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Stratégie Lean and Green : Roadmap d'analyse et de déploiement d'une politique de management alliant amélioration continue et développement durable en entreprise industrielle

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Résumé

« Stratégie Lean and Green : Roadmap d'analyse et de déploiement d'une politique de management alliant amélioration continue et développement durable en entreprise industrielle »

Ces travaux de thèse s'inscrivent dans le cadre d'une recherche ciblée sur l'association des performances industrielles et environnementales, et s'intéressent ainsi à l'élimination des « gaspillages » dans les processus de fabrication avec une démarche orientée vers le développement durable. En effet, si les outils issus du « Lean Manufacturing » sont d'ores et déjà reconnus comme permettant des gains certains en termes de productivité et d'élimination des activités à non-valeur ajoutée (« mudas »), les entreprises doivent aujourd'hui faire face à de nouveaux challenges sociétaux afin de pérenniser leur activité. Ainsi, la création de valeur et le renforcement de la compétitivité passent à présent nécessairement par une dimension environnementale. La problématique majeure réside alors dans l'adéquation et l'imbrication que peuvent prendre les outils issus de stratégies « Lean» et « Green » au sein d'entreprises manufacturières possédant des caractéristiques culturelles et des processus variés. La mise au point d'une roadmap de déploiement adaptable et accessible aux entités les moins matures a ainsi constitué un objectif scientifique majeur pour répondre à la problématique posée. Ces travaux de thèse sont basés sur une analyse suivie de l'état de l'art scientifique et industriel. Conjointement, différentes évaluations au sein de grandes entreprises et PME de la région alsacienne, mais aussi des observations menées sur différents sites de production étrangers, ainsi que des enquêtes de bonnes pratiques industrielles ont permis le développement d'une méthodologie scientifique répondant aux exigences « Lean » et « Green ». La mise en valeur des aspects sociaux est abordée par le biais de l'implication et de la valorisation des employés dans les processus d'améliorations. Ces travaux présentent sous forme d'articles scientifiques l'élaboration d'une roadmap d'évaluation et d'implémentation, inscrite dans une démarche d'amélioration continue des performances de l'entreprise, complétée par un modèle de sélection d'indicateurs environnementaux, une « Maison du Lean and Green » référençant les outils à employer dans une telle démarche et un modèle de maturité particularisé pour le niveau de déploiement de stratégies Lean and Green.

Glossaire des termes clés

Amélioration continue - L'amélioration continue, également connue sous le nom de Kaizen (« bon changement ») ou encore méthodes PDCA (Plan Do Check Act) est une culture d'entreprise consistant à une remise en cause constante de l'existant afin de trouver de nouvelles opportunités et de mettre en place des améliorations concrètes avec un investissement minimum.

Lean Manufacturing - Méthode de production issue des techniques du Toyota Production System (TPS), le Lean repose sur de nombreux outils et des principes fondateurs tels que l'élimination des gaspillages, l'amélioration continue, ou la production en Juste-à-Temps.

Développement Durable - D'après la définition du rapport Bruntland de 1987, le développement durable est un développement qui répond aux besoins de la génération présente sans compromettre la capacité des générations futures de répondre aux leurs. Il doit se baser sur trois piliers fondamentaux : Economique, Social, Environnemental.

Gaspillages ou Mudas - Les gaspillages dans les processus de fabrication sont des activités ou des flux superflus n'apportant aucune valeur ajoutée au produit pour le client. Dans cette étude, sont considérés les gaspillages reconnus du Lean (production en excès, défauts de fabrication, mouvements et stocks en excès, processus inappropriés, transports non optimisés, attentes, et perte du potentiel des ressources humaines) ainsi qu'une catégorisation des gaspillages environnementaux (usage excessif de ressources, d'eau, d'énergie, création excessive de déchets, émissions de gaz à effet de serre, pollution, eutrophisation, et manque de considération de la santé et de la sécurité).

Genba Walk et Genchi genbutsu - Le genba walk représente le fait d'observer les processus sur le terrain tels qu'ils fonctionnent "réellement" (genba = atelier) et a pour objectif de faciliter les prises de décision en permettant à l'encadrement managérial de rester connecté à la réalité du fonctionnement des lignes de production. Le genba walk est une des applications du principe du Genchi Genbutsu (« aller, regarder, voir ») utilisé dans le TPS.

Indicateurs de performance ou KPIs - Les indicateurs de performance, également dénommés KPIs (Key performance indicators) sont des outils de management permettant de contrôler des informations ciblées à des intervalles définis. Indispensables dans le cadre des méthodes d'amélioration continue, ils peuvent être déclinés aux niveaux organisationnels et processus.

Indicateurs environnementaux - Les indicateurs environnementaux sont des indicateurs de performance reflétant des informations sur les impacts environnementaux d'une activité donnée.

Management top-down et bottom-up - L'étude propose une démarche Lean and Green s'appuyant sur un déploiement de la méthode utilisant une approche conjointe ascendante et descendante afin d'aligner les stratégies organisationnelles en actions opérationnelles concrètes.

Management Visuel - Le management visuel consiste à gérer la transmission d'information par un affichage ciblé. Décliné au niveau du processus de fabrication, il prend la forme de « tableaux de bords » indiquant les résultats des indicateurs clés de performance et permettant ainsi de piloter les opérations en équipe.

RSE - La responsabilité sociétale des entreprises est l'application des concepts du développement durable au sein de l'industrie. Reposant sur les mêmes principes fondateurs, elle est toutefois plus généralement considérée comme l'application de règles éthiques et sociales au sein de l'entreprise et de la chaine d'approvisionnement.

TPS - Le Toyota Production System regroupe les techniques de production développées pendant plusieurs décennies au sein de Toyota à la suite de la Seconde Guerre Mondiale. Kiichiro et Eiji Toyoda, de la famille fondatrice de Toyota, mais surtout l'ingénieur Taichi Ohno, sont considérés comme les principaux fondateurs de ce système. La vision du TPS commence à se faire connaitre dans le monde occidental à la fin des années 70.

VSM - Le Value Stream Mapping est un outil de management du Lean Manufacturing consistant à cartographier les actions et données quantitatives associées à un ou plusieurs processus dans le but d'obtenir une vision exhaustive et notamment de détecter les actions à non-valeur ajoutée pour le client.

5S - Le 5S est un des outils principaux du Lean Manufacturing, permettant d'optimiser les conditions de travail de la chaine de production en assurant notamment l'organisation de l'espace, la propreté et la sécurité (Seiri : « ranger », Seiton : « ordonner », Seiso : « entretenir, nettoyer », Seiketsu : « standardiser », Shitsuke : « pérenniser et progresser »).

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Introduction

Ce chapitre présente le contexte dans lequel les travaux de thèse ont été menés, et revient sur l'historique des deux concepts centraux de l'étude, le Lean et le Green au sein des processus de fabrication. Les deux notions sont alors mises en perspective, en parallèle d'une synthèse des travaux de recherche fondateurs dans le domaine. La problématique de recherche et la méthodologie adoptée sont ensuite explicitées. L'originalité et l'apport scientifique de nos travaux sont ainsi détaillés avant de présenter brièvement les contributions, rédigées sous forme d'articles, composant l'architecture de ce manuscrit.

Ce travail de thèse a été réalisé au sein du laboratoire Icube de l'université de Strasbourg et financé par une bourse de valorisation de recherche de la région Alsace dans le cadre du projet Green LEM (Green Lean Engineering and Manufacturing). Les travaux présentés dans ce manuscrit s'intéressent à la performance industrielle et à la performance environnementale en conjuguant le Lean manufacturing au Développement durable. Ils s'inscrivent dans le cadre d'actions menées par deux programmes connexes :

- Le club Lean and Green, fondé en 2009 et pérennisé par l'Agence de développement économique du Bas-Rhin (ADIRA 2015), sous forme de rencontres industrielles et scientifiques réunissant chaque trimestre une cinquantaine de participants sur les thèmes touchant à la performance industrielle, à la performance environnementale et au développement durable. L'animation du club, portée par l'ADIRA, a en outre pour vocation de promouvoir les partages d'expériences, l'échange des bonnes pratiques ainsi que les partenariats, lors de visites techniques de différents sites industriels.

- Le programme « Perfoest » du pôle de compétitivité « Véhicule du Futur », qui vise à promouvoir l'excellence de la filière automobile dans les régions Alsace et Franche Comté. Ces travaux de recherche s'inscrivent également partiellement dans le cadre du projet « INGEPROD » (Ingénierie Hautement Productive) labélisé par le pôle en 2011.

1 Le Lean and Green, une approche croisée mais pas opposée

Le Lean et le Green sont aujourd'hui de plus en plus représentés dans la littérature relative à la production manufacturière. Cette section propose une approche historique mettant en parallèle ces deux concepts.

1.1 Histoire du Lean

Issu des techniques du Toyota Production System, le concept du « Lean », se basant sur une gestion « sans gaspillages », s'est aujourd'hui démocratisé et est ainsi évoqué dans de nombreuses publications n'étant plus limitées au monde scientifique et organisationnel. Il nous paraît intéressant d'évoquer plus en détail son développement ainsi que le contexte dans lequel la notion a vu le jour.

La Toyota Motor Company tient son nom de la famille d'inventeurs et d'industriels Toyoda. Officiellement fondée en 1937, elle a connu d'importantes difficultés financières consécutives à la Seconde Guerre Mondiale, notamment dues à un stock croissant de voitures invendues. En 1950, son directeur Kiichiro Toyoda, qui avait initié les prémices du principe du Juste-à - Temps, démissionne et son cousin Eiji Toyoda, qui a étudié aux Etats-unis les méthodes de production américaines, prendra la tête de la société (Holweg 2007).

Au cours des mêmes années, un ingénieur de Toyota, Taiichi Ohno, prend part aux recherches de développement de la productivité au sein de l'entreprise. Avec pour objectif principal de réduire les coûts en éliminant le gaspillage, C'est lui qui donnera l'impulsion décisive vers la véritable élaboration du système de production de Toyota. En effet, Ohno a fait valoir son approche de bon sens « sans a priori » et a ainsi apporté une vision novatrice capitale dans le développement de la philosophie du Juste-à-Temps (Cusumano 1985).

Le résultat fut une capacité de produire une variété considérable de voitures dans des volumes relativement faibles et à un coût compétitif, en modifiant la logique classique de la production de masse ; des adaptations qui étaient nécessaires aux circonstances économiques de l'époque (Cusumano 1985). Toyota a ainsi peu à peu trouvé des façons de combiner les avantages de la production en petites séries avec des économies d'échelle dans la fabrication et l'approvisionnement. La mise en œuvre des techniques organisationnelles du TPS a toutefois pris un temps considérable, Ohno ayant en réalité engagé un cycle d'apprentissage continu composé d'itérations successives, durant plusieurs décennies (Holweg 2007). Selon Fujimoto et son étude sur l'évolution du système Toyota (Fujimoto 1999), c'est donc cette «capacité d'apprentissage dynamique» qui est au cœur du succès de Toyota et de son fameux système de production.

Le TPS n'a ainsi été formellement documenté qu'en 1965, lorsque certains systèmes ont commencé à être déployés chez les fournisseurs du constructeur. En conséquence, le développement de la TPS était largement inaperçu et a seulement commencé à attirer l'attention suite à la première crise pétrolière en 1973 (Ohno 1988). Ainsi, si les manuels destinés aux fournisseur en 1965 marquent les premiers documents officiels de TPS visibles de l'extérieur, ce sont les contributions de (Sugimori, Kusunoki et al. 1977) qui furent les premières à proposer un point de vue en anglais sur la question.

Suite à cette prise de conscience, plusieurs publications scientifiques et rapports gouvernementaux de grande envergure ont été menées, discutant ouvertement de l'écart de performance entre les États-Unis et le Japon (on peut notamment citer (Hayes 1981) ou encore (Abernathy and Clark 1982)). La question était également de savoir comment mesurer les différences entre les méthodes de productions japonaises et celles utilisées dans les industries manufacturières occidentales. La première initiative en ce sens fut menée par le Massachusetts Institute of Technology (MIT) via une étude menée par Jones sur le site de Renault Flins en 1986 (Holweg 2007).

L'ouvrage « Le système qui va changer le monde : Une analyse des industries automobiles mondiales dirigée par le Massachusetts Institute of Technology», publié en 1990 pour la première fois (Womack, Jones et al. 1990) , a depuis connu un succès populaire incontestable dans différentes langues (Womack, Jones et al. 1993). Cet ouvrage rédigé par James Womack, Daniel Jones et Daniel Roos qui y démystifient les techniques industrielles japonaises a été reconnu comme étant la source primitive d'explications des méthodes du TPS rassemblées sous l'égide du « Lean Manufacturing ». Il est en fait l'aboutissement de plusieurs années d'études initiées par John Krafcik et poursuivies au sein du programme IMVP (international Motor Vehicle Program) par l'équipe du MIT dédiée.

La mise en œuvre de la pensée Lean a ainsi connu un essor significatif dans les cercles académiques et industriels depuis le milieu des années 1990, et les concepts du Lean ont bénéficié d'un intérêt et de développements de plus en plus importants (Hines, Holweg et al. 2004).

Pendant que l'essence même des principes du Lean tels que décrits par Womack, Jones et Roos continue de se disséminer à travers le monde, les experts adaptent les outils et les principes au-delà de la fabrication : le Lean touche désormais à la logistique et à la distribution, aux services, au domaine de la santé, à la construction, à la maintenance et même au gouvernement.

Malgré le fait d'une grande majorité d'application «Lean» réussies, l'approche Lean a été critiquée à de nombreuses reprises, notamment par rapport à son manque de prise en compte des facteurs humains (Hines, Holweg et al. 2004), cela malgré le fait que le respect de l'humain est pourtant intégré aux principes fondateurs du système. Ainsi, trop souvent appliqué d'une manière principalement axée sur des profits économiques à court et moyen termes, le Lean et ses applications présentent de nombreux paradoxes, plus ou moins apparents. Mais c'est avant tout une démarche d'amélioration continue qui utilise des principes validés, et des outils adaptés à la situation, au contexte et à l'objectif (Roche 2013).

Stenzel (Stenzel 2007) présente ainsi le Lean comme n'étant ni une tactique de fabrication, ni un programme de réduction des coûts, mais comme une véritable stratégie d'entreprise. D'autres auteurs voient quant à eux le Lean comme « une démarche de développement des personnes par la résolution de problèmes » (Roche 2013).

Un examen plus approfondi concernant les définitions, développements et travaux de recherche liés aux concepts primitifs du Lean peuvent être trouvés dans (Hines, Holweg et al. 2004, Holweg 2007, Shah and Ward 2007, Moyano-Fuentes and Sacristán-Díaz 2012) ainsi que dans les travaux de thèse de (Hoppmann 2009).

1.2 Histoire du « Green »

Par comparaison au développement des méthodes Lean, les concepts liés à l'Environnement, intégré à la notion de Développement durable, sont relativement récents.

Le concept fondateur de la notion de développement durable est considéré de façon quasi unanime comme provenant du rapport Brundtland de la Commission Mondiale sur l'Environnement et le Développement de 1987 (Bruntland 1987). Dans ce rapport, le Développement Durable, dénommé alors « soutenable », est défini comme « un développement qui répond aux besoins de la génération présente sans compromettre la capacité des générations futures à répondre aux leurs ». Ainsi, le développement durable s'appuie sur la pérennité de trois piliers fondamentaux : Economique, Social et Environnemental.

En effet, depuis la fin des années 1980, les thèmes de l'éthique organisationnelle, de la responsabilité sociale et du développement durable font l'objet d'un intérêt croissant (Pérez 2005), (Mercier 2004), (Nijhof, Cludts et al. 2003). En 1996, Gendron et Provost (Gendron and Provost 1996) mettent en avant l'idée que cette tendance écologique et sociale allait continuer à s'accentuer au cours des prochaines années.

Dans le même temps, la perception de l'environnement au sein de l'industrie a énormément évolué au cours des dernières décennies, passant progressivement de méthodes de résolution de problèmes de type « curatif » à des traitements « préventifs » grâce à la prise de conscience globale des pollutions directes et indirectes des processus de fabrication. Cette tendance « durable » semble bien irréversible et il est nécessaire pour les entreprises de se réorienter face à ces nouveaux challenges.

En effet, longtemps considéré comme un ensemble de ressources illimitées, subordonnée aux besoins de l'activité économique, la qualité de l'environnement apparait aujourd'hui comme une préoccupation collective qui doit être intégrée aux activités productives (Boiral 2005). Ainsi, y compris au niveau macro-économique, la prise en compte de l'environnement est de toute part considérée. Il y a 43 ans, les économistes du club de Rome (Club de Rome 2015) lançaient leur rapport « Halte à la croissance » (Meadows, Meadows et al. 1972), pointant les limites imposées par la finitude des ressources naturelle. Le rythme d'une croissance qui ne prend pas encore assez en compte les préoccupations environnementales n'ayant pas faibli depuis, de grandes fonctions régulatrices du capital naturel comme la stabilité du climat ou la protection de la biodiversité sont menacées (De Perthuis and Jouvet 2013).

En réponse à ces actions du club de Rome, différents auteurs tels que Dasgupta, Heal, Solow et Tiglitz (Dasgupta and Heal 1974) ont proposé de prendre en compte les effets du progrès technique ou de substitution entre le capital physique et les ressources épuisables. Ces auteurs démontrent ainsi que les limites de la croissance portent moins sur l'épuisement des ressources que sur la capacité du progrès technique à assurer la poursuite de la croissance. Leur théories reposent ainsi sur des hypothèses de substitution qui peuvent, à moyen terme, être validées et plausibles pour des ressources non-renouvelables, mais beaucoup plus hypothétiques si on prend en compte un point de vue plus holistique considérant la diversité des écosystèmes ou encore le changement climatique.

D'un point de vue politique, la première action tangible de cette prise de conscience écologique est la signature en 1992 au sommet de la Terre à Rio de la convention-cadre des Nations unies sur les changements climatique (CNUCC) (Nations Unies 1992) qui a propulsé la question du réchauffement climatique sur le devant de la scène internationale (De Perthuis and Jouvet 2013) et qui a débouché en 1997 à la signature du protocole de Kyoto. Ce protocole préconisait l'introduction d'une tarification internationale pour amorcer une réduction des émissions de gaz à effet de serre.

En sus de la dégradation de l'environnement, les divers impacts d'une croissance non-vertueuse sur l'ensemble de la société humaine sont en effet importants et ne peuvent être laissés sans réactions : érosion des cultures locales, délocalisations et fermetures d'usines, utilisation excessive d'emballages et création massive de déchets, utilisation de substances nocives etc. (Crane and Matten 2007) (Gabriel and Gabriel 2004). Progressivement, certaines entreprises prennent un virage éthique en adoptant un type de gestion basé sur les trois piliers du Développement Durable (Depoers 2005) (Depoers, 2005).

Parallèlement, dès le début des années 1990, l'environnement est devenu un critère émergent de sélection de l'entreprise pour les clients et consommateurs. Cette apparition résulte de la pression exercée sur les industries, amenées à communiquer et à rendre des comptes sur leurs activités à l'égard de la collectivité (Devin 2003).

Cette pression est elle-même relayée par les travaux des institutions supranationales. Le sommet de la Terre de Rio en 1992 (Nations Unies 1992) puis les sommets internationaux suivants interviennent ainsi dans la continuité de l'idée émise initialement par Bruntland (Bruntland 1987).

D'un point de vue factuel, l'Agence internationale de l'énergie impute à 37% la part de l'industrie dans le réchauffement climatique (International Energy Agency 2013). En Europe, 40% de la consommation d'électricité est liée à la fabrication de produit, alors que l'industrie compte pour 30 à 40% des émissions de Gaz à effet de serre (European Energy Agency 2012). Ainsi, la réduction des consommations en ressources naturelles et en énergie est au centre de l'attention des industriels (Garetti and Taisch 2011) qui peuvent jouer un rôle majeur dans la réduction de ces impacts.

La prise en compte des préoccupations environnementales et à fortiori du Développement Durable dans sa globalité peut s'avérer complexe au premier abord, car les organisations désirant adopter cette idéologie doivent poursuivre trois objectifs indissociables intégrant l'écologie, l'équité, et la création de valeur. La difficulté principale est donc de concilier « environnement » –*principes de vies collectives* – et « économie » – *recherche d'efficience* –, et de savoir comment opérationnaliser et mesurer conjointement ces démarches (Mathieu and Reynaud 2007), (Boiral 2005).

Les travaux présentés dans ce manuscrit s'intéressent majoritairement aux piliers environnementaux et économiques tout en intégrant explicitement la notion sociale par le biais de la sécurité, de la valorisation, et de l'implication des employés dans l'amélioration des processus.

2 Des préoccupations économiques et environnementales à l'émergence du « Lean & Green » : genèse d'une approche intégrée

La réponse des firmes face aux pressions externes évoquées précédemment a été analysée dans de nombreuses contributions. Certains travaux confirment l'idée d'un modèle économique classique, considérant la pollution comme une externalité négative dont la prise en compte entraîne des coûts pouvant hypothéquer la productivité des entreprises ; l'argument économique est alors souvent mis en avant pour retarder ou remettre en cause l'opportunité de certains programmes de réduction de la pollution.

A l'inverse, certains discours des entreprises et des gouvernements autour du concept de développement durable ont popularisé une vision « gagnant-gagnant» des relations existantes entre les actions environnementales et les intérêts économiques. Ainsi, au début des années 90, de nombreux travaux se sont attachés à promouvoir la mise en œuvre de stratégies environnementales centrées sur les principes du développement durable (Schmidheiny 1992) (Robins 1992). Ces travaux ont démontré les avantages pouvant découler des initiatives environnementales : économies de matières et d'énergie, réduction des coûts de traitement des contaminants et des frais d'enfouissement des déchets, amélioration de l'image de l'entreprise, amélioration des procédés, innovations technologiques, etc. Les enjeux environnementaux commencent alors à apparaitre comme des opportunités d'améliorations.

Porter fut ainsi l'un des premiers à démontrer que les pressions environnementales et les investissements « Green » contribuent à améliorer la compétitivité des entreprises (Porter 1991) (Porter and Van Der Linde C. 1995) tel qu'analysé dans (Ambec and Barla 2002). Selon Porter, la réduction des différentes formes de production tend à stimuler l'innovation et à accroitre la productivité.

Cette logique vertueuse impliquant de minimiser les ressources utilisées et les déchets rejetés est au centre de la quête d'éco-efficience telle que définie par (DeSimone and Popoff 1997) (Boiral 1998) (Boiral, Baron et al. 2014).

La promotion de cette logique d'éco-efficience appelle pour certains des changements radicaux dans les pratiques des entreprises (Hawken, Lovins et al. 1999), tandis que pour d'autres la quête d'éco-efficience se confond avec celle d'une meilleure productivité et illustre au contraire « comment la recherche du profit dans une économie de marché permet généralement de réconcilier la croissance économique et la protection de l'environnement » (Desrochers 2003).

Instanciées sur des terrains opérationnels, ces théories économiques peuvent ainsi être considérées comme des visions précurseur du Lean and Green.

Les travaux de Boiral (Boiral 2005) précisent et redéfinissent cette vision « gagnant-gagnant » des implications économiques des actions environnementales en proposant un élargissement et une mise en contexte des réflexions sur ce thème via cinq facteurs régulièrement négligés :

- Distinction entre actions préventives et palliatives,
- L'efficacité marginale des actions environnementales,
- la réponse aux normes et le processus d'innovation technologique,
- Les pressions des parties prenantes et la valorisation des actions environnementales,
- La performance environnementale comme conséquence de l'excellence manufacturière.

C'est vers ce dernier point que nos travaux se sont orientés, en regard du caractère de plus en plus indissociable des activités liant l'amélioration de la compétitivité et les politiques de développement durable des entreprises. Le cadre dans lequel est inscrit notre sujet vise même à dépasser cette dichotomie en prônant une approche totalement intégrée. Ainsi, dans certaines contributions pionnières de la fin des années 90, les préoccupations environnementales tendent à être intégrées dans les activités quotidiennes des entreprises, au niveau des méthodes de travail et des procédures, de manière à pouvoir traiter à la source les différentes formes de pollution (Boiral 1998) (Florida 1996).

La méthodologie Lean and Green, en ligne avec cette vision, représente ainsi l'opportunité de transformer les préoccupations environnementales en opportunités d'amélioration par le biais de l'élimination commune des gaspillages. Les résultats en termes de bénéfices environnementaux interviennent alors comme de véritables indicateurs de bonne performance globale de l'entreprise, intégrés aux routines et pratiques quotidiennes de management de l'entreprise.

On peut considérer que Florida (Florida 1996) fut le premier instigateur d'une vision Lean and Green dans l'entreprise (Bergmiller 2006),(Fercoq 2014) ; grâce à son étude menée à la Carnegie Melon University dans laquelle il explore les relations entre pratiques manufacturières et performance environnementale à travers différentes études de cas, interviews et questionnaires. Les conclusions démontrèrent qu'une combinaison de pratiques organisationnelles et d'avancées technologiques implémentées en même temps qu'un système de minimisation des déchets était plus efficient qu'une approche de mise en place unitaire de ces méthodes. Cependant, son étude n'apporte pas de réponse quant au lien effectif entre bonnes pratiques Lean et bonnes pratiques Green.

Dans la même lignée, les travaux de Rothenberg et al. (Rothenberg, Pil et al. 2001) réalisés dans le domaine de l'industrie automobile ont permis de lier des indicateurs de performance environnementale à des indicateurs de performance en termes de production. La complémentarité entre les deux types de mesures avait alors été soulignée, de même que le lien favorable entre production Lean et performances Green.

Plus proche de nous, les études de Corbett et Klassen (Corbett and Klassen 2006) préconisent qu'une approche intégrée d'un point de vue managérial permet de concilier Lean et Green de manière optimale. Dans la même filiation, les travaux de thèse de Bergmiller (Bergmiller 2006) proposent une typologie des situations de complétude entre approche Lean et approche Green.

Les travaux menés à l'université de Cardiff par l'équipe de P. Hines (Hines 2009) sont une contribution majeure à la théorie du Lean and Green dans le sens où ils ont été les premiers à proposer une catégorisation des gaspillages (mudas) Green en parallèle des mudas du Lean identifiés par Toyota. Cependant, leur vision tend vers une convergence entre les 2 concepts via la mise en place de différents outils mais ne s'intéresse pas à une intégration forte de ces concepts.

Parallèlement, les travaux proposés par Pojasek (Pojasek 2008) présentent une stratégie intégrée menée autour de 3 vecteurs : Le Lean, le système de management Green et une structuration de l'excellence pour promouvoir des performances durables. Dans son modèle, Pojasek propose d'aligner les approches Lean et Green pour la conduite des programmes d'amélioration continue. Les travaux de Cabral et al 2012 (Cabral, Grilo et al. 2012) quant à eux misent sur le déploiement du concept intégré LARG (Lean, Agile, Resilient, Green). Les

4 paradigmes ont le même objectif : satisfaire, au meilleur coût possible pour tous les acteurs de la chaîne logistique, les besoins des clients. Cette intégration s'intéresse cependant essentiellement à lier les systèmes managériaux.

Plus récemment encore, les travaux de Dues et al. (Dües, Tan et al. 2013) (Table 1) synthétisent les objectifs du management Lean et du management green, et mettent en parallèle les objectifs principaux et les focus de chacune de ces approches managériales.

	Management Lean	Management Green
Objectif principal	Maximiser les profits grâce à la réduction des coûts (Carvalho and Cruz-Machado 2009)	Réduire les risques et les impacts environnementaux – Améliorer l'efficacité écologique de l'entreprise et leurs partenaires (Zhu, Sarkis et al. 2008)
Focus	Réduire les coûts et amélioration de la flexibilité grâce à l'élimination continue des non valeurs ajoutées sur l'ensemble de la chaîne logistique (Vonderembse, Uppal et al. 2006) (Mollenkopf, Stolze et al. 2010)	Réduction de l'impact écologique des activités industrielles grâce à l'élimination des déchets et la suppression des pollutions (Carvalho and Cruz-Machado 2009) (Mollenkopf, Stolze et al. 2010)

Table 1 : Objectifs et Focus des managements Lean et Green (Dües, Tan et al. 2013)

Enfin les travaux de thèse de Fercoq (Fercoq 2014) proposent une vision quantitative de l'intégration Lean/Green centrée sur le management des déchets des activités économiques pour promouvoir une démarche conduisant à une performance équilibrée pour l'entreprise. Ses travaux proposent ainsi un modèle quantitatif pour l'éco-efficience et un modèle quantitatif pour l'éco-responsabilisation.

La Figure 1 présente les apports des contributions évoquées et notre positionnement dans leur lignée, en se basant sur les catégories définies initialement par Bergmiller (Bergmiller 2006) (convergence Lean and Green, transcendance Lean and Green, Synergies Lean and Green).

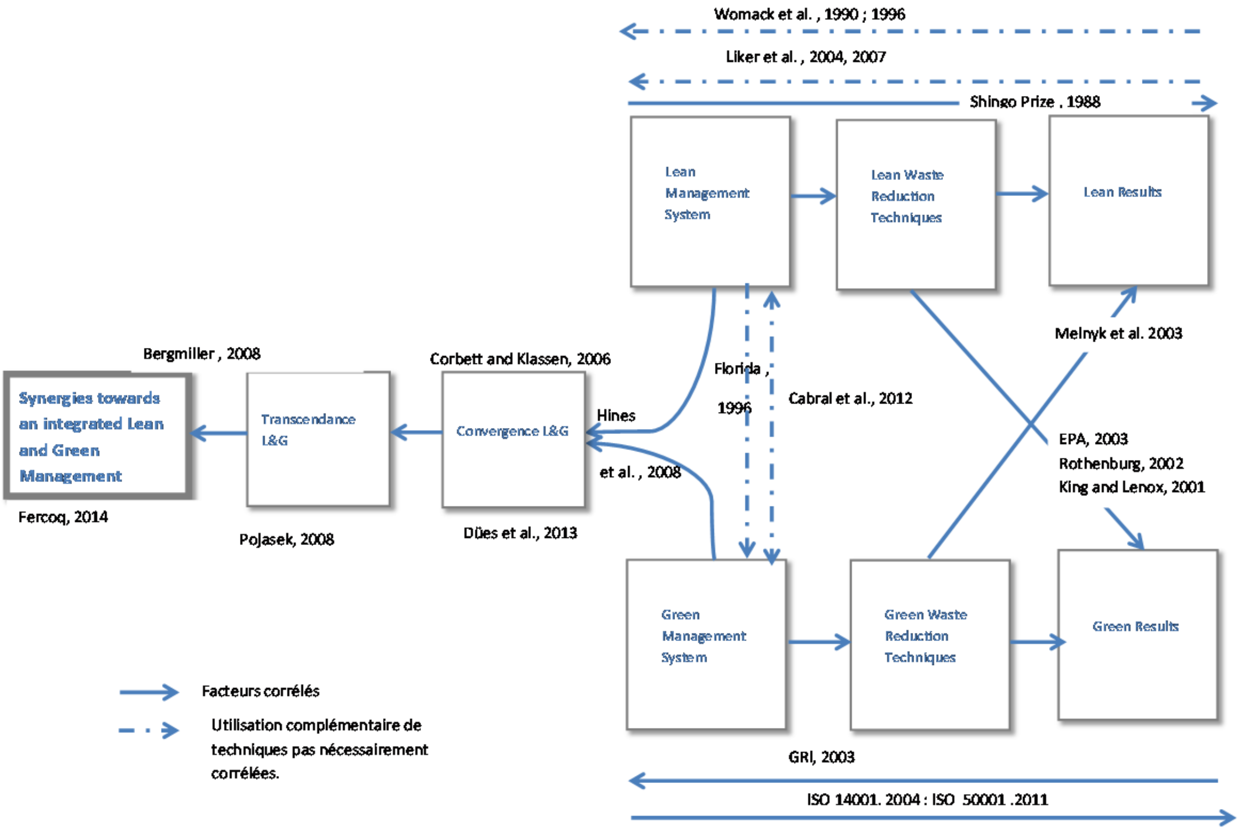

Figure 1 : cartographie des contributions en Lean and Green (adapté de Bergmiller, 2006)

Afin d'expliciter l'apport de nos contributions au sein de ce domaine d'étude, nous présentons dans la section suivante la problématique et les enjeux de nos travaux de recherche.

3 Problématique de recherche

L'éradication des gaspillages d'un point de vue processus via une politique de performance industrielle et d'amélioration continue de type « Lean » est un enjeu majeur des entreprises industrielles et permet d'obtenir des gains certains en termes de compétitivité. Toutefois, la création de valeurs passe nécessairement aujourd'hui par une dimension environnementale. Le lien entre cette politique de chasse aux gaspillages « Lean » et la prise en compte d'une perspective de développement durable semble ainsi très fructueux (Bergmiller and McCright 2009). Les entreprises doivent adopter une stratégie équilibrée où le Lean intègre des pratiques respectueuses de l'environnement (Mollenkopf, Stolze et al. 2010). A l'image de certains fleurons de l'industrie, tel Toyota, le déploiement d'une stratégie Lean intégrant les problématiques environnementales est un axe de développement privilégié dans la vision de l'entreprise. Cependant, la problématique majeure réside dans l'adéquation et l'imbrication que peuvent prendre les outils issus des politiques « Lean » et « Green » au sein d'entreprises manufacturières en prenant en compte leurs caractéristiques de maturité.

Même si la faisabilité et la rentabilité de la démarche « Lean and Green » n'est plus à prouver d'un point de vue industriel (Bergmiller and McCright 2009), (Yang, Hong et al. 2011), (Dües, Tan et al. 2013); un certain manque d'expertise existe dans la définition de voies de déploiement de politiques liant les synergies du « Lean and Green ».

Notre question de recherche principale se pose alors ainsi :

Comment intégrer conjointement des méthodologies Lean et Green au travers de modèles d'évaluation des performances et de déploiement au sein d'entreprises manufacturières possédant des processus, cultures et maturités différentes ?

La mise au point d'une roadmap de déploiement adaptable à la stratégie de l'entreprise et de ses acteurs devient ainsi un objectif scientifique majeur pour répondre à la problématique posée.

Nous considérons en ce sens le point de vue de Blanc et Monomakhoff (Blanc and Monomakhoff 2008), qui définissent l'établissement de plans d'actions au niveau managérial comme un dispositif permettant de pallier les difficultés de déploiement des objectifs stratégiques formalisés par les directions générales. Au-delà d'une obligation de résultat, la méthode veut fournir les moyens pour atteindre ces objectifs (Fall 2009).

4 Enjeux et originalités des travaux de recherche

En regard de la problématique définie précédemment, le cœur de ces travaux de recherche consiste à fournir un cadre méthodologique aux managers et décideurs de l'entreprise désireux de pouvoir traduire une stratégie globale Lean and Green vers des actions opérationnelles concrètes sur le terrain. Il convient alors pour l'entreprise de pouvoir s'évaluer de manière interne et externe et d'avoir les moyens de s'inscrire dans un processus d'amélioration continue.

Afin de mener à bien ces travaux et de tenir compte des problématiques actuelles des industriels, nous avons choisi deux principaux inducteurs de performance (au sens de (Silem and Martinet 2009) et (Addouche, Dafaoui et al. 2005)) et avons ensuite orienté nos recherches bibliographiques et études de terrains en conséquence :

- Inducteur de performance n°1 : *Définir des indicateurs environnementaux ad hoc pour la mise en œuvre du Lean and Green,*

- Inducteur de performance n°2 : *Définir une stratégie pour déployer et accroître l'efficience de la mise en œuvre des outils Lean and Green.*

Ces deux inducteurs de performance caractérisent les enjeux principaux de nos travaux et sont complémentaires. Les verrous et enjeux qui y sont associés sont détaillés en Table 2.

Inducteurs de performance	**Verrous associés**
n°1- Définir des indicateurs environnementaux ad hoc pour la mise en œuvre du Lean and Green	• Quels indicateurs environnementaux sont actuellement utilisés ? • Comment procéder pour les sélectionner efficacement avec un recul suffisant? • Comment utiliser les connaissances capitalisées (bonnes pratiques) efficacement ? • Quels indicateurs utiliser pour un benchmarking environnemental ?
n°2- Définir une stratégie pour déployer et accroître l'efficience de la mise en œuvre des outils Lean and Green	• Comment organiser les actions pour définir une vision à la fois court terme et long terme de la performance Lean and Green ? • Comment s'assurer d'un déploiement efficace du Lean and Green?

Table 2 : Inducteurs de recherche et verrous associés

La vision essentiellement qualitative de nos travaux est une originalité forte permettant de proposer une méthodologie complète de déploiement, qui lie les niveaux organisationnels et opérationnels au sein de la boucle d'amélioration continue de la démarche. Ainsi, nos apports complètent les précédentes contributions en proposant une vision didactique et dynamique du pilotage de l'évaluation des performances et du déploiement de la démarche.

En effet le Lean and Green est, à l'instar du Lean, une démarche d'apprentissage utilisant des principes validés et des outils adaptés à la situation, au contexte et à l'objectif (Roche 2013).

5 Méthodologie de recherche et approche suivie

5.1 Positionnement thématique et cadre d'analyse

Ce travail de recherche s'inscrit dans le cadre des travaux en sciences et techniques de la production (STP). Celles-ci relèvent d'une approche basée sur la multi et la transdisciplinarité et sont ainsi plurielles en s'inspirant méthodologiquement et conceptuellement de la multitude des sciences existantes, questionnant en permanence les silos disciplinaires traditionnels existants en recherche (Duchemin 2013).

Notre cadre d'analyse intègre cette transdisciplinarité et considère l'entreprise étudiée comme un système holistique (Rhodes, Ross et al. 2009).

5.2 Méthodologie de recherche

Nous avons mené un certains nombres d'études de terrain basées sur l'évaluation, la classification et l'amélioration des performances vers les pratiques des entités les plus matures en Lean and Green. Ainsi, notre recherche est basée à la fois sur des objectifs descriptifs et instrumentaux, et sa méthodologie est une approche croisée menée autour de deux vecteurs : « case study » et « grounded theory ».

La démarche « case study » est considérée dans le cadre de la définition de (Yin 2008). Elle a pour objectif de permettre aux chercheurs de conserver les caractéristiques globales et significatives d'événements de la vie réelle (processus organisationnels et de management, niveau de maturité des industries ...); ce contexte étant tout à fait pertinent en regard du panel d'entreprises que nous pouvons observer. D'autre part, l'essence même d'une étude de cas est d'éclairer une décision ou un ensemble de décisions (Schramm 1971). Ainsi, notre objectif est clairement ciblé vers la construction de théories permettant de mixer l'élaboration et la configuration d'un cadre d'observation et de réflexion pour pouvoir mener une description dense et précise des situations; avec l'ambition de pouvoir être réutilisées à terme dans d'autres études avec des configurations différentes de manière à vérifier des théories et des hypothèses nouvelles nécessitant des tests plus importants (George and Bennett 2005) (Lijphart 1971).

Parallèlement, nos travaux empruntent une démarche issue de la « grounded theory » (théorie ancrée). Celle-ci se réfère à un ensemble de méthodes inductives systématiques pour effectuer une recherche qualitative visant au développement d'une théorie. La «grounded theory» désigne deux facettes : un procédé constitué de stratégies méthodologiques flexibles d'une part, et les produits issues d'enquêtes d'autre part. De plus en plus, les chercheurs utilisent le terme pour désigner les méthodes d'enquête pour la collecte et, en particulier, l'analyse des données (Charmaz 2003).

Ainsi, à travers différentes études réalisées auprès des partenaires du Club Lean and Green mais également auprès d'autres entreprises régionales menant une politique Lean, nous avons collecté et capitalisé un certain nombre de données. Basée sur une analyse qualitative de ces données, notre démarche se rapproche plus de la vision proposée par (Strauss and Corbin 1990) de la grounded theory. Ainsi à la différence des premiers écrits sur cette démarche (Glaser and Strauss 1967), les modèles que nous proposons ne sont pas fondés uniquement sur les données. Dans cette vision, à l'instar des propositions faites par (Engward 2013) ou encore (Seidel and Urquhart 2013), les données sont structurées de manières à révéler les théories et concepts sous-jacents. La théorie est interprétée par le chercheur et la première phase de codification est réalisée de manière active par le chercheur.

La Figure 2 présente de manière schématique la méthodologie de recherche adoptée en partant des études de terrain et des sources bibliographiques pour aboutir à des modèles ainsi que des prescriptions d'utilisation dans un environnement donné. Ceci nous permettant ensuite de préconiser une méthodologie de déploiement globale, sans oublier une boucle de retour (et de validation) via d'autres études industrielles.

