain anomalies (see more at http://www.customs.gov.sg/about-us/national-single-window/tradexchange#sthash.YXdPDumN.dpuf).
    - Toyota established in 1943 the Kyohokai Association, a cooperative association which now includes 221 of the Toyota suppliers and through it, they regularly gather to discuss about supply chain issues (see more at http://www.toyota-global.com/company/history_of_toyota/75years/data/automotive_business/production/purchasing/nihokai/index.html).
15. **Monitor international political instability**, although this should not be a major concern, it should be monitored depending on the countries of import and export (Dittman, 2014). For example, Egyptair has addressed this risk by creating stable schedules in certain markets and more flexible ones in those countries with an uncertain scenario.
16. **Insurance.** One of the latest strategies in supply chain management, impulse by insurance companies like Zurich and Allianz, but this has not been studied in detailed by any researcher or academic.
17. **Data and Predictive Analytics**. Although it is not very widely spread, the latest techniques in data analytics and predictive analytics can help to make better decisions. TESCO for example uses data analytics to make better decisions related to forecasting. Predictive analytics help to identify potential risks in their supply chains before they cause disruptions. BorgWarner, an automotive industry, developed a mathematical model based on hidden Markov theories that predicts the likelihood of supplier's risk by analyzing performance data (Geriant, 2014).
18. **Visualization**. HP, CISCO and IBM are relevant examples of companies that successfully employ technology to visualize and assess risks within their supply chain. CISCO used a heat-map during the Japanese earthquake as a communication tool showing the impact of the disaster on specific suppliers. HP employs visualization to

optimize its network and IBM uses geospatial mapping to track meteorological or political events that could eventually threat its supply chain (Geriant, 2014).

Monitoring and Review

All the steps described above should not be taken as a static one-time process and should be periodically reviewed. Some external disruptions, such as those due to meteorological events may not change over time, but most risks (such as those due to internal processes), should band together with a monitoring program, evaluating plans, procedures, and capabilities through periodic review, testing, post incident report and any other monitoring plan (Supply Chain Risk Leadership Council, 2011; SupplyChainOpz, 2016). Whenever a disruption occurs, an analysis should follow to help evaluate the causes and also to do quality and internal controls. This are made to understand what happened, to identify any possible internal breaks and finally to understand what can be done in the future to avoid another disruption from the same source. Lessons learned from previous disruptions represent a useful tool to develop new strategy plan to avoid future disruptions.

Figure 2.6: Dynamism of the SCRM process



2.4. Conclusion

Globalization, continuous changes in technology and complexity in markets makes companies more vulnerable, more exposed to risks but also in a continuous need to increase their competitive advantage (Sodhi, et al., 2012) (Jajja, et al., 2018). Additionally, the widespread with catastrophic and large scale consequences of what were initially localized incidents such as the fire at a semiconductor plant in New Mexico (Norrman & Jansson, 2004), an earthquake in Japan (Saenz & Revilla, 2014) or a volcanic eruption in the remote Iceland (Lee & Preston, 2012), have encouraged companies to invest in prevention measures and risk management control processes (Ho, et al., 2015). As such, successful companies in disruptive times deployed their Supply Chain Risk Management plan that becomes decisive in managing risks and disruptions.

The present chapter summarizes some of the most successful managerial practices that global corporations have been successfully implementing in their daily supply chain operations and that have resulted not only in a disruption minimization but also in a creation of competitive advantage with respect to other companies operating in the same market. However, to successfully implement the aforementioned practices, companies first need to develop a series of supply chain capabilities that are required to create resilience, such as flexibility, visibility, integration, agility or collaboration among others. Additionally, new research studies suggest that novel trends such as synchromodality or less researched capabilities such as ambidexterity or cooperation will also increase the firm's resilience. In the following chapter, Chapter 3, we will present these concepts, their relation in resilience creation and we will explore potential gaps not yet addressed.

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ANNEX 2.1 – Aligning Supply Chain Design for Boosting Resilience

The present Annex includes the paper *Aligning supply chain design for boosting resilience* published in Vol. 61, 2018 in Business Horizons Journal.

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Aligning supply chain design for boosting resilience

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KEYWORDS
Supply chain risk;
Disruptions;
Supply chain vulnerabilities;
Resilience;
Supply chain design

Abstract Many researchers have analyzed the effect of disruptive events, such as natural disasters and economic and market forces, on global supply chains. However, there is a lack of consensus on delineating a universal collection of supply chain risk management practices that will help companies operate in a global market with large-scale disruptions. In this article, we present an analysis, in conjunction with a worldwide online survey, based on successful global brands and their supply chains. We propose a framework that deploys the dynamics of building supply chain resilience, first linking the design of the supply chain portfolio (local versus global scope, as well as strategic responsiveness versus cost reduction) with supply chain vulnerabilities (external versus internal). We describe the transition between different supply chain structures as a way of coping with disruptions and thus proactively developing resilience. In this article, we introduce both a supply chain risk management approach and the reactive-by-deployment mode, as illustrated by successful global company examples.

1. Supply chain risk management

Supply chain risk management received international attention in the aftermath of the September 11 terror attacks, when disruptions in the transportation system revealed the fragility of companies that relied on just-in-time practices and offshore production (Sheffi, 2015). In particular, supply chain

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risk management became a much-needed research topic after Hurricane Katrina in 2005, the Japanese earthquake and tsunami in 2011, and most recently, the horrific fire in a clothing factory in Bangladesh, which caused serious disruptions to the global supply chain. Currently, we are facing more such disruptions. For example, closed-border policies due to international immigration tensions, terrorist attacks that limit freight transportation, and problems resulting from high-impact political situations such as the U.K.'s Brexit are all disruptive events that restrict international trade. Apart from the humanitarian and social effects, these types of events are revealing the vulnerability of value networks.

Such disparities illustrate that many companies need a solid and holistic strategy to respond adequately to large-scale disruptions. One of the most worrisome conclusions that can be drawn from these recent major events is that most firms ignore or fail to recognize high-impact risks. Moreover, even among companies that recognize such risks, many neglect to assess the potential impact in sufficient detail and cannot respond accordingly. Many managers continue to struggle to create contingency rules and procedures for complex, dynamic, and high-risk business situations. In this regard, the MIT Scale Network study reported that approximately 60% of managers do not actively engage in supply chain risk management or simply consider such actions as ineffective (Saenz & Revilla, 2014).

Consequently, one of the objectives of this article is to answer this question: Why, despite our accumulated knowledge of dealing with disasters and companies' extensive experience in building and running global market supply chains, do so many enterprises still struggle to cope with large-scale disruptions?

In our view, one answer is that risk management is still a relatively new discipline in the supply chain management field. A lack of quick wins to provide momentum to efforts has resulted in a lack of effective managerial guidance in developing a framework when deploying risk management practices and selecting the best supply chain structures and associated strategies. Additionally, this article addresses another important question: How can companies cope with these disruptive events and build resilience while minimally impacting their value chain?

The main contribution of this article is to analyze the dynamics of reactive and proactive risk management to create resilience in supply chains through a holistic vision that begins when companies initially design a product and its supply chain. We propose that companies should first analyze their competitive strategies in terms of market competition and develop their different supply chains accordingly without losing sight of the assumed risks. Companies might require a supply chain based on cost reduction versus responsiveness. As such, local and global suppliers must be an integral part of company plans and scenarios given our current trend of globalization. A thorough understanding of the sources of vulnerabilities is also essential. Companies must be able to develop and implement the most effective risk management tools for their particular supply chains. We have proposed a closed-loop framework that integrates the close relationships between supply chain design and building resilience in a dynamic setting that can be used by any enterprise regardless of operation area.

We also analyzed and contrasted the most relevant risk management orientations with the practices that successful companies use regarding supply chain risk management. Our innovative framework integrates proactive and reactive risk management and uses robust tools and best practices from companies whose supply chain risk management has been tested during major disruptions. Proactive risk management should be rooted by design to provide resilience in products and corresponding supply chains. At the same time, such efforts should be integrated with reactive risk management tools deployed and customized according to the specific disruptive episode.

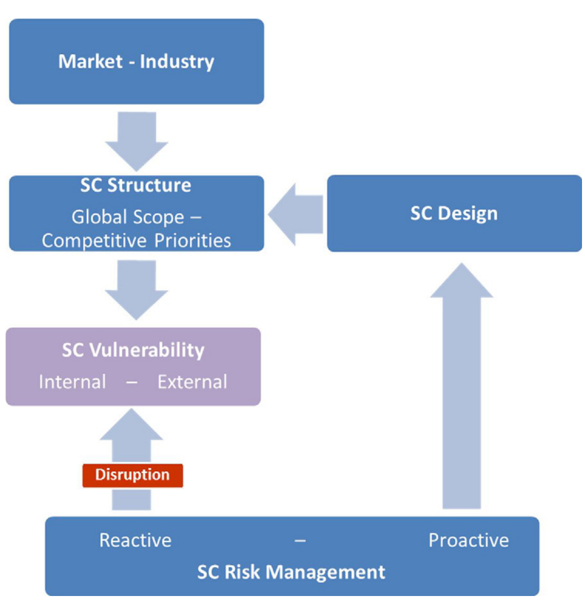
This article is structured as follows. We start by introducing the framework that tackles the dynamics of building supply chain resilience. We then deploy each sequence of steps, illustrated with relevant and practical examples from companies. We examine the main characteristics for structuring and designing a supply chain and their implications for levels of vulnerabilities. We illustrate four different supply chain scenarios, briefly reviewing existing best practices of well-known companies in the supply chain arena. A description of proactive and reactive supply chain risk management follows. We describe how a proactive approach provides the feedback connection with the origin of supply chain design. In the Appendix, we present our research methodology.

2. Dynamic supply chain design: The origin and the end

Companies adopt supply chains based on an industry's idiosyncrasies. A deep understanding of why supply chains are designed in a given way helps managers identify vulnerabilities and implement risk mitigation measures. This leads us to the concept of supply chain resilience by design. That is, companies should design and build their supply chains not only with the objective of optimizing operational procedures, but also with the goal of achieving resilience.

The way in which a supply chain is designed to tackle both market and industry mandates efficiently has important implications for dealing with potential supply chain risks. Once companies envision their target market strategically, they must consider the particular design of the supply chain and take into account two main characteristics: the supply chain scope (local or global) and competitive priorities (responsiveness or cost-reduction). At this stage, it is important to understand the vulnerabilities that such a type of supply chain implies, both from internal and external sources. This knowledge can help to design and achieve a resilient supply chain dynamically adapted to respond to unexpected changes and anticipated disruptions by continuous monitoring and an understanding of its vulnerabilities. Figure 1 illustrates the dynamics of this framework and shows how the proactive mitigation approach creates a closed-loop process. This process ensures that the supply chain is protected by inherently resilient capabilities and prepares the reactive tools for deployment in the event of a disruption. In Sections 2.1—2.2, we develop each of the constitutive elements of this framework.

Figure 1. The dynamics of building supply chain resilience



2.1. Supply chain competitive priorities: Cost reduction versus responsiveness

The first step in building supply chain resilience is determining whether the company's supply chain is cost-oriented or based on market responsiveness. The cost reduction-oriented approach means prioritizing supply chain cost minimization above other objectives. Examples of these types of supply chains would include those from industry areas such as commodities, mining, or mature markets in which demand is relatively stable. When the order-to-delivery requirement is the top priority, responsiveness becomes the key strategic objective. Market-responsive businesses compete in terms of product customization, market segmentation, and demand modification (Waller, Dabholkar, & Gentry, 2000). Examples of industries that follow this competitive orientation include companies that offer high-service levels, as well as those operating in highly unpredictable demand markets and short lead-time markets. In the cost reduction-oriented case, business channels are driven by the final price, which requires a low-cost supply chain. In the responsiveness case, business channels demand a particular time-horizon delivery time, which requires a responsive and fast supply chain (Table 1).

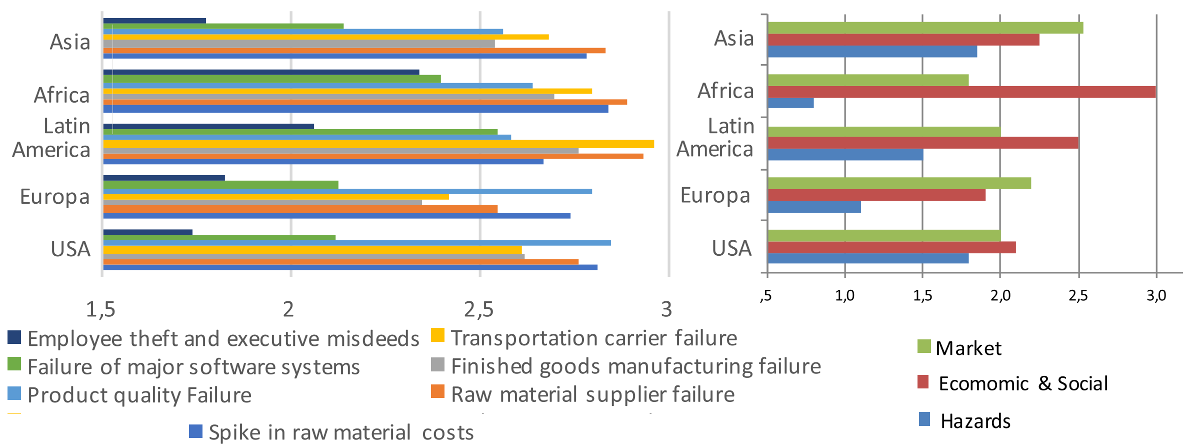
A continuum of tradeoffs exists for competitive priorities between responsiveness and cost-reduction orientation since each of these approaches requires a distinctively different supply chain. These categories should not be viewed as dichotomous (i.e., one supply chain must fall into one group), but rather as a spectrum with two extreme strategic types as end points. Therefore, the key decisions in supply chain design lie in leveraging the most efficient source for cost and speed.

The following questions may help managers establish their supply chain priorities (Olavson, Lee, & DeNyse, 2010): What are the levels of customer responsiveness that we want to achieve in order to compete in certain sales channels? What are the financial goals of our business costs and market inventory in which we want to compete? However, depending on how the supply chain has been designed, companies have to face different intrinsic vulnerabilities (Park, Hong, & Roh, 2013). In the past decades, we have witnessed how sources of vulnerabilities within the supply chain—internal vulnerability—can bring disruptions to light in the normal flow of materials. Particularly, supply chain competitive priorities (responsiveness versus cost reduction) determine internal vulnerabilities within the supply chain, as represented in the exterior perimeter X-axis of Figure 2.

Table 1. Supply chain competitive priorities

Supply chain competitive priorities		
Supply chain responsiveness	**Supply chain cost optimization**	**Metrics**
Respond quickly/agility	Lowest possible cost	Lead times
Flexible inventory	Minimize inventory	Inventory turnover
Easier to customize	Low customization	Product configurations
Configured-to-order	Build-to-order	Number of SKU and number of standardized components

Figure 2. Types of internal and external sources of vulnerability per world region*



*See Appendix: Research methodology

Internal vulnerability sources have to do with the degree of tightness of connections, or fit, between the various parts of the supply chain system. Although cost-reduction strategies are used to create more rigid and tightly coupled systems, there is also a loss of process flexibility. Such a loss propagates problems and implies increased tension and conflict along the supply chain. As a result, the more supply chains evolve toward a cost-reduction orientation, the less flexible the supply chain will be in response to non-planned operational changes, and thus have higher internal vulnerability. Conversely, a supply chain designed for offering a greater market response provides a higher and faster reaction capability and consequently less vulnerability.

2.2. Supply chain scope: Local versus global

Supply chain strategy decisions should be accompanied by a definition of the supply chain scope, which falls into one of two categories: local or global (see Table 2). More favorable agreements with local key suppliers or logistics service providers could encourage a faster, seamless supply chain. Other decisions require evaluating the impact on global operations from different sources of supply chain cost reductions, such as outsourcing certain manufacturing functions to nations with lower labor prices, which would favor a global supply chain. However, these decisions may bring significant levels of supply chain

Table 2. Supply chain global scope features

Supply chain global scope		
Supply chain local	**Supply chain global**	**Metrics**
Compact	Dispersed	Number of supply chain nodes and dispersion
Intranational	International	Number of countries
Culturally homogeneous	Culturally heterogeneous	Cultural distance

dependence on globalization not only from global supply, but also to global networks as a response to global demand. Moreover, due to the increasing complexity of the markets in which companies operate, global supply chains are more prone to larger threats and uncertainties than local supply chains (Hohenstein, Feisel, Hartman, & Giunipero, 2015).

As companies expand their operations and value networks globally, the external environment also threatens companies' usual performances. Political upheavals, regulatory compliance mandates, increasing economic uncertainty, rapid changes in technology, diverse customer expectations, constraints in access to capacity, and natural disasters are examples of such external vulnerabilities. Figure 2 depicts external vulnerabilities in the Y-axis related to the supply chain feature of global scope.

External vulnerabilities cannot be reduced generally since they are not under the control of the supply chain manager or other such functional managers. External vulnerabilities are directly related to the degree of global operations within a supply chain. We recognize three categories of external vulnerabilities: hazards (fire, floods, hurricanes, earthquakes, or tsunamis), market forces (sudden demand change, price collapse, or competition), and economic or social forces (recession, labor instability, political events, or currency devaluation, among others).

2.3. Supply chain vulnerabilities: Internal versus external

According to the abovementioned view, global supply chains face global risks due to dynamic and volatile environments (changes in the economic, social, and labor markets, or in political contexts). Even though such supply chains benefit from global outsourcing, distance and cultural differences (which also makes them more vulnerable) may make them harder to control. According to the results of the MIT Scale Network study (see Appendix), the patterns of internal versus external vulnerability vary significantly between world regions. Figure 2 shows how internal sources of vulnerability play a variety of roles in different world regions such as, for instance, the degree of impact from raw material supplier failures in Asia compared with Europe.

In general, we conclude that although internal vulnerabilities occur more frequently than external vulnerabilities, the impacts are lower. This implies that supply chains should deploy different vulnerability monitoring mechanisms depending on the world region in which the company operates, keeping in mind that such mechanisms are not equally efficient in all regions.

2.4. Supply chain portfolio

Having determined the supply chain scope as well as its competitive priorities, we suggest managers integrate these two design characteristics into a matrix to identify the right design for every supply chain, such as one described in Figure 2. The four cells of the matrix represent the four possible combinations of supply chain scope and competitive priorities represented in four quadrants.

2.4.1. Responsive and global supply chains

Supply chains designed for high-value products imply that stockouts are expensive, and consequently, service levels should be more favorable to a responsive supply chain. One of the most widely studied companies using this type of strategy is Hewlett Packard (HP); its global postponement strategy allowed it to optimize resources and gain subsequent competitive advantages. Other companies such as Airbus devote entire business units to providing continuous, fast maintenance and support services, which requires a global supply chain network that is ready to offer immediate service when a plane is in need of technical on-site assistance. Tesla, the electric car manufacturing company, can also be framed in Quadrant A as it builds highly customizable vehicles that rely on a global supply chain. These are examples of global companies that can easily mitigate internal vulnerabilities using flexible inventory and agile responsiveness and thus have become more resilient (Christopher & Holweg, 2011).

2.4.2. Cost reduction and global supply chains

This type of supply chain typically includes high levels of standardized components required by simpler products manufactured or assembled in low-cost factories that have a clear cost-reduction orientation for their supply chains. One example of such a company is the well-known, low-priced fashion retailer Primark, which uses suppliers spread around the world. Its business strategy, based on a lean global tight network operation, makes it more vulnerable to disruptions, especially since external vulnerabilities can be accentuated by internal vulnerabilities. Such was the case when a devastating fire broke out at a Bangladeshi factory in 2013, killing more than 1,000 people and causing supply chain disruption and reputational damage for Primark and other retailers such as Walmart and Sears. These companies, looking for cost minimization, lost control of their supply chains and did not acknowledge having sub-tier suppliers in the collapsed factory (Sheffi, 2015).

2.4.3. Cost reduction and local supply chains

We can use the local scope analysis to identify examples of how competitive priorities and scope factors can have an impact in different companies. For example, perishable food supply chains provide a good example of local and cost-reduction features. This type of chain is used by companies such as Mercadona, the giant Spanish food retailer that relies on local bakeries for its pastries and baked items. Recognizing that customers appreciate local markets, the company's logistics operation supposes a higher percentage of the final product price, which requires minimal costs. In this case, the local scope of the suppliers allows Mercadona to also minimize the scope of potential internal vulnerability.

2.4.4. Responsive and local supply chains

Companies that provide products with long shelf lives can opt to use different supply chain strategies with remote sourcing. Whirlpool and its household appliances are centrally located in regional warehouses in order to reduce order-to-delivery time (Alsop, 2010). In this case, the supply chain derives its speed from storing inventory close to customers and from shipping by air from a dispersed manufacturers' network at a high-cost premium. These types of options for supply chain design afford lower levels of vulnerability, as companies can react quickly both in terms of geographical scope and operation flexibility in the event of a disruption.

However, in a complex environment, some companies do not fit into a single category, and it is hard to find a one-size-fits-all scheme. Some companies develop a supply chain portfolio depending on different markets or products they want to deploy. Take, for example, the case of retailer Zara, whose supply chains could be easily separated: one for basic garments and one for trendy clothing. Basic garments, like white T-shirts, are slow-moving items, with a stable and predictable demand that makes them suitable to outsource from distant global suppliers who aim to minimize costs (Quadrant B in Figure 2). However, Zara also represents trendy, fast-moving items that offer high variety at a cost of demand uncertainty, and thus requires a responsive strategy that depends on close European suppliers and fast reaction to unexpected demand changes (Quadrant D in Figure 2) (Chopra & Sodhi, 2014).

Starbucks is another company in which we can see two very distinct supply chains. In the U.S., unroasted coffee beans are supplied globally from Africa, Asia, and Latin America in ocean containers according to the company's Coffee Sourcing Guidelines (CSG) and CAFE guidelines (Coffee And Farmer Equity). Coffee producers are approved as suppliers and meet all of Starbuck's requirements for a green and sustainable supply chain (Quadrant A, Figure 2). On the other hand, freshly packaged savory food and sweets, dairy products, and beverage items are supplied locally because of their perishability, quality, and local taste (Quadrant C, Figure 2). Chipotle, on the other hand, mostly relies on local farmers to supply the restaurant needs of fresh products such as tomatoes or lettuce, which are then prepared in the kitchens.

In summary, globally dispersed companies are often under pressure to minimize costs while managing supply chain operations that are stretched across multiple countries. Opportunities for achieving higher levels of efficiency through price reduction versus responsiveness, and global versus local, are not without cost. Although efficiency helps to smooth supply chain operations, it might also open new sources of vulnerability if disruptions occur. Thus, understanding how the design of each type of supply chain determines its level of vulnerability becomes important. Moreover, this knowledge will also help managers recognize the need for alignment with comprehensive risk management approaches, as we will examine in the next section.

3. Aligning supply chain design and risk management for boosting resilience

The current turbulent environment and complex global value networks demonstrate that vulnerability should be carefully considered along with supply chain scope and competitive priority (Hohenstein et al., 2015). Taking into consideration the framework based on the matrix described in the previous section, managers working to achieve optimal efficiency in global supply chains must skillfully integrate the relationship between supply chain portfolios, the vulnerabilities it may face, and supply chain risk management.

A study of the scope of different supply chains, as well as competitive priorities and vulnerabilities, enabled us to devise various approaches to supply chain risk management and identify the best match of design requirements for managing disruption. We propose the use of two risk management approaches working in tandem in developing supply chain resilience, depicted in Figure 4, which complements and further develops Figure 1.

3.1. Proactivity through the supply chain design

In the first approach, companies should anticipate their actions to mitigate risks starting at product and process conception. Proactivity is achieved through the design of the product, the supply chain, and awareness of all risk components at each step to monitor resilience. Interactivity of these three components ensures that both products and supply chains are 'de-risked.' New product developers and designers embark on collaborative cross-functional activities to mitigate risks in terms of components, equipment, manufacturing sites, processes, and external services. Supply chain engineers work with technicians and analysts from manufacturing and purchasing functions, as well as in inter-organizational teams, collaborating upstream with key suppliers, downstream with vendors, and connecting nodes with logistics service providers providing flexibility to the network (Saenz & Revilla, 2014). This means not only designing the initial supply chain, but also dynamically redesigning it to mitigate the consequences of a particular disruption and help in post-disaster recovery. Such a design process implies transitioning between the four supply chain modification quadrants presented in Figure 3 to establish a dynamic network that can quickly change under adverse circumstances and is thus resilient by design.

Cisco is a company that has successfully learned, albeit the hard way, how to integrate a supply chain design and supply chain risk management in which proactive capabilities are continuously deployed (Saenz & Revilla, 2014). Cisco integrates risk awareness while innovating its product and supply chain. The company identifies product components with risk qualifications that are outside established tolerances in an effort to de-risk its supply chain. To monitor resilience, Cisco also uses an index to assess time-to-recover (TTR) for all capabilities, both while designing the supply chain and when confronting a particular disruption. The company also realized the importance of proactively analyzing cultural issues when managing risks. Such issues were treated as critically important when Cisco deployed its supply chain risk management in the face of the Japanese tsunami (Park et al., 2013). In regards to cultural considerations, some research has proposed learning about country idiosyncrasies as a proactive risk prevention and mitigation measure. A corporate crisis in China, for example, requires a clear a priori understanding of the unique Chinese conjuncture in terms of partnerships or relationships with key stakeholders, as well as in institutional contexts (Yang & Jiang, 2015).

3.2. Reactive by deployment

In the second approach, we elaborate on how companies can face disruption by being reactive by deployment, which complements the previous approach. Reactive supply chain risk management practices, through incident management and business continuity management plans, are limited to

Figure 3. Supply chain structure and its vulnerability

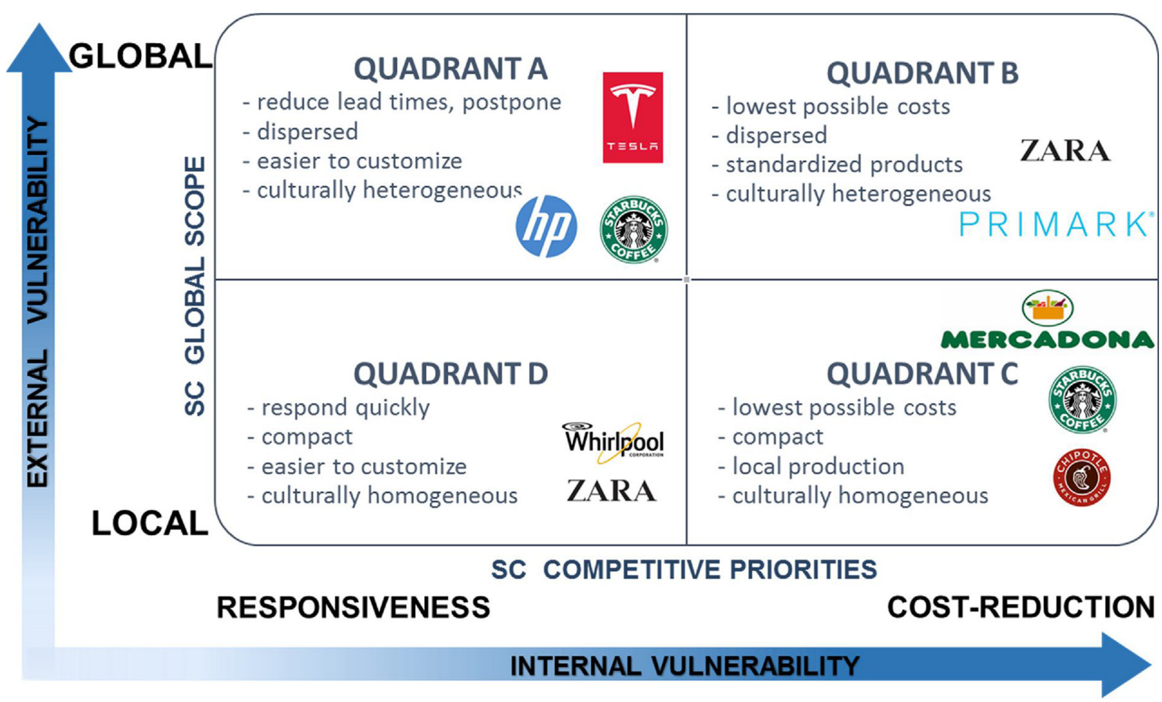
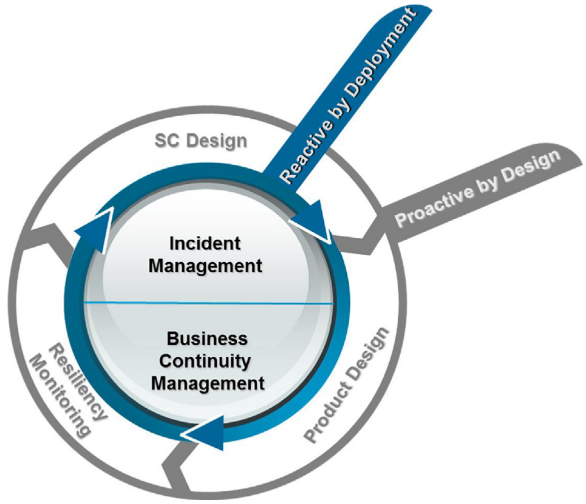


Figure 4. Aligning supply chain design and risk management



respond only in the event of a disruption. With such management, companies can anticipate disruptions by monitoring the impact of events on the company's supply chain. Reactive business continuity measures enable supply chain analysts to solve contingencies as they emerge, activating cross-functional response teams tailored to the nature and impact of the problem (Saenz & Revilla, 2014). These teams, using the different sensors and signals implemented during the product and supply chain design, map critical product components and network nodes, and subsequently monitor and audit for business continuity. Effective risk management is implemented (Figure 4) only when the two approaches—proactive by design and reactive by deployment—are well coupled.

Many companies use different approaches. Regarding reactive risk mitigation practices, when dealing with disruptions caused by product recall, quality, or safety issues, some companies have experimented with the creation of regulatory fits in their communications. However, Avnet and Laufer (2015) found that this practice can be counterproductive, amplifying the negative effect of the disruption.

Many companies, such as Unilever or Schneider Electrics, have implemented control towers that, among other functions, increase visibility and detect any potential disruption in daily operations (Sheffi, 2001). Business continuity management provides an outline response of the specific plans that need to be followed in order to recover from a given disruption and maintain operations at a normal level (Duncan, Yeager, Rucks, & Ginter, 2011). In the implementation of its business continuity plan, Starbucks identifies signals of potential disruptions and implements, if needed, reactive mitigation measures through centers of excellence that are customized depending on the nature of the disruption (Bradley, 2014; Sheffi, 2015). Business continuity plans have proven to be critical when it comes to dealing with major disruptions. Procter & Gamble (P&G) set a best practice example with its response during and after Hurricane Katrina, managing to quickly restore operations and clearly prioritize workers' safety. This effective operation during such a disastrous disruption was possibly due to a combination of proactive and reactive mitigation tools (Sheffi, 2015).

3.3. The dynamics of building supply chain resilience

When the threat of supply chain disruption occurs, senior managers need to combine the available risk management infrastructures in terms of dedicated information, resources, and human decision making. Managers also need to synergistically deploy the ability to reconfigure existing resources in a dynamic manner, such as procedures for monitoring the flow of goods along the overall supply chain and the reprioritization of workflows, quickly acquiring new resources if necessary (Ambulkar, Blackhurst, & Grawe, 2015). Nevertheless, in order to be efficient, both supply chain risk management approaches, reactive and proactive, must be nourished to maintain continuous dynamic awareness and learn from big or small disruptions to enhance current mitigation practices and train personnel.