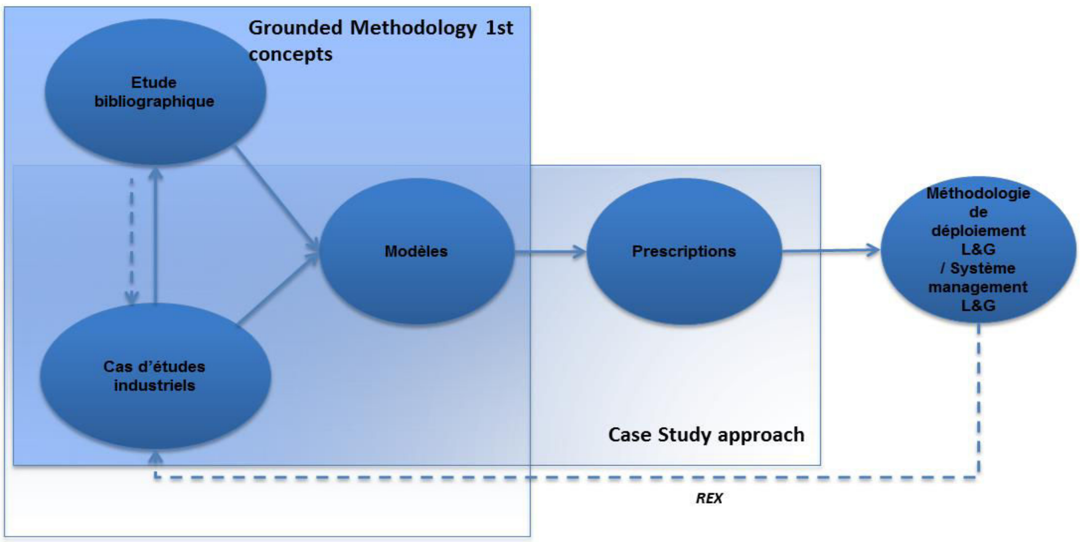

Figure 2 : Méthodologie de recherche adoptée

5.3 Axe d'étude « gaspillages L&G »

Nos travaux sont basés sur un objectif central d'élimination des gaspillages « Lean and Green », également dénommés selon le terme japonais « mudas ». Si les mudas du Lean issus du modèle de production de Toyota sont catégorisés depuis de nombreuses années, les mudas du Green ont été définis avec précision pour la première fois dans les travaux de Peter Hines (Hines 2009). Ainsi, nous avons mené l'ensemble de notre étude sur la base de la classification des gaspillages présentée en Figure 3, dans l'objectif de leur identification et élimination commune au sein des processus de fabrication, mais également afin de mettre en lumière l'ensemble des potentiels d'améliorations et de bénéfices des actions Lean and Green.

Figure 3 : Les "mudas" du Lean et du Green selon P. Hines (2009)

6 Architecture de la contribution scientifique

Afin de répondre à la problématique définie précédemment ainsi qu'aux verrous inhérents, notre contribution est architecturée sous la forme de 4 articles scientifiques dont les apports respectifs sont détaillés en Figure 4.

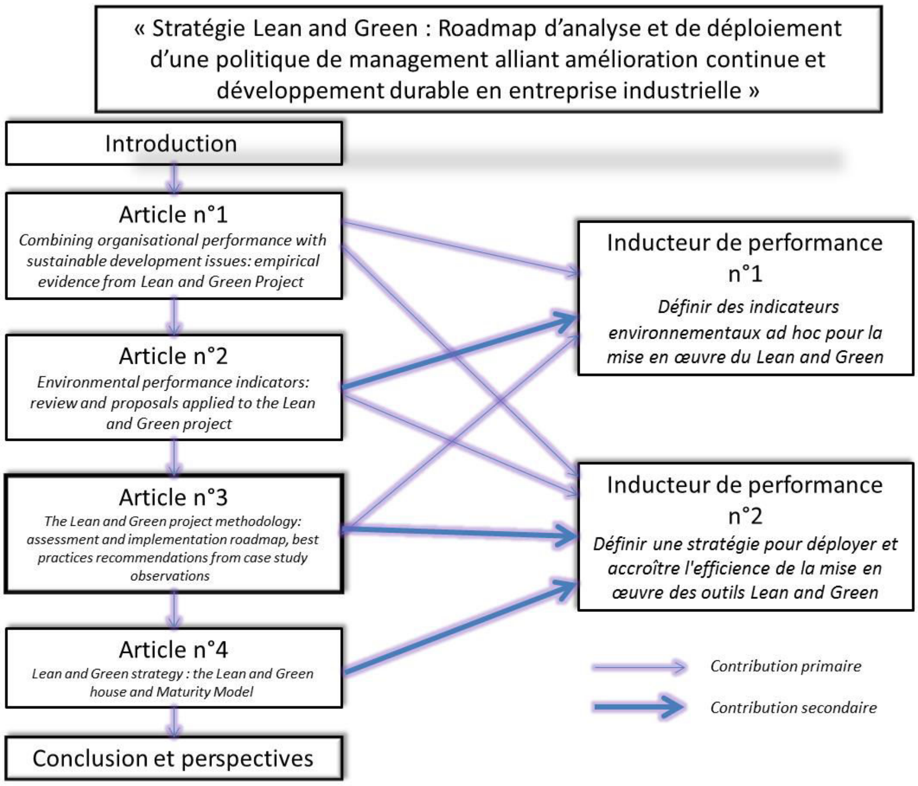

Figure 4 : Architecture générale du manuscrit de thèse en regard des inducteurs de performance proposés

Un premier article publié dans le volume 85 du Journal of Cleaner production est intitulé *« Combining organisational performance with sustainable development issues: empirical evidence from Lean and Green Project ».* A partir d'une analyse de la littérature exhaustive basée sur les mudas du Green tels que définis par P. Hines (Hines 2009), l'article propose un référentiel axé sur l'évaluation Lean and Green des entreprises et offrant en outre la possibilité de se comparer à d'autres entreprises.

Ce premier article permet de donner des éléments de réponse en regard du verrou associé à l'inducteur de performance n°1 « Quels indicateurs utiliser pour un benchmarking environnemental? ».

Le deuxième article, intitulé « *Environmental performance indicators: review and proposals applied to the Lean and Green project* » se propose de fournir un cadre d'aide à la décision pour la sélection d'indicateurs environnementaux ad hoc dans le cadre d'une démarche Lean and Green. Ainsi, sur la base d'un état de l'art scientifique et normatif, et d'une étude détaillée des rapports environnementaux des entreprises du CAC40, cette contribution s'applique à proposer un modèle de sélection simple à mettre en œuvre ainsi que des recommandations de mise en œuvre.

Ce second article s'intègre pleinement dans la réponse à l'inducteur de performance n°1 *«Définir des indicateurs environnementaux ad hoc pour la mise en œuvre du Lean and Green »* et tout particulièrement aux verrous « quels indicateurs environnementaux sont actuellement utilisés ? » et « comment procéder pour les sélectionner efficacement avec un recul suffisant? ».

Le troisième article propose une vision plus pointue de la méthodologie, en intégrant le référentiel d'évaluation à une méthode de déploiement Lean and Green élaborée dans une perspective d'amélioration continue. Pour cela, une roadmap majoritairement ciblée vers les PME est proposée, ainsi qu'une analyse de résultats de « benchmarking » environnemental auprès d'un panel d'entreprises partenaire. Les résultats sont accompagnés de recommandations et bonnes-pratiques dédiées élaborées sur la base des observations menées.

Ce troisième article présente ainsi une réponse originale à l'inducteur de performance n°2 *«Définir une stratégie pour déployer et accroître l'efficience de la mise en œuvre des outils Lean and Green »* ; en se focalisant sur la levée des verrous « Comment organiser les actions pour définir une vision à la fois court terme et long terme de la performance Lean and Green ? » et « comment s'assurer d'un déploiement efficace du Lean and Green? ».

Dans une moindre mesure, cet article répond également d'un point de vue didactique au verrou *« Définir une stratégie pour déployer et accroître l'efficience de la mise en œuvre des outils Lean and Green »* de l'inducteur de performance n°1.

Le quatrième article de cette thèse propose en point d'orgue de ces travaux une contribution orientée sur la stratégie de mise en place d'une politique Lean and Green au sein de l'entreprise. En prenant de la hauteur par rapport aux expérimentations industrielles, il propose d'abord, à partir d'une enquête étendue dédiée, une analyse des pratiques Lean and Green qui confirme les tendances constatées au cours des précédentes observations. Les initiatives d'entreprises expertes, incluant deux sites de production majeurs de Toyota, sont également mises en avant. Dans la deuxième partie, grâce à une étude détaillée des interactions existantes entre les mudas du Lean et du Green, les outils stratégiques sont mis en lumière. L'ensemble des éléments précédents permet alors de présenter une *Maison du Lean and Green*, permettant de guider stratégiquement le déploiement de la méthodologie. Il est également développé un modèle de maturité, adapté des concepts du Capability Maturity Model Integration (CMMI) et permettant aux décideurs de situer leur progression dans le déploiement de la politique Lean and Green de leur entreprise.

Ce dernier article permet ainsi de contribuer à l'inducteur de performance n°2 « *Définir une stratégie pour déployer et accroître l'efficience de la mise en œuvre des outils Lean and Green* » en proposant une vision intégrée et outillée du déploiement Lean and Green.

En conclusion de ces travaux, un bilan de la mise en œuvre des inducteurs de performance étudiés est présenté. Enfin, l'évocation des limites des propositions permet d'ouvrir des perspectives de recherche s'intéressant notamment au déploiement de méthodologies Lean and Green dédiées à d'autres phases et processus du cycle de vie.

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Article 1: "Combining organizational performance with sustainable development issues: the Lean and Green Project benchmarking repository"

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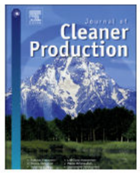

Combining organizational performance with sustainable development issues: the Lean and Green Project benchmarking repository*

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Abstract

To become and remain competitive, companies must adopt evolving strategies. Lean Manufacturing is one such strategy used in several industrial companies. It is based on the identification and elimination of waste in various production processes. The originality of our work consists in proposing an approach which adds environmental and social dimensions to the consideration of economic earnings received through Lean actions. Adopting a case study research methodology, we analysed the literature and the practices of 21 Alsatian industrial companies in order to assess how Lean and Green actions could be enhanced when used together. Based on our analysis, we propose a framework for Lean and Green management, which includes Lean indicators, Green performance indicators and Green intentions indicators. This framework enables a consortium of companies to benchmark their Lean and Green practices in order to target the best in class and the associated best practices.

Keywords: Lean manufacturing; Green manufacturing; sustainability, performance indicators, industrial experiments

1 Introduction

1.1 Lean today and the sustainable development wave

Many companies have already implemented Lean Manufacturing thinking within their programs. Lean Manufacturing thinking or "Lean" is a practice that helps companies to identify and eliminate waste through continuous improvement, by controlling their Lean tools. Lean identifies seven types of waste: overproduction, waiting, transportation, defects, inappropriate processing, unnecessary inventory and unnecessary motion. The aim of eliminating those types of waste is to increase efficiency, reduce costs, improve customer response time, and contribute to improved quality, greater profitability, and an enhanced public image (Bergmiller and McCright, 2009c).

Companies should however achieve efficiency not only by implementing practices such as Lean, but also by improving their environmental impact. The Green approach, or "Green", can sometimes result in impressive reductions in waste generation, in energy and raw material consumption, and in the use of hazardous materials. Green can also afford a company the status of a socially responsible organization (Miller et al., 2008). As with Lean, seven types of waste can be identified with Green: excessive water usage, excessive power usage, excessive resource usage, pollution, rubbish, greenhouse effects and eutrophication. Some authors also define an eighth type of waste for Green: poor health and safety (Hines, 2009).

1.2 Finding the right repository for implementation: a major scientific challenge

Lean is now mastered by a large number of companies. Lean & Green could provide a method for companies to develop a tool to measure both productivity and environmental performance based on qualitative and quantitative analysis. The purpose of this method would be to adapt the tools of Lean manufacturing to environmental performance, as shown in (Bergmiller and McCright, 2009c) from a modelling point of view.

In this context, our research questions deal with the following issues:

- Can we easily transpose and apply the Lean methodology to sustainable development goals?

- Which audit methodology and deployment strategy should be adopted to tackle the issues of energy consumption and waste recovery (carbon tax) to achieve Lean policy-oriented sustainable development?
- Which repository is able to make a reliable link between Lean maturity and the level of commitment to Green, in various companies?

The latter point also raises other questions: is the link between Lean and Green a real advantage as opposed to implementing two distinct approaches? What are the benefits of joint practices?

In order to answer these questions, it is particularly important to define the relevant performance indicators. This enables companies to produce an efficient Lean and Green dashboard, so that those committed to such a procedure can be benchmarked, and the best in class and best practices in terms of Lean and Green actions can be targeted.

The above questions were addressed in the "Lean and Green" project set up within the Alsatian companies presented in this article.

The study of these issues requires a mixed research approach based both on a study of the literature and on feedback and outputs from industrial experiments and audits. Since we are focusing on contemporary phenomena within a real-life industrial context, we have adopted a case study methodology (Yin, 2008). The research objective of this case study is based on both descriptive and instrumental objectives. Our goal is targeted purely towards theory building, in which we combine a configurative framework providing a dense description to be used for other studies, and plausibility probes used to check untested or inadequately tested theories and hypotheses (George and Bennett, 2005) (Lijphart, 1971).

As one of the aims of the project was to establish a Lean and Green repository to map the various companies according to their organizational performance and their "Green" performance, the study depicts the roadmap followed to build the repository, as well as the first analyses of the positioning of the various companies within this repository. The originality of our work is therefore that it presents a simple repository based on a sound analysis of the literature and on three questionnaires which can be used by all kinds of companies. This repository enables the companies to measure the correlation between their Lean and Green actions, and to benchmark their position on Lean and Green policies in order to identify the best practices to adopt. We first present the background of the experiment and the various stakeholders embedded within the project, and then review the literature on the topic of Lean and Green. After concluding that no existing framework is suitable for our consortium, we present our own framework used in the Lean and Green project and the first results of our enquiry. This offers an opening onto new perspectives and avenues for further research.

2 Project background

2.1 The industrial consortium

This project, initiated by the Alsace Region, was built around stakeholders from different fields. The main goal was to observe and map Lean and Green practices within a community of seven major industrial companies (contractors) from the Alsace area and at two of their suppliers (only Small and Medium Enterprises (SMEs)) for each contractor (See Table 1). The industrial partners also included:

- Consultancy firms responsible for conducting field audits at contractors and their suppliers. They were in charge of defining the Value Stream Map for the Lean perspective and the Green perspective within each of the industrial facilities in the consortium. They also provided solutions for improvement.

- ICUBE/ University of Strasbourg: a research laboratory responsible for designing the Green repository as well as the Lean & Green repository, and then producing an analysis and synthesis of the audits performed by consultants.

- ADIRA: The Economic Development Agency of Bas-Rhin assisted companies in implementing the Lean & Green Project and coordinated the project.

- Alsace Region and DIRECCTE: Provided funding for the Lean and Green project.

The contractors were: Alstom, Millipore, Steelcase, GM, Kraft foods, Soprema and SALM, a kitchen furniture manufacturer.

Company		Business Sector
E11	Steelcase (Contractor)	S1 : Semi-finished product processing & assemby
E12	SME	
E13	SALM (Contractor)	
E14	SME	
E15	SME	
E16	SME	
E17	Alstom (Contractor)	
E18	SME	
E19	Millipore (Contractor)	
E21	SME	S2 : Transports / Logistics
E22	SME	
E31	GM (Contractor)	S3 : Raw materials processing
E32	SME	
E33	Soprema (Contractor)	
E34	Kraftfoods (Contractor)	
E35	SME	
E36	SME	
E41	SME	S4 : Packaging
E42	SME	
E43	SME	
E44	SME	

Table 1: Industrial consortium with business sectors

2.2 *Establishing the project roadmap*

The project was initiated in September 2010 and ended in December 2011. The first task was to design questionnaires for the consultancy firms to carry out efficient audits. Drawing on the data found in the literature (see Section 3), the project consortium decided to build three questionnaires to send to the various stakeholders of the project. These three questionnaires were the basis on which the Lean and Green indicators were built. They were designed in a complementary way, in order to get feedback from different points of view on the companies: a priori level of awareness regarding Green topics; qualitative data from the middle management, and finally quantitative data from the top management. The first one was a multiple-choice questionnaire intended to provide an a priori understanding of each company's level of "Green awareness" before and after the consultants' Lean audit, but before any “Green” discussions. It was intended to be filled in by any employee of the companies involved in the project (see Appendix 1).

The second questionnaire was a qualitative enquiry on the way companies monitor their waste, energy, raw materials, water, etc. consumption, in order to understand how they fit into the Lean philosophy, in the first instance, and into the Green philosophy, in the second instance. This questionnaire adopted the same philosophy as the one used for the Shingo Prize ranking (Shingo Prize, 2013). It was targeted at production managers and zone leaders (see Appendix 2).

The third questionnaire was designed to quantitatively track the various consumptions (waste, energy, raw materials, water) of the companies audited, as well as their production indexes, in order to then be able to compare these with their “Green” results. It was targeted at facilities managers, as well as business unit managers and heads of production plants (see Appendix 3).

Once the audits had been carried out, we proceeded to the analysis of the three questionnaires (a priori, qualitative, and quantitative) in order to obtain the ad hoc ratios and indicators necessary to rank the companies (Mickwitz et al., 2006) (see Figure 1). This was done by benchmarking them against the state of the art. The results are presented in the next section.

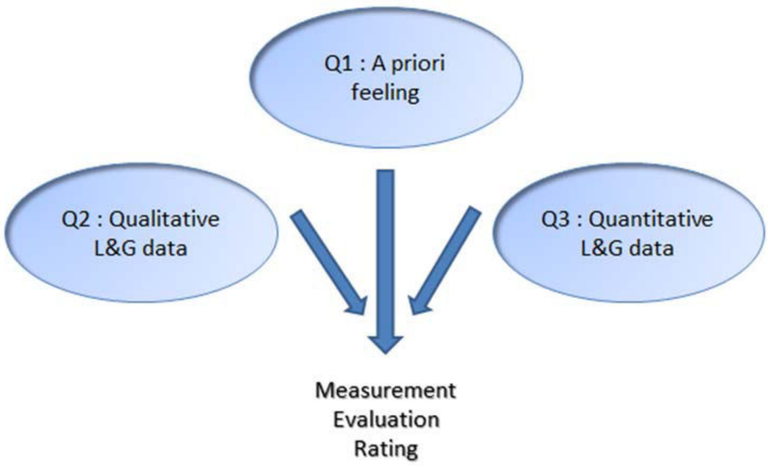

Figure 1: The three questionnaires pattern

3 Literature review

We first investigated the existing literature on Lean and Green topics. Our analysis revealed that while the subject is not widely addressed yet, it is mobilizing strong and visible interest. The concept of sustainability, defined by the 1987 Brundtland Commission Report as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", can no longer be overlooked and is one of the main areas of focus of current economic development. The linking of Lean Manufacturing, a well-known and commonly used efficiency system to eliminate non-value added elements in production, to "Green", a new way of thinking responsibly, is gaining ground as a solution to achieve sustainability.

To review the literature, we searched for Lean and Green themes implicitly embedded within general concepts of design and manufacturing associated with environmental and sustainability concerns.

As shown in Table 2, most research linking Lean practices with Green or Environmental approaches has limited its focus to single Lean practices or environmental approaches, rather than analyzing multiple measures of environmental performance. This relative scarcity can be explained by the fact that the relationships between Lean and environmental aspects are influenced by various factors such as culture or resource usage in the production of quality products (Sawhney et al., 2007), and that they also vary depending on the Lean principles under consideration (Sarkis, 2003). Some implementation schemes have been initiated since 2008, but few frameworks exist. A concrete general outline to simultaneously implement Lean and Green paradigms or even to link economic and environmental performance is still lacking. Research in this domain is however growing and elicits genuine interest.

Although we found around 150 interesting papers dealing with the importance of rethinking development and manufacturing processes with sustainable practices, we focused predominantly on those that have been published since 2008 (about 80). The reading grid presented in this section analyses 46 references and is a representative illustration of the most interesting papers that we found.

Most of these papers discuss the general link between economic and Green issues (Gunasekaran and Spalanzani, 2012) (Maxwell et al., 2006; Maxwell and van der Vorst, 2003) (Rusinko, 2007) (Taisch et al., 2010) (Schoenherr, 2011). About 20 papers specifically talk about blending the Lean and Green principles, such as (Kleindorfer et al., 2005) (Dües et al., 2012) (Kainuma and Tawara, 2006) (Dakov and Novkov, 2007) (Bergmiller and McCright, 2009a) (Simons and Mason, 2003). Few papers really deal with our "manufacturing application" goal (Yang et al., 2011) (Parveen et al., 2011) (Bergmiller and McCright, 2009b) (Sawhney et al., 2007) or explore a truly innovative focus (Katsamaki et al., 2011).

Even though, as mentioned earlier, we focused on papers published since 2008, it was important to include some of the most referenced and well-known papers of the past decade dealing with our subject, as they have had a real impact on subsequent investigations (King and Lenox, 2001) (Kainuma and Tawara, 2006) (Maxwell and van der Vorst, 2003) (Pimenova and van der Vorst, 2004) (Simons and Mason, 2003) (Zhu and Sarkis, 2004).

The entries in the classification table, Table 2, were taken from the work of Professor Peter Hines from Cardiff University in the UK (Hines, 2009). The "Lean" and "Green" notions at the top of the table refer respectively to the traditional eight types of Lean waste (commonly known as overproduction, defects, unnecessary motion, unnecessary inventory, inappropriate processing, transportation, waiting and lost people potential), and to the eight Green mudas that Peter Hines proposed on the same theme: greenhouse gases, eutrophication, resources usage, power usage, pollution, rubbish, water usage and poor health and safety. The economic, social and environmental pillars of sustainable development were also added to the reading grid, as well as the notions of product life cycle and supply chain relationships which are interesting areas of focus of the study, as we will see later.

The degree of importance of each entry in a reference is represented by the crosses. Thus, one cross in the table corresponds to a notion which is at least alluded to in the text, two crosses to a more developed notion, and three crosses to a notion which is seen as an area of focus.

We see in the grid that the three pillars of sustainable development, i.e. the environmental, economic and social dimensions, are well represented. However, compared to economic and environmental concerns, the social dimension is still clearly neglected. Every paper cited the environment at least, which could be expected, but while almost all of them (93%) made the connection with economic opportunities, only 60% felt the need to include social concerns. Yet social concerns need to be taken into account if sustainability is truly to be achieved. More research should therefore focus on this aspect.

While the subject is still new and has few concrete applications, a few recently published papers, such as (Dües et al., 2012), explore the possibilities of synergy between Lean and Green. They argue that Lean is a catalyst for the implementation of Green in manufacturing companies, and that Green will help to maintain best practices in Lean (Bergmiller and McCright, 2009a, b; Dakov and Novkov, 2007; Dües et al., 2012). However, the reference table shows that papers have often dealt with the Lean and Green paradigms on a macroscopic level, and that only 30% of these papers offer an overview of Lean and Green waste. Some papers, like (Bergmiller and McCright, 2009b), have dealt with Lean and Green and linked them to business without exploring them in any detail.

References	LEAN										GREEN											
References	Overproduction	Defects	Unnecessary Motion	Unnecessary Inventory	Inapropriate Processing	Transportation	Waiting	Lost People Potential	**Economic**	**Social**	Greenhouse Gases	Eutrophication	Resources Usage	Power Usage/Energy	Pollution	Rubbish	Water Usage	Poor Health & Safety	**Environment**	Case/Datas study	Lifecycle	Supply Chain Relationships
Ab Rahman et al., (2009)					X				X		X		X	X	X		X	X	X	X		
Ageron et al., (2011)				X		X	X	X	X	X	X		X		X			X	X	X	X	XX
Akamp & Müller, (2011)						X		X	X	X			X					X	X	X		XXX
Bergmiller & McCright, (2009c)					X	X	X	X	X					X				X	X			X
Bergmiller & McCright, (2009b)		X			X		X		X				X						XX	X		
Bergmiller & McCright, (2009a)		X			X	X	X	X	X				X		X			X	X	X		
Bose & Pal, (2012)		X		XX		X	X	X	X	X	X		X	X	X	X		X	X	X	X	XX
Chardine-Baumann, (2011)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	XX
Comoglio & Botta, (2012)					X	X					X		X	X	X		X	X	X	X		
Dakov & Novkov, (2007)	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X			X
Duarte et al., (2011)		X		X	X	X	X	X	X	X	X		X	X	X		X	X	X		X	XX
Dües et al., (2012)	X	X	X	X	X	X	X		X	X	X		X	X	X		X		X		X	X
Espadinha-Cruz et al., (2011)				X			X		X										X	X		XX
Gunasekaran & Spalanzani, (2011)		X		X	X	X	X		X	X	X		X	X	X		X	X	X		X	XX
Gustashaw & Hall, (2008)		X			X	X	X	X	X	X	X		X	X	X	X	X		X	X	XX	X
Hines, (2009)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Hussey & Eagan, (2007)					X			X	X	X			X		X			X	X	X	X	X
Kainuma & Tawara, (2006)				X		X	X		X		X		X	X	X	X			X	X	XX	XX
Katsamaki et al., (2011)					X		X									X		X	X	X	XX	
King & Lenox, (2001)				XX	X			X	X			X			XX			X	XX	XX		
Kleindorfer et al., (2005)		X		X	X	X	X	X	X	X			X	X	X			X	X		X	X
Kogg & Mont, (2012)							X		X	X	X		X				X	X	X	X	X	XXX
Koplin et al., (2007)									X	X			X						X	X	X	XXX
Mashaei et al., (2011)			XX											XX					X	X		
Maxwell & Van der Vorst, (2003)						X			X	X	X		X	X		X		X	X		XX	X
Maxwell & Van der Vorst, (2006)	X								X	X			X	X	X	X		X	X	X	XX	X
May et al., (2011)					X		X		X	X			X	X					X	X	XX	X
Mickwitz et al., (2006)					X	X			X	X	X	X	X		X				X	X	X	
Miller et al., (2008)					X				X	X	X		X	X	X	X		X	X		X	
Mollenkopf et al., (2010)	X	X	X	X	X	X	X		X	X	X			X	X	X		X	X		X	XXX
Paju & Johansson, (2010)	X				X	X	X		X	X	X	X	X	X	X	X	X		X		X	
Parveen et al., (2011)	X	X		X	X	X	X	X	X		X		X	X	X	X	X		X	X		X
Pimenova & Van der Vorst, (2004)									X	X	X		X	X	X	X		X	X	X		
Rusinko, (2007)					X				X				X	X	X	X	X		X	X		X
Sarkis et al., (2011)									X	X	X		X		X				X		X	XX
Sawhney et al., (2007)	X	X		X	X			XX	X		X			X	X	X	X	XX	X	X		X
Schoenherr, (2011)					X		X		X	X					X	X			X	XX		X
Seuring & Muller, (2008)									X	X									X		XX	XXX
Simons & Mason, (2003)			X		X	X	X		X		X		X	X	X				X	X	X	X
Taisch et al., (2010)									X	X			X	X		X		X	XX		XXX	
Vachon & Klassen, (2008)		X		X	X	X	X		X						X	X			X	X	X	XXX
Vachon & Mao, (2008)								X	X	X	X		X	X	X	X			X	X		XX
Venkat & Wakeland, (2006)		X		X	X	XX	X		X		XXX	X	X	X	X	X	X	X	X	X		X
Yang et al., (2011)	X				X		X	X	X	X					X				X	X	X	
Zhu & Sarkis, (2004)		X		X		X	X		X		X		X	X	X	X		X	X	X	X	XX
Zhu et al., (2012)				X					X				X	X	X	X		X	X	X		XX

Table 2: Lean and Green literature grid

Some mudas are quite popular in research papers whereas others are scarcely found. On the Lean side, “inappropriate processing”, essentially understood as the “need for process improvement”, is the most quoted type of waste, in 63% of references. It is followed by “waiting” and “transportation” (58% and 52%, respectively), which are important elements of the Lean line. The less popular mudas are “unnecessary motion” and “overproduction”, which seem to be confined to papers focused on Lean. On the Environmental side, the most popular terms are “resource usage” (76%), “pollution” (74%) and “power usage” (65%) which can, in fact, be seen as general types of waste. Unsurprisingly, the least discussed environmental muda is “eutrophication”, found in only 13% of papers, most likely because the term is not yet widespread. Some authors prefer talking about general “wastewater”, which remains regrettably unclear as to the kind of waste treated. “Greenhouse gases” and carbon footprint concerns have a better performance with 56%, due to the now well-known issue of global warming.

Most papers support their allegations with complete case studies or data studies (70%).

An original contribution of this study is to show that the largest single source of publications is the US (32%), followed by the United Kingdom (11%), from which some of the most interesting papers that we found originate ((Hines, 2009) (Dües et al., 2012)). Scandinavian countries also feel concerned about new ecological issues ((Kogg and Mont, 2012) (Paju et al., 2010)) and have produced 8.7% of the references. We also noted a real emergence of Chinese contributions, with approximately the same publication level as Italy, Germany and France (about 6.5% each) (Figure 2).

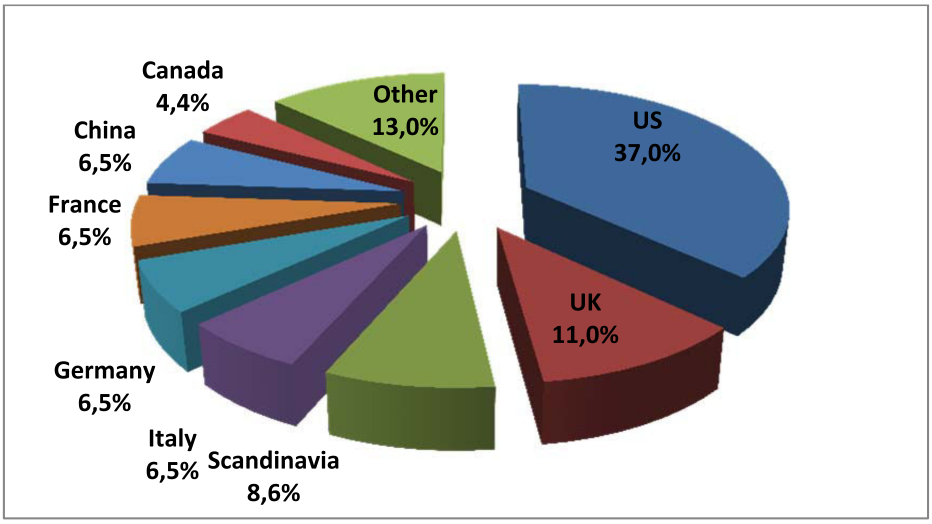

Figure 2: Geographical origins of Lean and Green contributions

As mentioned above, important issues can be addressed by linking Lean and Green, as stated in (Gustashaw and Hall, 2008) and implied by Vachon in (Vachon and Klassen, 2008). One of the stakes pertains to the economic benefits that can be derived from renewed thinking about quality production. Most papers discuss these benefits, particularly (Rusinko, 2007; Yang et al., 2011).

Others, like Bergmiller (Bergmiller and McCright, 2009a), suggest that the pursuit of lean and Green objectives in parallel has more chances of being successful, and that the focus on total waste reduction that can be obtained by associating Lean and Green can lead to cost reductions. This point is crucial for spreading the integration of Lean and Green in manufacturing systems.

Another interesting research path looks at the realm of possibilities afforded by considering the entire product life cycle, from the extraction of raw materials to the final disposal. We notice from the reading grid that the recognition of the life cycle, which one could expect to be obvious, is not so common and is mentioned in only 27 out of 47 references. There is a lack of focus on the entire product life cycle, or perhaps on product-based approaches. However, this is partially compensated by the papers' significant interest in supply chain concerns (70 %). Considering the entire life cycle also implies taking into account each actor in the whole supply chain. To increase efficiency, it is necessary to communicate with stakeholders in order to obtain information and thus to make the life cycle as clear and transparent as possible. Several interesting papers discuss supply chain relationships (Ageron et al., 2011; Akamp and Müller, 2011; Bose and Pal, 2012; Kogg and Mont, 2012; Sarkis et al., 2011; Vachon and Mao, 2008; Zhu et al., 2012) sometimes even including the Lean and Green paradigms (Azevedo et al., 2012; Duarte et al., 2011; Kainuma and Tawara, 2006; Mollenkopf et al., 2010; Parveen et al., 2011; Yang et al., 2011). This search for dialogue in the supply chain is necessary for several reasons. Sustainable means not forgetting the Economic, Environment and Social pillars. The Human Factor should certainly not be neglected and should be placed at the centre of new ways of thinking production, next to Economic and Environmental actions, as a condition for achieving real sustainability. Moreover, environmental legislation is becoming more stringent for manufacturers. The most important European policy, REACH (Registration, Evaluation and Authorization of Chemicals), issued by the ECHA (European Chemicals Agency) (ECHA, 2013), has the particularity of applying to each company in the supply chain. REACH makes it compulsory to monitor hazardous substances received and delivered, that is to say, not only what is going out in the downstream supply chain but also products or raw materials obtained upstream. Every stakeholder is thus affected and the legislation is automatically observed throughout the supply chain. This could be an example of a positive evolution, especially since research like (May et al., 2011) proves that many companies still consider environmental issues as a constraint or a low priority, instead of using them as a real opportunity for progress. As a result, these companies often just meet the minimum legal requirements. A system like REACH could provide a viable way of slowly but surely changing mindsets.

As explained in (May et al., 2011), for a number of reasons it is hard for manufacturing companies to make a product design stage sustainable. Firstly, as we saw earlier, costs and company priorities play a big role, despite growing demand from stakeholders, clients, and academia. Secondly, existing tools have not yet been adapted and the tools produced in the literature are not mature enough and are often not recognized by industry. There is still a lack of understanding among companies, which think of integrating sustainability too late in product life-cycle phases. Yet it has been proved that product design, the very first stage of the life cycle, will determine around 80-90% of a product's impact in further phases.

Even though the work of Peter Hines provided a number of tools that could be used to carry out a Lean and Green case study, the framework proposed was too complicated and therefore not suitable. On the panel, most of the companies involved in the project were SMEs without any expertise or resources to dedicate to the Green agenda in particular.

In the popularized scientific literature, we found three books (Esty and Winston, 2009) (Wills, 2009) (Winston, 2009) with rather disappointing content regarding our specific purpose: they offered only macroscopic solutions and were mainly concerned with return on investment.

We also investigated the literature on environmental issues in order to find simple and ready-to-use indicators to compare the various companies on our panel. We therefore drew on the contents of the Global Reporting Initiative (GRI, 2013) to study the environmental impact and sustainable development reports of eight companies quoted in the CAC 40 index (since 2002 it has been compulsory for these companies to provide a report on their environmental impact), as the reports were mostly built around the GRI recommendations. Of the 145 indicators studied, it was not possible to find one that was common to all of these companies. As a result, these repositories were impossible to use for comparing the "Green" performance of the companies on our panel.

We also studied the framework of the National Round Table for the Environment and Economy (NRTEE, 2012) advocating climate prosperity in Canada, as well as the framework of the French Environment and Energy Management Agency (Ademe, 2013) (Bilan Carbone method, 2013). The main shortcoming of these repositories was that setting them up and rolling them out was a huge undertaking. As the companies on our panel were mainly SMEs, using them in their entirety was not suitable either. We therefore built our own repository, which we present in the next section.

4 Proposing a Lean and Green repository for SMEs

Data concerning Lean performance were easier to obtain: a ranking from the qualitative questionnaire was available and we could rely on the consultants' impressions to produce a ranking from 0 to 20 of the Lean maturity of the companies audited. We therefore focused our analysis on the Green side of the repository.

4.1 First impressions about Green initiatives

The first questionnaire was built around 3 topics, in order to get a general feeling about the "Green" maturity and "Green conscientiousness" of the employees:

- The first part concerned their attitude towards energy consumption,

- The second part dealt with their respective company's ecological impact with regard to waste,
- The third part considered employees' feelings regarding the environmental management set up in the company.

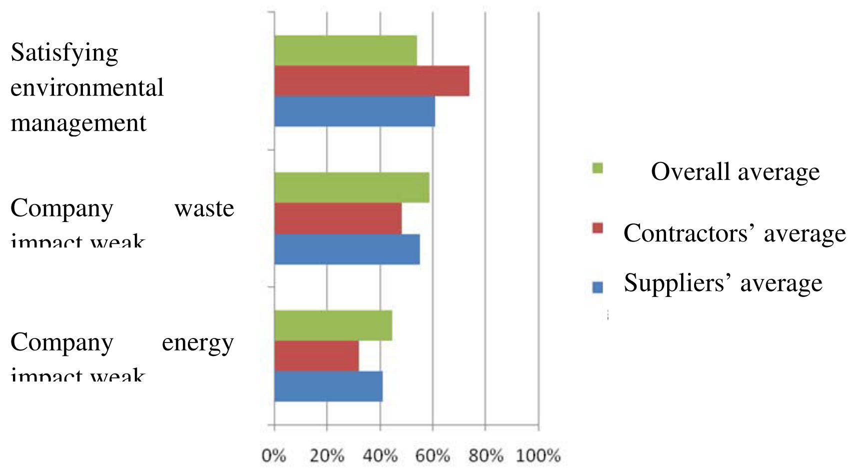

Figure 3: A priori "Green conscientiousness" of the employees of the companies on the panel studied

Compiling the data from the first questionnaire provides interesting feedback, shown in Figure 3. Hence, looking at the contractors, we see that on average employees are confident about the environmental management of their company. This can be explained mainly by the fact that these companies have been running ISO 14001 certification programs for a long time and have corporate environment-friendly programs.

On the other hand, the employees working for suppliers, mainly SMEs, are more confident about the weak impact that their companies have on the environment in terms of waste and energy consumption. This can also be explained by the industrial culture that is significantly different in those SMEs where the ecological dimension of production is not at the center of the firms' governance policies.

4.2 Green initiative / Green performance

In order to have an indicator of Green initiative which could easily be used and understood within the various firms on the panel, we chose to rank the grades (in %) obtained through the qualitative audit from A to E, using the well-known eco-indicator diagram (Figure 4). The best companies were awarded a B (in order to leave a margin for improvement) and the worst ones a D, with the others falling in-between. This was done in such a way that all the employees of the companies could directly locate the position of their company and gain awareness about this ranking.

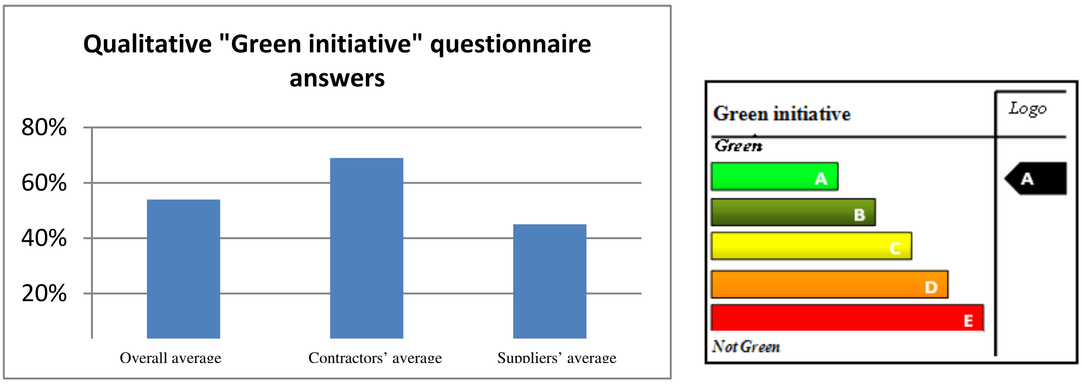

Figure 4: Green initiative questionnaire averages and Green initiative indicator

Analyzing the data in Figure 4, we note that contractors are better organized than suppliers regarding Green matters. These results therefore show the opposite of those derived from the first questionnaire. The cultural gap between suppliers and contractors in terms of their eco-friendly attitude can also explain this difference in feedback.

Nevertheless, we cannot rely only on this first indicator to compare the performances of the various companies that make up the panel. Comparing effective and qualitative measures is necessary in order to handle a reasoned rating. Thanks to the answers to the quantitative questionnaire, we propose six indicators that can be used to compare the results of the 21 companies studied in terms of their impact on the environment. These indicators are gathered together in a radar diagram and explained in Table 3 (Teq CO_2 refers to tons of CO_2 equivalent).

Indicators	Composition	Units
Teq CO_2 / 1000 T finished product	Teq CO_2 = Teq CO_2 (electricity + fuel consumption + Gas)	T/T
Teq CO_2 / Turnover	Teq CO_2 = Teq CO_2 (electricity + fuel consumption + Gas) ;	T/M€
	Turnover of one section of the company	
T Waste / 1000 T finished Product	Waste = hazardous industrial waste + non-hazardous industrial waste	T/T
T Waste / Turnover	Waste = hazardous industrial waste + non-hazardous industrial waste	T/M€
Water consumption/ 1000 T finished product	Water	m^3/T
Water consumption/ Turnover	Water ; Turnover of one section of the company	m^3/T

Table 3: Quantitative "Green" indicators

The major problem with these results was that it was difficult to compare the data since the 21 companies audited (contractors and suppliers) came from different domains (namely transformation and assembly of semi-finished products, raw material transformation, transportation and logistics, packaging). We therefore needed to adopt a relative scale in order to situate the companies in each domain. We chose to use the same indicator as for the Green initiative (A to E using the eco-indicator). We calculated the ranking for each of the six indicators in each industrial domain by giving an A to the best one and a D to the worst one, and calculating the intervals based on this range.

The major asset of this representation is that, as presented in Figure 5, some companies within the same industrial domain can perform quite well in terms of TeqCO2/ turnover but have a relatively poor performance when it comes to the Teq CO2/ T finished products ratio, meaning that they must increase their CO2 reduction efforts.

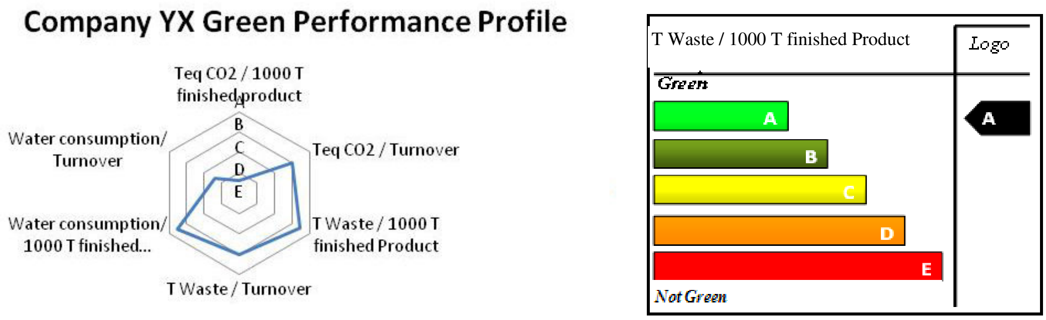

Figure 5: Quantitative "Green" performance indicators

To have a better idea of the correlation of Green performance and Green initiative, we tried to plot these two factors within the same industrial domain.

Theoretically, the objective was to find both Green performance and Green initiative with the same level, reflecting the fact that the companies had set up managerial rules and conscientiousness in terms of ecological impact with relevant and fact-based actions. Regarding the semi-finished product transformation and assembly domain (Figure 6), most of the companies lay on the bisector line. One company was awarded a good grade for its design initiative but a very bad one for its Green performance. This can be explained by the fact that this company had only recently rolled out its Green framework and had no historical visibility of the measures.

We therefore found the "best in class" companies in the top right corner of the diagram. Most of them (75%) were contractors who were mature in terms of their environment-friendly behaviour. This matches the results of the a priori questionnaire, since their employees were convinced of the good organizational management set-up in these big companies with corporate environmental programs.

A number of companies were awarded good scores for their Green performance, even though their results were not so impressive with regard to their Green initiative. This can be explained by the size of these companies (fewer than 30 employees for most of them). They did not have a very rigid framework in place for tracking measures but were nevertheless aware of their impact on the environment (which was usually quite low since they are small entities). In these specific cases, a framework lighter than the questionnaire used in our study could be necessary in order to improve their results.

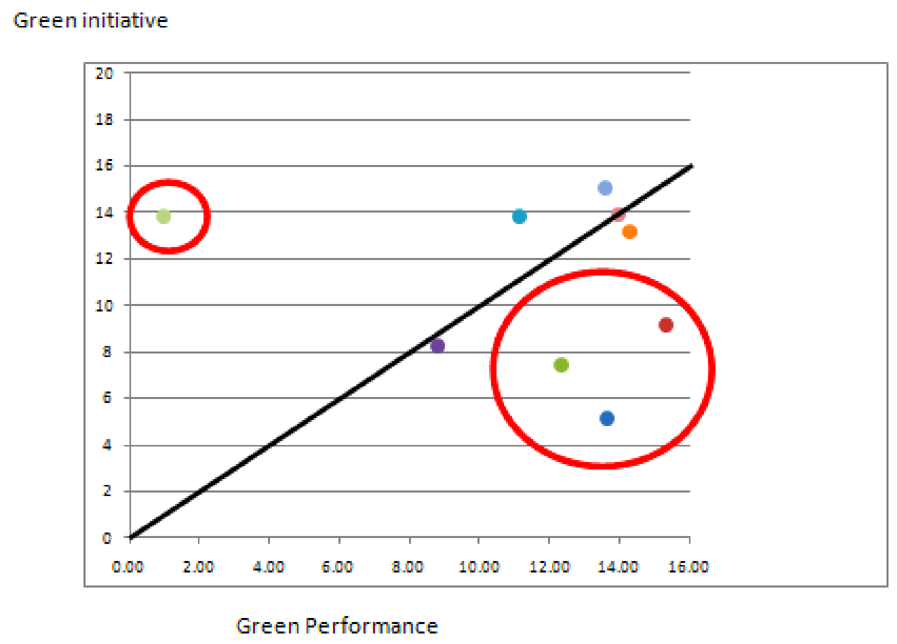

Figure 6: Green initiative and Green Performance plotting

In addition to the first impression questionnaire, our "Green" repository is therefore composed of seven indicators: one measuring the Green initiative by means of a qualitative questionnaire, and six indicators giving an overview of quantitative data. The latter six indicators must be analysed within coherent industrial domains.

Since one of the aims of our study was to verify the correlation between Lean action and Green actions, the last section presents our results concerning the correlation of these two aspects.

4.3 Lean and Green Matrix

In order to build the Lean and Green Matrix for the whole panel of companies, we need to have a common view of the indicators, despite the fact that these companies operate in different industrial domains.

The "Green initiative" indicator is therefore better than the "Green Performance" indicator, since it provides a common notion across the panel. This can therefore be understood as a "Green maturity" indicator.

Regarding the Lean indicators, as stated previously, compiling the data was easier since the scores were directly available from the qualitative audit. These scores were nevertheless correlated with global scores given by the consultants regarding the Lean maturity of these companies.

Figure 7 shows the plotting of this Lean and Green correlated information. These results are based on the feedback from 12 of the 21 companies on the panel since we were not able to gather all the results from the various companies.

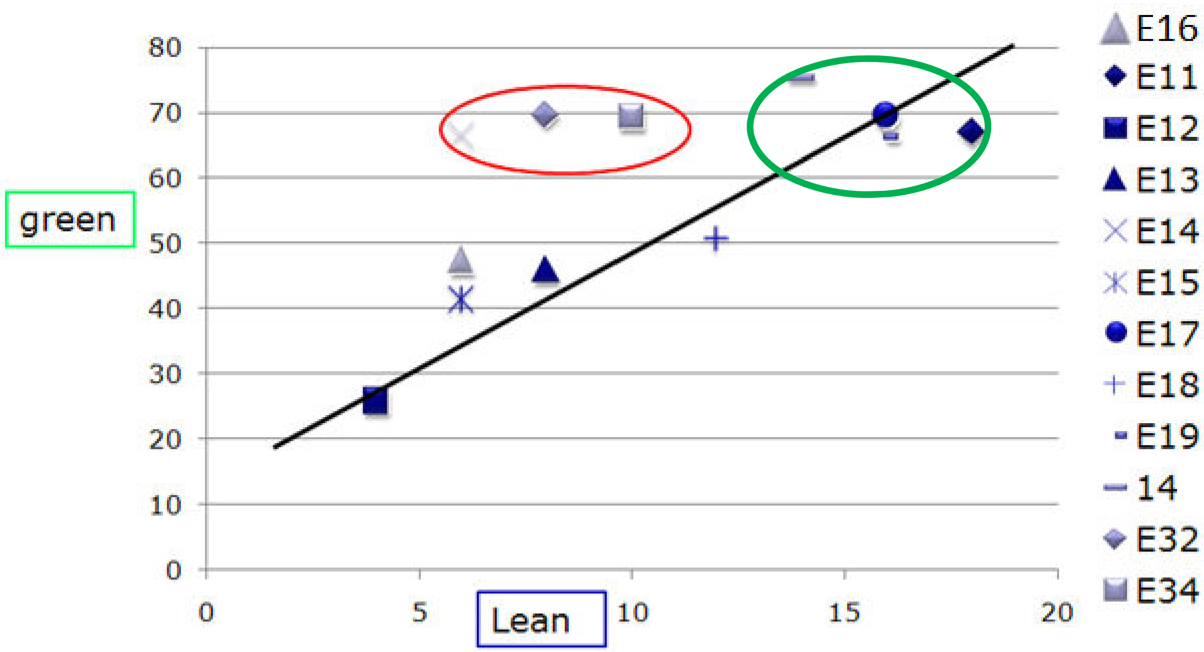

Figure 7: Lean and Green Matrix

The first thing to note from this matrix is the global correlation between Lean maturity and Green initiative in the companies. The "best in class" are once again the contractors. The weakest scores were awarded to suppliers. The average is better for Green initiative than for Lean maturity. Apart from the fact that the "Green" programs are younger in the audited companies than are the Lean initiatives, this performance can also be explained by the global severity of the framework used in the qualitative questionnaire regarding Lean aspects, as well as the higher level of experience of the consultants in the Lean domain than in the Green domain.

The global output of this matrix reveals the existing synergy between Lean and Green maturity: the better the company masters the Lean, the better the results in terms of Green initiative will be. This synergy must be improved, since from a certain level of maturity, Green actions and Lean actions must be undertaken as a whole in order to meet a common target: the quintessence of the Value Stream Mapping, in terms of both cash flow and societal benefits. As an illustration, the consultants' most frequent recommendation was to install photovoltaic cells on the roofs of the facilities.

5 Repository Summary

The analysis of the Lean and Green literature reveals shortcomings in a ready-to-use Lean and Green repository. This study therefore proposes a repository for analyzing the synergies between Lean and Green practices (including indicators allowing the companies to measure their ability to run a Lean and Green policy). The repository also enables the companies to benchmark their practices with other companies, irrespective of their domain of activity or their location. Based on 3 questionnaires targeted at several stages of management within the companies, our repository has the advantage of promoting easy-to-use indicators, based on data that can be gathered without any difficulty.

The results of our survey and study of Alsatian SMEs have provided a tool that can be used to target and promote best practices for Lean-oriented sustainable development, and to improve competitiveness. This tool also enables us to define specific metrics for this approach to improve Lean and Green, in order to allow companies to become the best in class in their industry (Zhu and Sarkis, 2004). Companies could furthermore improve their public image by developing a marketing strategy based on Green and sustainable development (Miller et al., 2008). The repository is able to make a reliable link between Lean maturity and the level of commitment to Green, in various companies. The previous section shows that linking Lean and Green is a real advantage as opposed to implementing two distinct approaches, owing to the synergies created by the implementation of these two concepts jointly.

Another major focus in this study is the scientific and educational value of linking Lean and Green. We could create a repository integrating original antagonistic constraints such as environment and logistics. Capitalizing “Green” knowledge within the Lean philosophy and allowing students to confront issues regarding Lean as the heart of business strategy concern should provide students with tangible and useful competences needed to make the industry more competitive (Hussey and Eagan, 2007).

Last but not least, our interest in this Lean and Green policy is motivated by the fact that it can serve to gradually yet significantly improve the competitiveness of Alsatian companies currently faced with competition from low-cost labour countries, by providing them with the competitive advantage of quality.

6 Conclusion

Increasingly, manufacturers are beginning to recognize the importance of going Green in an era of environmental responsibility. Unlike Lean manufacturing, which focuses on ways to improve operations and cut waste from the customer's perspective, Green initiatives look at ways to eliminate waste from the environmental perspective. Looking at operations from a "Green" perspective can benefit not only the environment, but manufacturers and customers as well. With today's tight credit market, rising raw materials costs, the high price of transportation, stiff global competition and a weak dollar, Lean and Green manufacturing can provide the competitive advantage and profitability that many manufacturers are looking for.

In this article we have proposed a repository to link Lean and Green maturity of industrial companies. We have used a qualitative questionnaire inherited from the Lean philosophy. We have also built a quantitative questionnaire and quantitative indicator in order to capture the real consumption and environmental impact of the companies we studied. Regarding the deployment of this repository, it appears that contractors fare better than SMEs. This can be explained by the general efforts that need to be made in order to enter a "Green" production system. The plotting of Lean maturity and Green initiatives allowed us to identify the fact that contractors have a real advance on SMEs, but can act as catalysts or models for SME suppliers. This can be a major asset not only for targeting the best Lean and Green practices, but also for improving their practices in terms of Lean and environmental impact, to make the companies studied more competitive on the global market.

Further work on the topic could nevertheless be pursued: the repository needs to be more detailed in order to match the business in each industrial domain more closely. Performance indicators could be refined, for example. From a research perspective, guidance must be given on the real benefits of deploying Lean and Green actions by depicting models of Return On

Investments, taking into account the size of the companies as well as their business domain. This is a major challenge to be tackled in order to convince more and more companies, and specially SMEs, to adopt this Lean and Green methodology.

Acknowledgements

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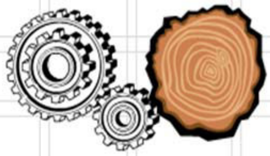
Appendix 1: "A priori" questionnaire extract

LEAN & GREEN APPROACH							
Company :		Function :					
Name :		Date :					
This questionnaire is aimed to evaluate your company environmental impact perception . Thank you for checking one choice for each question below.							
I / Your company's consumption assessment		Not relevant	Non existant	Low	Medium	Significant	Very significant
11	How much electricity do you think your company uses ?						
12	How much petrol for vehicles do you think your company consumes ?						
13	How many packages do you think your company needs ?						
II / Your company's outputs assessment (environmental impact)		Not relevant	Non existant	Low	Medium	Significant	Very significant
21	How much wastewater do you think your company generates?						
22	How much greenhouse gases do you think your company produces?						
III / Your company's environmental management organization		YES	NO				
31	Do you know your company's environmental policy ?						
32	Do you always know where your raw materials come from ?						



Appendix 2: Lean qualitative questionnaire extract

Lean Audit

Weight		Key factor	No Process	Set up Process	Monitored Process	Comments
100		Maturity Level →	1	2	3	0,0
Strategy Planning	A	Strategy planning process settled	Evidence Missing	Process defined to settle objectives. Links with global strategy. Persons in charge are involved.	Process monitored	
	B	Strategy roll-out through action plans	Evidence Missing	Schedule and explanations are given to all employees.	Setting up evidence	
150		Maturity level →	1	2	3	0,0
Lean Management	B	Measures and visual results	Evidence missing	Results put up per category with objectives : employees, quality, costs, services, time.	Factory's results indicators are up to date and regularly reviewed	
	C	Continuous improvement table	Evidence missing	Continuous improvement table set up with each participant name	Actions and ideas records are used and up to date	
125		Maturity level →	1	2	3	0,0

Appendix 3: Quantitative Green questionnaire

Green performance

Quantitative questionnaire

Quantitative data
Turnover of the last year (k€)
Tons of finished products per year (t)
Tons of manufacturing wastes per year (t)
Annual water consumption (m^3)
Annual electric consumption (kilowatt -hour)
Natural gas annual consumption (m^3 or kWh)
Other gases consumption per year (m^3 or kWh)
Annual fuel consumption for heating systems (l)
Annual gas cunsumption for all vehicles (m^3 or kWh)
Fuel annual consumption for equipments (forklift trucks and others) (l)

Article 2: “Environmental performance indicators: review and proposals applied to the “Lean and Green” project”

Environmental performance indicators: review and proposals applied to the "Lean and Green" project

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Abstract

Monitoring key performance indicators (KPI) is a major concern for manufacturing companies seeking a comprehensive way to measure, assess and improve their performance objectives. Since the introduction of the concept of sustainable development in industry, environmental indicators have become a widely debated topic. In this paper, we first synthetize the current state of the art, including scientific literature and normative reviews on quality and environmental indicators aimed at supporting sustainability. We then analyse the environmental reporting of 23 of the CAC 40 companies in order to assess the portrayal of environmental indicators in communication by some of the biggest firms, and to work towards a homogenization of indicators. The study is then continued within the framework of the "Lean and Green project" implemented in several industrial manufacturers from the Alsace region of France, and proposes an indicator selection model and best practices recommendations coming from both benchmarking and scientific literature observations. The study provides an overview of the history and current state of environmental KPI development in industry and highlights important recommendations, especially intended for small and medium-sized enterprises (SMEs), which could lead to better performance results.

Keywords: Key Performance Indicator; Environmental indicators; Lean and Green manufacturing; GRI; Indicators homogenization; SMEs; Indicator selection.

1 Introduction: performance indicators in the industry, towards environmental concerns

"Green growth" aims at pursuing economic development while preventing environmental degradation and investing in the environment as a driver of economic growth. Ensuring that SMEs fully participate in green growth is the key to the large-scale uptake of sustainable practices. The OECD Green Growth Strategy proposes a green growth model that outlines the policies that are required to make the transition and provides a set of indicators to evaluate the efficiency of measures undertaken and assess progress towards greener growth (OECD, 2011). Taking into account the lack of competence of SME's in this field, as well as the multitude of potential indicators, this original study seeks at promoting a pragmatic model providing guidance and a significant linkage between environmental indicators and performance. The study was done in the context of the "Lean and Green" project, initiated by the Alsace region of France in collaboration with the Alsatian Economic Development Agency (Adira, 2015). Conducted among major Alsatian manufacturing firms and SMEs, the project was described in more detail in a previous contribution (Verrier et al., 2014). In this paper, we develop research focused on performance indicators, which are of major concern to the manufacturing industry and for the thoroughness of the research project. To build the study on reliable foundations, we first synthesized state of the art main contributions on industrial indicators from both scientific literature and the industrial standards field; we then analysed the environmental reports of some major multinationals in order to assess how environmental performance external communication is presented. Gaining additional feedback from among the Lean and Green consortium partners, we finally built a selection model, including recommendations and best practice guidelines.

Performance Indicators, usually referred to as Key Performance Indicators (KPIs) in organizational management, are very important management control elements in the setting up of continuous improvement "Plan-Do-Check-Act" (PDCA) methodologies. They represent potentially powerful tools for monitoring and attaining performance objectives.

Industrial performance is very dependent on market variations and has to be increasingly responsive to fluctuations. In the past, economic and financial results were commonly the only indicators used in organization performance assessments. Since the 1990s, both the industrial and scientific communities began to criticize the use of financial indicators as the most common way to assess entire organization results (Berrah, 2002). Moreover these indicators were mainly used for passive result reports rather than for active monitoring and corrective targets.

Nowadays, information and data have increasingly to be both quickly available and reliable, allowing top management to take decisions based on correct indications. Thus, contemporary technical and economic methods often consider performance indicators as management tools covering the whole organization. Large firms as well as SMEs must be aware of their own objectives and possess appropriate resources to assess the situation compared to those objectives. As stated (Kurdve and Daghini, 2012), the right identification and choice of variables and monitoring parameters is essential, particularly in the case of complex systems management.

Basically, indicators are chosen information, matched with a criterion, for the observation of evolution at defined intervals. They have also been defined as “information allowing a defined objective to be reached in the most effective way” (Lorino, 1996).

KPIs may be seen as sensors (which can, incidentally, also be the case for several industrial basic measurements or additional data) with a feedback loop. In this way, the measure is information and the set objective is the comparison reference. Feedback allows actions in relation to the result by comparison to the objectives, according to PDCA reasoning.

KPIs are qualitative or quantitative information depicting process or organization results at a given instant. Measures allow a given performance level to be upheld or improved, critical malfunctions detected or remaining work estimated, while keeping an overview, knowledge and command of the process in question.

At the tertiary level, financial profit indicators, return on investments or supplier delivery schedules are usually the first indicators of interest. At the operational level, most common indicators follow the “cost time quality management” triangle, such as the defect rate, service level, or waiting time.

While there are several well-balanced indicators for assessing quality and lean performance, environmental indicators are a more recent phenomena, which have grown at the same time as sustainable manufacturing awareness, since the early nineties (Hammond et al., 1995). We therefore need to complete our Lean and Green project by a further exploration of environmental indicator and reporting situations in manufacturing processes.

Environmental indicators are performance indicators reflecting in various ways the environmental impact of a defined activity. In our research, they will be more specifically targeted towards manufacturing process emissions and consumption monitoring.

In addition to the previously-cited advantages of common performance indicators, better evaluating environmental performance allows for knowledge of a firm’s environmental impact, opportunities for environmental improvement identification, benchmarking among other similar companies, internal and external communication on results, regulatory compliance, and even employee awareness and involvement enhancement (Paillé et al., 2014).

2 Environmental performance indicators: state of the art

2.1 Scientific literature review

Indicator terms and definitions have been widely addressed in recent decades, leading in the late 1990s and early 2000s to some ambiguities and confusion in the general definition of the concept of an indicator (Gallopin, 1997) (Veleva and Ellenbecker, 2001). In 2002, it was stated (Tyteca, 2002) that procedure standardization and measurement quantity represent major concerns for the environmental indicator debate. Since then, a lot more contributions have been made, without really coming to a successful consensual conclusion. One of the main reasons for this is the enormous amount of different and evolving variables which have to be considered when various and specific areas, fields, process, and situations have all to be addressed and analyzed.

This is probably why, despite some very interesting contributions, we still observed in the course of our research that the selection of indicators is not organized enough, and, even more seriously, not as open and transparent as it should be.

Several papers address and review the general research proposals for a better understanding of environmental sustainability assessment and frameworks (Cloquell-Ballester et al., 2006; Moldan et al., 2012; Singh et al., 2012; Van Gerven et al., 2007), sometimes applied to specific geographic areas or fields (Hsu et al., 2012). Interesting indicators taking into account the three pillars of sustainable development are also presented (Gallardo-Vázquez and Sanchez-Hernandez, 2014).

Since the choice among pre-established indicator listing is not easy, several contributions also investigate the decision-making process.

In this way, some papers propose new visions for the establishment of indicators (Bodini, 2012) or decision and management models, focusing on the defense sector (Myhre et al., 2013; Ramos et al., 2007), or applied to Life Cycle Impacts (Lim and Park, 2009) or meta-performance indicators evaluation (Ramos and Caeiro, 2010) .

One of the best known models is the Pressure-State-Response (PSR) system, based on the causal chains concept, introduced by the OECD in 1991 (OECD, 2003) and widely depicted (17) in 1995 for the world environment institute. Many contributions recall and sum up PSR model evolution and several rely on it to explore ways towards derived models applications (Niemeijer and de Groot, 2008) (Van Gerven et al., 2007) (Niemeijer, 2002).

Niemeijer and de Groot offer a very complete contribution with a first exhaustive review of existing frameworks and a second part proposing a framework for selecting indicators (23). The authors notably argue that an indicator can be interpreted effectively only as part of a consistent and comprehensive set. Thus, their proposal does not focus on the individual selection of environmental indicators, but as a set, where each indicator is joined to the others by causal chains.

Nevertheless, despite the relevance of these decision-making approaches, our research is most closely allied to manufacturing companies, and in particular approaches within the reach of SMEs; for that purpose our work is situated between the complex meta-design models and the over-simple indicator lists often proposed by industrial reports. Our aim is also to lead the study through the scope of a Lean and Green strategy.

Few papers specifically address performance indicators in manufacturing companies; one of the main reasons is probably the extensive existing normative and organizational reports on this subject, as we will see in the second part of this section. However, more studies should be made of the link between normative suggestions and on-site results. Even fewer papers link Lean and Green themes to manufacturing indicators. However, Besseris and Kremmydas did apply embedded Lean and Green indicators to a very specific technical manufacturing process case study (Besseris and Kremmydas, 2014).

As a result, most of the papers analyzed look at structures at a macro-level, with environmental impact measurement for the whole site; other authors look more specifically at companies' needs, such as Herva, which provides a detailed overview of the main indicator categories and best-known calculation methods, with some focus on supply chain life cycle (Herva et al., 2011). The contribution is however positioned in the field of global product and services and cannot be easily linked to our own research topic.

This lack of proposal cohesion is not only found in the industrial context but also in the sector of public administration reports(Mazzi et al., 2012) . Many indicators are displayed as an absolute value or with no common denominators, which appear to lack relevance. These results will be confirmed by our study of the CAC 40 firms' environmental reports, presented in the third section.

One of the main difficulties for firms, and especially for SMEs which are not familiar with management methodologies, is to find correct and easy to use indicators among the diverse indicator listings and roadmaps which often lack cohesion and homogenization.

We propose a flexible and adjustable approach via the Lean and Green strategy, which is more in accordance with previous contributions such as that by Kurtz, Jackson and Fisher (Kurtz et al., 2001), by focusing on the everyday needs of firms and SMEs and offering those companies the first methodological steps towards concrete environmental performance management.

Environmental KPIs handling, as an inherently industrial subject, has been widely addressed in reports by international organizations and in several normative references.

2.2 Normative and organizational references review

2.2.1 The International Organization for Standardization (ISO)

ISO 9001 is a widespread norm on quality management systems and continuous improvement that could be considered as the "ancestor" of the ISO norms aimed towards industrial performance management (ISO, 2015). The ISO 9001:2008 standard specifies, in Section 8, four aspects of monitoring and measurement: customer satisfaction, internal audit, process checks and products checks. The guidance contained therein, especially in the section devoted to data analysis, is very close to indicator management but it provides a general structure and broadly addresses the added value of data collection and analysis, rather than providing indicator examples, decision-making guidelines or a concrete system deployment approach.

ISO 9001 has been widely used in parallel with Lean management systems among manufacturing firms. In order to clarify the existing synergies between the two methodologies and how they can be applied together, in 2011, the French national ISO representative (AFNOR) released the FD X50-819 standard (AFNOR, 2011). In addition, the ISO 9001 revision that should be released in 2015 will eventually feature Lean recommendations (notably through risk management and waste tracking) as well as a deployment system approach enhancement (Micklewright, 2014).

The AFNOR also released in 2000 the FD X 50-171 norm (AFNOR, 2000) on the topic of “indicators and dashboards”. This national norm provides interesting elements for the setting up of a concrete quality indicators management system, and features examples and dashboard representations.

ISO 14001, ISO 50001 and ISO 26000 followed the ISO 9001 quality management system, in the respective areas of environmental, energy and social responsibility management.

The 14001 ISO norm provides structural guidance for environmental management with a focus on operational aspects. Thus, in its 14031 sub-section the standard features environmental indicator classifications and examples.

In ISO 14001, the 14031 ISO Standard on Environmental Performance Evaluation defines three kinds of environmental indicators, which are referred to in some scientific contributions (Henri and Journeault, 2008).

- Environmental condition indicators (ECI), providing information about surrounding environment conditions at different levels (e.g. global, local, national…). Some interesting examples are: contaminant concentration in ambient air (µg/m3) or surface soil (mg/Kg) or even population of a specific species within a critical area (#/m2).

Then there are Environmental Performance Indicators (EPI) which are subdivided into two categories:

- Management performance indicators (MPI), having four sub-categories for providing information on management’s efforts for improving environmental performance. Examples are: environmental cost ($/year), percentage of achieved environmental target (%) or time lost because of environmental incidents (person or hours/year).

- Operational performance indicators (OPI), which are of the most interest for our manufacturing process-oriented research case, are aimed at providing information on a specific process or operational operation, such as raw material used per unit (Kg/unit), Hazardous waste generated per unit of products (Kg/unit) or pollutants emissions in the air or water, without forgetting the waste water discharged per unit of product (1000L/unit).

ISO 14001-compliance can be further linked as a part of the Eco-Management and Audit Scheme (EMAS), which is a regulation helping organizations in their voluntary environmental management system monitoring and performance reporting. EMAS-registered organizations are required to provide reports based on specific KPIs in six environmental areas (Energy efficiency, Material efficiency, Water, Waste, Biodiversity, and Emissions). The corresponding KPIs are however expressed in absolute values.

The 50001 ISO standard on energy management systems was released in 2011. Energy performance being a specific and major part of environmental improvement, this recent norm proposes a structure for energy efficiency system management. The main content of the norm as well as the first observations from companies with early compliance adoption are well addressed by Chiu, Lo and Tsai (Chiu et al., 2012). ISO 50001:2011 already presented some energy performance indicator examples, such as energy consumption divided by production or comparison between realized and targeted consumption on an annual basis. A new subdivision of the standard, released in 2014 and called ISO 50006, provides more specific general principles and guidance for energy performance measurement using “energy baselines” (EnB) and “energy performance indicators” (EnPI).

The gap between scientific literature models and real industrial needs and deployment in the energy field is described by Bunse (Bunse et al., 2011). More research should link energy efficiency with global environmental policy deployment - the two seem mostly to be treated separately.

We may also quote the ISO 26000 standard released in 2010, which addresses societal responsibility and provides an overview of social and environmental indicators through the societal scope. This standard has been linked to the Global Reporting Initiative (GRI) guidelines, that will be detailed in the next chapter, in a jointly published report in 2014 (ISO and GRI, 2014).

2.2.2 The Organization for Economic Co-operation and Development

In the early nineties, the OECD (OECD, 2015) developed the Pressure – State – Response (PSR) model, a widely used simplification of the first “Stress – Response” approach proposed by Rapport and Friend in 1979. This model then became the basis for further adaptations, of which the most well-known are the Driving force – State –Response (DSR) of the United Nations and the Driving force –Pressure –State – Impact – Response (DPSIR), that was eventually drawn up by the European Environment Agency (EEA) (Van Gerven et al., 2007).

As analyzed by Gallopin, in the original PSR framework depicted by the OECD (OECD, 2003), the term pressure is employed to indicate pressures exerted on the environment by human activity; state refers to quality and quantity of natural resources; and the response means how society is responding to these changes through specific environmental, economic and sectorial policies (Gallopin, 1997). A feedback loop then connects the response to the pressure, which complete this system based on causality chains, and also turn it into a system comprising continuous improvement principles.

The OECD also depicts several categories of indicators, including: core environmental indicators (CEI), designed for tracking environmental progress and performance; key environmental indicators (KEI), a reduced set of core indicators aimed at wider communication purposes; the sectoral environmental indicators (SEI), designed to promote environmental integration in specific sector policies; and decoupling environmental indicators (DEI), measuring the decoupling of pressure from economic growth and then evaluating progress toward sustainable development.

In line with current societal trends, the OECD more recently released guidelines for multinational enterprises, involving responsibility aspects in various domains (e.g. human rights, bribery)(OECD, 2011).

To complete these state of the art elements with operational-oriented observations, we studied some of the public environmental performance reports of multinational companies, based on the recommendations of the international GRI guidance. Potentially interesting indications are expected as big firms are usually the earliest certification adopters and the prime targets of organizational guidelines.

An earlier and similar background study was mentioned in our previous work (Verrier et al., 2014). The study revealed an important heterogeneity in the firms' reporting. The purpose of the next section is to extend this study and update previous results.

3 CAC 40 firms environmental performance report study

3.1 The Global Reporting Initiative

The Global Report Initiative is an international organization which actively promotes sustainability reporting standardization. Formed in 1997 and expanded in the early 2000s, GRI's mission is to facilitate “changes towards a sustainable global economy”(GRI, 2014).

They drew up and released the now widespread GRI Guidelines, used by around 4000 companies and organizations in the world for their sustainability reports. One benefit of these guidelines is that they can be used by large organizations, like industry groups, public agencies and even smaller enterprises.

The GRI Guidelines contain the GRI Indicator Protocol Set, which includes a large range of KPI listing sections, such as economic performance, energy, biodiversity, emissions, security, or human rights.

Widely considered as one of the strictest and more reliable guidelines, even in the academic field (Brown et al., 2009), this guidance tool should lead to substantial improvement in the transparency of reports and the benchmarking process.

According to “GRI Indicators Protocols Set Environment” version 3 (GRI, 2006), environmental indicators should be structured to depict the inputs and outputs of the organization, leading in turn to negative impacts on the environment. The inputs evoked are mainly energy, water and raw materials usage. The outputs are mainly emissions in the air, soil and/or water as well as manufacturing wastes. In the organizational structure representation, GRI also considers the concept of biodiversity, which is understood as a natural resource which can be directly polluted by the outputs. Transportation and products/services sections represent further possibilities to harm the environment and are actually a way of looking at some further stages of the product life-cycle through customers and suppliers.

A total of 30 environmental indicators, coded from EN1 to EN30, are thus listed and classified by the following aspects: Materials; Energy; Water; Biodiversity; Emissions, Effluents and Waste; Products and Services; Compliance; Transport; and Overall. Two kinds of KPIs are proposed: the ones considered as essential are defined as “core”, the related “non-compulsory" ones are defined by "add" (e.g. EN8 "Total water withdrawal by source" is the core indicator for the water aspect, while EN9 "Water sources significantly affected by withdrawal of water" and EN10 "Percentage and total volume of water recycled and reused" are the corresponding added indicators). An overview of the whole GRI indicator index is provided in Appendix 1.

3.2 The CAC 40 index

The CAC 40, the stock market index of the 40 most important values on the Paris stock exchange (Bourse), covers a large range of industrial sectors. Since 2002, an annual public environmental report is compulsory for these firms and most of them have based their reports on the GRI Guidelines.

We chose 23 of the CAC 40 firms and analyzed their 2012 public environmental performance reports (released in 2013) in order to study their external communication through environmental KPIs. We concentrated on reports from the manufacturing sector but also selected some from the energy supply, heavy construction, transport and services sectors, in order to obtain a more exhaustive data overview. In the same way, we also added two huge firms that are not currently included in the CAC 40 index: Peugeot Citroën (PSA), which left the index in 2012 and will probably return in 2015, and Air France, which left in 2009, to complete the study.

3.3 Analysis and results

The correlation matrix between GRI environmental KPIs and their occurrence in the firms' public reports can be seen in Appendix 2. The firms are organized in the following sectors: Energy; Manufacturing Industries (including food products, chemicals, electric and electronic equipment, car maker and construction); Heavy Construction; and Telecommunication, Transport and Services.

One of our preliminary findings was that - depending on the company - the reports were not always easily accessible. Usually available on the firm's website, annual public reports may be declined in several sections or, on the contrary, in only one reference for every kind of performance, and generally have various and diverse names In rare cases, environmental indicators were even dispersed in several reports. This indicates the first potential difficulties in handling benchmarking objectives.

As for environmental KPI gathering, GRI is evoked in almost every report as the referential used for the reporting methodology. However, while some reports feature summary grids which explicitly mention GRI KPIs and a link to the corresponding page in the report, others only mention indicators in the text, which makes them more difficult to find. In some other cases, GRI KPIs are not even mentioned, even though equivalent indicators are reported in various sections of the report. In the latter case, occurrences were indicated in the correlation matrix when the displayed indicators closely matched GRI KPIs.

The first thing we observed in the correlation matrix was that three firms were clearly displaying 25 or more GRI indicators, while the average was only 14 (figure 1). Danone is the only firm in our sample that explicitly detailed the 30 GRI indicators in a dedicated section of its annual report. The heterogeneity of the results is illustrated in Figure 1.

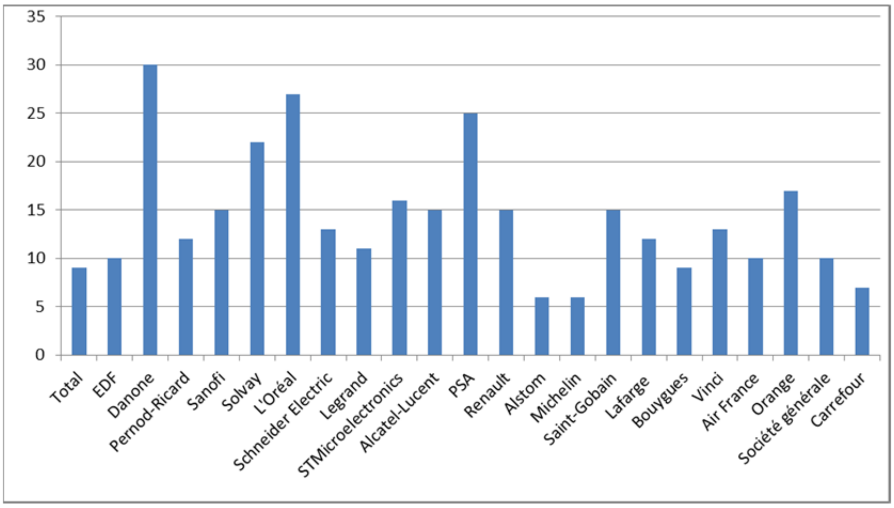

Figure 1: Number of displayed environmental KPI by firm

We also noted that the efforts in the indicators reporting initiative do not seem correlated to the business sector. Even in the case of similar reporting of results, the chosen indicators do not generally match each other.

The matrix overview also showed that the sections of "emissions, effluents and wastes", "energy", and "water" contain the most important number of reported indicators.

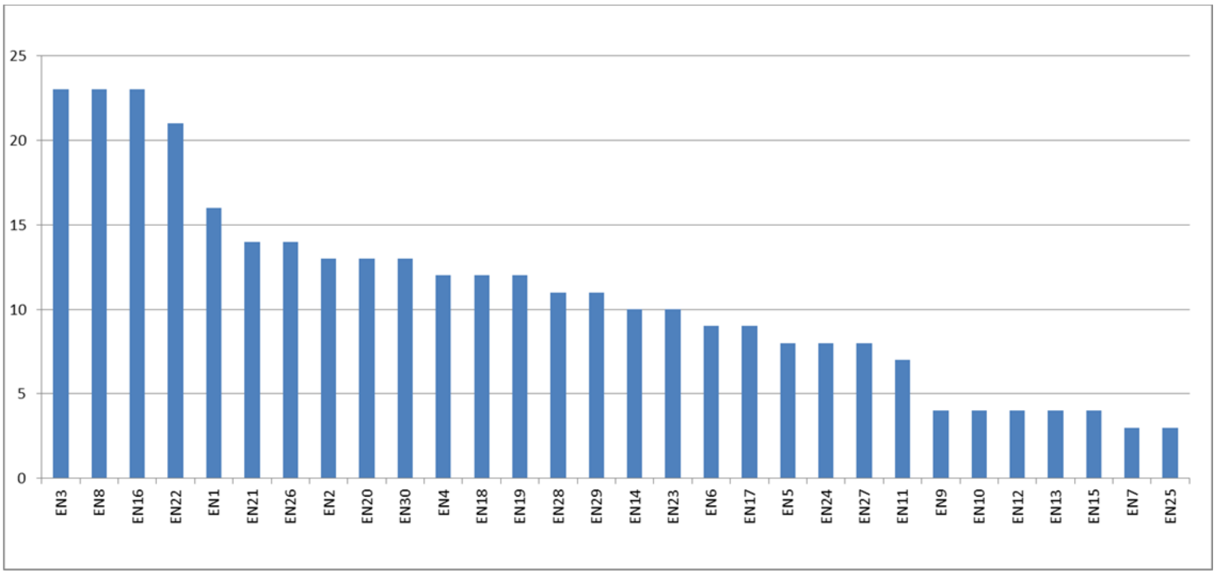

Figure 2: Number of occurrence per GRI's KPI

As we can see in Figure 2, the three following key indicators were displayed in every firm's report:

- EN3: Direct energy consumption by primary energy source
- EN8: Total water withdrawal by source
- EN16: Total direct and indirect greenhouse gas emissions by weight

The following indicators were also well addressed:

- EN22: Total weight of waste by type and disposal method
- EN1: Materials used by weight or volume

These indicators may be considered as the most easy to collect. Another key point is that they are also the most well-known by the general public, especially greenhouse gases, often reduced to CO_2 emissions, which are frequently known as the main cause of climate change and air pollution.

Nevertheless, even if these indicators distinguish themselves among the others, the ones used next are barely quoted by half of the studied companies, although CAC 40 should represent mature and leading companies.

We also noticed that firms often use slightly different methods to report data. EN3 is reported by some as the total direct and indirect energy consumption together; others detail consumption by primary energy sources, like coal, natural gas, nuclear power, biofuel or solar power. Measurement units are also very diverse (e.g. MWh/m², GWh, Terajoules, m^3 or liters).

Even if the basic assessment unit remains m^3, water consumption measurement is not very much better standardized and, as a result, reported in a lot of variations.

The corresponding GRI's KPI, EN8, asks for total withdrawal by type of source, which leads to several kind of classification interpretation in the reports.

Probably for the reasons cited above, greenhouse gases emissions are reported for the majority in the same unit: 63% are expressed in Mt eq. CO2. Nevertheless, the difficulty in distinguishing between direct and indirect emissions still remains.

The total amount of produced wastes indicator (EN22) is generally well-handled, however numerous reporting methods were also observed, due to the very variable kinds of wastes and ad hoc treatments. Rubbish production is also very dependent on the business sector and industrial process. The reporting unit used by the majority of firms is total tonnage per year, which is a good start, although "absolute" indicators cannot be used for proper benchmarking.