The dynamics developed to reach resilience can clearly be understood when we think of global disruptions such as those associated with the economic recession. For example, Whirlpool was aware of its vulnerabilities and made strategic decisions on designing and restructuring its supply chains, moving from Quadrant B to D (see Figure 3) in order to reduce exposure to internal and external vulnerabilities (Alsop, 2010). Because of the housing crisis, the company faced a collapse of the household appliances market. Simultaneously, it also faced internal vulnerabilities from operational contingencies, such as the closure of a number of production facilities, which required the company to furlough workers. However, Whirlpool continued to serve the market, deploying a reactive risk management approach while facing these particular disruptions. To manage this increase in vulnerability, the company decided to enhance both efficiency and resilience, focusing on its responsiveness capacity. The company proactively redesigned its supply chain by consolidating product brands all over the world and increasing the use of standardized components. “Now you might have only 4 different controls for 20 different (washer) models,” said the Vice President of Supply Chain at Whirlpool Corp (Sheffi, 2015, p. 171). By consolidating its inventory into warehouses located within a day’s drive of one another, the company reduced logistics costs in the North American region by 12%, while cutting delivery time to customers by more than 5 days (Alsop, 2010).

Amazon has also adapted its supply chain to respond to the highly dynamic market in which it operates, creating new distribution centers close to the biggest cities to satisfy immediate demand with a time delivery of just a few hours. This new model has been expanded to Madrid and London, as well as to other European cities. Amazon is a great example for illustrating the importance of supply chain redesign for building resilience, as it is transitioning in a continuum along the several quadrants of Figure 3.

Chipotle is another example of a company implementing a dynamic approach to its supply chain risk management, moving from Quadrant C to B in Figure 3. Since late 2015, due to a lack of quality control in individual facilities, the company had outbreaks of E. coli and norovirus related to its local food suppliers. Hundreds of people were affected, which led to a drop in sales in 3 consecutive quarters (Oyedele, 2016). As a result, Chipotle has been exploring new ways to redesign its supply chain to minimize food safety-related risks with more global suppliers while maintaining its differentiating essence. This implied that they had to face additional global uncertainties (Berfield, 2015).

There are other examples that illustrate how the redesign of the distribution network—transitioning from lower to higher quadrants as shown in Figure 3—can create resilience, taking advantage of a global network by moving operations to regions where external vulnerabilities are under control. Consider, for example, the 2010 volcano eruption in Iceland, which caused a major global disruption with the closure of European air space for several days. FedEx’s European hubs, located in Cologne, Frankfurt, Paris, and Stansted, were all closed, as well as any alternatives. As a consequence, FedEx’s operations came to a halt for 5 days. In contrast, TNT suffered almost no disruption as it immediately switched air hubs from northern Europe to Spain, and transferred its air-freight transportation to road transportation in central and northern Europe (Sheffi, 2015). During this same disruption, a Japanese Nissan plant saw an impact in the production of three car models because a critical component produced in Ireland could not be delivered (Graf & John, 2010). BMW, however, quickly reacted to the same disruption, finding alternative ways to transport transmission components from Europe to its North American factories (Sheffi, 2015).

More recently, the financial collapse of ocean cargo company Hanjin has again tested companies that rely on global supply chains. As containers piled up at both ends of Hanjin’s routes, companies such as Walmart, Target, and J.C. Penney had to manage with their lack of available stock, and were not ready for the holiday shopping season. Because of these difficulties, Hanjin had to dynamically reconfigure its network, redesigning routes and avoiding the ports that were highly affected, even transferring goods to alternative global cargo companies. However, a situation such as Hanji’s also signaled the beginning of a disruption, because shipping rates increased as a direct result of a reduction in the overall worldwide shipping capacity.

4. Fostering supply chain resilience

Although recent research streams have attempted to find a universal supply chain risk and disruption management practice, our own theoretical and empirical research confirms that this universality is not possible. Successful global organizations have built a key attribute in today’s economy, creating resilience by focusing on risk-management practices, as well as integrating the idea of resilience from initial conceptualization of a product and its supply chain, thereby integrating the risk awareness into a single design process. In this regard, successful supply chain risk-mitigation management practices can balance proactive mitigation capabilities with reactive capabilities that require customization of the deployment within the supply chain design in the face of a disruptive incident. Our proposed framework might serve as the skeleton for supporting executive directors in the deployment of resilience in a dynamic manner. Companies should first be aware of the nature of their supply chain and understand its vulnerabilities before attempting to design a risk management plan.

Appendix. Research methodology

This study is part of the MIT Global Scale Risk Initiative, led by the Center for Transportation and Logistics at MIT, and with the collaboration of several academic institutions. This initiative combines two complementary approaches. First, a large-scale worldwide online survey was used as a base for data gathering. A total of 1,403 supply chain managers at decision-making levels and in strategically oriented positions from different industries, representing 69 countries, provided their insights on dealing with supply chain risks. The target respondents' profile included age (63.2% older than 40), gender (82.2% males and 14.4% females), and education (62.1% held a university or master's degree). Respondents averaged 12.9 years of experience in their respective industries, with senior managers comprising 32.6% and vice presidents comprising 32%.

Based on an analysis of these responses, the second part of the study has identified some successful cases of supply chain risk management. In-depth interviews with key supply chain company representatives have enabled the research team to examine their risk management practices.

The results highlight the relative novelty of the supply chain risk management field within companies, and its evident lack of organization. According to the study, approximately 60% of the surveyed managers do not actively work on supply chain risk management, nor consider it effective. Managers lack a framework for guidance in the deployment of such practices, as well as the ability to make decisions on the best approaches for the particular supply chain dynamics they are facing.

The authors can provide several publications showing empirical results and recommendations from the overall research initiative.

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Chapter 3

Literature Review and Gaps Identification

3.1. Introduction

In this chapter, existing academic literature is reviewed to have a clear understanding of which are the capabilities that lead supply chain resilience, how they interrelate, and which are their outcomes. This chapter consequently provides an overview of the relevant literature and identifies the existing gaps and research questions that are later explored in the present dissertation.

3.2. Literature Review on Supply Chain Resilience

Supply chain resilience has been in the agenda of supply chain managers as a key enabler to the success of firms, ensuring the continuation of the firm operations during disruptions and eventually generating long-lasting competitiveness (Pettit, et al., 2010; Liu, et al., 2018). The literature on supply chain resilience is abundant with researchers attempting to present a collection of supply chain risk management practices (Lee, 2004; Tang, 2006), the study of the resilience dimensions (Wieland & Wallenburg, 2013; Scholten & Schilder, 2015) or a development of supply chain resilience framework (Pettit, et al., 2013; Ambulkar, et al., 2015; Saenz, et al., 2018); however, there are only a limited number of researches such as Petti et al. (2013), Chowdhury and Quaddus (2017) and Liu et al. (2018) present a comprehensive conceptualization and measurement of resilience. Understanding how companies developed resilience is still underdeveloped (Wieland, et al., 2016) and additional work is needed to understand how the supply chain design can minimize disruptions and generate competitive advantage as one of the main key functions of supply chain managers is to maintain the firms' operation even under critical circumstances generated by disruptions and unforeseen events (Brusset & Teller, 2017). However, the avoidance of disruptions is not the only consequence of supply chain resilience creation. Hendricks and Singhal (2005) argue that companies investing in resilience leads to a better performance under extreme circumstances, while Jüttner et al.

(2003) stressed that those firms that invest in resilient capabilities improve their overall business performance.

In the present chapter, we present a literature review of the construct of resilience as well as the antecedents and performance outcomes analyzed in the existing supply chain literature. Subsequently, we present the identified gaps that are presented as potential lines of research.

3.2.1. Concept of Supply Chain Resilience

Resilience is a multidisciplinary, multidimensional and hierarchical concept (Kamalahmadi & Parst, 2016; Chowdhury & Quaddus, 2017) whose origins can be found in the ecological studies (Ponomarov & Holcomb, 2009). In this regard, resilience was defined in this context as the persistence and ability of a system to absorb changes and still persists (Holling, 1973). Resilience was later adopted in engineering fields defining it as "the stability near an equilibrium steady state, where resistance to disturbance and speed of return to the equilibrium are used to measure the property" (Holling, 1996, p. 33). However, these two disciplines have not been the only one that have investigated the concept of resilience and other areas like social, socio-economic, physiology, economic, emergency and disaster management, sustainable development, organizational and supply chain have also been researching the concept, antecedents and effects of resilience (Kamalahmadi & Parst, 2016). Three major disruptions marked the beginning of the study of supply chain resilience: the fuel protests in 2000, the outbreak of the Foot and Mouth Disease in 2001 (Pettit, et al., 2010) and the 9/11 terrorist attack (Sheffi, 2001, 2005a). Since then, resilience has positioned itself as recurrent hot topic in the supply chain research agenda (Wieland, et al., 2016) as a way to reduce and overcome exposure to risk (Scholten & Schilder, 2015) and create a competitive advantage (Pettit, et al., 2010). However, and even though, researchers have been working on this concept over 15 years now, there is still no consensus on its conceptualization and measures (Chowdhury & Quaddus, 2017). Table 3. summarizes the most relevant definitions.

Table 3.1: Definitions of Supply Chain Resilience

Definition of Resilience	Reference
"Adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function"	(Ponomarov & Holcomb, 2009, p. 131) Adopted by Scholten and Schilder (2015) and Kamalahmadi and Parst (2016)
"Ability of a supply chain to cope with change"	(Wieland & Wallenburg, 2012)
"Ability of a system to return to its original state, within an acceptable period of time after being disturbed"	(Brandon-Jones, et al., 2014)
"Capability of the firm to be alert to, adapt to, and quickly respond to changes brought by a supply chain disruption"	(Ambulkar, et al., 2015)
"Supply chain's ability to be prepared for unexpected risk events, responding and recovering quickly to potential disruptions to return to its original situation or grow by moving to a new, more desirable state"	(Hohenstein, et al., 2015)
"Network-level attribute to withstand disruptions that may be triggered at the node or arc level"	(Kim, et al., 2015)

3.2.2. Antecedents of Supply Chain Resilience

In the same way that there is no clear consensus on the supply chain resilience definition, the antecedents that lead to resilience are presented among the different research studies with some sort of discrepancy (Scholten, et al., 2014). In this sense, some researchers such as Scholten et al. (2014) and Liu et al. (2018) have summarized in their research work the different studies that have analyzed the antecedents of supply chain resilience. Table 3 summarizes on the one hand the antecedents that have been identified as having a great impact on supply chain resilience creation and that, at the same time, have not been sufficiently analyzed from an empirical perspective.

Table 3.2: Antecedent for resilience (adapted from Scholten & Schilder (2015))

Reference	**Visibility**	**Integration**	**Flexibility**	**Agility**	**Collaboration**	**Coopetition**	**Robustness**	**Innovation**	**Ambidexterity**	**Synchro-modality**	**SCRM**
Christopher and Peck (2004)	√		√	√	√						
Reinmoeller and Van Baardwijk (2005)					√						
Sheffi and Rice (2005)	√		√	√							
Sheffi (2005a,b)	√		√	√							
Faisal, et al. (2006)					√						
Bakshi and Kleindorfer (2009)				√		√					
Ponomarov and Holcomb (2009)	√	√	√	√							
Pettit et al. (2010, 2013)	√		√	√							
Azadegan and Dooley (2010)								√			
Blackhurst et al. (2011)	√		√	√							
Jüttner and Maklan (2011)	√			√							
Wieland and Wallenburg (2012, 2013)	√	√	√	√	√						
Brandon-Jones et al. (2014)	√						√				
Scholten et al. (2014)	√		√	√	√						
Amblukar et al. (2015)									√		√
Hohenstein et al. (2015)	√		√	√							
Reggiani et al. (2015)							√				
Kamalahmadi and Parst (2016)	√		√	√	√						√
Lee and Rha (2016)									√		
Zhang and Pel (2016)										√	
Chowdhury and Quaddus (2017)		√	√								
Jain et al. (2017)	√			√							
Lee and Song (2017)										√	
Liu et al. (2018)		√		√							

In the following section we present the capabilities and antecedents identified in Table 3, expanding its definition and implications in the creation of supply chain resilience.

VISIBILITY

Supply chain visibility refers to the knowledge of the status of the supply chain operation (Pettit, et al., 2013) and is defined as "the identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times of these events" (Francis, 2008, p. 182). The flow of knowledge needs to include detailed information of what goes on in other parts of the supply chain (Christopher & Lee, 2004) as well as infrastructure and any other relevant information regarding stakeholders or the environment in which the supply chain operates. At the same time, this information needs to flow in a timely and complete manner so the different players in the supply chain can operate consequently (Francis, 2008; Scholten & Schilder, 2015). This detailed knowledge of the supply chain enables firms to reduce potential risks (Chopra & Sodhi, 2004), allowing managers to anticipate to potential disruptions and create effective response and recovery strategies (Jüttner & Maklan, 2011). As such, visibility is related to resilience, constituting one of its antecedents (Scholten & Schilder, 2015).

INTEGRATION

From a supply chain perspective, integration relates to the degree of cooperation and coordination in the supply chain, either internally (departmental level) or externally (between the different agents of the supply chain) (Cao, et al., 2015; Liu, et al., 2018). Integration is defined as "the degree to which an organization strategically collaborates with its supply chain partners and manages intra- and inter-organization processes to achieve effective and efficient flows of products, services, information, money and decisions, with the objective of providing maximum value to its customers" (Zhao, et al., 2008, p. 374). Supply chain integration is highly related to information sharing, allowing supply chain partners to quickly react to disruptions and withstand upheavals (Liu, et al., 2018). Integration does not only allow supply chains to respond to sudden changes that may lead to disruptions (Wieland & Wallenburg, 2013) but it also facilitates firms to anticipate to customer needs in a changing environment (Flynn, et al., 2010).

FLEXIBILITY

Supply chain flexibility has long been considered as one of the strategies in supply chain risk mitigation (Jüttner, et al., 2003) as it has the objective of responding to market demand changes (Xiao, 2015). Therefore, flexibility is seen as a required capability to quickly and effectively respond to volatile and dynamic market environment while adapting to unforeseen events (Ponomarov & Holcomb, 2009; Williams, et al., 2013; Scholten & Schilder, 2015; Kamalahmadi & Parst, 2016). In that sense, supply chains that develop high levels of flexibility are more capable of successfully manage a disruption compare to their non-flexible market competitors (Skipper & Hanna, 2009), which is subsequently translated as a differentiating aspect in competitive markets (Streedevi & Saranga, 2017). However, even though flexibility is said to minimize or even avoid the effects of unforeseen events, it should be balanced with the need for efficiency (Scholten & Schilder, 2015). There are multiple sources of flexibility, but at in order to be analyzed in research work, authors make a differentiation between externally-driven flexibility (product type, volume, variety or customization) and internally-driven flexibility (labor and assets) (Williams, et al., 2013).

COLLABORATION

Collaboration is defined as the interdependent relationship developed among supply chain partners that closely work together to create mutually beneficial outcomes (Defee & Fugate, 2010; Pettit, et al., 2010). Supply chain partners that collaborate are seen as more trusted, showing a sense of responsibility and helping the rest of the partners to anticipate to potential disruptions (Wieland & Wallenburg, 2013). Collaboration helps to reduce uncertainty by distributing risk (Reinmoeller & Van Baardwijk, 2005). Consequently, collaboration between the different partners enables the integration of the supply chain as a whole, making it possible to understand the supply chain as a whole, which is needed to build supply chain resilience (Scholten, et al., 2014). Several studies have attempted to understand how different collaboration strategies can increase supply chain resilience, such as communication and cooperation (Wieland & Wallenburg, 2013), cooperative contracts (Bakshi & Kleindorfer, 2009) or timely information sharing . (Scholten & Schilder, 2015).

COOPETITION

The concept of coopetition was first introduced by the founder of Novell and further expanded by (Brandenburger & Nalebuff, 1996; Bouncken & Frederich, 2012). Coopetition is a phenomenon of dynamic inter-firm relationships (Pathak, et al., 2014) and it is defined as a dynamic process in which different actors engage in cooperation while simultaneously competing in other scenarios (Wallenburg & Schäffler, 2014; Bouncken, et al., 2015). By engaging in coopetition, firms can aim for a bigger market of the business while simultaneously competing for the same market share (Bouncken & Frederich, 2016). Even though it was presenting as a promising concept and several researchers documented coopetition strategies between big leading firms such as IBM and Apple or Sony and Samsung (Bouncken & Frederich, 2012), it is not a concept that has been widely study in the supply chain research literature, existing a large research gap on this specific topic. However, it has been identified by (Wieland, et al., 2016) as a research theme that should become important in the agendas of future research themes in supply chain management as it is envisioned as an enabler for supply chain resilience and risk mitigation management (Bakshi & Kleindorfer, 2009).

AGILITY

Supply chain agility refers to the "rapid system reconfiguration in the face of unforeseeable changes" (Bernardes & Hanna, 2009, p. 30). It is based on a continuous search for an efficient response to changes crated by unpredictable and dynamic global market environments (Scholten, et al., 2014). In order to develop agility, supply chain firms should first build on visibility, flexibility and velocity, which are presented as antecedents of agility which are at the same time also needed to develop a resilient supply chain (Scholten, et al., 2014). While visibility implies a clear understanding of the overall supply chain condition, including upstream and downstream partners; velocity is understood as the speed of recovery after a disruption (Liu, et al., 2018). Agility is positively related to the creation of resilience as in the event of a potential disruption, supply chains that have agile capabilities can quickly react to bring the supply chain to operate back to normal as fast as possible (Wieland & Wallenburg, 2012). In the opposite situation, less agile firms will drag down partners of their supply chains when expose to disruptions (Liu, et al., 2018).

ROBUSTNESS

A robust supply chain is the one that is capable of maintaining its functions despite any internal or external disruptions (Brandon-Jones, et al., 2014). It is able to continue operations, retaining the same stable status it had before changes occurred (Wieland & Wallenburg, 2013). It resists the impact of disruptions rather responding with reactive strategies (Wallace & Choi, 2011). Because of that, for some authors, robustness should not be considered as a static concept where both the systems and its operations remain unchanged during a disruption, but as dynamic concept where the supply chain modifies certain structural or component aspects in order to maintain operations at the same pre-disruption level (Brandon-Jones, et al., 2014). However, other researchers like (Wieland & Wallenburg, 2012) present the concept of robustness as the proactive anticipation and resistance to change without adapting the initial supply chain configuration.

AMBIDEXTERITY

Ambidexterity is defined supply chain capability to simultaneously develop exploitative and exploratory processes (Kristal, et al., 2010; Strese, et al., 2016). Ambidexterity encompasses two processes, exploration and exploitation, and it has been presented as a multidimensional, second-order construct reflecting those two processes (Kristal, et al., 2010). Exploration implies that firms are capable of recognizing and understanding the existence of novel external knowledge that is potentially valuable for the company; while exploitation implies that the knowledge previously assimilated in the exploration phase is used to create and improve existing processes (Saenz, et al., 2014). Ambidexterity help firms not only to deal with new business paradigms, but it also improves flexibility, inter-organizational relationships and competitive advantage (Lee & Rha, 2016). The development of ambidextrous capabilities has been linked to the creation of supply chain resilience as the knowledge and innovation created through organizational learning can leverage the firm's ability to adapt to uncertainty and reconfigure based on past or externally learned experiences (Lee & Rha, 2016).

INNOVATION

Innovation is understood as the implementation of newly developed ideas to create and enhance products and processes (Sarooghi, et al., 2015). There is not just one type of innovation and researchers have been distinguishing between different types of innovation: new products development, strategies and improvement in existing products (Gopalakrishnan & Damanpour, 1994; Damanpour & Gopalakrishnan, 2001; Saenz, et al., 2014). Increasingly, innovation is seen as a critical element for companies in order to remain afloat in dynamic and highly competitive environments where firms need to introduce new creative products and processes (Sarooghi, et al., 2015). However, innovation is not only related to operational or strategic outcomes and, because innovation is positively related to effective response to sudden market changes (Mainela & Puhakka, 2008), it has been related to resilience (Azadegan & Dooley, 2010). Nevertheless, although innovation has been envisioned as a key enabler of the firm's long-term performance and survival, the relationship between innovation and resilience has been overlooked (Kamalahmadi & Parst, 2016).

SYNCHROMODALITY

The last antecedent that we are going to analyzed is synchromodality. Synchromodality is the most recent concept that has emerged in logistics and transportation and is considered as promising enabler to supply chain risk mitigation, efficiency and sustainability (Kurapati, et al., 2017; Lee & Song, 2017). The concept of synchromodality was introduced in 2010 by Dutch researchers (Oonk, 2016) and builds on four other well-established and known transportation concepts: multimodality, intermodality, combined and co-modal transportation (Reis, 2015). The novelty of this concept comes along with a lack of deep understanding of its antecedents and performance outcomes, there is no consensus on the definition and so far, there is no research that presents a holistic approach of the concept and the capabilities that supply chain firms needs to develop in order to embrace it. One of the most recent definitions of synchromodality is the one presented by (Li, et al., 2017) that defines it as a step forward from intermodality where shippers engage with transportation and logistics companies in a mode-free booing and allows timely switching among different transport modes based on real-time information of the overall supply chain environment.

SUPPLY CHAIN RISK MANAGEMENT

Supply Chain Risk Management (SCRM) refers to the group of practices that companies develop with the objective of reducing the negative effects of disruptions associated to the different operational, market or environmental risks (Tang, 2006). The concept of SCRM was first introduced in 2003 (Rowat, 2003; Lavastre, et al., 2012) and since then, many studies have shed light on the mechanisms that lead to sucessful supply chain risk management practices (Hallikas, et al., 2004; Ritchie & Brindley 2007; Zsidisin & Ritchie 2009; Lavastre, et al., 2012; Ho, et al. 2015). However, even though all researchers agree that the ultimate goal of any SCRM is the reduction of potential disruptions, there is still a lack of understanding on how the implementation of certain SCRM practices can minimize certain type of disruption or if these practices would work better in certain context than others, such as firm size, market or industry type.

3.2.3. Outcome of Supply Chain Resilience

In this section, we will focus on the logistics and transportation performance outcomes that have been analyzed in the supply chain and logistics literature with the aim of investigating, in subsequent chapters, if there is a relationship between resilience and these outcomes.

EFFICIENCY

Supply chain efficiency constitutes an important topic in the supply chain management as it can improve customers' service level and help managers' decision-making processes in terms of resource allocation strategies (Nikfarjam, et al., 2015). Efficiency has been largely analyzed in the supply chain and management arena and, as a result it can be understood as a multidisciplinary term, with ambiguous definitions depending on the specific research field (Lichocik & Sadowski, 2013). For example, when dealing with transportation problems, logistics efficiency is defined as the ability to manage the logistics related functions and resources wisely (Fugate, et al., 2010), being measured as the ratio of used resources against results (Langley & Holcomb, 1992; Fugate, et al., 2010). Ivanov et al. (2014) argue efficiency and resilience may be positively related, representing efficiency a direct outcome of resilience. At the same time, other authors estate that both efficiency and resiliency are needed to mitigate disruptions (Birkie, 2016), suggesting that the creation of resilience can lead to long-term, improving the efficiency of the supply chain (Shukla, et al., 2011; Birkie, 2016).

EFFECTIVENESS

Effectiveness is referred to as a measurement of how well a company is meeting the demand (Pfeffer & Salancik, 2003). The ultimate aim of the effectiveness development is to generate differentiation by providing additional value to customers (Möller & Törrönen, 2003). Effectiveness is measured as the ratio between actual vs. expected or predefined objectives (Fugate, et al., 2010). and in the particular field of transportation and logistics it has been defined as "the extent to which the logistics function's goals are accomplished" (Fugate, et al., 2010, p. 44). Many authors have discussed if there is a duality between efficiency and effectiveness and, as such, there is yet no clear consensus whether the investment on strategies that aim to increase effectiveness penalize the creation of efficiency (Davis & Pett, 2002; Möller & Törrönen, 2003; Walters, 2006; Selldin & Olhager, 2007; Fugate et al., 2010). For that reason and, the positively related between efficiency and resilience (Shukla, et al., 2011; Birkie, 2016), opens the door to the analysis of resilience and the creation of effectiveness.

LOGISTICS DIFFERENTIATION

Logistics differentiation is understood as the result of providing the best comparative net value services to customers (Fugate, et al., 2010). Transportation and logistics services are understood as a central component of the supply chain and, as such, their value creation is perceived as a differentiate advantage (Flint, et al., 2005; Fugate, et al., 2010). In that sense, when logistics companies offer to (Franco-Santos, et al., 2007) shippers services that are perceived of superior value, that is usually translated in a competitive advantage (Hitt, et al., 2016). Subsequently, transportation and logistics firms can differentiate themselves from competitors by creating value through the "inimitably of their logistics" and by developing a superiority when compared to competitors (Fugate, et al., 2012). The way logistics differentiation is measured is by comparing performance to competitiors (Fugate, et al., 2010).

ORGANIZATIONAL PERFORMANCE

Organizational performance relates to the different organizational units that are involved in the supply chain process, i.e. individuals, teams, processes and functions (Forza & Salvador, 2000). It is measured by a mixture of productivity, turnover, return on equity and other financial and operational indicators (Richard & Johnson, 2001) however, subjective measures such as managers perceptions are also included in the definition of operational performance (Bobbitt, 2004). When it comes to the relationship between resilience and organizational performance, there is a scarcity in the amount of research done so far, with a limit number of studies empirically conceptualizing or analyzing the effect of resilience on performance (Akgün & Keskin, 2014; Chowdhury & Quaddus, 2017).

3.3. Research Gaps

The literature review presented in the previous section serve as the basis for the identification of existing research gaps of antecedents and outcomes of resilience. Figure 3. presents the relationships that have not been tested yet empirically or whose presented research is so far limited and overlooked.

Figure 3.1: Identified gaps

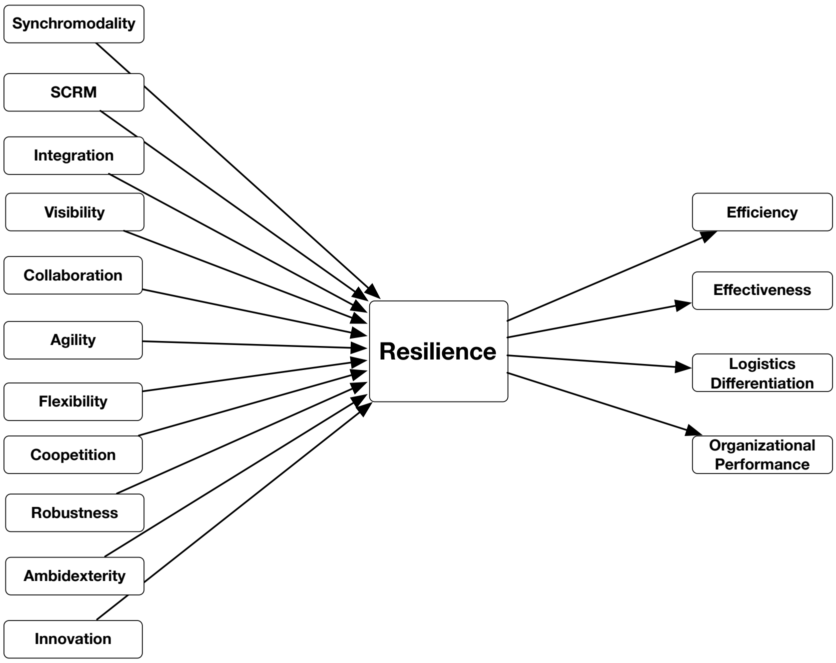

Table 3.3: Gaps identified in previous studies

Gap identified	**Source**
Synchromodality → Resilience	Lee and Song (2017)
Ambidexterity → Resilience	Lee and Rha (2016)
Integration→Resilience	Wieland and Wallenburg (2013)
Visibility → Resilience	Hohenstein, et al. (2015), Scholten and Schilder (2015)
Agility→Resilience	Wieland and Wallenburg (2012)
Flexibility → Resilience	Hohenstein, et al. (2015)
Collaboration→Resilience	Kamalahmadi & Parst (2016)
Coopetition→Resilience	Reggiani, et al. (2015) and Zhang, et al. (2015)
Robustness→Resilience	Scholten and Schilder (2015)
Innovation→Resilience	Kalamadi and Parst (2016) and Saenz, et al. (2018)
SCRM→Resilience	Ambulkar, et al., (2015) and Kamalahmadi and Parst (2016)

Resilience→Efficiency	Fugate, et al. (2010) and Ivanov, et al. (2014)
Resilience→Effectiveness	Shukla, et al. (2011) and Birkie (2016)
Resilience→Logistics Differentiation	Fugate, et al. (2010)
Resilience→Organizational Performance	Jüttner, et al. (2003) and Chowdhury and Quaddus (2017)

3.4. Research Methodologies

Based on the gaps identified in the literature review, we proposed along with our sponsored company to prepare a survey that would help us to empirically analyzed the different relationships shown in Figure 3.. The survey, that can be found in ANNEX 3.1, was developed following the recommendations from Saris and Gallhofer (2007) and Dillman et al. (2014). As the questionnaire is the foundation for this dissertation, we followed a rigorous process to develop and validate the different constructs presented in Figure 3.. The operationalization of each of the constructs was either adapted of adopted from previously operationalized concepts that have been tested and validated in high ranked supply chain research journals, ensuring the initial quality of our study. Table 3. presents a summary of the source of each of the constructs' operationalization. All items in the questionnaire were measured using a seven-point Likert scale, with different meaning as can be seen in ANNEX 3.1.

Once the questionnaire was designed, we conducted a pilot test with field experts with the objective of purifying and pretesting the different scales. To this extent, we contacted with 52 supply chain and logistics experts, including 9 faculty members. All the pilot test respondents were initially interviewed and requested to test the survey for a validity check. This initial step suggested minor adjustments in terms of wording and survey organization.

To the best of our knowledge, this is questionnaire is the first one to include the operationalization of the synchromodality construct. The development and validation of synchromodality items and scale is further detailed in Chapter 4 of this dissertation.

Table 3.4: Source for each of the constructs' operationalization

Construct	Source
Visibility	Williams, et al. (2013)
Integration	Danese, et al. (2013)
Ambidexterity	Saenz, et al. (2014)
Coopetition	Bouncken and Frederich (2016)
Agility	Wieland and Wallenburg (2013)
Flexibility	Williams, et al. (2013)
Robustness	Wieland and Wallenburg (2013)
Synchromodality	Reis (2015), Tavasszy, et al. (2015) and Pfoser (2016)
Resilience	Ambulkar (2015) and Ponomarov and Holcomb (2009)
Efficiency	Fugate, et al. (2010)
Effectiveness	Fugate, et al. (2010)
Innovation	Saenz, et al. (2014)
Logistics Differentiation	Fugate, et al. (2010)
Organizational Performance	Fugate, et al. (2010) and Chowdhury and Quaddus (2017)

3.5. Conclusion

In the present chapter we have presented a summary of the existing work regarding supply chain resilience, its antecedents and outcomes. Since, the concept of resilience started to gain attraction from supply chain practitioners, many research studies have focused on two main areas: (1) on understanding of the capabilities that companies should develop to create resilience, and (2), on the operational implications of creating a resilient supply chain. However, these latter studies are mainly theoretical, existing a lack of empirical methodologies.

Based on the work developed on chapters 2 and 3, we can see that the study of resilience has been mainly focused on the analysis of the relationship between buyer and product supplier, with little attention being paid to the role that logistics and transportation companies can play in the resilience creation for the overall supply chains (Esper, et al., 2007; Wallenburg & Schäffler, 2014). However, evidence shows that these firms can play a key role avoiding disruptions and generating value to the supply chain (Saenz, et al., 2018). Several examples are worth mentioning. The 2010 volcanic eruption in Iceland had serious effects on companies like the supermarket supply chain TESCO which suffer shortage of fresh products imported from the US, South East Asia and Europe. Similarly, BMW and Nissan had to suspend production in several plants in Germany and Japan because of disruption to supplies (Graf & John, 2010). However, companies that had involved FedEx in their transportation and logistics operations were able to minimize this disruption, resuming their normal operations sooner than other affected firms thanks to FedEx agility in switching transport modes (Tronson, 2010), an early antecedent of synchromodal operation. In the Neatherlands, two different pilot projects implemented by the Port of Rotterdam and a Fast-Moving Consuming Goods (FMCG) company are showing promising results linking the implementation of synchromodality with more resilient and efficient supply chains. However, the novel transportation and logistics approach of synchromodality has not yet been fully developed. There is still limited research on the topic, which translates in lack of theoretical consensus. Additionally, the evidence of the relationship between synchromodality, resilience and efficiency is merely based on on-going case studies and insufficient theoretical studies, existing a research gap in the study of the effect that synchromodality as on the supply chain performance. Following this existing gap, Chapter 4 utilizes a multi-research methodology using a four-stages approach to conceptualize, develop and validate a new measurement model for synchromodality. Chapter 5 delves into the outcomes of synchromodality. Using a multi-methodology approach it contributes to the understanding of synchromodality by providing insights of the effect that the implementation of this novel concept has on the supply chain. Additionally, this chapter deepens in the understanding of the relationship between efficiency and resilience.