The choice of reported indicators, absolute or relative assessments, units and presentations and perimeter definitions, are but some of the several varying parameters making comparisons between companies' real efforts impossible. Veleva and Ellenbecker remind us of the importance of allowing comparisons among companies, and the "four key indicator dimensions" that are necessary to promote better indicator understanding and communicability: unit of measurement; type of measurement (absolute or "adjusted", that we call "relative" in our study); the period of measurement; and the limits of the measure (Veleva and Ellenbecker, 2001).

Our study of several CAC 40 firms' annual environmental reports shows significant, but still insufficient, efforts towards a policy of environmental performance reporting since our previous findings. Such difficulties may only partially be explained by the various business sectors. Indeed, we observed that results are more dependent on individual initiatives than on similarities in industrial activity.

Because data is sometimes only partially provided by companies, results should have been dramatically poorer in the case of a stricter evaluation methodology, including for example the units' homogenization rate.

Niemeijer and de Groot observed a similar "upstream" problem when comparing the recommendations on stratospheric ozone depletion assessment from both OECD and EEA in 2001 (Niemeijer and de Groot, 2008). The comparison shows substantial differences in the selection of relevant indicators, even though it was for the same purpose. And as we mentioned in the literature review, other papers (Mazzi et al., 2012) also show the difficulty in comparing public administration communications with a survey on EMAS-registered Italian public administrations.

The trustworthiness of our study is also partly completed and confirmed by Boiral who explored overall communication characteristics in 23 reports from firms in the energy and mining sectors (Boiral, 2013). Indeed, despite the A or A+ application level GRI had given to the studied companies, the author stressed the opacity and superficiality of the reports and finally compared them to "simulacra". Other recent contributions (Meng et al., 2014) (Fernandez-Feijoo et al., 2014) advised cautious interpretation of a firm's disclosures and analyzed the firms' behavior towards corporate societal responsibility (CSR) reporting . They notably found that stock market companies disclose more information than private companies but with less credibility. "Greenwashing" methods and misleading reports are not, however, what our present research is focused on, though it is important to point out that industrial communication methods, especially when there is a lack of strictness and precision, lead to difficulties in improving model research findings. However, our study contributes to this research field through finding similar results by in-depth exploration of the specific communication on environmental indicators in firms' reports.

According to the results of our study so far, we can say that much relevant guidance exists through models and reports. Notably, ISO norms also take into account the important PDCA methodology, something that new practitioners should be made aware of. However, if we consider that indicator benchmarking is difficult, even among large firms, we can conclude that very few models are attainable for less mature companies, like SMEs. Indeed, analyses tend to show that giving an abundance of indicator listings makes it difficult for non-initiated companies to react quickly and place themselves in long-term performance profitability.

In this sense, the Lean mentality, featuring "step-by-step" daily continuous improvement, makes particular sense. Moreover, Lean is generally better known and accepted than environmental concerns; the association of Lean and Green themes may thus simplify the setting up of environmental performance indicators.

4 Selection and implementation of environmental indicators: best-practices applied to the Lean and Green project

In the first part of this section, we will look at ways to adapt the Lean and Green project among SMEs by proposing a simple model for environmental indicator selection; then, in the second part, best practices in implementation of the recommendations. Our proposals are based on previous investigations.

4.1 Indicator selection model

4.1.1 Environmental indicators prioritizing benchmarking

Some environmental indicators are frequently cited in scientific and normative literature: in the previous chapter we looked at the ones that are primarily used by CAC 40 firms in public communications. In order to concretely link these common recommendations with a company's monitoring priorities, we decided to conduct a short benchmarking. For that purpose we picked ten firms from the Alsatian Lean and Green cluster panel (some of them SMEs), coming from different representative business sectors. We asked them to give the five environmental indicators they actually follow, or would probably follow in order of priority, by descending order. Table 1 shows the results in prioritization order.

	Electricity	Water	Gas	Rubbish	VOC	Other priorities
E1	3	4	2	1	5	• Efforts towards recycling
E2	1	2		4		• Foundry liquids monitoring
E3	1	2		3		• Rubbish recycling rate • Main raw material monitoring
E4	1			3	2	• Rubbish monitoring details (costs – recycling rate…)
E5	1	3	2	4		
E6	1	3	2	4		• Rubbish monitoring • Gasoline consumption
E7	2	3	1	4		• Carbon footprint
E8	1	2	3	4	5	• Water pollution measurement • Product life cycle analysis
E9	1			2		• Setting up of first environmental indicators
E10	2	3	1	5	4	• Emissions reduction

Table 1: Environmental indicator prioritization in the L&G panel

The indicators were ranked from 1 (main priority) to 5 (least). Most companies specified four similar indicators as a priority for their company's overall results. If electricity and gas consumption are considered jointly as an "energy consumption" indicator, we can see three indicators that should be defined as a compulsory starting point, whatever the organization's activity field or type:

- Electricity and/or gas (energy) consumption
- Total water withdrawal
- Rubbish production

These first basic KPI recommendations could lead to the detection of important hidden problems in processes: two companies benchmarked from the electricity product sector detected water leaks thanks to water consumption analysis divided by manufacturing areas, preventing them from further excessive withdrawal or potentially serious deterioration.

We can see the importance of rubbish monitoring, including cost and recycling rates, in the environmental priorities indicated by the companies. On the basis of these indications, we could recommend that companies set up, as a second phase, indicators corresponding more specifically to their activity: notably raw material usage and monitoring. This stage could even be expanded by linking it to rubbish monitoring, via the recycling rate and amount of raw materials coming from recycling products (corresponding to the EN2 GRI indicator).

VOC (Volatile Organic Compound) emissions was the indicator in fifth (and final) position in the panel sample answers, but it was not cited enough to represent a "compulsory" recommendation. This kind of emission is specific to some process (e.g. painting), and has particular impact on ozone depletion. This indicator could be extended to "air emission" monitoring in further selection stages.

Even if these results might be seen as common sense, it was nonetheless necessary to clearly establish these first steps towards environmental KPIs monitoring that were missing up to now. Empirical studies on larger scales could be conducted.

These results are very close, but do not match exactly, the most common indicators in the CAC 40 firms annual reports; this is because greenhouse gases are not primordial as an internal performance driver but very important in an external communication and benchmarking procedure.

4.1.2 Environmental flows

As the GRI considered for its guidelines the general input and output at the different organizational level activities, so can we apply this concept to the process scale, through environmental Value Stream Mapping "VSM"-like methodologies.

At organizational levels, non-specific and general indicators can be used, but deeper in the company processes, indicators must be chosen accordingly to specific needs (Besseris and Kremmydas, 2014).

VSM is one of the most important Lean manufacturing tools. It employs standard symbols to analyze flows and represent processes as they really work, and is completed by some precise information, such as timing or amount of material. What is of interest for our model of that tool, is the ability to visualize an overview of a particular area of activity. When adapted to our environmental indicators concern, this "big picture" allows an easy visualization of the main environmental flows in a process, and therefore the ability to deduce the most important indicators needed to monitor that process.

The more apparent flows should be specific raw materials, energies or rubbish. But we may also cite some common process stages with hidden improvement potential: material treatment (e.g. cutting, processing, cleaning, preparation, soldering, bonding, painting, finishing); process and machinery consumables (e.g. oils, cleaning products); and packaging.

4.1.3 Environmental KPIs selection through green waste seeking

As a further step toward indicator selection through the Lean and Green methodology, we suggest the integration of “Muda” (process wastes, i.e. non-value-added activities for the customer in the Lean thinking) observation adapted to environmental flows. In the previous research (Verrier et al., 2014) we chose to link Lean and Green paradigms through the elimination of both lean and environmental wastes along the manufacturing processes, by using the eight environmental wastes proposed by Peter Hines (Hines, 2009), with an objective of total waste reduction, leading to total quality production.

The eight environmental wastes are defined as: greenhouse gases, eutrophication, excessive resource usage, excessive water usage, excessive power usage, pollution, rubbish and poor health and safety.

By searching for the wastes that an organization or process is likely to be subjected to, the need for specific indicators monitoring should be better understood and lead to more efficient KPI requirements. We thus propose a comparative table with examples of indicators able to cope with specific environmental waste results measurement, improvement or eradication (Table 2). We also indicate in the table, whenever possible, the corresponding GRI indicators, that could be used as a standard. Eutrophication waste, which is the excessive increase of nutrients in water or terrestrial ecosystems, is considered for the purposes of this study as a part of pollution waste because of the similarities between the corresponding related indicators. Most established companies may, however, make separate and specific eutrophication assessments.

Green Muda	Indicative indicators
Excessive resource usage	• Raw materials used (EN1) • Recycled materials amount (EN2) • Eco-design rate
Excessive water consumption	• Water withdrawal (EN8) • Water recycled and reused (EN10)
Excessive power usage	• Energy consumption (EN3-EN4)
Greenhouse gases	• Greenhouse gas emissions (EN16)
Pollution and Eutrophication	• Other emissions in the air including acidification and ozone-depleting substances (EN19 – EN20) • Number of signifiant spills (EN23) • Wastewater treatment initiatives • Chemicals used in process • Transports monitoring
Rubbish	• Total rubbish production (EN22) • Hazardous rubbish amount • Treatment and recycling rate by type of waste
Poor health and safety	• Type and amount of chemicals used in process • Regulatory compliance (EN28) for hazardous substances (RoHS, REACH…) • Number and circumstances of employees expositions to hazardous substances

Table 2: Correlations between green muda's elimination and KPI selection

Each indicator can be used on both an organizational level and/or for specific activity areas, process or machinery. For example, the energy consumption measurement can be set up for a key machine to control its performance year-by-year. By comparing the cost-performance ratio, both potential environmental and economic improvements can be made.

Indicators can be set as a first step as absolute values, but should turn into relative ratio (e.g. establish consumptions by turnover and by a defined tonnage of products) as soon as possible in order to produce reliable assessment data for both internal control and external benchmarking purposes.

We should mention here that some well-known quality tools for performance assessment can also be used as indicator tracking trails (e.g. Pareto charts; Ishikawa cause-and-effects diagram; Failure mode, effects and critically analysis (FMECA); 5 Whys). Indeed, Lopes

Silva et al. have studied the application of some of these tools to overall cleaner production programs (Lopes Silva et al., 2013).

We can summarize the previous section with the model representation in Figure 3:

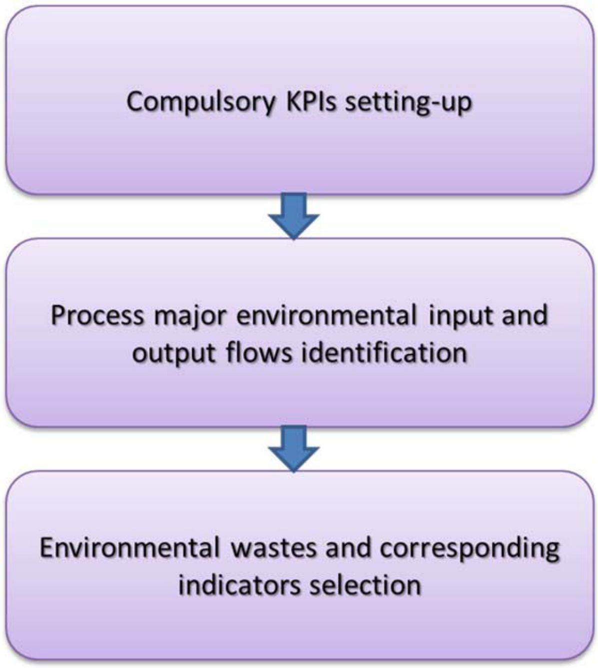

Figure 3: Environmental Indicators selection model

4.2 Indicators implementation recommendations

The guidelines contained in this section are our own selection taken from scientific papers, industrial organizational reports and observations from the Lean and Green panel collaboration, of the important elements to be considered in the indicator implementation process. We may notably cite the major contribution made by Gallopin which was well summed-up by Perotto and defined some important elements to the domain (Gallopin, 1997) (Perotto et al., 2008).

As we said in the introduction, these days firms need to be able to react and take corrective action rapidly and performance indicators are more and more used as performance "drivers" and not only as passive performance result indications (Figure 4).

To be efficient, an indicator system should tie a top-down management leading objective to a bottom-up feedback, providing knowledge on the operational situation.(Asif et al., 2013).

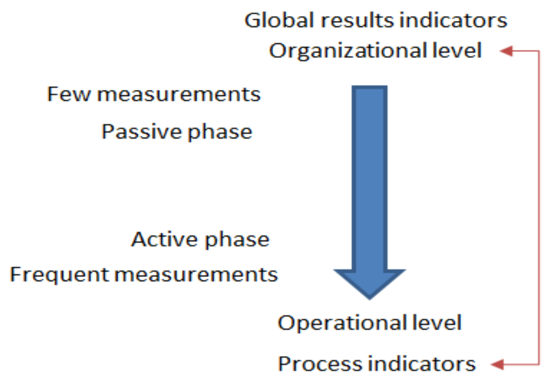

Figure 4: Synthesis of the relations between process indicators and results indicators

Elements to be considered before any indicator implementation:

- Properly defining objectives and the context of implementation (specificities)
- Never using too many or too few indicator measurements
- Including global results (absolute values) as well as comparing ratios (relative values, for example /tons of finished product)
- Involve every stakeholder

Indices to measure an indicator's reliability (Tyteca, 2002):

- Relevance (significant of the studied phenomena)
- Achievability (accessible data)
- Objectivity (observable values)
- Transmissibility (avoiding misunderstanding between stakeholders)

A simple measure should never be an end in itself: it is a tool that needs to be converted into results, analyzed and updated. It is pointless to set up indicators without making proper use of them.

Another point to be careful with is the validity of measurements (by sensors as well as by calculations); even after a correct indicator selection, validity must be regularly checked (the initial context is subject to fluctuations). It must also be borne in mind that even when validity is proven, a certain risk of measurement uncertainty exists and must be taken into consideration in the interpretation of indicator results. (Perotto et al., 2008).

Internal communication on corporate environmental policy and visual environmental indicator management may encourage employee involvement, which in turn can enhance environmental performance (Paillé et al., 2014). In order to share leading and federating objectives among production teams, some firms even display indicators directly in the production processes areas.

5 Conclusions and further research

Environmental indicators enable firms to measure their environmental performance. In practical terms, they can be used to create a measuring, benchmarking and monitoring tool to track the environmental performance of small and medium enterprises (SMEs). In this paper, we have made an extended study of environmental performance indicators, including a state of the art on the existing scientific and normative literature, specifically oriented towards environmental indicators selection and proposals for implementation models. We then studied the public environmental performance reports of 23 representative firms from the CAC 40 index. Our findings show a lack of cohesion and homogeneity between the different reporting policies. It was also clear that initiating KPI monitoring could be difficult for less established companies like SMEs. An important finding of our research is that, in spite of their inherent importance, the environmental indicator selection process is more dependent on the firm's maturity than on business sector characteristics.

Hence, our analyses to date, completed by industrial observations in Alsatian firms and SMEs from the Lean and Green project cluster, meant we were able to put together a "first steps" KPI pragmatic selection model and best practices recommendations for the setting-up process. Our model is composed of three implementing stages (common bases, environmental flow vision, environmental waste tracking). It is progressive, adaptable at organizational or operational level and adjustable to companies' specificities and needs.

Our work should enable companies and practitioners to easily initiate environmental performance indicator monitoring in their processes, through flows observation and daily continuous development towards lean-based thinking. This would enable a significant link to be made between environmental indicators and environmental performance.

An additional line of research could be the incorporation of social indicators for monitoring total corporate social responsibility (i.e. including economic, social and environmental paradigms). Social and societal concerns could be easily added to corporate policy management by linking them to environmental concerns through "health and safety" waste management. Hazardous chemical substances represent a danger both for the environment and human beings; in non-optimized production processes employees are likely to be the most affected.

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Appendix 1: GRI environmental indicators index from the "Indicators Protocols Set Environment", v.3, 2006.

Aspect: Materials

CORE	EN1	Materials used by weight or volume.
CORE	EN2	Percentage of materials used that are recycled input materials.

Aspect: Energy

CORE	EN3	Direct energy consumption by primary energy source.
CORE	EN4	Indirect energy consumption by primary source.
ADD	EN5	Energy saved due to conservation and efficiency improvements.
ADD	EN6	Initiatives to provide energy-efficient or renewable energy-based products and services, and reductions in energy requirements as a result of these initiatives.
ADD	EN7	Initiatives to reduce indirect energy consumption and reductions achieved.

Aspect: Water

CORE	EN8	Total water withdrawal by source.
ADD	EN9	Water sources significantly affected by withdrawal of water.
ADD	EN10	Percentage and total volume of water recycled and reused.

Aspect: Biodiversity

CORE	EN11	Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas.
CORE	EN12	Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas.
ADD	EN13	Habitats protected or restored.
ADD	EN14	Strategies, current actions, and future plans for managing impacts on biodiversity.
ADD	EN15	Number of IUCN Red List species and national conservation list species with habitats in areas affected by operations, by level of extinction risk.

Aspect: Emissions, Effluents, and Waste

CORE **EN16** Total direct and indirect greenhouse gas emissions by weight.

CORE **EN17** Other relevant indirect greenhouse gas emissions by weight.

ADD **EN18** Initiatives to reduce greenhouse gas emissions and reductions achieved.

CORE **EN19** Emissions of ozone-depleting substances by weight.

CORE **EN20** NO_x, SO_x, and other significant air emissions by type and weight.

CORE **EN21** Total water discharge by quality and destination.

CORE **EN22** Total weight of waste by type and disposal method.

CORE **EN23** Total number and volume of significant spills.

ADD **EN24** Weight of transported, imported, exported, or treated waste deemed hazardous under the terms of the Basel Convention Annex I, II, III, and VIII, and percentage of transported waste shipped internationally.

ADD **EN25** Identity, size, protected status, and biodiversity value of water bodies and related habitats significantly affected by the reporting organization's discharges of water and runoff.

Aspect: Products and Services

CORE **EN26** Initiatives to mitigate environmental impacts of products and services, and extent of impact mitigation.

CORE **EN27** Percentage of products sold and their packaging materials that are reclaimed by category.

Aspect: Compliance

CORE **EN28** Monetary value of significant fines and total number of non-monetary sanctions for non-compliance with environmental laws and regulations.

Aspect: Transport

ADD **EN29** Significant environmental impacts of transporting products and other goods and materials used for the organization's operations, and transporting members of the workforce.

Aspect: Overall

ADD **EN30** Total environmental protection expenditures and investments by type.

Appendix 2: Correlation matrix between GRI environmental KPIs and their occurrence in CAC 40 firms' public environmental performance reports

KPIs		Materials		Energy					Water			Biodiversity					Emissions, Effluents, Waste										Products & Services		Compliance	Transport	Overall
Firms		EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	EN13	EN14	EN15	EN16	EN17	EN18	EN19	EN20	EN21	EN22	EN23	EN24	EN25	EN26	EN27	EN28	EN29	EN30
Energy	Total	x		x					x								x				x	x	x						x		x
	EDF	x		x			x		x								x				x	x	x		x						x
Manufacturing Industries (Food products - Chemicals - Elec. equipment - Automotive - Construction sectors)	Danone	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Pernod-Ricard	x		x	x				x	x							x			x		x	x		x				x		x
	Sanofi	x	x	x					x	x		x				x	x			x	x	x	x				x			x	x
	Solvay		x	x	x	x	x		x			x	x	x			x	x	x	x	x	x	x	x	x		x		x	x	x
	L'Oréal	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x		x
	Schneider Electric		x	x	x	x			x						x		x	x		x	x		x				x			x	
	Legrand			x	x	x			x								x	x		x			x				x		x	x	
	STMicroelectronics	x		x	x				x		x						x	x	x	x		x	x	x			x	x		x	x
	Alcatel-Lucent	x	x	x	x				x								x	x	x	x	x		x	x			x	x	x		
	PSA	x	x	x		x	x		x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	Renault	x	x	x		x			x			x					x		x		x	x	x	x			x	x		x	
	Alstom			x	x				x								x					x	x								
	Michelin			x					x								x			x			x				x				
	Saint-Gobain	x	x	x	x				x								x	x	x		x	x	x	x			x		x		x
	Lafarge	x	x	x	x				x		x	x			x		x				x		x								x
Heavy construction	Bouygues		x	x			x		x						x		x		x								x	x			
	Vinci	x	x	x			x		x						x		x		x				x		x		x		x		x
Transports, Telecom, Other Services	Air France			x					x						x		x			x	x	x	x		x						x
	Orange		x	x	x	x	x	x	x						x		x		x			x	x	x			x	x	x	x	
	Société générale	x		x			x		x						x		x		x				x							x	x
	Carrefour	x	x	x					x								x							x						x	

Article 3: "The Lean and Green project methodology: assessment and implementation roadmap, best practices recommendations from case study observations”

The Lean and Green project methodology: assessment and implementation roadmap, best practices recommendations from case study observations

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Abstract

The quest for industrial performance linked to sustainability means that industrial firms need to promote eco-efficiency policies at a strategic level. The association of Lean manufacturing and environmental concerns is therefore of major interest nowadays, in both academic research and manufacturing industries, as a tangible way of complying with those constraints. This study presents an original Lean and Green roadmap, enabling strategic issues to be converted into operational action. It is intended to help practitioners and especially SMEs to take the first steps towards Lean and Green continuous improvement procedures. The project was conducted through iterative case-study research, based on Lean and Green investigations conducted within major firms and SMEs from the Alsace region of France. Enhanced by an extended literature review, this paper presents the Lean and Green assessment and implementation roadmap, an environmental benchmarking analysis, as well as best practice recommendations, including Lean, environmental and social concerns.

Keywords: Lean and Green roadmap; Green manufacturing; Industrial best practices; Case study

1 Introduction

Identifying and eliminating non-value-added waste (also known by the Japanese term “muda”) in manufacturing processes is now of major interest to industrial companies. When used as an embedded industrial performance policy, maximized by continuous improvement, the Lean methodology has already proved its ability to increase competitiveness, since its origins in the Toyota Production System (TPS).

Industry is facing new challenges, as environmental regulations and customer expectations play an increasingly important role. The aim of our research was therefore to link “green” concerns to “Lean” methods, through the elimination of Lean wastes and Green wastes, enabling firms to achieve total quality management.

While focusing on environmental concerns, we also consider the triple bottom line (TBL) included in Corporate Social Responsibility (CSR), corresponding to the application in the industrial field of the three pillars of sustainability as defined by the Brundtland Commission in 1987 (Economic - Environmental - Social).

As has been demonstrated from a qualitative point of view in previous research (Verrier et al., 2014) and confirmed by scientific literature (Dües et al., 2013; Fercoq, 2014), the link between the Lean and Green axes appears to be a suitable way to turn current industrial constraints into potential for growth.

Linking Lean and Green actions in a roadmap should increase competitiveness and benefits - including costs and the reduction of environmental impact - optimize processes and employee involvement and reinforce customer satisfaction.

The Lean and Green Project (Verrier et al., 2014) was initiated by the Alsace region of France and coordinated by the Economic Development Agency of the Bas-Rhin (ADIRA)(Adira, 2015) since 2010. Its objective is to define and enhance industrial best practices in Alsatian firms and SMEs, using an approach associating Lean manufacturing and sustainable development.

The project followed a case-study approach as a research methodology and was conducted through an iterative collaboration method with ADIRA and the industrial partners. The roadmap presented is therefore itself subject to a continuous improvement approach. This new contribution includes the results of the second edition of the Lean and Green project, started in 2013 and conducted for a year and a half. We enhanced the experiments, results and findings of both editions by the presentation of a Lean and Green practical deployment roadmap, designed to be used by less mature companies like SMEs, and linking strategic issues to operational action. According to Blanc et al., a roadmap is a formal framework detailing the action plans that contribute to a strategy implementation. In the case of the Lean and Green management deployment, the use of a formal roadmap is aimed at structuring the actions, assessing the workload and proposing ad hoc benchmarking and management indicators linked to efficiency and sustainability.

The project was built around stakeholders from various scientific and industrial fields, including the Icube Research Laboratory, consultancy companies, SMEs and major firms representative of the regional industrial network. It was funded jointly by the Alsace Region and the Ministry of the Economy.

The next section presents an updated and extended review of literature on environmental issues relating to firms' performances. The deployment roadmap is described in detail in section 3, then the results of the benchmarking procedure are presented and analysed. Finally, social considerations, through recommendations based on industrial observations, are introduced.

2 Latest scientific publications

Our previous extensive literature review on Lean and Green topics (Verrier et al., 2014), particularly highlighted recent interesting contributions to this field (Bergmiller and McCright, 2009a; Duarte et al., 2011; Dües et al., 2013; Simons and Mason, 2003). The latest update of this review, focusing on the current decade, confirms the growing interest in the association of environmental and productive performance. The number of contributions has almost doubled in only three years, evidence of the growing importance of this research field. However, few papers have chosen to investigate Lean and Green topics through the elimination of their inherent mudas in production processes. Indeed, Lean and Green approaches are still widely treated at the macroscopic level, which is not unusual considering the relative novelty of this subject and the different specificities and complexities of manufacturing processes. In order to be as representative as possible, the present review has been expanded to literature on supply chains, as the study of manufacturing processes cannot be totally isolated from the life cycle that surrounds them.

Global consideration of environmental practices in traditional manufacturing processes is dealt with by some interesting recent publications, which propose new case studies and outlines (Ahemad.A.Rehman et al., 2013) (Asif et al., 2013) (Thoumy and Vachon, 2012). Some authors complete this general association by studying Green Manufacturing to Product Life Cycle Management and Information Systems (Vadoudi et al., 2014) (Meteyer et al., 2014). Roy says that the association of quality and green performance in production areas may represent a positive evolution for Environmental Management Systems (EMS) (Roy et al., 2013), while Heras-Saizarbitoria et al. recall that internal sources of motivations are key elements for better EMS outcomes (Heras-Saizarbitoria et al., 2015).

Interest in green supply chains has not decreased: interesting and extensive literature reviews on green supply chain management have been published by several authors (Fahimnia et al., 2015b; Subramanian and Gunasekaran) (Martínez-Jurado and Moyano-Fuentes, 2014). Several very recent papers propose models on the supply chain level (Dubey et al., 2015), with a thorough mathematical tradeoff approach between cost and environmental supply delivery tactical planning (Fahimnia et al., 2015a), green partner selection (Wu and Barnes, 2015), or a conceptual assessment model derived from Lean, Green and Resilient data analysis (Govindan et al., 2014) (Cabral et al., 2012). Other interesting papers have developed analyses on supply chain and corporate environmental strategies alignment (Wu et al., 2014) and on the effects of Lean and supply management on environmental practices and performances (Hajmohammad et al., 2013). Duarte and Cruz-Machado specifically handled Lean and Green themes along a supply chain assessment framework (Duarte and Cruz-Machado, 2015).

In general, social concerns are also addressed more frequently, especially through the association of Corporate Social Responsibility (CSR), representing the integration of the three pillars of sustainability in the industry, with their potential effects on financial performance (Gallardo-Vázquez and Sanchez-Hernandez, 2014). Authors notably explore how socially-related activities and metrics can be added to sustainable manufacturing exploration and quality management to foster competitive advantages (Brown et al., 2014) (Frolova and Lapina, 2014) (Golini et al., 2014) (Herrera, 2015).

This increasing treatment of social and ethical concerns continues in the field of supply chain strategies (Klassen and Vereecke, 2012). However, there is still a lack of concrete applications, notably between Lean supply chain and social performance ad hoc metrics (Martínez-Jurado and Moyano-Fuentes, 2014). This positive trend should be the subject of further research and developed in the near future, in association with Lean and Green concerns.

An increasing number of papers address the influence of Lean methods and tools on the reduction of environmental impacts. Jabbour et al. find evidence that Lean management has a positive impact on environmental management, which itself has a positive impact on operational performance (Jabbour et al., 2013). Chiarini underlines interesting links between specific basic Lean tools and their consequences on environmental performance (Chiarini, 2014), and the results reinforce the relevance of the approach used in the Lean and Green Project. Similarly, Faulkner and Badurdeen developed a value stream mapping-oriented methodology, called Sus-VSM (Faulkner and Badurdeen, 2014).

Several research projects have now specifically addressed Lean and Green themes associated to manufacturing processes (Pampanelli et al., 2014) (Chiarini, 2014) (Galeazzo et al., 2014) (Diaz-Elsayed et al., 2013) (Kurdve et al., 2014). Bergmiller was one of the first to explore this area in 2006 (Bergmiller, 2006). Most of these contributions, including our previous research paper (Verrier et al., 2014), are included in a dedicated issue of the Journal of Cleaner Production, Volume 85 (Dhingra et al., 2014). Few research projects proposed a Lean and Green framework, but most confirmed the ability of Lean and Green thinking to substantially reduce resource usage and increase cost benefits. Pampanelli, Found and Bernardes develop a Lean and Green model for manufacturing cells in Brazilian automotive companies and consider that previous implementation of a Lean basis was a prerequisite to establishing the model (Pampanelli et al., 2014). While, on the contrary, Galeazzo, Furlan and Vinelli consider that each approach can be implemented either sequentially or simultaneously (Galeazzo et al., 2014). Parallel implementation was already widely debated by Bergmiller (Bergmiller and McCright, 2009a). As our research is especially intended for SMEs, while being based on observations in major firms, our roadmap starts with a comprehensive assessment, which and can be used by companies with experience of Lean implementation or not.

These contributions are close to our research topic, a mark of its swiftly growing importance. All of the above-mentioned research projects have added valuable data, ideas and food for thought to this field of research.

Empirical studies in the environmental field have gained greater importance and have laid the foundations for further research based on practical data and modeling (Fahimnia et al., 2015b). Our research has similar goals: fostering real links between academic studies and industry through industrial collaboration, coupled with thorough scientific research. In addition to its focus on SMEs and on case studies in French firms, the originality of our work lies in the search for Lean and Green mudas as a catalyst for parallel implementation of Lean and Green thinking in total waste reduction. In the next section we present the Lean and Green Project roadmap in line with these characteristics.

3 Emphasizing Lean and Green benefits among manufacturing firms: Lean and Green assessment and deployment roadmap

As it is often difficult for SMEs to implement new organizational information technology systems (Le Duigou et al., 2012), our research aimed to propose an adaptable methodology, primarily based on cultural and behavioral changes.

Kaizen (Japanese for “good change”) and Plan-Do-Check-Act (PDCA) (Deming, 1994) continuous improvement methodologies are at the center of Lean thinking, enabling new industrial processes and organization to be viewed from a different angle. Indeed, as has often been observed since the Toyota Production System became widespread in many firms, Kaizen is about small but constant enhancements that lead to simple but concrete improvements at little cost. Continuous improvement is all about taking a global view, correcting problems at source, moving ahead on solid bases, rather than beginning with substantial changes. It can make significant improvements to a firm’s production processes and organization.

That is why a company’s size or sector of activity are not determining issues for the success of Lean and Green deployment; its success mainly depends on adaptation to process specificities, corporate philosophy and employee involvement.

Improvement projects are commonly led by “kaizen teams”, composed of multidisciplinary employees, meeting on a regular basis with a defined objective. An example of a well-developed application of this method can be found at the French Toyota Plant in Onnaing (France),where every employee have meetings among kaizen teams for approximately one hour every two weeks.

In any system, waste can be defined as anything that does not add value to the product or provide a service for the customer. In manufacturing processes, the eight Lean wastes or “muda” are defined as: overproduction, defects, unnecessary motion, unnecessary inventory, inappropriate processing, transportation, waiting and lost people potential; they all lead to potential disorganization as well as loss of benefits and motivation.

As for environmental issues, they are often tackled from the normative and legislative points of view without any global policy; even companies certified under the International Organization for Standardization (ISO) 14001 sometimes only did this for their clients' satisfaction without making real use of its inherent benefits. However, as Garbie reminds us, sustainable development assessment is important for manufacturing companies for both self-assessment and to determine their requirements for further positive development (Garbie, 2014).

In our study we look at eight green manufacturing wastes as defined by Peter Hines (Hines, 2009): greenhouse gases, eutrophication, excessive resource usage, excessive power usage, pollution, rubbish, excessive water usage, and poor health and safety.

The following assessment model and recommendations are the result of our research in both the scientific field and industrial observation through our partnership with the ADIRA. Our work particularly targeted industrial improvement objectives, coupled with many scientific references in order to enhance the resulting recommendations. We also based our findings on models drawn up by national and international organizations, which themselves have widely influenced existing scientific literature (ADEME, 2015; E2M, 2015; GRI, 2014; OECD, 2015; OREE, 2015).

Since our study is intended for both large firms and SMEs, Lean is considered essentially to mean Lean thinking, waste elimination, and basic tools. The benchmarking process focused on environmental results, as this was a prerequisite of the industrial partnership. Lean and Green audits were generally held during three half-days, and were based on three questionnaires relevant to every kind of manufacturing industry. The questionnaires aimed to highlight a firm's qualitative and quantitative characteristics and were submitted to a polyvalent internal "kaizen" team, the members of which were directly concerned by the targeted processes or activities.

The roadmap, used both to assess and implement the procedure, featured two exclusively "green-oriented" and one "Lean and Green" qualitative questionnaires. The first one was designed to provide a preliminary insight into the level of environmental consciousness of each team member of their own company's consumption and impact. The second questionnaire was a qualitative survey of Lean and Green themes submitted to two internal experts, to assess the way Lean and Green procedures were handled in the company. The third questionnaire was a quantitative survey to collect environmental consumption and emission data.

The chronology was:

- Preliminary submission of the quantitative questionnaire to the internal environmental manager
- Meeting: presentation of the approach, the team and the targeted processes
- Establishment of Lean Value Stream Mapping
- Discussions and courses of action
- Introduction of the green topic: study of the first questionnaire
- Green mapping on the shop floor and debriefing on improvement potential in a meeting room
- Study of the level of maturity of the setting up of Lean and Green methodologies with the second questionnaire
- After analysis of the questionnaires: general debriefing, recommendations, issuing of reports

For the launching of the audit to be successful, the method must be explained and presented to all the internal employees who are involved. The field of study must be delimited and the approach must be planned and well organized.

The field and perimeter of the study must be chosen according to possibilities and priorities. For a very small enterprise it might be better to study its activity as a whole, but to choose a specific production line in bigger firms.

Attention must especially be paid to processes with the most environmental improvement potential or with major environmental concerns. At the outset, the approach should be targeted towards a sector where progress is easier to reach. It is also important to bear in mind whether an approach will bring more value to the final customer.

The Lean and Green Project questionnaires were set at the organizational level; however they can also be applied to specific activity areas or processes.

3.1 First environmental assessment steps: questionnaire n°1

The first questionnaire has been slightly modified since our previous research (Verrier et al., 2014) in line with the teams' comments and answer rate. This questionnaire is aimed at providing a snapshot of how each team member, coming from the different activity fields but linked by the L&G project, initially assesses, without preliminary observations, their own company's environmental consumption and impact (Appendix 1).

It has three parts: the first is about resource consumption estimation, including energies; the second is based on emissions, including production of rubbish; and the third asks questions to judge the maturity of the company's environmental policy.

This questionnaire often gives interesting preliminary results on the consistency of environmental consciousness and communication by top management within a given company. Several heterogeneous answers may illustrate a lack of maturity in corporate communication policy, and should raise participants' awareness of environmental impacts and the importance of communication.

The results may also highlight the importance of monitoring appropriate key performance indicators and handling their communication through visual management. Specific research on the key performance indicators applied to the Lean and Green Project was carried out in a parallel study[1].

If the company is not mature enough to submit the questionnaire to its team it can initially only be completed by the person in charge. But, whatever the case, this first internal questioning gives a snapshot of the overall "feeling" within a company and highlights the first possible areas for improvement.

3.2 Qualitative L&G assessment questionnaire

The second questionnaire was initially developed by Steelcase as an internal tool to assess production site performance. It was adapted to the Lean and Green Project and has been used since the first edition of the project. The questionnaire uses the same philosophy as the Shingo

Prize Ranking (Shingo Prize, 2014): a qualitative investigation supported by an Excel file, targeting internal managers in charge of Lean and environmental development respectively. The questions concern the internal level of project development of several aspects of Lean and Green management (e.g. strategy planning processes, risk analysis, setting-up of the main Lean tools, regular meetings, environmental impact reduction projects…). Automatic grading gives a qualitative assessment percentage, indicating the maturity of the project set up and actions undertaken. An extract of the questionnaire is available in our previous research paper (Verrier et al., 2014).

As the questionnaire is not available in its entirety for reasons of confidentiality, and as it could present a relative difficulty to apprehend for SMEs, we have produced a simplified questionnaire, enabling an overview of the maturity in both Lean and Green projects deployment. It also details an easy calculation system in order to make possible a quick internal or external benchmark qualitative assessment (Appendix 2).

3.3 Environmental flows and L&G waste mapping

A production process can be visualized as a system of incoming and outgoing flows related to the environment. The main inputs are usually linked to energy and material resources, but also to additional implied substances. Apart from the final product, output flows are often linked to rubbish and emissions liable to have negative effects on humans and the environment.

Unnecessary consumption, leading to unnecessary pollution, must be considered as waste and avoided as far as possible. In fact, in the majority of cases, environmental waste brings no added value to the customer and, on the contrary, may directly affect production quality and costs.

Value Stream Mapping (VSM) is an essential Lean manufacturing tool which uses standard symbols to represent, inter alia, time and quantity process flows. We already looked at the importance of a simplified environmental value stream mapping adaptation in order to find easy-to-use progress indicators[1]. On a larger Lean and Green audit methodology scale, being able to visualize the main environmental flows of a particular area of activity, through green mapping, is of great interest for detecting potential environmental waste, and therefore to be able to control it.

Lean VSM has been well documented in scientific literature since the end of nineties (Rother and Shook, 1999), while sustainable-oriented VSM, especially at supply chain level, has seen growing interest in the last decade (Torres and Gati, 2009) (Simons and Mason, 2003).

Considering the complexity and variations of each process in similar companies or even within the same company, there are still few papers dealing with specific process oriented mapping. However, Brown et al. (Brown et al., 2014) successfully implemented the Sus-VSM model in different construction environments (Faulkner and Badurdeen, 2014). It has also been proved by Chiarini that VSM can be used efficiently for identifying environmental impact (Chiarini, 2014).

The relevance of our approach is more specifically confirmed by Wills, who explored how environmental value stream mapping could add positive benefits to environmental management policies (Wills, 2009). However, in our study we consider green mapping as a tool that can be implemented both to a greater or lesser extent (e.g. organizational, production process, process parts), instead of mainly looking at plant macro-level stream maps.

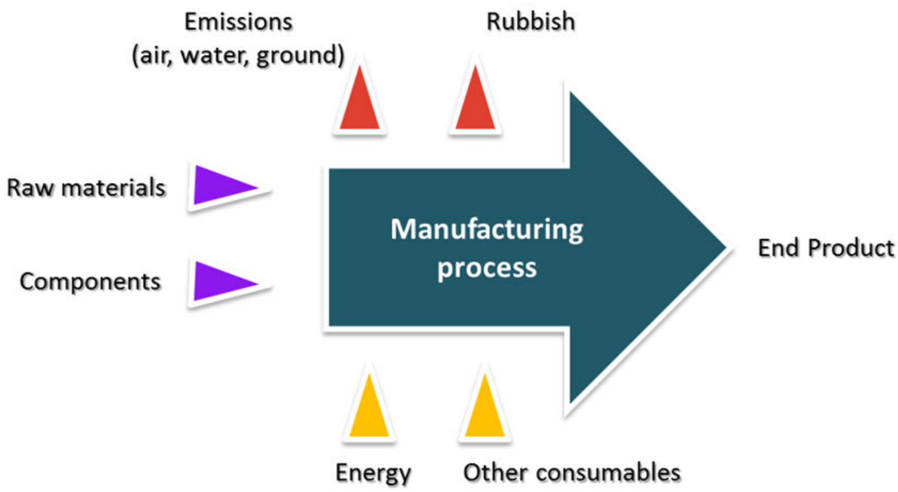

Figure 1: Green mapping flows

We propose the following green mapping method, based on the input and output depicted in Figure 1:

- Visit the production process site in action
- Gather as many information flows as possible by observing input and output

- Complete the mapping by quantitative and additional data with the aid of the operational team members (e.g. quantities, hidden machinery flows)
- Hold a meeting with the L&G kaizen team to share the different results and highlight improvement potential
- Prioritize and schedule the changes

Prioritization may be done according to the considerations shown in Figure 2:

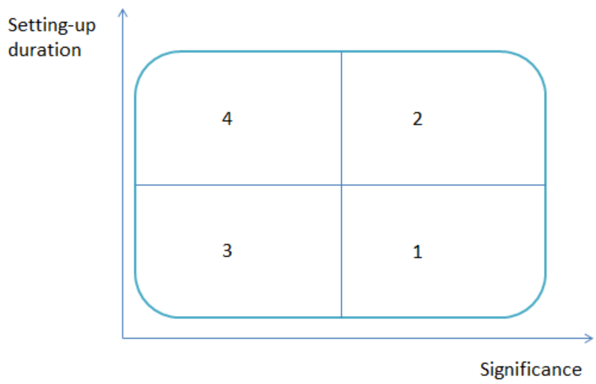

Figure 2: L&G improvement projects prioritization matrix

The duration of the setting up period, including finding the necessary means, is a potential difficulty for project development. "Significance" represents the importance of the potential improvements of the development.