Finally, we will also explore how the implementation of different SCRM approaches can affect the level of resilience achieved. To that end, we will address several gaps previously identified in the literature. First, there is yet, to the best of our knowlegde, a lack of understanding of the impact of how the development of a SCRM culture, materialized through a formal risk management structure, can reduce disruptions and increase resilience. Second, existing literature suggests that collaboration among supply chain partners leads to resilience. For that reason, taking into consideration the increasing interconnection that supply chains are developing, it seems only logic to investigate if a collaborative approach on existing SCRM will contribute to a even larger resilience. Third, most of the researches are focus on large and global firms, with little information on how small and medium firms deploy different approaches to increase resilience.Finally, there is a gap in the type of methodologies employed in these type of analyses, requiring for new empricial and analytical tools.

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ANNEX 3.1 – Resilience Survey

COVER LETTER

Thank you for collaborating with us in this research Project about Risk Management in Logistics and Transportation companies.

We know this is a busy time of the year for you, but we hope that you will take some time to participate in this survey which takes approximately 15 minutes. Once the study of the survey is complete you will receive a summary of the study in return to your participation.

We guarantee your confidentiality and anonymity. Your responses will be kept confidential and used only for this study. Individual responses will not be shared or made public. Only aggregated results will be reported.

If you have any questions about the administration of the survey, please contact Beatriz Acero, ZLC PhD Researcher, at bacero@mit.edu.

SURVEY

1. Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

	Strongly disagree						Strongly Agree
We actively plan day to day supply chain activities to meet customers' needs	1	2	3	4	5	6	7
We consider our customers' forecasts in our logistics activities planning	1	2	3	4	5	6	7
We monitor the performance of partners/subcontractors in our logistics network in order to adjust operational plans	1	2	3	4	5	6	7
Our major customers share timely and complete demand forecast information with us	1	2	3	4	5	6	7
Our major customers provide us with timely and complete information regarding loading readiness status in the distribution network (e.g., distribution centers, transportation)	1	2	3	4	5	6	7
We provide shipment location/tracking data to our customers in line with the agreed specification	1	2	3	4	5	6	7
We gather information from various sources to understand the overall demand and supply market level information	1	2	3	4	5	6	7
Our major partners/subcontractors share timely and complete information with us about order delivery dates and hours	1	2	3	4	5	6	7
Our major customers provide us with timely and complete advance shipment notification	1	2	3	4	5	6	7
We gather timely and complete information from various sources to understand the overall transport network status (traffic update, customs delays….)	1	2	3	4	5	6	7
Our major partners / subcontractors provide us with timely and complete information of changes in operations due to incidents or disruptions	1	2	3	4	5	6	7
Our major customers provide us with timely and complete information of changes in operations due to incidents or disruptions	1	2	3	4	5	6	7

2. Please indicate the approximate percentage use of the different transport modes in your operating network

	Air Freight	Rail	Inland Waterways	Maritime	Road
Percentage use					

3. Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

	Strongly disagree						Strongly Agree
We use different transport modes in one integrated shipment	1	2	3	4	5	6	7
Our customers give us the flexibility to decide which transport mode to use	1	2	3	4	5	6	7
We use sophisticated dynamic planning of transport routes	1	2	3	4	5	6	7
We dynamically use multiple stakeholder data (port data, vessel data, terminal data, logistics platforms…) to optimize transport planning	1	2	3	4	5	6	7
In order to optimize resources, we continuously revise the transport modes we assign to each service	1	2	3	4	5	6	7
For each load unit, we work with our customers to select the best transport option	1	2	3	4	5	6	7

4. Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

	Strongly disagree						Strongly Agree
Our services/equipment/operations are designed to be easily modified	1	2	3	4	5	6	7
We can quickly change the volume of products we handle or transport	1	2	3	4	5	6	7
We can easily change the scale of our processes	1	2	3	4	5	6	7
We can process different products in the same facilities at the same time	1	2	3	4	5	6	7
We can change quickly from one transport service to another	1	2	3	4	5	6	7
Our services can easily be changed from a local to a global scale, and vice versa	1	2	3	4	5	6	7
Our firm can easily change its services from responsiveness to cost oriented and vice versa	1	2	3	4	5	6	7
For a long time, our operations retain the same stable situation as they had before changes occur	1	2	3	4	5	6	7
When changes occur, our supply chain grants us much time to consider a reasonable reaction to fulfil customer needs	1	2	3	4	5	6	7
Without adaptations being necessary, our supply chain performs well over a wide variety of possible disruptive scenarios	1	2	3	4	5	6	7
After suffering the negative consequences of a disruption, we keep operating	1	2	3	4	5	6	7
We are able to cope with changes caused by supply chain disruptions (i.e. unexpected events)	1	2	3	4	5	6	7
We are able to adapt to the supply chain disruption easily	1	2	3	4	5	6	7
We are able to provide a quick response to the supply chain disruption	1	2	3	4	5	6	7
We are able to provide a high awareness at all times	1	2	3	4	5	6	7
We are able to continuously monitor the network transport	1	2	3	4	5	6	7
We proactively prepare our processes (e.g. through BCP) for unexpected events	1	2	3	4	5	6	7

5. Please indicate the speed of reaction with which your company can engage in the following activities should changes occur (1=too slow to 7=too fast)

	Too slow					Too fast
Adapt service delivery times	1	2	3	4	5	6	7
Adapt level of customer service	1	2	3	4	5	6	7
Adapt delivery reliability	1	2	3	4	5	6	7
Adapt responsiveness to changing customer needs	1	2	3	4	5	6	7

6. For the following items, please rate your firm's performance on logistics activities in comparison to your major competitors (1 = far below competitors to 7 = far above competitors)

	Far below competitors						Far above competitors
Damage free deliveries	1	2	3	4	5	6	7
Finished goods inventory	1	2	3	4	5	6	7
Forecasting accuracy	1	2	3	4	5	6	7
Time between order receipt and delivery	1	2	3	4	5	6	7
Time on backorder	1	2	3	4	5	6	7
Total inventory turns	1	2	3	4	5	6	7
On-time delivery	1	2	3	4	5	6	7

7. In your judgement, how did your BUSINESS UNIT perform relative to its major competitors in the previous fiscal year with respect to each criterion? (1=much worse to 7=much better) (If your company is not divided into business units or divisions, please answer the questions based on the overall company).

	Much worse than competitors					Much better than competitors
Market share growth in our primary market	1	2	3	4	5	6	7
Sales growth	1	2	3	4	5	6	7
Percentage of new product sales generated by new products	1	2	3	4	5	6	7
Return on sales	1	2	3	4	5	6	7
Return on assets	1	2	3	4	5	6	7
Return on investments	1	2	3	4	5	6	7

8. For the following items, please rate your business unit's performance on logistics activities for the previous fiscal year

	Poor						Excellent
Percent of orders shipped to customers from the primary location designated to serve those customers	1	2	3	4	5	6	7
Percent of orders shipped on time	1	2	3	4	5	6	7
Percent of shipments requiring expediting	1	2	3	4	5	6	7
Average order cycle time (time in days between order receipt and order delivery)	1	2	3	4	5	6	7

Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

As a general note for this question:
Customer: any entity that you work for or that requests transport or logistic services to your company
Partner/Subcontractor: Any entity that you work with (either under a contract or alliance form) to obtain mutual benefits

9. In regard to transport orders, our relationship with the customer has allowed us to:

	Much worse than competitors					Much better than competitors
Lower transportation costs	1	2	3	4	5	6	7
Lower indirect costs	1	2	3	4	5	6	7
Lower total costs	1	2	3	4	5	6	7
More efficiently use of financial resources	1	2	3	4	5	6	7

10. In regard to transport orders, our relationship with the partners/subcontractors has allowed us to:

	Much worse than competitors						Much better than competitors
Lower transportation costs	1	2	3	4	5	6	7
Lower indirect costs	1	2	3	4	5	6	7
Lower total costs	1	2	3	4	5	6	7
More efficiently use of financial resources	1	2	3	4	5	6	7

11. Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

	Strongly disagree						Strongly Agree
We are in close competition with our partner	1	2	3	4	5	6	7
An active competition with our partner/subcontractor is important to us	1	2	3	4	5	6	7
Our partner is also our competitor, with whom we pursue a common goal in the project	1	2	3	4	5	6	7
Our relationship with the partner/subcontractor has helped us to jointly invest in common innovation projects	1	2	3	4	5	6	7
We work as a partner with our customers	1	2	3	4	5	6	7
We are comfortable sharing problems with our customers	1	2	3	4	5	6	7
We are comfortable sharing problems with our partners/subcontractors	1	2	3	4	5	6	7
We believe that cooperating with customers is beneficial	1	2	3	4	5	6	7
We believe that cooperating with partners/subcontractors is beneficial	1	2	3	4	5	6	7
We emphasize openness of communications in collaborating with our partners/subcontractors	1	2	3	4	5	6	7
We emphasize openness of communications in collaborating with our customers	1	2	3	4	5	6	7

Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

12. With our major customers we share changes in…..

	Strongly disagree						Strongly agree
the preferences of other companies involved in our network	1	2	3	4	5	6	7
technology	1	2	3	4	5	6	7
strategies and policies of our organization	1	2	3	4	5	6	7

13. With our major partners/subcontractors we share changes in…..

	Strongly disagree					Strongly agree
the preferences of other companies involved in our network	1	2	3	4	5	6	7
technology	1	2	3	4	5	6	7
strategies and policies of our organization	1	2	3	4	5	6	7

14. We make joint decisions with our major customers on…

	Strongly disagree						Strongly agree
cost reduction programs	1	2	3	4	5	6	7
quality improvement programs	1	2	3	4	5	6	7
transportation and logistics planning	1	2	3	4	5	6	7
costs and benefits that result from common programs for improvement	1	2	3	4	5	6	7
the implementation of sustainability programs	1	2	3	4	5	6	7
capital investments	1	2	3	4	5	6	7

15. We make joint decisions with our partners/subcontractors on…

	Strongly disagree						Strongly agree
cost reduction programs	1	2	3	4	5	6	7
quality improvement programs	1	2	3	4	5	6	7
transportation and logistics planning	1	2	3	4	5	6	7
costs and benefits that result from common programs for improvement	1	2	3	4	5	6	7

the implementation of sustainability programs	1	2	3	4	5	6	7
capital investments	1	2	3	4	5	6	7

16. The relationship with our major customers has helped us to…

	Strongly disagree						Strongly agree
develop new strategies to compete in the market	1	2	3	4	5	6	7
develop new products for our market	1	2	3	4	5	6	7
introduce improvements in existing services	1	2	3	4	5	6	7
jointly invest in common innovation projects	1	2	3	4	5	6	7
Jointly invest in common innovative sustainability projects	1	2	3	4	5	6	7

17. The relationship with our partners/subcontractors has helped us to…

	Strongly disagree						Strongly agree
develop new strategies to compete in the market	1	2	3	4	5	6	7
develop new products for our market	1	2	3	4	5	6	7
introduce improvements in existing services	1	2	3	4	5	6	7
jointly invest in common innovation projects	1	2	3	4	5	6	7
Jointly invest in common innovative sustainability projects	1	2	3	4	5	6	7

Finally, we would like to get some basic information so that we can compare the responses across the participants

18. Tell us about your job

	What is your current position?	What is your functional area of work?	Years of experience in current position	Country from where you work
Job position and experience				

19. Tell us about your Business Unit (if your company is not divided into business units or divisions, please answer the questions based on the overall company)

	Annual Revenue (€)	Full time employees worldwide
Your Business Unit		

20. In which geographical areas does your firm operate? (more than one answer is possible)

Only national level	Western Europe	Central America
Northern Europe	Northern Africa	Norther America
Southern Europe	Sub-Sahara Africa	Middle East
Central Europe	South America	Asia
Eastern Europe		
Other (please specify):		

21. What is the type of your firm activities? (multiple answers possible)

Logistics Service Provider	Value-added services (customization, conditioning…)	Consulting
Transport Operator	Customs	Good tracking
Freight Forwarder	Data Analytics	Packing
Warehousing		
Other (please specify):		

22. What is the company's value proposition – what distinguishes itself from its competitors (multiple answers possible)

Price	Full service	Reliability
Geographical coverage	Accessibility	Capability
Innovation	Agility	Efficiency
Other (please specify):		

THANK YOU!
To receive a summary of the results, please provide us your email address below.
Your email and responses will be kept confidential and used only in this research study. Only aggregated results will be reported

23. Email address:

ANNEX 3.2 – Resilience Survey Operationalization

INTEGRATION (Adapted from Danese et al. (2013))

Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

We actively plan day to day supply chain activities to meet customers' needs

We consider our customers' forecasts in our logistics activities planning

We monitor the performance of partners/subcontractors in our logistics network in order to adjust operational plans

We work as a partner with our customers

We are comfortable sharing problems with our customers

We are comfortable sharing problems with our partners/subcontractors

We believe that cooperating with customers is beneficial

We believe that cooperating with partners/subcontractors is beneficial

We emphasize openness of communications in collaborating with our partners/subcontractors

We emphasize openness of communications in collaborating with our customers

VISIBILITY (Adapted from Williams et al. (2013) and Danese et al. (2013))

Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

Our major customers share timely and complete demand forecast information with us

Our major customers provide us with timely and complete information regarding loading readiness status in the distribution network (e.g., distribution centers, transportation)

We provide shipment location/tracking data to our customers in line with the agreed specification

We gather information from various sources to understand the overall demand and supply market level information

Our major partners/subcontractors share timely and complete information with us about order delivery dates and hours

Our major customers provide us with timely and complete advance shipment notification

We gather timely and complete information from various sources to understand the overall transport network status (traffic update, customs delays….)

Our major partners / subcontractors provide us with timely and complete information of changes in operations due to incidents or disruptions

Our major customers provide us with timely and complete information of changes in operations due to incidents or disruptions

SYNCHROMODALITY (Adapted from Reis (2015), Pfoser et al. (2016) and Tavasszy et al. (2015))
Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

We use different transport modes in one integrated shipment

Our customers give us the flexibility to decide which transport mode to use

We use sophisticated dynamic planning of transport routes

We dynamically use multiple stakeholder data (port data, vessel data, terminal data, logistics platforms…) to optimize transport planning

In order to optimize resources, we continuously revise the transport modes we assign to each service

For each load unit, we work with our customers to select the best transport option

FLEXIBILITY (Adapted from Williams et al. (2013) and Swafford et al. (2006))
Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

Our services/equipment/operations are designed to be easily modified

We can quickly change the volume of products we handle or transport

We can easily change the scale of our processes

We can process different products in the same facilities at the same time

We can change quickly from one transport service to another

Our services can easily be changed from a local to a global scale, and vice versa

Our firm can easily change its services from responsiveness to cost oriented and vice versa

ROBUSTNESS (Adapted from Wieland and Wallenburg (2013))
Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

For a long time, our operations retain the same stable situation as they had before changes occur

When changes occur, our supply chain grants us much time to consider a reasonable reaction to fulfil customer needs

Without adaptations being necessary, our supply chain performs well over a wide variety of possible disruptive scenarios

After suffering the negative consequences of a disruption, we keep operating

RESILIENCE (Adapted from Ambulkar et al. (2015) and Ponomarov and Holcomb (2009))

Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

We are able to cope with changes caused by supply chain disruptions (i.e. unexpected events)

We are able to adapt to the supply chain disruption easily

We are able to provide a quick response to the supply chain disruption

We are able to provide a high awareness at all times

We are able to continuously monitor the network transport

We proactively prepare our processes (e.g. through BCP) for unexpected events

AGILITY (Adapted from Wieland and Wallenburg (2013))
Please indicate the speed of reaction with which your company can engage in the following activities should changes occur (1=too slow to 7=too fast)

Adapt service delivery times

Adapt level of customer service

Adapt delivery reliability

Adapt responsiveness to changing customer needs

LOGISTICS DIFFERENTIATION (Adapted from Fugate et al. (2010))
For the following items, please rate your firm's performance on logistics activities in comparison to your major competitors (1 = far below competitors to 7 = far above competitors)

Damage free deliveries

Finished goods inventory

Forecasting accuracy

Time between order receipt and delivery

Time on backorder

Total inventory turns

On-time delivery

ORGANIZATIONAL PERFORMACE (Adapted from Fugate et al. (2010))
In your judgement, how did your BUSINESS UNIT perform relative to its major competitors in the previous fiscal year with respect to each criterion? (1=much worse to 7=much better) (If your company is not divided into business units or divisions, please answer the questions based on the overall company)

Market share growth in our primary market

Sales growth

Percentage of new product sales generated by new products

Return on sales

Return on assets

Return on investments

EFFICIENCY (Adapted from Fugate et al. (2010))

For the following items, please rate your business unit's performance on logistics activities for the previous fiscal year

Percent of orders shipped to customers from the primary location designated to serve those customers

Percent of orders shipped on time

Percent of shipments requiring expediting

Average order cycle time (time in days between order receipt and order delivery)

EFFECTIVENESS (Adapted from Saenz et al. (2014))

Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

In regard to transport orders, our relationship with the customer has allowed us to:

Lower transportation costs

Lower indirect costs

Lower total costs

More efficiently use of financial resources

In regard to transport orders, our relationship with the partners/subcontractors has allowed us to:

Lower transportation costs

Lower indirect costs

Lower total costs

More efficiently use of financial resources

COOPETITION (Adapted from Bouncken and Frederich (2016))

Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

We are in close competition with our partner

An active competition with our partner/subcontractor is important to us

Our partner is also our competitor, with whom we pursue a common goal in the project

Our relationship with the partner/subcontractor has helped us to jointly invest in common innovation projects

AMBIDEXTERITY (Adapted from Saenz et al. (2014))

Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

With our major customers we share changes in…..

the preferences of other companies involved in our network

technology

strategies and policies of our organization

With our major partners/subcontractors we share changes in…..

the preferences of other companies involved in our network

technology

strategies and policies of our organization

We make joint decisions with our major customers on…

cost reduction programs

quality improvement programs

transportation and logistics planning

costs and benefits that result from common programs for improvement

the implementation of sustainability programs

capital investments

We make joint decisions with our partners/subcontractors on…

cost reduction programs

quality improvement programs

transportation and logistics planning

costs and benefits that result from common programs for improvement

the implementation of sustainability programs

capital investments

INNOVATION (Adapted from Saenz et al. (2014))

Please tell us the extent to which you agree or disagree with the following statements (1=strongly disagree to 7=strongly agree)

The relationship with our major customers has helped us to…

develop new strategies to compete in the market

develop new products for our market

introduce improvements in existing services

jointly invest in common innovation projects

jointly invest in common innovative sustainability projects

The relationship with our partners/subcontractors has helped us to…

develop new strategies to compete in the market develop new products for our market

introduce improvements in existing services

jointly invest in common innovation projects

jointly invest in common innovative sustainability projects

ANNEX 3.3 – MIT Global Risk Survey

Introduction

MIT is conducting a global survey of experiences and attitudes toward Supply Chain Risks and Risk Management. Please help by adding and experiences to our growing knowledge base on supply chain risks.

The survey is directed toward supply chain, business and financial management professionals in manufacturing, retail and wholesale disruption companies located in many different regions of the world. Our objective is to understand how regional and cultural differences affect how people think about and manage supply chain risk.

The estimated time to complete this survey is: 12 minutes.

Your participation is voluntary. You may decline to answer any or all questions. You may exit from the survey at any time, without adverse consequences. Your responses will be kept confidential and used only for this study. Individual responses will not be made public and only aggregate results will be reported.

You are welcome to receive a summary of the survey findings when the study is completed, and to receive the summary you will need to provide your email address. If you chose to provide your email address, you are allowing MIT to both send you a summary of the study findings and to contact you, if needed, to voluntarily clarify or further explain your responses.

Thank you in advance for your participation.

Dr. Bruce Arntzen
MIT Supply Chain Risk Project Team

1. What is your main job function?
   - ☐ Risk Management or Business Continuity Planning
   - ☐ Supply Chain, Logistics, or Operations Management
   - ☐ Sourcing, Purchasing, or Supplier Management
   - ☐ Financial Management
   - ☐ General or Adminstrative Management
   - ☐ Engineering, Marketing or Sales
   - ☐ Other (please specify):

Opinions about Risks

2. There are two ways to mitigate supply chain risks:
    a. Planning and Implementing RISK PREVENTION Measures
    b. Planning and Practicing EVENT RESPONSE Measures

    How should your company spend its efforts?

	Spend much more effort planning and implementing RISK PREVENTION measures	**>>**	**Devote equal effort to each**	**>>>>**	**Spend much more effort planning and practicing EVENT RESPONSE measures**
Select a response					
Comments?					

3. Where in your company is the best position to do the following:

	Should be directed centrally	**Should be mostly directed centrally**	**Should be mostly directed at each site (locally)**	**Should be directed at each site (locally)**
Planning Risk Prevention Measures				
Implementing Risk Prevention Measures				
Planning Event Response Actions				
Performing Event Response Actions				
Comments?				

4. How closely does your company share the same sense of urgency around on-time delivery with:
    - Your most important suppliers?
    - Your most important customers?

	Different Sense of Urgency	**>>**	**>>>**	**>>>>**	**Same Sense of Urgency**
How well do your suppliers share your company's sense of urgency for on-time delivery?					
How well does your company share the same sense of urgency around on-time delivery as your customers?					
Other (please specify)					

Supply Chain Risks

5. Internal events

How often has your supply chain (at your site) been disrupted by these events?

Consider only MAJOR disruptions.

	Never	Rarely	About Yearly	Weekly or Monthly	Almost Daily	N/A
Spike in energy costs						
Inventory write-off due to new design change						
Cash crisis due to customers delaying payment						
Price collapse due to a new competitor						
Sales collapse due to a new competing product						
Cash crisis due to sudden drop in credit rating						
Spike in raw material costs						
Raw material supplier failure						
Finished goods manufacturing failure						
Transportation carrier failure						
Product quality failure						
Failure of major software systems						
Employee theft and executive misdeeds						
Other Supply Chain Risks (please specify)						

6. External events

How often has your supply chain (at your site) been disrupted by these events?

Consider only MAJOR disruptions.

	Never	Rarely	About Yearly	Weekly or Monthly	Almost Daily	N/A
Hurricanes, tornados or typhoons						
Earthquakes or tsunamis						
Floods or mudslides						
Fire or explosions						
Extended loss of electricity (>1 day)						
Disease or infestation						
Product tampering or counterfeit products						
Economic recession or market collapse						
Protracted labor disputes						
Sudden currency devaluation						
Computer virus or cyber attack						
Civil unrest or terrorism						
Other Supply Chain Risks (please specify)						

7. Considering everything, what are the three most important risks to your supply chain

	Supply Chain Risks
1st most important	
2nd most important	
3rd most important	
Other (please specify)	

FAILURE MODES

1. How frequently have you experienced the following types of supply chain disruption?

   Consider MAJOR disruptions only.

	Never	**Rarely**	**About Yearly**	**Weekly or Monthly**	**Almost Daily**	**N/A**
Your own internal operations are interrupted (e.g. power failure, machine breakdown, fire, etc.)						
You cannot communicate with vendors, customers, or other sites (e.g. systems fall, internet down, etc.)						
You lose supply of quality materials (e.g. supplier fails or cannot deliver, bad product quality, etc.)						
You cannot ship or deliver your products (e.g. no transportation, ports closed, roads blocked, etc.)						
Your people are not available (e.g. mass illness, work stoppage, etc.)						
You run out of cash (e.g. credit tightens, customer payments late, etc.)						
Sudden drop in customer demand (e.g. new competitor, financial crash, etc.)						
Other Supply Chain Risks (please specify)						

2. What type of disruptions are the most important for your company at your site to be prepared for?

	Supply Chain Risks
1st most important	
2nd most important	
3rd most important	
Other (please specify)	

SUPPLY CHAIN RISK MANAGEMENT

1. Tell us about Supply Chain Risk Management at your company:

	Yes, and it is effective	Yes, but it is not very effective	No	I do not know	N/A
We have a "Risk" manager or group					
We have a "Business Continuity" manager or group					
We have a Business Continuity Plan					
We actively work on supply chain risk management					
Our risk manager goes beyond just buying insurance to work on supply chain issues					
We work with customers on supply chain risk management					
We work with suppliers on supply chain risk management					
We have a formal security strategy					
We monitor world events for incidents that affect us					
We have an emergency operations center					
We work with law enforcement and emergency management authorities on risk management					
We simulate different supply chain risks and disruptions					
We analyze incidents to identify process improvements					
Comments?					

2. Which supply chain risks do you think are UNIQUE or MORE PREVALENT in your region than in other parts of the world?

BACKGROUND INFORMATION

We would like to get some basic information so that we can compare the responses across the participants.

1. Tell us about yourself

	Age	Gender	Education	Primary field of study
Age, Gender, Education, Nationality				

2. What countries and settings have you lived in and worked in?

	Countries you grew up in?	Setting where you grew up?	Country you work in now?	Setting where you work now?
Countries and settings				

3. What languages do you speak?

	Primary language spoken as a child	Primary language spoken at work	Secondary language spoken at work
Languages spoken			

4. What industry is your company in?

	What industry?
Industry	
Other industry (please specify)	

5. Tell us about your company:

	Size of annual revenues (globally) in USD	Number of people at your site	Number of people worldwide
Your company			

6. Tell us about your job (please select the closest match):

	How long have you worked for this company?	What is your job level?	What function are you in?	How long have you worked in this industry	How long have you worked in this function
Job and supply chain position					

Chapter 4

Synchromodality and the Effect on Logistics Differentiation: Construct Development and Empirical Examination

4.1. Introduction

The upward predictions of freight volume demand along with fuel price in a continuous rise, has put a significant pressure on shippers, transportation companies and policy makers to look for innovative technological and operational strategies that would make supply chains more efficient and sustainable, integrating the different transport modes and alleviating the increasingly overburdened road infrastructure. In front of a more digitalized world, companies are paying special attention to the path for aligning their operations with the access of data and technology that allows higher flexibility and visibility of their logistics networks. Furthermore, fast-growing competition is pressuring both shippers and Transportation and Logistics Service Providers (T&LSPs) to find strategies and competences to differentiate themselves. In this sense, synchromodality has emerged as an innovative concept towards a more sustainable, efficient, mode balance and optimized freight service network (ALICE, 2015; Dong, et al., 2018). In this research, we develop the definition of synchromodality as a multimodal transportation planning system where the different agents involved in the supply chain, work in an integrated and flexible way that enables them to dynamicall adapt the transport mode they used based on real-time information from stakeholders, customers and the network.

One of the consequences of the novelty of this concept is that few research studies exist regardless of the promising managerial an operational applications. For example, through a pioneer pilot study, the Port of Rotterdam partnered with shippers, transportation providers and coordinators to analyze the implications on environmental, efficiency and reliability of the implementation of synchromodality (Lucassen & Dogger, 2012). This pilot project attracted other major companies with major operations located in The Netherlands. For example, Nutricia, a Danone group company specialized in baby food and clinical nutrition, and Bavaria, a leading Dutch brewery company, partnered with the logistics company Samskip in 2014 to implement synchromodality in their European supply chains. This partnership resulted in a 50% reduction of CO_2 emissions and an easier and efficient management of the operations, especially during disruptions, and a highest quality service (Samskip, 2018; Topsector Logistiek, 2018). In parallel, researchers are working in the quantification of the impact of synchromodality on the overall supply chain. Dong et al. (2018) analyzed the network of a large shipper, currently applying intermodality on specific transportation lanes, and concluded that switching to synchromodality would lead to a 6% logistics cost savings and a 30% emissions reduction. This last figure is similar to the one obtained by Zhang and Pel (2016) in their simulation analysis of the effect of synchromodality on the Port of Rotterdam. Some researchers like Lee and Song (2017) have gone one step ahead suggesting a positive relationship between synchromodal applications with resilience, which helps to position this novel concept as a promising operational management research topic as disruptions in the supply chain can represent up to a 40% reduction in stock returns (Hendricks & Singhal, 2015). However, synchromodality is still at an incipient stage (Kurapati, et al., 2017; Dong, et al., 2018) and yet, to our knowledge, no study has presented a unified, holistic approach. As a result, current theory and understanding of the practices leading to synchromodality is uncomplete, and additional research is needed to comprehend the theoretical and applied aspects of synchromodality in both managerial and practical ways.

In this study, we aim to contribute to the existing literature by establishing the foundations of a rapidly growing concept on logistics research with promising applied results. We define, operationalize, and validate synchromodality from a transportation and supply chain perspective and analyze the different factors that contribute to its development. Furthermore, the implications of synchromodality in the performance of the logistics network are unknown, as well as the corresponding competitive advantage. To this end, using data from the European T&LSPs network of a leading multinational manufacturing company, we aim to address the existing research gap by deploying both a qualitative and a quantitative approach and, to the best of our knowledge, is the first to adopt a multidimensional conceptualization of synchromodal resources and practices.

The paper is structured as follows. In the next section we present a systematic literature review of the synchromodal concept and an overview of the different studies. This initial stage helped us to identify the different dimensions of synchromodality that are later validated with interviews of field experts. Our findings are used in the quantitative stage to develop and validate the scale for the construct of synchromodality through a pilot test. We then proceed to test the instrument using an Exploratory Factor Analysis, followed by a Confirmatory Factor Analysis and Path Analysis based on SEM to identify the optimum measurement model and the effect of synchromodality on logistics differentiation as evidence for competitive advantage. We conclude this paper with some ending remarks, managerial implications and limitations, and avenues for future research.

4.2. Synchromodality Conceptual Framework

4.2.1. Theoretical Background on Synchromodality

Synchromodality is the most recent concept that has emerged in the operations of freight transport chains; as such, it has received increased attention from academia, research institutions, and R&D departments of transportation and logistics companies. Despite the novel name, synchromodality is not a new way of dealing with freight transport but rather an evolution of four well-established and widely recognized concepts: multimodal, intermodal, combined and co-modal transportation (Reis, 2015).

The first concept, multimodality**,** appeared in the 1980s as a means to facilitate the "orderly expansion of the world trade," (UNCTAD, 1980) and it is simply defined as the transportation of goods in which at least two different types of modes are involved. The need to create a more efficient use of resources that would favor competition and reduce the share of road mode (Commission of the European Communities, 1997) led to the concept of what is known as intermodality, which includes three new concepts: integration, load unit, and door to door (Reis, 2015). In intermodality, the container or swap unit travels from origin to destination using different modes (SteadieSeifi, et al., 2014). The concepts of combined transport and co-modal transport have received the least attention. The idea of combined transport appeared with the aim to alleviate road congestion in central Europe and reduce CO_2 by shifting part of the freight transportation from roads to more sustainable modes such as rail, air, or inland waterways and, as such, it is simply defined as a type of intermodal transport in which road was

not the main transport mode used (UN/ECE, 2001). In co-modality, the deployment of new technologies along with more cooperative and integrative systems allows for an efficient use of the different transportation modes either alone or in combination, resulting in an optimal and sustainable utilization of resources (European Commission, 2006 ; SteadieSeifi, et al., 2014).
We finally arrive at the concept of synchromodality, a term that was first introduced in 2010 by Dutch researchers (Reis, 2015) It was rapidly seen to have the potential to develop reliable, cost-effective and sustainable freight (Kurapati, et al., 2017). Consequently, since its conceptualization, synchromodality has received steadily increased attention, as it combines all its precedents' characteristics with an additional real-time decision dimension. However, it would be interesting to understand why synchromodality would succeed when previous concepts such as intermodality or co-modality have not yet attained the expected results regarding sustainable and efficient distribution of the freight movements (Behdani, et al., 2016; Dong, et al., 2018). The reason may lie in the combination of synchromodal benefits with advances in technology and other trends such as digitalization that enable companies to take action based on real-time data.