A practical way to routinely apply this methodology in production processes is to run at organizational level the so-called Genchi Genbutsu approach, meaning "go, look and see", most often applied through "Genba Walk" ("walking in the real place", represented by the factory floor in manufacturing processes). This approach means taking top management and engineers to the production lines in order to identify wasteful and non-value-added activities and to try to find practical improvements. As explained by Tisbury (Tisbury, 2011), such a practice should be done by managers on a daily basis to give them a better understanding of how the process is actually working. Other connected benefits are waste identification, promotion of team work and improved relations between management and employees (which is helpful for the quick resolution of any problems that crop up).

Thus, in addition to mapping flows, the Genba Walk enables identification of Lean and Green wastes directly on the shop floor, and therefore completes the identification of potential improvements (Figure 3).

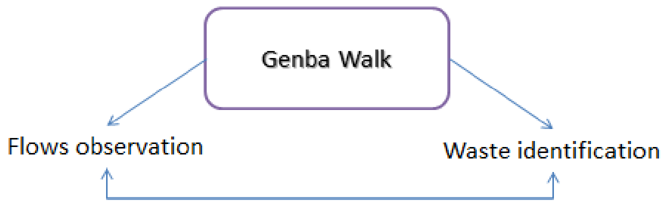

Figure 3: Highlighting of flows and wastes through genba walk

In collaboration with Siemens, we developed a Lean and Green wastes Genba Walk support tool. This "wastes observation" sheet, completed with pragmatic examples, is reproduced in Appendix 3. It should allow Lean and Green practitioners to set up a regular Genba Walk.

3.4 Quantitative green questionnaire

In order to complete the benchmarking information gathered by the qualitative inquiries, the third questionnaire collects quantitative data on environmental consumption and emissions, either for the whole site (in the case of our benchmarking project) or for a defined process. It should be completed by an internal environmental manager. This data, converted into relative ratios, is essential for environmental assessment and improvement among firms and SMEs.

There were two versions (exhaustive and synthetic) of the third questionnaire for the first Lean and Green Project; which were revised and merged into one for the second edition in line with the feedback received. The updated version takes into account a diversified range of consumption and emission indicators, while concentrating on the essential ones, so as to gather the most reliable data possible. It also features an introduction with preliminary specifications of key points and asks for precise information on the areas concerned.

As we can see in Appendix 4, questions are divided into three chapters, covering general information, consumptions/input flows and emissions/output flows.

3.5 Lean and Green assessment methodology setting up synthesis

Following on from the detailed presentation of the main stages of the Lean and Green assessment and deployment roadmap, this section details the implementation synthesis, adapted in accordance with the PDCA continuous improvement methodology (Figure 4).

One of the key factors to bear in mind when initiating a new policy deployment is to begin with a strong top-down management structure. This is even more important in the case of SMEs, which might lack maturity and resources (Boiral et al., 2014). In line with the Lean "Hoshin Kanri policy" deployment whose aim is to align the strategy goals with tactics management and with operational actions, linking top-down management to bottom-up feedback is especially important for the development of appropriate key performance indicators[1] and to eliminate wastes coming from insufficient internal communication. The importance and efficiency of such a methodology is notably described by Asif et al. (Asif et al., 2013). The initiation of "Genchi Genbutsu" through Genba Walk is an effective way of synergistically linking these factors.

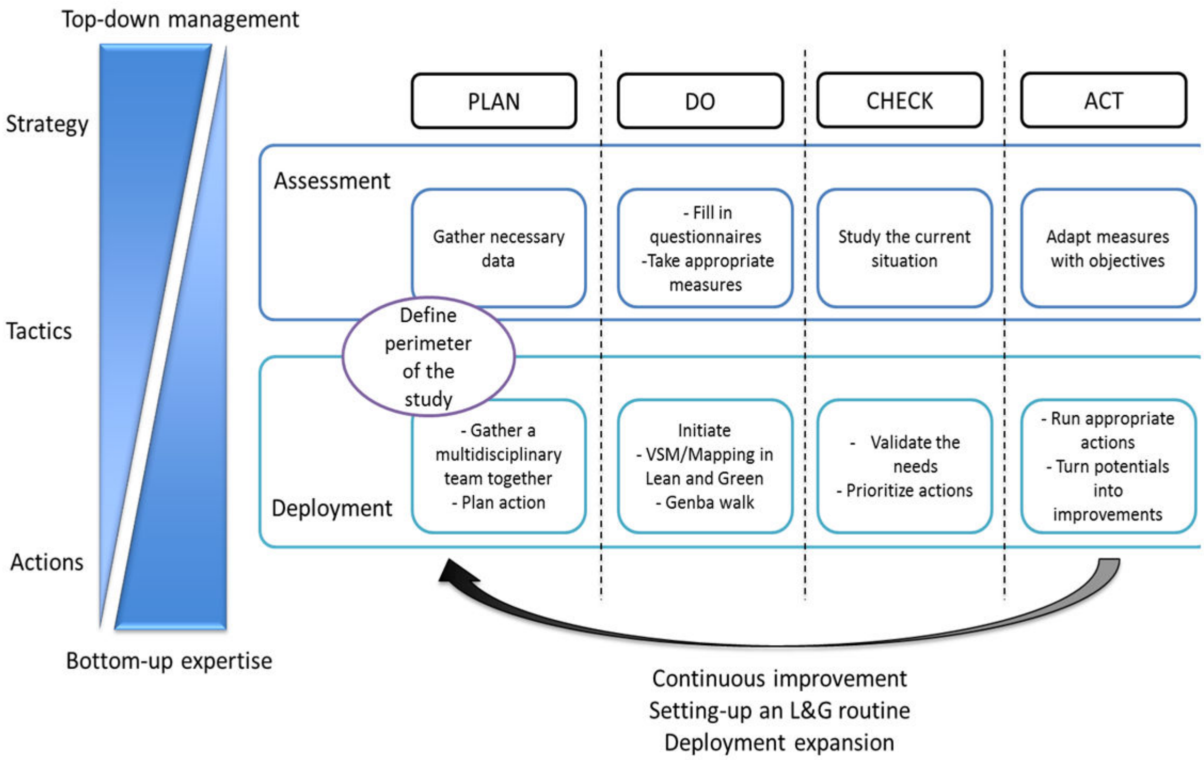

Figure 4: Deployment setting-up synthesis

Appropriate communication by top management within the firm on the approach to be made and its expected evolution inside a “pilot process” enhances the extension of the deployment to the whole organization. If the first project is successful, it means that the same approach will be better accepted by employees and easier to adapt to the whole company.

As we saw, this approach can be used by any kind of manufacturing organization. In firms that are already familiar with continuous improvement, this method can give real added value and efficiency to production processes. Whereas SMEs, which are not used to Lean and Kaizen methods, will, as a first step, be able to detect several easily set up major improvement potentials.

This method of systematic research, identification and elimination of non-value-added activities may steer the company towards more agility and a better ability to react quickly.

Lean and Green wastes are often found in similar steps of the production process. Nevertheless, environmental interests are not always in perfect symbiosis with Lean interests. In such cases, the conflict ratio must be handled on a case-by-case basis, according to the company’s specificities, in order to better profit from the association of both interests (Dües et al., 2013).

In any case, Lean and Green methodology must not be considered as an end in itself but as a systematic routine approach designed to identify evolution objectives.

Our approach is complementary to the cost-analysis oriented Material Flow Cost Accounting (MFCA) approach depicted in the ISO 14051 part of the ISO 14001 norm. The joint implementation of these methodologies should allow the identification of environmental wastes and material flows as well as their inherent cost, leading to easier “return on investment” calculations.

4 Lean and Green 2 benchmarking: assessment results and discussions

4.1 Results

As one of the partnership’s conditions was the realization of a green benchmarking, the results presented in this section embed Lean and Green themes but are focused on environmental assessments of the firms and SMEs audited during the second edition of the Lean and Green Project, in 2013. The project and audits were carried out using the methodology described in the previous section.

The business sectors of the participating companies are shown in Figure 5. Those involved in several activities were considered to belong to the sector corresponding to the process that was studied within them.

E1.1	S1 : Semi-finished product processing and assembly	Food Industry
E1.2		Electric power supply
E1.2.b		
E1.3		
E1.4		Elec/Mechanics
E1.5		Furnitures
E2.1	S2 : Transports / Logistics	Transports
E2.2		Waste Sorting
E3.1	S3 : Raw materials processing	Food industry
E3.2		
E3.3		
E3.4		Chemistry
E3.5		Crystal Factory
E3.6		Mechanics
E3.7		Metallurgy
E4.1	S4 : Packaging	Social Organization

Figure 5: Detailed business sectors of audited companies

A total of 16 companies were audited, among which three wanted to keep their data totally or partially confidential and one required personalized audit support. This latter firm, an ESAT social organization (French work assistance institute), needed to set up a new packaging line in partnership with a contractor and supplier, which were part of the Lean and Green cluster. As we will see in more detail in a later section, this company had surprisingly good productive performance results. We therefore decided to emphasize its social awareness and involvement to give an impetus to the Lean and Green Project towards enhanced safety and social concerns.

Although the reasoning in this section is based on the 16 audits and reports, the data of only 11 companies could be represented in the final benchmark ranking.

The most recurrent Lean and Green recommendations proposed to companies by the consulting firms' experts are shown in Table 1 in order to highlight major improvement potential.

Lean and Green recommendations	Repetition
5S reinforcement/Safety/Lean basis	*8 (66,7%)*
Shopfloor Visual management	*6 (50%)*
Green indicators setting up	*5 (41,7%)*
Communication/Personnel recognition	*4 (33,3%)*
Ergonomics	*4 (33,3%)*
Waste reducing/reusing	*3 (25%)*
Supply chain L&G collaboration	*2 (16,7%)*

Table 1: Main Lean and Green recommendations identified on factory floors

There has been some evolution in the main recommendations of the audit reports since the project's first edition in 2011. This is probably due to a higher overall awareness of elementary environmental behavior (e.g. turning off electric equipment when not in use). We also noticed that the installation of photovoltaic panels is no longer of great interest due to changes in public subsidies making solar energy investment more difficult for SMEs.

The recommendation which is gaining increasing importance is reliable environmental indicators to measure and better monitor the consumption and emissions of production processes. This aspect has turned out to be a key element in Lean and Green methodology deployment among firms and has been the subject of a dedicated joint research[1].

Experts had to stress Lean basis reinforcement in two-thirds of the companies - major firms as well as SMEs and novice practitioners. This is an important point as it illustrates that continuous improvement resides in constant progress objectives, even when Lean routine is already implemented.

Finally, we should highlight the recommendation of improving communication with suppliers and customers in order to enhance supply chain transparency and efficiency.

4.1.1 Questionnaire n°1 results

As was mentioned above, the à priori questionnaire should be completed before any discussions in order to get a first insight into the firm's actual environmental impact and corporate communication among employees.

The questionnaire is based on qualitative enquiries in three sections. The section on consumption and emissions is evaluated by 5 levels, while internal environmental policy is rated by nine binary questions (i.e. confirm or disprove).

An equivalence-based calculation then converts the qualitative appraisals into a numeral grading (from 1 to 5, 1 being the lowest, corresponding to "very high" impact, 5 the highest, corresponding to "non-existence" of impact) which is then converted into percentages.

To complete these calculations and assess their relevance, the disparity of the participants' results is also graded on three levels, from "Not significant" to "Substantial".

A higher final rating thus signifies that impact is considered to be not very significant, implying a well-implemented environmental corporate policy, whereas a lower rating implies a higher impact estimation and incorrectly implemented internal communication. Graphical results are shown in Figure 6 and detailed results are visible in Appendix 5.

Although small companies seem to be aware of their lack of maturity in environmental policy, they are rather more confident on their consumption and emission impacts, which is also normally the case of most firms. However, impacts seem to have been more accurately evaluated in general (by comparison to quantitative results and on-site observations) than in the first Lean and Green Project edition.

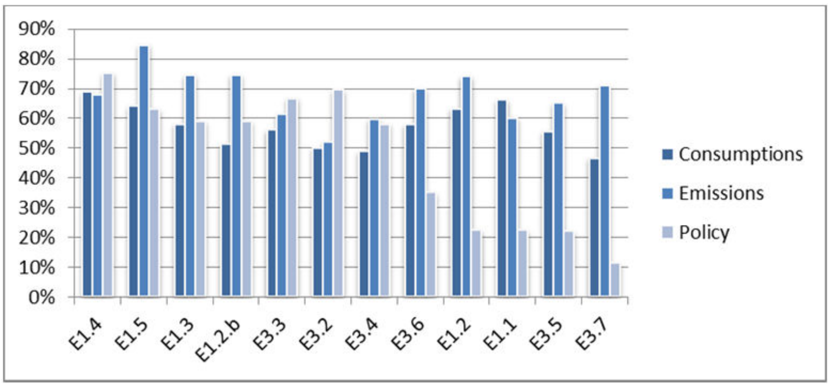

Figure 6: Results of preliminary environmental qualitative assessment

4.1.2 L&G qualitative questionnaire results

The qualitative questionnaire, based on an excel program, calculates the percentage of the three possible maturity levels of each of the Lean and Environmental project categories.

During the launch of our collaboration with the ADIRA, this questionnaire was one of the key elements for establishing a positive synergy between Lean and Green themes in manufacturing industries. We will now focus on analysis of the environmental results, considering the percentage to be a Green “initiative” rating for the firm.

Some business sectors, such as metallurgy or chemicals, imply the handling of difficult or hazardous raw materials and are therefore subjected to very stringent environmental and safety regulations; this explains the above average results of those firms.

As shown in Figure 7, the average score for the Lean and Green second edition non-confidential panel is about 56.2%.

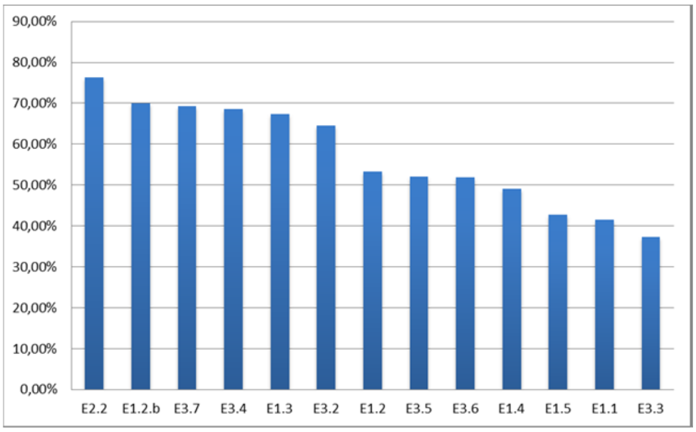

Figure 7: "Green initiative" assessment results

4.1.3 Green quantitative questionnaire and final benchmarking results

In our previous research (Verrier et al., 2014) we chose six relative indicators (i.e. proportionate ratios) in order to carry out benchmarking and compare the firms on impartial bases. The Green performance ratios that were chosen, each calculated by both annual turnover (in M€) and finished products (by 1000t), are:

- Release of greenhouse gas in Teq Co_2 (calculated on the basis of electricity, gas and fuel consumption in order to standardize the results, since the directly related question in the quantitative questionnaire was not always completed by less mature firms)

- Manufacturing rubbish production (tons of common and special/hazardous industrial waste)

- Water consumption in m^3

We also used the "green initiative" assessment from the qualitative questionnaire as a global performance indicator to complete the benchmarking data.

The greenhouse gas indicator is an assessment of the organization's impact on global warming through the calculation of "carbon dioxide equivalent" emissions into the air. It was essential to include this criterion as a determining benchmark indicator because it is frequently used these days. However, even if it is often used in the public domain, this parameter alone cannot be scientifically considered as an exhaustive perception of an organization's environmental impact.

We therefore also chose the "water consumption" and "rubbish created by manufacturing processes" indicators, as they are both important environmental parameters as well as being generally well measured in firms, at least at the organizational level[1].

In order to supplement the estimation of a firm's "carbon equivalent" emissions into the air, we also chose to calculate an additional separate section: the "acid equivalent" output, indicating the acid potential of So_2, No_x and NH_3 gases released into the atmosphere, with a single unit. This data will not however be used in the global benchmarking assessment, but will be put at the disposal of the firms for information.

The calculation of carbon dioxide and acid equivalents being particularly complex, since the origin of an electrical kWh cannot be determined with exactitude, we have chosen to use the "Bilan Produit" Life Cycle Analysis (LCA) software, where we entered the energy consumption data for each firm. This software was developed by the French Environmental and Energy Management Agency (ADEME) (ADEME, 2015), which uses it for calculating the internationally-renowned Ecoinvent Swiss Life Cycle Inventories Database (Ecoinvent, 2015). An example of calculation is available in Appendix 6.

4.1.4 Assessment and benchmarking graphical frames

In order to convert the six quantitative indicators into a single global and comprehensible rating, each result is expressed by 20 points (corresponding to the usual French grading system). The data, which may be very disparate depending on the company, is treated through a reverse logarithmic scale calculation system (i.e. important consumptions or emissions receive a low performance grading and vice versa). To allow for future improvement, the maximum grading is fixed at 17 points. As for the green initiative indicator, corresponding to the results of the second questionnaire on green qualitative maturity, the percentage is simply directly converted into its equivalent in 20 points.

The benchmarking synthesis is inspired from the graphical representation commonly used in building construction or household appliances, featuring five color stages graded from 'A' to 'E'. Thus, performance ratings are ordered by corresponding ranges (i.e. 0-4/20 equals E; 4-8 equals D; 8 -12 equals C; 12-16 equals B and 16-20 equals A) (Figure 8).

This has the advantage of enabling companies to quickly situate their position among other L&G partners.

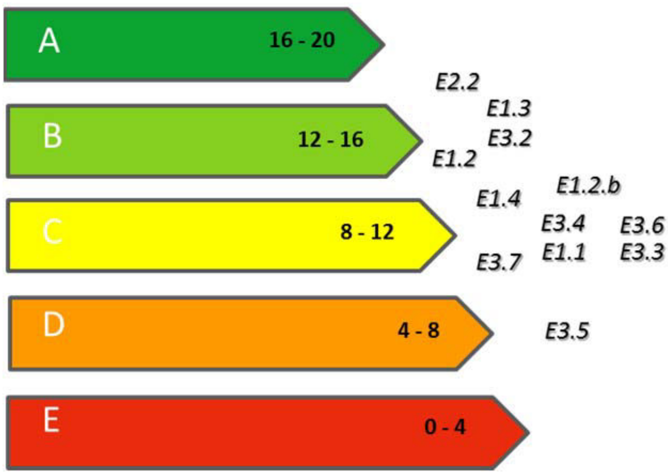

Figure 8: Benchmarking synthesis representation

Potential improvements are highlighted for each firm by a graphical diagram displaying their individual results (Figure 9). The diagrams are also used to highlight details of the compared performances for each indicator. These results complete the first guidance given by the audit reports.

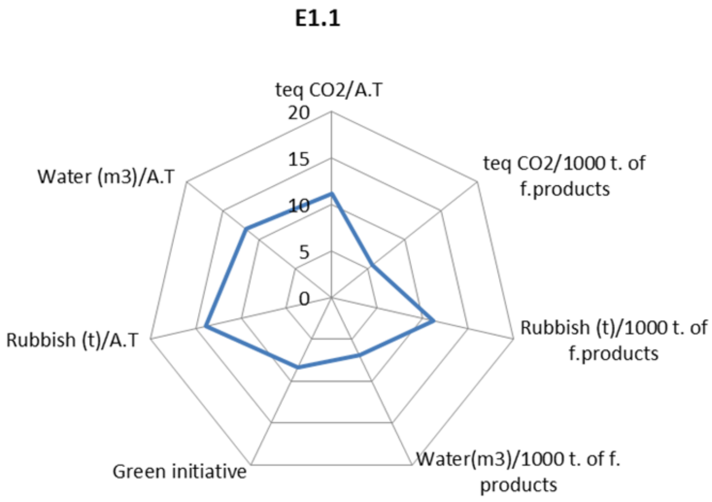

Figure 9: Details of individual quantitative performances

4.2 Results discussions and recommendations

4.2.1 Project discussions

Firms working in the sector of raw material processing often have higher energy-consuming and polluting production processes. They thus suffer from a discrepancy between their environmental initiatives and high-impact quantitative data. The principal recommendation for this sector is to anticipate regulations as far as possible and implement voluntary progress approaches, inspired by standards such as the ISO 50001 (International Organization for Standardization) (ISO, 2015) on Energy Management Systems.

The sector of "semi-finished product processing and assembly" comprises relatively "clean" industries which tend to have higher than average ratings. We observed that the differences in their environmental performance are essentially a result of their Lean maturity; which supports previous findings on the synergistic links between Lean and Green paradigms(Verrier et al., 2014).

Attention should also be drawn to important practical general recommendations, such as fostering the reinforcement of basic Lean principles (especially 5S implementation and PDCA strategic thinking), setting-up and monitoring environmental indicators, enhancing ergonomics in the workspace, the promotion of local loops and the optimization of loading amounts (especially for transport).

The importance of the Lean-basis reinforcement is highlighted by the largest firms' communication policies. For example, Toyota clearly expresses in its external communications the will to use Kaizen and Genchi Genbutsu as pillars for continuous improvement.

We also observed, through the practices of some of the major firms involved in the L&G panel, the importance of internal visual communication on corporate development policy directly to the shop floor, helping to unite all the staff with common objectives.

Several firms made a lot of progress through L&G project implementation by things like correcting waste and security flaws or improving rubbish sorting. They then gained enough confidence to run continuous improvement methodologies on both Lean and environmental subjects.

Practical tools were also created during the project, such as the "muda observation sheet", developed in collaboration with a Lean team from Siemens and aimed at facilitating waste investigations during Genba Walk sessions. A Lean and Green methodological guideline (Leduc et al., 2014) for Alsatian manufacturers and SMEs, including key points and tools, was drawn up with the leading partners.

4.2.2 The subject of societal involvement

As mentioned in the previous section, the consideration of employees' involvement in corporate vision and policy could be of major interest for fostering performance and continuous improvement methodologies. Conventionally, both the Lean and Kaizen approaches originally put human resources at the heart of any production system. Longoni (Longoni et al., 2013) notes that the consideration of both human resource and technical tools is essential for successful Lean implementation.

Implementation of Lean recommendations ignoring human factors would make improvements in operational performance harder in the long-term and could pose significant risks to two Lean and Green mudas: lost human potential (i.e. the waste of people's intelligence) and poor health and safety (leading to possible security flaws, accidents, illness and absenteeism, as is well described by Taubitz (Taubitz, 2010)).

Martinez-Jurado and Moyano-Fuentes argue that employee involvement is vital for implementing environmental practices (Martínez-Jurado and Moyano-Fuentes, 2014). In return, environmental concerns are a good way of linking economic projects to social concerns and uniting the whole company in common sustainable objectives.

In the same way, health and safety issues must not be perceived as constraints but as opportunities to bind Lean, economic and environmental synergies together.

One of the larger firms involved in the L&G cluster, from the food industry sector, is developing a new social method based on this philosophy. They now particularly focus on social indicators with some interesting innovations, such as monitoring the rate of "presenteeism" instead of "absenteeism". Their maturity in Lean tools helped them to deploy such an approach at their production site, which in turn has strengthened the Lean aspect and created new links between production, environment and human resource management.

Another company from the panel was of particular interest. As mentioned previously, the social "ESAT les Tournesols" company is able to compete with traditional companies and even surpass some of them in terms of productivity and competitiveness. In order to better understand these results, a survey was conducted with the Director, which highlighted the very interesting benefits that came from the company's strong investment in both employee well-being and customer satisfaction. The main points we noted were:

- Strong top-down drive for progress (Kaizen state of mind)
- Concern about improvement of working conditions
- Promotion and enhancement of skills and motivation

Thus, we can conclude that production processes that are implemented in a societal responsible manner are a reliable way to attain global quality production and innovation (Herrera, 2015). Some interesting levers of progress have been highlighted by recent scientific literature (Fercoq, 2014) (Faulkner and Badurdeen, 2014) (Brown et al., 2014).

Conclusion

In this paper we presented a Lean and Green roadmap intended to help industrial firms to fully implement the two paradigms by a joint top-down and bottom-up approach.

The roadmap is based on L&G assessments and improvements that were conducted among Alsatian companies in partnership with the ADIRA, industrial observations, and on an extended scientific literature review.

As many variables in organizational and production systems have to be taken into account, we propose an adaptable method of applying Lean and Green methodology to all manufacturing companies through accessible implementation key points and best practice recommendations.

Continuous improvement approach must begin with the drive to daily progress and then be adapted to the structure and its inherent and specific objectives. One of the best ways to successfully implement the roadmap, especially for SMEs, is to work on a specific production line to initiate improvements before applying the methodology project-by-project to the whole company.

According to Thoumy and Vachon, managers should not hesitate to involve employees in long-term changes in working methods and environmental challenges as this will actually reduce resistance to change, instead of presenting them with short-term projects with little consideration of cultural change or employee involvement (Thoumy and Vachon, 2012).

Moreover, taking environmental concerns into consideration in Lean development policies facilitates the spontaneous integration of health and safety issues as well as improvements in working conditions. There is a positive link between environmental management, including top management support and employee participation, on environmental performance (Tung et al., 2014) (Paillé et al., 2014) (Longoni et al., 2014). A better working atmosphere translates into more efficiency and reliability both in the production process and in the whole company.

In addition to improving the production process, a Lean and Green corporate policy can enhance the company's image as well as its monitoring of conformity to regulations.

Even more substantial progress can be made if partners along the supply chain are involved in creating a "total quality" chain, both upstream and downstream the production process. The sharing of best practices between customers and suppliers enhances and reinforces the competitiveness of all the stakeholders(K. Zokaei et al., 2010).

As suggested by Vadoudi (Vadoudi et al., 2014), further research could also link Lean and Green methodology to more specific product-oriented sustainable design or life-cycle management (Goepp et al., 2013) (Gmelin and Seuring, 2014) (Vallet et al., 2013). Indeed, eco-design procedures have the power to significantly reduce environmental impacts along the entire life cycle, including the manufacturing stage; while L&G methodologies may in turn foster the reduction of downstream environmental impacts.

[1] : B. Verrier, B. Rose, E. Caillaud "*Environmental performance indicators: review and proposals applied to the Lean and Green project*", submitted to the Journal of Environmental Management.

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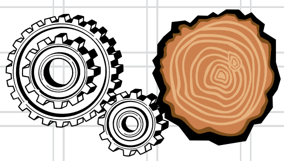
Appendix 1: A priori questionnaire

LEAN & GREEN Approach

Company :		Function :					
Name :		Date :					

This questionnaire is aimed to evaluate your perception about the environmental impact of your company . Please tick one choice for each question below.

I / How would you assess the following consumptions in your company:		Not applicable	Non existant	Low	Medium	Significant	Very significant
1	Electricity						
2	Petrol for transports						
3	Gas						
4	Industrial oils						
5	Amount of packaging						
6	Plastics						
7	Papers						
8	Metals						
9	Water (for production)						
II / How would you asses the following emissions coming from your company:		Non applicable	Nulle	Faible	Moyenne	Importante	Très importante
10	Polluted wastewater						
11	Issues coming from emitted hazardous substances						
12	Emissions in the air (greenhouse gases...)						
13	Amount of rubbish produced						
III / The environmental policy management in your company		Yes	NO				
14	Do you know the environmental policy of the company ?						
15	Do you think that the company manage environmental procedures in processes?						
16	Are you aware of the life cycle of the products ?						
17	Do you think that origins of raw materials are controlled?						
18	Do you think that projects are led to reduce the use of energy?						
19	Do you think that projects are led to reduce consumables used in processes?						
20	Are you aware of a policy to reduce greenhouse gases emissions?						
21	Are you aware of a policy to reduce water consumptions?						
22	Do you think that projects are led to reduce the production of rubbish?						



Appendix 2: Simplified Lean and Green qualitative assessment

LEAN	No process (0)	Set-up process (0,5)	Monitored process (1)	Rating
Lean / Continuous improvement deployment				
Measurement of production process indicators (service level, production times…)				
Visual management				
Process standardization				
Risk management				
Just-in-time procedures				
Employees involvement				
Management of production areas (5S)				
Value Stream Mapping				
Regular observations on plant floor (Genba Walk)				

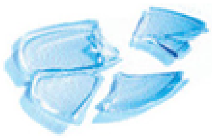
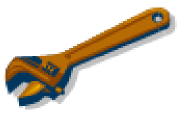
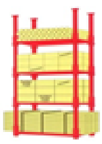
GREEN		No process (0)	Set-up process (0,5)	Monitored process (1)	Rating
Improvement projects					
Indicators measurements and control :	Consumptions				
	Emissions				
Projects to reduce consumptions					
Energy diagnosis					
Use of renewable energies					
Rubbish monitoring					
Visual management					
Control and reductions of hazardous substances					
Supply chain relationships (raw material origins and characteristics)					

The respondent must cross the maturity level which is in accordance with the ten corresponding projects described. The stages of “no process”, “set-up process” and “monitored process” respectively match with a rating of 0, 0.5 or 1. Thus, the maximum possible rating for each question is 1 and the sum of the ratings will give an estimation of the deployment of the Lean and of the Green projects on 10 points.

Like in the green benchmarking presented in the chapter 4 of this paper, results could be represented through a visual representation of A, B, C and D maturity stages.

Appendix 3: Lean and Green wastes observation sheet

Date: Name:

Type of waste	Examples	Observations
DEFECTS 	Critical condition of raw materials Internal non-conformity Process defaults Lack of controls and measures Customers complaints…	
OVERPRODUCTION 	Excessive waiting products in-process Important size of lot Finished product waiting for delivery…	
UNNECESSARY MOTION 	Excessive movements Difficult access to materials Repackaging Inappropriate workstation ergonomics …	
INAPPROPRIATE PROCESS 	Complicated/Complex processes Standard non defined Volatility, instability Unsuitable or restrictive I.T. system Lack of communication …	
WAITING 	Cycle times non optimized No value added activities Non available machineries …	
TRANSPORTATION 	Non optimised transportation routes Poor management of spaces Unnecessary motions …	
UNNECESSARY INVENTORY 	Excessive waiting raw material, pieces, or tools Multiplication of stocking areas Undersized/oversized stocking spaces…	

Date: Name:

Type of waste	Examples	Observations
EXCESSIVE RESOURCE USAGE 	Excess of material in products Too many different materials (lack of eco-design) Rare/precious materials (rare earth elements, copper...)...	
EXCESSIVE WATER USAGE 	Inappropriate use of water in processes Cooling systems Non-detected leaks Defective equipment Non treated wastewater ...	
EXCESSIVE POWER USAGE 	Energy-greedy processes Domestic consumption Lack of measurements Lack of optimizations ...	
GREENHOUSE GASES 	Fossil fuel and hydrocarbon Air conditioning Aerosol (fluorinated gases) Transports Chemical fertilizers ...	
POLLUTION 	Lack of control and treatment of hazardous wastes and substances Toxic wastewater Underground leaks/Soil contamination Toxic discharges...	
EXCESSIVE RUBBISH 	Excessive packaging Excessive materials No waste reclamation Sorting mistakes Excess of defects ...	
POOR HEALTH AND SAFETY 	Unavailable PPE Non observed safety instructions Hazardous material or chemicals in products/process Lack of ergonomics optimization	

Appendix 4: Quantitative questionnaire

• Perimeter of the study and frequency of measurements must be adapted in accordance with strategic objectives

General Information
Turnover of the last year (k€) :
Tons of finished products per year (t):

Annual consumptions/ Input flows		
Electricity		
Electricity consumption (kWh)		
of which	Industrial Process	
	Management	
Water		
Water consumption (m^3)		
of which	Industrial Process	
	Management	
Gas		
Gas consumption (m^3 or kWh)		
of which	Industrial Process	
	Management	
Fuel		
Fuel consumption (l)		

Annual emissions / Output flows		
Air		
Greenhouse gas emissions (teq. Co_2)		
Acid gas emissions (teq. acid)		
Water		
Wastewater (m3)		
Industrial waste		
Tons of manufacturing waste (t)		
of which	Hazardous wastes	

Appendix 5: Detailed results of questionnaire n°1

	Consumptions		Emissions		Policy	Disparity
E1.4	69%	3,44/5	68%	3,4/5	75%	Substantial
E1.5	64%	3,2/5	85%	4,23/5	63%	Not significative
E1.3	58%	2,9/5	74%	3,72/5	59%	Medium
E1.2.b	51%	2,57/5	75%	3,73/5	59%	Medium
E3.3	56%	2,8/5	61%	3,06/5	67%	Medium
E3.2	50%	2,5/5	52%	2,6/5	69%	Medium
E3.4	49%	2,44/5	60%	2,98/5	58%	Substantial
E3.6	58%	2,89/5	70%	3,5/5	35%	Not significative
E1.2	63%	3,16/5	74%	3,7/5	22%	Medium
E1.1	66%	3,33/5	60%	3/5	22%	Single respondent
E3.5	56%	2,78/5	65%	3,25/5	22%	Single respondent
E3.7	47%	2,33/5	71%	3,55/5	11%	Not significative

Appendix 6: Example of carbon and acid equivalent calculation

	Greenhouse Gases (kg CO2 eq)	Acidification (kg SO2 eq)		Greenhouse Gases (kg CO2 eq)	Acidification (kg SO2 eq)
	Consideration of every given consumptions			*Considération of electricity consumption only*	
E1.2.b	8,43E+05	1,48E+03		1,49E+05	8,49E+02

Indicators	
Energy consumption NR (MJ eq)	3,08E+07
Resources consumption (kg Sb eq)	6,90E+03
Greenhouse gases GWP 100 mod (kg CO2 eq)	8,43E+05
Acidification (kg SO2 eq)	1,48E+03
Eutrophication (air water soil) (kg PO4--- eq)	4,53E+02
Photochemical Pollution (kg C2H4)	8,55E+01
Aquatic Toxicity (kg 1,4-DB eq)	8,65E+04
HumanToxicity (kg 1,4-DB eq)	3,26E+05

BILAN PRODUIT

Article 4: "Lean and Green strategy: The Lean and Green House and Maturity deployment model"

Lean and Green strategy: The Lean and Green House and Maturity deployment model

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Abstract

Industrial firms are having to face increasing environmental and societal challenges in order to sustain their processes. The association of Lean manufacturing to Green concerns has therefore grown in both the industrial and academic fields over the last decade. Following on from the "Lean and Green Project", which led the development of a roadmap focused on the tracking and elimination of wastes in production processes, this paper intends to enhance previous studies by giving an implementation structure to specific Lean and Green tools and best practices. The paper features a synthesized state of the art on L&G topics and environmental indicators, as well as an extended survey on Lean and environmental practices implemented by firms. The results are completed by an in-depth analysis of the synergies between Lean and Green wastes and the tools that may eliminate them and strengthen the quality of the manufacturing process in order to gather best practices in an original Lean and Green house. Finally, the last section of this paper presents a CMMI-based Lean and Green maturity model.

Keywords: Lean and Green; Best practices; Industrial surveys, Lean and Green House, Lean and Green Maturity, KPIs, Lean and Green roadmap.

1 Introduction

Since the 1990s, the concept of sustainable development has been of interest to industry. Defined by the World Commission on Environment and Development (better known as the "Brundtland Commission") in 1987, as "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs", the term is more and more widespread, and quoted in the majority of firms' strategic public communications (Moldan et al., 2012) .

Corporate social responsibility (CSR), along with the Triple Bottom Line (TBL) (Elkington, 1998), is a business strategy commonly adapted from the three pillars of sustainable development (i.e. Economic, Social, Environmental). While firms have obviously always taken economic concerns into account in their performance management, the current economic and ecological crisis has acted as an impetus to link them to more exhaustive sustainability goals.

Linking industrial performance to sustainability pressures leads industry to promote eco-efficiency strategies and the association of Lean manufacturing and environmental concerns appears to be a tangible way to answer these constraints and is therefore of growing interest to both academics and industrialists.

Lean methodology has already proved to be important to manufacturing firms as an enhancer of competitiveness since it spread worldwide through the Toyota Production System (TPS). One of the main objectives of lean manufacturing is the identification and elimination of non-value added activities, known as "wastes" or by the Japanese term "muda", in production processes.

Our research project lies in the association of Lean and Green themes for joint elimination of those manufacturing wastes. The eight Lean wastes are commonly known as overproduction, defects, unnecessary motion, unnecessary inventory, inappropriate processing, transportation, waiting and lost people potential; they all lead to potential disorganization as well as loss of profits and motivation. In the same way, environmental impacts can be considered as green wastes.

Therefore, we will consider in our study the eight green manufacturing wastes as they have been defined by Peter Hines (Hines, 2009): greenhouse gases, eutrophication, excessive resource usage, excessive power usage, pollution, rubbish, excessive water usage, and poor health and safety.

Our research called "the Lean and Green Project" (Verrier et al., 2014) was initiated by the Alsace Region of France and coordinated by the Economic Development Agency of the Bas-Rhin (ADIRA)(Adira, 2015) in 2010. Built with stakeholders from various scientific and industrial fields, including the Icube research laboratory, consultancy companies, SMEs and major firms that are representative of the industrial network of the region, the project aims to highlighting industrial best practices by the association of lean manufacturing and sustainable development. Based on a case-study approach, the project was conducted through an iterative collaboration with the stakeholders.

A main aim of our research is to find ways for firms and especially SMEs to cope with the difficulties of dealing with regulatory requirements while fostering the economic, environmental and social pillars of sustainability. Another scientific question is to find an appropriate way to combine and implement L&G tools and methodologies within firms that have different corporate cultures and process specificities.

Another important issue is fostering the use of appropriate Key Performance Indicators (KPIs) within companies, so that they are aware of their own objectives and possess the appropriate resources to assess the situation compared to them. The choice of monitoring parameters is therefore essential, particularly in the case of complex systems management (Kurdve and Daghini, 2012), but also for less mature companies like SMEs for which the homogenization and simplification of the choice of indicators is of particular interest.

In this way, our previous research, especially intended for SMEs, includes an extended investigation on environmental performance KPIs and provides an indicator setting-up model[1] based on prioritization, observation flows and identification of wastes (see Appendix 1). We have also developed a roadmap[2] whose objective is to implement step-by-step a Lean and Green routine procedure by observation and assessment of production processes using dedicated questionnaires, Genba Walk, Value Stream Mapping, and workforce involvement (see Appendix 2). The efficiency of our project in the long-term is based on a strong bond between top-down and bottom-up management.

After presentation of a synthetized literature review on Lean and Green topics and environmental KPIs, this paper presents the results of an extended surveys on firm's L&G practices and emphasize the correlations between Lean and Green mudas and the corresponding tools that can help to eliminate them. We hope therefore to enhance the implementation of the Lean and Green roadmap through the development of a Lean and Green house and a maturity model.

Our work has also been guided by the knowledge of several important industrial or organizational reports, including : the Organisation for Economic Co-operation and Development (OECD, 2011, 2015), the Global Reporting Initiative (GRI, 2006), the United States Environmental Protection Agency (EPA, 2007), E2 Management Corporation (Johansson, 2007), the French Environment and Energy Management Agency (ADEME, 2015) and the *"Organization for environmental consideration in the industry" (OREE) (OREE, 2015).*

2 Synthetized state of the art

We will present in this section a synthetized state of the art on Lean and Green topics and environmental performance indicators. While taking into account the more important contributions that have influenced these research fields, the review is especially focused on recent contributions (2008 to 2015).

2.1 From the association of environmental and financial performance to Lean and Green considerations

Some contributions from the beginning of the last decade were at the forefront in the association of environmental and operational performances through causal relationships and had a real impact on subsequent investigations (Maxwell and van der Vorst, 2003) (Pimenova and van der Vorst, 2004) (Zhu and Sarkis, 2004) (Schaltegger and Synnestvedt, 2002). Nowadays, the relevance of the subject is confirmed by the number of related interesting contributions (Gunasekaran and Spalanzani, 2012) (Rusinko, 2007) (Schoenherr, 2011), which have almost doubled since the beginning of the decade. Most papers still discuss the overall consideration of environmental practices in traditional manufacturing processes although interesting recent publications have added case studies and frameworks to the topic (Ahemad.A.Rehman et al., 2013) (Asif et al., 2013) (Thoumy and Vachon, 2012).

The association of Lean Manufacturing, derived from the Ohno's Toyota Production System, with environmental paradigms, also came to light at the beginning of the last decade. King and Lenox and Simons and Mason were among the pioneers in associating Lean and Green performances, respectively focusing on the interactions between quality and environmental management (King and Lenox, 2001) and the elimination of wasteful activities in the supply chain (Simons and Mason, 2003). Some authors, such as Bergmiller, also specifically addressed Lean and Green principles in the following years (Bergmiller and McCright, 2009a) (29), and suggested that they could lead to waste and cost reduction, with more chance of being successful if they were implemented in parallel. More recently, Dües et al. explored the real synergies between Lean and Green practices and argued that Lean is a catalyst for the implementation of Green in manufacturing companies, and that Green may help in return to maintain best practices in Lean (Dües et al., 2013).

These contributions have proved to be of interest in the association of Lean and Green paradigms for industrial companies, especially when many firms still consider environmental issues as a constraint instead of seeing them as opportunities for progress (May et al., 2011).

Despite Lean and Green paradigms still often being treated at a macroscopic level instead of being investigated through the elimination of mudas in production processes (Verrier et al., 2014), several recent papers have addressed Lean and Green themes associated to manufacturing processes (Pampanelli et al., 2014) (Chiarini, 2014) (Kurdve et al., 2014) (Jabbour et al., 2013). Most of these contributions were published in a dedicated issue of the Journal of Cleaner Production, Volume 85 (Dhingra et al., 2014). Only few studies proposed Lean and Green models but most confirmed the ability of a joint Lean and Green philosophy to reduce the usage of resources and increase cost benefits. In line with these results, suggesting positive synergies between Lean and Green paradigms, the originality of our research notably lies in the parallel search for Lean and Green mudas as a catalyst both for total waste reduction and the implementation of Lean and Green thinking in management procedures.

Several papers address environmental concerns at the supply chain level. In recent contributions, Dubey et al. presented a green supply chain management model (Dubey et al., 2015) and Faulkner and Badurdeen developed a value stream mapping-oriented methodology called Sus-VSM (Faulkner and Badurdeen, 2014). As for Duarte and Cruz-Machado, they specifically handled Lean and Green themes along a supply chain assessment framework (Duarte and Cruz-Machado, 2015).

The social aspects of sustainability have been the least considered until now although they are attracting increasing interest. Authors notably explore how social concerns can be included in sustainable manufacturing exploration and quality management in order to foster competitiveness (Brown et al., 2014) (Frolova and Lapina, 2014) (Golini et al., 2014).

2.2 *Environmental performance indicators*

Key Performance Indicators (KPIs), or simply performance indicators, are very important management control elements in the setting up of continuous improvement methodologies.

KPIs are qualitative or quantitative information illustrating process or organization results at a given instant. While keeping knowledge and command of the studied process, regular measures allow the detection of critical malfunctions. They notably have been defined as "information allowing a defined objective to be reached in the most effective way" (Lorino, 1996). As for environmental indicators, they reflect in various ways the environmental impact of a defined activity.

As an inherently industrial subject, Environmental KPIs has been more particularly addressed in reports by international organizations and in several normative references.

The International Organization for Standardization (ISO) (ISO, 2015) published several norms of reference intended for manufacturing industries. Besides the ISO 9001 reference on quality and the recent ISO 26000 on social responsibility, ISO 14001 and ISO 50001have respectively dealt with environmental and energy management.

In its 14031 sub-section, the ISO 14001 standard features environmental indicator classifications and examples. The ISO 14001 compliance can also be linked to the Eco-Management and Audit Scheme (EMAS), a regulation oriented toward voluntary performance reporting. In this case, organizations are required to provide KPIs in six environmental areas (Energy efficiency, Material efficiency, Water, Waste, Biodiversity, and Emissions).

The 50001 ISO standard, released in 2011, proposes a structure for energy efficiency system management and presents some energy performance indicator examples. Its ISO 50006 subdivision, released in 2014, proposes guidance for energy performance measurement using "energy baselines" (EnB) and "energy performance indicators" (EnPI).

The Organization for Economic Co-operation and Development (OECD, 2015) developed in the early nineties the Pressure – State – Response (PSR) model, which became the basis of many further investigations and adaptations.

The OECD also depicts several categories of KPI, including core environmental indicators (CEI), designed for tracking environmental progress and performance, and key environmental indicators (KEI), a reduced set of core indicators, aimed at wider communication purposes.

In the academic field, indicators have been widely addressed in recent decades. Some ambiguities and confusion in the definition of the concept have been observed by interesting contributions (Gallopin, 1997) (Veleva and Ellenbecker, 2001).

The PSR model developed by the OECD was widely depicted by Hammond et al. in 1995 for the World Environment Institute (17). More recently, Niemeijer and de Groot offered a important contribution also derived from the PSR concept (23). They notably argue that an indicator should be interpreted as part of a comprehensive set where indicators are linked by causal chains.

In addition to being based on a Lean and Green strategy, the subject of our research is most closely allied to manufacturing companies, and within the reach of less mature ones like SMEs; the studies proposed as part of the Lean and Green project are therefore situated at the boundary between complex meta-design models and indicator lists often proposed by industrial reports.

3 Industrial surveys

In the two editions of the Lean and Green Project, audits were conducted among around 25 firms and SMEs exclusively from the Alsace Region. A dedicated survey was then conducted in 56 companies in order to overview how strategies in the fields of continuous improvement and environmental management are dealt with within manufacturing firms.

Although the majority of the firms were from the North-East of France, three of them were international companies located abroad (Germany, Turkey and Australia). The respondents were engineers in continuous improvement, environmental managers, or even CEOs in the case of small enterprises.

The participating companies were large, medium-sized and small businesses. The highest number of employees for one production site was about 18 000 in the automotive sector; the lowest was 25 for an aluminum fence manufacturer from the Alsace Region; the average number of employees was 1 208. This places our survey in the context of the study of larger firms than in the initial Lean and Green Project.

The manufacturing sectors represented in the survey were mainly electronic and mechanical equipment, the automotive industry, chemicals, the food industry, plastic suppliers and metallurgy.

As can be seen in Appendix 3, the survey was divided into five main parts. The first one asked for general information on the site, the number of employees and current certifications. The second part was devoted to Lean management and practices deployment, including the main tools used on a regular basis, the Lean process wastes in the production processes and a short qualitative assessment of continuous improvement initiatives. Part three was devoted to green deployment practices and on the whole featured the same elements as the previous section, though oriented towards environmental concerns. The fourth part aimed to evaluate how social concerns and especially employees' involvement were currently handled. Finally, as a conclusion, the last part asked for a general qualitative assessment, inspired from Likert-type scales, of the three themes evoked in the previous sections, and was completed by questioning the existence of projects associating Lean and Green themes within the company.

3.1 Results and analysis

The first main question was about certifications that the companies handled. Besides several internal certifications, ISO standards specific to the respective business sectors and other national and international norms (including ISO 50001, AS/NZS 4801:2001, "Global Star", and "NF Environnement"), three major international standards were represented in the majority of companies. The first one being the ISO 9001 standard on quality management systems with a rate of 77% of certification among the panel, followed by the ISO 14001 on environmental management systems, handled by around half of the respondents (52%). The third most common norm was OHSAS 18001, the internationally used British Standard Occupational Health and Safety Assessment Series, ticked by 20% of the respondents (Figure 1).

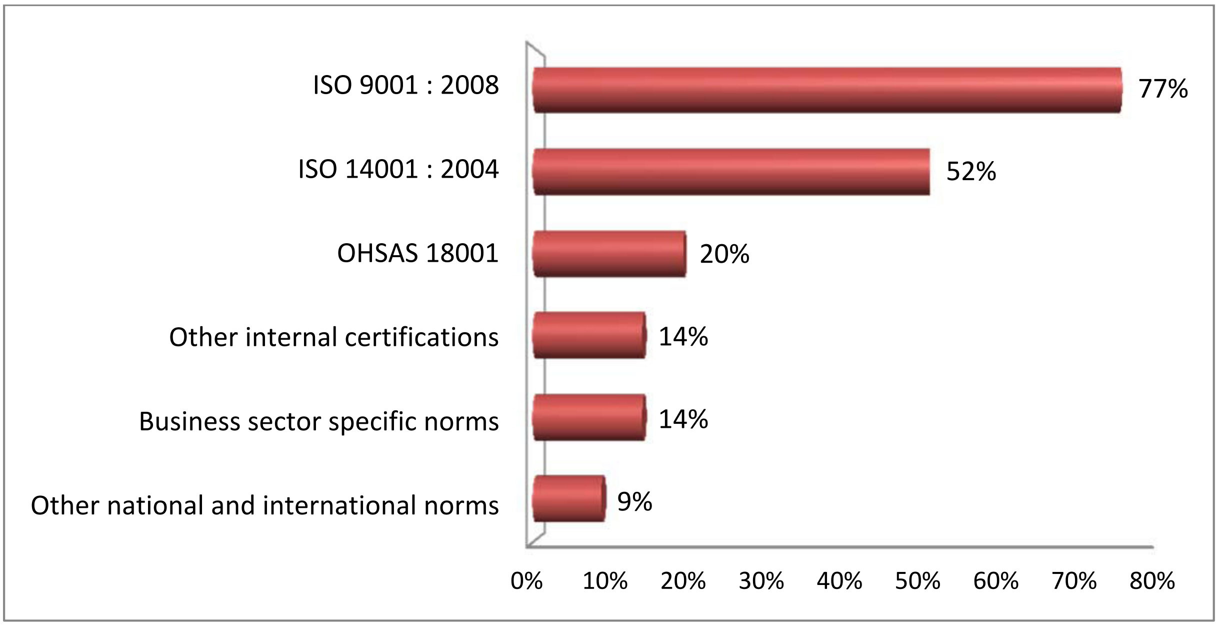


Figure 1: Certifications handled by the firms

These three norms may be considered to be the three pillars of sustainable development, quality being one of the first preoccupations of firms in order to keep their economic competitiveness. It is promising to see that these themes are the most represented; however it is also very clear that efforts remain to be made in order to better balance them and notably reinforce social preoccupations.

Maturity in the setting-up of Lean-oriented continuous improvement practices is shown in Figure 2. We can see that half of the respondents considered that their company monitors a clear risk management process, 43% a project deployment strategy and only 37% a proper visual management on continuous improvement performance and procedures.

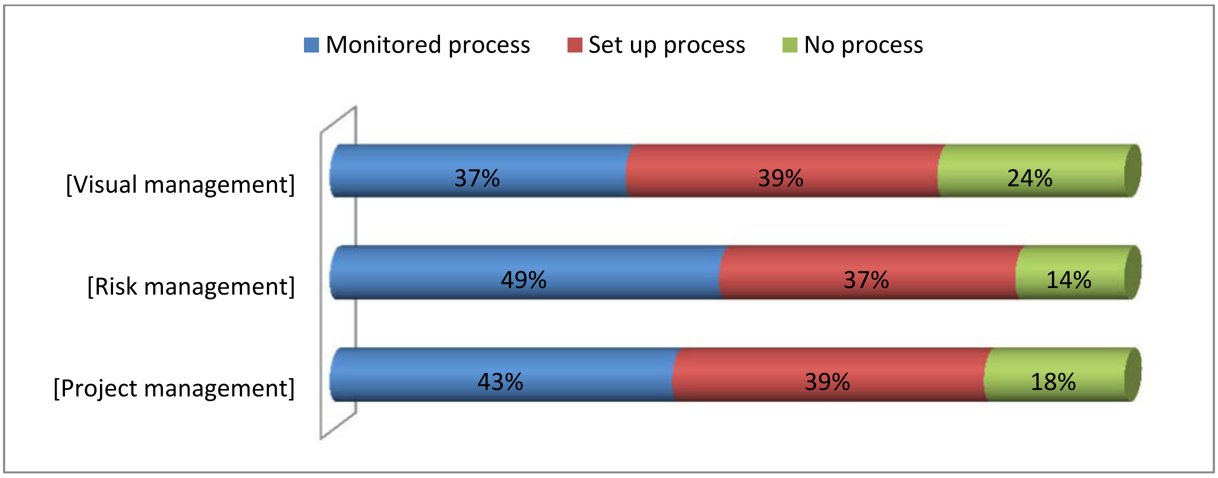


Figure 2: Maturity level of deployment of general lean projects

The ratings for the setting up of green processes were significantly lower (Figure 3). Energy diagnoses were conducted by 38% of the respondents; while only 34% considered the monitoring of indicators of consumption as being truly mastered. This last result was however balanced by the 48% of "at least set-up" answers. The real weakness, corresponding to equivalent result in Lean, were to be seen in the visual management monitoring: only 27% declared such a process as monitored while almost half of them judged that no such process existed.

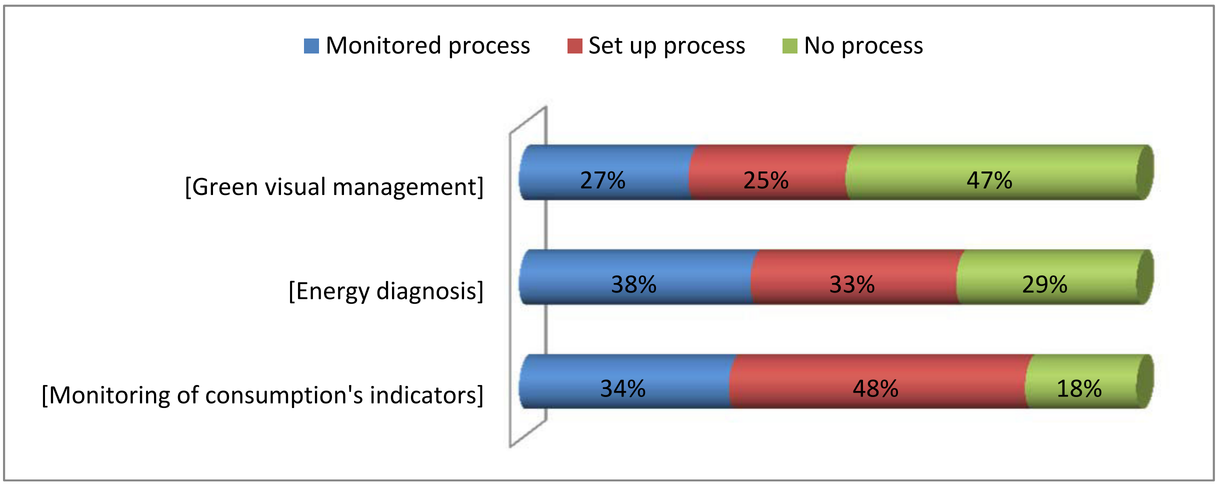


Figure 3: Maturity level of deployment of general green projects

Yet visual management is a way to unite employees and the whole company towards common objectives and better corporate performance (Paillé et al., 2014).

The last results illustrate how lean procedures are most often well-known and handled by comparison to green procedures which are often only in the beginning of their deployment among firms. This is one of the reasons why we chose to work on an adaptable Lean and Green deployment methodology where Lean may drive Green or be simultaneously implemented. The main Lean tool used in production processes was by far the 5S (82%) the purpose of which is to maintain a high level of order, arrangement and efficiency (Seiri or sort; Seiton or straighten; Seiso or shine; Seiketsu or standardize; Shitsuke or sustain) (Figure 4). Followed by the Kanban inventory control system (61%), and the mistake-proofing Poka Yoke (55%), the utilization rate of other tools then rapidly decreased. The versatility of employees and "Top 5" were respectively supported by 53% and 52% of the respondents. "Top 5" consists of short briefing sessions (usually of about 5 minutes each morning) on the shop floor and relies on visual management. Value Stream Mapping followed with a rating of 47%. Lean tools and their correlation to Lean and Green mudas will be looked at in detail in the following section of this paper.

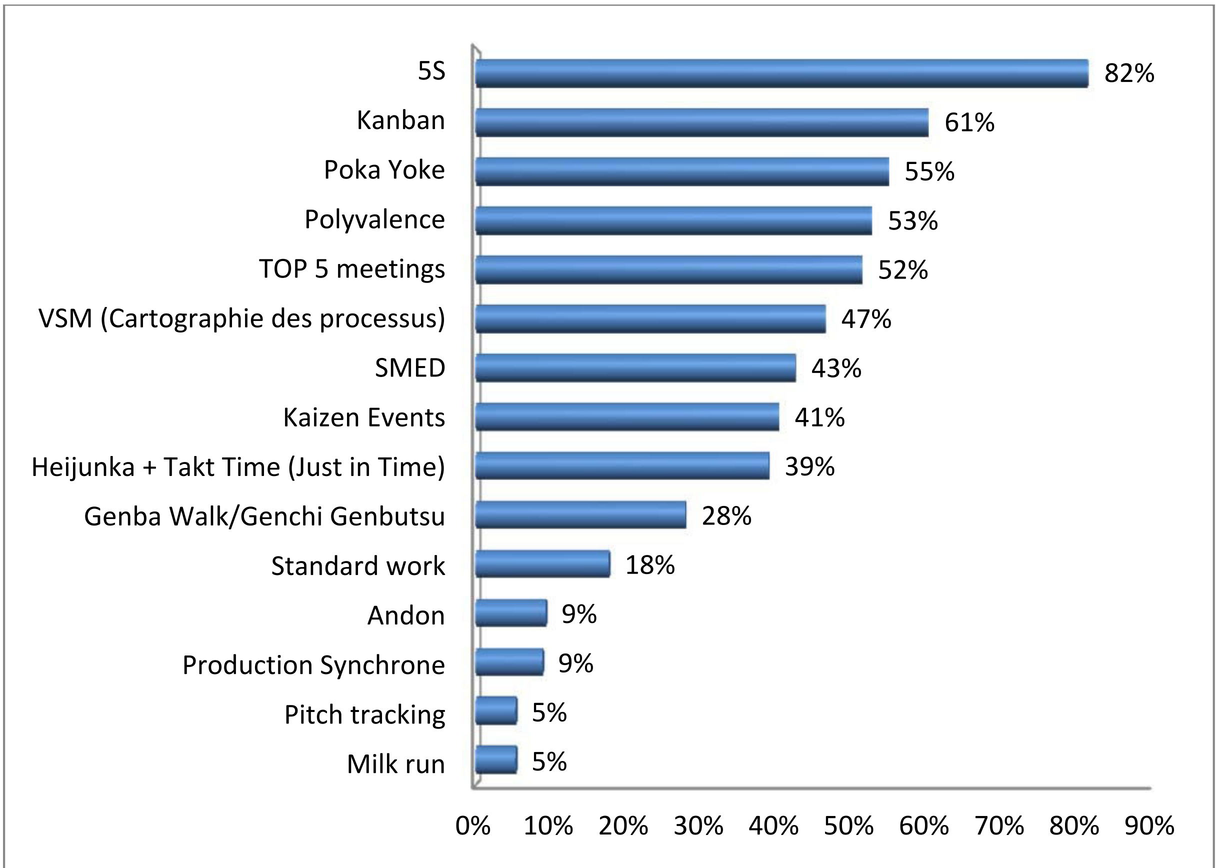
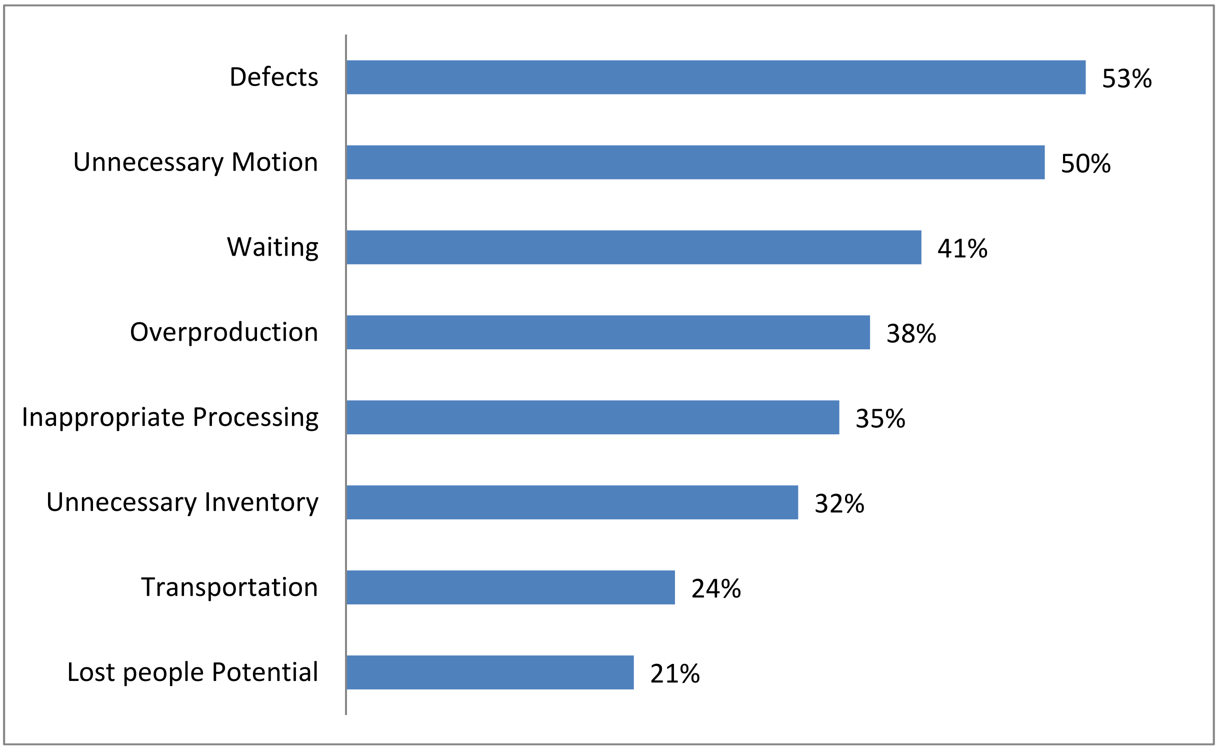


Figure 4: Implementation of lean tools

Figure 5 shows the results for Lean and Green wastes found in the production processes, in descending order.



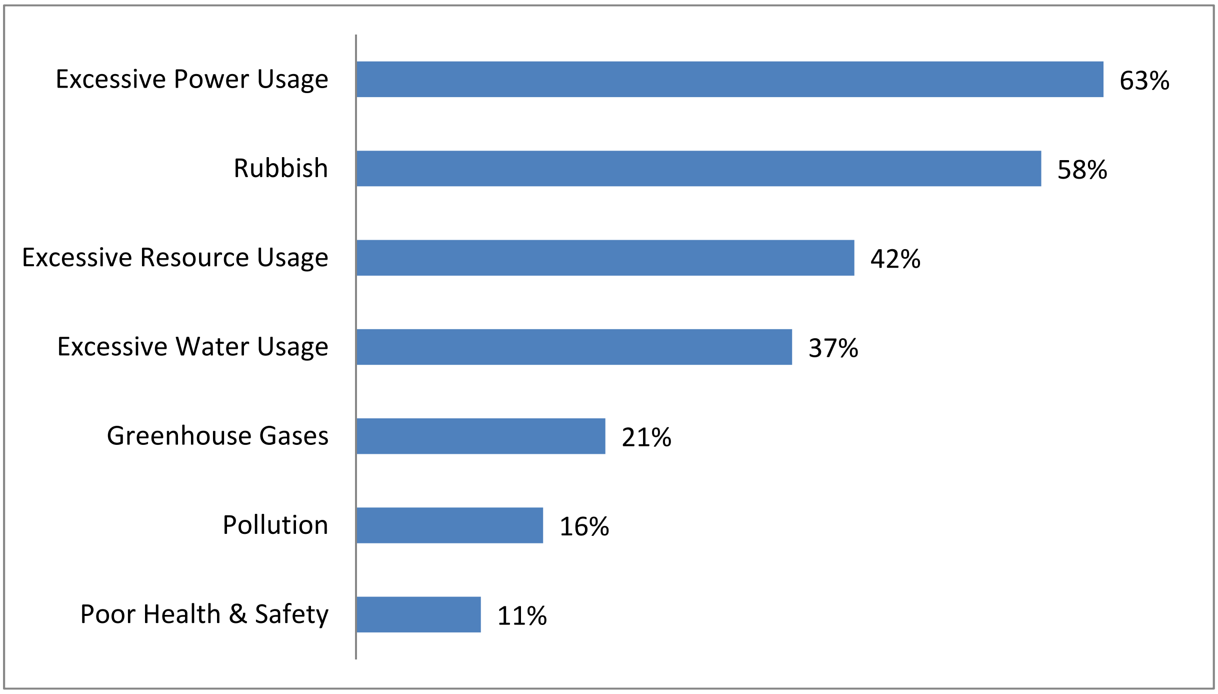


Figure 5: Mostly commonly encountered Lean and Green wastes in production processes

Around half of the respondents experienced defects and unnecessary motion in their production processes, followed by the mudas of waiting (41%), overproduction, inappropriate processing and unnecessary inventories (respectively 38, 35 and 32%).

63% of the respondents indicated that their company had already experienced excessive energy use. As the global issue of energy saving is nowadays at the center of both environmental and economic interests, awareness of this kind of waste has been heightened and its existence is therefore more easily recognized.

The green wastes that were observed the most were rubbish production (58%), excessive resource usage (42%) and excessive water usage. Poor health and safety was the least represented: only 11% of the respondents acknowledged that their company had encountered such an issue. The overall results appear to be consistent, however the percentage of "poor health and safety" should be taken with a pinch of salt, since this muda may still be difficult for some companies to admit to. Eutrophication, representing the excessive increase of nutrients in water or terrestrial ecosystems, was not directly included in the wastes proposed to respondents as it is difficult to apprehend at the manufacturing stage and is more easily considered as part of the "pollution" muda.

These results must be viewed in the light of the potential misreading or non-acceptance of waste by some companies.

The general outline of the principal business performance indicators clearly follows the common "cost-time-quality management" triangle.

The percentage ratings of the most commonly noted green indicators can be seen in Figure 6. "Energy used" (essentially electricity and gas) and "rubbish monitoring" have been chosen as the main indicators by respectively 72% and 69% of the respondents; followed by water consumption (56%). The release of volatile organic compounds (VOC) into the air was cited by 19% of the companies.

These results confirm, on a larger scale, the recommendations on benchmarking among ten firms from the Lean and Green panel[1]: the control of energy and water consumption and the production of rubbish being the first compulsory steps towards the setting up of Green indicators. In addition, they are the most easy to set up and can result in significant progress at both the organizational and operational levels. The other tendency, seen in the previous benchmarking - that is to say the next important step - the control of greenhouse gas, was confirmed by the other respondents' answers, which also indicate an interest in water pollution (mentioned by around ten companies).

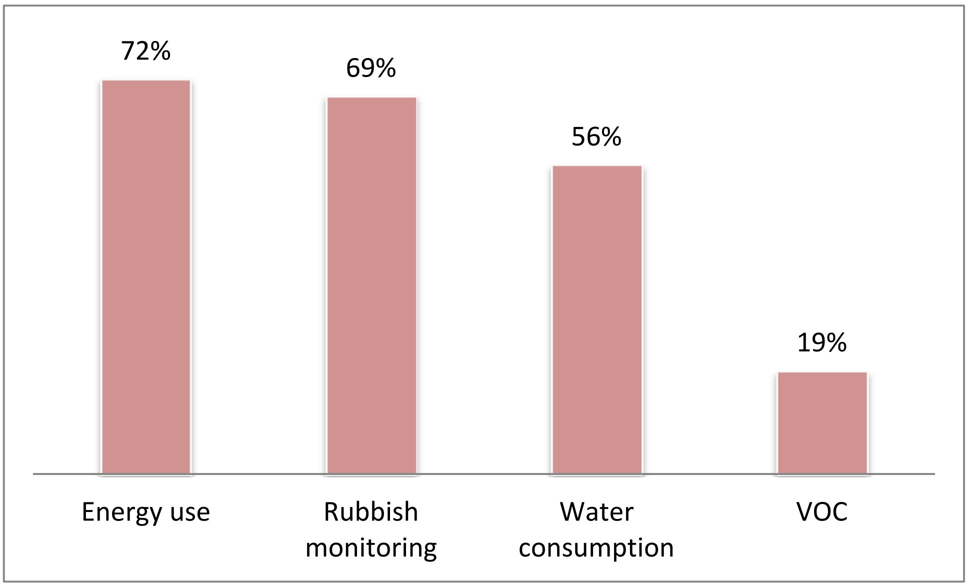


Figure 6: Most common green indicators

The above results already give substantial indications on how Lean and Green practices are handled in major firms and SMEs. In our previous research[1] we saw that the business sector of a company is not the most determinant factor for differences in these practices and that maturity plays a more important role. We therefore decided to determine what characteristics indicate maturity and highlighted the results of the most mature companies on the panel.

As can be seen in Figure 7, size appears as a determining factor for the use of continuous improvement practices in companies.

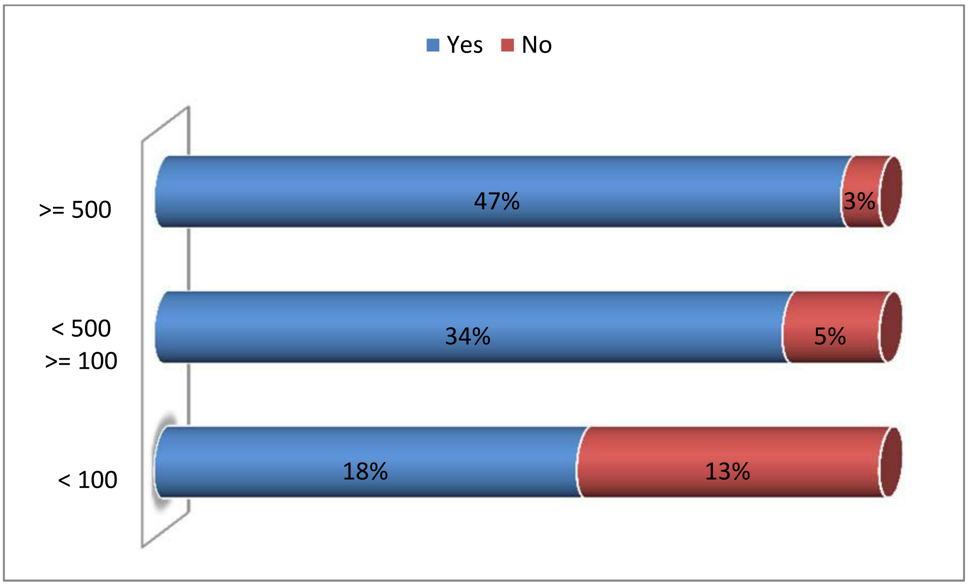


Figure 7: Comparison between the size and the use of continuous improvement practices

Corporate size also seems to play an important role in the maturity and benefits of environmental management, as larger firms are likely to possess a higher level of resources (Heras-Saizarbitoria et al., 2015). This could be confirmed by the qualitative answers concerning commitment to green concerns according to the company's size.

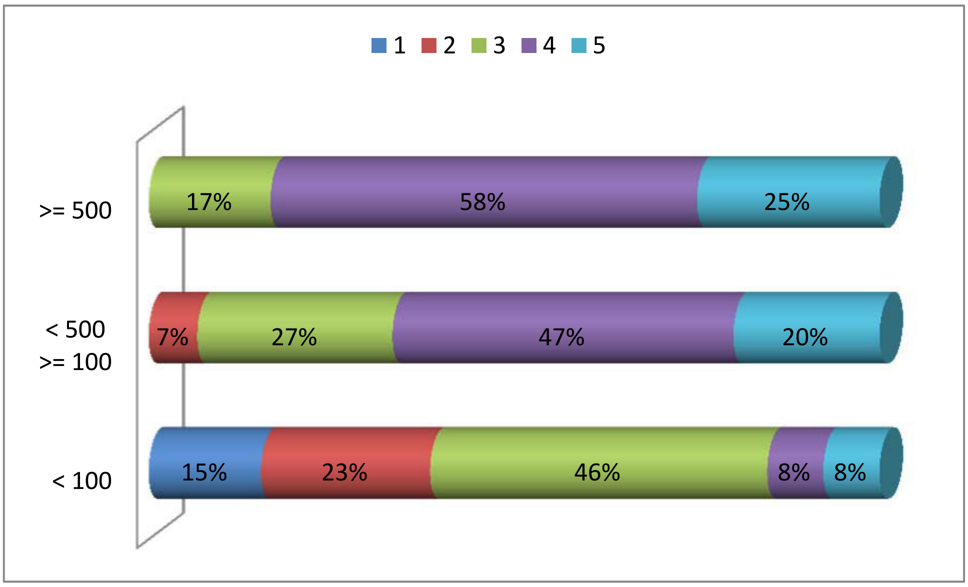


Figure 8: Environmental qualitative ratings according to the size of the firm

Figure 8 illustrates how results significantly shift towards higher ratings as the company's size increases. In firms of 100 or less employees, all ratings were represented (e.g. from "1: not yet significant" to "5: considered as a priority"). Most of these small and medium enterprises chose the middle rating of "3" (46%); "1" and "2" were respectively chosen by 15 and 23%, while the higher ratings of "4" and "5" only by 8% each. In firms of 500 or more employees, the lower ratings were never indicated, whereas "3" was ticked only by 17%, "4" by 58% and "5" by 25% of them.

Regarding certifications, the relationship between ISO 9001 and successful implementation of ISO 14001 in manufacturing firms has been well depicted by Zhu who underlined a potential synergistic link between quality, continuous improvement and environmental management (Zhu et al., 2013). Other studies highlighted concrete differences on environmental initiatives and organizational performances between Canadian SMEs holding both certifications and those holding only ISO 9001 (Roy et al., 2013).

Three criteria were therefore considered as appropriate in the context of this study for the selection of mature companies: the size (more than 500 employees on the plant site), the certifications awarded (at least ISO 9001 and ISO 14001 or internal equivalent standards), and the qualitative level of environmental initiative (at least a rating of 4/5). In other contexts, several criteria could have been added in order to open the scope to smaller enterprises presenting good voluntary initiatives. However, for the moment, only a minority of them are able to compete with larger firms on these themes. The main aim of our study is precisely to enable small and medium enterprises to access by themselves a satisfying maturity level in Lean and Green practices.

Twenty-one companies, mainly coming from the electronic, mechanical and automotive sectors, corresponded to the selection parameters.

As the replies to questions on social concerns were significantly more positive in mature companies, we will also highlight the corresponding results in this section.

Not surprisingly, the results of the selected firms were substantially better in the setting up of both Lean and Green oriented practices. For the Green section, all respondents declared the projects as at least set up. Green "visual management" and "energy diagnosis" were declared as monitored by 52%, and the "control of consumption indicators" by 62%. In the Lean section, "project management" was considered as monitored by 75% of the respondents, "risk management" by 70% and "visual management" only by 50%.

Lean tools appear as significantly better known and used than in the average results from the total panel. 95% use “5S”, 85% “Kanban”, 75% both “Poka yoke” and “Top 5” (daily short meetings on the shop floors). They are followed by “Just in Time” procedures (65%), “Single minute Exchange of Die” (SMED) (60%), and VSM (50%). Despite its importance, the practice of the “Genba Walk” on the shop floor was only indicated by 35% of the respondents.

Eco-designing products, awareness of raw material origins, and strong supply chain relationships were particularly highlighted by the mature firms, with respectively 79, 92 and 68% of support.

Some practices regarding social concerns and innovative evolution towards more sustainability achievement should also be underlined. Communication of the corporate policy through a devoted document and encouraging employees to share social values help to clarify the vision of the firm and increase the involvement of the whole company. A majority of mature firms have a “suggestion box” system on the shop floor, while around 30% also consult employees on important matters.

Training programs are mainly evoked as a way of fostering and encouraging the development of skills, but annual individual meetings, solicitation of an employee’s expertise and employee empowerment were also interesting results.

The results of this survey correspond to the observations seen among French Alsatian companies during the “Lean and Green Project” (Verrier et al., 2014). These first results could be thoroughly confirmed by further studies on an extended scale in order to maximizing the accuracy of the qualitative data.

3.2 The cradle of Lean thinking: Observations on Toyota production sites

Thanks to the development of the Toyota Production System by Taiichi Ohno and Eiji Toyoda, the automotive sector has been a pioneer in Lean manufacturing and Lean management methodologies for several decades; it is also one of the most economically healthy sectors worldwide (Staeblein and Aoki, 2015). Japanese automotive economic growth steadily increased from 2009 to 2012, except for 2011 due to the earthquake disaster (Nkomo, 2012). The automotive industry also has several reasons for leading the way in environmental and sustainability concerns (Govindan et al., 2014). Car manufacturers are aware that their products traditionally require resources and energy to be used and customers thus have higher expectations of newly designed cars. Moreover, the automotive sector is subjected to particularly stringent compliance rules, especially in recycling objectives in Europe, due to European Directive ELV (End of Life of Vehicles) 2000/53/EC (Millet et al., 2012).

This section therefore highlights some practices from Toyota (Onnaing, France and Toyota-shi, Japan) based on on-site observations and public communications.

The parent company of Toyota Motor Corporation is based in Toyota-Shi, Japan. Toyota's development policy, both for financial and sustainability concerns, is based on three key priorities: Growth, Efficiency and Stability (Corporation, 2014). The continuous improvement methodology applied in the manufacturing processes is based on challenge, Kaizen thinking ("change for better"), and Genchi Genbutsu ("go and see" to observe on the shop floor how the manufacturing process truly works, commonly applied through the "Genba Walk"). Another pillar supporting the Toyota method is teamwork and respect for people. Every employee is responsible for preventing a flawed product from continuing any further along the production line, thanks to the famous Andon system, developed on-site through detailed "Andon boards". Lean tools and methods are thoroughly observed during the stamping, welding, painting and assembly processes.

Toyota indicates voluntary efforts towards compliance with the CSR core subjects in the ISO 26000 standard and also towards general social contribution activities (Toyota, 2015). They also aim to stay ahead of customers' environmental expectations and notably commercialized the first mass-produced hydrogen fuel cell vehicle in 2015.

The production site in Onnaing, France is directly under the supervision of its parent company, it follows the same TPS rules and tools and uses 30% less plant space than traditional car manufacturers. Environmental indicators are closely controlled and reported back to Japan once a month. They notably prioritize monitoring of: reductions in the energy needed per vehicle produced; industrial water self-sufficiency (thanks to an internal waste water treatment system); the amount of rubbish generated and COV emissions from the painting process. Their primary environmental preoccupations are therefore to reduce and reuse as far as possible. Green visual management is however not very widespread on the shop floor. Continuous progress is encouraged by 50 minutes' teamwork on kaizen development ideas for every employee once every fortnight.

Environmental and social aspects are thus increasingly evoked and integrated into the traditional Toyota Way, which proves the interest of the Lean and Green approach at both the organizational and operational level.

An increasing number of approaches now consider it important to associate Lean and environmental themes and deploy them with equal importance in production processes. However, up to now few of these approaches specifically fuse Lean and Green paradigms. In order to enhance the practices highlighted in the above section, we will look for additional Lean and Green synergies in relation to their respective wastes and tools.

4 Correlations between Lean and Green mudas and tools

The chart in Table 1, originally released by the US Environmental Protection Agency (EPA) (EPA, 2007), may be considered as a first step towards showing concrete synergies between Lean and Green wastes. The table, originally based on observations made in American firms and showing which environmental issues are likely to be found at the same time as specific Lean wastes, has been adapted to underline the Green "Hines" mudas used in our project.

Lean Muda	***Associated green impacts***
Overproduction	*- Unnecessary use of energy and raw materials, further safety troubles in case hazardous substances are involved, potential increase of direct output emissions*
Unnecessary inventory	*- Excessive power usage for heating/cooling/ lighting …* *- Potential extra material used and rubbish production due to added packaging and possible products deterioration*
Transport	*- Energy usage in transports* *- Generated emissions in the air* *- Special risks in case of hazardous freight (spills…)*
Unnecessary motion	*- Potential more space (energy) and packaging (materials) required for unnecessary motions*
Defects	*-Waste of raw materials and energy* *-Management of re-treatments (energy, disposal…)*

Innapropriate processing	*- Unnecessary energy and raw materials needed, more rubbish and emissions created, potentially hazardous processes*
Waiting	*-Spoiled energy and resources, potential material damages*
Lost people potential	*- Lost potential for improvement*

Table 1: Lean mudas and their associated green impacts

We can therefore more explicitly link Lean and Green wastes as follows:

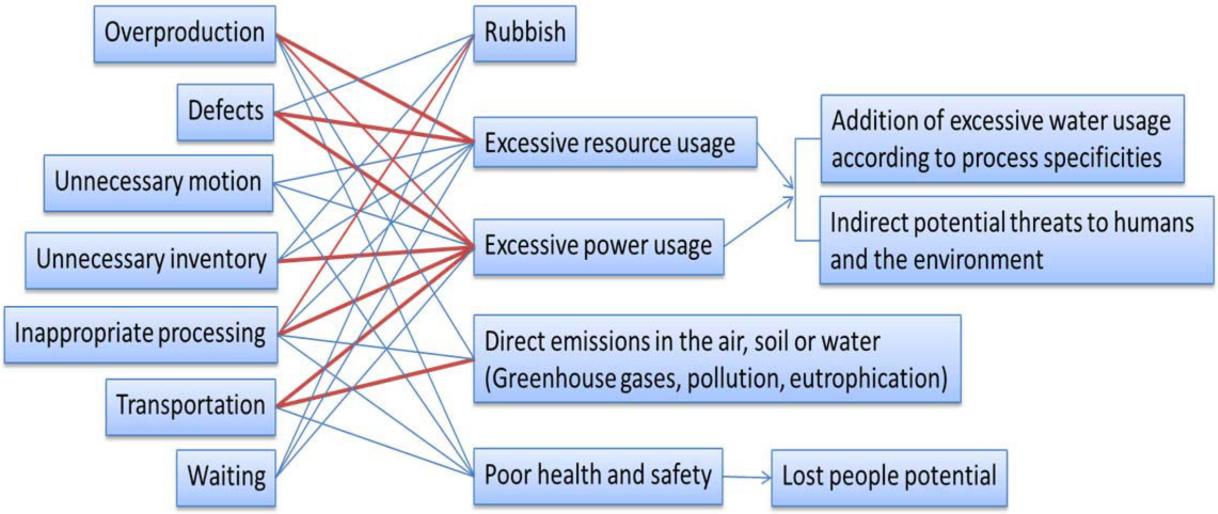


Figure 9: Causal links between Lean and Green wastes

The links in red represent the Green mudas that are likely to be hidden behind the corresponding Lean waste, while the links in blue represent a potential risk.