In this study, we postulate that synchromodality presents a supply chain competitive advantage through logistics differentiation. Today's global economy is mainly characterized by demanding customers striving to success in highly competitive environments. Because of that, supply chains and logistics managers should aim for more than cost optimization and ensure that they are offering their customers a differentiated and competitive value service (Fugate et al., 2010). In the supply chain field, offering services that are perceived as being of superior value can be translated in a competitive advantage (Hitt, et al., 2016) and, especifically in the transportation and logistics, firms can differentiate themselves from competitors as they create value through the "inimitably of their logistics" and by developing a superiority when compared to competitors (Fugate, et al., 2012). Therefore, we propose that firms that deploy synchromodality perform better, creating logistics differentiation.
To understand the benefits of synchromodality, we first need to fully explore what it is and the different theoretical perspectives surrounding it. Unfortunately, researchers have not yet agreed on the definition of the term (Behdani, et al., 2016), and there is some ambiguity in the concept and an absence of a common theoretical framework, which motivates us to conduct a holistic and methodical systematic literature review.

4.2.2. Systematic Literature Review

A systematic literature review enables high-quality research and new knowledge creation (Meredith, 1993) through bias minimization, critical interpretation, and a transparent and inclusive approach to existing published research studies (Hohenstein, et al., 2015). Consequently, it becomes essential in achieving reliable and accurate conclusions (Rousseau, et al., 2008) and establishing the foundation for further theory development and progress in the research field.

Following the methodology developed by Light and Pillemer (1984) and Hohenstein et al. (2015), in approaching a systematic literature review, we began with the identification of all relevant information sources. Multiple online databases such as EBSCO, Emerald Insight, Science Direct, IEE Explore Digital Library and Taylor and Francis Online were used to minimize bias (Hohenstein, et al., 2015). The search was done using the keywords "synchromodal*" and "synchro-modal*" and limited to fields in logistics, transport, and supply chain. We initially focused our research on peer-reviewed academic journals as this material is subject to strict publication requirements, facilitating the quality of the research study (Light & Pillemer, 1984; Rousseau, et al., 2008). However, as the research area is quite novel, we also decided to include studies from conference proceedings, paying special attention to those published in peer-reviewed journals such as *Transportation Research Procedia* and *Procedia Engineering* as a way to guarantee the quality. New ideas and works in progress are commonly presented at conferences, thus it was important to include this source of information. After removing all duplicates, this initial search resulted in 57 research works.

We proceeded to read all the abstracts of the 57 works to determine the relevancy to synchromodality. We excluded 9 articles not related to transportation, logistics, or supply chain. We also ruled out 14 articles whose focus was other than synchromodality, and therefore we considered a total of 34 articles in our second round of review. In the second phase, we proceed to read all 34 papers, cross-referencing citations and bibliographies to ensure that no important contribution was missed and that all relevant published work was included in our research. This step resulted in the addition of 19 new titles.

We had a total of 53 research publications evenly spread between conference proceedings and journal papers each of the years. The full list was subsequently analyzed following a coding schedule and coding manual (Touboulic & Walker, 2015). This analysis included all relevant bibliographic information: study title, author, journal, ISSN/ISBN, year, DOI, keywords, subject, and so forth. We then added type of paper, methodology, perspective, and relevant information regarding the topic of synchromodality (definition, differentiate characteristics). No restrictions were placed on dates or years of paper publications. Figure 4.1 represents distribution of the publications since the synchromodality concept emerged, with a steep increase beginning in 2014. In total, 53 academic papers have been published since the concept was originated, with the first paper on the concept appearing in 2012.

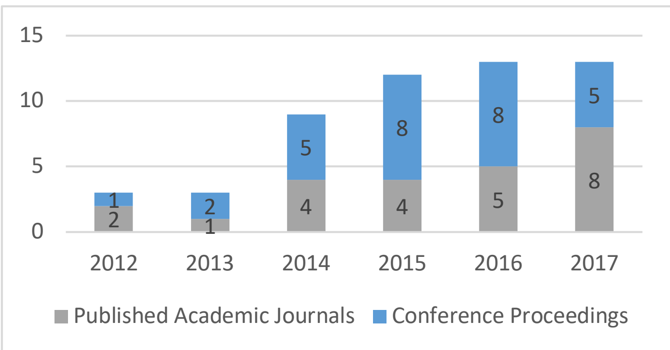
Eighty-nine percent of the articles were published between 2014 and 2017, and more than half of those publications (around 55%) were published in 2016 and 2017, confirming the increasing interest. Conference proceedings were prevalent during the first years—almost double the number of published papers in academic journals. This seems reasonable, as researchers usually present their work at conferences and later in scientific journals once the study is mature. This trend, however, reverted in 2017 when publications in peer-reviewed journals accounted for 62% of the total publications in that year. Overall, four papers did not fall into the transportation or logistics area. Three had a supply chain orientation, and another had a focus on perishable goods. Papers were evenly distributed between theoretical and operations planning with only 8% classified as empirical—in the majority of the cases using a case study methodology.

It can be observed in Figure 4.1 that the publication growth rate of synchromodal-related studies is not exponential. However, the trend resembles the one experienced by other concepts during their first years of existence such as resilience as studied by Kamalahmadi and Parst (2016) and even exceeds the attention that concepts such as coopetition or sustainability in supply chain received in the first years, as reported by Dorn et al. (2016) and Chen et al. (2017). However, this is not the only indication of the relevance of this emerging concept. The fact that it has made its way through top research journals in such a short period and around half of the publications that appeared in 2017 publications appeared in level A-journals is a clear indicative of the topic research and practical potential. Table 4.1 summarizes the journals where the analyzed papers have appeared.

Table 4.1: Journals where the Reviewed Articles Have Been Published

Journal	**SJR2017**	**Number of Publications**	**Years of Publication**
Transportation Research Part B	2,742	1	2017
European Journal of Operational Research	2,505	2	2014,2017
Decision Support Systems	1,806	1	2016
Transportation Research Part E	1,694	2	2017
Journal of Transport Geography	1,558	2	2015,2016
Flexible Services & Manufacturing Journal	1,553	1	2017
Water Resources Management	1,355	1	2014
Transportation Research Part D	1,195	1	2017
Safety Science	1,054	1	2017
European Journal of Transport & Infrastructure Research	0,536	1	2016
Research in Transportation Business & Management	0,395	1	2016
Maritime Economics & Logistics	0,391	3	2014,2015,2016
Mathematical Problems in Engineering	0,277	1	2015
International Journal of Electronic Government Research	0,214	1	2012
Sustainability	0,146	1	2017
International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering		1	2013
International Journal of Supply & Operations Management	--	1	2014
LogForum	--	1	2012

Figure 4.1: Publications of Synchromodality related articles per year



4.2.3. Conceptual Development of the Construct

As summarized in Table 4.2, the analyzed journals include a wide array of synchromodality definitions. A review of these definitions showed that even though no consensus exists on a precise definition of synchromodality, there are some underlying characteristics that repeat as presented in Table 4.3. First, as an evolution of previously developed and well-known concepts, synchromodality embraces all of the intermodal and co-modal transportation characteristics (Reis, 2015). In other words, it includes the use of two or more transport modes in an integrated, efficient, and sustainable way. However, synchromodality goes one step further, as it has the ability to adapt the network to the dynamically changing environments in which global companies are currently operating. The movement of goods is no longer dictated by pre-fixed or pre-arranged schedules and routes but a by flexible mode-free booking planning operations (Zhang & Pel, 2016). Shippers dictate when and where the goods should be delivered, and the transportation chain has the flexibility to operate as needed to meet customer requirements (Tavasszy, et al., 2015; Lin, et al., 2016). Under this scenario, T&LSPs play an essential role in the operationalization of synchromodality. The choice among different available transport modes is based on customer requirements such as shipping time, cost, or shipping conditions (whether a refrigerated transportation is required, for example) as well as on external information, such as the network status and other operational-related circumstances (SteadieSeifi, et al., 2014), which pose visibility as a one of the unique dimensions of synchromodality. Visibility is achieved through the gathering of multiple stakeholder data. This information could include, but would not be limited to, information regarding demand, delays, transit times, pricing, network congestion, and so forth (Resi, 2015; Behdani, et al., 2016). Therefore, the operationalization of the transport chain is no longer fixed and contractually predefined, but rather dynamically adapted and periodically revisited according to information received in real time (Reis, 2015). The large amount of real time data in the deployment of synchromodality implies that different partners in the supply chain have to work in an integrated way (van Riessen, et al., 2015; Behdani, et al., 2016), which positions integration as another of the distinctive features of synchromodality.

Table 4.2: Definitions of Synchromodality

Reference	***Synchromodality Definition***
(ECT, 2011)	*"Optimally flexible and sustainable transport system created in which companies are always assured of optimum transport combinations depending on the circumstances – product, required speed, physical conditions etc – and can easily switch between modes of transport if necessary"*
(Pleszko, 2012)	*"Innovative, promising idea of flexible and sustainable utilization of transport resources based on the co-operation of carriers representing various transport modes, adjusted to customer requirements and current transport capacities"*
(Haller, et al., 2015)	*"Evolution of inter- and co-modal transport concepts, where stakeholders of the transport chain actively interact within a cooperative network to flexibly plan transport processes and to be able to switch in real-time between transport modes tailored to available resources. The shipper determines in advance only basic requirement of the transport such as costs, duration and sustainability aspects. Thus, transport processes can be optimized and available resources and fully utilized"*
(SteadieSeifi, et al., 2014)	*"Synchromodal freight transportation is positioned as the next step after intermodal and co-modal transportation, and involves a structured, efficient and synchronized combination of two or more transportation modes. Through synchromodal transportation, the carriers or customers select independently at any time the best mode based on the operational circumstances and/or customer requirements"*
(Buiel, et al., 2015)	*"Synchromodality is the flexible and sustainable deployment of different modes of transport in a network under the direction of a logistics service provider, so that the customer is offered an integrated solution for his (inland) transport"*
(Tavasszy, et al., 2015)	*"Vision of a network of well-organized and interconnected transport modes, which together cater for the aggregate transport demand and can dynamically adapt to the individual and instantaneous need of network users"*
(van Riessen, et al., 2015)	*"Concept of optimizing all network transportation in an integrally operated network, making use of all transportation options in the most flexible way"*
(Xu, et al., 2015)	*"Synchromodal freight transportation involves a structured, efficient, and synchronized combination of two or more transportation modes"*
(Behdani, et al., 2016)	*"Integrated view of planning and uses different transportation modes to provide flexibility in handling transport demands"*
(Kapetanis, et al., 2016)	*"Synchromodality is effectively an evolution of a multimodal supply chain applying ICT (Information and Communications Technology) to gain efficiency, i.e. Minimize costs and time"*
(Pfoser, et al., 2016)	*"Evolution of inter- and co-modal transport concepts, where stakeholders of the transport chain actively interact within a cooperative network to flexibly plan transport processes and to be able to switch in real-time between transport modes tailored to available resources"*
(Zhang & Pel, 2016) *adopted from DINALOG*	*"If a shipper enters a contract with a logistics company that only covers price, time of delivery and level of quality, this gives the logistics supplier the freedom to opt (flexibly) for other modes of transport. This could be train, boat or airplane. Speed, cost reductions and sustainability are advantages that appeal to both the shipper and the logistics company. Important conditions for promoting synchromodality are: good coordination, regulations and contracts."*
(Li, et al., 2017)	*"Synchromodal freight transport moves one step forward from intermodal freight transport by adopting the mode-free booking concept and allowing timely switching among available modalities according to the real-time information of the freight transport process"*

(Dong, et al., 2018)	*"A multimodal strategy that incorporates the flexible choice of freight transportation modes into shippers' management of supply chain process"*

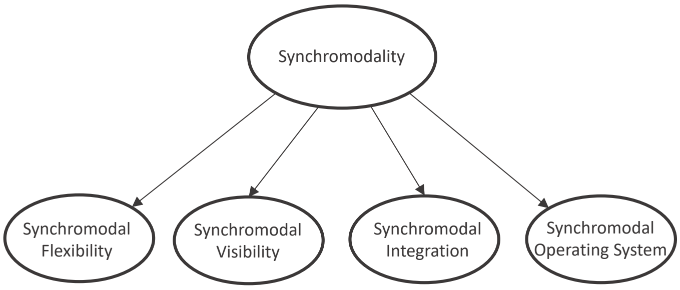
Table 4.3: Differentiating Factors of Synchromodality

Differentiating factors	***References***
Different transport modes in one integrated shipment	(Reis, 2015; Tavasszy, et al., 2015; Xu, et al., 2015; Behdani, et al., 2016; Kapetanis, et al., 2016; Pfoser, et al., 2016; Zhang & Pel, 2016; Kurapati, et al., 2017)
Mode-free bookings	(SteadieSeifi, et al., 2014; Reis, 2015; Tavasszy, et al., 2015; Kapetanis, et al., 2016; Zhang & Pel, 2016; Li et al., 2017)
Sophisticated dynamic planning of transport routes	(Pfoser, et al., 2016)
Multiple stakeholder data to optimize transport planning	(Reis, 2015; van Riessen, et al., 2015; Pfoser, et al., 2016; Kurapati, et al., 2017; Li, et al., 2017)
Real time switching of transport modes	(SteadieSeifi, et al., 2014; Reis, 2015; Tavasszy, et al., 2015; van Riessen, et al., 2015; Lin, et al., 2016; Pfoser, et al., 2016; Kurapati, et al., 2017; Li, et al., 2017)
Continuous work with stakeholders	(Reis, 2015; Xu, et al., 2015; Pfoser, et al., 2016)

4.2.4. Construct Summary: Synchromodal Definition and Dimensions

Our systematic literature review analysis enables us to determine the concept of synchromodality from both a theoretical and operational point of view. First, using the different definitions found in the literature and summarized in Table 4.2, we define synchromodality as a *multimodal transportation planning in which different agents in the transport chain work in an integrated way to flexibly adapt the transport mode based on real-time information from stakeholders, customer needs and network constraints*. Secondly, we can observe four dimensions in synchromodality: (1) synchromodal flexibility, (2) synchromodal visibility, (3) synchromodal integration, and (4) synchromodal operating system.

Figure 4.2: Synchromodality Dimensions



Synchromodal Flexibility (SF)

The definition of synchromodality indicates that synchromodal networks embrace flexibility (Buiel, et al., 2015; Zhang & Pel, 2016; Dong, et al., 2018). Firms can flexibly plan operations, but they can also adapt transport mode based on real-time information, which is then communicated to increased overall flexibility of the entire supply chain in which they operate. From the logistics perspective, flexibility is defined as the "capability to adapt to new, different, or changing requirements" (Defee & Fugate, 2010 p. 183). It can also be understood from a supply chain perspective, as the supply chain ability to respond and adapt to unexpected circumstances (Skipper & Hanna, 2009; Scholten & Schilder, 2015; Kamalahmadi & Parst, 2016), which is consequently translated as a differentiating aspect in uncertain and competitive markets (Moon, et al., 2012; Streedevi & Saranga, 2017).

Synchromodal Visibility (SV)

The literature review suggests that synchromodal environments rely on the use of real- time information from multiple sources in order to optimize and dynamically review transport operationalization (Kamalahmadi & Parst, 2016; Kurapati, et al., 2017; Li, et al., 2017). Information flows between shippers and T&LSPs as well as from multiple stakeholders such as port data, vessel data, terminal data, logistics platforms, network (van Riessen, et al., 2015). The knowledge of the status of the supply chain and its environment (Pettit, et al., 2013) is what constitutes the visibility of the system. However, in the case of synchromodality, the flow of information is not enough "per se" and must be performed in a timely and complete manner in which the different supply chain players can then function (Francis, 2008; Scholten & Schilder, 2015).

Synchromodal Integration (SI)

Integration is a key feature in synchromodality and, as such, van Riessen et al. (2015) and Behdani et al. (2016) define synchromodality as an integrated operated network. From a supply chain perspective, integration is defined as "the degree to which an organization strategically collaborates with its supply chain partners and manages intra- and inter-organization processes to achieve effective and efficient flows of products, services, information, money and decisions, with the objective of providing maximum value to its customers" (Zhao, et al., 2008 p.374). Integration allows supply chains to respond to sudden changes in demand (Wieland & Wallenburg, 2013), helping firms to anticipate to customer needs in a changing environment (Flynn, et al., 2010) by facilitating the flow of information, materials, products and services across the different partners of the supply chain (Kim & Schoenherr, 2018).

Synchromodal Operating System (SOS)

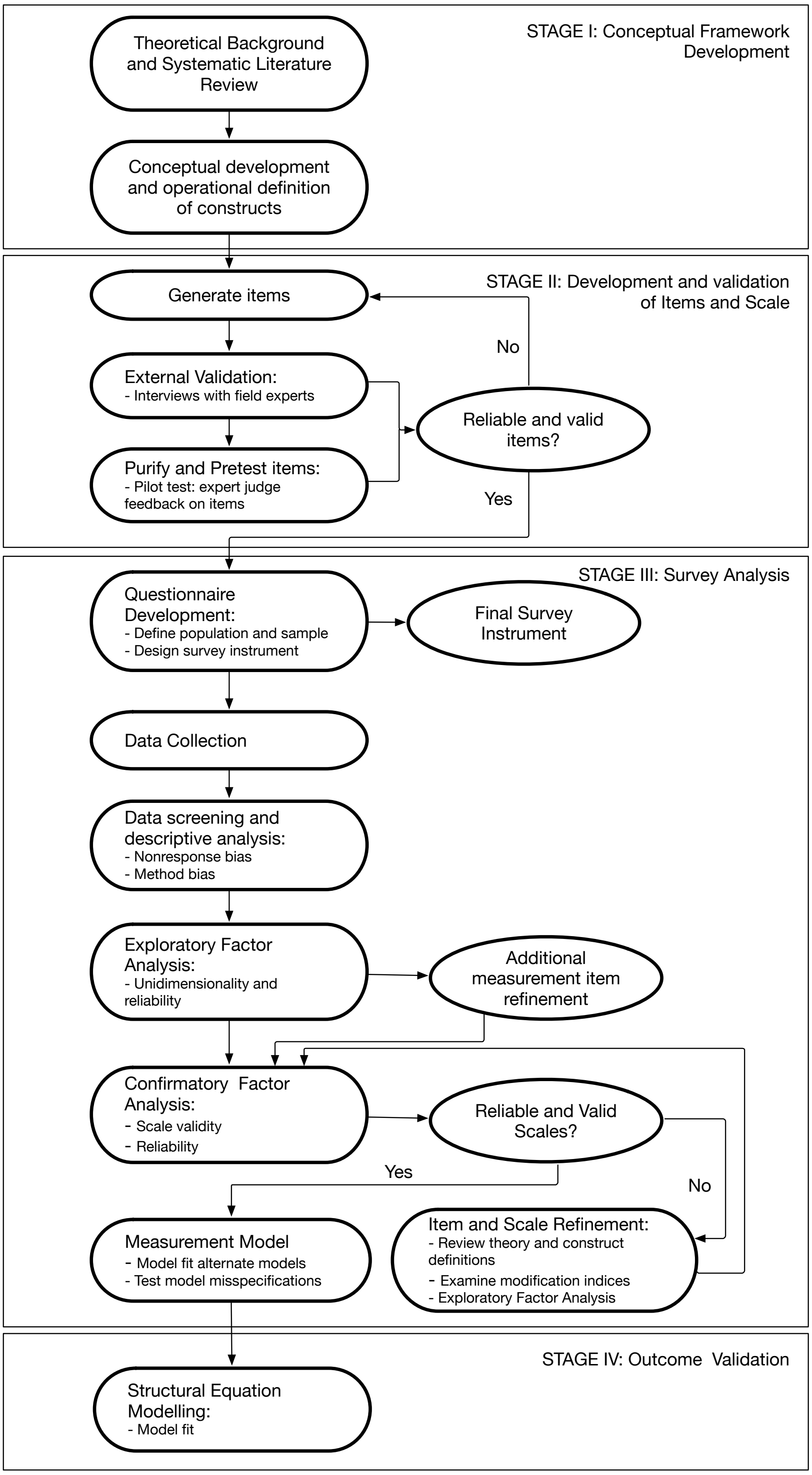
Finally, synchromodality has an operationalization dimension (Verweij, 2011). Like other transportation problem, operational aspects such as mode and routing choice need to be taken into consideration. Similar to intermodality, a concept from where synchromodality evolves, the shipper uses different transport modes in one integrated shipment (Kapetanis, et al. , 2016; Zhang & Pel, 2016; Kurapati, et al., 2017) and each shipment is completed in a mode-free way (Resi, 2015; Zhang & Pel, 2016; Li, et al., 2017). However, the operationalization is done based on a sophisticated dynamic tool (Pfoser, et al., 2016) in which real-time information from multiple stakeholder (Resi, 2015; van Riessen, et al., 2015; Pfoser, et al., 2016) can be used to immediately switch transport services on different transport modes based (Pfoser, et al., 2016; Kurapati, et al., 2017; Li, Negenborn & de Schutter, 2017).

4.3. Development and Validation of Synchromodality Items and Scale

In the development and validation of a new construct in the operations management (OM) field, researchers face two main challenges: appropriateness of the construct domain, measurement items selection as well as their reliability and validity (Little, et al., 1999; Menor & Roth, 2007). To ensure that items used in the construct operationalization truly measure what they are supposed to measure (Churchill, 1979), we developed the methodology shown in Figure 4.3, adapted from Menor and Roth (2007) and from Chan et al. (2016).

The systematic literature review developed in the previous section, was complemented by in-depth discussions with supply chain and logistics executives experts in synchromodality. This exploratory qualitative research aided us to validate each of four synchromodal dimensions. The aim of this qualitative step was to determine the content validity of synchromodality, establishing a construct domain that could be generalized with practices that were relevant. We approached seven practitioners that were currently involved in synchromodal projects within their organizations, providing a suitable context to further advance in the theory-based conceptualization for synchromodality made in the previous stage. The synchromodal logistics experts were then asked their vision on synchromodality, the dimensions it is composed of and how it was or could be implemented in their organizations. Interviews were recorded, scripted, coded and categorized to identify the underlying dimensions of synchromodality. The findings of these interviews were matched with the dimensions identified in our systematic literature review to ensure the content validity of our measurement instrument. Managers agreed that synchromodality will position supply chains with a competitive advantage through the creation of an integrated network. A number of managers highlighted the need to make quality information available in real time, specifically the one related to forecasting, load status and physical network status. The respondents also emphasized the flexible dimension of synchromodality, as this novel concept can make supply chains adapt more easily to changes due to internal or external disruptions. Finally, managers discussed how they envision the operationalization of synchromodality through mode-free booking and flexible transport mode switching.

Figure 4.3: Methodology for a New Construct Development Model and Outcome Validation



Based on our systematic literature review and on the interview findings, we proposed twenty measurement items that captured the four different dimensions of synchromodality, following the recommendations from Saris and Gallhofer (2007) regarding questionnaire developments. The operationalization of the first three dimensions was done using previously operationalized and validated constructs from the supply chain and logistics field and adapted to the synchromodal context. Each item was assessed using a 7-point Likert-type scale ranging from 1 to 7 (1 = strongly disagree to 7 = strongly agree).

Synchromodal Flexibility is the first dimension identified. Its operationalization was adapted from Swafford et al. (2006) and Williams et al. (2013). The items selected and subsequently adapted capture the capability of the T&LSPs to handle customer delivery requirements and external changes. Synchromodal Visibility has been adapted from Williams et al. (2013). The items capture the firms' capability to obtain and process timely and accurate information of the operations and external constraints. Synchromodal Integration has been adapted from Danese et al. (2013) and Flynn et al. (2010). The items capture the external integration of the T&LSPs with customers and other partners involved in the firms' daily operations. Finally, we proceeded to identify the items that describe Synchromodal Operating System. This is a newly developed construct where the items capture the operating nature of the concept based on the findings of our theoretical and qualitative research methodology.

Once the initial operationalization was established and, as the construct has not been operationalized, we proceeded to purify, refine, and pretest the different measurement items using a pilot test. This procedure, recommended by Lashwe (1975) and implemented in the initial operationalization of OM constructs (Menor & Roth, 2007; Ambulkar, et al., 2015) involves a scale purification through a substantive validity check and a substantive validity of measure in terms of how well the items reflect the measured construct. This pilot test was conducted in English among 52 respondents with an international background in supply chain, consisting of 43 executives in the logistics and transportation field and 9 research faculty experts. We checked the content and validity with each respondent and began by asking them two questions:

1. Is the item relevant to the understanding of synchromodality (Likert scale 1 to 7)?
2. From your professional/academic experience, would you add or modify any of those items?

To evaluate the items that should remain in our operationalization, we analyzed the items substantive validity using two measures: proportion of substantive validity (p_{sa}) and substantive validity coefficient (C_{SV}) (Anderson & Gerbin, 1991). The coefficient p_{sa} is defined as "the proportion of respondents who assign an item to its intended construct" desired (Anderson & Gerbing, 1991, p. 734). It ranges from 0 to 1, with higher values as desirable and indicating greater substantive validity. The substantive validity coefficient is calculated using the formula $C_{SV} = \frac{n_c - n_0}{N}$, with n_c as the number of experts believing that the item is significantly contributing to the operationalization of synchromodality and n_0 as a negative answer. C_{sv} value ranges between -1 and +1, with those closer to +1 indicating a high validity and those going to -1 indicating a low validity. Items with p_{sa}> 0.7 and c_{sv}> 0.5 were retained.

After these steps, the 20 items were reduced to 18. The wording of four items was also slightly changed. The experts' recommendations were used to improve the items construction, refine the wording to include new demographic questions based on the experts' previous research experience. During the pilot test, the respondents reported no difficulties completing the questionnaire.

4.4. Survey Analysis

After refinement of our research instrument, we moved to the next stage of our methodology in order to confirm measurement reliability and validity. We developed an online survey questionnaire using the 18 remaining items from the previous stage. The questionnaire was entirely developed in English.

To carry out our research, we partnered with a multinational manufacturing company that we would refer to as *ConsumerCo*. We decided to choose this company for several reasons. First, *ConsumerCo* is a global leader in its manufacturing market both at European and global level. Second, the company has a strong focus on developing logistic supply chain practices to achieve excellence. Third, *ConsumerCo* allocates significant investment to R&D and are looking at synchromodality in a strategic and differentiate manner, to the point that they have launched several synchromodal pilot projects. Finally, the company has a strong presence in Europe. As the concept of synchromodality is relatively new and mainly embraced by European companies, it seemed logical to put the initial focus on this regional area. The operationalization of synchromodality is done by transportation and logistics companies, hence it made sense to define our unit of analysis as the transportation and logistics service providers based in Europe.

Additionally, we included in the survey the construct of logistics differentiation that would be analyzed in a later stage in the overall model. This construct was measured using existing scale items that were slightly adapted to the context from the research work of Fugate et al. (2010).

We worked closely with the responsible of the transportation and logistics department from *ConsumerCo* to identify the key informants from each firm that would be able to respond the survey in the most accurate way, as in most of the cases, a unique respondent was making the decisions regarding the constructs subject to analysis in this study. To avoid any bias, we did not include *ConsumerCo* in any of the communications, and we did not reveal the companies the research collaboration with *ConsumerCo*. Confidentiality was guaranteed. To increase the response rate, we followed the recommendations from Dillman et al. (2014). We contacted a total of 210 companies through email, stating the purpose of our research and inviting them to answer our online survey. To improve the response rate, we contacted them again to explain what we were studying and why their help was important. As an incentive, we offered each of the participants a managerial summary of our research results. Regular reminders were sent out to increase the response rate. As a result, we received a total of 110 usable responses, which represented a 52% response rate. The respondents represent a wide sample of the transportation and logistics business in Europe in terms of firm size (measured both in terms of number of employees and revenue), which helped to avoid large firm bias (Williams, et al., 2013). Out of the surveyed firms, 52.7% had less than 500 employees, 27.5% had between 500 and 1,000, and 19.8% were very large firms with over 1,000 employees. In terms of revenue, 42.9% of the companies had revenues of less than $500 million, 37.5% had between $100 and $500 million, 18.7% had revenues between $500 million and $20 billion, while only 1.1% had revenues of over $50 billion (see Table 4.4).

Respondents' positions and responsibilities also represented a wide variety: 94.6% of the respondents had managerial or technical positions while only 5.4% of the respondents were top executives or CEOs. Only 25.6% had less than 3 years of experience, 55.2% had between 3 and 12 years of experience, and 19.2 had over 12 years. Respondents were mainly working in Operations & Planning (29.4%), Business Development (39.1%) or Management (16.3%) (See Table 4.5).

Table 4.4: Respondent's Firm Characteristics

Annual revenue	% of respondents	Firm's Activities*	% of respondents
Under $1 million	3.3%	Logistics Service Provider	68%
$1 - $10 million	7.7%	Transport Operator	66%
$10 - $100 million	31.9%	Warehousing	48%
$100 - $500 million	37.3%	Freight Forwarder	40%
$500 million - $1 billion	5.5%	Value-added services	27%
$1 - $5 billion	8.8%	Customs	21%
$5 - $20 billion	4.4%	Good tracking	16%
$20 - $50 billion	--	Consulting	10%
Over $50 billion	1.1%	Packing	6%
		Data Analytics	3%
Geographical presence	**% of respondents**	**Geographical presence**	**% of respondents**
Central Europe	16.5%	Middle East	4.3%
Western Europe	15.1%	Northern Africa	4.1%
Eastern Europe	13.5%	South America	3.0%
Southern Europe	13.3%	Central America	2.7%
Northern Europe	13.0%	Only at national level	2.1%
Asia	4.8%	Sub-Sahara Africa	1.6%
Northern America	4.3%	Other	1.6%

*certain firms fall into different categories

Table 4.5: Respondent's Firm Differentiating Value

Firm's Differentiating Value	% of respondents	Firm's Differentiating Value	% of respondents
Reliability	65.7%	Geographical coverage	48.6%
Efficiency	64.8%	Agility	42.9%
Full service	54.3%	Price	40.0%
Capability	53.3%	Accessibility	32.4%
Innovation	49.5%	Other (Sustainability)	2.9%

Table 4.6: Respondent's Characteristics

Job title	% of respondents	Years in current position	% of respondents
CEO	5.4%	1-3 years	25.6%
Head of Department	40.9%	4-6 years	9%
Team Leader	30.1%	7-12 years	46.2%
Team Member	32.6%	Over 12 years	19.2%
Area of work	**% of respondents**	**Country**	**% of respondents**
Operations	21.8%	Spain	12%
Planning	7.6%	France	10%
Business Development	39.1%	Belgium	8%
General Management	16.3%	Italy	8%
Others	15.2%	UK	8%
		Germany	7%
Full time employees	**% of respondents**	The Netherlands	7%
1-50	6.6%	Poland	7%
51-100	12.1%	Austria	6%
101-500	34%	Romania	4%
501-1000	27.5%	Latvia	3%
Over 1000	19.8%	Ireland	2%
		Lithuania	2%
		Others	14%

Common method bias could present a problem, as we collected information from a single respondent per firm (Huber & Power, 1985; Podsakoff, et al., 2003), which can potentially lead to misleading conclusions (Campbell & Fiske, 1959). Most recent research agrees that the most convenient way to deal with common method bias is by collecting the information from multiple respondents (Ketokivi & Schroeder, 2004). However, more than 50% of our sample was formed by SMEs (defined as companies with less than 500 employees) from a single industry, who provides the logistics and transportation services to a focal company which is the empirical purpose of the present study. In these cases, finding more than one suitable respondent able to provide well-informed answers can constitute an impossible task in most of the cases (Kull, et al., 2018). Consequently, we carefully select the key respondents within each firm that were able to provide solid information regarding the different aspects of our study, which mitigates the effect of common method bias (Flynn, et al., 2018; Montabon, et al., 2018). Furthermore, single respondent difficulties can be compensated using a multi-methodology approach, such as incorporating interview from field experts to ground the research (Montabon, et al., 2018) as we did in stage II of the research (refer to figure 4.3).