We immediately see that excessive power usage is the most important Green muda and is potentially affected by every Lean muda. It is most likely to be provoked by overproduction, defects, unnecessary inventory, inappropriate processing and transportation. The next muda is excessive resource usage. Directly affected by overproduction and defects, it is potentially also provoked by motion, inventory, inappropriate processing and waiting. Depending on the process specificities, resource and power usage can both represent excessive water usage, or potentially be the cause of indirect harm to people and the environment in the previous and following stages of the product life cycle (e.g. raw material extraction). These wastes are followed by rubbish, direct emissions (greenhouse gas, pollution or eutrophication) and poor health and safety.

Poor health and safety and lost people potential are somewhat special, as they are both usually the "eighth" muda of each theme, but can also be added as important mudas for increasing social concern in the manufacturing process, by restoring human resources to their central place. Lean, environmental and social preoccupations can indeed be directly linked through safety concerns.

Lost potential is also special as it may lead to spoiled opportunities for improvement in both Lean and Green wastes. Moreover, "poor health and safety" directly lead to "lost people potential".

The wastes evoked in the results of the surveys correspond to the Green wastes that are more likely to occur due to Lean wastes. These common Green mudas should therefore be corrected as a priority, through the elimination of the corresponding Lean wastes, thanks to appropriate Lean tools, in addition to the implementation of a proper Lean and Green methodology, as presented in Appendix 2.

Thus, we see the following causal effects of Lean tools on Lean mudas, based on on-site observations and information provided by recognized Lean experts, such as the Kaizen Institute (Kaizen Institute, 2015)(Figure 10).

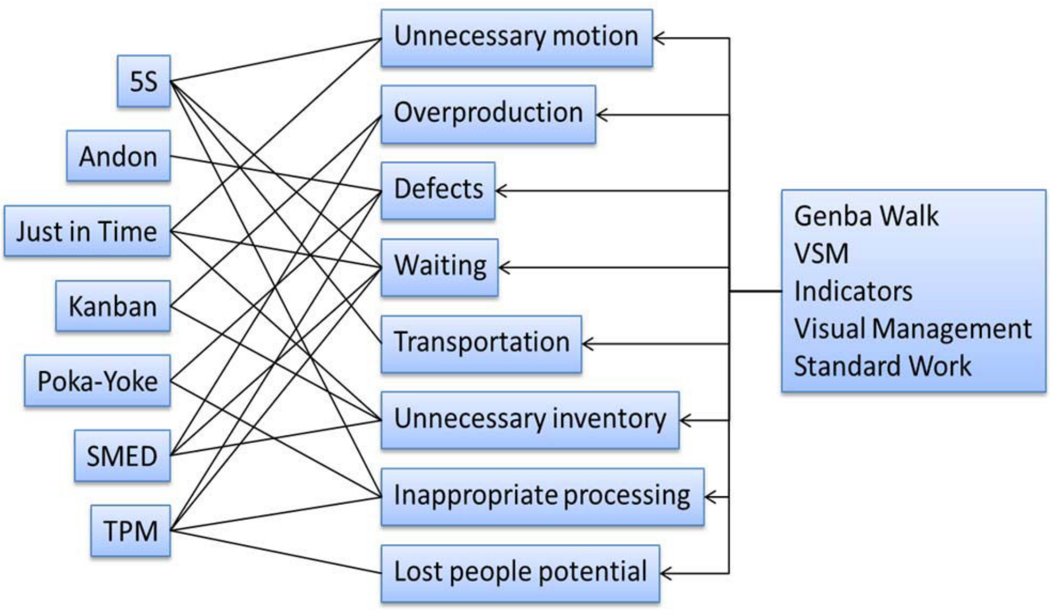


Figure 10: Lean tools and their action on Lean mudas

The tools to on the right can be considered as the most important Lean tools. They have a potentially beneficial influence on all Lean mudas and are organizational strategic drivers. In addition, they are equally beneficial to Green mudas. The Genba Walk, linked to Value Stream Mapping, is the most powerful tool for associating Lean and Green paradigms in production process, through the objective of waste elimination. It allows visualizing flows of production, highlighting opportunities for improvement and clearly exposing waste. The setting up of key performance indicators may influence behavior, encourage progress, help to achieve organizational objectives and quantify wastes. All these benefits are enhanced by visual management, especially the share of common objectives. Standard Work is also a top tool, aiming at systematically applying best practices. However, it should be constantly challenged and this could make it difficult to set up, especially for small and medium enterprises, which is why we have not included it as a compulsory step towards Lean and Green implementation.

5S is also a very important Lean tool, which is efficient both on the principle Lean wastes and Green wastes. An interesting contribution from Chiarini underlines the correlations between the implementation of five Lean tools and their consequences on environmental performance (Chiarini, 2014). According to the author, 5S helps to reduce mistakes during the rubbish sorting process, which in turn also improves recycling and prevents potential hazardous mistakes (solvents or chemical products). In addition, 5S can lead to less repetitive strain injuries (RSI) and is therefore particularly beneficial to the waste of poor health and safety.

Chiarini also underlines the benefits of VSM in identifying the environmental impacts of production processes and cite TPM (i.e. proactive and preventive maintenance) as a direct factor towards environmental improvement, due to its ability to increase machine life and reduce the potential negative effects of a non-optimized functioning (e.g. emissions). However, like Standard Work, this tool is not easily accessible to SMEs and can only be implemented after a Lean and Green methodology has already been efficiently set up.

As Dües et al. remind us (Dües et al., 2013), in some cases Lean and Green practices are not perfectly compatible, especially in the field of transport (e.g. short lead-times and frequent replenishment versus the reduction of greenhouse gas emissions). However, compromises can usually be found through the involvement of the concerned employees and top management, which can in turn lead to collateral advantages (e.g. local partnerships).

5 The Lean and Green House

Our studies including scientific reviews, on-site observation and industrial cases, surveys and Lean and Green correlation analysis, based on the importance of considering Green wastes alongside Lean wastes - have enabled the development of the original Lean and Green House presented in this section (Figure 11).

To date, not many systems based on the "Lean House" from TPS and embedding environmental concerns have been proposed. Kurdve analyzed some of them, including the Volvo system, illustrated by Nord in 2012 (Kurdve, 2014). Peter Hines developed an adaptation of the Lean House by highlighting some important practices in the delivery, environment and quality pillars. The originality of our work lies in the proposal of clear, exhaustive and concise best-practices that any company, including SMEs, can run to manage their Lean and Green performance at the organizational and operational levels. These tools and practices are moreover linked to each other, thanks to study of the correlations between Lean and Green mudas, so that any action may bring potential benefits to all three Lean, Human and Green pillars.

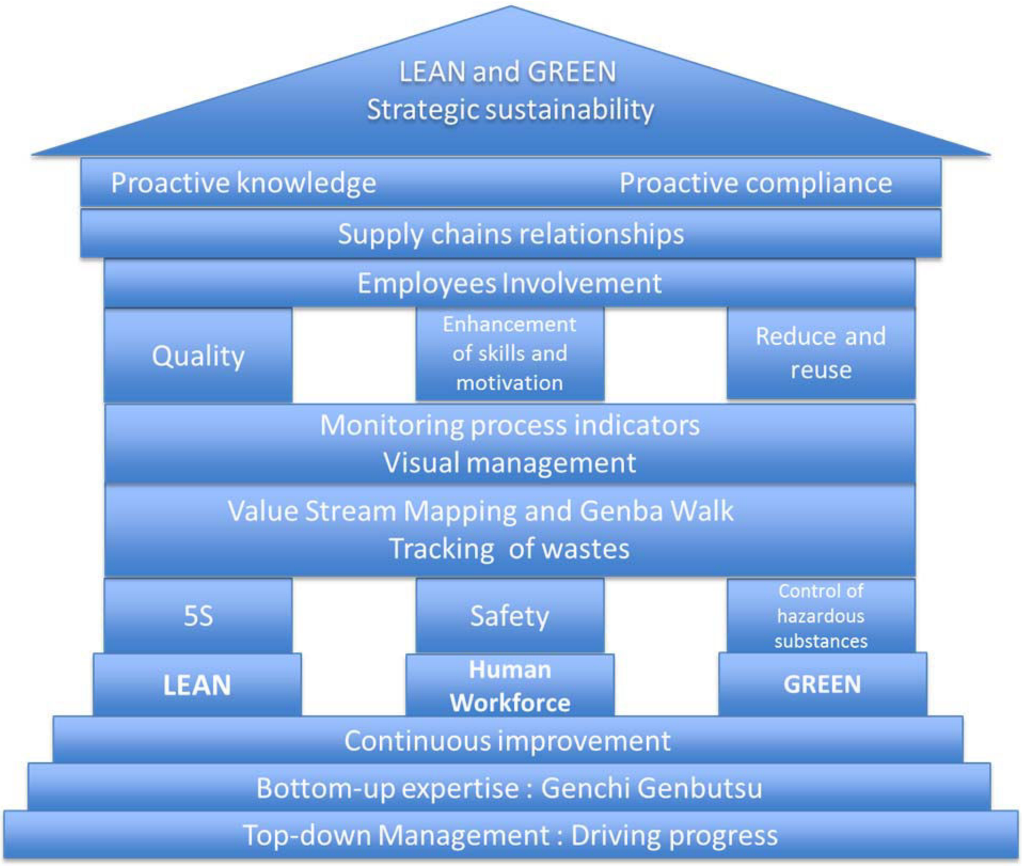


Figure 11: The Lean and Green house

The major strategic tools described in the above section effect most Lean and Green wastes and are therefore considered to be the main common principles. Top-down management is the foundation for implementing long-term and efficient action, whereas bottom-up feedback relays correct information back to that management (Asif et al., 2013) (Kurdve et al., 2014).

Positive links between human resource strategies through cultural behavior (e.g. employee training and their involvement in the environmental protection culture), and the enhancement of environmental performances, are confirmed by interesting contributions (Paillé et al., 2014) (Fercoq, 2014; Tung et al., 2014). Paillé argues that employees become more committed, satisfied and willing to behave as "good citizens" when they feel they are supported by their organization (Paillé and Boiral, 2013).

Relationships with suppliers and key stakeholders are included because they are an important way of ensuring strong social sustainability leading to competitive advantages (Herrera, 2015).

Our work is in accordance with the Shingo guiding principles, which put emphasis on cultural enablers and continuous process improvements as the bases of operational excellence (Shingo Institute, 2012).

6 Lean and Green maturity model

Maturity models appeared alongside the first quality management studies and their use was an enormous step towards performance improvement approaches (Estampe et al., 2013). One of the best and most widespread models today is the Capability Maturity Model Integration (CMMI), which, in five stages, provides sequences for improvement as well as a basis to assess the deployment maturity of specific projects or organizations (Institute, 2015). Created by the Software Institute (SEI, 2015) and originally designed for services and engineering activities, this model has since been declined in every kind of organization, as its aim is to be adjustable to diverse needs and approaches.

Thus, we chose to adapt this reliable model to our Lean and Green strategy to enhance the formalization of assessment and deployment in the approach (Figure 12).

Zokaei et al. already depicted four stages of Lean and Green maturity with the use of both approaches within companies (K. Zokaei et al., 2010). Our own model accords with this previous study whilst taking a slightly different look at the stages of Lean and Green synergies, based on our own observations and research. Our maturity model is also enhanced by Lean and Green best-practices, the deployment of which must follow the successful deployment of the previous stages.

Several maturity models indirectly related to our subject have recently been published, especially on energy management (Antunes et al., 2014) (Introna et al., 2014; Ngai et al., 2013) and also on eco-design (Pigosso et al., 2013).. The IT company Intel also developed a CSR maturity curve model, which is discussed in scientific literature by (Herrera, 2015) or (Jacobson, 2013).

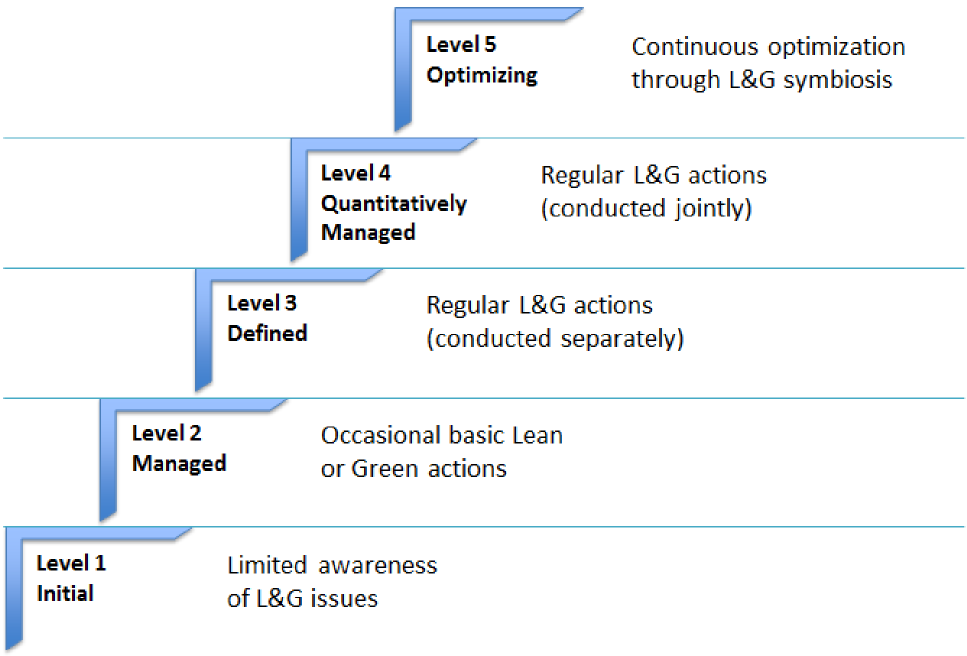


Figure 12: Lean and Green maturity model

<u>Level 1, Initial</u>: The company has limited consciousness of most L&G issues and the fact that they might co-exist. There is no monitoring of environmental indicators or guiding principles from the top management.

<u>Level 2, Managed</u>: Basic Lean or Green action is occasionally conducted. The company is aware that non-value-added wastes might be present in production processes and can be reduced. Action for improvement is limited and essentially driven by regulatory requirements. Capability: The major environmental indicators (energy, water, production of rubbish) are

controlled at the organizational level (global results indicators). There is consciousness of the main Lean tools, notably the need for managing production space (5S).

Level 3, Defined: Lean and Green action is conducted separately but on a regular basis, and there is consciousness that both Lean and environmental practices can add value to the company: they are united in a global strategy conducted by the top management. The main Lean and Green wastes are known. Capability: Major environmental indicators and indicators related to process specificities (raw materials, machines consumables…) are declined at operational levels to become process drivers. There is action to install or improve tools on the shop-floor. To that purpose, the Genba Walk is occasionally carried out and there is limited internal communication with employees on L&G themes. Progress towards objectives is measured and visual management has been partially set up.

Level 4, Quantitatively managed: Lean and Green action is considered to be of major importance and is conducted on a regular basis through strong top-down and bottom-up management. Waste is continuously tracked to improve L&G performance. Capability: the Genba Walk is integrated into daily routine; indicators are set up and monitored in total harmony with objectives and needs. In addition to constant improvement of working and safety conditions, Lean and Green visual management and meetings on the shop-floor are widely used to promote employee involvement and suggestions. Employees are always involved in process improvements.

Level 5, Optimizing: L&G objectives are conducted in symbiosis. The company is aware of all direct and indirect correlations stemming from any action and is therefore able to enhance their positive effects. The company is in constant and effective continuous optimization, there is anticipation and proactive action. Through this constant reinforcement of basics, linked to the extension of its objectives, the company has reached an efficient Lean and Green strategic sustainability. Capability: the company efficiently monitors all Lean and Green tools with consciousness of their common benefits at every level.

7 Conclusion

As there is no single way to achieve Lean and Green sustainability among companies with many different specificities and various processes (Kurdve, 2014), our research aimed to facilitate the choice and implementation of effective and easily used Lean and Green tools.

This contribution enhances the previous studies conducted as part of the “Lean and Green Project” and presents an extended survey of the Lean and Green practices applied by a panel of 56 manufacturing firms coming from various business sectors. Emphasis is put on best-practices through the results of the most matures companies on the panel and a study of Toyota commitments based on their public communication and on-site observations both in Onnaing, France and Toyota-Shi, Japan.

The results are enhanced by a thorough study of Lean and Green existing correlations and synergies through their respective wastes and tools, which particularly highlighted three “top” tools which, as organizational strategic drivers, may have positive effects on all Lean and Green mudas in addition to enhancing the involvement of employees. These tools, easily accessible to less mature companies, are the Genba Walk, Lean and Green VSM, Key Performance Indicators, and Visual Management.

Out studies, including scientific reviews, on-site observation, industrial case studies, surveys and waste correlation analysis, have enabled the development of an original Lean and Green House, which features clear and concise best-practices that any kind of company can run in order to manage their Lean and Green performance at both the organizational and operational level. The workforce is considered to be a pillar that cannot be dissociated from Lean and Green efficiency.

We also chose to adapt the CMMI maturity model to our Lean and Green methodology in order to enhance the formalization of assessment and deployment in the global approach.

The Lean and Green House and the maturity model presented in this contribution are specifically based on accessible procedures aimed at fostering synergistic Lean and Green implementation within manufacturing firms. For this reason, and because the subject has already been widely covered by specialized scientific and industrial literature, the setting up of more “expert” Lean tools is not covered here. However, as Chiarini already said, it would be interesting to further explore the correlations between the deployment of specific “expert” Lean tools and their effects on Green performances (Chiarini, 2014), in order to optimize knowledge in the setting up of higher maturity stages.

Another important angle is the extension and adaptation of Lean and Green methodology to other specific product life-cycle stages. The link to eco-design and end-of-life management (Pialot, 2012; Vadoudi, 2014) could be particularly strong.

[1] : B. Verrier, B. Rose, E. Caillaud "*Environmental performance indicators: review and proposals applied to the Lean and Green project*", submitted to the Journal of Environmental Management.

[2] : B. Verrier, B. Rose, E. Caillaud "*The Lean and Green project methodology: assessment and implementation roadmap, best practices recommendations from case study observations*", submitted to the International Journal of Production Economics.

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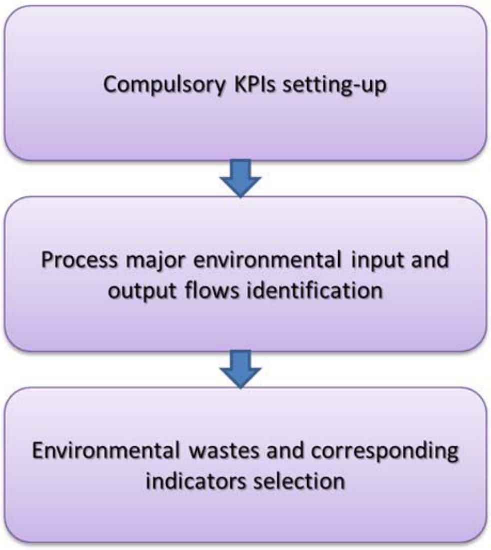
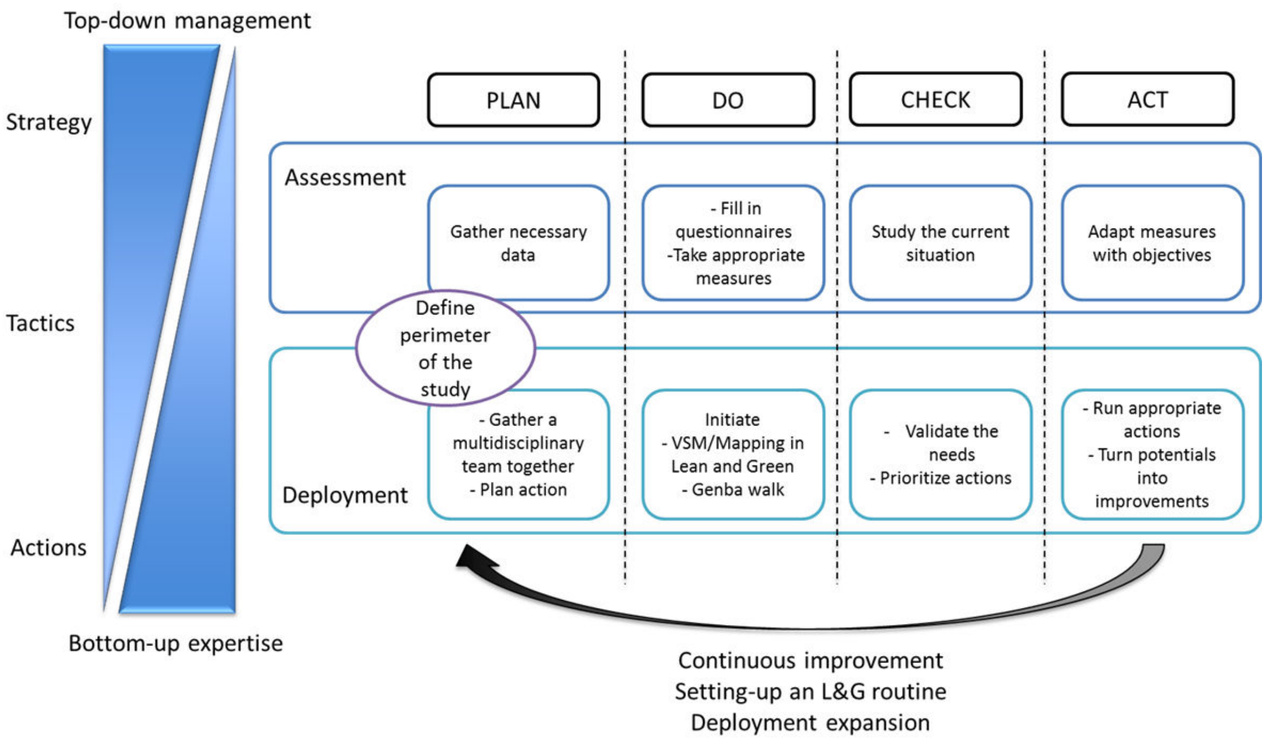
Appendix 1: Environmental indicator setting up model



Appendix 2: Synthetic Lean and Green assessment and deployment roadmap



Appendix 3: Survey model on Lean and Green practices

Lean and Green practices

ICube Laboratory, Strasbourg

I) General information

I.1 Where is located the plant site?

I.2 What is its business sector?

I.3 What is the total number of employees on site?

I.4 What are the company current certifications?

- ☐ ISO 9001 : 2008
- ☐ ISO 14001 : 2004
- ☐ OHSAS 18001 : 2007
- ☐ ISO 50001 : 2011
- ☐ ISO 26000 : 2010
- ☐ EMAS
- ☐ Other:

II) Lean deployment

II.1 Is the company involved in continuous improvement methodologies?

II.2 Are some of these Lean tools used on a regular basis?

- ☐ 5S
- ☐ Kanban
- ☐ Poka Yoke - Mistake-proofing
- ☐ SMED ("Single minute exchange of die")
- ☐ Versatility of human resources
- ☐ Value Stream Mapping
- ☐ Daily short meetings
- ☐ Heijunka (production leveling) + TAKT Time ("Just in Time" tools)
- ☐ Genba Walk - Genchi Genbutsu
- ☐ Andon (problem alert)
- ☐ Kaizen events (planned session for improvement)

II.3 Are some other specific tools used?

II.4 Which Lean wastes arlready have been faced in production processes?

- ☐ Defects
- ☐ Overproduction
- ☐ Unnecessary motion
- ☐ Inappropriate processing
- ☐ Waiting
- ☐ Non-optimized transportation
- ☐ Unnecessary inventory

II.5 Setting-up assessment of continuous improvement initiatives

	No process	Set-up process	Monitored process
Formalisation of project management	○	○	○
Risk management strategies	○	○	○
Visual management/ Indicators display	○	○	○

II.6 What are the lean and process performance indicators monitored and dislayed in priority?

III) Green deployment

III.1 Which Green wastes arlready have been faced in production processes?

- ☐ Excessive resources usage
- ☐ Excessive water usage

- ☐ Excessive power usage
- ☐ Greenhouse gases
- ☐ Pollution or harmful spillage in the environment
- ☐ Non recycled rubbish production
- ☐ Poor health and safety

III.2 Are the new products eco-designed?

- ○ Always
- ○ When possible
- ○ Not yet as a priority

III.3 Does an exchange about environmental characteristics of the products with suppliers and customers exists? (Green supply chain relationship)

- ○ Yes, always
- ○ Yes, in case of regulatory requirements
- ○ Generally not necessary

III.4 In the same way, are the origins of raw materials always controled?

- ○ Yes
- ○ No
- ○ Partially

III.5 Setting-up assessment of green initiatives

	No process	Set-up process	Monitored process
Monitoring indicator of consumptions and emissions	○	○	○
Visual management/ Indicators display	○	○	○
Energy diagnosis for the whole site	○	○	○

III.6 What are the green performance indicators monitored and dislayed in priority?

IV) Social responsibility deployment

IV.1 Does the company have a defined policy regarding its values and code of conduct? ?
(Improvement projects, health and safety, social values, other involvements...)

- Yes, a written document clarifies those dispositions
- Yes, there is no document but values are orally transmitted within the company
- Not yet

IV.2 Are every employees initiated into those values?

- Yes, absolutely
- Only if there is a particular need
- Not yet

IV.3 Are employees encouraged to develop their expertise? In what ways?

IV.4 Does a suggestion system exists and/or are employees sometimes consulted for important questions regarding process management?

- Suggestion for improvement system
- Employees are consulted
- Not yet

IV.5 What are the social performance indicators monitored in priority?

V) General assessments and conclusion

V.1 In general , how would you assess : - the company's commitment to social concerns ?

	1	2	3	4	5	
Not yet significant	○	○	○	○	○	Considered as a priority

V.2 - the company's commitment to environmental concerns ?

	1	2	3	4	5	
Not yet significant	○	○	○	○	○	Considered as a priority

V.3 - the company's maturity in continous improvement process ?

	1	2	3	4	5	
Setting-up not achieved	○	○	○	○	○	Monitored and up to date process

V.4 Does the company promote its environmental and social competences?

- ○ Yes, both
- ○ Mainly the environmental competences
- ○ Not yet

V.5 Did the company already experience projects combining Lean to Sustainable development? Are some of them currently in progress? Are there examples of associated benefits?

V.6 Do not hesitate to make additional comments below

Thank you for your contribution

Conclusion

Ces travaux de thèse s'inscrivent dans le cadre du projet de recherche Green LEM. Nous nous sommes intéressés, d'un point de vue essentiellement qualitatif, à la synergie existante dans la mise en œuvre d'actions Lean et Green au sein des processus de fabrication d'entreprises manufacturières.

La contribution de cette thèse a donc consisté à répondre à comment définir, déployer et améliorer une véritable stratégie Lean and Green à travers la création et la mise en œuvre d'une roadmap d'analyse et de déploiement d'une politique de management alliant amélioration continue et développement durable en entreprise industrielle. Pour ce faire, nous avons articulé notre contribution autour de deux inducteurs de performance. Cette section présente le bilan des contributions ainsi que que les limites qui y sont associées. Différentes perspectives de recherche à ces travaux sont ensuite proposées.

1. Synthèse des contributions

Au cours de ces travaux de thèse, nous nous sommes intéressés à la problématique de recherche suivante : **Comment intégrer conjointement des méthodologies Lean et Green au travers de modèles d'évaluation des performances et de déploiement au sein d'entreprises manufacturières possédant des processus, cultures et maturités différentes ?**

La Figure 1 présente une vision synthétique du positionnement de nos contributions, suivant un axe opérationnel (outils/méthodes) et suivant un axe plus organisationnel (déploiement/vision stratégique).

Le premier article, publié dans un volume spécial « Lean and Green » du Journal of Cleaner production et intitulé « *Combining organisational performance with sustainable development issues: empirical evidence from the Lean and Green Project* » propose une première analyse de la mise en place d'un référentiel d'évaluation Lean and Green au sein d'un panel d'entreprises manufacturières. Ainsi, l'objectif de recherche était d'analyser la performance du duo Lean et Green mis en œuvre via l'évaluation des pratiques de 21 entreprises à partir du développement de 3 questionnaires et d'indicateurs dédiés. L'analyse est renforcée par une étude exhaustive de l'état de l'art sur le concept du Lean and Green. Cette première étude nous a permis de qualifier la synergie existante entre les concepts du Lean et du Green en regard des entreprises considérées.

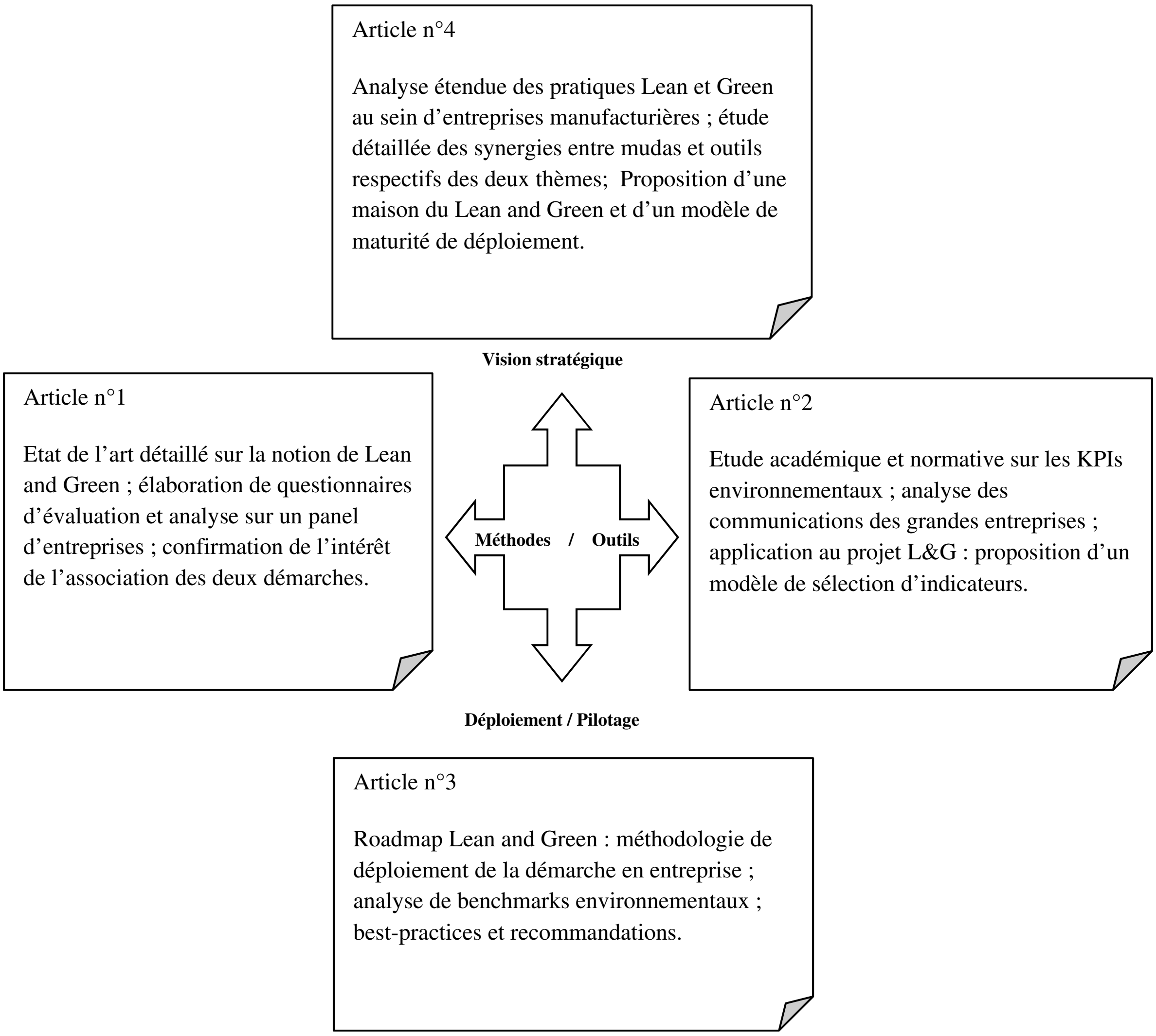


Figure 1 : Synthèse et positionnement des articles

Le deuxième article, intitulé « *Environmental performance indicators: review and proposals applied to the Lean and Green project* » présente une étude de la littérature, un bilan des modèles et normes existants ainsi qu'une analyse des rapports environnementaux de sociétés classées au CAC40. Enfin, il y est développé un modèle de sélection d'indicateurs environnementaux simple et pragmatique, adapté au cas du projet Lean and Green. Les conclusions de cette étude soulignent une certaine hétérogénéité dans l'utilisation d'indicateurs environnementaux par les grandes firmes. Cette contribution propose donc également des bonnes pratiques et des recommandations accessibles quant à la mise en place d'indicateurs à destination des PME, dans l'objectif d'atteindre plus rapidement de meilleures performances en Lean and Green.

Nous avons présenté en introduction de ce manuscrit les 2 inducteurs de performance ayant permis de répondre à cette problématique *(Définir des indicateurs environnementaux pour la mise en œuvre du Lean and Green et Définir une stratégie pour déployer et accroître l'efficience de la mise en œuvre des outils Lean and Green).*

Ces deux articles contribuent majoritairement à répondre aux verrous de l'inducteur de performance n°1 en proposant un état de l'art exhaustif sur la notion d'indicateur environnemental, des ratios d'évaluation des performances, un modèle de sélection des indicateurs Lean and Green et des bonnes pratiques pour mettre en œuvre ces indicateurs dans les PME (Table 1).

	Inducteur de performance n°1 *Définir des indicateurs environnementaux ad hoc pour la mise en œuvre du Lean and Green*	**Contribution**	**Article**
Verrous	Quels indicateurs environnementaux sont actuellement utilisés ?	Etat de l'art sur les indicateurs environnementaux Enquêtes comparatives	2+4
	Comment procéder pour les sélectionner efficacement avec un recul suffisant?	Modèle décisionnel basé sur les flux et gaspillages L&G pour la sélection d'indicateurs	2
	Comment utiliser les connaissances capitalisées (bonnes pratiques) efficacement ?	Modèle d'implantation pas à pas Recommandations et bonnes pratiques	2
	Quels indicateurs utiliser pour un benchmarking environnemental ?	Déploiement d'indicateurs relatifs d'évaluation au travers de questionnaires	1+3

Table 1 : Inducteur de performance n°1 et contributions correspondantes

Les deux articles suivants s'attachent à une contribution orientée majoritairement vers un axe stratégique de déploiement et de pilotage d'une méthodologie Lean and Green.

Ainsi, l'article n°3, intitulé « *The Lean and Green project methodology: assessment and implementation roadmap, best practices recommendations from case study observations* » propose une roadmap originale de déploiement de la méthodologie, permettant de traduire des objectifs stratégiques en action opérationnelles. Basée sur une méthode d'évaluation et de prise de conscience de l'existence des gaspillages Lean et Green au sein des processus de fabrication, cette roadmap propose des actions simples et concrètes pour la mise en œuvre d'une procédure d'amélioration continue liant les aspects Lean and Green. Elle est réalisée dans l'objectif de rester accessible aux petites et moyennes entreprises. Une analyse de comparaison des performances environnementales au sein du panel d'entreprises participant à la seconde édition du projet, ainsi que la mise en lumière de bonnes pratiques s'intéressant également aux préoccupations sociales, complètent cette contribution.

Le quatrième et dernier article composant ce manuscrit de thèse, intitulé « *Lean and Green strategy : the Lean and Green house and Maturity Model* » prend de la hauteur en formalisant un cadre d'implémentation des outils de la méthodologie Lean and Green. Ainsi, à partir d'une revue synthétique de la littérature liée à des bonnes pratiques industrielles mises à jour sur la base d'observations et d'enquêtes, cet article présente une étude des corrélations entre mudas du Lean et mudas du Green ainsi que les outils qui leur sont associés de manière à proposer un cadre d'implémentation sous forme d'une « maison du Lean and Green ». En faisant l'analogie avec les niveaux de maturité proposés par le CMMI, la dernière phase de cette contribution porte sur la proposition d'un modèle de maturité Lean and Green.

Ces deux articles contribuent majoritairement à répondre à l'inducteur de performance n°2 (Table 2) et à définir comment les objectifs de déploiement Lean and Green peuvent correspondre dans les faits aux stratégies voulues par la direction. Cette consistance stratégique alors acquise permet de donner une vision à court et à long terme dans l'organisation des actions pour la performance Lean and Green, et de s'assurer d'une stratégie de déploiement incrémentale cohérente.

<table>
<tr><th></th><th>Inducteur de performance n°2
Définir une stratégie pour déployer et accroître l'efficience de la mise en œuvre des outils Lean and Green</th><th>Contribution</th><th>Article</th></tr>
<tr><td rowspan="5">Verrous</td><td rowspan="3">Comment organiser les actions pour définir une vision à la fois court terme et long terme de la performance Lean and Green ?</td><td>Etat de l'art sur la notion de Lean and Green</td><td>1+3+4</td></tr>
<tr><td>Stratégie d'implantation par l'évaluation initiale puis routinière des performances Lean and Green</td><td>1+3</td></tr>
<tr><td>Coordination de la montée en compétence des entreprises via la définition d'un modèle de maturité Lean and Green</td><td>4</td></tr>
<tr><td rowspan="2">Comment s'assurer d'un déploiement efficace du Lean and Green?</td><td>Définition d'outils simples et clairs</td><td>1+2+3</td></tr>
<tr><td>Définition d'une stratégie de déploiement incrémentale et cohérente</td><td>3+4</td></tr>
</table>

Table 2 : Inducteur de performance n°2 et contributions correspondantes

2 Limites de nos propositions

Notre approche qualitative de la mise en œuvre d'une stratégie Lean and Green, réalisée de manière à être aussi complète que possible, peut néanmoins posséder certaines limites que nous détaillons dans cette section.

D'un point de vue du cycle de vie du produit tout d'abord : notre approche est essentiellement focalisée sur la phase de production du produit manufacturé. Même le cycle de vie des entrants et sortants de cette phase de production sont considérés, notamment en terme d'émissions dans l'environnement ou de considération de l'origine des matières premières, nous n'avons volontairement pas pris en compte de manière détaillée d'autres phases du cycle de vie, et avons ainsi défini ces limites au périmètre d'étude dans un souci de clarté et de simplicité des modèles proposés, afin de promouvoir une mise en œuvre directe et efficiente.

Ce constat peut être considéré comme une limite dans la mise en œuvre *des inducteurs de performances n°1 et 2.*

Concernant l'inducteur de performance n°2 en tant que tel, notre approche est également limitée d'un point de vue gestion de projet : la stratégie de déploiement du Lean and Green n'intègre pas de données temporelles pour faciliter sa planification par les industriels. Les étapes proposées dans les modèles Lean and Green ne sont ainsi pas bornées dans le temps. Cette prise de position était nécessaire afin que chaque entreprise puisse mettre en place son propre canevas d'accès à une stratégie Lean and Green en termes de déploiement temporel. Nous soulignons cependant que le Lean and Green doit être mis en place de manière incrémentale et que son déploiement, à l'instar de celui des méthodes Lean, ne suit pas une progression linéaire (Liker and Meier, 2008).

De même, notre stratégie n'intègre pas de scénario organisationnel type pour manager la mise en place de cette stratégie Lean and Green en termes d'affectation des rôles de chaque acteur dans le processus d'amélioration continue.

Ceci s'explique notamment par le fait que nos travaux sont directement orientés vers une mise en œuvre dans des entreprises de type PME. Dans ce contexte, les fonctions sont souvent transverses et les rôles que peuvent prendre les différents acteurs du processus d'amélioration sont difficiles à formaliser de par la structure managériale souvent limitée de ces entreprises Ainsi, beaucoup de PME ne possèdent pas de managers dédiés à l'amélioration continue ;

notre stratégie Lean and Green propose cependant une ligne directrice leur permettant de déployer une méthode et des outils opérationnels répondant aux demandes stratégiques.

3 Perspectives

Dans un contexte d'amélioration continue des méthodologies proposées, un certain nombre de perspectives peuvent naître de ces travaux.

Nous avons vu que notre proposition est limitée par rapport au cycle de vie global du produit dans le sens où elle s'intéresse spécifiquement aux processus de production. Ainsi, la mise en place de procédures Lean and Green pourrait être liée à une prise en compte élargie des autres processus du cycle de vie. Si l'optimisation de la phase d'utilisation est souvent intrinsèquement intégrée par les processus d'écoconception des produits, particulièrement dans les secteurs de l'automobile et des équipements électriques, nous voyons naturellement deux perspectives de travaux pouvant intégrer, dès la conception, les problématiques Lean and Green à des processus intervenant à d'autres phases du cycle de vie:

- sur la phase de conception du produit,
- sur la phase la de fin de vie produit.

Dans la phase de conception du produit, un certain nombre de travaux ont traité le sujet (May et al., 2011), (Rossi et al., 2014), (Johansson and Sundin, 2014) ; illustrant le potentiel de synergies entre le développement de produit Lean et le développement de produits Green, sans toutefois montrer un lien formel entre les deux actions. Cependant, en amont des travaux proposés dans cette thèse, un focus intéressant pourrait être fait sur la charnière entre écoconception et production Green lors de la phase d'industrialisation. Dans cette phase, il s'agirait d'optimiser les consommations en énergies et matières des processus de fabrication des produits. En ce sens, il faudrait, dans la phase amont de conception, intégrer, en complément des problématiques du Design For Manufacturing and Assembly (DFMA) (Bayoumi, 2000) (Boothroyd, Dewhurst et al. 2010), des contraintes englobant les aspects Green. Ces contraintes pourraient être telles que la quantité d'énergie, de gaz ou de fluide nécessaires pour l'obtention ou la mise en place d'un élément; ou encore le taux de rebut matière pour un procédé ou une machine donnée. Outre un montage Lean du produit, cette contrainte supplémentaire dans le DFMA pourrait permettre une évaluation plus fine de l'empreinte environnementale du produit durant sa phase de production. Cela pourrait également prendre en considération le pilier « Santé et sécurité au travail » en proposant des modes d'actions sûrs pour les opérateurs appelés à travailler sur le montage du produit en prenant en compte a priori les risques de TMS ou autres maladies professionnelles ou risque de blessures potentiels.

De manière symétrique, à l'autre bout du cycle de vie produit, la même problématique pourrait être utilisée pour le démantèlement du produit fini. Dans cette perspective, en lien avec une étude lors de la phase de conception de Design for Disassembly (Soh et al., 2015), il s'agirait de s'intéresser au désassemblage rapide, facile et « propre » du produit, en gardant à l'esprit non seulement une vision Green du produit (possibilité de valoriser les différents composants) mais également une vision Lean and Green dans le processus de démantèlement. Cette perspective pourrait également mettre l'accent vers le volet social du développement durable en proposant, comme pour l'assemblage, des modes de démantèlement simples, rapides et protégeant la santé des opérateurs ayant à intervenir dans le processus.

Ce point de vue plus global du déploiement Lean and Green pourrait alors s'intégrer dans une démarche d'écologie industrielle et faciliter la découverte des synergies existantes lors de l'étude du métabolisme industriel d'un territoire donné.

Une autre perspective de recherche se dessine également quant à l'intégration des préoccupations sociales dans la roadmap de déploiement. En effet, notre stratégie Lean and Green intègre principalement les aspects liés à l'implication et à la sécurité des travailleurs, à l'instar du dernier muda Green évoqué par P. Hines (Hines, 2009) « *défauts de santé et de sécurité* » et du muda lean « *perte de potentiel humain* ». Cependant, l'évolution de ces stratégies vers une intégration encore plus efficace de l'axe social, de manière à développer l'épanouissement tout en libérant l'efficacité et l'engagement au travail serait un axe de recherche intéressant. Il pourrait aussi traiter de la prévention des risques de risques psycho-sociaux, lors de la mise en place du Lean and Green vers une perspective d'intégration totale des perspectives « Lean, Green and Safe ». Cet axe de recherche pourrait être investigué en collaboration avec des chercheurs en psychologie du travail.

Une autre perspective peut être évoquée, dans un objectif d'opérationnalisation de la stratégie de déploiement Lean and Green. Il s'agirait ainsi de particulariser la roadmap et sa mise en pratique en fonction d'un secteur d'activité donné et même envisager d'ouvrir la démarche à d'autres supports que les entreprises manufacturières. Ainsi, cela pourrait intéresser notamment le déploiement du Lean and Green dans les services : à l'heure où la rationalisation des ressources et la recherche de l'efficience commence à être intégré dans les tâches administratives (déploiement du Lean Office).

Enfin, une perspective concerne l'ouverture de l'étude à d'autres zones géographiques, à la fois pour l'aspect de benchmarking des pratiques Lean and Green, et de mise en place des procédures. Ainsi, à l'instar de visites industrielles réalisées au Japon au cours des travaux de thèse; une étude pourrait par exemple comparer les pratiques Lean and Green des firmes japonaises et des firmes occidentales en prenant en compte les différences socio-culturelles et industrielles existantes.

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Diapositives de soutenance de thèse

Soutenance de thèse
Strasbourg le 22 juin 2015

Stratégie LEAN & GREEN :

Roadmap d'analyse et de déploiement d'une politique de management alliant amélioration continue et développement durable en entreprise industrielle

Doctorante : **Brunilde Verrier** Encadrant : **Bertrand ROSE**
Directeur de thèse : **Emmanuel CAILLAUD**

1

Cadre de la thèse

- S'inscrit dans le projet Green LEM (Lean Engineering and Manufacturing) financé par la Région Alsace
  - Partenariat avec l'Agence de Développement Economique du Bas-Rhin (ADIRA)
  - Programme Perfoest labélisé par le pôle de compétitivité Véhicule du Futur

2

Sommaire

Démarche
Histoire du Lean

Lean

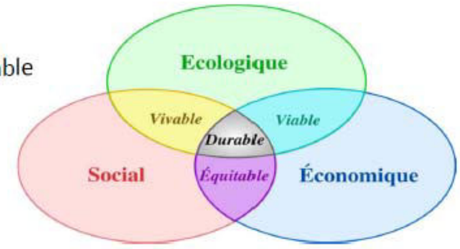
- Production sans gaspillage issue des techniques du Toyota Production System

- Au cœur du succès de ce système :
  - Capacité d'apprentissage dynamique et continu (Fujimoto,1999)

- Une équipe du MIT fait connaitre le TPS (Womack and Jones,1990)
  - Naissance du terme Lean Manufacturing

- Critiqué pour son impact sur le bien-être au travail (cadences élevées)

Démarche
Histoire du Green



- Concept fondateur du Développement Durable
  - Rapport Bruntland (1987)

- Evolution importante au sein de l'industrie
  - Du « curatif » au « préventif »
  - Prise de conscience des pollutions directes et indirectes (biodiversité, climat, écosystèmes)

- Les entreprises doivent s'adapter et se réorienter
  - Industrie : de 30 à 40% des émissions de GES en Europe (EEA,2012)

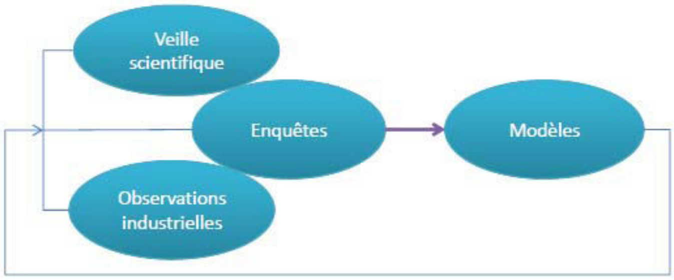
Démarche
Problématique et verrous

Lean and Green
- Transformer les préoccupations environnementales en opportunités d'améliorations

Problématique
- Comment intégrer conjointement des méthodes L&G au sein d'entreprises possédant des processus variés et des maturités différentes?

Inducteurs de performance
- Définition d'indicateurs environnementaux ad hoc
- Élaboration d'une roadmap pour déployer la démarche et transformer les stratégies en actions opérationnelles (Blanc, 2008)

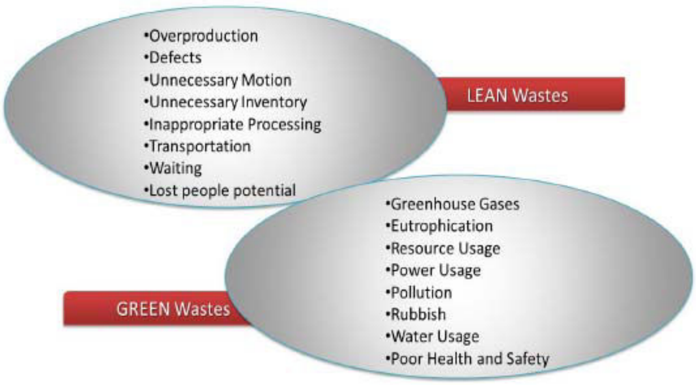
- Case study et Grounded theory
  - Etudes de terrain éclairant la construction de théories (Yin 2008)
  - Stratégies issues d'enquêtes dans le cadre de recherches qualitatives (Charmaz 2003)



  - Processus d'amélioration continue par adaptations et itérations
  - Interprétations à la lumière de la littérature scientifique et normative

Démarche
Méthodologie

- Objectif central d'identification et d'élimination des « mudas » Lean and Green (Hines,2009)



Etat de l'Art du Lean and Green
Travaux fondateurs

- Vision « gagnant gagnant » dès le début des années 90

  - Les investissements environnementaux peuvent contribuer à améliorer la compétitivité des entreprises (Porter,1991) (Boiral,1998)
  - Nécessité de traiter à la source les pollutions industrielles (Florida,1996)
  - Etude des relations entre production Lean et performance environnementale (King et Lenox,2001)

- Premières contributions exposant les bénéfices d'une approche intégrée L&G (Simons et Mason,2003) (Bergmiller,2006)

Etat de l'Art du Lean and Green
Analyse des contributions

- Considération de plus en plus forte dans la littérature scientifique

  - Encore majoritairement évoqué : lien général entre intérêts économiques et environnementaux (Gunasekaran et Spalanzani,2011)

  - Intérêt significatif au niveau de la supply chain (Zhu et al.,2012) (Duarte et Cruz-Machado,2015)

  - Intérêt grandissant sur association spécifique L&G (Jabbour et al.,2013) (Dües et al.,2013)

- Etude des références par gaspillages L&G

Etat de l'Art du Lean and Green

Analyse des contributions

References	Overproduction	Defects	Unnecessary Motion	Unnecessary Inventory	Inappropriate Processing	Transportation	Waiting	Lost People Potential	Economic	Social	Greenhouse Gases	Eutrophication	Resources Usage	Power Usage/Energy	Pollution	Rubbish	Water Usage	Poor Health & Safety	Environment	Case/Datas study	Lifecycle	Supply Chain Relationships
	LEAN										GREEN											
Ab Rahman et al., (2009)					x				x		x		x	x	x		x	x	x	x		
Ageron et al., (2011)				x		x	x	x	x	x	x		x		x			x	x	x	x	XX
Akamp & Müller, (2011)						x		x	x	x			x					x	x	x		XXX
Bergmiller & McCright, (2009c)					x	x	x	x	x					x				x	x			x
Bergmiller & McCright, (2009b)		x			x		x		x				x						XX	x		
Bergmiller & McCright, (2009a)		x			x	x	x	x	x				x		x			x	x	x		
Bose & Pal, (2012)		x		XX		x	x	x	x	x	x		x	x	x	x		x	x	x	x	XX
Chardine-Baumann, (2011)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	XX
Comoglio & Botta, (2012)					x	x					x		x	x	x		x	x	x	x		
Dakov & Novkov, (2007)	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x	x			x
Duarte et al., (2011)		x		x	x	x	x	x	x	x	x		x	x	x		x	x	x		x	XX
Dües et al., (2012)	x	x	x	x	x	x	x		x	x	x		x	x	x		x		x		x	x
Espadinha-Cruz et al., (2011)				x			x		x										x	x		XX
Gunasekaran & Spalanzani, (2011)		x		x	x	x	x		x	x	x		x	x	x		x	x	x		x	XX
Gustashaw & Hall, (2008)		x			x	x	x	x	x	x	x		x	x	x	x	x		x	x	XX	x
Hines, (2009)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
Hussey & Eagan, (2007)					x			x	x	x			x		x			x	x	x	x	x
Kainuma & Tawara, (2006)				x		x	x		x		x		x	x	x	x			x	x	XX	XX
Katsamaki et al., (2011)					x		x									x		x	x	x	XX	
King & Lenox, (2001)				XX	x			x	x			x			XX			x	XX	XX		
Kleindorfer et al., (2005)		x		x	x	x	x	x	x	x			x	x	x			x	x		x	x
Kogg & Mont, (2012)							x		x	x	x		x				x	x	x	x	x	XXX
Koplin et al., (2007)									x	x			x						x	x	x	XXX
Mashaei et al., (2011)			XX											XX					x	x		
Maxwell & van der Vorst, (2003)						x			x	x	x		x	x		x		x	x		XX	x
Maxwell & Van der Vorst, (2006)	x								x	x			x	x	x	x		x	x	x	XX	x
May et al., (2011)					x		x		x	x			x	x					x	x	XX	x
Mickwitz et al., (2006)					x	x			x	x	x	x	x		x				x	x	x	
Miller et al., (2008)					x				x	x	x		x	x	x	x		x	x		x	
Mollenkopf et al., (2010)	x	x	x	x	x	x	x		x	x	x			x	x	x		x	x		x	XXX
Paju & Johansson, (2010)	x				x	x	x		x	x	x	x	x	x	x	x	x		x		x	
Parveen et al., (2011)	x	x		x	x	x	x	x	x		x		x	x	x	x	x		x	x		x
Pimenova & Van der Vorst, (2004)									x	x	x		x	x	x	x		x	x	x		
Rusinko, (2007)					x				x				x	x	x	x	x		x	x		x
Sarkis et al., (2011)									x	x	x		x		x				x		x	XX
Sawhney et al., (2007)	x	x		x	x			XX	x		x			x	x	x	x	XX	x	x		x
Schoenherr, (2011)					x		x		x	x					x	x			x	XX		x
Seuring & Muller, (2008)									x	x									x		XX	XXX
Simons & Mason, (2003)			x		x	x	x		x		x		x	x	x				x	x	x	x
Tatsch et al., (2010)									x	x			x	x		x		x	XX		XXX	
Vachon & Klassen, (2008)		x		x	x	x	x		x						x	x			x	x	x	XXX

Etat de l'Art du Lean and Green

Analyse des contributions

- Confirmation du potentiel du L&G pour réduire les besoins en ressources et les couts de production

- Discussions sur l'implantation :
  - Bergmiller & McCright, (2009) → implantation en parallèle
  - Pampanelli (2014) → implantation Lean = prérequis
  - Galezzao (2014) → séquentiellement ou simultanément

- De nombreuses entreprises voient toujours les problématiques environnementales comme une contrainte (May et al.,2011)

Etat de l'Art du Lean and Green
Analyse des contributions

- Majorité des approches traitées au niveau macroscopique
- Aspect social encore peu traité au sein de ces thématiques

- Apport de nos travaux:
  - Renforcer la synergie des méthodes L&G par l'élimination conjointe des mudas
  - Permettre d'appliquer la vision stratégique en actions opérationnelles en entreprise manufacturière
  - Mettre en lumière les bonnes pratiques
  - Renforcer la prise en compte du facteur humain

Méthodologie d'évaluation et de déploiement
Partenariat industriel

- Projet initial construit en 2010 autour de 7 donneurs d'ordres de différents secteurs d'activité et certains de leurs fournisseurs + entreprises de conseil

- Partenaires industriels regroupés au sein du club Lean and Green de l'ADIRA

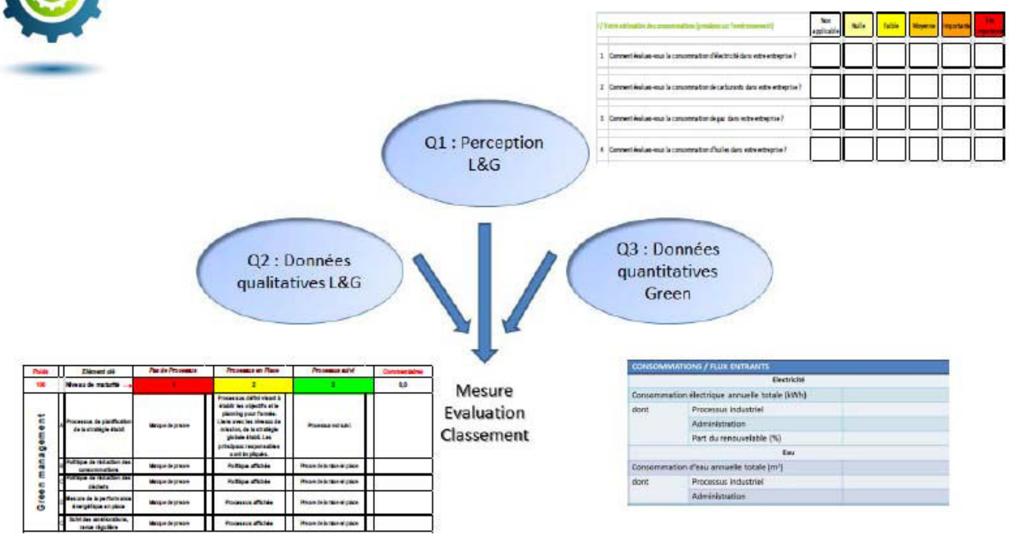
Méthodologie d'évaluation et de déploiement
Implantation de la démarche

- Sessions d'audits et observations sur sites industriels

> - Elaboration de questionnaires
> - Contribution principalement dédiée à l'expertise environnementale

> - Choix du périmètre
> - Présentation de l'approche
> - Cartographie Lean & Green, débriefing
> - Etude de questionnaires - benchmarking

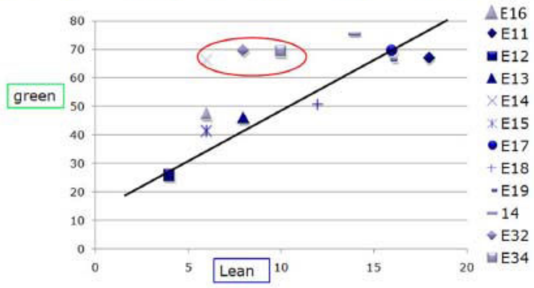
Méthodologie d'évaluation et de déploiement
Implantation de la démarche



- Le projet L&G1 a prouvé l'intérêt de l'association des deux aspects

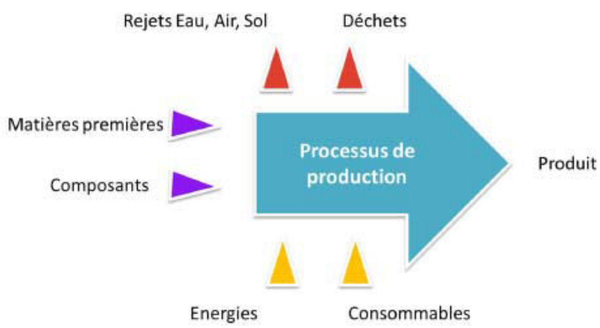
Corrélation positive
Maturité Lean = Implication Green

- Plus le Lean est maitrisé, meilleurs seront les résultats dans les initiatives Green



Méthodologie d'évaluation et de déploiement
Implantation de la démarche

- Cartographie Green
  - Visualiser flux intrants et sortants
  - Détection des potentiels d'amélioration



Méthodologie d'évaluation et de déploiement
Implantation de la démarche

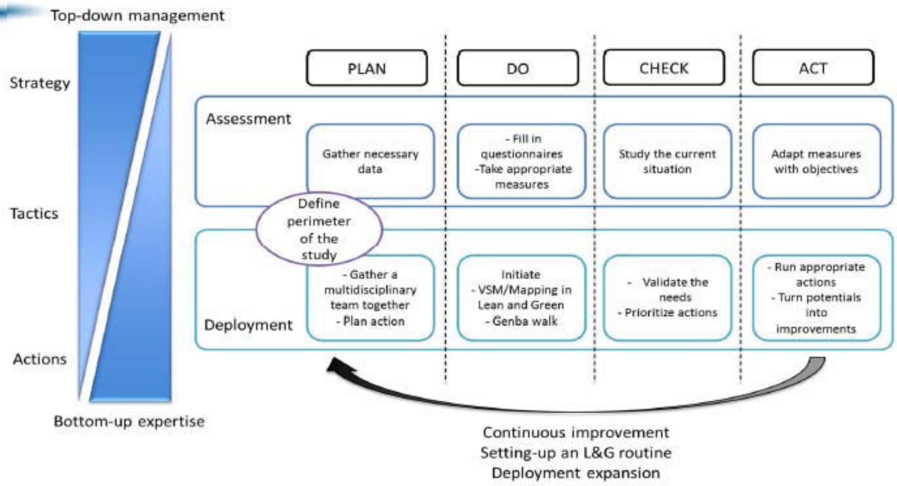
Méthode :

- Visiter processus cible en fonctionnement
- Compléter cartographie des intrants/sortants avec l'aide de l'équipe interne
- Partager les résultats, prioriser les actions

Genba walk :

- Marcher « où l'action se passe »
- Inclure le personnel dans les changements

Méthodologie d'évaluation et de déploiement
Synthèse d'implantation



La mesure des performances environnementales
Les indicateurs

- Eléments de contrôle primordiaux dans la mise en place de méthodes PDCA
- Dans le passé essentiellement destinés à un contrôle passif
  - ➢ Aujourd'hui doit se décliner en indicateurs de processus pour actions correctives

Information permettant à un acteur l'atteinte de son objectif, le plus efficacement possible (Lorino,1996)

Indicateurs environnementaux

- Définir les impacts d'une activité, contrôler les flux, détecter des incidents, évaluer et communiquer, conformité, impliquer les employés

La mesure des performances environnementales
Les indicateurs

- Comment choisir et mesurer les performances à suivre pour les entreprises débutant la démarche?
  - ➢ Etude sur les rapports environnementaux des entreprises du CAC 40
  - ➢ Manque d'homogénéité dans l'utilisation et le reporting des KPIs basés sur le GRI
  - ➢ Manque de cohésion également relevé par la littérature scientifique

(Hammond et al.,1995)(Niemeijer et De Groot,2008)(Mazzi et al.,2012)

Dans nos travaux :

- Frontière entre méta modèles complexes et « listings »
- Approche simple et ajustable pour appréhender le management des performances
- Vision des indicateurs green par le biais de l'élimination des gaspillages

La mesure des performances environnementales
Les indicateurs

KPIs \ Firms		Energy		Manufacturing Industries (Food products - Chemicals - Elec. equipment - Automotive - Construction sectors)															Heavy construction		Transports, Telecom, Other Services			
		Total	EDF	Danone	PernodRicard	Sanofi	Solvay	L'Oréal	Schneider Electric	Legrand	STMicroelectronics	Alcatel-Lucent	PSA	Renault	Alstom	Michelin	Saint-Gobain	Lafarge	Bouygues	Vinci	Air France	Orange	Société générale	Carrefour
Materials	EN1	X	X	X	X	X		X			X	X	X	X			X	X		X			X	X
	EN2			X		X	X		X			X	X	X			X	X	X	X		X		X
Energy	EN3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EN4			X	X		X	X	X	X	X	X			X		X	X				X		
	EN5			X			X	X	X	X			X	X								X		
	EN6		X	X			X	X					X						X	X		X	X	
	EN7			X				X														X		
Water	EN8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EN9			X	X	X		X																
	EN10			X				X			X							X						
Biodiversity	EN11			X		X	X	X					X	X				X						
	EN12			X			X	X					X											
	EN13			X			X	X					X											
	EN14			X				X	X				X					X	X	X	X	X	X	
	EN15			X		X		X					X											
Emissions, Effluents, Waste	EN16	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EN17			X			X	X	X	X	X	X	X				X							
	EN18			X			X	X			X	X	X	X			X		X	X		X	X	
	EN19			X	X	X	X	X	X	X	X	X	X			X					X			
	EN20	X	X	X		X	X	X	X			X	X	X			X	X			X			
	EN21	X	X	X	X	X	X	X			X		X	X	X		X				X	X		
	EN22	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	
	EN23			X			X	X			X	X	X	X			X					X		X
	EN24		X	X	X		X	X					X							X	X			
	EN25			X				X					X											
Products & Services	EN26			X		X	X		X	X	X	X	X	X		X	X		X	X		X		
	EN27			X				X			X	X	X	X					X			X		
Compliance	EN28	X		X	X		X	X		X		X	X				X			X		X		
Transport	EN29			X		X	X		X	X	X		X	X								X	X	X
Overall	EN30	X	X	X	X	X	X	X			X						X	X		X	X		X	

Région Alsace – Pôle Véhicule du Futur – ADIRA – Préfecture – Université de Strasbourg – INSA Strasbourg

La mesure des performances environnementales
Modèle de sélection

Etape 1:

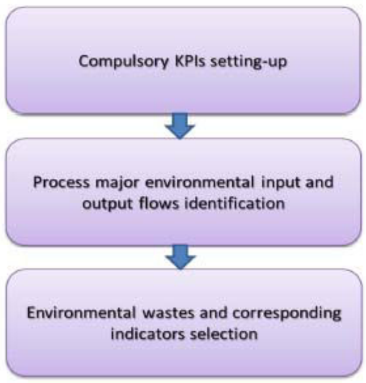
- Indicateurs « obligatoires »
  - Consommation énergétique (électricité et gaz), eau, production déchets
- Maturité plus déterminante que le secteur d'activité

Etape 2:

- Visualisation des flux intrants et sortants pour indicateurs spécifiques

Etape 3:

- Identification des gaspillages et indicateurs correspondants



Région Alsace – Pôle Véhicule du Futur – ADIRA – Préfecture – Université de Strasbourg – INSA Strasbourg

La mesure des performances environnementales
Modèle de sélection

Green Muda	Indicative indicators
Excessive resource usage	• Raw materials used (EN1) • Recycled materials amount (EN2) • Eco-design rate
Excessive water consumption	• Water withdrawal (EN8) • Water recycled and reused (EN10)
Excessive power usage	• Energy consumption (EN3-EN4)
Greenhouse gases	• Greenhouse gas emissions (EN16)
Pollution and Eutrophication	• Other emissions in the air including acidification and ozone-depleting substances (EN19 – EN20) • Number of signifiant spills (EN23) • Wastewater treatment initiatives • Chemicals used in process • Transports monitoring
Rubbish	• Total rubbish production (EN22) • Hazardous rubbish amount • Treatment and recycling rate by type of waste
Poor health and safety	• Type and amount of chemicals used in process • Regulatory compliance (EN28) for hazardous substances (RoHS, REACH…) • Number and circumstances of employees expositions to hazardous substances

La mesure des performances environnementales
Bonnes pratiques de mise en place

- Piloter les KPIs de manière active
- Lier la volonté organisationnelle aux feedback des mesures sur le terrain

- Implémenter au niveau organisationnel puis opérationnel
- Utiliser valeurs absolues et relatives

- Indices de fiabilité
  - Significatifs, accessibles, objectifs, transmissibles
  - Vérifier la validité de l'interprétation d'après le contexte

- Communication en visual management
  - Encourager implication des employés et améliorer les performances

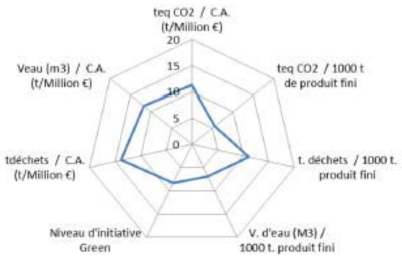
La mesure des performances environnementales

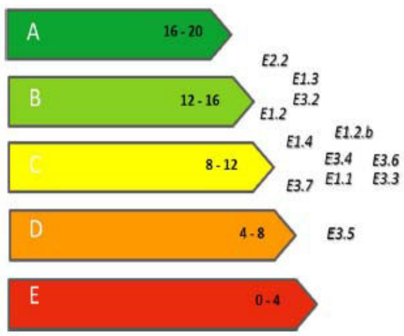
Résultats de benchmarking au sein du panel

- Benchmarking des performances quantitatives
  - Classement pour le club Lean and Green
  - Comparer et échanger les bonnes pratiques
- 6 indicateurs relatifs (ratios par chiffre d'affaire et par tonnes de produits finis)
  - Rejets GES– production déchets – consommation eau
- Système de calcul (échelle logarithmique inversée - notations équivalentes sur 20)
- Représentations par diagrammes et synthèse graphique
  - Voir les leviers d'amélioration et visualiser sa position générale dans le panel

La mesure des performances environnementales

Résultats de benchmarking au sein du panel





La mesure des performances environnementales

Résultats de benchmarking au sein du panel

- Gaspillages les plus rencontrés dans les processus de production :
  - Défauts, mouvements inutiles, utilisation excessive d'énergie, production de déchets
- Procédures Lean plus abouties, Green en retrait
- Grandes entreprises encore souvent plus matures
  - Catalyseurs potentiels pour fournisseurs et PME
- Utilisation Genba walk et Visual management en retrait
- Pour les entreprises à processus équivalents, résultats dépendant principalement de la maturité Lean

Optimisation de la méthode

Bonnes pratiques

Améliorations courantes
- Renforcement des bases Lean (5S et PDCA)
- Relations dans la supply chain (privilegier boucles locales, origine M.P)
- Renforcement politique et communication d'entreprise

Chantiers à moyen terme
- Mise en place d'indicateurs + visual management
- Amélioration sécurité et ergonomie
- Changement d'équipement (pertes d'énergie)
- Substitution de produits chimiques

Pratiques à long terme
- Anticiper les législations /approches de progrès volontaristes

(spécialement entreprises énergivores ou manipulant des substances dangereuses)
- Engager processus d'éco-conception

Optimisation de la méthode

Bonnes pratiques

Toyota Motor Corporation

- Croissance, efficience, stabilité
- Challenge de faire mieux (Amélioration continue, Kaizen)
- Genchi genbutsu
- Travail d'équipe et respect de l'humain
- Réduire et réutiliser
  - Indicateurs environnementaux reportés au Japon chaque mois
  - Valorisation des employés au sein d'équipes de réflexion Kaizen
  - Conformité volontaire points clés de l'ISO 26000
  - Innovation technologique (pile à combustible)

Optimisation de la méthode

Bonnes pratiques sociales

- Sécurité : opportunité de lier Lean, Economie et Environnement
- Non considération du facteur humain
  - Mudas «Lost people potential » et « poor health and safety »

Esat les tournesols

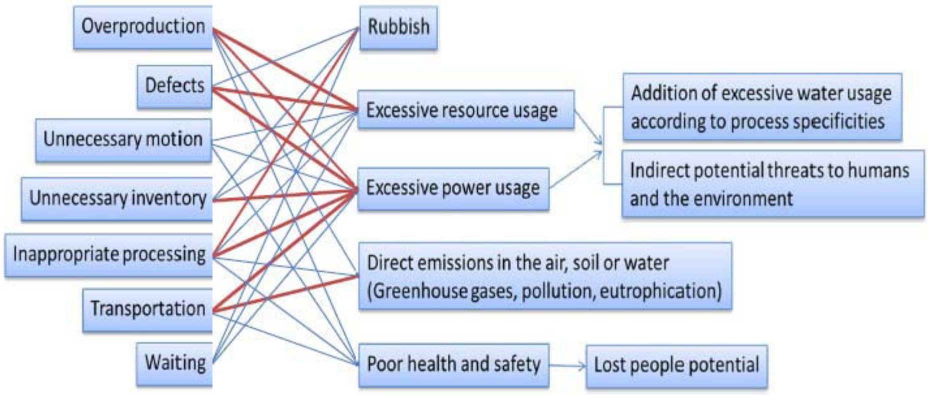
- Entreprise sociale à forte compétitivité
  - Forte implication de la direction
  - Volonté de progrès
  - Préoccupation des conditions de travail
  - Promotion des aptitudes et de la motivation

Optimisation de la méthode

Synergie des outils

- Corrélations et synergies entres outils et gaspillages du L&G

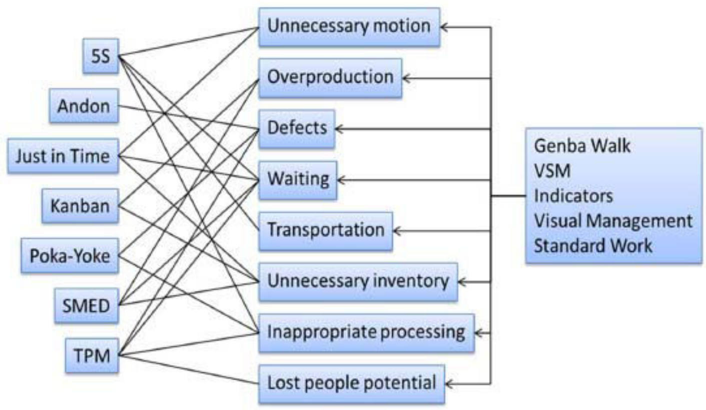
> Mudas Green cachés par des mudas Lean



Optimisation de la méthode

Synergie des outils

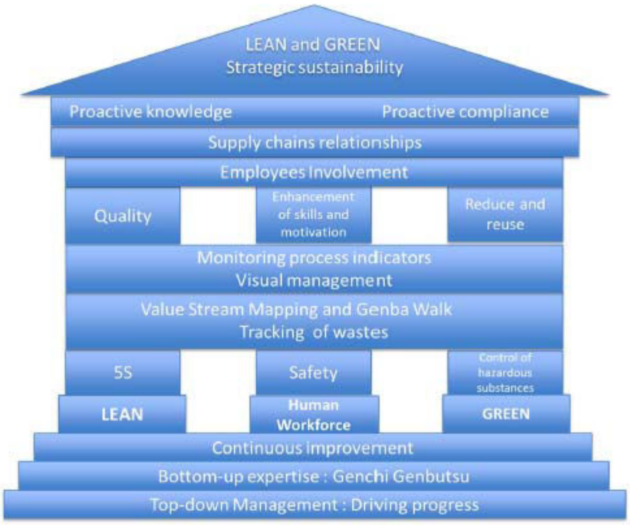
Corriger la source des gaspillages



Optimisation de la méthode

La Maison du Lean and Green

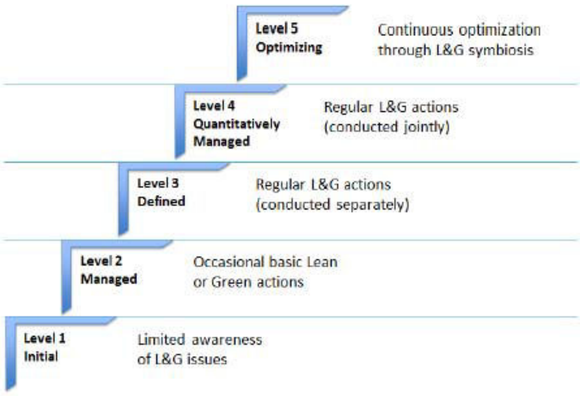
- Drivers de performance stratégique



Optimisation de la méthode

Référentiel de maturité

- Situer ses avancées dans l'implantation des méthodes L&G
  - Basé sur modèle CMMI : 5 phases
  - Base d'évaluation
  - Etapes détaillées



Conclusion des travaux
Synthèse

- Mise en œuvre des méthodes L&G d'un point de vue qualitatif

Travaux répondant aux inducteurs de performances définis

- Etat de l'art du L&G et des contributions académiques et normatives sur les KPIs
- Analyse de rapports et d'enquêtes dédiées
- Analyses et observations sur sites
- Modèle de sélection d'indicateurs
- Roadmap de déploiement et identification des bonnes pratiques L&G
- Etude des synergies L&G
- Maison du L&G
- Référentiel de Maturité

Conclusion des travaux
Limites et Perspectives

Limites
- Orientation sur la phase de fabrication
- Gestion de projet : aspects temporels non définis

Perspectives scientifiques
- Prise en compte élargie des autres phases du cycle de vie
  - Vision L&G produit et processus
- Intégration plus spécifique axe social

Perspectives industrielles
- Ecologie industrielle
- Ouvrir l'étude à d'autres zones géographiques
  - Benchmarking pratiques L&G Japon/France

Merci pour votre attention

Valorisations scientifiques

Congrès

B. Verrier, B. Rose, E. Caillaud, *Promoting best practices for industrial excellence integrated with sustainable development issues: the Lean and Green strategy,* 22ème Colloque international du Gerpisa, 4-6 juin 2014, Kyoto.

B. Verrier, B. Rose, E. Caillaud, *Sustainable manufacturing through Lean and Green approach: best practices and indicators,* IDETC/ICE ASME 2013, 4-7 août 2013, Portland (OR).

B. Verrier, *Stratégie Lean and Green,* Session poster aux 5èmes Journées Doctorales / Journées Nationales MACS, 11 et 12 juillet 2013, Strasbourg.

B. Verrier, B. Rose, *Eco-conception, analyse du cycle de vie et capitalisation des connaissances de produits électriques,* présentation au GT C2EI, Journées du GdR Macs STP, 17 et 18 Novembre 2011, Tarbes.

Publications

B. Verrier, B. Rose, E. Caillaud, H. Remita, *Combining organizational performance with sustainable development issues: the Lean and Green project benchmarking repository,* Journal of Cleaner Production, Elsevier,Vol. 85(15):83-96, 2014.

B. Verrier, B. Rose, E. Caillaud, *Environmental performance indicators: review and proposals applied to the Lean and Green project,* soumis à Journal of Environmental Management.

B. Verrier, B. Rose, E. Caillaud, *The Lean and Green project methodology: assessment and implementation roadmap, best practices recommendations from case study observations,* soumis à International Journal of Production Economics.

B. Verrier, B. Rose, E. Caillaud, *Lean and Green strategy : the Lean and Green house and Maturity Model,* soumis à Journal of Cleaner Production.

S. Leduc, B. Verrier, B. Spatz, H.-P. Michaud, *Lean and Green : Performance industrielle et environnementale,* Guide Méthodologique, ADIRA, 2014. Disponible sur http://www.adira.com/upload/documents/Entreprises_Actualites/ADIRAguideLeanGreen.pdf

Résumé court – Short Abstract

Stratégie Lean and Green : Roadmap d'analyse et de déploiement d'une politique de management alliant amélioration continue et développement durable en entreprise industrielle

Ces travaux de thèse s'intéressent à l'association des performances industrielles et environnementales avec une démarche d'amélioration continue orientée vers le développement durable et ciblent l'élimination conjointe des « gaspillages » Lean et Green dans les processus de fabrication. La problématique majeure réside dans la mise en place des outils L&G au sein d'entreprises manufacturières possédant des processus et caractéristiques culturelles variés. Basés sur une analyse suivie de l'état de l'art et d'enquêtes de bonnes pratiques, les travaux de recherche incluent plusieurs évaluations et observations sur sites industriels. La mise au point d'une roadmap de déploiement adaptable, mettant en valeur les aspects sociaux par le biais de l'implication et de la valorisation des employés, est ainsi complétée par un modèle de sélection d'indicateurs environnementaux, une « Maison du L&G » et un modèle de maturité particularisé pour le niveau d'implémentation de la stratégie.

Mots-clés : Production durable; Stratégie Lean and Green; Indicateurs de performance environnementaux; Bonnes pratiques industrielles

Lean and Green Strategy: Analysis and deployment roadmap for a management policy associating continuous improvement and sustainable development in manufacturing industries

This thesis addresses the association of industrial and environmental performances with a continuous improvement approach oriented toward sustainable development, and particularly seeks for the identification and elimination of Lean and Green "wastes" in manufacturing processes. The major issue lies in the deployment of L&G tools within manufacturing firms with various processes and cultural characteristics. Based upon a thorough state of the art and industrial surveys on best practices, the research includes several assessments and observations on manufacturing sites. The development of an adaptable roadmap of deployment highlighting social concerns through the involvement of employees in improvements is therefore completed with a selection model of environmental indicators, a "L&G House" and a maturity model for the strategy's implementation.

Keywords: Green Manufacturing; Lean and Green strategy; Environmental Key performance indicators; Industrial best-practices