Additionally, we perform a mix of a priori and post-hoc approaches (Podsakoff, et al., 2003): (1) the questionnaire was directly sent to respondents with knowledge in firm transportation operations and planning; (2) we guaranteed the confidentiality of the respondents; (3) to avoid ambiguity in the questions, we used items from previously operationalized constructs and performed a testing stage with professionals and academic researches as discussed in the previous section; (4) the design of each question in our survey instrument was addressed to characterize by objective description of the action or operation that can be answered by the real decision maker in the T&LSP company; and (5) we avoided using questions relating to more than one subject. The post-hoc approach of common method bias involved the application of Harman's test as described by (Podsakoff, et al., 2003). We performed an unrotated exploratory factor analysis and observed that no single factor appeared, and no factor added up more than half of the covariance.

We tested for nonresponse bias following the recommendations found in Rogelberg and Stanton (2007). We first performed a series of response facilitation approaches prenotification of participants, careful design, incentives, and reminders among others. Additionally, we tested for non-response bias by looking for statistically significant differences between early and late respondents (those who replied to the first email and those who replied to the reminder email)

(Armstrong & Overton, 1977). The test did not find any significant differences between the two groups, suggesting that non-response bias does not pose a problem.

Unidimensionality and Reliability

The reliability of the construct was evaluated following the two-step methodology proposed by Narsimhan and Jayaram (1998). This procedure evaluates construct reliability using an exploratory factor analysis (EFA) and the internal consistency calculating the Cronbach's alpha values. As detailed in Table 4.7 we obtained four factors that corresponded with each of the analyzed dimensions of synchromodality. Each factor had eigenvalues greater than 1 and a cumulative variation of 56.3%, thus exceeding the recommended cut-off value of 50% (Hair, et al., 2009). The appropriateness of the EFA was evaluated with the Kaiser-Meyer-Olkin (KMO) test and Barlett's test of sphericity. The KMO value of 0.73 exceeded the recommended cut-off value of 0.5, indicating the overall sampling adequacy. Barlett's test provided evidence of the validity of the instrument with a value of 315.48 (df= 16; p <0.001).

Table 4.7: Results of the Exploratory Factor Analysis.

	Factor Loadings			
Item	**Flexibility**	**Visibility**	**Integration**	**Operating System**
SF1	0.705			
SF2	0.730			
SF3	0. 824			
SF4*				
SV1		0.765		
SV2		0.830		
SV3		0.762		
SV4*				
SV5		0.816		
SI1			0.749	
SI2			0.814	
SI3			0.799	
SI4			0.924	
SOS1				0.745
SOS2				0.602
SOS3*				
SOS4				0.818
SOS5				0.694
Eigenvalue	1.791	2.865	2.745	2.182
Variation	0.105	0.169	0.161	0.128

**Item found non-significant*

Items with factor loading below 0.5 were identified as non-significant and consequently deleted (Hair, et al., 2009). The initial operationalization was consequently refined, and we retained 15 out of the 18 initial items. Internal consistency did not pose a problem as all Cronbach's alpha values were above the cut-off value of 0.70 (Fawcett, et al., 2014). We also validated internal consistency calculating the composite reliability score (rho or coefficient omega). All values were also above 0.7 (Fawcett, et al., 2014).

Validity

We assessed both convergent and discriminant validity. Convergent validity was assessed through a confirmatory factory analysis (CFA) (O'Leary-Kelley & Vokurka, 1998). Convergent validity occurs when the loading of the item on the expected factor is greater than 0.5 and, the average variance extracted is also greater than 0.5 (Fawcett, et al., 2014). In our case, the model suggested good validity as all values exceed the thresholds. Finally, to assess discriminant validity we performed four verifications: (1) the loading of each item was higher on its assigned construct than on any other one; (2) mean shared variance was below 0.5, and; (3) the square root of AVE was greater than any correlation estimates in each of the constructs (Fawcett, et al., 2014). Finally, we also obtained the heterotrait-monotrait (HTMT) ratio to test for discriminant validity as recommended by Henseler et al. (2015). Table 4.8 presents the HTMT results. All values are less than 0.85, confirming the discriminant validity of our scale.

As a result, we could conclude that evidence exists to suggest sufficient reliability and convergent and discriminant validity in our measurement model.

Table 4.8: HTMT Criteria for Discriminant Validity Test

	SF	SV	SI	STP
SF	--	--	--	--
SV	0.310	--	--	--
SI	0.327	0.293	--	--
STP	0.176	0.158	0.293	--
DiffLog	0.443	0.305	0.435	0.142

Table 4.9: CFA Measurement Statistics and Loadings.

Construct/Item	Mean (SD)	Construct Development Std loadings	Outcome Validation Std loadings
SYNCHROMODAL FLEXIBILITY [adapted from Williams et al. (2013) and Swafford et al. (2006)]			
Construct Development: AVE= 0.56; KMO= 0.7; Cronbach's α = 0.79; Composite reliability (rho, omega) = 0.79			
Outcome Validation: AVE= 0.56; KMO= 0.70; Cronbach's α = 0.79; CR = 0.79			
SF1 – Our services/equipment/operations are designed to be easily modified	5.02 (1.28)	0.77	0.77
SF2 – We can change quickly from one transport service to another	5.23 (1.23)	0.69	0.70
SF3 – We can easily adjust to different distribution delivery requirements to meet customers' demands	4.97 (1.27)	0.78	0.77
SYNCHROMODAL VISIBILITY [adapted from Williams et al. (2013)]			
Construct Development: AVE= 0.63; KMO= 0.78; Cronbach's α = 0.86; CR = 0.87			
Outcome Validation: AVE= 0.56; KMO= 0.78; Cronbach's α = 0.86; CR = 0.79			
SV1 – Our major customers share timely and complete demand forecast information with us	4.53 (1.55)	0.65	0.66
SV2 – Our major customers provide us with timely and complete information regarding loading readiness status in the distribution network (e.g., distribution centers, transportation)	4.61 (1.43)	0.71	0.71
SV3 – We gather timely and complete information from various sources to understand the overall transport network status (traffic update, customs delays…)	4.98 (1.29)	0.79	0.80
SV5 – Our major partners/subcontractors provide us with timely and complete information of changes in operations due to incidents or disruptions	5.34 (1.17)	0.89	0.89
SYNCHROMODAL INTEGRATION [adapted from Danese et al. (2013)]			
Construct Development: AVE= 0.68; KMO= 0.76; Cronbach's α = 0.89; CR = 0.89			
Outcome Validation: AVE= 0.66; KMO= 0.76; Cronbach's α = 0.89; CR = 0.85			
SI1 – We actively plan day to day supply chain activities to meet customers' needs	6.26 (0.90)	0.66	0.66
SI2 – We consider our customers' forecast in our logistics activity planning	6.25 (0.91)	0.74	0.75
SI3 – We believe that cooperating with our customers is beneficial	6.14 (1.01)	0.83	0.84
SI4 – We emphasize openness of communications in collaborating with customers	6.23 (0.92)	0.94	0.97
SYNCHROMODAL OPERATING SYSTEM [adapted from Reis (2015), Pfoser et al. (2016) and Tavasszy et al. (2015)]			
Construct Development: AVE= 0.51; KMO= 0.76; Cronbach's α = 0.80; CR = 0.80			
Outcome Validation: AVE= 0.51; KMO= 0.76; Cronbach's α = 0.80; CR = 0.80			

SOS1 - We use different transport modes in one integrated shipment	4.52 (2.25)	0.72	0.72
SOS2 – Our customers give us the flexibility to decide which transport mode to use	4.25 (1.98)	0.54	0.53
SOS4 - In order to optimize resources, we continuously revise the transport modes we assign to each service	4.74 (1.96)	0.84	0.84
SOS5 - For each load unit, we work with our customers to select the best transport option	4.59 (2.13)	0.72	0.72
LOGISTICS DIFFERENTIATION [adapted from Fugate et al. (2010)]			
Outcome Validation: AVE= 0.51; KMO= 0.76; Cronbach's α = 0.75; CR = 0.75			
For the following items, please rate your firm's performance on logistics activities in comparison to your major competitors			
LD1 – Damage free deliveries	5.50 (1.14)		0.57
LD2 – Time between order receipt and delivery	5.69 (0.95)		0.82
LD3 – Forecasting accuracy	5.41 (1.05)		0.57
LD4 – On-time delivery	5.94 (0.92)		0.78

4.5. Analysis and Results

4.5.1. Construct Development Model

The final stage of our research was to obtain measurement model for synchromodality. To this end, we tested several competitive models: (1) a one factor first-order model, or a model in which all 15 items are loaded on a first-order factor; (2) an uncorrelated four-factor, first-order model in which the items load on four orthogonal first-order factors, (3) a correlated four-factor, first-order model in which the items are loaded on four correlated first-order factors, (4) a four-factor, second-order model in which the four factors are loaded on a second-order factor and, finally (5) a four-factor, second-order model in which correlated errors are included, aiming to correct model misspecifications. Figure 4.4 and Table 4.10 present these five models and their results.

Models 1 and 2 were disregarded because 3 and 4 were clearly superior and most of the fit indices were far from the cut-off values suggested in Hair et al. (2009). Models 3 and 4 represent a considerable improvement in the fit indices, although they were not yet acceptable. Fit indices for models 3 and 4 were essentially the same. This posed the questions of which model should be further analyzed and whether our measurement model was in fact a second-order model. To answer this question, we analyzed both the Consistent Akaike Information Criterion (CAIC) and the target coefficient (T) as suggested by Moon et al. (2012). The Consistent Akaike Information Criterion (CAIC) evaluates the improvement of competing with lower CAIC values as they indicate better-fitting models (Moon, et al., 2012; Milfont & Duckitt, 2004). Thus, $CAIC_{Model\ 4}$= 5,054.43 is lower than $CAIC_{Model\ 3}$= 5,579.23, suggesting than the second-order model has a better fit. We additionally checked the target coefficient (T). This coefficient assesses the efficacy of second-order models by comparing the χ^2 of the first- and second-order model (Moon, et al., 2012; Marsh & Hocevar, 1985). This coefficient has an upper bound of 1, with higher values suggesting that the relationship among first-order factors is sufficiently captured by the higher-order factor (Segars & Grover, 1998). In our case, T had a value of 0.978, which suggested that the addition of a second order factor does not significantly increase χ^2, and implied that the second-order model should be acceptable over the baseline as a more accurate representation of the model measurement (Segars & Grover, 1998). Consequently, based on the conclusion of this analysis, we decided to use the second-order model.

Once the second-order construct model was confirmed, we proceeded to analyze misspecifications and expected parameter changes (EPC). This analysis was done following the recommendations from Saris et al. (2009) and suggested correlated errors between items SV1 and SV2 and items SI1 and SI2. This correlation makes theoretical sense because each pair of items share a unique component that has nothing to do with the other items of the construct to which they belong. V1 and V2 both rely on information from customers. In the same way, SI1 and SI2 relate to operational activities that depend in both cases on customer's information.

The resulting model, as shown in Table 4.10, has a χ^2=109.008 and a normed χ^2 of 1.297. The goodness of fit indices of CFI (0.969), TLI (0.961), RNI (0.969), SRMR (0.072) and RMSEA (0.052) meet the Hair et al. (2009) criteria. We analyzed this model for MI/EPC and no further change was suggested. The analysis of the path loadings between synchromodality and the underlying first-order factors are all significant. These results seem to point out that synchromodality can be conceptualized as a multidimensional measure consisting of synchromodal visibility, flexibility, integration, and operating system and modeled as a four-factor, second-order model.

Table 4.10: Alternative Measurement Models for Synchromodality

Fit Indices	**Model 1: One-factor first-order model**	**Model 2: Uncorrelated first-order model**	**Model 3: Correlated first-order model**	**Model 4: Four-factor second-order model**	**Model 5: Four-factor second-order model with correlated errors**
Chi-square (df)	643.087 (90)	189.153 (90)	161.376 (84)	165.008 (86)	109.008 (84)
Chi-square / df	7.15	2.10	1.92	1.92	1.297
CFI	0.30	0.88	0.903	0.901	0.969
TLI	0.19	0.85	0.878	0.879	0.961
NRI	--	--	--	0.901	0.969
SRMR	0.21	0.14	0.069	0.077	0.072
RMSEA	0.24	0.10	0.092	0.091	0.052
CAIC			5,579.23	5,054.43	

Figure 4.4: Analyzed Construct Development Models

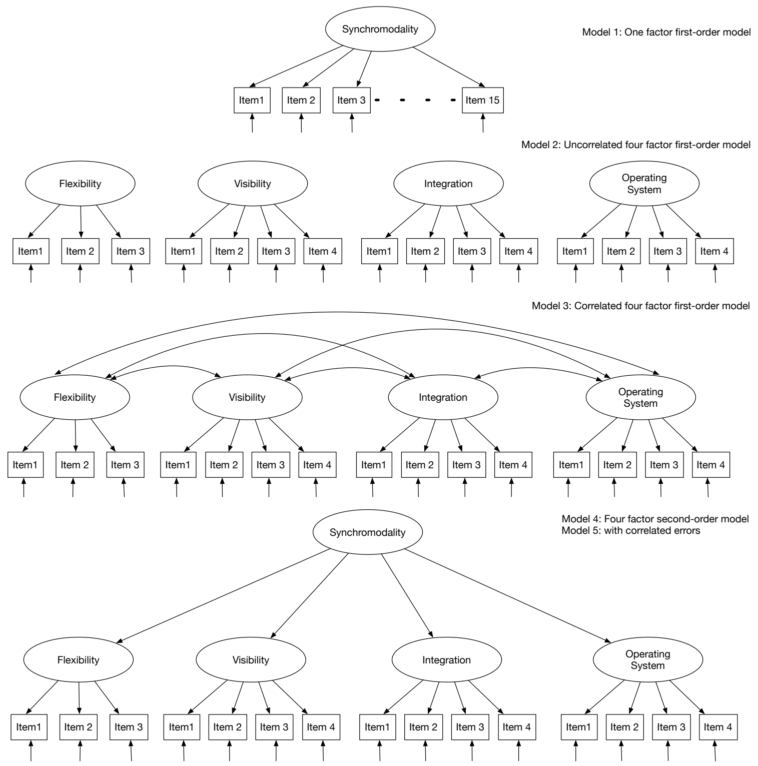
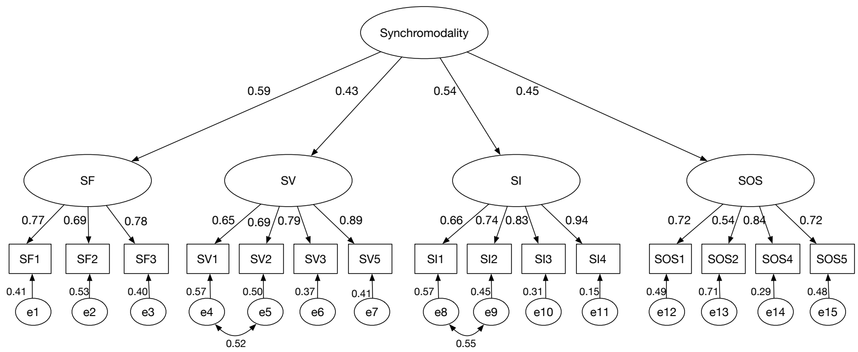


Figure 4.5: Four-Factor Second-Order Model of Synchromodality with Correlated Errors (Model5)



4.5.2. Outcome Validation Model

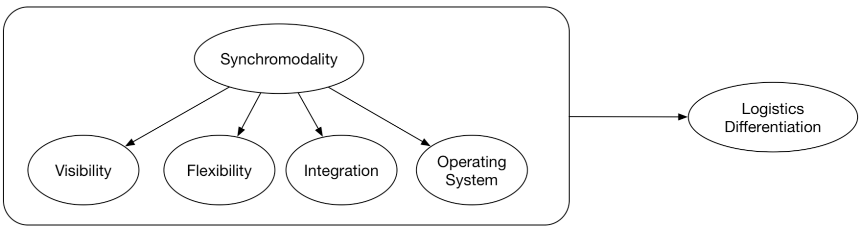
We used structural equation modelling to analyze the effect of synchromodality on logistics differentiation, using the construct development model measured and validated in the previous section.

The reliability of the measurement scales was assessed calculating the Cronbach´s α, obtaining a value of 0.75, surpassing the suggested lower bound of 0.7 (Fawcett, et al., 2014). The assumed construct dimensionality was supported by an EFA. A subsequent CFA provided a good model fit (Normed χ^2=1.35.; CFI=0.95; TLI=0.938; SRMR=0.069 and RMSEA=0.056). Table 4.9 summarizes the results of CFA.

Convergent validity was analyzed through factor loadings, composite reliability (CR) and average variance extracted (AVE). First, high factor loadings (all greater than 0.5 and significant at $p < 0.001$) indicated high convergence (Hair, et al., 2009). Second, composite reliability values were, for all the constructs, greater than 0.7, suggesting convergent validity and internal consistency (Hair, et al., 2009). Convergent validity was also supported as the AVE values were greater than 0.5. Finally, discriminant validity was assessed by analyzing the HTMT matrix and by comparing the AVE values to the squared correlations of the remaining constructs. The result of both tests, presented in Table 4.8, supported for discriminant validity.

The structural model presented in Figure 4.6 indicates a good model fit (Normed χ^2=1.37.; CFI=0.945; TLI=0.935; SRMR=0.080 and RMSEA=0.058). When testing H1, the path from synchromodality, measured as a second-order construct, to logistics differentiation reveals a high standardized coefficient of 0.71 and significant ($p<0.05$), providing support for our hypothesis suggesting that synchromodal networks are associated with logistics differentiation.

Figure 4.6: Outcome Validation Model



Finally, we performed an evaluation of the potential endogeneity of the model that might arise through omitted variable bias (OVB); in other words, the proposed relationship of synchromodality and logistics differentiation cannot be correctly interpreted due to omitted causes (Antonakis, et al., 2010). Endogeneity, in the OM research studies, has been largely ignored up to very recently (Ketokivi & McIntosh, 2017), however it is something that should be carefully addressed as it could lead to flawed conclusions and misguided advice to practitioners (Ketokivi & McIntosh, 2017; Sande & Ghosh, 2018). Following the suggestions by Ketokivi and McIntosh (2017), when dealing with SEM analysis it is possible to apply an equivalent methodology to identify endogeneity. By adding correlations between disturbance terms, we can examine whether the model fit significantly improves. To follow this suggested approach, we looked at the modification indices (MI) of the path model, as well as the expected parameter changes (EPC) (Saris, et al., 2009). This analysis did not suggest any changes goodness fit when adding correlations between the different disturbance terms of the model (refer to Figure 4.5). Even though, fully eliminating endogeneity is unlikely, we strongly believe that it does not pose a problem in our analysis.

4.6. Conclusion

Synchromodality is a novel concept that has received increasing attention from researchers and practitioners over the past years as it is envisioned by practitioners, policy makers in the EU and researchers as a step forward in transportation efficiency, sustainability, resilience, modal shift and, in general, an overall competitive advantage in the supply chain. However, despite this attention, a lack of theoretical and empirical research remains. First, there has been no agreement on the definition of synchromodality as no study has attempted to develop a conceptual framework for it. Secondly, to our knowledge, no valid measures of synchromodality have been developed. Finally, there is also a lack of empirical evidence of the creation of logistics differentiation due to the implementation of synchromodality. With all that into account, the present study attempts to further the theory and understanding of synchromodality through the conceptual development and empirical validation of an instrument to measure its construct.

Through a comprehensive newly developed four-stage methodology, we first identified four dimensions in the construct of synchromodality: visibility, flexibility, integration, and operating system based on a systematic literature review and interviews with field experts. We then proposed a 20-item measurement scale for synchromodality that was subsequently purify and validate into a 15-item measurement scale using a pilot test. We hypothesized five different models: a one factor first-order model, an uncorrelated four factor first-order model, a correlated four factor first-order model, a four factor second-order model and four factor second-order model with correlated errors to fix misspecifications. After comparing and testing the correlated four-factor, first-order model and the four-factor, second-order model, we found evidence that suggested that synchromodality is a multidimensional concept manifesting flexibility, visibility, integration, and operating system.

The present study can be considered a starting point for supply chain and transportation managers from shippers and T&LSP companies considering the implementation of synchromodality in their daily operations. This research also presents a diagnostic tool for supply chain and transportation practitioners to assess their firms' synchromodal capability and to establish a common language to identify, implement and manage synchromodal-related aspects. In addition, our empirically validated four-dimension framework can help managers to look at the transportation part of their supply chain, not as a mere operationalization but as a holistic way to operate with flexibility, visibility and integration as the core of the supply chain. As a consequence, the study does not only set the foundation of the capabilities and resources that companies aiming to establish synchromodality should develop with the different partners and stakeholders of their supply chain, but also corroborates the theoretical hypothesis that synchromodality creates a competitive advantage through a logistics differentiation.

However, as with all research, the study presents some limitations that should be noted. First, this study only uses data from global operating transportation and logistics companies based in Europe. Even though synchromodality is a concept that has emerged in Europe, it would be interesting to replicate it in other regional areas with a strong transport and logistic market such as North America or Asia. This research is focused on the logistics network of a manufacturing firm in a specific industry, it would also be interesting to expand the research to other network contexts, such as the automotive or electronic industries where intermodality is already a common practice and where synchromodality could bring additional benefits. This extension would help to validate the generalizability of the proposed conceptual framework and the corresponding measurement model. A longitudinal analysis of the effects of strategic alliances deploying synchromodality could also throw light on the benefits of this new concept. A replication of the research over time complemented with operational data from score cards would help to analyze the effect that the consolidation of synchromodality has on logistics performance and it would, at the same time, permit a second analysis of the endogeneity of the model. Finally, it would be interesting to complement the present study with the use of secondary data by integrating in the model objective performance data from the companies that participated in the survey.

To conclude, we suggest continuing this research by analyzing the expected outcomes that adoption of this novel concept could have on supply chains such as sustainability, resilience or efficiency; as well as the effect of potential mediating or moderating variables.

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Chapter 5

The Trade-offs of Resilience and Efficiency in Synchromodal Supply Chains: An Empirical Analysis

5.1. Introduction

In the current dynamic economic environment, much has been written about global supply chains gaining a competitive advantage through better execution of distribution strategies, while also remaining resilient during disruptions (Fugate, et al., 2012). Furthermore, innovative digital paradigms of the new era are making supply chains more vulnerable and prone to disruptions. As such, quick and efficient synchronization with network partners becomes a key differentiator in market competition (Kane, et al., 2017). With a few exceptions such as Esper et al. (2007), Sanchez et al. (2015) or Wallenburg and Schäffler (2016), this pressure has driven many firms to concentrate resources on the buyer-supplier product relationship and leave aside transportation and logistics companies—although these companies can also play a key role in the optimization and value creation of the supply chain. For example, during the 2010 volcanic eruption in Iceland, shippers working with FedEx were able to resume normal operation sooner than other affected firms thanks to the company's flexibility in switching transportation modes (Saenz, et al., 2018).

Motivated by the search of new trends, companies have started to look at their transportation and logistics partners as strategic supply chain enablers rather than mere commodities that can be easily substituted if the price is not low enough. At the same time, governmental institutions are also looking at ways to encourage freight movers to make more effective and sustainable use of resources (McKinnon, 2015; Dong, et al., 2018).

With these objectives in mind, researchers have been studying ways in which supply chains can involve their logistics partners to create more resiliency and efficiency (Oonk, 2016). One of these concepts is synchromodality, which was first proposed in 2010 (Resi, 2015), and since then has received increasing attention from academics, managers, and policymakers. Synchromodality is defined as multimodal and mode-free transportation planning in which shippers and logistic companies work in an integrated and flexible way, making operational decisions based on real-time information from stakeholders, customers, and other involved agents (Pfoser, et al., 2016; Acero & Saenz, 2018; Dong, et al., 2018). This innovative planning is due to a high degree of integration of the different supply chain partners, as well as making large amounts of information visible (ports, vessels, or logistics platform data) that could critically affect the operations both directly and indirectly (Resi, 2015).

The first application of synchromodality occurred in the Port of Rotterdam and showed a common implementation path in supply chains, thereby making synchromodality one of the main pillars for the Dutch logistics economic sector (Oonk, 2016) and other companies operating in the area. For example, Seacon Logistics partnered with a fast-moving consumer goods company to establish a control tower that allows them to efficiently manage the supply chain through synchromodal strategic and operational decisions (Topsector Logistiek, 2018a). Similarly, two non-competitive companies, Nutricia and Bavaria, have partnered with the logistics company, Samskip, to implement synchromodality in their European supply chains. This partnership has led to a more efficient and resilient supply chain (Samskip, 2018; Topsector Logistiek, 2018b).

These promising results are positioning synchromodality as an increasingly important area of research, especially as transportation and logistics managers aim to differentiate from competitors, not only by winning and maintaining contracts with shippers, but also by establishing long-term relationships to develop a competitive advantage. However, even though synchromodality benefits have been largely theoretically hypothesized (ALICE, 2015; Zhang & Pel, 2016) and several pilot projects are being implemented in Europe, only a limited number of studies have analyzed its benefits (Kurapati et al., 2017). The study carried out by Dong et al. (2018) concluded that the application of synchromodality could lead to an increase in efficiency, while research presented by Zhang and Pel (2016) or Lee and Song (2017) suggests that the adoption of synchromodality can create a competitive advantage in the event of a disruption, leading to more resilient supply chains. However, based on extant existing literature on resilience and efficiency, there are no clear results on the effects of these two synchromodal supply chain outcomes. As some studies have indicated, resilient firms can react to disruption faster and increase their market share at the expense of competitors (Saenz & Revilla, 2014;

Hendricks & Singhal, 2005; Liu, et al., 2018). As such, certain companies are able to redesign their supply chains with flexible mechanisms, such as moving from a global to a local orientation, thereby enabling them to minimize risk exposure and increase situational awareness while maintaining their differentiating essence (Saenz, et al., 2018). However, this is not a "one size fits all" kind of strategy and investing in capabilities that lead to resilience is not necessarily correlated with more efficient supply chains (Chopra & Sodhi, 2014). For example, Zara, a clothing and accessories retailer, has supply chains that offer both a responsive and resilient orientation or a cost-efficient approach depending on the type of garment (basic vs. trendy) and the predictability of customer demands (Saenz, et al., 2018; Chopra & Sodhi, 2014). This suggests that no clear relationship between resilience and efficiency exists and, depending on the nature of the supply chain and the market orientation, a trade-off between the two outcomes may be inevitable. Subsequently, the question of how these relationships might be affected by synchromodal contexts in which the supply chain operates motivates us to further investigate this phenomenon.

The answer to this question might result in some managerial actions that could motivate shippers and logistics firms looking to implement synchromodality through the development of strategic alliances and lead to a competitive advantage in the form of more efficient and/or resilient supply chains.

The multimethodology approach developed in this paper allows us to further investigate whether synchromodality is positively related to both efficiency and resilience. The remainder of the paper is structured as follows. The next section provides the theoretical foundations of our proposed model and corresponding hypotheses. We then present the database and measures, including an assessment of the quality of measures used in the proposed model. We evaluate the relationships expressed in our model through structural equation modeling (SEM) and present a configuration approach that seeks to identify different outcome patterns. We conclude with ending remarks, managerial implications, limitations, and avenues for future research.

5.2. Theoretical Background and Conceptual Development

The following section reviews existing research work on the concepts of synchromodality, efficiency, and resilience, and establishes the research model based on a configurational approach.

5.2.1. Synchromodality

In the transportation field, synchromodality is a novel concept in which shippers give transportation and logistics firms total freedom to decide—based on real-time information from orchestrators involved in the supply chain—the transportation mode to be used (Li, et al., 2017; Dong, et al., 2018). Synchromodality is conceived as the natural evolution of the well-known transportation concept of intermodality (SteadieSeifi, et al., 2014). Since its first usage in 2010, synchromodality has been considered the future in terms of efficient and resilient supply chains and transportation networks (Lee & Song, 2017; Dong, et al., 2018), and it has been assimilated into the research and innovation agenda of European institutions, researchers and practitioners. In this sense, simulation-based research shows that supply chains that implement synchromodality could save up to 6% in logistics costs and reduce CO2 emissions by 30% (Zhang & Pel, 2016; Dong, et al., 2018).

Synchromodality can be thought of as a multidimensional concept composed of flexibility, visibility, integration, and operational systems (Acero & Saenz, 2018). Synchromodal environments embrace synchromodal flexibility (SF) (Buiel, et al., 2015) by adapting the transport mode used for each shipment that is based on available information, daily operational adjustments, and specific shippers' requirements and network constraints in terms of operations, services, and delivery (Acero & Saenz, 2018). Subsequently, supply chains operating in synchromodal environments dynamically review and adapt their operations using real-time information (Kamalahmadi & Parst, 2016; Kurapati, et al., 2017; Li, et al., 2017) obtained from multiple stakeholders such as logistics platforms, ports, vessels, terminals, or operator data (van Riessen, et al., 2015). Such real-time knowledge of the supply chain status and its environment constitutes synchromodal visibility (SV), a dimension of synchromodality. In this context, the flow of information in a supply chain needs to occur in a timely and thorough manner (Francis, 2008; Scholten & Schilder, 2015) that incorporates all the different agents involved. As such, synchromodality refers to a series of integrated supply chain processes (van Riessen, et al., 2015; Behdani, et al., 2016). Supply chain integration refers to the degree of cooperation and coordination in the supply chain (Cao, et al., 2015; Liu, et al., 2018), as well as alignment between logistics companies and shippers in terms of communications to improve daily operations and adapt to customer needs (Danese, et al., 2013). Through the development of synchromodal integration (SI), firms can anticipate changes and customer needs and demands in a dynamically changing environment (Flynn, et al., 2010; Weiland & Wallenburg, 2013). Finally, like in any other transportation approach, synchromodality has an operational dimension (Verweij, 2011) related to the system mode and routing choice. In this case, a synchromodal operating system (SOS) refers to the ability to be able to use different transport modes in one shipment line (Kapetanis, et al., 2016; Zhang & Pel, 2016; Kurapati, et al., 2017), which is facilitated through shippers' free-booking reservations that indicate delivery requirements (Resi, 2015; Zhang & Pel, 2016; Li, et al., 2017).

5.2.2. Resilience

Resilience is a multidisciplinary, multidimensional, and hierarchical concept (Kamalahmadi & Parst, 2016; Chowdhury & Quaddus, 2017) that has become relevant in supply chain management in terms of the capability to confront disruption and unforeseen events (Brusset & Teller, 2017). Resilience was first defined in ecological studies as the persistence and ability of a system to absorb change and continue to function (Holling, 1973). This definition was later adopted by other areas, including supply chain management, which has also been researching the concept of resiliency, as well as its antecedents and effects or outcomes (Kamalahmadi & Parst, 2016).

Existing studies suggest that resilience is a key capability and a powerful way to manage and recover from supply chain disruption (Sheffi, 2005; Ambulkar, et al., 2015). The concept is defined as a firm's adaptive capability to maintain a high, continuous, situational awareness in order to quickly adapt, respond, and overcome changes from a supply chain disruption (Ambulkar, et al., 2015). As the study of resilience in the supply chain field has gained relevance, research has analyzed causes and consequences of major supply chain disruptions (Sheffi, 2005, 2015) as well as different mitigation strategies and resilient capabilities in the buyer-supplier, product-related relationships.

However, the literature on resilience in logistics firms is less abundant (Mattsson & Jenelius, 2015) even though logistics firms have played a pivotal function in managing disruption in much of the major turmoil that has historically affected global supply chains and transportation. The majority of the resilience studies with a transportation and logistics perspective have focused on network analyses (Cox, et al., 2011), with a few exceptions that have examined supply chains (Wallenburg & Schäffler, 2016). Additionally, in the majority of such studies, a simulation or case study approach was used. As such, an empirical research gap exists on the problematic issues encountered when measuring resilience from a transportation point of view (Reggiani, et al., 2015). Accordingly, it remains unclear how logistics firms can develop resilience capabilities in their supply chains.

5.2.3. Efficiency

Efficiency is another multidisciplinary term, with ambiguous definitions depending on the research field (Lichocik & Sadowski, 2013). In the transportation field, logistics efficiency is defined as the ability to manage logistics-related functions and resources wisely (Fugate, et al., 2010). Efficiency is considered one of the four pillars of a firm's logistics strategy (McGinnis & Kohn, 2002), and it deals with internal logistics operations and activities, creating value and defining the supply chain performance (Fugate, et al., 2010). In this context, efficiency is referred to as the ratio of used resources against results (Langley & Holcomb, 1992; Fugate, et al., 2010). Consequently, in firms' transport and logistics operations, efficiency is considered an important indicator of performance and competitive advantage, playing a key role in the development of the overall supply chain (Nikfarjam, et al., 2015) and providing desirable service levels to both shippers and customers (Fugate, et al., 2010).

5.3. Hypotheses Development

In the following section, we explain the hypotheses presented in the model developed in Figure 5.1.

5.3.1. Development of Resilience and Efficiency in Synchromodal Supply Chains

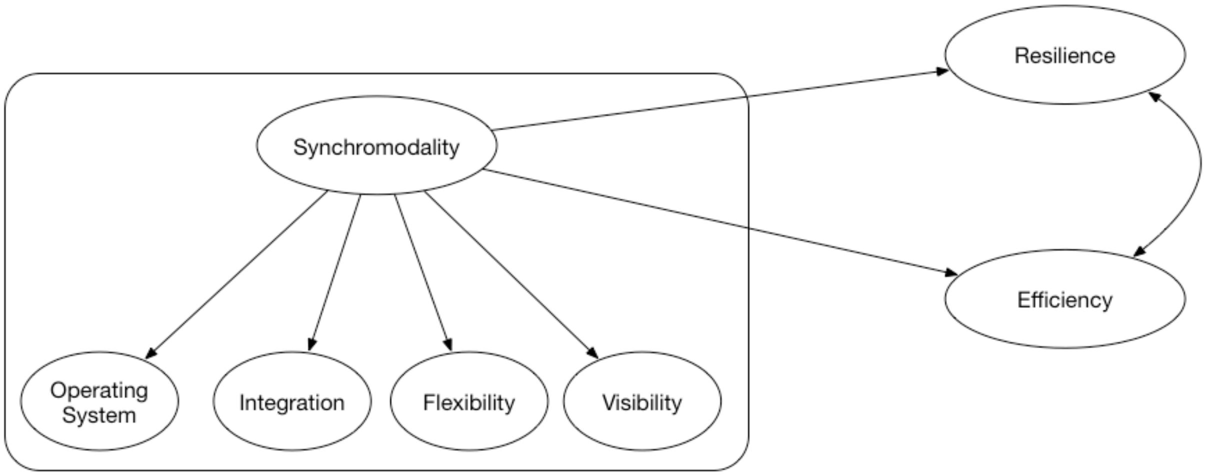
The relationship between synchromodality and resilience was first established by Lee and Song (2017) and reinforced by Tavasszy (2018) who suggested that supply chains operating in synchromodal contexts are more resilient and prone to minimal disruptions. Resilience has been considered a necessary characteristic of supply chains that aim to compete in a dynamically changing environment both in the short and long term (Pettit, et al., 2010). In the search for resilience, organizations have focused their attention on supply chain designs, creating proactive enterprises capable of dealing with disruptions (Saenz, et al., 2018). The development of certain proactive capabilities such as visibility, integration, and flexibility, has enabled firms to be more capable in creating resilience (Pereira, 2009; Skipper & Hanna, 2009; Pettit, et al., 2010; Weiland & Wallenburg, 2013; Hohenstein, et al., 2015; Chowdhury & Quaddus, 2017). First, through improved visibility that provides real-time information sharing of synchromodality, supply chains can increase their resilience and prevent disruptions. Secondly, the flexible dimension of synchromodality implies that a supply chain is designed to be more capable of adapting and reconfiguring resources to change the delivery mode according to external inputs and customer requirements. Third, synchromodal operations require a high level of integration between different agents that compose the supply chain. Integration facilitates effective and efficient flows of information, services, and decisions (Zhao, et al., 2008), thereby enabling quick reactions to sudden changes (Wieland & Wallenburg, 2013) and facilitating anticipation of customer needs in dynamic environments (Flynn, et al., 2010). Finally, the operational dimension of synchromodality makes the system capable of switching between different transport modes according to logistics and shipper needs. This synchromodal ease to shift between modes can play a key factor in avoiding disruptions. Thus, we believe that synchromodality contributes to the development of more resilient supply chains. As such, we propose the following hypothesis:

H1. Synchromodal supply chains are positively related to resilience

One of the underlying motivations in the development of supply chain synchromodality is the increase of operational efficiency. The development of more integrated and flexible supply chains allows for logistics and transportation companies to offer optimized services based on shippers' requirements and infrastructure status (ALICE, 2015). This desired outcome has been suggested both by the existing, albeit limited, theoretical research and applied pilot tests. On the one hand, synchromodal supply chains are conceived to effectively integrate all partners and stakeholders through careful operation planning, which leads to a performance improvement in the supply chain (Lichocik & Sadowski, 2013; Dong, et al., 2018). On the other hand, the implementation of synchromodality in supply chains have resulted on more efficiently managed operations (Lucassen & Dogger, 2012; Samskip, 2018; Topsector Logistiek, 2018). Following these arguments, we propose the following hypothesis:

H2. Synchromodal supply chains are positively related to efficiency

Figure 5.1: Conceptual model



5.3.2. A taxonomy of the efficiency-resilience duality: a configuration approach

Our research is grounded in the configurational approach that establishes patterns or profiles capturing the complexities of the organizational reality (Miller, 1986; Ketchen & Shook, 1996). Instead of the conventional pairwise-relationship approach, the configuration theory describes an organization as a set of interrelated activities (Flynn, et al., 2010). This approach establishes theoretical or empirical patterns or profiles that capture the complexity of the enterprise reality and facilitate a holistic analysis of the researched phenomenon (Revilla, et al., 2013; Cao, et al., 2015). This approach is deemed useful in handling complex relationships, such as one defined by resilience and efficiency, because it facilitates the identification of patterns that have may not emerged with a traditional theoretical approach (Flynn, et al., 2010), instead of focusing on defining an ideal relationship type (Bozarth & McDermott, 1998). Because firms might emphasize different strategies in their supply chain designs, such as responsiveness vs. cost oriented or global vs. local (Saenz, et al., 2018), several configurations of resilience and efficiency outcomes may exist. A configurational analysis facilitates a holistic analysis of the relationship between resilience and efficiency in synchromodal contexts.

It could be argued that synchromodal companies and supply chains with a focus on efficiency through a cost-oriented strategy will find resilience hard to achieve, as some of the necessary capabilities could be counter to the operational efficiency of the supply chain, as additional resources might have to be deployed (Chopra & Sodhi, 2014; Birkie, 2016). However, an efficiency-oriented strategy does not always result in a loss of resilience. For example, ALICE (2015) has stated that continuous review of the transport mode used for each shipment leads to both efficiency and resilience; however, it could conversely be argued that resilience obtained through the availability of different transport modes could also translate into redundancy that consequently reduces efficiency. This contradiction is what Birkie (2016) refers to as the paradox of efficiency practices and resilience. He also summarizes different arguments that defend trade-offs and synergies between efficiency and resilience. Ivanov et al. (2014) argue that a supply chain's resilient design may increase both service levels and costs. On the other hand, some authors have argued that both efficiency and resilience are needed to mitigate disruptions (Shukla, et al., 2011; Birkie, 2016), which implies that the creation of resilience can lead to long-term savings without affecting the efficiency of the synchromodal supply chain, as shown in existing pilot tests (Topsector Logistek, 2018a,b). Considering the spectrum of combinations, we could conclude that a need for the development of a taxonomy exists based on the different synchromodal idiosyncrasies of the involved firms. Thus, we propose the following hypotheses:

H3. *The relationship between efficiency and resilience depends on the synchromodal context of the supply chain.*

H4. *In synchromodal contexts, an emergent taxonomy can be developed for efficiency and resilience based on the firm's synchromodal dimensions.*

5.4. Methodology

5.4.1. Questionnaire Design

We used survey-based research methodology (Hair, et al., 2009; Saris & Gallhofer, 2007) to collect data for the proposed Figure 5.1 model and associated hypotheses. In addition, we developed a rigorous process to validate the constructs. First, we used previously well-developed measurement scales whose reliability and validity is well established and sets the foundation for the quality of our study. To this end, each of the survey constructs was either adapted or adopted from previously established and validated items in specialized research. The conceptualization of the synchromodality construct was adopted, as a second-order construct, from the research work of Acero and Saenz (2018) in which each of its four dimensions (flexibility, visibility, integration and operating systems) was adapted from previously operationalized and validated constructs. Items measuring resilience were adopted from Ambulkar et al. (2015), while the construct of efficiency was adapted from Fugate et al. (2010), which describes efficiency in terms of optimal use of resources. All questionnaire items were measured using a seven-point Likert scale that corresponded with 1 as "strongly disagree" and 7 as "strongly agree." Once the questionnaire was designed, we carried out qualitative preliminary research through a pilot test that helped to refine and pretested the scale items. We arrived at 52 respondents consisting of 43 industry executives and 9 faculty members. We also interviewed experts in supply chain logistics and transportation and requested that they test the survey for a validity check. Minor adjustments in terms of wording were made based on the experts' suggestions. Table 5.3 summarizes the different measurement items and descriptive of the scales.

5.4.2. Sampling and Data Collection

The unit of analysis for this research was European logistics companies, and the preferred target respondents were mid-level managers with knowledge of their firms, operations, and strategies. The target frame consisted of the 283 logistics companies of a major global shipper. We chose to work with this company because they are currently involved in synchromodal practices with several logistics companies of various sizes. This sort of purposive sampling was developed with the aim of attaining both a moderate level of external validity and a generalizability of the results (Gligor, et al., 2015). We used a web-based survey following the recommendations from Saris and Gallhofer (2007) and Dillman et al. (2014) to increase the response rate. An initial email was sent to the 283 contacts in the data set requesting their participation in our online survey and research study. The email recipients comprised key managers and decision makers within the logistics firm that could provide well-informed answers to different construct-related questions. In our message, we explained the purpose of the research along with the offer of an executive summary of the findings as an incentive to participate and increase the response rate. After regular reminders, we received a total of 157 responses, representing a 55% response rate. Table 5.1 and Table 5.2 present the profile of each company and the respondents, reflecting the diversity among the participant firms based on annual revenue, number of employees, and geographical coverage.

Table 5.1: Demographics of responding companies

Annual revenue	% of respondents	Geographical presence*	% of respondents
Under $1 million	6.5%	Central Europe	56.3%
$1 - $10 million	9.4%	Western Europe	52.5%
$10 - $100 million	30.9%	Eastern Europe	47.5%
$100 - $500 million	31.7%	Southern Europe	47.5%
$500 million - $1 billion	7.2%	Northern Europe	45.6%
$1 - $5 billion	10%	Asia	21.5%
$5 - $20 billion	3.6%	Northern America	20.9%
$20 - $50 billion	--	Middle East	17.7%
Over $50 billion	0.7%	Northern Africa	16.5%
Full time employees worldwide	**% of respondents**	South America	13.9%
1-50	10.8%	Central America	12.7
51-100	11.5%	Only at national level	10.1%
101-500	29.5%	Sub-Sahara Africa	7.6%
501-1000	23.7%	Other	7.6%
Over 1000	24.5%		

*certain firms fall into different categories

Table 5.2: Demographics of respondents

Job title	% of respondents	Country from where the respondent's work	% of respondents
CEO	10%	Spain	13.7%
Head of Department	37.1%	France	9.2%
Team Leader	30%	Belgium	8.6%
Team Member	22.9%	Germany	8.4%
Area of work	% of respondents	Italy	8.1%
Operations	28.5%	The Netherlands	6.5%
Planning	9.7%	Poland	5.7%
Business Development	42.3%	Romania	5.7%
General Management	19.5%	Austria	5.0%
Others	--	United Kingdom	5.0%
Years in current position	% of respondents	Croatia	2.1%
		Latvia	2.1%
1-3 years	21.3%	Lithuania	2.1%
4-6 years	24.4%	Others	17.8%
7-12 years	24.4%		
Over 12 years	29.9%		

Since data was collected from single respondents within a single firm, the common method bias could present a problem (Huber & Power, 1985; Podsakoff & Organ, 1986). Recent research, such as the study by Ketokivi and Schoreder (2004) suggested the use of multiple respondents as a way to deal with this bias. However, as our unit of research analysis targeted a single industry (logistics providers) composed of a large percentage of medium firms with idiosyncrasies, it would have been extremely challenging to find more than one key informant with informed answers to all the survey constructs. To assess this potential problem, we conducted a mix of *a priori*- and *post-hoc* approaches (Podsakoff, et al., 2003). The questionnaire was directly sent to respondents with knowledge in the daily operations of the transportation firm that were also involved in the decision-making process regarding the constructs analyzed in this research. This careful selection of respondents was seen as a measure to mitigate the effect of common method bias (Flynn, et al., 2018). The use of previously operationalized constructs, as well as a testing stage with professionals and faculty members, helped to avoid ambiguity in the questions. Finally, questions that related to more than one subject were avoided. In this *post-hoc* approach, we used the Harmon's single-factor test (Podsakoff & Organ, 1986; Podsakoff, et al., 2003), which consists of observing a number of factors that arise after performing an unrotated exploratory-factor analysis. Results revealed six different factors with eigenvalues greater than 1.0 or over 62% of the variance. Since no single factor accounted for more than half of the variance, the common method bias did not represent a problem.

Finally, we checked for a potential response bias comparing "on time" responses received versus "late" responses (Armstron & Overton, 1977). Our t-test found no significant differences between the two groups, suggesting that a non-response bias did not represent a problem.

5.4.3. Reliability and Validity

Reliability of the different constructs was evaluated using an exploratory factor analysis (EFA) and calculating the Cronbach's alpha value to obtain internal consistency (Narsimhan & Jayaram, 1998). The EFA results, presented in Table 5.3, reveals high loadings (>0.60) on the items that corresponded to the construct intended for measurement and lower loadings on the items not intended for measurement, demonstrating construct unidimensionality (Flynn, et al., 2010). The EFA appropriateness was evaluated with the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity. The KMO value of 0.79 indicated overall sampling adequacy, as it exceeded the recommended cut-off value of 0.5 (Chowdhury & Quaddus, 2017). Bartlett's test provided evidence of the validity of the instrument with a value of 410.7 (df= 22; p <0.001). Internal consistency was evaluated calculating the Cronbach's alpha values as well as the composite reliability score (also known as rho or the coefficient omega). In both cases, the values exceeded the cut-off value of 0.70 (Nunnally, 1978; Fawcett, et al., 2014). Content validity was established through a careful and critical evalutation of existing constructs that were previously operationalized, tested, and used by domain experts (Flynn, et al., 2010).

Table 5.3: Measurement items with descriptive of the scales and factor loadings

Construct/Item	Mean (SD)	Standardized loadings	Factor loadings
FLEXIBILITY [adapted from Williams et al. (2013) and Swafford et al. (2006)] AVE = 0.53; KMO= 0.70; Cronbach's α = 0.77; Composite reliability (rho, omega) = 0.77			
FX1 – Our services/equipment/operations are designed to be easily modified	4.90(1.33)	0.76	0.83
FX2 – We can change quickly from one transport service to another	5.23(1.23)	0.71	0.71
FX3 – We can easily adjust to different distribution delivery requirements to meet customers' demands	4.69(1.39)	0.72	0.66
VISIBILITY [adapted from Williams et al. (2013)] AVE = 0.56; KMO = 0.73; α = 0.82; CR = 0.83			
V1 – Our major customers share timely and complete demand forecast information with us	4.51(1.49)	0.60	0.83
V2 – Our major customers provide us with timely and complete information regarding loading readiness status in the distribution network (e.g., distribution centers, transportation)	4.54(1.41)	0.62	0.89
V3 – We gather timely and complete information from various sources to understand the overall transport network status (traffic update, customs delays…)	5.05(1.31)	0.70	0.57
V4 – Our major partners/subcontractors provide us with timely and complete information of changes in operations due to incidents or disruptions	5.07(1.25)	0.86	0.61
INTEGRATION [adapted from Danese et al. (2013)] AVE= 0.61; KMO = 0.74; α = 0.87; CR = 0.86			
I1 – We actively plan day to day supply chain activities to meet customers' needs	6.17(0.91)	0.66	0.95
I2 – We consider our customers' forecast in our logistics activity planning	6.11(0.93)	0.67	0.89
I3 – We believe that cooperating with our customers is beneficial	5.99(1.06)	0.87	0.56
I4 – We emphasize openness of communications in collaborating with customers	6.09(1.08)	0.81	0.61
OPERATING SYSTEM [adopted from Acero and Saenz (2018)] AVE = 0.52; KMO = 0.75; α = 0.80; CR = 0.81			
OS1 - We use different transport modes in one integrated shipment	4.54(2.13)	0.75	0.79

OS2 – Our customers give us the flexibility to decide which transport mode to use	4.13(1.94)	0.56	0.58
OS3 - In order to optimize resources, we continuously revise the transport modes we assign to each service	4.64(1.91)	0.84	0.83
OS4 - For each load unit, we work with our customers to select the best transport option	4.68(2.08)	0.70	0.67
RESILIENCE [adopted from Ambulkar et al. (2015)]			
AVE = 0.70; KMO = 0.79; α = 0.89; CR = 0.90			
RS1 – We are able to cope with changes caused by supply chain disruptions (i.e. unexpected events)	5.63(1.04)	0.88	0.79
RS2 – We are able to adapt to the supply chain disruption easily	5.43(1.15)	0.87	0.78
RS3- We are able to provide a quick response to the supply chain disruption	5.70(1.08)	0.89	0.95
RS4 – We are able to provide a high awareness at all times	5.50(1.14)	0.65	0.71
EFFICIENCY [adopted from Fugate et al. (2010)]			
AVE = 0.64; KMO = 0.77; α = 0.87; CR = 0.87			
For the following items, please rate your business unit's performance on logistics activities for the previous fiscal year			
EF01 – Percent of orders shipped to customers from the primary location designated to serve those customers	4.57(1.15)	0.83	0.86
EF02 – Percent of orders shipped on time	4.55(1.37)	0.77	0.75
EF03 – Percent of shipments requiring expediting	4.66(1.29)	0.96	0.98
EF04 – Average order cycle time (days between order receipt and order delivery)	4.65(1.43)	0.60	0.61

A confirmatory factor analysis (CFA) was used to evaluate convergent validity, linking each measurement item to its corresponding construct and setting the covariance among the constructs free (O'Leary-Kelley & Vokurka, 1998). The model provided good fit ($\chi 2$(df)=334.274 (213); CFI=0.94; TLI = 0.93; RMSEA = 0.060; SRMR = 0.060). The lowest composite reliability value was 0.77, exceeding the recommended minimum value of 0.6 (Bagozzi and Yi, 1988). Furthermore, the proposed model suggested good validity, as both the loadings of the items and the average variance extracted were greater than 0.5 (Fawcett, et al., 2014). Finally, discriminant validity was also assessed through four verifications following the recommendations of Fawcett et al. (2014) and Henseler et al. (2015). First, the loading of each item was higher on its assigned construct than on any other. Second, the mean shared variance was below 0.5. Third, the correlation estimates in each of the constructs was below the square root of the AVE, as shown in Table 5.4. Finally, we performed the heterotrait-monotrait (HTMT) ratio to test for discriminant validity as presented in Table 5.5 and obtained values below the threshold of 0.85, thus confirming the discriminant validity of the scales. As a result, we could conclude enough evidence to suggest sufficient reliability and convergent and discriminant validity in our measurement model.

Table 5.4: Test for Discriminant validity

	SOS	SF	SV	SI	Resilience	Efficiency
SOS	0.72					
SF	0.19*	0.73				
SV	0.32***	0.32***	0.75			
SI	0.19**	0.47***	0.19*	0.78		
Resilience	0.27***	0.63***	0.35***	0.48***	0.84	
Efficiency	-0.05	0.30***	0.20*	0.33***	0.30***	0.80

Notes: ***p<0.001; **p<0.01; *p<0.05; The square roots of the AVE are shown on the diagonal

Table 5.5: HTMT criteria for discriminant validity test

	SOS	SF	SV	SI	Resilience	Efficiency
SOS						
SF	0.20					
SV	0.27	0.31				
SI	0.20	0.43	0.16			
Resilience	0.29	0.63	0.38	0.48		
Efficiency	0.10	0.28	0.30	0.29	0.30	

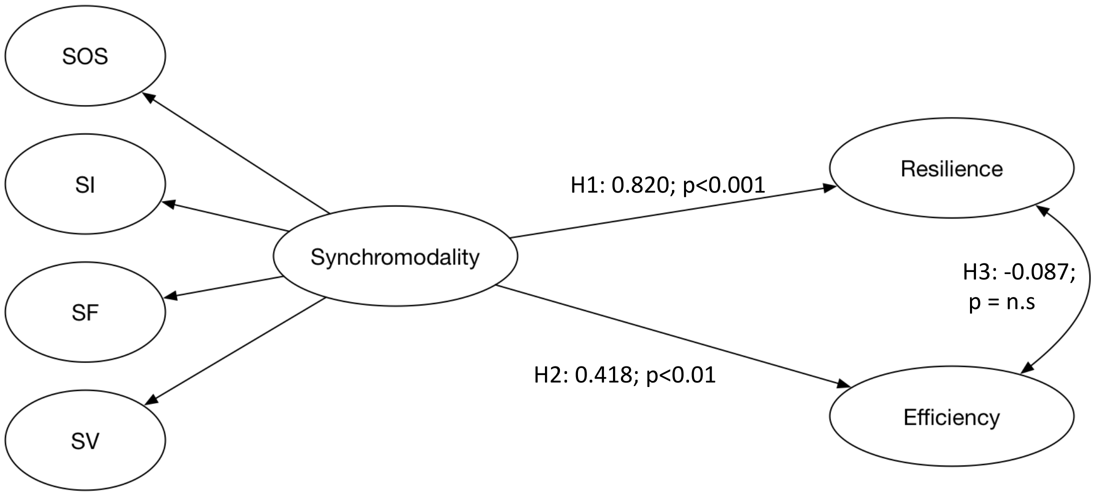
5.5. Analysis and Results

5.5.1. Structural Model Analysis

The previously hypothesized relationships presented in Figure 5.1 were evaluated using structural equation modeling, and the results are shown in Figure 5.2. The model provides a good fit (($\chi 2$/df) = 1.57; CFI = 0.94; TLI = 0.93; RMSEA = 0.060; SRMR = 0.069). As suggested by Acero and Saenz (2018) in their construct validation for synchromodality, we reproduced the second-order, four-factor model, maintaining the correlated errors in two of the construct items. The path analysis from synchromodality to resilience and efficiency reveals a high-standardized coefficient for H1 and H2, while the coefficient for H3 is rather low. The path coefficient from synchromodality to resilience is positive and significant (path coefficient = 0.82; $p<0.001$) as well as the coefficient for efficiency (path coefficient = 0.418; $p<0.01$). The results thus support and corroborate both H1 and H2. The relationship established in Hypothesis 3 between resilience and efficiency is low and non-significant (path coefficient = -

0.087; p = n.s). In summary, synchromodal contexts increase both resilience and efficiency in supply chains. However, there was not enough evidence to establish a generalizable significant relationship between resilience and efficiency in these types of contexts.

Figure 5.2: Structural model results



$\chi 2/df$ = 1.57; CFI = 0.94; TLI = 0.93; RMSEA = 0.060; SRMR = 0.069

As a last step in this research stage, we looked for potential endogeneity in the model. Endogeneity arises when the analyzed relationships cannot be properly explained due to neglected causes, which lead to an omitted variable bias (Antonakis, et al., 2010). Endogeneity has been recently included in (Operations Management) OM studies as an additional test to avoid reaching flawed conclusions (Ketokivi & McIntosh, 2017; Sande & Ghosh, 2018). Additionally, the research led by Ketokivi and McIntosh (2017) guided researchers in the evaluation of endogeneity in studies in which Structural Equation Modelling (SEM) methodology is applied. To that extent, we analyzed whether the model fit improved significantly when adding correlations between disturbance terms as suggested by examining modification indices (MI) and expected parameter changes (EPC) of the path model (Saris, et al., 2009). We encountered no suggestions to make any changes in the goodness fit. As such, endogeneity does not represent a problem in our research model.

5.5.2. Configuration Analysis

Our last hypothesis, H4, posits that a taxonomy for resilience and efficiency can be developed based on the synchromodal dimensions of the supply chain. A configurational analysis can help us to better investigate the relationship between these two outcomes (resilience and efficiency) based on synchromodal dimensions. To that extent, a combination of cluster analysis and ANOVA has been suggested as a good approach to perform a configurational analysis (Flynn, et al., 2010; Revilla, et al., 2013; Cao, et al., 2015). In doing so, we divided our configuration analysis into two stages. First, we identified the different patterns of synchromodal outcomes and then compared them across the different groups. For the first part, we used a cluster analysis to classify the respondents based on their profiles on the synchromodal outcomes. To determine the number of clusters, we first used Ward's hierarchical clustering procedure, applying the Euclidean distance and the agglomeration schedule. We then used a non-hierarchical clustering analysis to obtain the final clusters (Hair, et al., 2009). The percentage of change in the agglomeration coefficient, as shown in Figure 5.3, has its highest percentage of change when the number of clusters changes from 4 to 3, indicating that the appropriate number of clusters is 3, which was also supported doing a random sampling of the dendrograms. The results of this cluster analysis are presented in Figure 5.4 and Table 5.6, with three-outcome configurations emerging. Table 5.6 characterizes the clusters based on the final centers. We labeled these clusters according to the levels of resilience and efficiency. The first cluster, or *imbalance*, includes 58 firms and is characterized by firms with high levels of resilience but moderate levels of efficiency. Cluster 2, or *moderate performers*, includes 32 firms with moderate levels of both resilience and efficiency. Finally, cluster 3, or *high performers*, consisting of 67 firms, has the highest levels of resilience and efficiency.

Figure 5.3: Percentage change in the agglomeration coefficient

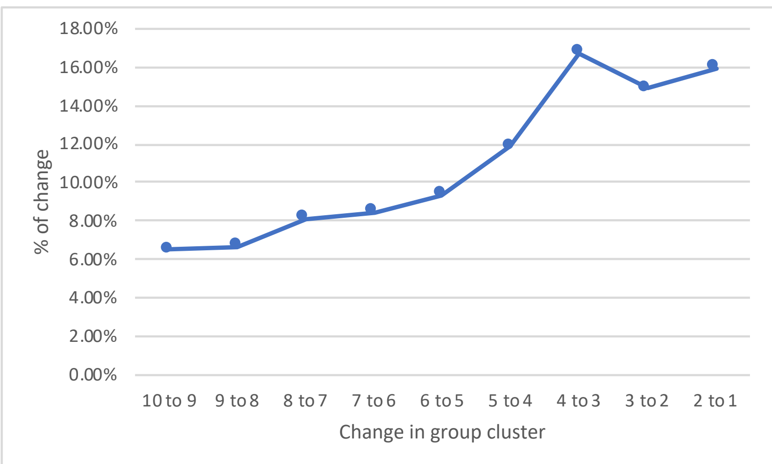
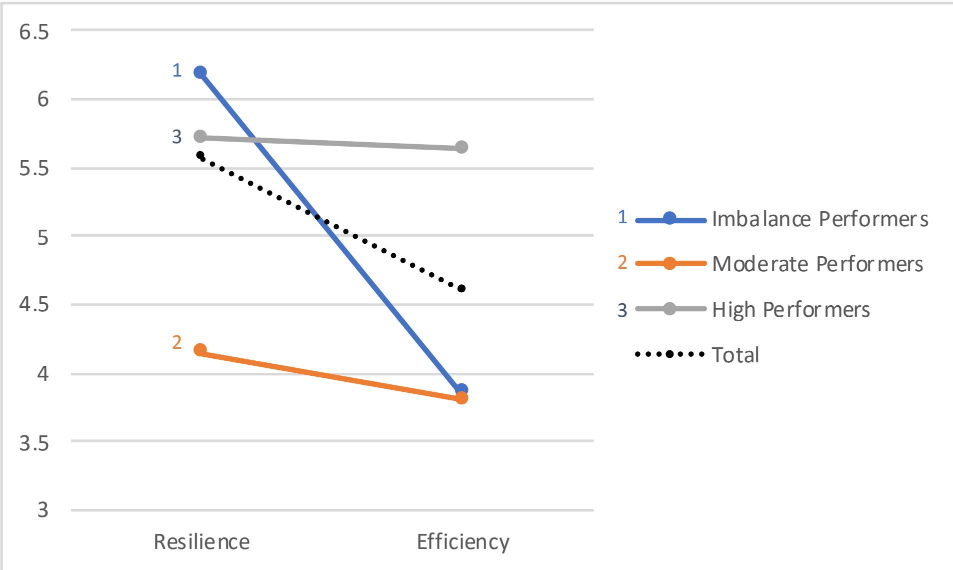


Table 5.6: Cluster results for Resilience and Efficiency

	Mean (SD) of the cluster group				
	Cluster 1 Imbalance Performers	Cluster 2 Moderate Performers	Cluster 3 High Performers	Total	F (ANOVA)
Resilience	6.17 (0.52)	4.15 (0.83)	5.72 (0.58)	5.56 (0.97)	114.376***
Efficiency	3.86 (0.87)	3.80 (0.75)	5.64 (0.70)	4.61 (1.18)	103.291***
N	58	32	67	157	
Main group differences (Tukey test)					
Resilience			(1-2)*** ; (2-3)***		
Efficiency			(1-3)*** ; (2-3)***		

Note: * p<0.05; **p<0.01; ***p<0.001

Figure 5.4: Taxonomy of Resilience and Efficiency in Synchromodal networks



To understand the underlying dimensions that define the three previously identified clusters, we performed a canonical discriminant analysis, summarized in Table 5.7. Two functions emerged, both with eigenvalues larger than one, and with the first function explaining approximately 58% of the total variance. Table 5.8 reveals that, although both performance outcomes were important in forming Function 1 and Function 2, resilience dominates in the first function (imbalance) while a relative equilibrium of both resilience and efficiency are apparent in the second function (responsiveness). The positive loading of resilience versus the negative loading of efficiency reflects the imbalance or trade-off of the outcomes, dividing the patterns into those with higher and lower performance trade-offs. This function also presents the greatest differentiator between clusters. Function 2 reflects the responsiveness level of the firm. In this case, both dimensions were important in forming the function, dividing clusters into a high- and moderate-responsiveness orientations.

These discriminant functions are also represented in Figure 5.5, which shows how the three clusters are differentiated based on imbalance and responsiveness, as well as the synchromodality level, represented by the ball's diameter. Accordingly, synchromodal companies can be clustered into groups with different levels of performance based on trade-offs and responsiveness features.

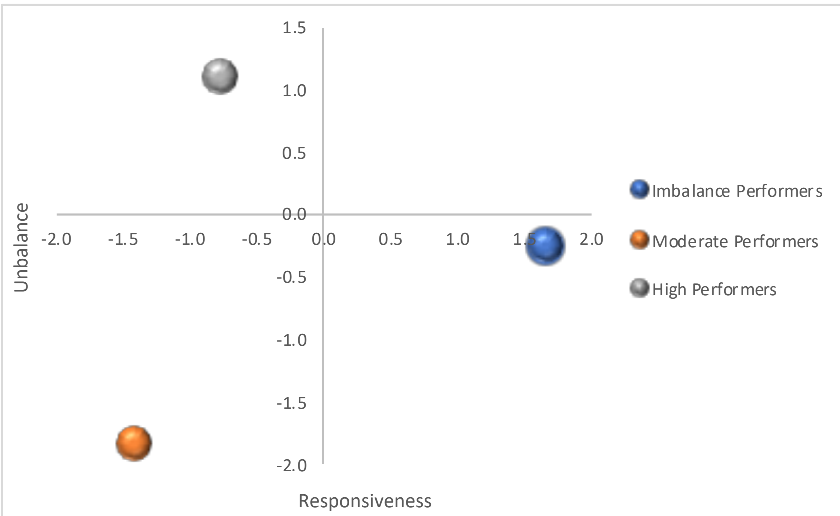
Table 5.7: Discriminant Analysis

Function	Eigenvalue	Percentage of Variance	Cumulative Variance	Canonical Correlation
1	1.717	57.7	57.7	0.795***
2	1.258	42.3	100.0	0.746***

Table 5.8: Standardized canonical discriminant

	Function 1	Function 2
Resilience	0.962	0.454
Efficiency	-0.756	0.749

Figure 5.5: Cluster centroids



Finally, we used ANOVA and Tukey tests to identify significant differences between clusters in terms of the four synchromodal dimensions: visibility, flexibility, integration, and operational system. The results of these two tests, along with the basic descriptive statistics for each cluster of constructs, are presented in Table 5.9. The ANOVA test shows significant differences in the levels of synchromodal dimensions as the result of variations in the supply chain-network performance orientations.

This last step allowed us to perform a deeper analysis of the potential differences between clusters. In terms of synchromodal flexibility, differences were particularly significant between the imbalanced cluster and the moderate performers cluster. Synchromodal supply chains with a high resilience orientation but a moderate emphasis on efficiency have more flexibility; such chains are also more integrated and have developed operating systems. Synchromodal supply chains with moderate effects of resilience and efficiency also have the lowest development of synchromodal dimensions (synchromodal flexibility, visibility, integration, and operating systems). Finally, synchromodal supply chains with the highest levels of visibility correspond to the highest levels of resilience and efficiency.

Table 5.9: Results of cluster analysis and ANOVA results for synchromodal dimensions

	Mean (SD) of the cluster group					
	Cluster 1 **Imbalance Performers**	**Cluster 2** **Moderate Performers**	**Cluster 3** **High Performers**	**Total**	**F (ANOVA)**	**Brown - Forsythe**
SF	5.29 (1.04)	3.97 (1.01)	5.00 (1.02)	4.90 (1.13)	17.736***	17.876***
SV	4.83 (1.25)	4.23 (0.95)	5.02 (0.96)	4.79 (1.11)	5.880**	6.088**
SI	6.27 (0.73)	5.42 (0.92)	6.24 (0.75)	6.08 (0.85)	14.133***	12.901***
SOS	4.92 (1.54)	3.85 (1.26)	4.44 (1.69)	4.50 (1.60)	4.911**	5.426**
Synchromodality	5.32 (0.67)	4.87 (0.84)	5.11 (0.71)	5.10 (0.67)	28.477***	26.113***
N	58	32	67	157		

Main group differences (Tukey test)	
SF	(1-2)***; (2-3)**
SV	(1-2)*; (2-3)**
SI	(1-2)***; (2-3)***
SOS	(1-2)**
Synchromodality	(1-2)***; (2-3)***

Note: * p<0.05; **p<0.01; ***p<0.001

Table 5.9 also shows that the imbalanced cluster and the high performers' cluster perform similarly in terms of synchromodal dimensions. The imbalanced cluster presents the highest values of synchromodal flexibility, visibility, integration, and operating systems while the moderate performers cluster presents the lowest values of the four dimensions. The findings from the ANOVA and Tukey analyses shows that among the different dimensions that form synchromodality, synchromodal integration presents the highest levels across the three different configurations, whereas synchromodal flexibility and synchromodal visibility are relatively high levels and operating systems present the lowest level. There is no significant difference in the degrees of synchromodal operating systems among the imbalanced, moderate, and high performers groups, indicating that the identified clusters do not have much predictive power in explaining this operating synchromodal dimension. This is an interesting result that reinforces previously developed synchromodal frameworks and emphasizes that synchromodality is defined by an infrastructure that not only facilitates changes in transportation mode, but also an integrated, flexible, and visible supply chain.

Overall, the configurational analyses of the ANOVA and Tukey tests support H3 and H4: namely, that efficiency and resilience do not relate in a unique way in a synchromodal context. Additionally, based on the dimensions of supply chain synchromodality, a taxonomy can be developed for efficiency and resilience.

5.6. Discussion and Implications

Building on the synchromodality existing research (Zhang & Pel, 2016; Acero & Saenz, 2018; Dong, et al., 2018), our study contributes to an understanding of this novel and popular concept. So far, the few published studies have been based on single case studies (Lucassen & Dogger, 2012; Zhang & Pel, 2016) or simulations (Kapetanis, et al., 2016; Lin, et al., 2016; Li, et al., 2017; Van Riessen, et al., 2017). Lin et al. (2016) and Dong et al. (2018) found that synchromodality was related to efficiency, whereas Lee and Song (2017) stipulated a positive relationship with resilience. Although we began our analysis by considering that previous theoretical hypotheses on the performance effect of synchromodality have not been empirically tested, our research in fact provides evidence of existent relationships. We expanded this research using a SEM path analysis that provides empirical evidence of a strong and statistically significant relationship between synchromodality and both efficiency and resilience. This implies that companies that promote a synchromodal environment in their daily operations are not only more efficient from a logistics and transportation perspective, they are also less prone to disruptions, as the dimensions required to implement synchromodality requires a higher situational awareness.

We complemented our findings from the path analysis using a configurational approach. The non-significant relationship between the two outcomes of synchromodality led us to think about the previously analyzed trade-off between resilient and efficient supply chains. As such, we tackled this dichotomy using a configurational approach. Our research contributes to the literature of logistics performance and extends prior research on the trade-off between logistics efficiency and resilience. To the best of our knowledge, the current research is one of the first to adopt a configuration approach in exploring this trade-off, and we present an innovative method to analyze different patterns in synchromodal supply chains. While some studies have found that efficiency was negatively related with resilience (Ivanov, et al., 2014), others (Shukla, et al., 2011; Birkie, 2016) have found a positive relationship between these two operational outcomes. Our configurational study based on a cluster analysis indicates that an investigation of the relationship between efficiency and resilience can only be fully examined when all the dimensions of synchromodality are considered together, as proven by H3 and H4. In general, three different patterns or profiles were identified in our study: imbalanced performers, moderate performers, and high performers.

Our findings indicate significant differences in efficiency and resilience levels regarding the three configuration patterns and depending on the level of synchromodality achieved by the supply chains, the outcomes measured as resilience and efficiency will vary. Lowest levels of synchromodality are associated with the lowest levels of performance, reinforcing the idea that synchromodal supply chains have a competitive advantage in terms of resilience and efficiency. Companies who develop synchromodality above average are the ones that find the optimum balance between resilience and efficiency, increasing both outcomes simultaneously. However, we can also observe that achieving high levels of synchromodality does not necessarily increase the efficiency of the supply chain. These are interesting outcomes aligned with the existing theory, confirming the hypothesis that there is no one unique relationship in terms of resilience and efficiency in the synchromodal context. While the highest level of resilience characterizes the imbalanced and high performers groups, companies in the moderate performers group show only a moderate level of resilience. On the other hand, firms that fall under the imbalanced and moderate performers clusters present below average levels of efficiency, while the highest levels of efficiency correspond to the companies of the high performers cluster.

As such, one could infer that synchromodality and resilience pair up at the expense of efficiency. Establishing as a baseline companies with the lowest levels of synchromodality (cluster 2, *moderate performers*), we can observe that synchromodal companies that deploy slightly higher levels of flexibility, visibility and integration (cluster 3, *high performers*), do not only increase their synchromodal level, but also increases both the resilience and efficiency of the supply chain they operate at. However, for synchromodal companies that make an extra effort, reinforcing their flexibility and operating system, translates in an increase of resiliency with a considerate drop in the efficiency of the system (cluster 1, *imbalance performers*). One possible explanation for this behavior is that synchromodal supply chains aiming to develop high levels of synchromodality and resilience need to make extra investments in assets and resources that will, consequently, make them less efficient. It seems that there is an optimum level of flexibility, visibility, integration and operating systems that companies seeking to implement synchromodality need to develop in order to achieve resiliency without compromising the overall profitability of the supply chain. Finally, our analysis provides evidence of extreme outcomes. As such, companies operating in high risk environments whose main focus is to minimize disruptions can take advantage of synchromodal operations as it will considerate increase their resilience while maintaining moderate levels of efficiency.

5.7. Conclusions and Further Research

The present study offers three contributions to the literature. First, building on the existing work of synchromodality (Kapetanis, et al., 2016; Lin, et al., 2016; Zhang & Pel, 2016; Li, et al., 2017; Van Riessen, et al., 2017; Acero & Saenz, 2018; Dong, et al., 2018), our research analyzes and provides empirical evidence of the implications of applying synchromodality to the overall supply chain. Second, it develops a taxonomy of efficiency and resilience, providing empirical evidence that links the four synchromodal dimensions (Acero & Saenz, 2018) with the two previously discussed outcomes. Third, although most studies have focused on supply chain efficiency or resilience either separately (Ambulkar, et al., 2015; Liu, et al., 2018) or in terms of trade-offs (Birkie, 2016; Saenz, et al., 2018), this study goes further by empirically proving the dual impact that synchromodality and its four underlying dimensions have on resilience and efficiency at the same time.

Furthermore, this study provides insights for managers on how synchromodality may affect their transportation and logistics partners in the overall supply chain operations. Our results show that depending on the synchromodal context, supply chains are not only more efficient from a logistics perspective, but also more resilient in times of disruptions. At the same time, we also find that companies investing in synchromodality may face a drastic trade-off between efficiency and resilience.

Although our study contributes both to the academic and managerial audiences, additional research is needed to fully understand the effect of synchromodality and its outcomes. As the concept and implementation synchromodality matures and expands to a greater number of countries, future researchers could collect additional data and compare findings with those of this study. For example, the data used in this study is cross-sectional, but the use of longitudinal data could provide additional information on the evolution of the relationships between synchromodality dimensions and responsiveness and performance optimization outcomes. It would also be interesting to analyze how the levels of efficiency and resilience of synchromodal supply chains evolve with the development of strategic alliances between shippers and logistics providers. Finally, in our research we focused on the transportation and logistics network of a shipper from a specific manufacturing market. It would be interesting to see if the results obtained could be extrapolated to other industries, such as non-perishable foods or technology, with different time constraints and shipment requirements.

5.8. References

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Chapter 6

Implementation of a Collaborative and Formal Supply Chain Risk Management Structure on Disruption Minimization.

6.1. Introduction

During the past two decades, supply chains have become more global with the objective of reducing costs and increase market penetration as well as competitive advantage. However, globalization has also increased supply chain interconnectivity, and, as a result, supply chains are not only more complex but more vulnerable (Ambulkar, et al., 2016). To address this challenges and concerns, supply chain risk management (SCRM) emerged as an important area of research both for practitioners and academic researchers (Ho, et al., 2015), playing a decisive role in successfully managing business and operation activities in a proactive manner (Lavastre, et al., 2014).

Supply chains are expose to a vast number of risks, and many studies have attempted to classify them based on their cause, drivers or consequences (Jüttner, et al., 2003; Chopra & Sodhi, 2004; Christopher, 2005; Kleindorfer & Germaine, 2005; Kiser & Cantrell, 2006; Tang, 2006; Tang & Tomlin, 2008; Trkman & McCormack, 2009). Given the numerous risks supply chains face in their daily operations, SCRM has become decisive not only to minimize potential disruptions but to position firms with a competitive advantage. SCRM plans should not be seen as static or simple “recipes” that would, with minor adjustments, serve all firms (Saenz, et al., 2018). First, companies need to understand the environment they are operating at, the vulnerabilities they are facing and how the active work with other members of the supply chain can help them to better face disruptions. The first thing that companies do to face vulnerabilities and mitigate potential disruptions is to develop an active risk management strategy within their operations. However, not all firms materialize their work on SCRM through a formal structure in the form of dedicated personnel and departments that follow what is widely known as a

Business Continuity Plan (BCP). Additionally, not all the risks that companies face are intrinsically caused by the firms operating activities as many vulnerabilities are externally caused by other supply chain partners (key suppliers, transportation and logistics partners…) and by the environment where the firm is operating. Consequently, it makes sense to deploy collaborative risk management practices to deal with disruptions. However, to the best of our knowledge, no research study has estimated the causal effects of the implementation of SCRM process in disruption occurrences. Consequently, the purpose of this present study is to explore how an active SCRM along with formalization of the risk management processes and collaboration strategies affect the propensity to have certain type of disruptions.
estimate the causal effect associated with treatment effects

Our research uses data collected through the Center for Transportation and Logistics (CTL) at Massachusetts Institute of Technology under the MIT Global SCALE Risk Initiative. Using responses from 1,461 supply chain risks managers working in firms in 69 countries, we estimate the causal effects that the different SCRM approaches have on disruption propensity. To that end, we used a multivalued treatment effect methodology, advancing from the traditional causal effects' tools of regression analysis or binary treatment effects used in the majority of Operations Management studies that attempt to analyze causal effects of different supply chain capabilities on resilience and disruption minimization.

The remainder of the paper is structured as follows. The next section provides the theoretical foundation and hypothesis of our proposed empirical model. Afterwards, we present the description of the sample data and of the methodology used in the analysis. This section is followed by a result discussion and we conclude with some ending remarks, managerial implications, limitations, and avenues for future research.

6.2. Theoretical Framework and Hypotheses Development

In this research work we postulate that in firms with active supply chain risk management processes, the propensity to suffer disruptions can be mitigated by the deployment of formal and collaborative risk management structures.

6.2.1. Risks, Disruptions and Supply Chain Risk Management

Supply chain risk has been receiving an increase attention in the operations management research as the optimal management of risk can improve the performance and resilience (Ellis, et al., 2010; Zhao, et al., 2013). Like for the general term of risk, there is an extant number of definitions for supply chain risk (Rao & Goldsby, 2009). Some relate to the specific context, such as supply (Zsidisin, 2003; Ellis, et al., 2010; Zhao, et al., 2013), others to information or (Jüttner, et al., 2003) or market, while other focus on a more general vision (Wagner & Bode, 2006; Bogataj & Bogataj, 2007; Ho, et al., 2015). However, as Jajja et al. (2018) suggest in their research, the multiple definitions that exist in the literature about supply chain risk evolve around the idea that risks are the sum of probable events that lead to disruption based on: (1) internal operations (Christopher & Peck, 2004; Tummala & Schoenherr, 2011); (2) supplier operations (Zsidisin, 2003; Ellis, et al., 2010; Zhao, et al., 2013); (3) market context (Chen & Paulraj, 2004; Zhao, et al., 2013); and (4) transportation operations or delivery means (Ravindran, et al., 2010; Zhao, et al., 2013).

The research field of supply chain risk management emerged as an approach to reduce vulnerability to risk and, as a result, during the past decade, it has attracted numerous researches and practitioners aiming to find a way of creating operational and managerial competitive advantage through risk control (Rangel, et al., 2015). Even though the term SCRM first appeared in the 2003 (Rowat, 2003; Lavastre, et al., 2012), there is still no consensus on its definition. One of the first academic definitions was proposed by Jüttner et al. (2003) and Jüttner (2005) stablishing that SCRM aims to reduce supply chain vulnerability through coordinated risks identification and management approach by involving all partners of the supply chain. Norrman and Jansson (2004), Tang (2006) and Wieland and Wallenburg (2012) emphasize this collaboration aspect of SCRM. The first ones define it as a collaborative approach that deals with risks and uncertainties that can potentially impact the supply chain, while Tang (2006), Wieland and Wallenburg (2012) or Ho et al. (2015) define SCRM as the collaboration among the different supply chain partners with the objective of reducing potential disruptions while guarantying continuity in the operations. It can be noted that all these definitions present some limitations as they focus on specific elements of the SCRM, underestimating the formal implementation component of risk management strategies.

Several studies have attempted to create a SCRM conceptual framework process. The majority of these proposed conceptual frameworks are either qualitative or quantitative-based, and they initially focused on two aspects: either risk identification and assessment, risk identification and mitigation, or risk assessment and mitigation (Ho, et al., 2015). From there, conceptual frameworks have evolved to three (Lavastre, et al., 2012), four (Hallikas, et al., 2004; Ho, et al., 2015) and even five-stage processes (Ritchie & Brindley, 2007; Foerstl, et al., 2010; Kern, et al., 2012), some of them including knowledge transfer step (Zsidisin & Ritchie, 2009).

The ultimate goal of any SCRM approach implemented in any firm is the reduction of potential disruptions. A supply chain disruption can affect just one firm, or it can spread to different supply chain partners. Disruption is defined as an isolated or a series of unexpected events that interrupt the normal operational flow with negative consequences (Chopra & Sodhi, 2004; Craighead, et al., 2007; Blackhurst, et al., 2011; Scheibe & Blackhurst, 2018). Supply chain disruptions may have catastrophic consequences, in terms of profit loss or even an entire shut down, as they spread through the entire system or network, with a potential ripple effect as it expands through the supply chain (Scheibe & Blackhurst, 2018). Consequently, companies need to develop an understanding of their supply chain risks along with an implementation of their SCRM processes to minimize the propensity to suffer a disruption and, as a consequence, be able to maintain their supply chain operations (Scheibe & Blackhurst, 2018).

6.2.2. Formalization of a Supply Chain Risk Management Structure

The development, implementation and active work of SCRM processes can be complemented through the implementation of a formal risk management structure. In this case, companies deploy part of their assets to stablish resource structure to manage supply chain related risks and disruptions (Ambulkar, et al., 2015). The implementation of active SCRM strategies can be approached at three different levels: operational, tactical and strategical (Lavastre, et al., 2014). We will focus in the exploration of the strategic aspect of SCRM processes, which implies the introduction of formal procedures such as the identification of potential risks and the use of a Business Continuity Plan (BCP) (Ambulkar, et al., 2015). This formal resource structure could be in the form of a specific department to prevent and deal with risks, the monitorization of certain supply chain process to early identify indications of disruptions or the implementation of information sharing and communication channels to manage risks and disruptions (Blackhurst, et al., 2011; Ambulkar, et al., 2015).

Companies can largely benefit from the formalization of a SCRM process as it has been related to reduce work ambiguity, increase task specialization, knowledge acquisition and information exchange, all of which lead to disruption minimization and resilience creation (Ambulkar, et al., 2015). However, a formal SCRM structure does not always necessarily leads to higher resiliency levels. For example, when dealing with high-impact disruptions, having a formalized SCRM structure may make companies to rely j kjon previously used mitigation approaches, leaving aside innovative or creative approaches (Sirmon, et al., 2007) as formalization is also related to more rigid processes (Gilbert, 2005). Setting aside the so-called high-impact, low-probability disruptions caused by force majeure events such as natural hazards, supply chains face recurrent risks, which are those derived from daily operations such as internal process interruptions, supplier related or market fluctuations (Chopra & Sodhi, 2014). Recurrent risks can be mitigated with certain supply chain risk management approaches (Chopra & Sodhi, 2014), and specifically with the implementation of a formal supply chain risk management structure with a clear risk and disruption minimization orientation (Ambulkar, et al., 2015).

The ultimate objective of any SCRM process is to create a resilient supply chain, capable of survive, adapt and grow in the face of turbulence, upheavals and unforeseen events (Pettit, et al., 2010; Brusset & Teller, 2017) by reducing or even eliminating the frequency of problems and their consequences (Lavastre, et al., 2014). Consequently, we hypothesize that by implementing SCRM processes through a formal structure, companies can reduce the propensity to suffer disruptions due to internal, supplier, market or transportation related operations.

> **H1a.** The implementation of a formal SCRM structure reduces the propensity of suffering an internal related disruption.
>
> **H1b.** The implementation of a formal SCRM structure reduces the propensity of suffering a supplier related disruption.
>
> **H1c.** The implementation of a formal SCRM structure reduces the propensity of suffering a market related disruption.
>
> **H1d.** The implementation of a formal SCRM structure reduces the propensity of suffering a transportation related disruption.

6.2.3. Collaborative Approach of Supply Chain Risk Management

The increased competition in global supply chain environments has led companies to create collaborative partnerships among the different supply chain members (Zhao, et al., 2013).
An active SCRM plan can highly benefit from collaboration between the different partners of the supply chain, as it has largely been researched how collaboration can increase supply chain resiliency (Blackhurst, et al., 2011; Ambulkar, et al., 2016). For many authors, collaboration is based on information exchange, either in real-time or the closest to it (Daugherty, et al., 2006; Simatupang & Sridharan, 2008; Nyaga, et al., 2010; Zhang & Cao, 2018). Supply chain collaboration is defined as the development of synergies and relationships among partners that closely work together to create mutually beneficial outcomes (Whipple & Russell, 2007; Defee & Fugate, 2010; Cao & Zhang, 2011). Additionally, Cao, et al. (2010) present a conceptualization of supply chain collaboration that has been adopted by multiple researchers (Scholten & Schilder, 2015). As such, collaboration is defined from multiple aspects: information-sharing, goal congruence, decision synchronization, incentive alignment, resource-sharing, collaborative communication and joint knowledge creation (Cao, et al., 2010). As all these aspects increase the visibility, flexibility and, ultimately, the resilience of the supply chain (Wieland & Wallenburg, 2013; Scholten & Schilder, 2015). Consequently, it should be expected that when companies incorporate a collaborative component to their SCRM processes, the resiliency effect should be augmented through a reduction of the propensity to suffer a disruption.

H2a. The implementation of a collaborative SCRM approach reduces the propensity of suffering an internal related disruption.
H2b. The implementation of a collaborative SCRM approach reduces the propensity of suffering a supplier related disruption.
H2c. The implementation of a collaborative SCRM approach reduces the propensity of suffering a market related disruption.
H2d. The implementation of a collaborative SCRM approach reduces the propensity of suffering a transportation related disruption.

6.2.4. Contextual drivers of SCRM

The operating context of the firm has an impact on the risk that the company faces and subsequently on the type of SCRM structure and collaboration developed and implemented by the firm (Lavastre, et al., 2014). Firm size, market sector and operating context influence how companies envision and implement their SCRM processes and strategies and in turn, their propensity to suffer disruptions.

Firm size

Firm size gives an indication of the amount of available resources (Cao, et al., 2009). As such, larger firms will have more material and human assets ready to be utilized than small and medium firms (SME). Additionally, while large firms may have an entire department devoted to SCRM, the limitation of resources in SMEs implies that some supply chain management activities like SCRM may be carried out by one or very few members with a partial dedication (Kull, et al., 2018). Larger firms tend to have a wider vision of the vulnerabilities they are exposed to, and their structural organization allows them to deploy more complex SCRM processes than SMEs. The size of the company can also influence the characteristics and operations of the SCRM approach, in terms of formalization, number of involved personnel, procedure definition or frequency of monitoring, among others (Lavastre, et al., 2014). It can also affect in the degree of formalization of the firm (ISO, OSHAS, etc.), which also contributes to the establishment and detail of a formal SCRM process (Lavastre, et al., 2014). Similarly, the effect of collaboration on disruption mitigation will also vary depending on the firm size. Larger firms tend to stablish dominant supply chain collaboration structures while SMEs tend to pursue collaborative alliances with other SMEs (Hong & Jeong, 2006). As SMEs tend to have less resources devoted to SCRM than large firms, they can greatly benefit from the synergies and added information than collaboration with either a larger or similar in size company may bring.

> **H3a.** The effect of the implementation of a formal SCRM structure is greater in large firms than in SMEs.
>
> **H3b.** The effect of the implementation of a collaborative SCRM approach is greater in SMEs firms than in large companies.

Operating sector

The activity sector in which the firm operates also influences how the different SCRM strategies are developed and implemented. Depending on the operating section, firms will face different risks and vulnerabilities in terms of demand uncertainty, product requirements (lifespan, transportation time and conditions, customization, innovation), legislation, market competition, etc. (Lavastre, et al., 2014). Service companies are characterized by having high level of customer's involvement, intangibility of products that are simultaneously produced and consumed and human resources intensity (Nie & Kellogg, 1999), while manufacturing firms tend to face different risks and vulnerabilities based more on operations, market requirements and demand fluctuations.

Manufacturing firms are characterized by the standardization of their operative processes, with established quality requirements and a regular pool of suppliers and clients. On the other hand, service companies tend to operate in more volatile environments, with a higher rotation of customers and with the specialization on more intangible goods also characterizes by their hard to predict demand. Consequently, it makes sense to believe that manufacturing companies will benefit the most from the implementation of a formal SCRM strategy while a collaborative SCRM strategy would benefit more service providers companies.

> **H4a.** The effect of the implementation of a formal SCRM structure is greater on manufacturing firms than in service providers.
> **H4b.** The effect of the implementation of a collaborative SCRM approach is greater on service provider companies than in manufacturing firms.

6.3. Research Method

6.3.1. Sample collection and description

This research is based on a survey-based methodology using a questionnaire was developed by researchers from the Center for Transportation and Logistics (CTL) at MIT under the MIT Global SCALE Risk Initiative. The questionnaire was developed after a careful review of the existing literature and following the recommendations from Saris and Gallhofer (2007) and Hair, et al. (2009). Once the questionnaire was design, it was validated through a pre-test which help to made minor adjustments to purify the survey items and correct deficiencies.

Data was gathered simultaneously during a two-month period, using a large-scale, worldwide online survey. The questionnaire targeted mid and high-level positioned supply chain managers and was designed with the objective of obtaining insight information about different supply chain risk management practices. To this end, and in order to reach a larger number of supply chain professionals, we engaged with several supply chain management professional associations like the Association for Operations Management – American Production and Inventory Control Society (APICS), the Council of Supply Chain Management Professional (CSCMP) and the Centro Español de Logística (CEL), among many others.

A total of 1,461 useful responses were received. Although the response rate varied among surveyed regions, the average response rate was 22%. With answers from 69 different countries, this study presents a wide variety in terms of cultures and industries. The basics demographic statistics of the respondents is as follows: 63 % were older than 40, 82% were males and 62% held a university or master's degree, over 64% of the respondents had management positions (equally distributed between senior managers and vice-presidents), the average years of industry experience were 12.9 years. Regarding the type of companies represented in this study the basic statistics are as follows: 34.4% were SMEs while 65.6% were large firms (with more than 300 employees); 12.3% had revenues of less than $10m, 34.1% had revenues between $11m and $100m, 25.8% had revenues between $101m and $500m while 27.8% had revenues between $500m and $1b. There was a wide representation from companies all over the world: 33.1% of the companies had their headquarters in the US, 11% in South Africa, 9.1% in Switzerland, 8% in Spain, 5% in Italy, 4.6% in India, 4.2% in Brazil and 3.7% in China.

6.3.2. Empirical methodology

To answer the question of whether the implementation of formal and collaborative SCRM structures have an impact on the propensity to suffer certain type of disruptions (internal, supplier, market and transportation related), we need to estimate the causal effect associated with treatment effects.

Traditionally, these empirical problems have been approached using binary treatments, where each subject could either receive the treatment or not receive based on a binary random variable, $D_i = \{0,1\}$, corresponding to what is known as the fundamental problem of causal inference (Holland, 1986). However, in our case as each of the firms can received one of several SCRM approaches. This type of problem is referred to as multivalued treatment effect problems (Imbens, 2000; Imbens & Wooldridge, 2009; Cattaneo, 2010; Wooldridge, 2010), in which we try to understand what would be the propensity of having a certain disruption under each of the SCRM processes or mechanisms (treatment level). This is what in econometrics is known as the average or mean for each potential outcome (POM). As only one SCRM mechanism can be observed in each of firm, the aim of the problem is to estimate the effect that moving from one SCRM mechanism to another would have on the propensity disruption.

We will follow the methodology developed by (Cattaneo, et al., 2013) to estimate multivalued treatment effects. We begin by considering a cross-sectional setting where each of the observed firms $i= 1, 2\ldots n$ has been assigned one of the $\mathcal{J}+1$ possible treatments level $j=0,1,\ldots\mathcal{J}$. For each firm i we observed the random vector $z_i = (y_i, w_i, x_i')'$, being y_i the observed outcome variable, w_i the treatment level and x_i' the vector of covariates or control variables. We also introduce the indicator variables $d_i(j)=\mathbf{1}(w_i=j)$, whose value equals 1 if firm i received treatment j and the value 0 otherwise.

The estimands and estimators of interest are described using the classical potential-outcome framework. The advantage of this model is that for each treatment level $j=0,1,\ldots\mathcal{J}$, it distinguishes between the observed outcome y_i and the $\mathcal{J}+1$ potential outcomes $y_i(j)$. Consequently, the observed outcome variable is defined by $y_i = \sum_{j=0}^{J} d_i(j) y_i(j)$. The distribution of each $y_i(j)$ corresponds to the distribution of the outcome variable that would occur if the firms were given treatment level j.

To understand the effects of receiving one treatment instead of other (i.e., one SCRM approach instead of other), we are interested in looking at two particular parameters: POM (Potential Outcome Means) and ATE (Average Treatment Effect). The POM for each treatment is the average of each potential outcome and it is defined as $POM_j=[E(y_j)]$, while ATE is the average effect of fiving each firm treatment j instead of j'.

To estimate POM and ATE, we will use the augmented inverse propensity score (AIPW) which was developed by (Robins, et al., 1994) for means estimation. The AIPW has very attractive theoretical properties, for example it has the advantage of being doubly robust whenever one of the two required models (treatment or outcome) are correctly specified. Additionally, estimated ATE will be unbiased when both propensity score and outcome models are known (Glynn & Quinn, 2010). AIPW calculates the estimated treatment effects using a three-step procedure (Glynn & Quinn, 2010). First, we use a multinomial logit model to compute the generalized propensity score that estimates the treatment model. Secondly, it estimates a separate regression model for the outcomes of each treatment model. In the third and final stage, the potential mean is calculated as a weighted mean of the already computed treatment-specific predicted outcomes, using the weights obtained in the first stage of the process.

Finally, two assumptions must be met to satisfactory estimate AIPW: confoundedness and common support (Imbens, 2000; Imbens & Wooldridge, 2009; Wooldridge, 2010; Cattaneo, et al., 2013). The first assumption relates to the conditional independence assumption (CIA) also known as selection on observables because it is assumed that the covariates to be held fixed are known and observed (Angrist & Pischke, 2009). Consequently, by controlling the right observed covariates (control variables) the potential outcome distributions are independent of the treatment level, minimizing omitted variable bias (OVB) and endogeneity. The survey used in this study covers a wide range of firm and respondents' characteristics, which makes us believe that OVB should not pose a problem. Finally, the common support assumption ensures that both the regression and matching estimands are restricted to covariate values where all different treatment level observations are found (Angrist & Pischke, 2009).

Treatments

The questionnaire in the MIT Global Scale Risk Initiative includes a set of questions related to the firm's SCRM (refer to Annex 3.3). In particular, it included questions related the use of a risk management structure ("We have a business Continuity Plan") and collaborative risk management strategies ("We work with customers on supply chain risk management" and "We work with suppliers on supply chain risk management"). Using these questions as a starting point, we formulate two different treatment levels:

1. The formalization of the SCRM process in companies that, at the same time, work actively on their supply chain risk mitigation and management practices. Companies that do not have that formal structure are coded with Value 1 while Value 2 is given to those with a formal risk management structure.

2. The deployment of collaborative strategies added to the active work on SCRM. To that end, Value 1 reflects the lack of collaboration with the different partners of the supply chain and Value 2 represents collaboration SCRM mechanisms.

Questions from the questionnaire that defined each of the two treatments were grouped and recoded as binary variables as presented in Table 6.1.

Table 6.1: Equivalence between survey questions and used variables

Original Survey Questions	New Variables
Treatment: SCRM formalization	
5. Supply Chain Risk Management *1. Tell us about Supply Chain Risk Management at your company:* […] "We have a Business Continuity Plan"	1. Lack of formal SCRM structure 2. Presence of a formal SCRM structure
Treatment: SCRM and collaboration	
5. Supply Chain Risk Management *1. Tell us about Supply Chain Risk Management at your company:* […] "We work with customers on supply chain risk management" and "We work with suppliers on supply chain risk management"	1. Lack of a collaborative SCRM 2. Presence of a collaborative SCRM
Disruption Outcomes	
4. Failure Modes *1. How frequently have you experience the following types of supply chain disruption:* […]	
"Your own internal operations are interrupted (e.g. power failure, machine breakdown, fire, etc.)"	Propensity to suffer an internal related disruption
"You lose supply of quality materials (e.g. supplier fails or cannot deliver, bad product quality, etc.)"	Propensity to suffer a supplier related disruption
"Sudden drop in customer demand (e.g. new competitor, financial crash, etc.)"	Propensity to suffer a market related disruption
"You cannot ship or deliver your products (e.g. supplier fails or cannot deliver, bad product quality, etc.)"	Propensity to suffer a transport related disruption

6.3.3. Outcomes

Our empirical model analyzes the effect that formalization and collaborative strategies applied to active SCRM approaches have on the propensity of having a disruption. The first disruption that we analyze is the one caused by internal related failures measured as disruptions caused by the interruption of internal operations (e.g. power failure, machine breakdown, fire, etc.). Additionally, companies can suffer supplier related disruption, due to a supplier failure, quality issues or late delivery, among others. The third outcome that we analyze is market related disruption, which would be the ones caused by sudden changes in demand, financial crashes, appearance of new competitors, etc. Finally, we will analyze transportation related disruptions. All these four outcomes are measured as binary variables (0,1) indicating whether or not the firm as suffered at least one disruption during the previous year.

6.3.4. Pretreatment Variables

We discussed in the methodology section that to estimate AIWP it is necessary to satisfy the selection on observables assumption in order to minimize OVB. To ensure this confoundedness assumption, we used a wide range of firm's characteristics variables that would control for the potential impact of firm's idiosyncratic on the adoption of the different SCRM approaches represented by each of the four treatments.

We first control for the geographical effects derived from the cultural and operational differences of working in different countries. As we received answers from risks experts representing 69 different countries, we decided to group the responses in 10 geographical clusters following the work performed by (Revilla & Saenz, 2014). Consequently, this categorical variable ranged from 1 to 10 (1 = Eastern Europe; 2 = Latin America; 3 = Latin Europe; 4 = Confucian Asia; 5 = Nordic Europe; 6 = Anglo; 7 = Sub-Sahara Africa; 8 = Southern Asia; 9 = Germanic Europe; and 10 = Middle East). Second, we control for firm size by adding a dummy variable coded 1 for large firms, with more than 300 employees, and 0 for small and medium enterprises, with less than 300 employees. Finally, we control for the type of industry. The questionnaire included 52 different industry types which were based on the NAICS (North American Industry Classification System) categories. This categorization was recoded in to a binary (1,0) variable indicating whether a firm operated in a manufacturing context or in a service provider one.

Table 6.2: Sample sizes and descriptive statistics

	All firms		*Active SCRM*	
Sample size	1,461		1,009	
Treatment: SCRM formalization				
3. Lack of formal SCRM structure	363		120	
4. Presence of a formal SCRM structure	1,098		889	
Treatment: SCRM and collaboration				
5. Lack of a collaborative SCRM	545		319	
6. Presence of a collaborative SCRM	916		690	
Disruption Outcomes	**Mean**	**Sd**	**Mean**	**Sd**
Propensity to suffer an internal related disruption	0.33	0.47	0.33	0.47
Propensity to suffer a supplier related disruption	0.51	0.49	0.52	0.50
Propensity to suffer a market related disruption	0.30	0.46	0.29	0.45
Propensity to suffer a transport related disruption	0.28	0.45	0.28	0.44
Control Variables	**Mean**	**Sd**	**Mean**	**Sd**
Large Firm	0.66	0.48	0.70	0.46
Manufacturer	0.66	0.48	0.66	0.47
Geographical Area	5.64	2.21	5.75	2.14

6.4. Results

The econometric model results described in the previous section are summarized in Tables 6.3 to 6.5. Table 6.3 shows the estimated potential mean of the four outcome variables for each treatment level or SCRM approach, as well as the expected average treatment effects, which represents the comparison between POMs or difference between getting one treatment effect instead of other. In particular, we are interested in the effect that the implementation collaboration and formalization of the SCRM structure have on the overall propensity to suffer a disruption.

Table 6.3: Average Treatment Effect estimates

	Outcome 1 Propensity to suffer an internal related disruption	Outcome 2 Propensity to suffer a supplier related disruption	Outcome 3 Propensity to suffer a market related disruption	Outcome 4 Propensity to suffer a transportation related disruption
Treatment: Formalized Active SCRM	**POM**	**POM**	**POM**	**POM**
1. Lack of a formal SCRM structure	0.43*** (0.04)	0.55*** (0.04)	0.30*** (0.04)	0.33*** (0.04)
2. Presence of a formal SCRM structure	0.32*** (0.01)	0.52*** (0.01)	0.29*** (0.01)	0.27*** (0.01)
	ATE	**ATE**	**ATE**	**ATE**
2 vs 1	-0.11** (0.05)	-0.03 (0.04)	-0.01 (0.04)	-0.06 (0.04)
Treatment: Collaborative Active SCRM	**POM**	**POM**	**POM**	**POM**
1. Lack of a collaborative SCRM	0.34*** (0.02)	0.57*** (0.02)	0.33*** (0.02)	0.33*** (0.02)

2. Presence of a collaborative SCRM	0.32*** (0.01)	0.51*** (0.01)	0.27*** (0.01)	0.26*** (0.01)
	ATE	**ATE**	**ATE**	**ATE**
2 vs 1	-0.02 (0.03)	-0.06** (0.03)	-0.06* (0.03)	-0.07** (0.03)

*significant at 10%, **significant at 5%, ***significant at 1%

Results indicate that the implementation of a formal Supply Chain Risk Management structure in the form of a Business Continuity Plan leads to a reduction in the propensity of suffering an internal related disruption (upper part of Table 6., Outcome 1). In particular, firms that develop a formalization of their SCRM approach suffer, on average, 11 percentage points (p.p.) less internal related disruptions than the ones that only work on their SCRM in an active way without the formal structure. In other words, average treatment effects are negative and statistically different from 0 [Outcome 1: (2 vs 1: ATE -0.11, $p<0.05$)], supporting our hypothesis H1a. However, we could not find any statistically significance to back up our hypotheses H1b, H1c and H1d. Additionally, we can observe in Table 6. that among the companies with active SCRM operations, those that deployed collaborative strategies with their suppliers and customers reduce on average their propensity to suffer suppliers, market and transportation related disruption. In particular, their estimated average effect on the propensity to supplier's disruption is 6 p.p lower than considering an active SCRM approach alone [Outcome 2: (2 vs 1: ATE: -0.07, $p<0.05$)]. This is the same effect that, on average, companies can expect of the reduction on market related disruptions [Outcome 3: (2 vs 1: ATE: -0.06, $p<0.10$)]. For transportation related disruptions, the effect is slightly larger. As such, companies that invest on collaboration in their active SCRM approach will suffer, on average, less transportation related disruptions [Outcome 4: (2 vs 1: ATE-0.07, $p<0.05$)]. These results support our hypotheses H2b, H2c and H2d.

To better understand the impact that collaborative and formalization strategies have on active SCRM approaches, our research also takes into account two contextual factors: firm size and industry of operation. Table 6.4 compares large and small and medium firms, defining SME as those with less than 300 employees. The first thing that we can observe is that the effect of adding a formalization strategy to the already active SCRM approach reduces internal related disruptions in both large and SMEs firms. However, the effect seems to be larger for small and medium companies than in larger ones [Outcome 1: (2 vs 1_{large}: ATE -0.09, $p<0.10$), (2 vs 1_{SMEs}: ATE -0.21, $p<0.10$)]. Table 6.3 also shows that, when dealing with suppliers' risks, potential means were significantly higher in SME firms that do not have a formal SCRM approach than in large firms (two-sided test on mean equality *(a)*). For this type for firms, the reduction on the disruption propensity is significant [Outcome 2: (2 vs 1_{SMEs}: ATE -0.24, p<0.01)]. This is a very interesting result that was not observed in Table 6.3 (outcome 2, upper part of the table), reinforcing the need of using mediators to better understand how the two studied treatments affect companies. No other significant effect is seen in this case, hence, partially supporting hypothesis H3a.

If SMEs firms take benefit when they add formalization to their active SCRM strategies, large companies are the ones benefiting from a collaborative SCRM approach. This is reflected in the results shown in Table 6.4, bottom half of the table. Specifically, disruptions caused by supplier, market and transportation drivers are significantly reduced for large companies [Outcome 2: (2 vs 1_{large}: ATE -0.09, p<0.05), Outcome 3: (2 vs 1_{large}: ATE -0.06, p<0.10), Outcome 4: (2 vs 1_{large}: ATE -0.08, p<0.05)], which partially supports hypothesis H3b.

Finally, we compared the effects of the different SCRM approaches taking into consideration the type of industry (refer to Table 6.5). We found that manufacturing companies can reduced their internal disruptions by the implementation of a formalized active SCRM [Outcome 1: (2 vs $1_{manufacturing}$: ATE -0.09, p<0.10)], while market and transportation disruptions can be significantly reduced with the implementation of collaborative SCRM practices [Outcome 3: (2 vs 1_{mnft}: ATE -0.08, p<0.10); Outcome 4: (2 vs 1_{mnft}: ATE -0.08, p<0.05)]. Similarly, service provider firms will significantly reduce supplier related disruptions with the deployment of both formal and collaborative SCRM. In particular, in the first case, disruptions will be reduced, on average, 14 p.p. [Outcome 2: (2 vs $1_{serv.provid.}$: ATE -0.14, p<0.10)], while if the strategies deployed are collaborative, supplier's disruptions are reduced on average 10p.p. [Outcome 2: (2 vs $1_{serv.provid}$: ATE -0.10, p<0.10)]. Lastly, the two-sided test on mean equality shows that the potential means were significantly higher for manufacturing firms. This partially supports H4a and H4b.

Table 6.4: Average Treatment Effects by Firm Size

	Outcome 1 Propensity to suffer an internal disruption			**Outcome 2** Propensity to suffer a supplier disruption			**Outcome 3** Propensity to suffer a market disruption			**Outcome 4** Propensity to suffer a transportation disruption		
	Large firms	SME		Large firms	SME		Large firms	SME		Large firms	SME	
Treatment: Formalized Active SCRM	**POM**	**POM**	**(a)**	**POM**	**POM**	**(a)**	**POM**	**POM**	**(a)**	**POM**	**POM**	**(a)**
1. Lack of a formal SCRM structure	0.42*** (0.05)	0.49*** (0.10)	n.s	0.51*** (0.05)	0.73*** (0.08)	**	0.32*** (0.05)	0.24*** (0.08)	n.s	0.35*** (0.05)	0.27*** (0.08)	n.s
2. Presence of a formal SCRM structure	0.33*** (0.02)	0.28*** (0.02)	n.s	0.53*** (0.02)	0.49*** (0.03)	n.s.	0.29*** (0.01)	0.30*** (0.02)	n.s	0.28*** (0.01)	0.25*** (0.02)	n.s
	ATE	**ATE**		**ATE**	**ATE**		**ATE**	**ATE**		**ATE**	**ATE**	
2 vs 1	-0.09* (0.05)	-0.21* (0.11)	n.s.	0.02 (0.05)	-0.24***(0.09)	***	-0.03 (0.05)	0.06 (0.08)	n.s.	-0.07 (0.05)	-0.02(0.09)	n.s.
Treatment: Collaborative Active SCRM	**POM**	**POM**		**POM**	**POM**		**POM**	**POM**		**POM**	**POM**	
1. Lack of a collaborative SCRM	0.35*** (0.03)	0.31*** (0.04)	n.s	0.60*** (0.03)	0.51*** (0.04)	n.s	0.33*** (0.03)	0.33*** (0.04)	n.s	0.35*** (0.03)	0.26*** (0.03)	*
2. Presence of a collaborative SCRM	0.33*** (0.02)	0.28*** (0.03)	n.s	0.51*** (0.02)	0.50*** (0.04)	n.s	0.27*** (0.01)	0.27*** (0.03)	n.s	0.27*** (0.01)	0.25*** (0.03)	n.s
	ATE	**ATE**		**ATE**	**ATE**		**ATE**	**ATE**		**ATE**	**ATE**	
2 vs 1	-0.01 (0.04)	-0.03(0.05)	n.s.	-0.09**(0.04)	-0.09(0.05)	n.s.	-0.06* (0.04)	-0.06(0.05)	n.s.	-0.08**(0.04)	-0.01(0.05)	n.s.

*significant at 10%, **significant at 5%, ***significant at 1%

(a) Significance of two-sided test on mean equality

Table 6.5: Average Treatment Effects by Industry of Operation

	Outcome 1 Propensity to suffer an internal disruption			**Outcome 2** Propensity to suffer a supplier disruption			**Outcome 3** Propensity to suffer a market disruption			**Outcome 4** Propensity to suffer a transportation disruption		
	Manufacturing	Service Provider		Manufacturing	Service Provider		Manufacturing	Service Provider		Manufacturing	Service Provider	
Treatment: Formalized Active SCRM	**POM**	**POM**	**(a)**	**POM**	**POM**	**(a)**	**POM**	**POM**	**(a)**	**POM**	**POM**	**(a)**
3. Lack of a formal SCRM structure	0.46*** (0.05)	0.34*** (0.05)	n.s	0.55*** (0.05)	0.54*** (0.07)	n.s.	0.27*** (0.50)	0.35*** (0.07)	n.s	0.32*** (0.05)	0.37*** (0.07)	n.s
4. Presence of a formal SCRM structure	0.35*** (0.02)	0.24*** (0.05)	***	0.58*** (0.02)	0.40*** (0.02)	***	0.31*** (0.01)	0.25*** (0.07)	*	0.27** (0.01)	0.26*** (0.02)	n.s
	ATE	**ATE**		**ATE**	**ATE**		**ATE**	**ATE**		**ATE**	**ATE**	
2 vs 1	-0.09* (0.06)	-0.10 (0.08)	n.s.	0.02 (0.06)	-0.14*(0.08)	*	0.04(0.05)	0.10 (0.07)	n.s.	-0.05(0.05)	-0.11(0.08)	n.s.
Treatment: Collaborative Active SCRM	**POM**	**POM**		**POM**	**POM**		**POM**	**POM**		**POM**	**POM**	
3. Lack of a collaborative SCRM	0.39*** (0.03)	0.24*** (0.04)	***	0.62*** (0.03)	0.49*** (0.05)	**	0.36*** (0.03)	0.29*** (0.04)	**	0.35*** (0.03)	0.28*** (0.04)	n.s.
4. Presence of a collaborative SCRM	0.36*** (0.02)	0.25*** (0.02)	***	0.57*** (0.02)	0.39*** (0.03)	***	0.28*** (0.02)	0.25*** (0.02)	n.s	0.26*** (0.02)	0.27*** (0.03)	n.s
	ATE	**ATE**		**ATE**	**ATE**		**ATE**	**ATE**		**ATE**	**ATE**	
2 vs 1	-0.03 (0.04)	0.01(0.05)	n.s.	-0.04(0.04)	-0.10*(0.06)	n.s.	-0.08* (0.04)	-0.03(0.05)	n.s.	-0.08**(0.04)	-0.01(0.05)	n.s.

*significant at 10%, **significant at 5%, ***significant at 1%

(a) Significance of two-sided test on mean equality

6.5. Discussion and Conclusions

The increasing complexity that global supply chains face along with the growing industry competition, position SCRM strategies as key tools in supply chain management plans. To advance in the understanding of how SCRM approaches can contribute to the minimization of disruptions, this research focus on the strategical aspect of SCRM process which involve the formalization of an active risk management structure, through the implementation of a Business Continuity Plan and a dynamic collaboration with the different supply chain suppliers and customers (Lavastre, et al., 2014). We analyze the effects of adopting, in an isolated way, a formalized and collaborative SCRM approach.

Our findings suggest that companies should choose their SCRM approach based on the type of disruption that concerns them the most. Companies operating in volatile market, like those where demand tends to suffer dramatic and unpredictable changes, should develop collaborative SCRM strategies, especially when talking of large manufacturing firms. The same would apply to companies that need to deal with high uncertainty and vulnerabilities in their transportation and logistics operations. For example, companies that operate in emerging economies with inability to attract and retain qualified personnel, upheavals due to unexpected borders closures or other operational risks such as backlogs and bottlenecking caused by the increase number of larger ships. In this case, collaborative practices would lead to a significant reduction of the propensity to suffer disruptions. When dealing with operational risks, formalization of a risk management structure seems to work for internal related disruptions while it is better to invest in collaborative risk management practices to deal to supplier's risks.

Additionally, our moderating analysis provide evidence of the effect that the firm's size and its operating context has on the propensity to suffer a disruption depending on the SCRM approach adopted. While large firms can benefit the most from collaborative practices, the implementation of formal risk management approaches will significantly reduce small firms' risks associated with their own internal operations. If we consider the effect that these two SCRM approaches have on firms depending on the type of industry they operate on, we can observe that manufacturing firms have, on average, a higher propensity to suffer disruptions and that a mix of collaborative and formal approaches will help to significantly reduce the four risks analyzed in this study.

As with all research, this study presents several limitations that can open lines for future work. Our study is based on a global survey and the responses have been aggregated based on previous statistical work analysis equivalence of the different subsets. It would be interesting to complement this research analyzing the effects of other moderators such as the level of internationalization of the firms, the central/local control of the risk management operations or the profile of the supply chain risk management responsible, in terms of gender, education or internationalization exposure. For that, additional data may be needed in order to increase the sample size and work with AIWP methodology. Additionally, the characteristics of the responsible or decision maker in supply chain risks aspects, in term of educational level, supply chain specialization and previous work experience, can influence the firm attitude towards risk and their perception of how the SCRM should look like. In the same way, the gender of the responsible of the SC risks may influence the risk approach of the overall company as some studies suggest that risk attitude differs with gender. As such, it would be worth exploring how the profile of supply chain risk managers affect the company perception of risks and their management approaches.

6.6. References

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Chapter 7

Conclusions and Discussions

7.1. Discussion and Managerial Implications

Through globalization, companies have expanded their pool of suppliers and customers in the continuous search of cost reduction and revenue increase. However, global supply chains are linked to an increased complexity and innumerable sources vulnerabilities that can turn into disruptions. These disruptions can occur due to a wide number of risks just as errors in forecast calculation, breakages in intellectual property, defects on product quality, suppliers' bankruptcy, transportation delays, labor strikes or natural disasters. Many researches have worked in the understanding of which are the capabilities and strategies that companies need to develop within their organizations and with their suppliers to avoid and mitigate unforeseen events and even create competitive advantage in times of disruptions. One example that illustrates these affects is the disruption due to fire that destroyed all radio-frequency chips from both Nokia and Ericsson's sole supplier in 2000 (Norrman & Jansson, 2004). However, while Ericsson struggled to respond, with losses of about $400 million, Nokia's flexible and agile supply chain design allowed them to quickly secure other sources (Trent, 2015), obtaining a competitive advantage over their direct competitor Ericsson.

Since the field of supply chain risk management emerged in the early 2000's, most of the efforts have evolved around the buyer-supplier product relationship. At the same time, most of these efforts have forgotten that transportation and logistics service providers can help to position supply chains with a competitive advantage not only because they play an important role in cost optimization but because they can help to create resilience and minimize disruptions. However, this trend is been slowly reverted and new logistics concepts, such as synchromodality, are emerging with the objective of increasing resilience and efficiency in global supply chains.

The objective of this thesis is to understand (1) which are the recent supply chain risk management practices that successfully lead to resilience and its effects on SC performance and competitive advantage; (2) as synchromodality has emerged as a novel and promising concept in logistics and transportation but it is still at an incipient development stage, we want to delve into this new concept by understanding which are the different factors that contributes to its development; (3) building on this work, we want to further understand how, as theoretically hypothesized by other authors, synchromodality leads to more resilient and efficient supply chains, and finally; (4) how the implementation of an active SCRM process, reinforced through formalization of a risk management structure and a collaborative approach, can increase the supply chain resilience by a minimization of certain disruption propensity. These four objectives are translated into four research questions and the main findings are summarized below.

Research Question 1: What are the latest trends on SCRM mitigation processes that lead to resilience and competitive advantage?

Based on a detail analysis of the SCRM best practices that global companies have successfully implemented during the past decades, we presented in our paper *Aligning supply chain design for boosting resilience* (Saenz, et al., 2018) a framework that could be used by supply chain managers in the deployment of resilience in a dynamic manner. We counclude that there is no universal supply chain risk and disruption management practice and that in order to design a SCRM, companies should first be aware of the nature of their supply chains and understand the vulnerabilities and risks that their supply chain face. Additionally, globalization and product diversification may require companies to deploy different supply chain designs within their organization, which consequently should be translated in different risk management approaches.

Research Question 2: Which are the supply chain capabilities that companies pursuing synchromodality should develop and how it affects the creation of competitive advantage?

Synchromodality is a novel concept that has received increasing attention from researchers and practitioners over the past years as it is envisioned by practitioners, policy makers in the EU and researchers as a step forward in transportation efficiency, sustainability, resilience, modal shift and, in general, an overall competitive advantage in the supply chain. However, despite this attention, a lack of theoretical and empirical research remains. First, there has been no agreement on the definition of synchromodality as no study has attempted to develop a conceptual framework for it. Secondly, to our knowledge, no valid measures of synchromodality have been developed. Finally, there is also a lack of empirical evidence of the creation of logistics differentiation due to the implementation of synchromodality. With all that into account, the present study attempts to further the theory and understanding of synchromodality through the conceptual development and empirical validation of an instrument to measure its construct.

Through a comprehensive newly developed four-stage methodology, we first identified four dimensions in the construct of synchromodality: visibility, flexibility, integration, and operating system based on a systematic literature review and interviews with field experts. We then proposed a 20-item measurement scale for synchromodality that was subsequently purify and validate into a 15-item measurement scale using a pilot test. We hypothesized five different models: a one factor first-order model, an uncorrelated four factor first-order model, a correlated four factor first-order model, a four factor second-order model and four factor second-order model with correlated errors to fix misspecifications. After comparing and testing the correlated four-factor, first-order model and the four-factor, second-order model, we found evidence that suggested that synchromodality is a multidimensional concept manifesting flexibility, visibility, integration, and operating system.

The present study can be considered a starting point for supply chain and transportation managers from shippers and T&LSP companies considering the implementation of synchromodality in their daily operations. This research also presents a diagnostic tool for supply chain and transportation practitioners to assess their firms' synchromodal capability and to establish a common language to identify, implement and manage synchromodal-related aspects. In addition, our empirically validated four-dimension framework can help managers to look at the transportation part of their supply chain, not as a mere operationalization but as a holistic way to operate with flexibility, visibility and integration as the core of the supply chain. As a consequence, the study does not only set the foundation of the capabilities and resources that companies aiming to establish synchromodality should develop with the different partners and stakeholders of their supply chain, but also corroborates the theoretical hypothesis that synchromodality creates a competitive advantage through a logistics differentiation.

Research Question 3: To what extent does synchromodality lead to more resilient and efficient supply chains?
Building on the synchromodality existing research (Zhang & Pel, 2016; Dong, et al., 2018), our study contributes to an understanding of this novel and popular concept. So far, the few published studies have been based on single case studies (Lucassen & Dogger, 2012; Zhang & Pel, 2016) or simulations (Kapetanis, et al., 2016; Lin, et al., 2016; Li, et al., 2017; Van Riessen, et al., 2017). Lin et al. (2016) and Dong et al. (2018) found that synchromodality was related to efficiency, whereas Lee and Song (2017) stipulated a positive relationship with resilience. Although we began our analysis by considering that previous theoretical hypotheses on the performance effect of synchromodality have not been empirically tested, our research in fact provides evidence of existent relationships. We expanded this research using a SEM path analysis that provides empirical evidence of a strong and statistically significant relationship between synchromodality and both efficiency and resilience. This implies that companies that promote a synchromodal environment in their daily operations are not only more efficient from a logistics and transportation perspective, they are also less prone to disruptions, as the dimensions required to implement synchromodality requires a higher situational awareness.

We complemented our findings from the path analysis using a configurational approach. The non-significant relationship between the two outcomes of synchromodality led us to think about the previously analyzed trade-off between resilient and efficient supply chains. As such, we tackled this dichotomy using a configurational approach. Our research contributes to the literature of logistics performance and extends prior research on the trade-off between logistics efficiency and resilience. To the best of our knowledge, the current research is one of the first to adopt a configuration approach in exploring this trade-off, and we present an innovative method to analyze different patterns in synchromodal supply chains. While some studies have found that efficiency was negatively related with resilience (Ivanov, et al., 2014), others have found a positive relationship between these two operational outcomes (Shukla, et al., 2011; Birkie, 2016). Our configurational study based on a cluster analysis indicates that an investigation of the relationship between efficiency and resilience can only be fully examined when all the dimensions of synchromodality are considered together, as proven by H3 and H4. Based on the dimension of efficiency and resilience, three different patterns or profiles were identified in our study: imbalanced performers, moderate performers, and high performers.

Our findings indicate significant differences in efficiency and resilience levels regarding the three configuration patterns and depending on the level of synchromodality achieved by the supply chains. Lowest levels of synchromodality are associated with the lowest levels of performance, reinforcing the idea that synchromodal supply chains have a competitive advantage in terms of resilience and efficiency. Companies who develop synchromodality above average are the ones that find the optimum balance between resilience and efficiency, increasing both outcomes simultaneously. However, we can also observe that achieving high levels of synchromodality does not necessarily increase the efficiency of the supply chain. These are interesting outcomes aligned with the existing theory, confirming the hypothesis that there is no one unique relationship in terms of resilience and efficiency in the synchromodal context. While the highest level of resilience characterizes the imbalanced and high performers groups, companies in the moderate performers group show only a moderate level of resilience. On the other hand, firms that fall under the imbalanced and moderate performers clusters present below average levels of efficiency, while the highest levels of efficiency correspond to the companies of the high performers cluster.

As such, one could infer that synchromodality and resilience pair up at the expense of efficiency. Establishing as a baseline companies with the lowest levels of synchromodality (cluster 2, *moderate performers*), we can observe that synchromodal companies that deploy slightly higher levels of flexibility, visibility and integration (cluster 3, *high performers*), do not only increase their synchromodal level, but also increases both the resilience and efficiency of the supply chain they operate at. However, for synchromodal companies that make an extra effort, reinforcing their flexibility and operating system, translates in an increase of resiliency with a considerate drop in the efficiency of the system (cluster 1, *imbalance performers*). One possible explanation for this behavior is that synchromodal supply chains aiming to develop high levels of synchromodality and resilience need to make extra investments in assets and resources that will, consequently, make them less efficient. It seems that there is an optimum level of flexibility, visibility, integration and operating systems that companies, seeking to implement synchromodality, need to develop in order to achieve resiliency without compromising the overall profitability of the supply chain. Finally, our analysis provides evidence of extreme outcomes. As such, companies operating in high risk environments whose main focus is to minimize disruptions can take advantage of synchromodal operations as it will considerate increase their resilience while maintaining moderate levels of efficiency.

Research Question 4: How does an active SCRM, along with the deployment of collaborative and formal supply chain risk management structure reduce the propensity to suffer certain disruptions?

The increasing complexity that global supply chains face along with the growing industry competition, position SCRM strategies as key tools in supply chain management plans. To advance in the understanding of how an active SCRM can contribute to the minimization of disruptions, this research focus on two different aspects of SCRM process which involve the formalization of an active risk management structure, through the implementation of a Business Continuity Plan, and a dynamic collaboration with the different supply chain suppliers and customers (Lavastre, et al., 2014). We analyze the effects of adopting, in an isolated way, a formalized and collaborative SCRM approach.

Our findings suggest that companies should choose their SCRM approach based on the type of disruption that concerns them the most. Companies operating in volatile market, like those where demand tends to suffer dramatic and unpredictable changes, should develop collaborative SCRM strategies, especially when talking of large manufacturing firms. The same would apply to companies that need to deal with high uncertainty and vulnerabilities in their transportation and logistics operations. For example, we could think of companies that operate in emerging economies with inability to attract and retain qualified personnel, upheavals due to unexpected borders closures or other operational risks such as backlogs and bottlenecking caused by the increase number of larger ships (KPMG, 2016). In this case, collaborative practices would lead to a significant reduction of the propensity to suffer disruptions. When dealing with operational risks, formalization of a risk management structure seems to work for internal related disruptions while it is better to invest in collaborative risk management practices to deal to supplier's risks.

Additionally, our moderating analysis provide evidence of the effect that the firm's size and its operating context has on the propensity to suffer a disruption depending on the SCRM approach adopted. While large firms can benefit the most from collaborative practices, the implementation of formal risk management approaches will significantly reduce small firms' risks associated with their own internal operations. If we consider the effect that these two SCRM approaches have on firms depending on the type of industry they operate on, we can observe that manufacturing firms have, on average, a higher propensity to suffer disruptions and that a mix of collaborative and formal approaches will help to significantly reduce the four risks analyzed in this study.

7.2 Limitations and Future Research

The present dissertation, like all research work, presents several limitations which also present some interesting extensions and future research work.

Chapter 4 only uses data from global operating transportation and logistics companies based in Europe. Even though synchromodality is a concept that has emerged in Europe, it would be interesting to replicate it in other regional areas with a strong transport and logistic market such as North America or Asia. This research is focused on the logistics network of a manufacturing firm in a specific industry, it would also be interesting to expand the research to other network contexts, such as the automotive or electronic industries where intermodality is already a common practice and where synchromodality could bring additional benefits. This extension would help to validate the generalizability of the proposed conceptual framework and the corresponding measurement model. A longitudinal analysis of the effects of strategic alliances deploying synchromodality could also throw light on the benefits of this new concept. A replication of the research over time complemented with operational data from score cards would help to analyze the effect that the consolidation of synchromodality has on logistics performance and it would, at the same time, permit a second analysis of the endogeneity of the model. Finally, it would be interesting to complement the present study with the use of secondary data by integrating in the model objective performance data from the companies that participated in the survey.

Finally, we suggest continuing this research by analyzing the expected outcomes that adoption of this novel concept could have on supply chains such as sustainability, resilience or efficiency; as well as the effect of potential mediating or moderating variables.

Although the work presented in Chapter 5 contributes both to the academic and managerial audiences, additional research is needed to fully understand the effect of synchromodality and its outcomes. As the concept and implementation synchromodality matures and expands to a greater number of countries, future researchers could collect information from additional sources of data, like secondary data, and compare findings with those of this study. For example, the data used in this study is cross-sectional, but the use of longitudinal data could provide additional information on the evolution of the relationships between synchromodality dimensions and responsiveness and performance optimization outcomes. It would also be interesting to analyze how the levels of efficiency and resilience of synchromodal supply chains evolve with the development of strategic alliances between shippers and logistics providers. Finally, in our research we focused on the transportation and logistics network of a shipper from a specific manufacturing market. It would be interesting to see if the results obtained could be extrapolated to other industries, such as non-perishable foods or technology, with different time constraints and shipment requirements.

Finally, Chapter 6 presents an explorative work based on an econometric analysis using a global survey with aggregated results. It would be interesting to complement this research analyzing the effects of other moderators such as the level of internationalization of the firms, the central/local control of the risk management operations or the profile of the supply chain risk management responsible, in terms of gender, education or internationalization exposure. For that, additional data may be needed in order to increase the sample size and work with AIWP methodology. Additionally, the characteristics of the responsible or decision maker in supply chain risks aspects, in term of educational level, supply chain specialization and previous work experience, can influence the firm attitude towards risk and their perception of how the SCRM should look like. In the same way, the gender of the responsible of the SC risks may influence the risk approach of the overall company as some studies suggest that risk attitude differs with gender. As such, it would be worth exploring how the profile of supply chain risk managers affect the company perception of risks and their management approaches.

7.3 References

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